# STUDIES ON GROWTH, DEVELOPMENT AND STORAGE OF POMEGRANATE (*Punica granatum* L.) cv. GANESH

**NANDA S.**

DIVISION OF HORTICULTURE
**UNIVERSITY OF AGRICULTURAL SCIENCES**
BANGALORE

1996

# STUDIES ON GROWTH, DEVELOPMENT AND STORAGE OF POMEGRANATE (*Punica granatum* L.) cv. GANESH

**NANDA S.**

Thesis submitted tothe
**University of Agricultural Sciences, Bangalore**
in partial fulfilment of the requirements
for the award of the Degree of

**Doctor of Philosophy**

in

**HORTICULTURE**

BANGALORE NOVEMBER 1996

Affectionately dedicated to
my Family Members

DIVISION OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

## CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON GROWTH, DEVELOPMENT AND STORAGE OF POMEGRANATE** cv. **GANESH"** submitted in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSOPHY IN HORTICULTURE** to the University of Agricultural Sciences, Bangalore, is a record of research work done by **Miss.NANDA.S.,** during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore
December , 1996

(**Dr.SHANTHA KRISHNAMURTHY**)
Principal Scientist & Head
PHT Division, I.I.H.R.

APPROVED BY:

Chairman: [**Dr.SHANTHA KRISHNAMURTHY**]

Co-Chairman: [**A.G.HUDDAR**]

Members : 1. [**Dr.K.R.MELANTA**]

2. [**Dr.S.S. JOSHI**]

3. [**H.T. GURUSIDDAPPA**]

## *ACKNOWLEDGEMENTS*

*It is with immense pleasure I express my profound sense of gratitude and indebtedness to **Dr.(Mrs.) Shantha Krishnamurthy,** Principle Scientist, I.I.H.R. and Chairman of my Advisory Committee for her invaluable guidance, close counsel, full co-operation, valuable suggestions, critical comments, and sustained interest shown through out the period of this investigation and in the preparation of the manuscript. It was indeed a pleasure studying under her able guidance.*

*To express my thanks and gratitude to **Dr.S.S.Joshi,** Professor of Botany, BSH College and a member of my Advisory Committee, is a difficult proposition. He has always been a constant source of encouragement and help through out the study.*

***Dr.K.R.Melanta,** Professor and Head, Division of Horticulture, G.K.V.K., **Sri.A.G.Huddar,** Professor of Horticulture, G.K.V.K. and **Sri.H.T.Gurusiddappa,** Professor of Statistics, BSH College, the other members of my Advisory Committee have been very kind and helpful whenever I approached them. I thank them whole heartedly.*

*To single out a few from among the staff of the PHT Division, I.I.H.R., Bangalore, will be a gross injustice and I am grateful to everyone of them.*

The thesis would never have been what it is but for the interest and help of all the staff members of College of Agriculture, Bijapur. It is they who have made me realise fully my requirements. It is impossible for me to thank them just by writing a few words.

For short gestation period of this thesis, I owe gratitude to all the staff members of Division of Horticulture, G.K.V.K., who offered me their valuable interest and help which I was only too happy to accept. I am greatful to them.

I offer my profound thanks to all the staff members of Botany Department, BSH College for their kind help and keen interest.

Special thanks to the staff of Fruit Crops Division, I.I.H.R., Bangalore.

My family members have been so understanding and encouraging that they infused in me a sense of security and confidence with which I have been able to achieve everything I desire.

Finally I am very thankful to all my friends who have helped me during my study.

Bangalore

**NANDA.S.**

## CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF PLATES

# INTRODUCTION

# INTRODUCTION

Pomegranate (*Punica granatum L.*) commonly known as Anar, Dalim, Matulum is an important fruit of tropic and subtropic regions of India. The wide adaptability, hardy nature, low maintenance cost, steady and high yields, fine table and therapeutic values, better keeping quality and possibilities for the plants into rest period when irrigation potential is low are some of the qualities which make the fruit ideally suitable for semi-arid and arid regions. However, the performance of the plant will be excellent if maintained with protective irrigation.

Pomegranate is a native of Iran (Evreinoff, 1949). Its cultivation is of considerable importance in countries like Spain, Morocco, Egypt, Iran and Afghanistan. In India it is grown in Maharashtra, Uttar Pradesh, Andhra Pradesh, Gujarat, Karnataka and Tamil Nadu. Its coverage in Karnataka is about 4651 hectares with an annual production of 109762 tons (Anon, 1994) and is mainly cultivated in Tumkur, Kolar, Bangalore, Dharwad, Bijapur and Belgaum districts.

The best quality fruit can only be grown in areas of cool and dry winters and hot and dry summers. The plant can however adopt to a wide range of climatic conditions. The fruits are sweet where the temperatures during fruit maturity are high for a long period. Fruit quality deteriorates in humid climate.

The fruit is very much liked for its cool and refreshing juice and a good variety gives about 40 per cent juice (Siddappa, 1943). The bark and rind are recognised astringents used in therapeutics for dysentry and diarrhoea (Asaphgoor, 1967). The flowers and rind are crushed to make a dye for colouring fabrics.

The edible portion of pomegranate is 60 per cent. It is having a high nutritive value and contains protein (1.87 g), fat (1.87 g), carbohydrates (18.59 g), total sugars (8.06 g), reducing sugars (6.42 g), pectin (0.51 g), acidity (0.46 g), mineral content (0.67 g), comprising of calcium (76.6 mg), phosphorus (40.0 mg), iron (0.68 g), sulphur (26.63 mg) and ascorbic acid (6.70 mg per 100 g) (Sood *et al.*, 1984).

A number of varieties of pomegranate are cultivated and are distinguished by shape of the fruit, colour of the rind, thickness of the rind, taste and colour of the aril. In India pomegranate is grown in kitchen gardens and commercial plantations have come up in recent years with the introduction of some improved cultivars like Ganesh (GB4.1) and Jyothi. With the recent developments in dryland horticulture, the production of this fruit has increased with more demand both in internal trade and export market. 'Ganesh' cultivar has aril with pinkish flesh having soft seeds with agreeable taste (Cheema *et al.*, 1954).

Depending upon the bahar treatment which is practised from October to March, pomegranate comes to harvest in different seasons like April-June (Ambehahar) and December-January (Hastabahar). Fruits are harvested when they are fully ripe and develop a waxy shining surface with pale yellow or reddish green skin.

As processed products are not popular compared to mango, more emphasis is laid presently on consumption of the fruit in the fresh form which calls for better storage conditions.

Pomegranate fruits lose water quickly and should be kept under 95 per cent relative humidity to minimize this loss. The tough skin of the fruit has numerous pores which permit the free water vapour movement (Elyatem and Kader, 1984). The fruits become misshapen and thus maintainance of fruit freshness during storage is a problem. Therefore, there is a need to study the rind structure to attempt for any post harvest treatments such as waxing to improve the quality and minimize the water loss.

A survey of literature revealed that no systematic study has been made with regard to maturity of fruit used for determining the shelf life and quality. Therefore there is a need to study the developmental changes following harvesting of fruits at optimum maturity stage and store them at optimum conditions for longer periods for maintaining the quality.

'Ganesh' cultivar grown in two agroclimatic conditions in Karnataka namely humid (Bangalore) and dry areas (Bijapur) show differences in quality especially the rind thickness, which affect the shelf life and quality of the fruit. Hence the fruits grown under Bangalore and Bijapur conditions were used for determining the shelflife and quality.

In the present investigation a study on changes during growth, development and storage of pomegranate fruits cv. Ganesh was made with the following objectives.

(i) To study the growth and development of pomegranate fruit cv.Ganesh grown under Bangalore and Bijapur conditions.

(ii) To study the storage behaviour of pomegranate fruit cv. Ganesh grown under Bangalore and Bijapur conditions.

(iii) To study the histological changes of pomegranate rind cv. Ganesh grown under Bangalore and Bijapur conditions during growth and storage.

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

Pomegranate cultivar has attained commercial importance recently especially with introduction and popularisation of soft seeded variety 'Ganesh' in Maharastra. Systematic research work on basic and applied aspects of this fruit has started only recently. Therefore the literature reviewed includes comparative studies on other fruits which are relevant to the present investigation "The Study of growth, development and storage of Pomegranate fruits cv.Ganesh".

## 1. FRUIT GROWTH AND DEVELOPMENT

### 1.1 PATTERN OF FRUIT GROWTH

Leopold (1964) stated that the growth of the fruit involves the enlargement of the ovary and the associated parts. Fruits exhibit mainly two types of growth patterns. Some fruits like apple, strawberry and melons exhibit 'sigmoid' type of growth whereas fruits like grapes, peaches, apricots, cherries and plums exhibit 'Double sigmoid' pattern of fruit growth. Sulladmath *et al.* (1979) reported the growth pattern to vary with species, variety and climate.

According to Zielinski (1955) pomegranate is a special horticultural fruit called 'balusta' and the individual fruits inside are the little drupes. Shulman *et al.* (1984) studied pomegranate fruit development and maturation in coastal plain and in Bet Shean valley of Isreal and reported that the growth curve of the pomegranate fruit from both climatic regions showed a single 'sigmoid' pattern thus suggesting that the pomegranate is a non-climateric fruit.

Pomegranate variety selection G.K.V.K.1, fruit took 126-130 days to mature from fruit set following a single sigmoid growth pattern (Dash, 1983). According to Prasanna Kumar (1986) the pomegranate fruit grows continuously from fruit set to harvest with periods of slow growth rate alternated with periods of fast growth rate. The pattern of fruit growth followed a "Single sigmoid curve" almost approaching a linear relationship. Saad (1990) reported the continuous growth of fruit indicating a single 'sigmoid' curve. Josan *et al.* (1979b) reported that after fruit set in pomegranate there was a rapid and continuous growth for 1-1 1/2 months followed by a period of slow growth for another 25 days. There after the fruit growth remained more or less the same. It was also observed that maximum fruit growth was during the second fortnight after fruit set.

Hittalmani and Rao (1976) suggested that the Kagzi lime fruit followed a 'sigmoid' pattern of growth and took 6 1/2 months to mature from the time of fruit set. The growth pattern could be divided into 3 distinct periods based on the rate of growth. The Period I being the period of rapid growth from first to fourth fortnight, Period II being the stage of steady increase in weight from fifth to nineth fortnight and Period III marked by an accelerated growth rate from tenth to thirteenth fortnight.

A study on the periodical changes in the fresh weight of developing 'Kalipatti' sapota fruit showed a 'double sigmoid' nature of growth and took about 10 1/2 months for full development of the fruit under Dharwad conditions (Sulladmath *et al.*, 1979). Kennard (1955) reported that in 'Paheri' mango all parts exhibited a 'sigmoid' type of curve when growth data such as length, diameter, fresh weight and volume were plotted against time.

**1.2 MORPHOLOGICAL CHANGES DURING FRUIT DEVELOPMENT**

**1.2.1 Changes in length and breadth**

Dash (1983) observed that in all the three cropping seasons (Ambebahar, Hastabahar, Mrig bahar) the length and diameter of pomegranate fruit G.K.V.K.1 increased continuously from fruit set to maturity. However, between the cropping seasons there were differences in length and diameter. In all the stages of growth the diameter of the fruit was more than the length. The highest increase in length and diameter was during second fortnight. Nath and

Randhawa (1959) recorded length and diameter of developing fruit of different varieties of pomegranate. They recorded maximum length of 7.6 and diameter of 8.5 cm in Dholka and minimum length (2.7 cm) and diameter (2.2 cm) in Japanese dwarf. The minor deviations in size with respect to weight may be due to the variations in the fruit form as sometimes they are obscurely ridged and many sided.

The gradual increase in length and diameter was recorded throughout the period of growth in pomegranate by Fouad *et al.* (1979) and Arie *et al.* (1984) in different varieties. However at the end of development the length and diameter of the fruit was almost equal.

Among the twentyone pomegranate cvs evaluated, the fruit size varied from 4.29 cm in Anar - Poste-safed Shirin to 6.50 cm in cv. Kazkai (Josan *et al.*, 1979). The twenty one pomegranate cvs evaluated by Malhotra *et al.* (1983) had the fruit length ranging from 3.9 in Afghan Kandhari seedling to 5.6 cm in Anar Shirin-e-Mohamad Ali. In fruit breadth the cv. Ganesh exceeded others by producing fruits as broad as 6.8 cm. Linear dimensions of the fruit viz., length and breadth increased continuously from set to maturity in pomegranate. However, the increase in length was more than breadth during early stage of growth. In the late period the increase in breadth was more pronounced (Prasanna Kumar, 1986).

The length and diameter of lime fruit increased continuously from set to maturity. The length of fruit was slightly more than the diameter throughout the growth period (Hittalmani and Rao, 1976). The increase in length and breadth from set to maturity in mango was reported by Pandey *et al.* (1973) and by Yusof and Mohamed (1987) in fruits of guava.

**1.2.2 Changes in fresh weight, volume and specific gravity**

Arie *et al.* (1984) showed two phases of growth in pomegranate fruits. A rapid phase until the mid June (Fruit set April 27th) and thereafter a gradual phase until harvest. He concluded that there was a constant rate of fresh weight increase throughout the growing season.

Shulman *et al.* (1984) during a study of pomegranate fruit development in Isreal, concluded that the fruit grows continuously from fruit set until after the commercial harvest time. The pattern of fruit growth showed a single 'sigmoid' curve for the variety 'Mule's head' whereas in the variety 'wonderful', the growth was more linear. In coastal plain the average fruits weighed 250 g in 'Mule's head' variety whereas it was 350 g in 'wonderful' variety. In Betshean valley the average fruit weight of 'Mule's head' was 350 g and that of 'wonderful' was 400 g. The smaller size of fruits in coastal plain was probably due to the cooler weather. According to Dash (1983) in pomegranate variety 'Jyothi', the fresh weight increased greatly during the second and sixth fortnight with decreased weights during other periods.

The growth and development of pomegranate fruit studied by Kumar and Purohit (1989) in Ganesh, Bassein seedless and Alandi variety showed a 'single sigmoid' growth pattern with a continuous increase in fresh weight of the fruits. The maximum growth in terms of fresh weight was observed around fruit maturity in all the three cultivars. In Ganesh and Bassein seedless varieties the fruits made very fast growth during three distinct periods between 30 to 40, 50 to 60 and 80 to 100 days after set. The fruit of seedling selection 'P23' pomegranate showed 'sigmoid' pattern of growth. The size, weight and volume of the fruit increased while the specific gravity decreased gradually throughout the growth period of fruit (Khodade *et al.*, 1990). Among the twenty-one cvs evaluated for physical characters, the fruit weight ranged from the lowest of 56.8 g each in cv. Afghan Khandhari seedling to as high as 124.7 g each in Kazkai (Malhotra *et al.*, 1983). According to Fouad *et al.* (1979) pomegranate fruit dimensions, weight, volume, rind weight and juice content increased for 12 weeks from petal fall in cv. De ha Grenouliere and 16 weeks in cv. Manfaloti under Giza conditions.

Gulhane and Gupta (1974) reported that the growth of guava fruits as judged by its weight and volume showed a steady increase during the entire period of its development until a fortnight prior to full maturity. The increase in weight and volume has been mainly contributed by the increase in moisture percentage and TSS content in fruits. Tripathy and Gangwar (1971) observed in guava that the specific gravity gradually decreased with the advancement of maturity indicating a slight decrease in the solid matter content of the fruits. Fruits having specific gravity of more than 1 were hard in texture, green in colour and fruits with less than 1.0 were soft and light yellow in colour. This indicated a good index for maturity.

According to Munasque (1987) the 'senorita' banana fruit exhibited a sigmoidal growth pattern. Growth was characterized by a slow rate followed by a rapid increase in size, volume, weight of finger, pulp and peel during fruit development.

Irwin mango fruits had a typical single 'sigmoid' growth curve. Fruits reached their maximum volume and fresh weight in 90 days with dry weight continuing to increase until ripe (Wang and Shiesh, 1990). Pandey *et al.* (1973) while studying biochemical changes in the developing mango fruit reported that the fruit weight, volume, length and breadth of the whole fruit continued to increase until the stage of maturity.

The specific gravity of the kazkai lime fruit showed a declining trend from fruit set to maturity. It was highest (1.46) during the second fortnight of the fruit growth and lowest (0.97) at fruit maturity. The decline in specific gravity may be due to the development of air spaces (Hittalmani and Rao, 1976).

As the fruits of three mango varieties viz., Himsagar, Sorikhas and peyaraphuli developed, the weight, specific gravity, total sugar and TSS of the fruits increased with a decrease in acidity (Mazumdar, 1976).

Guava fruits of the vietnamese type showed a 'sigmoid' growth curve. The maximum weight increase occurred between the weeks 10 and 12 (Yusof and Mohamed, 1987).

According to Heikal (1991) the incorporation of bitumen emulsion mixed with moistened sandy soil around pomegranate cv. Manfaloti trees, increased the fruit size, TSS content, total sugars and total acidity.

Singh *et al.* (1988) reported that the fruit size and TSS of pomegranate fruits were greatest in trees receiving the highest NPK rates.

### 1.2.3 Changes in the thickness of rind

Prasanna Kumar (1986) reported that the thickness (0.52) of the rind was maximum at 20 days after anthesis and it declined towards maturity. At maturity the cv. Ganesh had a thickness of 0.34 mm. Saad (1990) reported the growth of rind to be slower in pomegranate fruits exposed to sunlight than those in shade.

The rind thickness in different cvs. of pomegranate ranged from 0.13 mm in cv. Afghan Kandhari seedling to 0.27 mm in Bedana (Malhotra *et al.*, 1983). The thickness of the pomegranate rind cv. Jyothi decreased continuously with advancement of fruit growth till maturity in all the three crop seasons. The rind thickness decreased from 0.39 to 0.26 cm in June-July season, 0.39 to 0.25 cm in the October season and from 0.39 to 0.27 cm in January-March season from set till maturity (Dash, 1983).

The thickness of the rind in lime was maximum (2.7 mm) during the fourth fortnight following the fruit set. Thereafter it declined and at maturity the thickness was 2.0 mm (Hittalmani and Rao, 1976).

### 1.2.4 Changes in fruit firmness

The firmness of the fruit tissue is mainly due to the physical properties of the individual cell wall and the middle Lamella which contain the cementing pectic material.

Shivananda (1993) reported the firmness of pomegranate fruit to be 15.00 kg/cm$^2$ at harvest.

The immature green guava before week 12 had a hard and woody texture. The texture of the fruit decreased gradually on maturity except between weeks 12 and 14. The decrease in texture corresponded with decrease in density of fruit (Yusof and Mohamed, 1987).

### 1.2.5 Changes in rind and aril fresh weight

According to Dash (1983) the weight of aril and rind increased continuously from set till maturity in all the crop seasons. Till the end of first month, the weight of aril and rind were found more or less equal, but from the second month onwards till maturity the rind weight was less than the aril weight in all seasons. Prasanna Kumar (1986) reported a continuous increase in fresh weights of rind and aril. During the first 20 days of growth the rind weight was more as compared to aril. During 20 to 40 days, the weight of rind and aril were roughly balanced. From 40 days till maturity, the weight of aril was more than the rind in all the four varieties of pomegranate. At most of the stages of fruit development the aril constituted about half of the fruit weight.

The newly set fruit consisted mainly of rind portion. As the growth picked up the fresh weight of rind and aril increased continuously till maturity. The sharp increase in aril weight after 60 days is because of development of seed, fleshy aril and juice (Kumar and Purohit, 1989). The percentage of arils and aril : rind ratio increased continuously while the percentage of rind decreased gradually from anthesis till the maturity of pomegranate fruit (Khodade *et al.*, 1990).

During the early stage of fruit development the seed consisted mainly of a soft stone. With continued fruit growth, the stone had stopped growing while the juicy tissue continued to increase and constituted about half of the fruit weight during most stages of fruit development (Shulman *et al.*, 1984). The highest figures for seed weight (g/100 seeds) at maturity of pomegranate fruit was recorded for cv. Anar Shirin-e-Mohamad Ali (25.2 g) and lowest (14.7 g) for cv. Kali Shirin (Malhotra *et al.*, 1983).

In Mango cv. Dashehari, the inedible components such as stone and peel accounted for about 9.4 to 30 per cent of the total weight of the fruit at various stages of its development (Pandey *et al.*, 1973). The weights of rind and pulp in lime increased continuously till maturity according to Hittalmani and Rao (1976).

### 1.2.6 Changes in the Juice content

As the fruit matured the juice content of the seeded and seedless cvs of pomegranate continued to increase upto harvest as a result of increased fleshy aril portion of seeds (Kumar and Purohit, 1989). The increase in the juice content of the pomegranate fruit during development was also reported by Khodade *et al* (1990) and Fouad *et al.* (1979). Gafizov (1991) reported the juice percentage to be lower in small and large fruited types than in intermediate type of pomegranate. According to Shulman *et al.* (1984) from mid July it was possible to squeeze juice from the aril (flowering mid April). Juice content was less than 25 per cent of the total fruit weight at earlier growth period. As the fruits matured the juice content continued to increase upto harvest time. The juice content in 'Mule's Head' reached 35 per cent and 40 per cent and in 'wonderful' 40 per cent and 45 per cent, in the coastal and Bet Shean Valley, respectively.

The juice percentage varied from 62.5 per cent in Surakh Anar to 80.8 per cent in Anar Shirin-e-Mohamad Ali cvs. of pomegranate (Malhotra *et al.*, 1983).

In case of lime, there was no extractable amount of juice in the fruit until fifth fortnight from fruit set. Thereafter the content of juice rose continuously with maturity with some fluctuations and attanied a maximum value of 51.1 per cent at maturity (Hittalmani and Rao, 1976).

### 1.2.7 Changes in the respiration rate

Arie *et al.* (1984) studied the changes in the respiration rate of pomegranate fruits. By following the initial respiration rate of the fruit harvested at various stages of development, a gradual decline in respiration was observed both on the day of harvest and thereafter. The respiration pattern of a mature fruit was the non-climateric type with only traces of ethylene evolved on occasions. According to Shulman *et al.* (1984) no measurable ethylene was found during the second phase of fruit development (mid-Aug. onwards). The respiration of picked fruits, measured as $CO_2$ evolution was low and uniform from July to October.

Alphonso mangoes picked at any stage of maturity starting from fruit set and stored at room temperature show typical respiratory changes characteristic of a fully matured mango. Fruits picked during the earlier and later stages of development show respiration climacteric within 6-10 days. During the middle stages of development the preclimacteric trough continues to extend and the climacteric occurs after 10 days (Lakshminarayana, 1973).

The rate of respiration was high at the early stage of banana fruit development, then it decreased as the fruit matured (Munasque, 1987).

### 1.2.8 Changes in fruit rind - and juice colour

According to Shulman *et al.* (1984) in pomegranate cultivars 'Mule's head' and 'wonderful' of Isreal, fruit colour developed gradually and it served as a criterion for picking. The stage at which 70-90 per cent of the skin is red usually corresponds with a TSS/acid ratio suitable for commercial picking. The variety 'Ganesh' which will be greenish when young, will turn to reddish green when fully matured and will have rough appearance on the skin due to the presence of black dots (Patil *et al.*, 1977). Malhotra *et al.* (1983) while studying varieties of pomegranate revealed that the fruit colour was either pink or rose with varying intensities and all the shades belonged to the standard red colour. The colour of the P-23 pomegranate changed from initial greenish purple to deep pink with reddish and yellowish patches at maturity (Khodade *et al.*, 1990).

The lime fruits were light green at the beginning and yellow at maturity (Hittalmani and Rao, 1976).

The colour of the aril changed gradually from fruit initiation till maturity. The colour of aril was watery white at fruit set and turned deep red at maturity (Dash, 1983). The colour of the pomegranate juice varied from light pink to dark red depending on the cultivar and growing conditions. The colour of the juice is due to the presence of anthocyanins which was more intense in the coastal plain than in the Bet Shean valley probably because of enhanced accumulation of anthocyanins at lower mean temperatures prevailing in the coastal plain (Shulman *et al.*, 1984). Gil *et al.* (1995) studied the changes in pomegranate juice pigmentation during ripening and found that the pigmentation in juice increased with fruit ripening. The concentration of pigments in juice obtained from mature fruits ranged between 50 and 100 mg anthocyanin/g fruit weight of arils. Further, the development of anthocyanins in fruits from different positions in canopy were analysed. The total amount of pigments was smaller in those fruits with reddish skin (outer canopy) than in yellow skin (inner canopy). However fruit rind contained only two anthocyanin pigments (cyanidin and pelargonidin) as against six pigments in the juice.

Kriventson and Arendth (1981) observed that the most intensively coloured juice of pomegranate fruit contained 600 to 765 mg/100 g anthocyanins and the pale juice had about 200 mg/100 g anthocyanins.

### 1.2.9 Changes in the moisture content of the aril and rind

Translocation of water into fruits is greatly influenced by the external environmental conditions as well as the internal physiological status of plants. Climate influences the fruit enlargement by altering the plant water relation. Translocation of osmotically active solutes into the fruits is determined by the water content of the tissue as the tissue water content can alter the sap concentration.

The moisture per cent in aril increased slowly till maturity. It increased from 69.3 to 86.76 per cent in June-July crop, 68.9 to 83.3 per cent in October crop and from 69.4 to 86.5 per cent in January-March, whereas the moisture in rind decreased from 80.2 to 78 per cent in June-July crop, 80.15 to 78.2 per cent in October crop and from 80.4 to 78 per cent in January crop (Dash, 1983). The dry matter content of aril increased continuously till about 50 days in all the pomegranate cvs. and then declined gradually towards maturity. This decline indicates the increase in moisture content of the aril as a result of formation of juice in the fleshy aril. This corroborated the earlier observation of sharp increase in fresh weight of seeds after 60 days (Kumar and Purohit, 1989).

The moisture content of the guava fruits increased rapidly at the earlier stages of fruit set (from week 6 to 8), more gradually between weeks 8 and 14 and then levelled off (Yusof and Mohamed, 1987). According to Gulhane and Gupta (1974) the moisture content recorded in the developing fruits of guava showed fluctuations in two distinct stages.

In the first stage a gradual increase in moisture content was seen upto 45 days followed by a slight decrease upto 60 days after fruit set. The moisture percentage in the fruits again increased reaching maximum 135 days after fruit set. With the rapid increase in fruit size there was greater accumulation of water.

Lakshminarayana and Subramanyam (1966) studied the changes in the dry matter content of the developing 'calcutta round' sapota fruits. Their study revealed that the moisture content of fruit was low in the initial stages of fruit growth and increased thereafter before finally declining as the fruit approached maturity.

## 1.3 CHEMICAL CHANGES DURING FRUIT DEVELOPMENT

### 1.3.1 Changes in total acidity

In a study by Shulman *et al.* (1984) the acid content of the juice decreased with maturation. Acidity in 'Mule's Head' was very low (0.5%) even at early stage of fruit development. In 'wonderful' variety the acidity was very high at earlier stages and even at full maturation, it did not drop below 1.5 per cent in the coastal plain and below 0.9 per cent in the Bet Shean valley. Nerd (1965) showed that the predominant acids in pomegranate juice are malic and citric acids. Lee *et al.* (1974) reported that in pomegranate citric acid was the major organic acid in the fruits at 125 days of growth with succinic, tartaric, fumaric and malic acids also present. According to Dash (1983) the acidity of pomegranate fruit increased continuously with advancement of maturity in all three crop seasons. The highest percentage of titratable acidity (TA) was recorded (1.55%) in January crop whereas it was the lowest in October crop (1.27%). Nath and Randhawa (1959) reported that the pomegranate variety 'Dholka' contained 0.4 per cent, acidity, while Japanese Dwarf and Muscat white contained 0.6 per cent and 0.38 per cent, respectively at maturity. Dastermirov and Babaev (1969) reported the titratable acid (TA) content in two varieties of pomegranate Shirin Anar (0.64%) and Kyzyl-Kabul (1.34).

Malhotra *et al.* (1983) observed acidity ranging from 0.49 per cent to 2.30 per cent as citric acid in pomegranate cvs. of Punjab. According to Arie *et al.* (1984) the level of titratable acidity (TA) varied from one location to another and from one year to the next. As the fruit grew there was a gradual decline in TA content and a concomitant increase in TSS until the 2nd half of September. From this time on the TA and TSS remained at a fairly constant level. According to Kumar and Purohit (1989) the acidity of pomegranate of all three varieties decreased with age and varied from 0.6 to 0.78 per cent. They reported that titratable acidity could be used as criteria for fixing maturity standard and when the fruits of 'Ganesh' and 'Bassin seedless' reached 0.6 per cent, the fruits were ready for harvest.

The decrease in acidity with development of the fruits was also reported by Khodade *et al.* (1990) in pomegranate and in mango by Gangwar and Tripathy (1973), Mazumdar (1976) and Pandey *et al.* (1973).

The acidity in guava gradually increased during the entire period of fruit development (Gulhane and Gupta, 1974), while significant fluctuations was reported by Yusof and Mohamed (1987).

**1.3.2 Changes in the Ascorbic acid (vitamin C)**

Dash (1983) reported that the ascorbic acid increased continuously with advancement of maturity. The highest was recorded in January-March crop i.e., 8.1 mg/100 g and lowest in October crop i.e., 5.8 mg/100 g. Nath and Randhawa (1959) recorded 10 mg/100 g ascorbic acid in Dholka, 15 mg/100 g in Muscat white and 8 mg/100 g in Japanese Dwarf cvs of pomegranate.

The ascorbic acid contents in mango varieties Dashehari and Langra increased with the age of the fruits (Gangwar and Tripathy, 1973). According to Laxminarayana (1973) the ascorbic acid content in the ripe mango fruit showed a slightly higher loss during the ripening of fruits of advanced maturity than in fruits from earlier harvests.

The ascorbic acid contents calculated registered an increase upto 120 days after the fruit set and a successive decrease thereafter in fruits of guava (Gulhane and Gupta, 1974). The variations in its content are accounted to the varying moisture levels recorded in the fruit. The ascorbic acid content in Vietnamese guava showed a 'sigmoid' curve. The rate of increase was slow at the beginning, got progressively faster, and then slowed down again after 14 weeks (Yusof and Mohamad, 1987).

### 1.3.3 Changes in the Total Soluble Solids (TSS)

Dash (1983) reported that at all the stages of development, TSS of the pomegranate fruit cv.Jyothi increased continuously with advancement of maturity in all the crop seasons. The highest TSS (14.5$^{O}$B) was recorded in June-July crop. Shulman *et al.* (1984) reported that in two varieties of pomegranate the TSS of the juice increased gradually during fruit development. At the beginning of harvest in mid August the TSS of 'Mule's Head' variety was 11-14 per cent and reached 14-15 per cent later in September. Variety 'wonderful' reached 13-14 per cent TSS in mid August and 15-16 per cent by the end of September. According to Raturi and Hiwale (1991) the fruits obtained from Hastabahar crop had highest TSS (17.94%) and lowest acidity (0.23%). Arie *et al.* (1984) reported that pomegranate fruits reached horticultural maturity for commercial harvest when its TSS content attained a fairly constant level of 15 per cent and at this time the fruits appeared to be ripe in terms of quality.

The sugar content of the pomegranate juice measured as TSS increased gradually during fruit development. The increase in TSS from 30 to 120 days in 'Ganesh' variety was 3.7 to 8.2$^{o}$Brix (Kumar and Purohit, 1989). The TSS during growth and development of pomegranate increased with advancement of maturity and reached a maximum of 17.70 per cent (Khodade *et al.*, 1990). Nath and Randhawa (1959) recorded 9~~0~~ per cent TSS in Dholka and Japanese dwarf and 10 per cent in Muscat white pomegranate fruits.

Gangwar and Tripathy (1973) observed a little variation but an upward trend during growth and maturity in TSS from 7 to 8 per cent and from 4 to 8 per cent in the 'Dashehari' and 'Langra' mango varieties, respectively. The increase in TSS of mango cvs. Himsagar Sorikhar and Peyaraphuli during development was reported by Mazumdar (1976) and by Manasque (1990) in banana. According to Chongrak (1981) the percentage of TSS was found to be constant from early stage of fruit development till maturity in mango cv. 'Duncan'.

The TSS in the guava fruits increased gradually during the entire period of fruit development, the increase being rapid between 75 to 135 days (Gulhane and Gupta, 1974).

**1.3.4 Changes in the sugar content**

Lee *et al.* (1974) reported in pomegranate that the main sugars present in matured fruits were glucose and fructose and they are present in equal amounts in young fruits and by 125 days after flowering only glucose remained. Malhotra *et al.* (1983) studied different pomegranate cultivars in Punjab and reported that all the varieties studied were higher with reducing sugars. They constituted about 90 per cent of total sugars and non-reducing sugars were less than 1 per cent. High reducing sugars may be attributed to be a genetic characteristic of this fruit.

The reducing and total sugars increased continuously during fruit development and during ripening stage the increase was maximum (Prasanna Kumar, 1986). Khodade *et al.* (1990) reported that as the fruit matured, the total sugars of aril increased gradually. The reducing sugars and total sugars according to Dash (1983) increased with maturity of pomegranate. The reducing sugars increased from 0.099 to 2.55 per cent in June-July crop, 0.097 to 2.471 per cent in October crop and from 0.103 to 2.493 per cent in January to March crop from 30 days old to maturity. The highest total sugars was recorded in January crop (10.13%). The pomegranate varieties Shirin-Anar and Kyzyl-Kabul contained 13.64 per cent and 14.8 per cent sugars respectively at maturity (Dastermirov and Babaev, 1969).

In mango fruit Pandey *et al.* (1974) reported that the concentration of reducing sugars reached a peak at maturity (3.76 g). The level of non-reducing sugars remained lower than that of reducing sugars till maturity. The increase in sugars of mango during development was also reported by Gangwar and Tripathy (1973) in varieties Dashehari and Langra, and in varieties Himsagar, Sorikhas and Peyaraphuli by Mazumdar (1976) and in Guava fruit by Gulhane and Gupta (1974). Total sugars which remained low during fruit development, accumulated towards maturity in banana (Munasque, 1990).

Yusof and Mohamad (1987) reported a linear increase in fructose level of guava fruits with maturity from 6 to 16 weeks and a 'sigmoid' increase in glucose upto week 12 of fruit set with a gradual linear increase thereafter.

## 1.4 QUALITY EVALUATION OF THE POMEGRANATE CULTIVARS

Patil *et al.* (1978) showed that pomegranate cultivar 'Ganesh' had an average fruit weight of 234 g, grain weight of 160 g, and a juice content of 78.7 per cent. The juice had 12.5 per cent TSS, 0.5 per cent acidity, 9.77 per cent sugars and a sugar-acid ratio of 19.54. Chemical composition of three varieties of pomegranate namely Akanar, Nabha and Chawla were studied by Sood *et al.* (1982). According to them; the varieties studied contained 58.32 per cent edible portion, 5.60 to 7.72 mg/ 100 g of ascorbic acid, 0.44 to 0.47 g total acidity, 6.24 to 9.0 per cent total sugars of which 5.60 to 7.53 per cent was reducing and 0.12 to 3.34 per cent non-reducing sugars. Variety chawla was found to be superior to Akanar and Nabha with respect to nutritive value.

Screening the quality of different pomegranate cultivars grown in Punjab have been made by Malhotra *et al.* (1982). They observed that TSS varied from 9.2 to 12.3 per cent, total sugars from 5.2 to 10.6 per cent, reducing sugars from 5.7 to 10.2 per cent, acidity from 0.62 to 2.26 per cent and ascorbic acid varied from 6.15 to 8.57 mg/100 ml juice. Mishra *et al.* (1983) screened different cultivars of pomegranates grown in Garhwal hills and found a variation in TSS from 11.5 to 13$^{o}$Brix, acidity from 0.4 to 2.73 per cent, sugars 6.75 to 10.4 per cent and ascorbic acid from 8.08 to 12.6 mg/100 mg juice. El-nnemr *et al.* (1990) analysed pomegranate fruits for various chemical constituents and found that the edible part of pomegranate fruit represented 82 per cent of the total fruit weight comprising of 78 per cent juice and 12 per cent seeds. The juice had 10.67 per cent total sugars, total acidity of 0.1 g/100 ml and 0.7 mg/ 100 ml of ascorbic acid. According to Leena Borah (1990) pomegranate cv. 'Ganesh' had 23.3 per cent outer rind, 8.5 per cent placenta, 68.3 per cent grains,

$12^{o}$Brix TSS, 0.31 per cent acidity and 2.95 pH. Juice was also moderately a good source of sugars (10.56%) and ascorbic acid (2.2 mg %). Jagtap *et al.* (1992) assessed the quality of twenty-nine cultivars of pomegranate, both indigenous and exotic types grown under semi-arid conditions. The average fruit weight varied from 62.8 g in Bedana to 214.2 g in G-137. Accordingly 10 cultivars had small fruit size, twelve had medium and seven had big sized fruits. Eighteen cvs. had the aril percentage of more than 64 indicating that more than 50 per cent of the cultivars had high edible portion. All the temperate zone cultivars had less juice content (50%). 'Ganesh' and 'P-26' were the best among them.

Purohit (1986) tested the three varieties Ganesh, Muskat and Alandi for soft seededness and found that Ganesh was the best soft seeded cultivar. Siddappa (1943) reported that the most popular 'Kandahar' pomegranate variety had large juicy grains yielding a rich purplish red juice with a mild acid-sweet taste. Cemeroglu *et al.* (1988) reported that depending on the cultivar the juice yield varied from 29-60 per cent. Dong and Yang (1994) reported that 'Tiepitian' a popular pomegranate variety with 500 g weight had good storage life. The fleshy arils, were bright red, large and juicy with TSS of 14-15.5 per cent. Ewaidah (1987) reported that the moisture, fibre, ash -and juice content of pomegranate were similar with other reports and the pulp was rich in P and K but low in Na, Ca, FC, Mg, Mn, Zn and Cu. According to Godara *et al.* (1989) Chawla and Nabha were the best dessert cultivars, having large fruit size, soft to medium hard seeds, high TSS and average juice and acidity. The cultivar Dholka was best for processing. The varieties Duo Hong, Duo Qing and Duo Bai produced high quality fruit with attractive appearance, large seeds and a high sugar content. Shi (1991) reported Taishan Dahongshiliow to be a top quality pomegranate with high TSS of 17-19 per cent with acidic sweet taste and a very juicy aril.

Sayed *et al.* (1985) recorded 63.76 per cent edible matter, 37.24 per cent rind, 74.8 per cent juice, 9.1 to 15.2$^{O}$B TSS and 15.5 mg per cent Vitamin C in ycd-1 pomegranate cultivar.

## 2. STORAGE OF FRUITS

The objective of successful storage is to enhance the shelf life of fruit by retarding the biochemical changes, reducing the microbial spoilage with retention of fruit quality. Several methods such as skin coating, chemical treatment, fungicidal treatment, packaging in film bags are used to enhance shelf life. Fruits are living commodities which are affected by temperature. Low temperature storage of fruit is a proven method for enhancing the shelf life by retardation of chemical reaction and also of microbial activity. Fruit and vegetables, when stored at low temperature maintain good appearance, flavour, taste, colour and texture for a long period.

Fruits may be subjected to chilling injury when exposed to very low temperatures nearing freezing point. However manifestation of this injury is dependent on variety and time of exposure. Precooling of the produce after harvest, maintenance of optimum relative humidity, proper maintenance of optimum low temperature are essential to have the advantage of cold storage (Shanmugavelu, 1987).

## 2.1 INFLUENCE OF POST-HARVEST TREATMENTS ON SHELF LIFE

(Skin coatings, wax emulsion, chemical and fungicides)

The post harvest spoilage in pomegranate is mainly caused by incipient infection of fungi from the field or by saprophytic fungi developing in transit and storage. This fungal spoilage results in undesirable changes in quality and appearance of the fruit. The important fungus infecting the fruits was the *Aspergillus* sp. (Padule and Keskar, 1989). They reported that the treatment of fruits with topsin (0.1%), bavistin (0.05 and 0.1%) and water dipping inhibited the growth of fungi and enhanced the storage life. Susama Philip (1979) observed a serious rot of pomegranate fruits during storage. She isolated the spoilage organism by artificial inoculations on injured fruits to establish the pathogenicity. Based on the symptoms and morphological and cultural characteristics after 8-10 days it was identified as *Aspergillus niger*. According to Srivastava and Tandon (1979) the disease starts in form of a brownish discolouration. Gradually it become blackish and little slimy. Heikal *et al.* (1966) reported that, pomegranate fruits washed and treated with a solution of 2 per cent and 4 per cent borax could be stored for two months at room temperature without any deterioration in quality. Kanwar and Thakur (1972) stated that packing fruits in straw sprayed with 5 per cent solutions of ammonium bicarbonate/ ammonium chloride/diphenylamine/sodium metabisulphite/ potassium metabisulphite or sulphur, either immediately or after inoculation with *Rhizobium arrhizus* or after an incubation period to establish infection indicated that sulphur compounds gave the highest percentage of fruit protection in both the cases and relatively good control of disease intensity. In 1977, they showed that, fruits treated with Borax and sodium metabisulphite, each at 3 per cent level gave satisfactory control against storage diseases. In 1973, they reported that 2-4-D at 500 ppm as post-infection dips gave 100 per cent protection against the disease during storage. Shekar (1979) revealed that bavistin (0.05%) benlate (0.05%) and dithane Z-78 (0.25%) effectively reduced the disease index caused by *Aspergillus niger* during storage.

Bacha and Ibrahim (1979) reported that pinolene as vapourguard at 2.5 per cent applied to pomegranate (cvs. Banati and Manfaloti) fruits helped in reducing fruit splitting and the treatment had no appreciable effect on chemical composition of the fruits. According to Sonawane (1986) the chemicals dithane Z-78, dithane M-45, potassium metabisulphite and captan effectively restricted the post harvest rot of pomegranate in range of 57.24 to 49.04.

Certain post harvest measures like dipping the fruits of pomegranate in boiling water for 2 minutes and in an anti-oxidant solution like bisdithiocarbonate containing maneb for 30 seconds reduced the scald incidence in cv. 'wonderful'. But storing the late harvested fruits in 2 per cent oxygen at 2$^{\circ}$C was found to be the most effective control measure (Arie and Or, 1986). Onur and Ari (1986) observed that under ordinary storage conditions waxol treated pomegranate fruits (cv. Gok Baghe) showed the maximum weight loss. Treglazova and Fataliev (1989) reported that in six cultivars of pomegranate, calcium chloride treatment ranging from 2 to 4 per cent was beneficial for storage upto 110 days and higher concentrations damaged the fruit.

GokBaghe fruits of pomegranate treated with antitranspirant (plant guard) and fungicide were stored at 1°, 5° or 10°C for 4 months. Weight loss was the lowest after 4 months of storage (6.2%) in fruits treated with plant guard and stored at 1°C (Koksal, 1989). At room temperature (25°C) and low temperature (8°C) fruits of pomegranate treated with waxol showed less spoilage (Shivananda, 1993). According to Joarder (1980) waxing of mangoes increased the shelf life and prevented the weight loss significantly but maleic hydrazide failed to retard spoilage. Simple hot water treatment had the marked effect to reduce the spoilage.

The suitability of wax emulsion to extend the shelf life of banana was studied by Shaikh *et al.* (1991). The coating reduced gaseous exchange between the fruit and the outside atmosphere and lost less weight. The treated bananas had a good taste after ripening without any unpleasant flavour.

**2.2 INFLUENCE OF FILM PACKAGING ON SHELF LIFE**

Since the early 1980's many studies have been conducted to explore the benefits of wrapping the fruits to modify the internal atmosphere so as to extend the shelf life. Film wrapping reduces moisture loss, retards softening and maintains firmness and internal quality during extended periods of storage.

Sadasivam *et al.* (1972) stated that polythene film checked weight loss but promoted decay and this disadvantage was overcome by use of perforated polythene. Pota *et al.* (1981) reported that the storage life of pomegranate (cv. Banluang) sealed in polythene bags and stored at $10^{o}C$ was extended upto 12 weeks with slight changes in quality. They also showed that pomegranate fruits placed in plastic baskets and held at room temperature for one week showed severe shrivelling and those placed in sealed polythene bags were rotten. Heikal *et al.* (1966) reported that pomegranate fruits treated with wax emulsion and wrapped in tissue paper reduced fruit weight loss significantly and weight loss was greatest at the higher temperatures.

According to Andres (1984) the mango fruits stored in fully sealed plastic bag showed the least weight loss percentage during the 42 days, however, fruits stored in perforated plastic bags had higher marketable fruits at the end of storage.

With cold storage individual wrapping reduced chilling injury in grape fruits (Miller and Risse, 1988). The use of fungicides coated onto films may provide a partial control for some types of decay. Joshua and Sathiamoorthy (1993) packed sapota fruits (cv.Pala) in polyethylene bags of 100, 150 or 200 guage and with 0, 0.2, 0.4 or 0.6 per cent perforation and stored them at ambient conditions (26-30°C and 50-60% RH) for 6 days. They found that percentage spoilage was lowest (30.1%) in bags of 100 guage and 0.4 per cent perforation and highest (98%) in the unperforated bags. The high percentage of spoilage in the unventilated bags was attributed to excessive accumulation of moisture leading to enhanced fungal growth.

Mature green mango fruits wrapped in PVC films of different gauges were stored at 10, 12°C and at room temperature (31°C). The maximum storage life of fruits held at ambient temperature was 12 days regardless of whether wrapped or not. There was no difference in firmness between wrapped and non-wrapped fruits (Ketsa *et al.*, 1992).

According to Shivananda (1993) at both room temperature and low temperature storage conditions, pomegranate fruits kept without wrapping showed desiccated appearance, had an acceptable colour, flavour and taste, while that of fruits wrapped with film showed good colour, freshness taste and flavour.

**2.3 INFLUENCE OF TEMPERATURES ON SHELF LIFE**

According to Mukerjee (1958), pomegranate fruits can be stored at 0 or 4.5°C with 80 to 85 per cent RH upto seven months without evidence of any spoilage or shrinkage. Heikal *et al.* (1966) reported that pomegranate fruits were kept well for 2 months at 32°F irrespective of waxing and wrapping.

According to Lloyd Ryall and Pentza (1974) pomegranate fruits are well adopted to cold storage conditions. They stated that at a temperature of 0°C with 90 per cent RH, fruits remain in marketable condition for atleast 8 to 9 weeks. Kader *et al.* (1984) studied the effect of temperature and duration on storage of pomegranate. They concluded that the fruits can safely be stored at 5°C for upto two months but for longer storage, 10°C appears to be the minimum safe temperature. Lutz and Hardenburg (1968) recommended 0°C with 90 per cent RH to keep pomegranates in good condition upto 4 months. Sulunke and Desai (1986) suggested storage temperature of 0 to 1.7°C with 85 to 90 per cent RH for storing 'Khandhar' pomegranate fruits for 11 weeks. Saxena (1987) reported that pomegranate fruits stored at 0°C and 4.5°C at 80-85 per cent RH did not undergo any shrinkage or spoilage for seven months. Koksal (1989) observed some diseases and physiological damages by storing pomegranate fruits (cv. Gor Baghe) at 1°C for 60 days while at ambient-storage conditions, skin dehydration was noticed. Hassan (1992) reported that partial drying of fruits at 20, 30 and 40°C with varying relative humidities, prior to storage showed that drying at 20°C with 47 per cent RH had high fungal decay while those dried at higher temperatures did not. Partial drying and storage was reported to be good for processing purposes.

Elyatem and Khader (1984) revealed that storage of pomegranate at 5$^{o}$C or lower resulted in symptoms of chilling injury produced as brown discolouration of skin, surface pitting and susceptibility to decay organisms. The severity of these symptoms increased with time and temperature decrease. During storage at 5$^{o}$C for 8 weeks, a slight brown discoloration of the locular septa was observed with only little changes in the composition of the fruits upto 3 months of storage. Onur and Ari (1986) showed that, pomegranates are susceptible to chilling injury if stored longer than one month at temperature of -3 to 5$^{o}$c. The minimum safe temperature for storage upto 2 months was 5$^{o}$C but for longer storage fruits should be kept at 10$^{o}$C to avoid chilling injury. Arie and Or (1986) reported the non-occurance of browning disorder (scald) in pomegranate cv. wonderful fruits stored at 0$^{o}$ to 6$^{o}$C upto 6 months. Kokal (1989) observed some diseases and physiological damages by storing pomegranate fruits (cv. Gok Bahge) at 1$^{o}$C for 60 days while at ambient storage condition skin dehydration was observed. According to Shivananda (1993) the maximum extension of shelf life of pomegranate at room temperature was for 3 weeks in fruits wrapped with film and at low temperature it was 10 weeks.

Eris and Turkben (1989) reported that the grapes stored at $0^{o}C$ and 90 to 95 per cent RH had their storage periods varying from year to year and cultivar to cultivar. It was shortest (8 weeks) in cv. 'cardinal' and longest (20 weeks) in cv. 'Muskule'.

According to George and Marriott (1985) who studied the effect of temperature on chilling injury of banana reported that the chilling damage was seen in all the cvs. at $6^{o}$ and $10^{o}C$ and it was found to be earlier at $6^{o}C$ than at $10^{o}C$. The severity of the chilling damage also increased with decreasing temperature and within the same storage temperature with increasing storage period.

Ramana *et al.* (1984) reported that low temperature storage of mangoes reduced the development of carotenoids even after ripening at room temperature. The occurrence of chilling injury was higher in fruits having higher TSS content at the time of storage at low temperature. Thus they were of the opinion that longer storage of the fruits at low temperature definitely reduces the overall quality.

According to Hewelt *et al.* (1989) loss of green colour in granny smith apples after 8 weeks of storage was strongly temperature dependent with almost complete yellowing occuring at 15 - and $20^{o}C$ and none at $0^{o}C$. Over wrapping trays of fruits with PVC film created modified atmosphere and prevented yellowing at all temperatures.

Joarder (1980) studied the effect of low temperature on prolongation of shelf life, he concluded that, mango cvs. 'langra' and 'Fazli' could be stored for one month successfully at temperature 1 to 12°C. Ji-Zl *et al.* (1994) reported that Mango cv. 'Zi Hua' stored at 2, 5, 8°C developed chilling injury after 15 days at 2°C, and after 34 days at 5°C. The injury was not observed in fruits stored at 8°C. Passam (1982) studied the storage potential of some mango cultivars. He found that at ambient temperature (28-32°C) the fruits could be stored for 3 to 8 days. At 14°C storage life was increased to 18 days. Enclosure of fruits individually in polythene bags increased storage life at both the temperatures, while treatment with 3 per cent sta-fresh wax increased storage at only ambient temperature.

Pineapple fruits harvested at different stages of development were stored at 2, 4, 6, 8, 10 and 12°C for 1 month and then held at 21°C for 4 days by Swarus (1990). Chilling injury occured at temperature less than or equal to 10°C and was more severe in the lowest temperature and internal browing was worst in the less mature fruit.

When bread fruits were individually packed in polyethene bags its storage life was 5 days at 28° when compared to non-packaged fruits which stored only for 2-3 days. Weight loss, shrinkage and softening were less in fruits stored at 8, 12 or 16°C than at 28°C. Packaging in combination with cold storage further reduced metabolic activity (Maharaj and Sankat, 1990).

**2.4 CHANGES IN PHYSICO-CHEMICAL CHARACTERS DURING STORAGE**

Since pomegranate fruits do not show a climacteric rise in respiration during post harvest storage, most of the biochemical changes takes place on the plant itself, that is prior to harvest. Hence post harvest changes during storage are minimum.

According to Padule and Keskar (1989) in pomegranate cv. 'Ganesh', post harvest losses in weight were primarily due to the weight losses in peel tissues. Elyatem and Kader (1984) reported that pomegranate are susceptible to water loss and should be kept under 95 per cent or higher relative humidity. Their apparently tough skin has numerous openings that permit free water vapour movement. Kader *et al.* (1984) reported in pomegranate (cv. Wonderful) fruits weight loss increased with increase in storage temperature (0-10°C) and duration of storage (4-16 weeks). Heikal *et al.* (1966) reported that pomegranate fruits waxed and wrapped in tissue paper showed no significant changes in TSS but there was a slight decrease in ascorbic acid content during prolonged storage and an increase in total sugars. Koksal (1989) stated that the rate of increase in weight loss varied depending on the storage duration and temperature. Weight losses at 1, 5, 10°C temperatures and at ambient storage after two months were found to be 4.9, 5.7, 4.6 and 8.2 per cent, respectively.

Lee *et al*. (1974) stated that pomegranate fruits showed a non-climacteric pattern of respiration and it decreased continuously during storage. According to Elyatem and Kader (1984) pomegranate cv. 'Wonderful' showed low respiration rate and traces of ethylene during storage. They did not observe any change in skin colour, juice colour and composition of fruit. Changes in soluble solids content during storage at 0, 10 or 30°C for upto 10, 6 or 1 week(s), respectively were not significantly different.

## 3. HISTOLOGICAL AND HISTOCHEMICAL CHANGES DURING GROWTH, DEVELOPMENT AND STORAGE OF FRUITS

Griffiths (1935) studied the structure of pomegranate rind of fresh fruits and dried fruits. He observed that both types of materials showed a similar cellular structure. The outer epidermis shows a few stomato and beneath it are rows of collenchymatous cells, the remainder of the tissue consists of a thin-walled parenchyma through which run fibrovascular strands. Numerous scattered groups of selerenchymatous cells are embedded in the parenchyma, many of the cells of which contain starch and calcium oxalate.

The outer walls of the outer epidermis are cutinised, but the inner walls are composed of cellulose. The collenchymatous tissue shows occasional intercellular spaces, but there are neither stone cells nor fibrovascular strands in this tissue.

Small areas of the cortical tissue contain starch grains which occur loosely packed in the cells. The sclereids occur singly and/or in groups and are very irregular in shape and size.

The ostioles vary in size and in some cases the stoma is replaced by a large opening, the guard cells having disappeared and the surrounding cells then contain a brownish pigment. Sections of the dried material exhibited bright yellow plates and masses of tannin filling the cells.

Prasanna Kumar (1986) studied the histology of the developing seed of soft-and hard seeded varieties of pomegranate. He found that ten days after fruit set the seed size of soft seeded varieties 'Ganesh' and 'Bassein seedless' was less as compared to hard seeded varieties 'Alandi' and 'Kabul yellow'. At 120 days after fruit set the seed size (including aril portion) in soft seeded varieties was more as compared to hard seeded varieties. Among the seven commercial pomegranate varieties studied for their soft seededness, varieties 'Bedana', 'Bassein seedless', 'Ganesh' and 'Dholka' were considered soft seeded. They had testa thickness < 0.5 mm, whole seed density < 0.06 g/ml, testa density < 0.4 g/ml and testa weight < 50 per cent of whole seed weight (Purohit, 1985).

Roth and Lindorf (1972) distinguished the citrus fruit parts as an exocarp or flavedo, mesocarp or albedo and an endocarp. The cells of epicarp were approximately isodiametric and polygonal except directly above the oil gland.

In plants, there is an epiculticular waxy layer super imposed on the cuticle to minimise water loss (Martin and Juniper, 1970). Miller (1982) reported that there was a good correlation between the development of cuticle and general fruit growth.

Saini *et al.* (1972) observed in a histochemical study of 'Dashehari' and 'Chausa' varieties of mango that the starch grains were major cell constituents of mesocarp after 60 days of fruit set. Further, they reported that the number of starch grains per cell increased upto maturity which might be accounted for increase in fruit weight. Shantha Krishnamurthy and Joshi (1989) observed that the epicarp of the mature Alphanso mango fruit had a thick waxy cuticle which became thinner during ripening when fruits were stored at 30$^{o}$C for 15 days. The reserve starch in mesocarp cells degraded almost completely by 15th day during storage with increased sugar content. Parikh *et al.* (1990) during their studies on structural changes in ripening mango reported that cells in the pulp of Alphanso mango fruit were large and parenchymatous in nature and lose their integrity at ripe stage due to cell hydrolysis. They contained abundant amount of polysaccharides consisting of mainly starch which degraded during ripening. Fruits from several plantain and cooking banana cultivars were assessed for their stomotal size and densities and these variations were related to weight loss during the post harvest period. There was no correlation between weight loss and the density or the size of the stomata on the fruit peel (Burdon *et al.*, 1993, 1994). Collin and Folliol (1990) examined the epidermis of plantains before and after storage. When plantains were kept at 100 per cent RH for 12 hours the stomata closed, indicating that stomatal closure alone was not a reliable guide to moisture stress within the fruit.

Rosenquist and Morrison (1989) studied the factors affecting the accumulation of culticle on berries. Factors investigated include cultivar, sun exposure and irrigation rate. Berries from clusters that developed in the canopy shade had less cuticle per unit surface area than berries from clusters developing in sun exposed positions.

Knecowaan tangerines with thin and thick peel were stored separately in open plastic baskets at ambient temperature and it was observed that thick peel fruits had significantly greater peel fresh weight, peel thickness and number of stomata. It is suggested that the thickness of the flavedo and the number of stomata are the major factors affecting weight loss (Ketsa, 1990).

Eight growth stages of granadilla during fruit development corresponding to following fruit sizes 6, 10, 18, 22, 30, 40,60 and 80 mm diameter studied for their anatomy. Continuous division occured in cells of the parenchyma and external epidermis during the first three stages. Maturation started at fourth stage and the placenta began to fill the locules and surround the seeds. At the eighth stage, the aril was observed originating from a thickening of the apex of the funiculus. All the processes occuring during fruit development influenced the final fruit shape and organoleptic characters (Mortenegro de Carrillo, 1988).

Apple cv. Jonagold harvested from intervals May-September and tissue samples taken from just beneath the skin, from the middle part of flesh and from near core was studied for their starch content by Ohmiya and Kakivchi (1990). Starch content was higher and showed a lower rate of decrease in the outer part of flesh than the inner part and middle parts. The granule size distribution in the different parts of the fruit did not change during fruit development.

Rotaru *et al.* (1989) studied the anatomy of apple varieties 'Tirol'ka Belaya Obhyknovennaya', 'Triol'ka Krasnaya Tsyganka Moldavskaya', 'Tsyganka Seraya' and 'Tsyganha Alaya'. The varieties had some features in common but there were differences between varietal groups and between varieties even within varietal groups. For eg. in the Tsyganka group the hypodermis of T'Alaya consisted of 1-2 cell rows and that of T'seraya and T'Moldarskaya of 4-5. The anatomical differences reflected differences in keeping quality which was better in Tirolka Belaya than Tirol'ka Krasnaya and better in Tsyganka Moldavskaya and Tsyanka Seraya than Tsyganka Alaya.

Histochemical techniques for localizing catecholamines were used on sections of ripening banana in order to identify the substances which causes browning. Fruits may discolor following mechanical injury and enzymatic browning of injured plant tissue has been attributed to tannins, a group of phenolic compounds. It is suggested that browning of ripening banana occurs during an increase in cell permeability which allows dopamine and polyphenol oxidase to react (Weaver and Charley, 1980).

Ultrastructural modifications due to aging in Golden Delicious apples during 7 months of storage was studied by Barsy *et al.* (1989). At harvest, the cells of the skin were healthy whereas flesh cells had already begun to age. After 3 months, the loss in the plastidial volume was 43 per cent in flesh cells. After 7 months in the flesh only a few mitochondria, fragments of membranes could be recognised.

# MATERIAL AND METHODS

# MATERIAL AND METHODS

The present study on growth, development and storage of pomegranate fruit cv. Ganesh was conducted in Post-harvest Technology Division of Indian Institute of Horticultural Research (IIHR), Bangalore, during the years 1994 and 1995. The investigations on histological changes of pomegranate fruit during growth and storage was carried out at Department of Botany, G.K.V.K., Bangalore, during the year 1995. Pomegranate fruits were collected from the experimental farm at Hessaraghatta for studies on changes in growth and development for Bangalore crop during 1994 and 1995 and a farmers field in Bagalkot for Bijapur crop during 1995. The meteorological data during the growth of the fruit in Bangalore and Bijapur conditions for the year 1995 are given in Appendix I and II respectively.

## 3.1 DETAILS OF THE EXPERIMENTAL MATERIAL

Twenty plants of pomegranate fruit cv.Ganesh were selected in one block at I.I.H.R. experiment station. The plants were 10 year old and received uniform cultural practices like irrigation, manuring and plant protection measures. The plants in the farmer's field at Bagalkot (Bijapur) were five year old, well maintained with similar cultural practices.

**Plate 1 :** Pomegranate cv. Ganesh at fruitset stage grown under Bangalore conditions.


1

For storage experiments the fruits grown around Bangalore and Bijapur areas were procured from HOPCOMS within 24 hours after harvest during the peak harvesting period.

### 3.2 DETAILS OF THE EXPERIMENT

#### 3.2.1 FRUIT GROWTH AND DEVELOPMENT

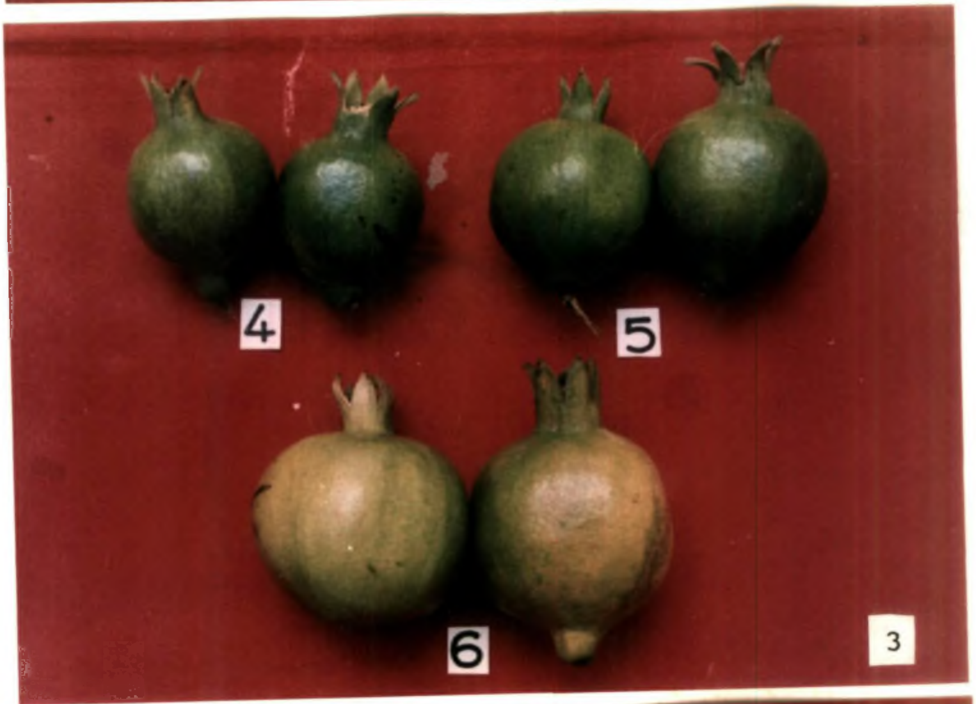
Even though pomegranate flowers thrice in a year, the number of flowers during January to February (Ambebahar) is maximum and is considered as the main flowering season. About fifty flowers from each of the twenty plants grown at IIHR were tagged on the day of fruit set which is indicated by the drying of stigmatic surface (Plate 1). Samples were collected periodically from these tagged fruits. For samples from Bijapur area, fruits at different development stages of growth were collected at once and bought to the laboratory. They were graded into different stages based on the size and taken for analytical studies.

#### 3.2.2 METHOD OF FRUIT SAMPLING

Ten fruits were randomly selected at Stage 1 (at fruit set), stage 2 (5 days after fruit set) stage 3 (10 days after set), stage 4 (15 days after fruit set) and subsequently at fortnightly interval upto stage 10 (At harvest) to study the physical characters. For changes in chemical composition fruits were sampled from stage 4 at 15

**Plates 2, 3, 4 :** Pomegranate cv. Ganesh at different stages of development grown under Bijapur conditions.


1
2
3
2


4
5
6
3


7
8
9
4

days interval upto 105 days (stage 10). The fruit samples of eight in each stage were collected in a polythene bag and brought to the laboratory for analysis on the same day.

Grading of pomegranate fruits from Bijapur into different stages of growth was decided based on the fruit diameter. They were as follows (Plates 2, 3 and 4):

Stage 1 (5.67 mm), stage 2 (8.17 mm),stage 3 (14.13 mm), stage 4 (19.73 mm), stage 5 (36.25 mm), stage 6 (67.72 mm), stage 7 (82.52 mm), stage 8 (97.63 mm), stage 9 (113.07 mm) and stage 10 (At harvest). Each stage consisted of eight fruits. Fruits at all the stages of growth (i.e. 1-10) were analysed for the physical parameters and chemical analysis was done from stage 6 onwards.

The details of physical parameters and chemical analysis recorded were as follows.

#### 3.2.2.1 Length and breadth

The length of the fruit from calyx end to the apex and the diameter at the equatorial plane were measured in centimeters using a vernier calipers.

#### 3.2.2.2 Fresh weight

With a help of an electronic balance the fresh weight of the fruit was recorded in grams.

### 3.2.2.3 Volume and specific gravity

The volume of the fruit was determined by the water displacement method in milli liters (ml) using a measuring jar and the specific gravity was calculated by dividing the weight of the fruit from the volume of water displaced.

### 3.2.2.4 Rind thickness

The thickness of the rind was measured in millimeters in the rind removed from the middle portion of the fruit using a vernier calipers.

### 3.2.2.5 Firmness

Before the fruits were cut for chemical analysis, the firmness of the fruit was measured using Instron Model 4201. A plunger of 10 mm diameter was used for puncturing at a speed of 100 mm/minute. The firmness was expressed as $Kg/cm^2$.

### 3.2.2.6 Fresh weight of the rind and aril

The rind and aril were carefully separated and their fresh weights were recorded in grams using an electronic balance.

### 3.2.2.7 Juice content

Aril from each fruit was pressed in a muslin cloth to extract the juice and it was measured in a measuring jar. The results are expressed in millilitres. The juice could be extracted only after 45 days after fruit set (Stage 6) in fruits grown in Bangalore and from 6th stage (67.72 mm diameter) in fruits from Bijapur crop.

**3.2.2.8 Seed weight (Residue)**

After the extraction of juice, the left over residue was weighed in an electronic balance. The weights are recorded in grams.

**3.2.2.9 Respiration rate**

For measuring the rate of respiration either a group of five fruits or individually depending on the size, were enclosed in one litre air tight container for one hour and the gas sample was analysed using a GC model HP 5890 series having a poropak Q column with TCD dectector using nitrogen as the carrier gas at a flow rate of 30 ml/minute. The per cent $CO_2$ was calculated with simultaneous running of standard $CO_2$ gas. The rate of respiration was calculated using the formula:

$$\frac{\text{Density of } CO_2 \times \% \; CO_2 \text{ in sample} \times \text{Volume} \times 60}{\text{Weight of sample (kg)} \times \text{Enclosing time (min.)} \times 100}$$

and expressed as mg $CO_2$/kg/hr.

**3.2.2.10 Juice colour**

Five millilitre of the extracted juice was taken in a 50 ml conical flask and diluted with water in the ratio of

1:4. It was mixed and the colour intensity of the diluted juice was observed at 510 nm using a spectronic 1201.

**3.2.2.11 Rind moisture**

Five grams of the rind was weighed in a petridish and dried in a hot air oven at 60°C for constant weight and the percentage of moisture was calculated.

**3.2.2.12 Total titratable acidity**

Until the juice could be extracted from the arils, five grams of the aril was weighed, macerated and transferred to volumetric flask. The volume was made upto 50 ml with water and filtered. Five ml of the filtrate was titrated against 0.1 N sodium hydroxide solution using phenolpthalein indicator.

When the juice was extractable from the aril, five ml of juice was taken in a volumetric flask and made upto 50. Five ml of filtrate was used for titration. The acidity was expressed as per cent citric acid/100 ml.

**3.2.2.13 Ascorbic acid (Vitamin C)**

Using 0.4 per cent oxalic acid, five grams of the crushed aril/extracted juice was taken in a volumetric flask, made upto 50 ml and filtered. Five ml of filtrate was titrated against the standard 2, 6, dichlorophenol indophenol dye. The ascorbic acid was expressed as mg for 100 ml of the juice.

**3.2.2.14 Total soluble solids (TSS)**

The TSS of the juice was recorded using a Erna hand refractometer (0-32) and expressed as degree Brix ($^{O}$B).

**3.2.2.15 Total - and reducing sugars**

At the earlier stages of fruit development i.e. at Stages 4, 5 and 6 (15, 30 and 45 days after fruitset, respectively) in Bangalore grown fruits and the stages 4 and 5 in fruits from Bijapur area, total and reducing sugars were estimated by the method of Shaffer Somogyi as described by Ranganna (1977).

Sugars were estimated by macerating 10 grams of the aril and transferring into a 250 ml volumetric flask. Two ml lead acetate was added to it. Excess lead was precipitated with 22 per cent potassium oxalate. The volume was made up with distilled water and filtered.

**i) Reducing Sugars**

Five ml of the filtrate was pipetted into a 25 x 200 ml test tubes. Five ml of Shaffer Somogyi reagent was added to it and heated in a boiling water bath for 15 minutes. The tubes were then cooled in running water. Two ml of iodide-oxalate and three ml of 2N $H_2SO_4$ were added from the sides of the test tubes and placed in cold water for five minutes with gentle mixing. This was then titrated with 0.05 N thiosulphate solution using starch as indicator. A suitable blank with water was also taken. The titre value of the test solution was substracted from that of the blank. Based on the titre value the sugars was calculated with reference to standard and expressed as percentage reducing sugars.

**ii) Total reducing sugars**

Twenty five ml of the filtrate from the sample was acidified with 10 ml of hydrochloric acid (1+1) and allowed to stand at room temperature for 24 hours for inversion. The solution was then neutralised with 20 per cent sodium hydroxide solution using phenolpthalein indicator. The volume was made upto 50 ml. This solution was used for estimating total sugars as in the case of reducing sugars. This was expressed as per cent total reducing sugars.

In stages of fruit where the juice could be extracted, sugars were estimated in the juice only.

Ten ml of juice was taken in a volumetric flask and made upto 250 ml with distilled water and filtered. The filtrate was used for estimating reducing sugars by the method of Lane and Eynon as described by Ranganna (1977). The reducing sugar content was expressed as per cent reducing sugars.

Total reducing sugars were estimated in the juice by acidifying 10 ml of the filtrate and hydrolysing it for 24 hours at room temperature. This was made up to 50 ml after neutralising and total reducing sugars were estimated by Lane and Eynon method. It was expressed as per cent total sugars.

### 3.2.3 STORAGE OF FRUITS

#### 3.2.3.1 Selection of fruits

Fully mature ripe, pomegranate fruits of uniform size grown in two areas (Bangalore and Bijapur) were collected from HOPCOMS, Bangalore, within 24 hours after harvest for storage studies. Maturity of the fruit was decided by the reddish yellow colour of the rind with waxy shining, opening of the calyx, uniformly deep red coloured, soft and juicy arils with high sugar content and freshness of the fruit. Fruits were brought to the laboratory, sorted and uniform sized fruits were selected. Deformed injured, diseased and bruised fruits were discarded.

#### 3.2.3.2 Treatments

The treatments were as follows:

1. **Untreated (control)**
2. **Pre-cooled**

   The temperature of the fruit was brought down from 25$^{\circ}$C to 8$^{\circ}$C by dipping the the polybag packed fruits in ice cold water at 2$^{\circ}$C for about 4 hours.

3. **Semperfresh**

Two per cent semperfresh solution was prepared by adding 1000 ml of water to 20 grams of semperfresh powder. The mixture was continuously stirred in a magnetic stirrer to get a uniform suspension. Fruits were then dipped in this for 5 minutes and air dried.

4. **Film wrap of individual fruit with BDF2001 (Trade Name)**

Individually fruits were sealed in small pouches of cryovac film (BDF 2001) of 100 guage thickness obtained from U.S.A. and passed through shrink tunnel at $350^{\circ}F$ for 15 seconds for shrinking.

5. **Film wrap of individual fruit with D955 (Trade Name)**

Individually fruits were sealed in small pouches of cryovac film (D 955) of 100 guage thickness obtained from U.S.A. and passed through shrink tunnel at $350^{\circ}F$ for 15 seconds for shrinking.

Fruits were divided into lots of 8 fruits per replicate. Three replications were used for each treatment.

#### 3.2.3.3 Storage temperatures

A preliminary study in cv. 'Ganesh' for fixing the optimum low temperature for maximum shelf life was carried out by storing the fruits at 5 to $8 \pm 1^{\circ}C$. The fruits developed chilling injury after 3 to 4 weeks (Plate 5) and could not be stored at $5^{\circ}C$ for longer period. The fruits kept at $8 \pm 1^{\circ}C$ had a shelflife of 12 weeks and retained their freshness without any symptoms of chilling injury. Hence the optimum temperature to store fruits in the present study was decided to be 8 ± 1°C. Besides 8 ±1°C storage, comparative shelf life was determined at 15 ± 1°C and 25 ± 1°C.

The treated fruits were stored at three temperatures namely 25 ± 1°C (RT) with 45 ± 5 per cent relative humidity (RH), 15 ± 1°C (LT) with 55 ± 5 per cent (RH) and 8 ± 1°C (LT) with 62 ± 5 per cent (RH).

At room temperature (RT) storage, there were four treatments excluding the treatment number 2 (pre-cooled). At low temperature (LT) there were five treatments.

#### 3.2.3.4 Method of storage and sampling

The treated fruits were packed in unventilated polybags of 150 guage and kept in ventilated cardboard cartons in the year 1994, but during 1995, the treated fruits were kept in ventilated card board cartons without packing in polybags, at both room and low temperature.

For analysis of the samples, the fruits stored at room temperature (25 ± 1°C) were taken once in five days and in fruits stored at low temperatures (15 and 8°C) it was taken at fifteen days interval. Each replication consisted of 8 fruits.

Among the three replications, the replicate number one ($R_1$) was kept for recording physiological losses in weight

**Plate 5 :** Development of chilling injury symptoms in pomegranate cv. Ganesh during storage at 5°C.


CHILLING INJURY
5

(PLW) and fruits from the other two replications were used for periodical chemical analysis and sensory evaluation. One fruit from each replication was removed and analysed for physical characters. For chemical analysis aril of the same fruit was used.

**3.2.3.5 Physiological losses in weight (PLW)**

Individual fruits in first replication were numbered one to six and kept for recording of PLW. Observations for PLW was recorded by weighing individually numbered fruits. Cumulative losses in weight were calculated and expressed as per cent physiological losses in weight.

**3.2.3.6 Physical and chemical characters**

The different physical and chemical parameters during storage were analysed as mentioned under studies on growth and development.

**3.2.3.7 Aril browning**

At different periods of storage the brownish coloured arils were separated from the good arils, weighed using an electronic balance and expressed as per cent brown arils. The brown arils were not used in the extraction of juice.

**3.2.3.8 Spoilage**

Observations on spoilage of fruits in different treatments during storage was recorded and were discarded regularly. The appearance of even a small water soaked sunken spot or rot the fruit was judged spoilt. The cumulative spoilage was expressed as per cent spoilage.

**3.2.3.9 Shelf life**

The storage life was determined by the fruit characters like freshness, colour of the rind, shape of the fruit, per cent brown spots on the rind, marketability and by sensory evaluation besides other chemical parameters.

**3.2.3.10 Sensory evaluation**

Sensory characters of fruits stored at RT were analysed after 25 days of storage for both the crops. For the fruits stored at 15$^{o}$C it was done after 10 weeks of storage in both the crops. For the fruits stored at 8$^{o}$C the sensory evaluation was carried out after 12 weeks storage. A panel of eight judges were taken for evaluation following Hedonic rating system (Amerino, 1965). Characters like freshness, taste, colour of aril, juiciness and off flavour were judged by scoring as follows:

Very good - 5

Good - 4

Acceptable - 3

Bad - 2

Very bad - 1

**3.2.3.11 Statistical analysis**

The experimental data were analysed statistically by methods adopted for completely randomised design (factorial) except for sensory evaluation, where simple CRD was used. The level of significance used in the 'F' test was at 5 per cent (Fisher, 1963).

## 3.3 HISTOLOGICAL STUDIES

### 3.3.1 Histology of the rind during growth

The rind of the pomegranate fruit during growth at stage 1 (at fruit set), Stage 5 (30 days after fruit set), Stage 7 (60 days after fruit set), stage 9 (90 days after fruit set) and stage 10 (At harvest) was sectioned in the crop grown under Bangalore conditions to study the histology of developing rind. For the crop grown under Bijapur area, histological changes of the rind were studied for the stages 1 (5.67 mm fruit diameter), Stage 5 (36.25 mm fruit diameter), Stage 7 (82.52 mm fruit diameter), Stage 9 (113.07 mm fruit diameter) and stage 10 which coincided with harvest.

### 3.3.2 Histology of the rind during storage

The histology of the rind in the fruits of untreated control, semperfresh treated and in the two film wrapped fruits stored at RT was studied after 15 and 25 days of storage in both the crops. However, fruits stored at lower temperature were not sectioned.

stored fruit, a very thin rind surface was taken using a sharp blade. The rind was mounted on the slide with water and observed under microscope. The changes observed were immediately photomicrographed. The study of surface epidermis was conducted only for the crop grown under Bangalore conditions.

### 3.3.4 Histology of the aril

The histological changes in the developing aril were studied at harvest and after storage with special reference to fresh aril and discoloured brown aril and photomicrographed.

### 3.3.5 Methodology

The rind and the aril portion of the fruit were first separated. The rind was cut into small pieces of 1 $cm^3$ using a sharp blade and fixed in Carnoy's B fixative (Ethyl Alcohol:Chloroform: Acetic acid in the ratio of 6:3:1 by volume) for two hours. For the floating material, the vials with the material were placed in a desiccator and connected to a vacuum pump to remove the air for about 10-15 minutes with a gradual increase in pressure.

Then the material was dehydralated using ethyl alcohol and n-butanol grades. The dehydrated tissue was infiltrated and embedded in paraffin of $58^{o}C$ by the paper boat technique.

Transverse serial sections of 12 um thickness were taken using a rotary microtome and affixed on slides using gelatin (1 per cent) adhesive. Subsequently the sections were subjected to deparaffinisation followed by histochemical staining for localisation of insoluble polysaccharides with periodic acid Schiff's (PAS) reagent (Jensen, 1962) and nucleic acids with methyl Green Pyronine (MGP) (Conn, 1936).

After staining, the sections were dehydrated using alcohol-n-butanol grades and mounted in DPX medium. The histological and histochemical changes were recorded through light microscope and photomicrographed. The length, breadth and thickness of various structures were measured and recorded using a calibrated oculometer. The characters measured were as follows:

a. Thickness of cuticle (um)

b. Epidermal thickness (um)

c. Length and breadth of both collenchymatous and parenchymatous cells (um).

### 3.3.6 Starch content in the rind

To study the behaviour of starch content in the rind, to the deparaffinised tissues a few drops of iodine solution were added. The staining of the starch granules to dark blue colour was observed under microscope during growth and storage and photomicrographed immediately.

# RESULTS

# RESULTS

The results on the study of growth, development and storage of pomegranate fruit cv.Ganesh are presented below. Since the growth pattern was similar in both the years (1994 and 1995) the data on growth and development has been presented for the year 1995 only, in Tables 1 and 2 for Bangalore and Bijapur crops, respectively.

## 4.1 FRUIT GROWTH AND DEVELOPMENT

### 4.1.1 Length and breadth

The data on the changes in the linear dimensions of fruit viz., length (A) and breadth (B) are presented in Figure 1. for the crops from both the area (Bangalore and Bijapur).

From Figure 1(A) it was seen that the length of the fruit increased through the developmental stages, from the fruit set stage till it attained full maturity. The rate of increase in length of Bangalore crop was slow upto 4th stage (15 days after fruit set) and then rate of increase was high upto stage 7 (60 days of fruit set) followed by a slow increase in next stages. The length of the fruit was 3.9 cm at stage 1 (10-12 days from anthesis, i.e. at fruit set) and it reached 14.6 cm at full maturity stage (Stage 10).

**Table 1: Changes in the physical and chemical characters of pomegranate fruit cv. Ganesh during development grown under Bangalore conditions.**

| Stages of Growth | Length (cm) | Breadth (cm) | Weight g) | Volume (ml) | Specific gravity (g/cc) | Rind thickness (mm) | Firmness ($Kg/cm^2$) | Rind weight (g) | Aril weight g) | Juice content (ml) | Seed content g) | Respiration (mg $CO_2$/Kg/hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.9 | 1.4 | 3.9 | 4.4 | 0.89 | 0.60 | - | - | - | - | - | 618 |
| 2 | 4.0 | 1.8 | 5.1 | 6.8 | 0.78 | 0.48 | 14.9 | 4.6 | 0.4 | - | - | 685 |
| 3 | 4.7 | 2.6 | 13.5 | 14.4 | 1.02 | 0.60 | 16.2 | 10.1 | 2.8 | - | - | 535 |
| 4 | 5.1 | 3.2 | 23.3 | 20.2 | 1.05 | 0.45 | 16.2 | 14.1 | 6.0 | - | - | 255 |
| 5 | 6.6 | 4.8 | 57.2 | 55.0 | 1.04 | 0.50 | 14.4 | 32.6 | 23.7 | - | - | 229 |
| 6 | 7.5 | 5.7 | 99.3 | 101.0 | 1.02 | 0.52 | 14.1 | 44.2 | 57.1 | 22.5 | 20.1 | 163 |
| 7 | 10.4 | 6.3 | 155.5 | 154.3 | 1.02 | 0.48 | 12.5 | 65.0 | 87.9 | 45.0 | 28.0 | 115 |
| 8 | 11.6 | 6.9 | 183.8 | 175.0 | 1.00 | 0.45 | 13.3 | 70.5 | 110.0 | 60.1 | 27.3 | 95 |
| 9 | 12.9 | 7.7 | 228.0 | 230.0 | 0.98 | 0.40 | 13.9 | 76.1 | 149.5 | 96.2 | 38.6 | 65 |
| 10 | 14.6 | 8.5 | 295.4 | 310.0 | 0.96 | 0.38 | 13.7 | 97.1 | 190.7 | 122.5 | 28.9 | 47 |

| Stages of Growth | Juice colour (OD) | Aril Moisture (%) | Rind Moisture (%) | Acidity (%) | Ascorbic acid (mg/100ml) | TSS ($^{o}$Brix) | Reducing Sugars (%) | Total Sugars (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - |
| 2 | - | 82.4 | 69.6 | - | - | - | - | - |
| 3 | - | 85.9 | 64.6 | - | - | - | - | - |
| 4 | - | 87.2 | 62.5 | 0.49 | 6.0 | 9.2 | 0.5 | 1.0 |
| 5 | - | 87.7 | 66.9 | 0.48 | 7.5 | 9.9 | 0.6 | 1.8 |
| 6 | - | 85.0 | 63.7 | 0.61 | 9.3 | 10.4 | 1.4 | 2.6 |
| 7 | - | 82.2 | 61.4 | 0.66 | 9.9 | 12.4 | 6.1 | 7.0 |
| 8 | 0.35 | 80.7 | 64.1 | 0. 1 | 11.1 | 14.4 | 8.6 | 9.1 |
| 9 | 0.42 | 80.4 | 66.3 | 0.48 | 12.5 | 15.6 | 9.2 | 10.1 |
| 10 | 0.46 | 80.2 | 66.2 | 0.43 | 13.7 | 16.7 | 10.0 | 11.0 |

Average of 8 fruits

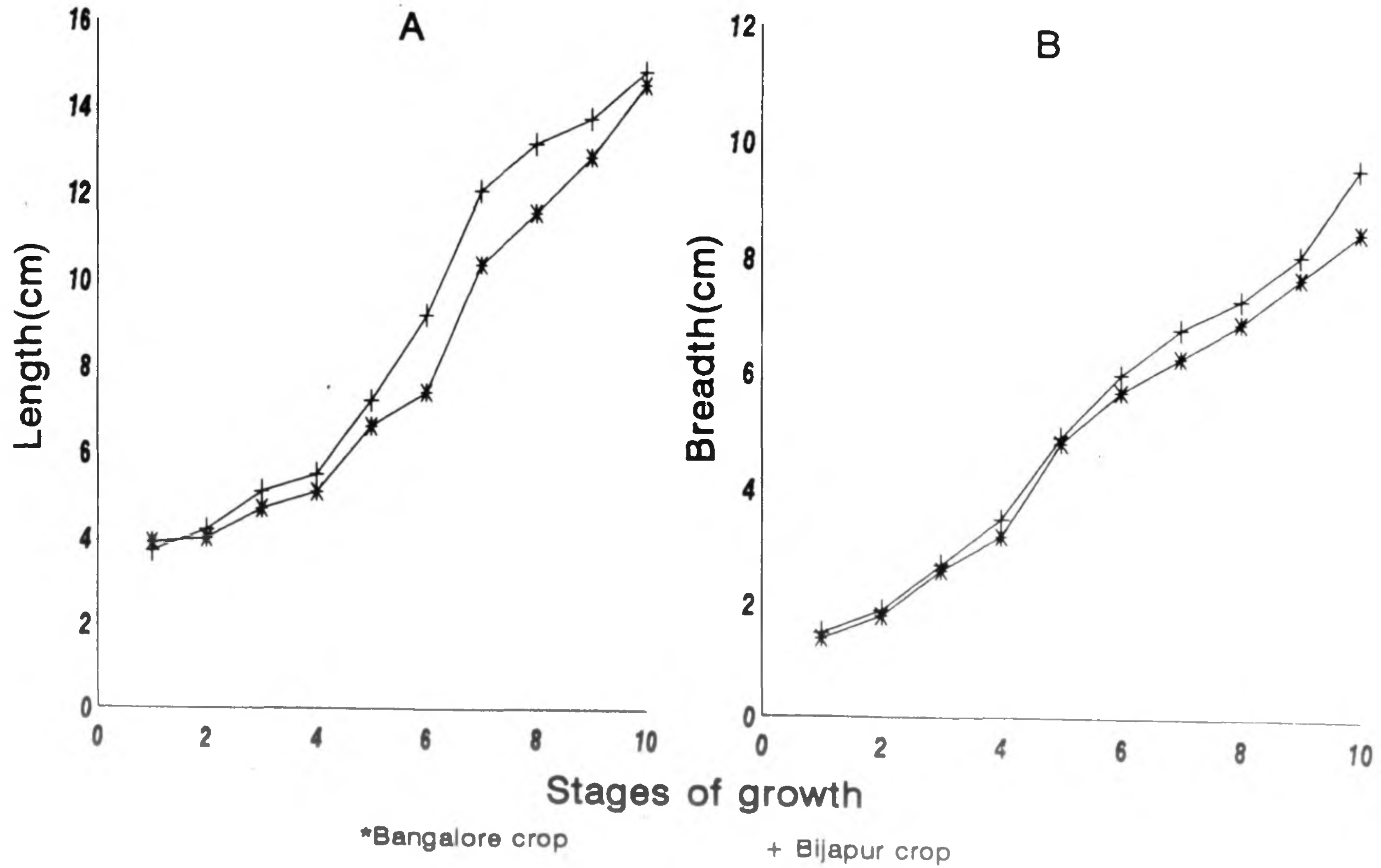
**Table 2: Changes in the physical and chemical characters of pomegranate fruit cv. Ganesh during development grown under Bijapur conditions.**

| Stages of Growth | Length (cm) | Breadth (cm) | Weight g) | Volume (ml) | Specific gravity (g/cc) | Rind thickness (mm) | Firmness ($Kg/cm^2$) | Rind weight g) | Aril weight g) | Juice content (ml) | Seed content (g) | Respiration mg $CO_2$/Kg/hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | 1.5 | 3.5 | 4.1 | 0.90 | 0.42 | - | - | - | - | - | 481 |
| 2 | 4.2 | 1.9 | 5.8 | 6. | 0.89 | 0.34 | 13.2 | 4.8 | 0.7 | - | - | 490 |
| 3 | .1 | 2.7 | 14.1 | 1 .4 | 0.93 | 0.37 | 13.9 | 9.5 | 3.1 | - | - | 338 |
| 4 | 5.5 | 3. | 27.2 | 23. | 1.21 | 0.34 | 13.4 | 15.8 | 11.1 | - | - | 297 |
| 5 | 7.2 | 4.9 | 6 .4 | 46.0 | 1.24 | 0.35 | 13.7 | 29.2 | 32.8 | - | - | 249 |
| 6 | 9.2 | 6.0 | 102.6 | 92.0 | 1.12 | 0.36 | 12.8 | 39.7 | 64.2 | 46.0 | 19.2 | 207 |
| 7 | 12.1 | 6.8 | 160.6 | 1 .0 | 1.06 | 0.36 | 12.3 | 54.4 | 96.6 | 66.2 | 2 .1 | 192 |
| 8 | 13.2 | 7.3 | 207.2 | 230.0 | 1.03 | 0.35 | 11.4 | 62.7 | 132.3 | 90.0 | 28.7 | 139 |
| 9 | 13.8 | 8.1 | 278.5 | 282.0 | 0.99 | 0.34 | 12.0 | 91.4 | 172.4 | 122.0 | 40.2 | 125 |
| 10 | 14.9 | 9.6 | 365. | 400.0 | 0.91 | 0.30 | 11.9 | 116.7 | 248.6 | 165.0 | 38.8 | 113 |

| Stages of Growth | Juice colour (OD) | Aril Moisture (%) | Rind Moisture (%) | Acidity (%) | Ascorbic acid (mg/100ml) | TSS ($^{o}$Brix) | Reducing Sugars (%) | Total Sugars (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - | - |
| 2 | - | 93.7 | 61.8 | - | - | - | - | - |
| 3 | - | 87.8 | 60.0 | - | - | - | - | - |
| 4 | - | 87.0 | 62.4 | 0.33 | .8 | 9.2 | 1.0 | 2.0 |
| | - | 85.1 | 63.9 | 0.29 | 7. | 10.7 | 1.1 | 2.3 |
| 6 | - | 81.0 | 60.0 | 0.42 | 9.4 | 13.1 | 9.0 | 9.5 |
| 7 | - | 80.4 | 9.8 | 0.44 | 10.8 | 14.0 | 10.3 | 10.5 |
| 8 | - | 80.6 | 59.1 | 0.45 | 14.1 | 14.2 | 10.6 | 10.9 |
| 9 | 0.35 | 81.1 | 62.0 | 0.40 | 15.8 | 15.8 | 11.3 | 11.7 |
| 10 | 0.38 | 82.0 | 60.4 | 0.35 | 17.9 | 17.2 | 13.0 | 14.3 |

Average of 8 fruits

Fig.1: Changes in length(A) and breadth(B) during development of pomegranate cv.Ganesh.



In the Bijapur crop which also followed a similar pattern of growth, the length at stage 1 was 3.7 cm and at stage 10 which co-incide with harvest it was 14.9 cm.

Similarly the breadth (B) of the fruit increased from the fruit set stage to maturity stage in both the crops. The rate of increase in breadth was more towards later stages of fruit maturity than in the earlier part of growth period.

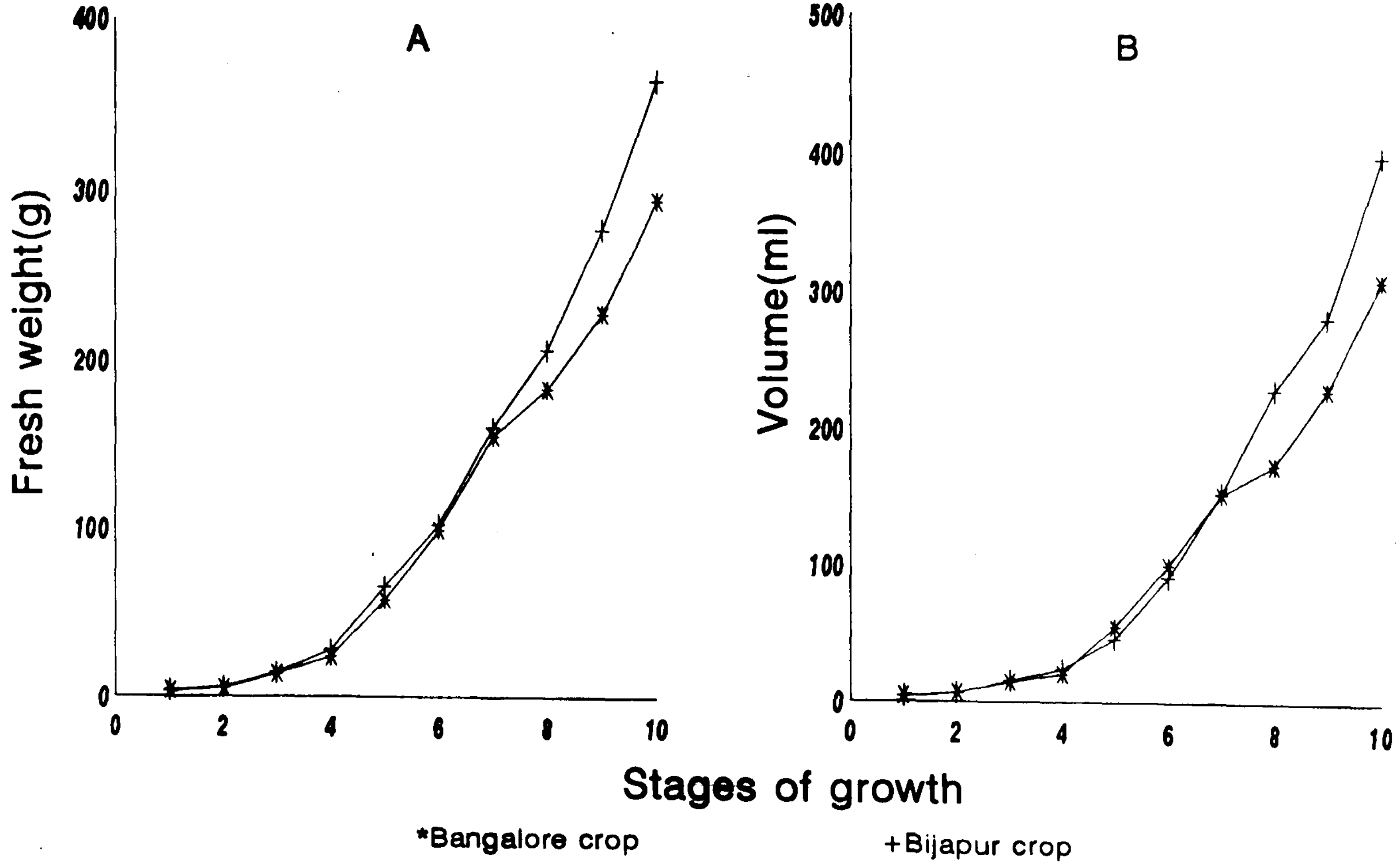
The breadth of the fruit in Bangalore crop on the day of fruit set (Stage 1) was 1.4 cm and at harvest maturity (Stage 10) it was 8.5 cm. In Bijapur crop the breadth of the fruit at stage 1 (at fruit set) was 1.5 cm and at stage 10 (harvest) it was 9.6 cm. At harvest the breadth of the fruit in Bijapur crop was slightly more than the breadth of Bangalore crop (8.5 cm).

**4.1.2 Fresh weight**

The observation on the changes in the fresh weight of fruit recorded at different stages of growth for Bangalore and Bijapur grown crops are presented in Figure 2.

From Figure 2(A) it was seen that the pomegranate fruit irrespective of growing conditions showed continuous increase in fresh weight from fruit set till harvest time. The pattern of fruit growth showed a linear relationship. The rate of increase in weight was slow upto 4th stage

Fig.2: Changes in fresh weight(A) and volume(B) during development of pomegranate cv. Ganesh



followed by a rapid increase upto the harvest stage. Maximum increase in weight was observed around fruit maturity.

The weight of the fruit in Bangalore crop at Stage 1 (at fruit set) was 3.9 g and it gradually increased upto stage 4 (15 days after fruit set) where it remained 23.3 g followed by a drastic increase to 295.4 g at harvest. In Bijapur crop the fresh weight of the fruit at stage 1 (set) was 3.5 g and increased to 365.5 g at stage 10 (harvest).

**4.1.3 Volume**

The data on changes in volume of the fruit during development recorded in two growing areas are given in Figure 2.

From Figure 2(B) it was found that the fruit volume increased with advancement in growth of the fruit in both the crops. The rate of increase was slow upto 4th stage followed by a gradual increase upto harvest stage.

At fruit set the volume was 4.4 ml and at maturity (i.e. after 105 days after fruit set) it increased to 310. ml in Bangalore crop. The increase in volume was greater during in the stage 5 (30 days after fruit set), stage 7 (60 days after fruit set) and stage 9 (90 days after fruit set).

In Bijapur crop, the volume of the fruit at stage 1 (fruit set) was 4.1 ml and at harvest it was as high as

400 ml. Maximum increase in volume was at the harvest stage of the fruit.

The volume of the fruit was more than the weight of the fruit towards harvesting stage irrespective of the growing conditions.

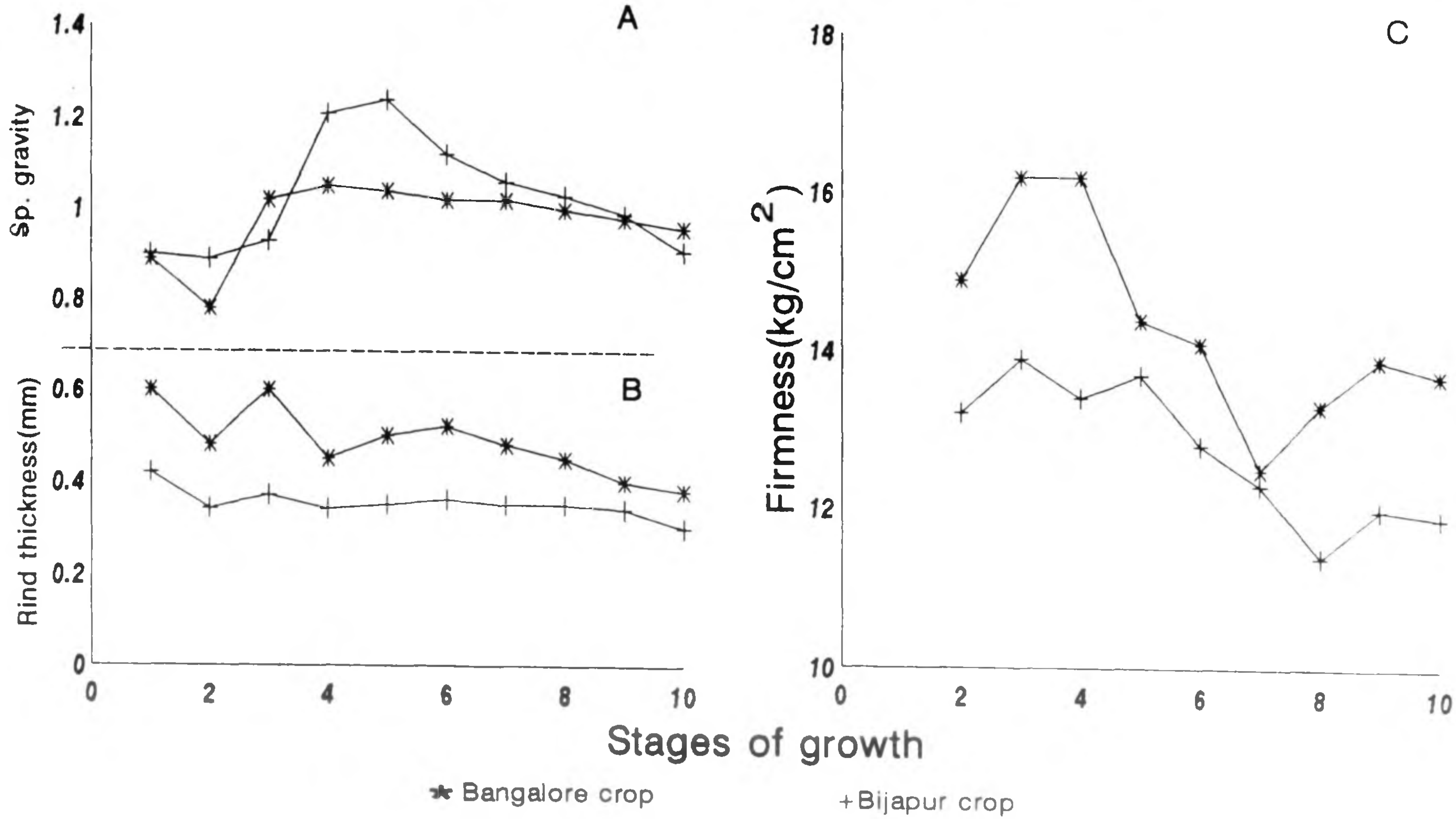
**4.1.4 Specific gravity**

The data on the specific gravity of the fruit during development for both the crops are presented in Figure 3.

From the Figure 3 (A) it was seen that the specific gravity in Bangalore crop was lower upto stage 2 (5 days after fruit set), it increased slightly in the next stage and then showed a gradually declining trend towards harvest maturity. The specific gravity was more than one from stages 2 to 7 and just around 1 at stage 8 (75 days after fruit set) and then started declining to about 0.96 towards harvest maturity.

In Bijapur crop, the specific gravity increased upto stage 5 (1.24) and then gradually declined towards harvest. The specific gravity was less than 1 upto stage 3, more than 1 from stages 4 to 8 and later it declined with increase in the size of the fruit reaching 0.91 at maturity stage (Stage 10).

Fig.3: Changes in specific gravity(A), rind thickness(B) and firmness(C) during development of pomegranate cv. Ganesh.



At harvest the specific gravity of the fruit of Bijapur crop was 0.91 as compared to Bangalore crop where it was 0.96.

**4.1.5 Rind thickness**

The data recorded for the rind thickness in pomegranate fruits of Bangalore and Bijapur crops during development are presented in Figure 3.

Data in Figure 3 (B) revealed that the thickness of the rind was maximum at stages 1 and 3 in Bangalore crop. It gradually declined at maturity stage. The thickness of the rind was 0.60 mm at fruit set and at stage 2 it slightly decreased to 0.48 mm. It again increased to 0.60 mm at stage 3 and then the thickness gradually decreased till the harvesting period to reach a thickness of 0.38 mm.

In Bijapur crop, the changes in rind thickness during the development also showed similar pattern. At stage 1 (at fruit set) the thickness of the rind was 0.42 mm and it gradually declined towards the harvesting stage to 0.30 mm.

**4.1.6 Firmness**

The firmness of the pomegranate fruit during development grown in Bangalore and Bijapur conditions are presented in Figure 3.

From the Figure 3(C) it was observed that the firmness of the fruit in Bangalore crop slightly increased from stage 1 (fruit set) upto stage 4, then showed a decrease followed by a stationary phase till 10th stage (harvest). At stage 2 the firmness of the fruit was 14.9 Kg/cm$^2$, reached a maximum of 16.2 Kg/cm$^2$ at stage 4, followed by a decrease to 13.7 Kg/cm$^2$ at harvest.

In case of Bijapur crop the changes in firmness of the fruit also showed a reducing trend from fruit set to maturity stage. At stage 2 the firmness of the fruit was 13.2 which decrease to 11.9 Kg/cm$^2$ at harvest.

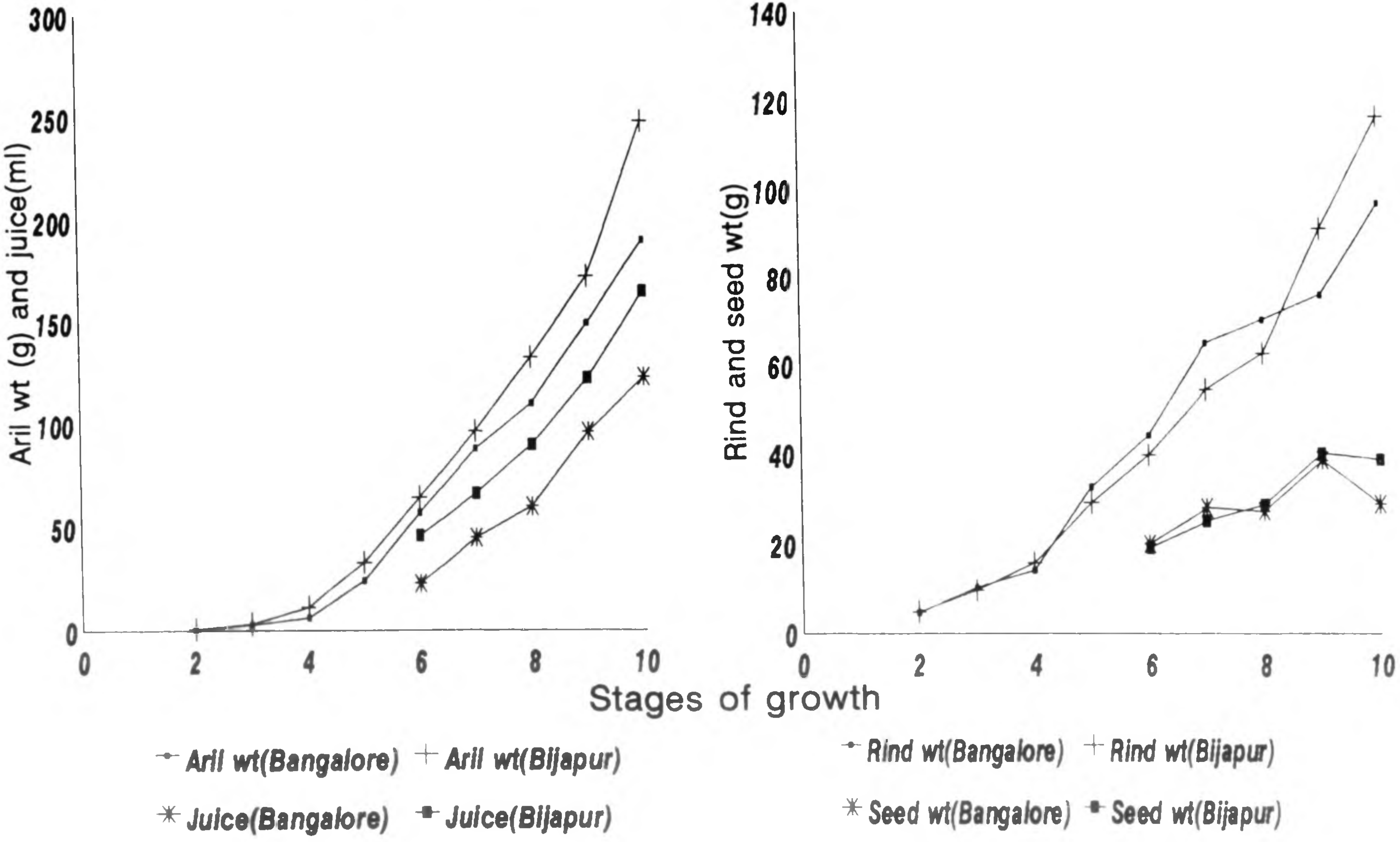
The firmness of the fruit at harvest was greatly lower in Bijapur crop (11.9 Kg/cm$^2$) than in the crop grown under Bangalore conditions (13.7 Kg/cm$^2$).

**4.1.7 Fresh weight of rind and aril**

The data on fresh weight of rind and aril during fruit development for the crops grown under Bangalore and Bijapur conditions are given in Figure 4.

From the Figure 4 it was seen that at stage 1 (at fruit set) the rind and the aril could not be separated. From stage 2 onwards the rind and the aril weight increased continuously upto maturity in both the crops.

Fig.4: Changes in aril weight, rind weight, juice - and seed content during development of pomegranate cv. Ganesh.



At stage 2 (5th day after fruit set) in Bangalore crop the rind weight was 4.6 g and it gradually increased to 14.1 at stage 4, followed by a rapid increase upto harvest to reach a weight of 97.1 g. In Bijapur crop, the rind weight at stage 2 was 4.8 g, then gradually increased to 15.8 g at stage 4 and a rapid increase to 116.7 g at harvest maturity stage.

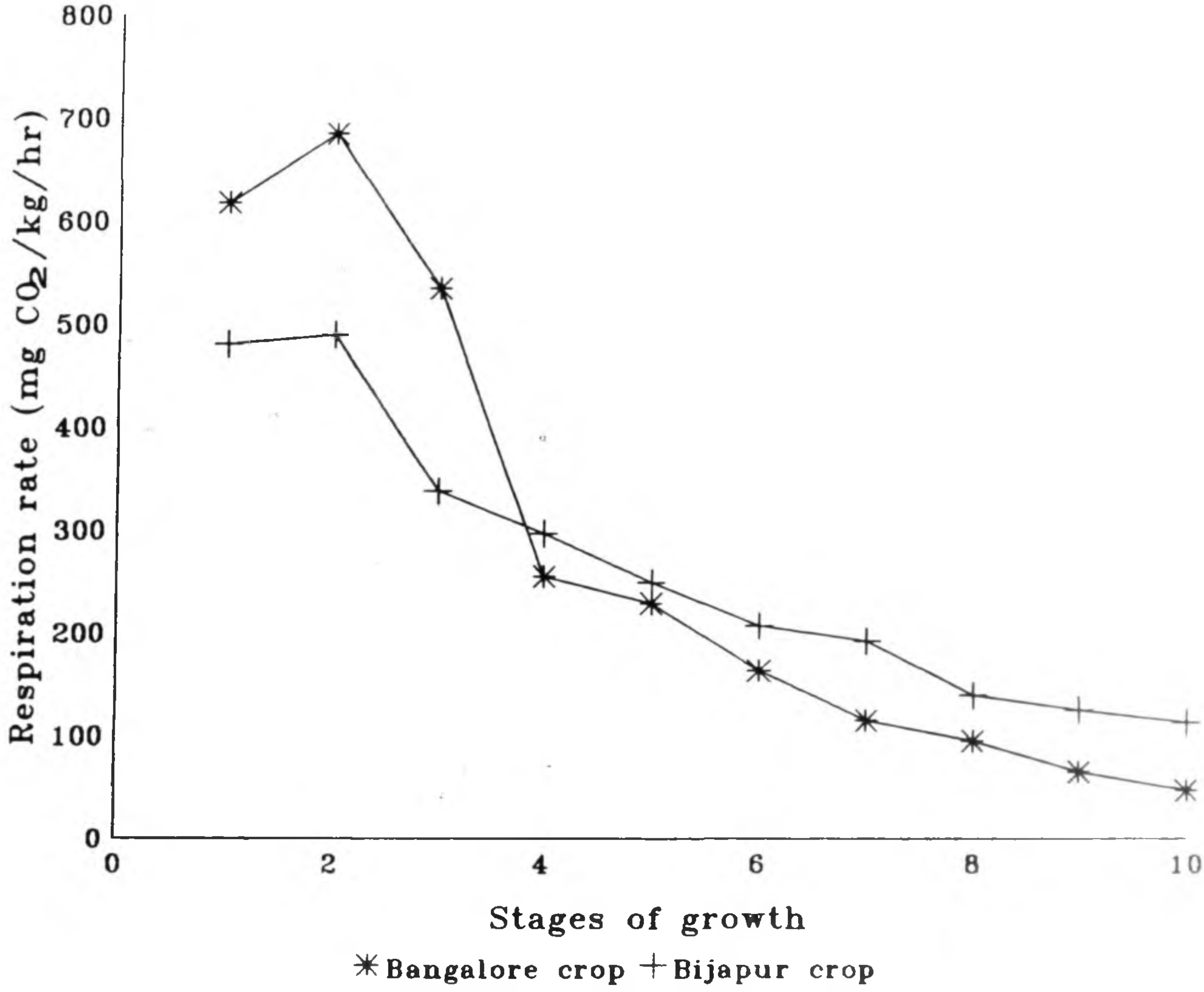
Similarly, the aril weight of the fruit at stage 2 in Bangalore crop was 0.4 g, it gradually increased to 6.0 g at stage 4, followed by a rapid increase upto harvest to 190.7 g. In Bijapur crop, the aril weight at stage 2 was 0.7 g and gradually increased to 248.6 g at stage 10 (harvest). The aril weight was higher in Bijapur crop than in the Bangalore crop at harvest.

Irrespective of the growing conditions, during earlier stages of growth (i.e. upto stage 4) the weight of the rind (14.1 g in Bangalore and 15.8 g in Bijapur crop) was higher than the aril weight (6.0 g and 11.1 g in Bangalore and Bijapur crops, respectively, at stage 4). At stage 5 the weights of rind and aril were almost the same. From stage 6 onwards the increase in weight of the aril was more than the increase in rind weight.

**4.1.8 Juice and seed content**

The data recorded on the juice and seed content of the

Fig. 5: Changes in rate of respiration during development of pomegranate cv. Ganesh.



fruit during development in both the crops are given in Figure 4.

As seen from Figure 4 juice could be extracted only from stage 6 in both the crops.

In Bangalore crop, the juice and the seed content of the fruit increased with advancement in development of the fruit. At stage 6 the juice extractable was 22.5 ml and it gradually increased to 122.5 ml as as the fruit developed into a fully mature stage. Maximum juice content was observed around harvesting stage of the fruit.

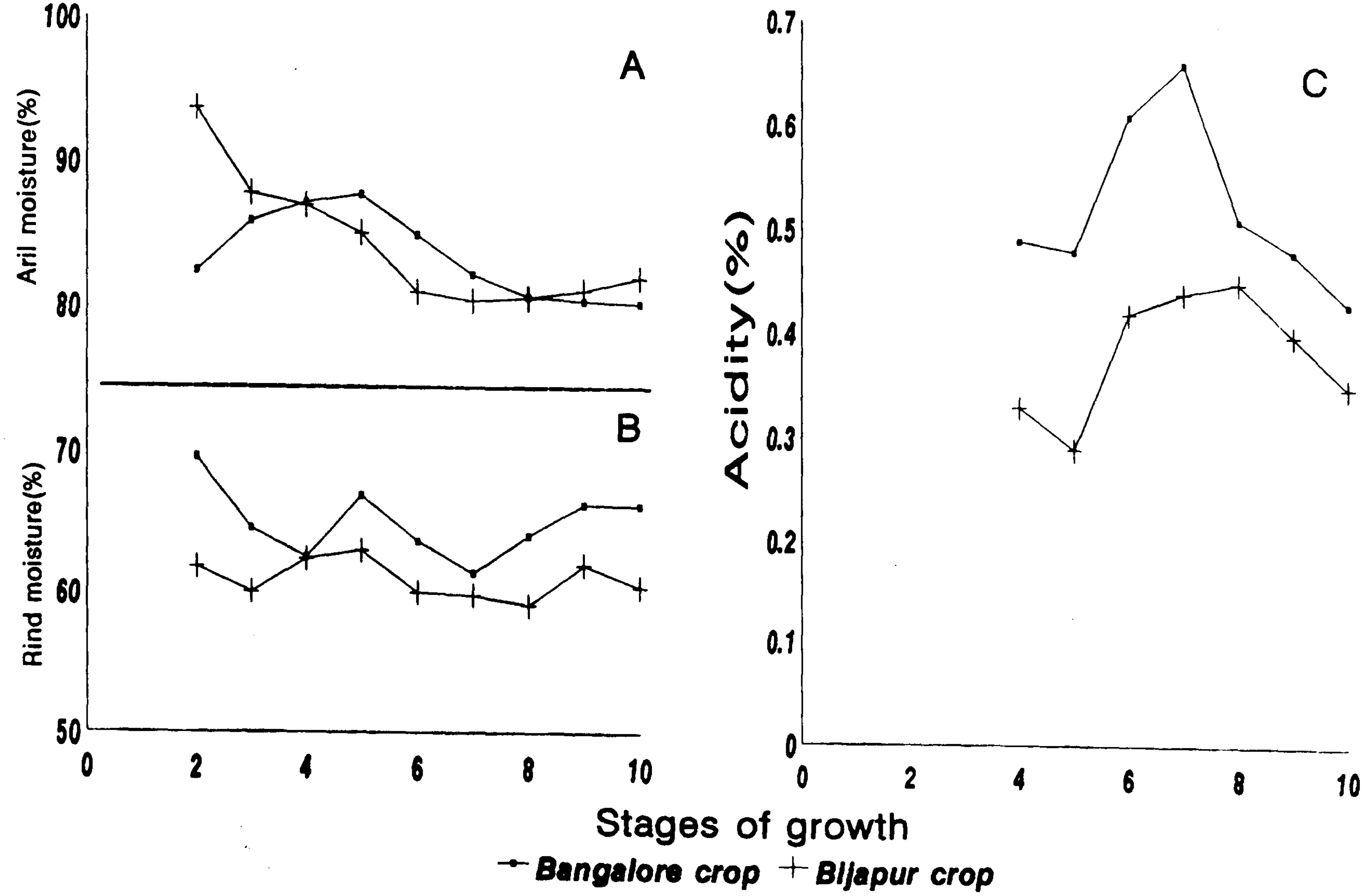
The seed weight at the 6th stage of development was 20.1 g and it increased to 28.9 g at harvest, that is after 105 days of development.

Similar trend of the increase in juice and seed content was observed in fruits of Bijapur crop. At stage 6 (Bijapur crop) the juice content was 4.6 ml with a seed weight of 19.2 g. At harvest the juice content increased to 165.0 ml with a seed weight of 38.8 g. The juice content of the fruit at harvest was higher here than in the Bangalore crop (122.5 ml).

**4.1.9 Respiration**

The data on the respiration rate of pomegranate fruit during development grown under Bangalore and Bijapur conditions are presented in Figure 5.

Fig.6: Changes in aril moisture(A), rind moisture(B) and acidity(C) during development of pomegranate cv. Ganesh.



From Figure 5 it was observed that the respiration rate of pomegranate decreased during the course of development of the fruit in both the growing conditions.

In Bangalore crop, maximum respiration of 685 mg $CO_2$/hr was observed at stage 2 followed by a decrease in stage 5 when the respiration rate was 229 mg $CO_2$/kg/hr. This was followed by a sudden decrease till the fruit reached harvest maturity. The minimum respiration was observed at harvest and it was 47 mg $CO_2$/kg/hr.

The respiration rates observed during the different stages of growth in the crop from Bijapur area also showed similar trend. The peak in respiration was observed at stage 2 (490 mg $CO_2$/kg/hr) and this decreased gradually upto stage 7 (192 mg $CO_2$/kg/hr) followed by a sudden decrease to 113 mg $CO_2$/kg/hr at harvest (stage 10). The respiration of fruits upto stage 3 was higher in Bangalore crop than in Bijapur crop. But from stage 4 onwards upto harvest the respiration rate of fruits in Bijapur crop was higher than the respiration rate in Bangalore crop fruits.

**4.1.10 Juice colour**

The data on the juice colour of the fruit during development in Bangalore and Bijapur crops are presented in Tables 1 and 2 respectively.

From the Table 1 it was observed that the juice colour in pomegranate fruits grown in Bangalore conditions was measured from stage 8 onwards (75 days after fruit set). At stage 8 the colour of the juice was 0.35 OD and it increased to 0.46 OD at harvest.

In Bijapur crop (Table 2) the juice colour was measured from stage 9. At stage 9 the colour of the juice was 0.35 OD and it increased slightly to 0.38 OD at harvest.

The juice colour of pomegranate in fruits from Bangalore crop was more than the juice colour of Bijapur crop at harvest.

**4.1.11 Moisture content of the aril and rind**

The observation on the moisture content of aril and rind during fruit development are presented in Figure 6 for both the crops.

From the Figure 6(A) it was seen that the moisture content of the aril in Bangalore crop increased upto stage 5 and then gradually decreased upto harvest maturity. But in Bijapur crop the aril moisture content decreased gradually from stage 2 upto stage 6 and then increased upto harvest (Stage 10).

In Bangalore crop the aril moisture content at stage 2 was 82.4 per cent, it increased to 87.7 per cent at stage 5 and then decreased to 80.2 per cent at harvest stage.

In Bijapur crop at aril moisture at stage 2 was as high as 93.7 per cent and it decreased to 80.4 per cent at stage 7 followed by a increase at stage 10 to 82 per cent.

At early growth period (upto stage 4) and at harvest the aril moisture content in Bijapur grown crop was high as compared to aril moisture of Bangalore crop.

Similarly the rind moisture (B) in Bangalore crop at stage 2 was 69.7 per cent. It decreased upto stage 4 to 62.5 per cent and in stage 5 it increased to 66.9. In stage 6 and 7 it decreased to 63.7 and 61.4, respectively and increased to 66.2 per cent at harvesting stage.

In Bijapur crop the rind moisture at stage 2 was 61.8 per cent. It increased to 63.0 per cent in stage 5 and then in stages 6, 7 and 8 it decreased to 60.0, 59.8 and 59.1 per cent, respectively followed by a increase to 60.4 per cent at stage 10 (harvest).

It was observed that at all the stages of development, rind moisture of Bijapur crop was less than the rind moisture of Bangalore crop.

**4.1.12 Titratable acidity**

The data on the titratable acidity of pomegranate fruit during development for the crops grown under Bangalore and Bijapur conditions are presented in Figure 6.

From Figure 6(C) it was observed that acidity decreased at stage 5, it gradually increased upto stage 7 followed by a decrease upto harvest maturity in both the crops.

In Bangalore crop the acidity as measured in juice was 0.49 per cent at stage 4, it increased to 0.66 per cent at stage 7 and then decreased to 0.43 per cent at harvest.

In Bijapur crop the acidity at stage 4 was 0.33 per cent, it increased to 0.45 per cent at stage 8 and decreased at stage 10 to 0.35 per cent.

At all the stages of development the acidity of Bijapur fruits was less than the acidity of Bangalore fruits.

**4.1.13 Ascorbic acid**

The data on the ascorbic acid content of the fruit during development in both the crops are presented in Figure 7.

From Figure 7(A) it was observed that the ascorbic acid content increased gradually upto stage 6 followed by a rapid increase upto harvest stage in both the crops.

In Bangalore crop at stage 4 the ascorbic acid content in juice was 6 mg/100 ml. At stage 5 it was 7.5 mg/100 ml. It increased gradually to 9.9 mg/100 ml at stage 7, and then rapidly increased to 13.7 mg/100 ml at harvest stage (105 days after fruit set).

In Bijapur crop, at stage 4 the ascorbic acid content was 5.8 m/100 ml. It was same as the ascorbic acid content of Bangalore crop at stage 5 (7.5 mg/100 ml) and then gradually increased to 10.8 mg/100 ml at stage 7 followed by a rapid increase at harvest to reach a maximum of 17.9 mg/100 ml.

From stage 6 onwards upto harvest the ascorbic acid in Bijapur fruits was more than the ascorbic acid content of Bangalore fruits.

**4.1.14 Total soluble solids (TSS)**

The data on the TSS of the pomegranate fruit during development grown in Bangalore and Bijapur conditions are presented in Figure 7.

The TSS of the fruit as seen in Figure 7(B) showed a gradual increase with increase in maturity of the fruit in both the crops. Though the TSS at stage 4 showed the same value (9.2$^{o}$B), during further development there was a higher TSS value upto stage 7 and at harvest (17.2$^{o}$B) in Bijapur crop as compared to Bangalore crop. In Bangalore crop, the TSS of the fruit at 15 days after fruit set (stage 4) was 9.2$^{o}$B. It increased gradually upto stage 6 (10.4$^{o}$B) followed by a rapid increase upto maturity and reached 16.7$^{o}$B TSS.

In Bijapur crop, the TSS of the fruit at 4th stage was 9.2$^{o}$B. It increased gradually upto stage 8 (14.2$^{o}$B) followed by a rapid increase at maturity stage and reached a TSS of 17.2$^{o}$B.

**4.1.15 Reducing - and Total Sugars**

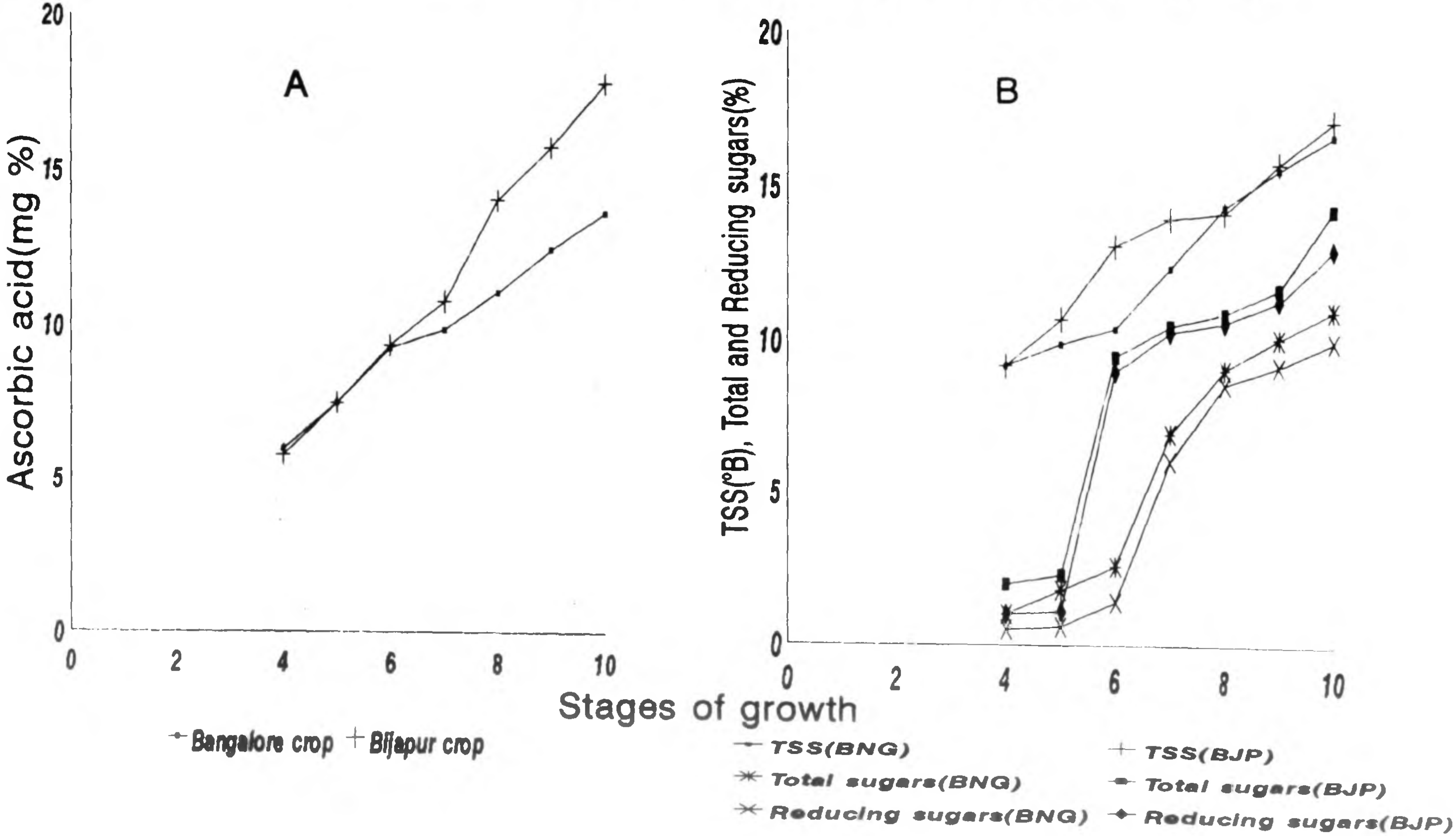
The data on the reducing - and total sugars recorded during the development of the fruit in Bangalore and Bijapur conditions are presented in Figure 7.

From Figure 7(B) it was observed that the total sugars and the reducing sugars increased gradually during the fruit development in both the crops.

The reducing sugars in Bangalore crop at stage 4 was 0.5 per cent. It had a reducing sugar content of 0.6 and 1.4 per cent at stages 5 and 6, respectively. The reducing sugars suddenly increased to 6.1 per cent at stage 7 and at harvest it had a high as 10 per cent reducing sugars. In Bijapur crop, the reducing sugars at stage 4 was 1.0 per cent. At stage 5 it was 1.1 per cent, it suddenly increased to 9.0 per cent at stage 6 and reached a maximum of 13.0 per cent at harvest.

At all the growth stages, the reducing sugars was more in Bijapur crop fruits than in the fruits of Bangalore crop.

Fig.7: Changes in ascorbic acid(A), TSS, total sugars and reducing sugars(B) during development of pomegranate cv. Ganesh.



Similarly the total sugars in Bangalore crop at stage 4 was 1.0 per cent and at stage 5 and 6 it was 1.8 and 2.6 per cent, respectively. It then suddenly increased to 7.00 per cent at stage 7 and reached to a maximum of 11.0 per cent at harvest. In Bijapur crop, the total sugars at stages 4 and 5 was 2 and 2.3 per cent, respectively and it suddenly increased to 9.5 at stage 6 and at harvest it had a maximum of 14.3 per cent.

At all the developmental stages, the total sugars in Bijapur crop was more than the total sugars in Bangalore crop. At all the stages of development out of the total sugars the reducing sugar content was more than the non reducing sugars in both the crops.

**4.1.16 Maturity and harvesting**

The pomegranate fruit cv. Ganesh required about 105-110 days from fruit set (i.e. 10-12 days of anthesis) to reach the stage of harvest maturity under Bangalore conditions (Plate 6). At this stage the fruits had a low specific gravity, constant fruit length and breadth, higher sugars and constant TSS. The fruits had developed glossy appearance and freshness. However, fruits harvested earlier than 105 days (i.e. 100 days after fruit set) did not have high sugars and constant TSS and had poor quality. The fruit harvested after 110 days of growth had a shelf life of less

**Plate 6:** Pomegranate fruit cv. Ganesh at harvest (BANGALORE CROP).

**Plate 7:** Pomegranate fruit cv.Ganesh at harvest (BIJAPUR CROP).


6


GANESH CV. AT HARVEST (BIJAPUR)
7

than 5 days at RT storage and percentage fruit cracking during storage was high since they were over ripe. Hence 105-110 days from fruit set was decided as optimum stage of maturity.

The fruit under Bijapur conditions were harvested at their maximum size (Plate 7) and optimum maturity of the fruit was decided by the physical indices like decrease in specific gravity, constant length and breadth of the fruit, reddish yellow colour of the rind with waxy shining surface, opening of calyx, uniformly deep red coloured soft and juicy arils, sweetness, freshness and by hearing to the specific sound when pressed by fingers and by the chemical characters like constant TSS, high sugar and low acid content.

**4.2 STORAGE OF FRUITS**

The present investigation was conducted to study the storage behaviour of pomegranate cv. Ganesh harvested at optimum maturity stage grown from two different agroclimatic conditions namely Bangalore and Bijapur. The treated fruits were stored at three temperatures viz., room temperature (RT) of 25 $\pm$ 1$^{o}$C with 45 $\pm$ 5 per cent RH and low temperature (LT) of 15 $\pm$ 1$^{o}$C with 55 $\pm$ 5 per cent RH and 8 $\pm$ 1$^{o}$C with 65 $\pm$ 5 per cent. The results obtained on the effect of treatments and storage temperature on the various physico-chemical characters are presented. The data on physiological losses in weight (PLW), weight of the rind, rind thickness and rind moisture content are presented for the years 1994 and 1995 as there were significant differences between the year. The data on other characters are given for the year 1995 only.

**4.2.1 Physiological losses in weight (PLW)**

The effect of treatments and storage temperature on per cent PLW of pomegranate fruit during 1994 and 1995 are presented in Tables 3 and 5, respectively for fruits of Bangalore crop and Table 4 and 6, respectively for Bijapur crop. The Figures 8 and 9 represent the PLW of both the crops in the year 1994 and 1995, respectively.

There was a significant increase in the per cent cumulative PLW in all the treatments during storage period of 25 days at RT in both the crops and in both the years. Similar was the trend at 15$^{o}$C for 10-12 weeks in fruits of Bangalore crop and during 8-10 weeks in fruits of Bijapur crop and at 8$^{o}$C for storage period of 12-14 weeks in Bangalore crop and for 12 weeks in fruits of Bijapur crop in both the years.

In Bangalore crop during the year 1994, at RT, the PLW of the untreated control fruits was high compared to other treatments at all storage periods. At the end of 25th day of storage, the untreated fruits had the highest PLW of 4.20 per cent while the lowest PLW of 1.33 per cent was recorded in BDF 2001 film wrapped fruits. The semperfresh

**Table 3 : Effect of treatments and storage temperature on the physiological losses in weight of pomegranate cv.Ganesh grown under Bangalore conditions during 1994.**

| | Physiological losses in weight of fruit (PLW) [Percent] | | | | | |
|---|---|---|---|---|---|---|
| **Storage in days** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | |
| **At 25 ± 1°C** | | | | | | |
| Untreated (Control) | 0.44 | 0.74 | 0.99 | 1.33 | 4.20 | 1.54 |
| Semperfresh (2%) | 0.28 | 0.66 | 0.92 | 1.10 | 3.24 | 1.24 |
| Film wrap (BDF2001) | 0.24 | 0.52 | 0.71 | 0.84 | 1.33 | 0.72 |
| Film wrap (D955) | 0.40 | 0.88 | 1.21 | 1.44 | 2.28 | 1.24 |
| Mean | 0.34 | 0.70 | 0.96 | 1.18 | 3.46 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.464 |
| Period | * | 0.526 |
| Interaction | * | 1.044 |

| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.34 | 0.49 | 0.54 | 0.76 | 1.00 | 1.50 | 0.74 |
| Pre-cooled | 0.22 | 0.73 | 0.78 | 1.10 | 1.44 | 1.48 | 0.98 |
| Semperfresh (2%) | 0.23 | 0.35 | 0.39 | 0.63 | 0.78 | 1.14 | 0.59 |
| Film wrap (BDF2001) | 0.18 | 0.33 | 0.40 | 0.60 | 0.74 | 0.91 | 0.52 |
| Film wrap (D955) | 0.21 | 0.40 | 0.48 | 0.65 | 0.86 | 1.01 | 0.61 |
| Mean | 0.23 | 0.46 | 0.51 | 0.70 | 0.96 | 1.19 | - |

| | | |
|---|---|---|
| Treatment | * | 0.163 |
| Period | * | 0.179 |
| Interaction | NS | - |

| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.44 | 0.63 | 0.85 | 1.12 | 1.36 | 1.67 | 1.92 | 1.14 |
| Pre-cooled | 0.27 | 0.52 | 0.63 | 0.92 | 1.12 | 1.29 | 1.51 | 0.89 |
| Semperfresh (2%) | 0.27 | 0.40 | 0.54 | 0.70 | 1.08 | 1.11 | 1.27 | 0.91 |
| Film wrap (BDF2001) | 0.14 | 0.26 | 0.42 | 0.62 | 0.84 | 1.06 | 1.22 | 0.64 |
| Film wrap (D955) | 0.15 | 0.29 | 0.51 | 0.79 | 0.92 | 1.10 | 1.25 | 0.82 |
| Mean | 0.25 | 0.42 | 0.59 | 0.83 | 1.06 | 1.24 | 1.43 | - |

| | | |
|---|---|---|
| Treatment | * | 0.092 |
| Period | * | 0.108 |
| Interaction | NS | - |

* - Significant at 5%  NS - Non significant

**Table 4 : Effect of treatments and storage temperature on the physiological losses in weight of pomegranate cv.Ganesh grown under Bijapur conditions during 1994.**

| | Physiological losses in weight (PLW) [Percent] | | | | | |
|---|---|---|---|---|---|---|
| **Storage in days** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | |
| **At 25 $\pm$ 1$^{o}$C** | | | | | | |
| Untreated (Control) | 0.48 | 0.76 | 1.39 | 2.56 | 4.95 | 2.03 |
| Semperfresh (2%) | 0.18 | 0.70 | 0.96 | 1.10 | 2.23 | 0.83 |
| Film wrap (BDF2001) | 0.15 | 0.29 | 0.42 | 0.49 | 0.57 | 0.38 |
| Film wrap (D955) | 0.14 | 0.28 | 0.46 | 0.55 | 0.63 | 0.41 |
| Mean | 0.24 | 0.51 | 0.81 | 1.17 | 1.85 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.176 |
| Period | * | 0.196 |
| Interaction | * | 0.393 |

| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 $\pm$ 1$^{o}$C** | | | | | | | |
| Untreated (Control) | 0.36 | 0.92 | 1.37 | 1.65 | - | - | 1.04 |
| Pre-cooled | 0.35 | 0.92 | 1.12 | 1.53 | - | - | 1.01 |
| Semperfresh (2%) | 0.32 | 0.52 | 0.84 | 1.03 | - | - | 0.68 |
| Film wrap (BDF2001) | 0.14 | 0.24 | 0.33 | 0.40 | - | - | 0.27 |
| Film wrap (D955) | 0.21 | 0.31 | 0.46 | 0.64 | - | - | 0.40 |
| Mean | 0.27 | 0.58 | 0.82 | 1.05 | - | - | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.200 |
| Period | * | 0.179 |
| Interaction | NS | - |

| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 8 $\pm$ 1$^{o}$C** | | | | | | | |
| Untreated (Control) | 0.40 | 0.50 | 1.09 | 2.02 | 2.47 | 3.52 | 1.67 |
| Pre-cooled | 0.29 | 0.49 | 0.75 | 1.30 | 1.41 | 1.84 | 1.01 |
| Semperfresh (2%) | 0.27 | 0.48 | 0.96 | 1.15 | 1.34 | 1.61 | 0.96 |
| Film wrap (BDF2001) | 0.19 | 0.29 | 0.46 | 0.70 | 0.81 | 0.88 | 0.55 |
| Film wrap (D955) | 0.24 | 0.32 | 0.45 | 0.59 | 0.78 | 0.85 | 0.53 |
| Mean | 0.27 | 0.41 | 0.74 | 1.15 | 1.36 | 1.74 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 1.08 |
| Period | * | 1.18 |
| Interaction | * | 2.64 |

* - Significant at 5%    NS - Non significant

**Table 5 : Effect of treatments and storage temperature on the physiological losses in weight of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | Physiological losses in weight (PLW) [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **5** | **10** | **15** | **20** | **25** | **Mean** | |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 6.70 | 11.49 | 13.92 | 16.27 | 17.96 | 13.27 | |
| Semperfresh (2%) | 5.49 | 7.76 | 7.85 | 8.05 | 8.35 | 7.51 | |
| Film wrap (BDF2001) | 0.43 | 0.78 | 0.97 | 1.24 | 1.50 | 0.98 | |
| Film wrap (D955) | 0.83 | 1.30 | 1.56 | 1.95 | 2.32 | 1.59 | |
| Mean | 3.36 | 5.33 | 6.07 | 6.87 | 7.55 | - | |
| | | | 'F' Test | CD at 5% | | | |
| Treatment | | | * | 0.414 | | | |
| Period | | | * | 0.463 | | | |
| Interaction | | | * | 0.927 | | | |
| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 7.65 | 15.50 | 19.13 | 25.14 | 30.70 | - | 19.27 |
| Pre-cooled | 9.76 | 16.66 | 19.24 | 24.95 | 28.93 | - | 20.26 |
| Semperfresh (2%) | 6.62 | 13.07 | 16.52 | 22.55 | 27.53 | - | 17.26 |
| Film wrap (BDF2001) | 0.25 | 0.71 | 1.17 | 1.47 | 2.16 | - | 1.15 |
| Film wrap (D955) | 0.41 | 1.60 | 2.31 | 3.35 | 3.66 | - | 2.27 |
| Mean | 4.94 | 9.51 | 11.67 | 15.49 | 18.60 | - | - |
| Treatment | | | * | 1.225 | | | |
| Period | | | * | 1.227 | | | |
| Interaction | | | NS | - | | | |
| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
| **Treatments** | | | | | | | |
| **At 8 ± 1°C** | | | | | | | |
| Untreated (Control) | 3.42 | 6.85 | 9.25 | 13.95 | 18.90 | 20.38 | 12.12 |
| Pre-cooled | 2.98 | 3.65 | 4.66 | 8.60 | 12.05 | 15.07 | 7.83 |
| Semperfresh (2%) | 2.28 | 3.19 | 4.03 | 7.14 | 10.66 | 13.08 | 6.73 |
| Film wrap (BDF2001) | 0.14 | 0.35 | 0.51 | 0.85 | 1.15 | 1.27 | 0.71 |
| Film wrap (D955) | 0.17 | 0.41 | 0.56 | 0.86 | 1.21 | 1.31 | 0.75 |
| Mean | 1.79 | 2.89 | 3.80 | 6.28 | 8.79 | 10.22 | - |
| Treatment | | | * | 0.748 | | | |
| Period | | | * | 0.819 | | | |
| Interaction | | | * | 1.832 | | | |

* - Significant at 5%    NS - Non significant

Table 6 : Effect of treatments and storage temperature on the physiological losses in weight of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.

| | Physiological losses in weight (PLW) [Percent] | | | | | |
|---|---|---|---|---|---|---|
| **Storage in days** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | |
| **At 25 ± 1°C** | | | | | | |
| Untreated (Control) | 14.56 | 18.14 | 20.31 | 22.37 | 23.81 | 19.84 |
| Semperfresh (2%) | 7.70 | 11.51 | 13.74 | 16.37 | 18.55 | 13.57 |
| Film wrap (BDF2001) | 0.36 | 0.56 | 0.66 | 0.93 | 1.11 | 0.72 |
| Film wrap (D955) | 0.56 | 0.88 | 1.04 | 1.42 | 1.69 | 1.12 |
| Mean | 5.79 | 7.77 | 8.94 | 10.27 | 11.29 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 2.260 |
| Period | * | 2.521 |
| Interaction | NS | - |

| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 7.32 | 13.75 | 20.04 | 23.11 | 27.14 | - | 18.27 |
| Pre-cooled | 10.00 | 13.55 | 20.07 | 23.79 | 25.95 | - | 18.67 |
| Semperfresh (2%) | 7.27 | 10.92 | 16.45 | 19.86 | 23.40 | - | 15.62 |
| Film wrap (BDF2001) | 0.29 | 0.44 | 0.81 | 1.09 | 1.55 | - | 0.83 |
| Film wrap (D955) | 0.35 | 0.56 | 1.00 | 1.32 | 1.88 | - | 1.02 |
| Mean | 5.09 | 7.84 | 11.67 | 13.83 | 16.78 | - | - |

| | | |
|---|---|---|
| Treatment | * | 0.146 |
| Period | * | 0.162 |
| Interaction | * | 0.374 |

| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 8 ± 1°C** | | | | | | | |
| Untreated (Control) | 7.81 | 11.98 | 16.61 | 20.20 | 23.42 | 25.60 | 17.60 |
| Pre-cooled | 7.18 | 11.03 | 15.97 | 19.08 | 21.90 | 23.85 | 16.50 |
| Semperfresh (2%) | 5.71 | 8.61 | 12.93 | 16.46 | 18.91 | 20.87 | 13.91 |
| Film wrap (BDF2001) | 0.28 | 0.44 | 0.74 | 1.04 | 1.30 | 1.58 | 0.89 |
| Film wrap (D955) | 0.25 | 0.38 | 0.61 | 0.80 | 1.02 | 1.22 | 0.71 |
| Mean | 4.24 | 6.49 | 9.37 | 11.52 | 13.31 | 14.62 | - |

| | | |
|---|---|---|
| Treatment | * | 1.082 |
| Period | * | 1.181 |
| Interaction | * | 2.648 |

* - Significant at 5%  NS - Non significant

Fig.8: Effect of treatments and storage temperature on the PLW of pomegranate cv. Ganesh grown under Bangalore(A) and Bijapur(B) conditions during 1994.

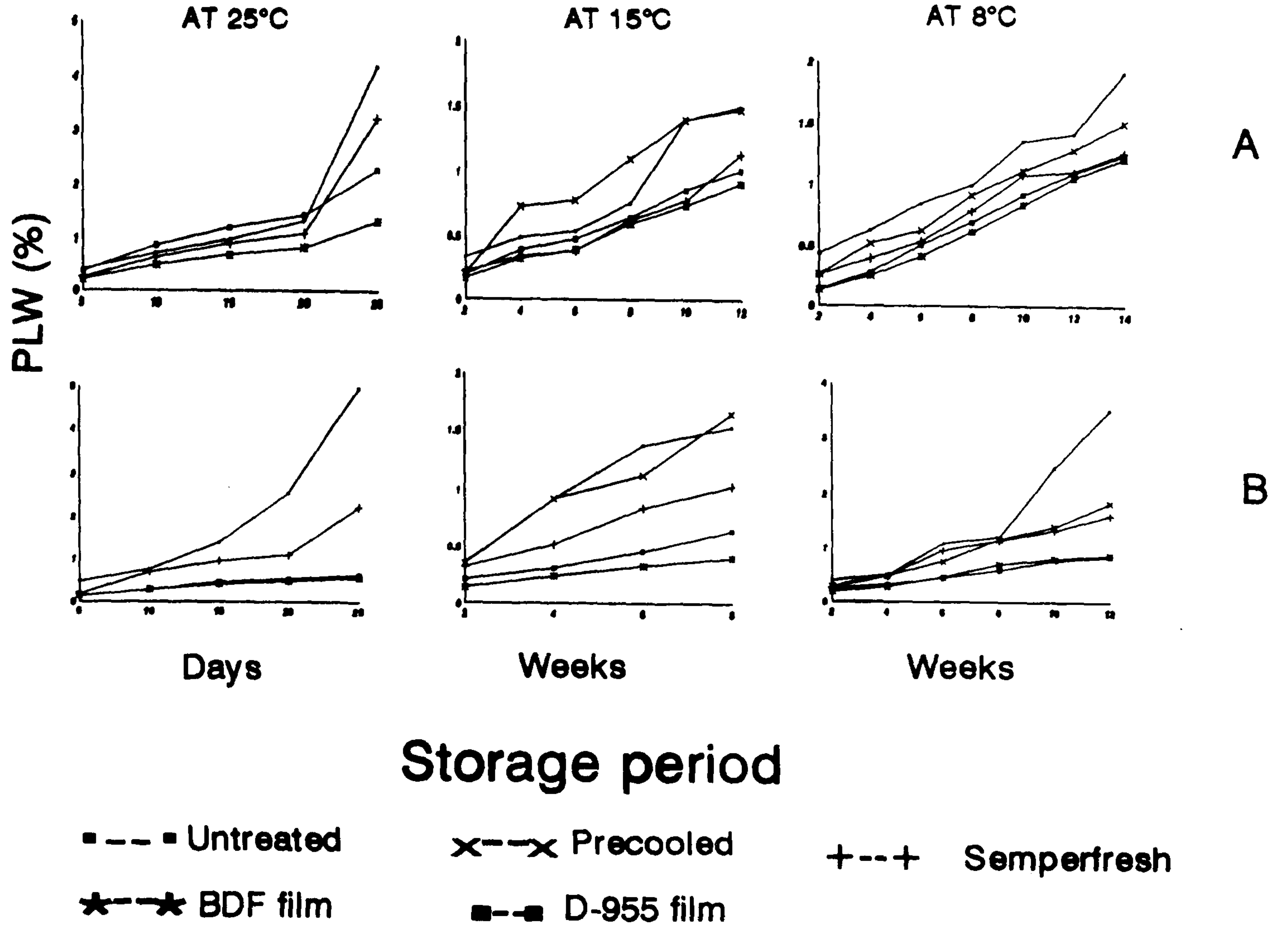
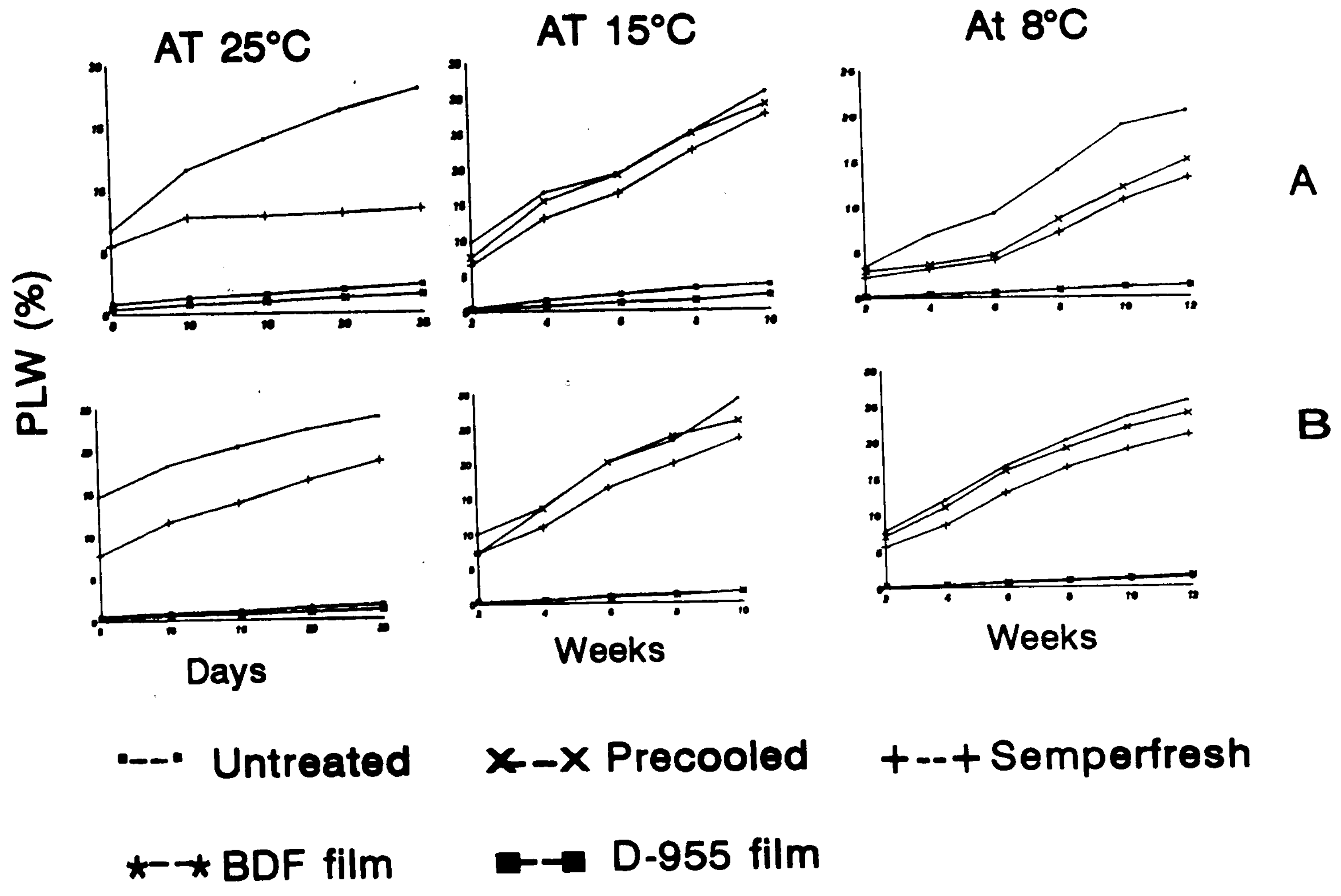


Fig.9: Effect of treatments and storage temperature on the PLW of pomegranate cv. Ganesh grown under Bangalore(A) and Bijapur(B) conditions during 1995.



treated fruits and D 955 film wrapped fruits had 3.24 and 2.28 per cent PLW, respectively.

At 15$^{o}$C after the storage period of 12 weeks the PLW of the untreated fruits was higher (1.50) than the pre-cooled fruits (1.48%). The BDF 2001 film wrapped fruits had a minimum PLW per cent of 0.91. The semperfresh and D-955 had a PLW of 1.14 and 1.01 per cent, respectively.

At 8$^{o}$C where the storage period extended upto 14 weeks, the untreated fruits had high PLW (1.92) as compared to other treatments. Although the PLW of pre-cooled and semperfresh treated fruits had same PLW (0.27%) on 2nd week of storage, the PLW of pre-cooled fruits was higher (1.51) than the semperfresh treated fruits (1.27%) at the end of 14 weeks of storage. The BDF 2001 and D955 film wrapped fruits had 1.22 and 1.25 per cent PLW, respectively.

In fruits of Bijapur crop (1994) after a storage period of 25 days at RT the untreated fruits had 4.95 PLW per cent. A minimum of 0.57 per cent was noticed in BDF film wrapped fruits. The semperfresh treated and D 955 film wrapped fruits had a PLW of 2.23 and 0.63 per cent, respectively.

At 15$^{o}$C after a storage period of 8 weeks, the untreated fruits had maximum PLW of 1.65 per cent while a minimum of 0.40 per cent was recorded in BDF 2001 film wrapped fruits.

The pre-cooled fruits had 1.53 per cent PLW followed by semperfresh (1.03%) treated fruits and D955 film wrapped fruits (0.64%).

At 8$^{O}$C after a storage period of 12 weeks, the untreated fruits had highest PLW per cent (3.52) while the lowest was observed in D955 film wrapped fruits (0.85%). The pre-cooled, semperfresh treated and BDF 2001 film wrapped fruits had 1.84, 1.61 and 0.88 PLW per cent, respectively.

In the year 1995 where the fruits were not packed in polythene bags the PLW of the fruits increased at all storage temperatures and in all the treatments in both the crops. In Bangalore crop at RT, the PLW of the untreated fruits was higher as compared to other treatments on all storage periods. At the end of 25 days of storage, the untreated fruits had the highest of 17.96 per cent while the lowest of 1.50 per cent was recorded in BDF 2001 film wrapped fruits. The semperfresh treated and D955 film wrapped fruits had 8.35 and 2.32 per cent PLW, respectively.

At 15$^{O}$C after the end of 10 weeks storage the PLW of the untreated fruits was higher (30.70%) PLW followed by pre-cooled fruits (28.93%). The BDF 2001 film wrapped fruits had a minimum PLW per cent of 2.16. The semperfresh treated fruits and D955 film wrapped fruits had a PLW of 27.53 and 3.66 per cent, respectively.

At $8^{o}C$ at the end of 12 weeks storage, the untreated fruits had high PLW (20.38) as compared to other treatments. Minimum PLW was recorded in BDF 2001 film wrapped fruits (1.27%). The pre-cooled, semperfresh treated and D955 film wrapped fruits had 15.07, 13.08 and 1.31 per cent PLW, respectively.

In Bijapur crop fruits (1995) after a storage period of 25 days at RT the untreated fruits had maximum PLW of 23.81 per cent. It was followed by semperfresh treated (18.55) and D955 film wrapped fruits (1.69) while a minimum PLW of 1.11 per cent was recorded in BDF 2001 film wrapped fruits.

At $15^{o}C$ after the end of 10 weeks storage period, maximum PLW of 29.14 per cent was recorded in untreated fruits while a minimum of 1.55 per cent was observed in BDF 2001 film wrapped fruits. The pre-cooled fruits had 25.95 per cent PLW followed by semperfresh treated fruits and D955 film wrapped fruits with 23.40 and 1.88 per cent, respectively.

At $8^{o}C$ at the end of 12 weeks storage, the untreated - fruits had 25.60 per cent PLW. Minimum PLW of 1.22 per cent was recorded in D955 film wrapped fruits. The pre-cooled and semperfresh treated fruits had 23.85 and 20.87 per cent, respectively while the BDF 2001 fruits had 1.58 per cent.

In general, it was observed that irrespective of the growing conditions, the PLW was high in RT storage followed by 15 and 8°C storage. The PLW per cent in the year 1994 was less than the PLW per cent of 1995 in Bangalore and Bijapur harvested crops since they were packed in polythene bags. The PLW of Bijapur fruits was more as compared to PLW of Bangalore fruits at all the three storage temperatures. The PLW of unwrapped fruits (untreated, semperfresh treated and pre-cooled) was higher than the PLW of wrapped fruits (BDF 2001 and D955) in both the crops at all the three storage temperatures in both the years.

Statistically the observed difference in PLW among the treatments and storage period were significant in both the crops and in both the years at all the three storage temperatures.

The interaction between treatments and storage period was significant at 25°C for both the crops and in both the years. At 15°C, the interaction between treatments and storage period was significant in Bijapur fruits only during 1995. At 8°C, the interaction between the treatments and storage period was significant in fruits of Bijapur in both the years and in only 1995 for Bangalore crop.

### 4.2.2 Rind weight

The effect of treatments and storage temperature on rind weight of pomegranate during 1994 and 1995 are presented in Tables 7 and 9, respectively for fruits of Bangalore crop and in Tables 8 and 10, respectively for Bijapur fruits. The Figure 10 represents the rind weight of both the crops in 1995.

In Bangalore crop during the year 1994 the rind weight at the beginning of storage was 33.4 per cent. At RT after 25 days of storage the rind weight decreased slightly in all the treatments as compared to initial value. The untreated fruits had a minimum of 26.5 per cent rind weight. The BDF and D955 film wrapped fruits had almost same rind weight of 31.0 per cent while the semperfresh treated fruits had 27.4 per cent.

At 15°C, after 12 weeks of storage period the rind of semperfresh treated fruits was lowest with 24.8 per cent while the highest rind weight was recorded in D955 film wrapped fruits (31.2%). The untreated and pre-cooled fruits had almost same rind weight of 26.0 per cent. The BDF 2001 film wrapped fruits had 28.8 per cent weight of the rind.

At 8°C after the end of 14 weeks storage the untreated fruits had lowest rind weight of 28.2 per cent while the semperfresh treated fruits had highest weight of rind at 32.3 per cent. The pre-cooled and BDF 2001 film wrapped fruits had almost equal weight of 31.5 per cent.

**Table 7 : Effect of treatments and storage temperature on the rind weight of pomegranate cv.Ganesh grown under Bangalore conditions during 1994.**

| | | Rind weight [Percent] | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 33.4 | 30.0 | 31.5 | 26.5 | 26.7 | 26.5 | 28.2 |
| Semperfresh (2%) | | 30.0 | 26.4 | 28.3 | 27.7 | 27.4 | 30.0 |
| Film wrap (BDF2001) | | 30.5 | 30.4 | 28.7 | 32.0 | 31.4 | 32.7 |
| Film wrap (D955) | | 32.4 | 33.3 | 33.4 | 30.7 | 31.0 | 32.2 |
| Mean | - | 30.7 | 30.4 | 29.1 | 31.8 | 31.0 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 33.4 | 36.0 | 32.3 | 30.2 | 30.8 | 29.2 | 26.7 | 31.0 |
| Pre-cooled | | 31.4 | 36.9 | 32.9 | 31.6 | 31.5 | 26.2 | 31.9 |
| Semperfresh (2%) | | 36.6 | 35.2 | 32.4 | 31.8 | 30.5 | 24.8 | 31.9 |
| Film wrap (BDF2001) | | 32.5 | 34.5 | 33.1 | 32.8 | 30.2 | 28.8 | 32.0 |
| Film wrap (D955) | | 32.0 | 33.9 | 33.1 | 30.0 | 32.7 | 31.2 | 32.1 |
| Mean | | 33.7 | 34.6 | 32.3 | 31.6 | 31.0 | 27.5 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **Mean** |
|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | | |
| Untreated (Control) | 33.4 | 34.5 | 32.5 | 33.6 | 27.9 | 30.7 | 30.5 | 28.2 | 31.3 |
| Pre-cooled | | 35.0 | 31.9 | 31.6 | 32.8 | 32.5 | 33.9 | 31.5 | 32.8 |
| Semperfresh (2%) | | 41.6 | 33.3 | 32.8 | 34.9 | 31.5 | 36.1 | 32.3 | 34.7 |
| Film wrap (BDF2001) | | 33.4 | 33.6 | 35.0 | 30.1 | 31.2 | 34.3 | 31.6 | 32.7 |
| Film wrap (D955) | | 33.3 | 31.3 | 29.9 | 30.4 | 31.7 | 29.3 | 29.3 | 30.7 |
| Mean | | 35.6 | 32.5 | 32.6 | 31.2 | 31.5 | 31.0 | 30.6 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%          NS - Non significant

**Table 8: Effect of treatments and storage temperature on the rind weight of pomegranate cv.Ganesh grown under Bijapur conditions during 1994.**

| Storage in days | Rind weight [Percent] At harvest | 5 | 10 | 15 | 20 | 25 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 30.3 | 31.1 | 34.5 | 30.8 | 33.5 | 27.5 | 31.5 |
| Semperfresh (2%) | | 32.7 | 31.7 | 29.7 | 29.7 | 30.1 | 30.8 |
| Film wrap (BDF2001) | | 33.7 | 31.9 | 31.0 | 26.4 | 33.4 | 31.3 |
| Film wrap (D955) | | 31.4 | 34.3 | 31.7 | 30.6 | 33.4 | 32.3 |
| Mean | | 32.2 | 33.1 | 30.8 | 30.1 | 31.1 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 30.3 | 34.9 | 31.0 | 28.2 | 25.0 | - | - | 29.8 |
| Pre-cooled | | 32.8 | 36.9 | 32.2 | 30.6 | - | - | 33.1 |
| Semperfresh (2%) | | 32.5 | 32.0 | 31.3 | 31.9 | - | - | 31.9 |
| Film wrap (BDF2001) | | 37.9 | 33.2 | 31.3 | 34.7 | - | - | 34.3 |
| Film wrap (D955) | | 38.8 | 32.0 | 31.6 | 33.9 | - | - | 34.1 |
| Mean | | 35.4 | 33.0 | 30.9 | 31.2 | - | - | 34.1 |

| | | |
|---|---|---|
| **Treatment** | **NS** | - |
| **Period** | **NS** | - |
| **Interaction** | **NS** | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 30.3 | 31.3 | 33.7 | 32.3 | 33.5 | 30.5 | 30.3 | 32.3 |
| Pre-cooled | | 30.8 | 34.7 | 32.4 | 32.7 | 29.1 | 28.3 | 31.3 |
| Semperfresh (2%) | | 32.1 | 33.7 | 28.7 | 32.2 | 28.6 | 31.3 | 31.1 |
| Film wrap (BDF2001) | | 32.6 | 30.5 | 32.7 | 33.3 | 33.0 | 35.0 | 33.2 |
| Film wrap (D955) | | 37.0 | 32.2 | 31.1 | 35.2 | 31.7 | 31.8 | 32.8 |
| Mean | | 32.8 | 32.8 | 31.4 | 33.8 | 30.6 | 31.5 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%　　　NS - Non significant

**Table 9: Effect of treatments and storage temperature on the rind weight of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | Rind weight [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 33.4 | 30.7 | 30.2 | 29.7 | 25.0 | 23.2 | 27.8 |
| Semperfresh (2%) | | 33.0 | 33.6 | 33.0 | 29.2 | 24.8 | 31.7 |
| Film wrap (BDF2001) | | 28.9 | 31.1 | 30.8 | 32.9 | 31.1 | 31.0 |
| Film wrap (D955) | | 33.7 | 35.5 | 31.7 | 30.1 | 30.1 | 32.2 |
| Mean | | 31.6 | 32.6 | 31.3 | 29.4 | 28.6 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 31.3 | 30.6 | 29.4 | 29.5 | 25.2 | 21.7 | - | 27.3 |
| Pre-cooled | | 32.5 | 31.7 | 30.4 | 28.8 | 26.8 | - | 30.0 |
| Semperfresh (2%) | | 31.9 | 31.3 | 29.5 | 28.6 | 28.0 | - | 29.9 |
| Film wrap (BDF2001) | | 31.9 | 31.1 | 32.5 | 30.2 | 29.6 | - | 31.0 |
| Film wrap (D955) | | 32.7 | 29.1 | 30.2 | 31.5 | 30.9 | - | 30.9 |
| Mean | | 31.9 | 30.5 | 30.4 | 28.8 | 27.4 | - | - |

| | | |
|---|---|---|
| Treatment | * | 1.330 |
| Period | * | 1.330 |
| Interaction | * | 2.973 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 33.4 | 32.2 | 31.5 | 31.3 | 30.5 | 29.1 | 26.9 | 30.2 |
| Pre-cooled | | 32.8 | 31.7 | 31.7 | 31.6 | 30.5 | 30.9 | 31.5 |
| Semperfresh (2%) | | 33.7 | 33.2 | 32.6 | 31.3 | 29.7 | 27.0 | 31.2 |
| Film wrap (BDF2001) | | 32.3 | 33.0 | 30.8 | 32.3 | 33.0 | 32.3 | 32.8 |
| Film wrap (D955) | | 34.9 | 32.3 | 32.1 | 35.4 | 33.4 | 29.9 | 33.6 |
| Mean | | 33.2 | 32.4 | 31.7 | 32.2 | 31.3 | 29.4 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%　　　NS - Non significant

**Table 10: Effect of treatments and storage temperature on the rind weight of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | Rind weight [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 29.9 | 30.3 | 29.1 | 27.1 | 24.2 | 21.5 | 26.4 |
| Semperfresh (2%) | | 27.1 | 24.4 | 24.1 | 25.8 | 25.1 | 25.3 |
| Film wrap (BDF2001) | | 28.2 | 29.6 | 25.8 | 29.7 | 27.9 | 28.2 |
| Film wrap (D955) | | 28.6 | 32.0 | 28.9 | 25.6 | 29.6 | 28.9 |
| Mean | | 28.5 | 28.8 | 26.5 | - | 26.2 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 1.924 |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 29.9 | 28.6 | 26.8 | 30.0 | 29.0 | 27.8 | - | 28.7 |
| Pre-cooled | | 29.2 | 29.5 | 30.7 | 27.5 | 21.3 | - | 27.6 |
| Semperfresh (2%) | | 29.8 | 27.9 | 31.9 | 25.2 | 21.2 | - | 27.2 |
| Film wrap (BDF2001) | | 31.8 | 30.5 | 30.5 | 30.6 | 28.0 | - | 30.3 |
| Film wrap (D955) | | 27.8 | 27.7 | 30.5 | 26.9 | 23.7 | - | 27.3 |
| Mean | | 29.4 | 28.5 | 30.7 | 27.8 | 24.4 | - | - |

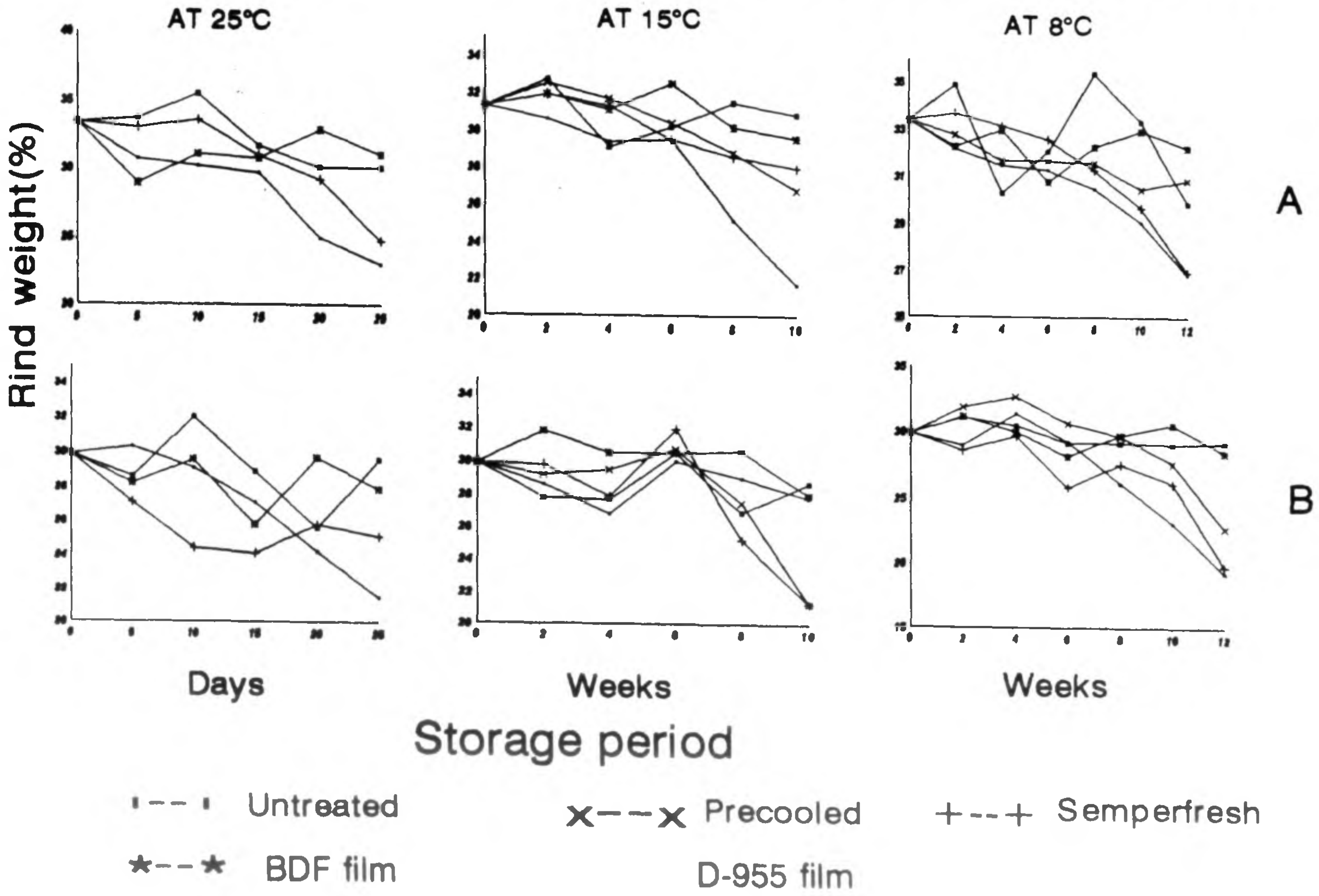
| | | |
|---|---|---|
| Treatment | * | 1.173 |
| Period | * | 1.173 |
| Interaction | * | 2.623 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 29.9 | 29.0 | 31.4 | 29.3 | 26.2 | 23.2 | 19.3 | 26.4 |
| Pre-cooled | | 31.9 | 32.7 | 30.7 | 29.7 | 27.7 | 22.8 | 29.2 |
| Semperfresh (2%) | | 28.6 | 29.7 | 25.9 | 27.6 | 26.2 | 19.8 | 26.3 |
| Film wrap (BDF2001) | | 31.2 | 30.0 | 28.2 | 29.8 | 30.6 | 28.5 | 29.7 |
| Film wrap (D955) | | 31.1 | 30.5 | 29.2 | 29.2 | 29.1 | 29.2 | 29.7 |
| Mean | | 30.3 | 30.9 | 28.7 | 28.5 | 27.4 | 23.9 | - |

| | | |
|---|---|---|
| Treatment | * | 1.624 |
| Period | * | 1.778 |
| Interaction | NS | - |

* - Significant at 5%　　　　NS - Non significant

Fig.10: Effect of treatments and storage temperature on the rind weight of pomegranate cv. Ganesh grown under Bangalore(A) and Bijapur(B) conditions during 1995.



In fruits of Bijapur crop (1994) the rind weight at the beginning of storage was 30.3 per cent. After a storage period of 25 days at RT the untreated fruits had lowest rind weight (27.5%) while the two wrapped fruits had highest and equal rind weight of 33.4 per cent. The semperfresh treated fruits recorded a rind weight of 30.1 per cent.

At 15°C after the end of 8 weeks storage the untreated fruits had a lowest of 25.0 per cent rind weight while the BDF 2001 film wrapped fruits had the highest (34.7%) rind weight per cent. The pre-cooled fruits, semperfresh treated and D 955 film wrapped fruits had 30.6, 31.9 and 33.9 per cent rind weights, respectively.

At 8°C, after 12 weeks of storage the pre-cooled fruits had lowest (28.3%) rind weight while the BDF 2001 film wrapped fruits had maximum (35.01%). The semperfresh treated and D955 film wrapped fruits had almost same rind of 31.3 and 31.8 per cent respectively. The untreated fruits recorded 30.3 per cent rind weight.

During the year 1995 in Bangalore crop the initial rind weight at the start of storage was 33.4 per cent. At RT after a storage period of 25 days, the rind weight of all the treatments decreased as compared to the initial value. The untreated fruits recorded a lowest rind weight of 23.2 per cent while the BDF 2001 film wrapped fruits recorded the highest (31.1%). The semperfresh treated and D955 film wrapped fruits had 24.8 and 30.1 per cent rind weights, respectively.

At 15°C, the rind weight at harvest was 31.3 per cent. After a storage period of 10 weeks the rind weight decreased in all the treatments. In untreated fruits the lowest rind weight of 21.7 per cent was recorded while the D955 film wrapped fruits recorded the highest of 30.9 per cent. The pre-cooled semperfresh treated and BDF 2001 film wrapped fruits recorded 26.8, 28.0, 29.6 per cent rind weights, respectively.

At 8°C, after 12 weeks of storage period the rind weights decreased in all the treatments. Minimum rind weight was recorded in untreated (26.9%) fruits while the maximum was recorded in BDF 2001 film wrapped fruits (32.3%). The D955 film wrapped fruits recorded 29.9 per cent while the pre-cooled and semperfresh treated fruits had 30.9 and 27.0 per cent, respectively.

In Bijapur crop fruits (1995) at RT after 25 days of storage the rind weight slightly decreased in all the treatment as compared to initial value of 29.9 per cent. It was minimum (21.5%) in untreated fruits and maximum (29.6) in D955 film wrapped fruits. The semperfresh treated and

BDF 2001 film wrapped fruits had 25 per cent and 27.9 per cent rind weights, respectively.

At 15$^{o}$C after 10 weeks storage, the rind weight decreased in all the treatments when compared to rind weight at harvest (29.9). The pre-cooled and semperfresh treated fruits both at 21.3 per cent had lowest rind weight. The BDF 2001 and D955 film wrapped fruits recorded 28.0 and 28.7 per cent rind weight while the untreated fruits had 25.8 per cent rind weight.

At 8$^{o}$C after the end of 14 weeks storage, the untreated fruits had minimum rind weight of 19.3 per cent while the D955 film wrapped fruits had maximum (29.2%). The semperfresh treated fruits had almost same (19.8) rind weight as that of untreated. The pre cooled and BDF 2001 film wrapped fruits had 22.8 and 28.5 per cent rind weight, respectively.

In general it was noticed that the rind weight of unwrapped fruits was lower than the wrapped fruits. The fruits of Bijapur crop had lower rind weight than the fruits of Bangalore crop in year 1995 and not much differences were observed during the year 1994 between the two crops. The rind weight was lower at 25$^{o}$C followed by 15 and 8$^{o}$C.

Statistical analysis did not show any significant differences in Bangalore and Bijapur fruits at all the three temperatures during the year 1994. In the year 1995 all the effects were significant at 15$^{o}$C for both the crops. At 24$^{o}$C the treatment differences was significant for Bijapur crop. At 8$^{o}$C, the differences between treatments and period of storage was significant for Bijapur crop.

### 4.2.3 Rind thickness

The effect of treatments and storage temperature on rind thickness of pomegranate during 1994 and 1995 are presented in Tables 11 and 13, respectively for fruits of Bangalore crop and in Tables 12 and 14, respectively for Bijapur crop. The Figure 11 represents the rind thickness of both the crops in 1995.

In Bangalore crop during the year 1994 the rind thickness at the beginning of storage was 0.44 mm. At RT after the end of 25 days storage, the untreated fruits had lowest rind thickness of 0.19 mm while the D955 film wrapped fruits had highest (0.30 mm). The semperfresh treated fruits and BDF 2001 film wrapped fruits had 0.20 and 0.27 mm rind thickness, respectively.

At 15$^{o}$C at end of 12 weeks storage, the untreated fruits had 0.22 mm thick rind while the BDF 2001 film wrapped fruits had a highest of 0.35 mm rind thickness. The pre-

**Table 11: Effect of treatments and storage temperature on the rind thickness of pomegranate cv.Ganesh grown under Bangalore conditions during 1994.**

| | | Rind thickness [mm] | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.44 | 0.32 | 0.32 | 0.32 | 0.27 | 0.19 | 0.28 |
| Semperfresh (2%) | | 0.30 | 0.30 | 0.27 | 0.21 | 0.20 | 0.26 |
| Film wrap (BDF2001) | | 0.35 | 0.32 | 0.30 | 0.32 | 0.27 | 0.31 |
| Film wrap (D955) | | 0.35 | 0.32 | 0.32 | 0.30 | 0.30 | 0.32 |
| Mean | | 0.33 | 0.31 | 0.30 | 0.27 | 0.24 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.034 |
| Period | * | 0.038 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **Mean** |
|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | | |
| Untreated (Control) | 0.44 | 0.40 | 0.37 | 0.32 | 0.27 | 0.22 | 0.22 | - | 0.30 |
| Pre-cooled | | 0.40 | 0.30 | 0.30 | 0.32 | 0.27 | 0.25 | - | 0.30 |
| Semperfresh (2%) | | 0.30 | 0.35 | 0.30 | 0.35 | 0.30 | 0.26 | - | 0.31 |
| Film wrap (BDF2001) | | 0.37 | 0.35 | 0.40 | 0.35 | 0.37 | 0.35 | - | 0.36 |
| Film wrap (D955) | | 0.37 | 0.35 | 0.42 | 0.30 | 0.35 | 0.32 | - | 0.35 |
| Mean | | 0.37 | 0.34 | 0.35 | 0.32 | 0.30 | 0.28 | - | - |

| | | |
|---|---|---|
| Treatment | * | 0.029 |
| Period | * | 0.032 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **Mean** |
|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | | |
| Untreated (Control) | 0.44 | 0.40 | 0.35 | 0.30 | 0.30 | 0.30 | 0.25 | 0.22 | 0.30 |
| Pre-cooled | | 0.32 | 0.35 | 0.32 | 0.37 | 0.30 | 0.27 | 0.25 | 0.31 |
| Semperfresh (2%) | | 0.37 | 0.30 | 0.32 | 0.32 | 0.32 | 0.30 | 0.27 | 0.31 |
| Film wrap (BDF2001) | | 0.37 | 0.32 | 0.37 | 0.37 | 0.35 | 0.37 | 0.30 | 0.35 |
| Film wrap (D955) | | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.30 | 0.30 | 0.33 |
| Mean | | 0.35 | 0.33 | 0.33 | 0.34 | 0.32 | 0.30 | 0.27 | - |

| | | |
|---|---|---|
| Treatment | * | 0.027 |
| Period | * | 0.032 |
| Interaction | NS | - |

* - Significant at 5%    NS - Non significant

**Table 12: Effect of treatments and storage temperature on the rind thickness of pomegranate cv.Ganesh grown under Bijapur conditions during 1994.**

| | Rind thickness [mm] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.30 | 0.27 | 0.25 | 0.23 | 0.21 | 0.17 | 0.22 |
| Semperfresh (2%) | | 0.28 | 0.25 | 0.25 | 0.22 | 0.19 | 0.23 |
| Film wrap (BDF2001) | | 0.30 | 0.30 | 0.27 | 0.30 | 0.27 | 0.29 |
| Film wrap (D955) | | 0.30 | 0.30 | 0.25 | 0.27 | 0.25 | 0.27 |
| Mean | | 0.29 | 0.27 | 0.25 | 0.25 | 0.22 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.024 |
| Period | * | 0.027 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.30 | 0.32 | 0.27 | 0.27 | 0.20 | - | - | 0.26 |
| Pre-cooled | | 0.30 | 0.30 | 0.30 | 0.25 | - | - | 0.28 |
| Semperfresh (2%) | | 0.30 | 0.30 | 0.27 | 0.27 | - | - | 0.28 |
| Film wrap (BDF2001) | | 0.40 | 0.32 | 0.32 | 0.28 | - | - | 0.33 |
| Film wrap (D955) | | 0.40 | 0.34 | 0.30 | 0.30 | - | - | 0.33 |
| Mean | | 0.34 | 0.30 | 0.29 | 0.27 | - | - | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.025 |
| Period | * | 0.023 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.30 | 0.35 | 0.27 | 0.30 | 0.25 | 0.19 | 0.16 | 0.25 |
| Pre-cooled | | 0.30 | 0.30 | 0.30 | 0.27 | 0.20 | 0.19 | 0.26 |
| Semperfresh (2%) | | 0.32 | 0.30 | 0.27 | 0.27 | 0.25 | 0.20 | 0.27 |
| Film wrap (BDF2001) | | 0.30 | 0.30 | 0.30 | 0.30 | 0.25 | 0.25 | 0.28 |
| Film wrap (D955) | | 0.30 | 0.33 | 0.27 | 0.30 | 0.30 | 0.25 | 0.29 |
| Mean | | 0.31 | 0.30 | 0.29 | 0.28 | 0.23 | 0.21 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.015 |
| Period | * | 0.019 |
| Interaction | NS | - |

* - Significant at 5%  NS - Non significant

Table 13: Effect of treatments and storage temperature on the rind thickness of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.

| | Rind thickness (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.40 | 0.37 | 0.27 | 0.25 | 0.17 | 0.14 | 0.22 |
| Semperfresh (2%) | | 0.30 | 0.30 | 0.30 | 0.27 | 0.24 | 0.28 |
| Film wrap (BDF2001) | | 0.45 | 0.35 | 0.32 | 0.32 | 0.32 | 0.35 |
| Film wrap (D955) | | 0.37 | 0.37 | 0.35 | 0.37 | 0.32 | 0.36 |
| Mean | | 0.35 | 0.32 | 0.30 | 0.28 | 0.24 | 0.23 |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.038 |
| Period | * | 0.043 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.38 | 0.27 | 0.25 | 0.22 | 0.19 | 0.17 | - | 0.22 |
| Pre-cooled | | 0.35 | 0.25 | 0.22 | 0.20 | 0.20 | - | 0.24 |
| Semperfresh (2%) | | 0.37 | 0.32 | 0.27 | 0.25 | 0.22 | - | 0.29 |
| Film wrap (BDF2001) | | 0.35 | 0.32 | 0.32 | 0.25 | 0.27 | - | 0.30 |
| Film wrap (D955) | | 0.35 | 0.30 | 0.30 | 0.30 | 0.27 | - | 0.30 |
| Mean | | 0.34 | 0.29 | 0.27 | 0.23 | 0.22 | - | - |

| | | |
|---|---|---|
| Treatment | * | 0.027 |
| Period | * | 0.041 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.40 | 0.37 | 0.32 | 0.30 | 0.25 | 0.24 | 0.22 | 0.28 |
| Pre-cooled | | 0.37 | 0.32 | 0.30 | 0.29 | 0.22 | 0.20 | 0.28 |
| Semperfresh (2%) | | 0.37 | 0.35 | 0.32 | 0.30 | 0.25 | 0.23 | 0.30 |
| Film wrap (BDF2001) | | 0.40 | 0.37 | 0.35 | 0.35 | 0.35 | 0.32 | 0.35 |
| Film wrap (D955) | | 0.40 | 0.40 | 0.37 | 0.37 | 0.32 | 0.32 | 0.36 |
| Mean | | 0.38 | 0.34 | 0.32 | 0.31 | 0.27 | 0.25 | - |

| | | |
|---|---|---|
| Treatment | * | 0.016 |
| Period | * | 0.018 |
| Interaction | NS | - |

* - Significant at 5%    NS - Non significant

**Table 14: Effect of treatments and storage temperature on the rind thickness of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | Rind thickness (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.35 | 0.30 | 0.25 | 0.25 | 0.22 | 0.12 | 0.22 |
| Semperfresh (2%) | | 0.32 | 0.25 | 0.22 | 0.22 | 0.20 | 0.21 |
| Film wrap (BDF2001) | | 0.35 | 0.30 | 0.30 | 0.23 | 0.25 | 0.28 |
| Film wrap (D955) | | 0.35 | 0.30 | 0.25 | 0.25 | 0.25 | 0.29 |
| Mean | | 0.33 | 0.26 | 0.27 | 0.23 | 0.20 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 0.028 |
| Period | * | 0.031 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.35 | 0.26 | 0.25 | 0.20 | 0.16 | 0.12 | - | 0.20 |
| Pre-cooled | | 0.25 | 0.22 | 0.20 | 0.19 | 0.16 | - | 0.21 |
| Semperfresh (2%) | | 0.27 | 0.25 | 0.27 | 0.20 | 0.15 | - | 0.23 |
| Film wrap (BDF2001) | | 0.30 | 0.32 | 0.32 | 0.25 | 0.22 | - | 0.28 |
| Film wrap (D955) | | 0.30 | 0.27 | 0.30 | 0.23 | 0.22 | - | 0.26 |
| Mean | | 0.28 | 0.26 | 0.27 | 0.21 | 0.17 | - | - |

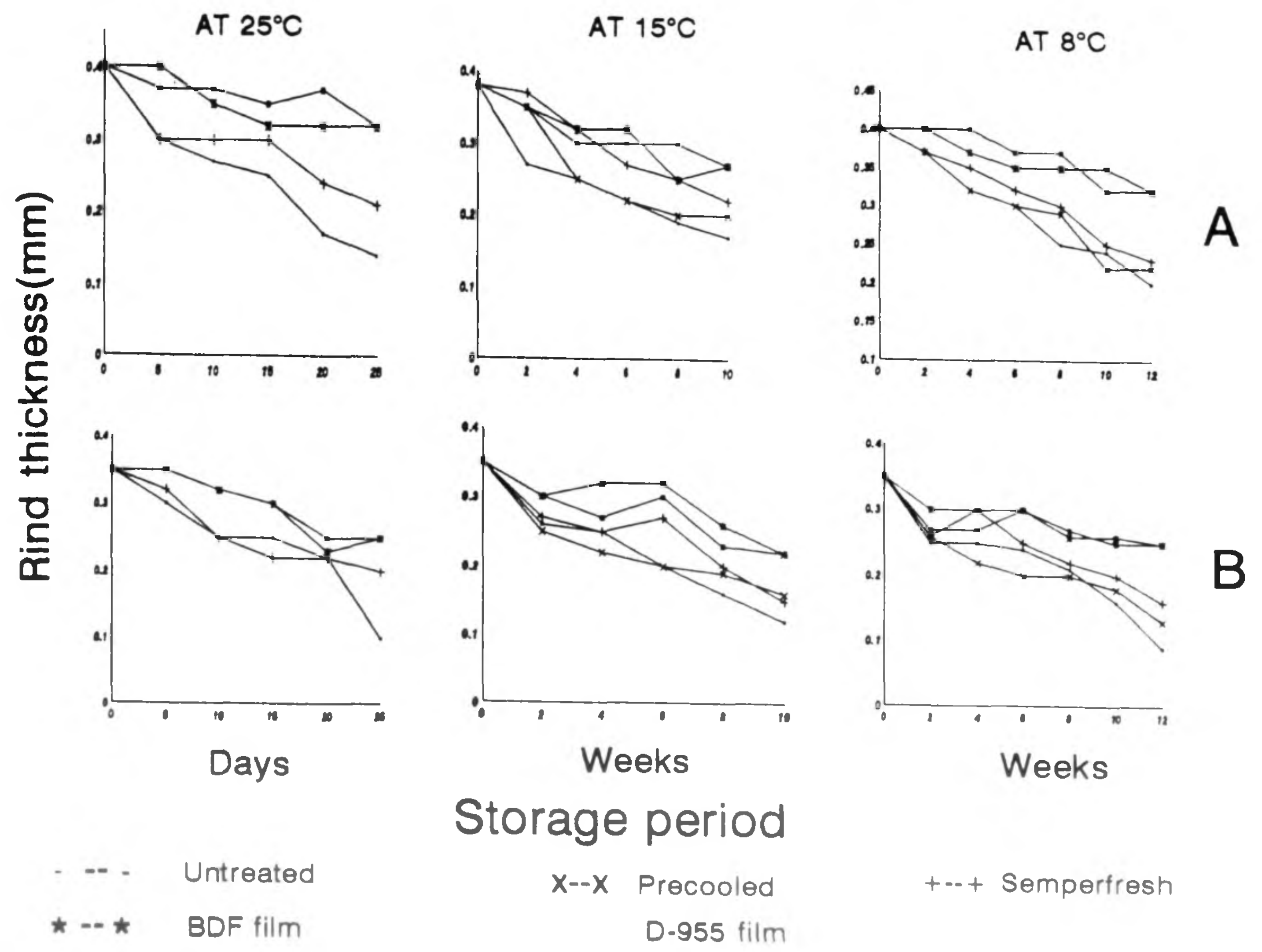
| | | |
|---|---|---|
| Treatment | * | 0.031 |
| Period | * | 0.031 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.35 | 0.25 | 0.25 | 0.24 | 0.21 | 0.16 | 0.09 | 0.20 |
| Pre-cooled | | 0.26 | 0.22 | 0.20 | 0.20 | 0.18 | 0.13 | 0.20 |
| Semperfresh (2%) | | 0.26 | 0.30 | 0.25 | 0.22 | 0.20 | 0.16 | 0.23 |
| Film wrap (BDF2001) | | 0.30 | 0.30 | 0.30 | 0.26 | 0.26 | 0.25 | 0.27 |
| Film wrap (D955) | | 0.27 | 0.27 | 0.30 | 0.27 | 0.25 | 0.25 | 0.27 |
| Mean | | 0.26 | 0.27 | 0.26 | 0.23 | 0.21 | 0.17 | - |

| | | |
|---|---|---|
| Treatment | * | 0.017 |
| Period | * | 0.018 |
| Interaction | NS | - |

* - Significant at 5%    NS - Non significant

Fig.11: Effect of treatments and storage temperature on the thickness of rind of pomegranate cv. Ganesh grown under Bangalore (A) and Bijapur(B) conditions during 1995.



cooled and semperfresh treated fruits had almost same rind thickness with 0.25 and 0.26 mm, respectively. The D955 film wrapped fruits had 0.32 mm thick rind.

At 8°C at the end of 14 weeks of storage, the untreated fruits had lowest rind thickness of 0.22 mm, while both the wrapped fruits had highest rind thickness of 0.30 mm. The pre-cooled and semperfresh treated fruits had 0.25 and 0.27 mm thick rind, respectively.

In the fruits of Bijapur crop (1994) the rind thickness at the beginning of storage was 0.30 mm. At RT after the storage period of 25 days, the untreated fruits had lowest rind thickness of 0.17 mm and the BDF 2001 film wrapped fruits had highest rind thickness of 0.27 mm. The semperfresh treated and D955 film wrapped fruits recorded 0.19 and 0.25 mm rind thickness, respectively.

At 15°C after 8 weeks of storage, the untreated fruits had lowest rind thickness (0.20 mm) while the D955 film wrapped fruits had highest (0.30 mm). The pre-cooled, semperfresh treated and BDF 2001 film wrapped fruits had 0.25, 0.27 and 0.28 mm thick rind, respectively.

At 8°C after 12 weeks of storage, the two film wrapped fruits had highest (0.25 mm) rind thickness while the untreated fruits had lowest (0.16 mm). The pre-cooled and semperfresh treated fruits had 0.19 and 0.20 mm rind thickness, respectively.

During the year 1995 in Bangalore crop the rind thickness at beginning of storage was 0.40. At RT after a storage period of 25 days, the two film wrapped fruits had maximum rind thickness of 0.32 mm. The untreated fruits had 0.14 mm and the semperfresh treated fruits had 0.21 mm thick rind.

At 15$^{o}$C the rind thickness at the beginning of storage was 0.38 mm and after a storage period of 10 weeks, the two film wrapped fruits had 0.27 mm rind thickness. The untreated fruits recorded 0.17 mm while the pre-cooled and semperfresh treated fruits had 0.20 and 0.22 mm rind thickness, respectively.

At 8$^{o}$C after a storage period of 12 weeks, the two film wrapped fruits had 0.32 mm rind thickness and the untreated fruits had 0.20 mm. The pre-cooled and semperfresh treated fruits had 0.22 and 0.23 mm rind thickness, respectively.

In the fruits of Bijapur crop (1995) the rind thickness at beginning of storage was 0.35 mm and at RT after a storage period of 25 days, the untreated fruits had the minimum rind thickness of 0.12 mm while the two film wrapped fruits had the maximum rind thickness of 0.25 mm. The semperfresh treated fruits had a rind thickness of 0.20 mm.

At 15$^{o}$C at the end of 10 weeks storage period, the two wrapped fruits had a maximum of 0.22 mm rind thickness while the untreated fruit recorded a thickness of 0.12 mm. The pre-cooled and semperfresh treated fruits had 0.16 and 0.15 mm thick rind, respectively.

At 8$^{o}$C after a storage period of 12 weeks, the untreated fruits recorded the lowest rind thickness of 0.09 mm while the highest rind thickness of 0.25 mm was recorded in the two wrapped fruits. The pre-cooled and semperfresh treated fruits recorded a rind thickness of 0.13 and 0.16 mm, respectively.

In general, the rind thickness of the unwrapped (untreated, pre-cooled and semperfresh treated) fruits was less than the rind thickness of the wrapped (BDF 2001 and D955) fruits at all the three storage temperatures after the end of their respective storage periods in both the crops and in both the years. The rind thickness of Bijapur fruits was less than the rind thickness of Bangalore fruits in both the years at all the three storage temperature at the end of their respective storage period. The decrease in rind thickness of the unwrapped fruits was high during the year 1995 than in the year 1994 as they were not packed in polybags. However not much differences were seen between the years in the unwrapped fruit. The reduction in rind thickness was high at RT followed by the LT in both the crops and in both the years.

Statistically the differences between the treatments and periods of storage was significant at all the three storage temperatures in both the years of Bangalore fruits and Bijapur fruits.

### 4.2.4 Firmness

The data on the effect of treatments and storage temperature on the firmness of pomegranate fruit grown around Bangalore and Bijapur area during the year 1995 are presented in Tables 15 and 16, respectively.

The firmness of the fruits in Bangalore crop at the beginning of storage was 12.8 $Kg/cm^2$. At RT after a storage period of 25 days the firmness of the untreated fruits was 12.5 $kg/cm^2$ and that of semperfresh treated fruits was 11.9 $Kg/cm^2$. The two wrapped fruits had more or less same fruit firmness of 9.5 $kg/cm^2$.

At $15^oC$ at the beginning of storage the firmness was 13.1 $Kg/cm^2$ and after a storage period of 10 weeks the firmness of the fruit decreased in all the treatments. A minimum of 7.60 $Kg/cm^2$ was recorded in semperfresh treated fruits and a maximum of 10.7 $Kg/cm^2$ was recorded in D955 film wrapped fruits. The untreated (8.1 $Kg/cm^2$) and pre-

**Table 25: Effect of treatments and storage temperature on the firmness of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | Firmness [Kg/cm$^2$] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 $\pm$ 1$^{o}$C** | | | | | | | |
| Untreated (Control) | 12.8 | 12.7 | 11.0 | 12.8 | 13.3 | 12.5 | 12.5 |
| Semperfresh (2%) | | 12.4 | 10.8 | 13.1 | 12.1 | 11.9 | 12.1 |
| Film wrap (BDF2001) | | 12.1 | 13.2 | 12.6 | 12.7 | 9.7 | 12.1 |
| Film wrap (D955) | | 12.0 | 11.4 | 11.2 | 11.2 | 9.6 | 11.1 |
| Mean | | 12.3 | 11.6 | 12.4 | 12.4 | 10.9 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 $\pm$ 1$^{o}$C** | | | | | | | |
| Untreated (Control) | 13.1 | 11.9 | 10.9 | 9.7 | 9.3 | 8.1 | 10.0 |
| Pre-cooled | | 11.5 | 11.6 | 11.1 | 10.4 | 8.3 | 10.6 |
| Semperfresh (2%) | | 10.2 | 11.9 | 10.3 | 10.5 | 7.6 | 10.1 |
| Film wrap (BDF2001) | | 12.2 | 12.7 | 12.2 | 11.3 | 10.4 | 11.8 |
| Film wrap (D955) | | 13.0 | 12.0 | 11.8 | 11.1 | 10.7 | 11.7 |
| Mean | | 11.7 | 11.8 | 11.0 | 10.5 | 9.0 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.950 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 $\pm$ 1$^{o}$C** | | | | | | | | |
| Untreated (Control) | 12.8 | 12.9 | 9.8 | 9.2 | 10.6 | 10.1 | 10.1 | 10.4 |
| Pre-cooled | | 12.9 | 10.9 | 10.6 | 10.7 | 10.0 | 9.5 | 10.8 |
| Semperfresh (2%) | | 12.5 | 9.9 | 9.9 | 10.3 | 10.4 | 10.2 | 10.5 |
| Film wrap (BDF2001) | | 11.7 | 12.5 | 11.5 | 11.5 | 11.3 | 10.4 | 11.5 |
| Film wrap (D955) | | 8.9 | 9.8 | 11.3 | 11.4 | 11.2 | 11.2 | 10.6 |
| Mean | | 11.8 | 10.6 | 10.5 | 10.9 | 10.6 | 10.3 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%          NS - Non significant

**Table 16: Effect of treatments and storage temperature on the firmness of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | | Firmness [Kg/cm$^2$] | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 $\pm$ 1°C** | | | | | | | |
| Untreated (Control) | 12.3 | 11.8 | 10.5 | 12.5 | 11.3 | 10.1 | 11.2 |
| Semperfresh (2%) | | 11.3 | 10.7 | 10.4 | 8.4 | 10.6 | 10.3 |
| Film wrap (BDF2001) | | 12.5 | 11.7 | 10.8 | 12.4 | 11.9 | 11.9 |
| Film wrap (D955) | | 12.1 | 11.3 | 12.6 | 10.8 | 11.2 | 11.7 |
| Mean | | 12.0 | 11.0 | 11.6 | 10.7 | 10.9 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 $\pm$ 1°C** | | | | | | | |
| Untreated (Control) | 12.3 | 10.5 | 11.5 | 9.8 | 8.7 | 10.9 | 10.2 |
| Pre-cooled | | 12.1 | 12.1 | 10.8 | 10.3 | 11.9 | 11.5 |
| Semperfresh (2%) | | 9.4 | 12.1 | 10.0 | 10.5 | 9.5 | 10.3 |
| Film wrap (BDF2001) | | 10.6 | 9.8 | 10.2 | 8.7 | 9.4 | 9.8 |
| Film wrap (D955) | | 11.2 | 10.1 | 11.1 | 10.8 | 8.2 | 10.3 |
| Mean | | 10.8 | 11.1 | 10.2 | 9.8 | 10.6 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | * | 1.596 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 $\pm$ 1°C** | | | | | | | | |
| Untreated (Control) | 12.3 | 9.6 | 11.1 | 9.8 | 9.1 | 8.6 | 8.1 | 9.4 |
| Pre-cooled | | 12.0 | 13.8 | 9.0 | 8.6 | 8.6 | 8.0 | 9.9 |
| Semperfresh (2%) | | 11.0 | 11.3 | 9.5 | 8.7 | 9.1 | 9.9 | 9.6 |
| Film wrap (BDF2001) | | 8.9 | 12.3 | 9.9 | 9.5 | 8.5 | 9.4 | 9.8 |
| Film wrap (D955) | | 11.3 | 11.2 | 10.8 | 11.0 | 8.6 | 8.2 | 10.2 |
| Mean | | 10.6 | 11.9 | 9.8 | 9.4 | 8.7 | 8.3 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.910 |
| Interaction | NS | - |

* - Significant at 5%  NS - Non significant

cooled (8.3 $Kg/cm^2$) fruits recorded more or less same firmness. The BDF 2001 film wrapped fruits had a firmness of 10.4 $Kg/cm^2$.

At 8°C after a storage of 12 weeks, the firmness of the fruit decreased in all the treatments. The pre-cooled fruits recorded minimum of 9.5 $Kg/cm^2$ while the D955 film wrapped fruits recorded maximum of 11.2 $Kg/cm^2$. The untreated (10.1), semperfresh treated (10.2) and BDF 2001 film wrapped (10.4) fruits recorded more or less same firmness.

In the fruits of Bijapur crop the firmness at the beginning of storage was 12.3 $Kg/cm^2$. At RT, after a storage period of 25 days, the firmness of the fruit decreased in all the treatments. The untreated and semperfresh treated fruits had a firmness of 10.1 and 10.6 $Kg/cm^2$, respectively. The firmness of BDF 2001 film wrapped and D955 film wrapped fruits was 11.9 and 11.2 $Kg/cm^2$, respectively.

At 15°C after 10 weeks of storage, the firmness of the fruit decreased in all the treatments. Maximum decrease was observed in D955 film wrapped (8.2 $kg/cm^2$) fruits while the minimum decrease was observed in the pre-cooled (11.9 $kg/cm^2$) fruits. The semperfresh treated (9.5) and BDF 2001 film wrapped (9.4 $kg/cm^2$) fruits had more or less same firmness.

At $8^{o}C$ after a storage period of 12 weeks, the firmness decreased in all the treatments. Maximum firmness of 9.9 $Kg/cm^2$ was observed in semperfresh treatment. The untreated and pre-cooled fruits had the same firmness of 8.0 $Kg/cm^2$. The BDF 2001 film wrapped and D955 film wrapped fruits had 9.4 and 8.2 $Kg/cm^2$ firmness, respectively.

In general, the firmness of the fruits decreased in all the treatments at all the temperatures of storage in both the crops.

Statistically no differences were observed at RT in both the crops, among the treatments, storage period and their interactions. At $15^{o}C$, the differences between storage period was significant for Bijapur crop while the interactions between treatments and storage period was significant for Bangalore crop. At $8^{o}C$, the differences between storage period was significant in only Bijapur crop fruits.

### 4.2.5 Aril weight

The data on the effect of treatments and storage temperature on aril weight of pomegranate grown around Bangalore and Bijapur conditions in the year 1995 are presented in Tables 17 and 18, respectively.

**Table 17: Effect of treatments and storage temperature on the aril weight of pomegranate cv.Ganesh grown around Bangalore conditions during 1995.**

| | Aril weight [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 58.9 | 59.7 | 58.8 | 60.9 | 63.8 | 70.0 | 62.6 |
| Semperfresh (2%) | | 64.6 | 64.6 | 63.9 | 65.9 | 66.0 | 65.0 |
| Film wrap (BDF2001) | | 65.2 | 63.5 | 61.8 | 63.0 | 62.0 | 63.1 |
| Film wrap (D955) | | 61.9 | 65.8 | 65.5 | 63.9 | 62.4 | 63.6 |
| Mean | | 62.9 | 63.2 | 63.0 | 64.1 | 65.1 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 64.9 | 65.1 | 63.3 | 64.1 | 65.8 | 67.8 | 65.26 |
| Pre-cooled | | 67.8 | 61.8 | 65.1 | 66.4 | 67.7 | 65.81 |
| Semperfresh (2%) | | 66.8 | 66.2 | 68.6 | 69.8 | 68.8 | 68.09 |
| Film wrap (BDF2001) | | 62.0 | 65.6 | 65.5 | 68.2 | 66.9 | 65.67 |
| Film wrap (D955) | | 64.6 | 69.9 | 68.5 | 66.3 | 67.1 | 67.31 |
| Mean | | 65.2 | 65.3 | 66.3 | 67.3 | 67.7 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 58.9 | 63.9 | 63.3 | 63.0 | 65.3 | 66.6 | 69.0 | 65.2 |
| Pre-cooled | | 61.5 | 64.0 | 61.2 | 62.3 | 63.6 | 64.3 | 62.8 |
| Semperfresh (2%) | | 65.8 | 65.7 | 64.4 | 64.7 | 67.4 | 66.9 | 60.5 |
| Film wrap (BDF2001) | | 61.2 | 60.7 | 64.1 | 64.7 | 64.7 | 68.3 | 64.1 |
| Film wrap (D955) | | 65.9 | 62.5 | 66.0 | 65.0 | 65.8 | 66.5 | 65.3 |
| Mean | | 63.7 | 64.2 | 63.8 | 64.4 | 65.6 | 66.6 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%          NS - Non significant

Table 18: Effect of treatments and storage temperature on the aril weight of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.

| Storage in days | At harvest | 5 | 10 | 15 | 20 | 25 | Mean |
|---|---|---|---|---|---|---|---|
| | Aril weight [Percent] | | | | | | |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 63.2 | 64.1 | 67.4 | 69.3 | 68.1 | 69.9 | 67.8 |
| Semperfresh (2%) | | 66.8 | 67.5 | 67.1 | 69.1 | 71.8 | 68.5 |
| Film wrap (BDF2001) | | 64.1 | 65.0 | 68.2 | 66.6 | 67.4 | 66.1 |
| Film wrap (D955) | | 65.7 | 64.7 | 66.2 | 66.1 | 65.4 | 65.6 |
| Mean | | 65.0 | 66.1 | 67.8 | 66.4 | 68.6 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 63.2 | 62.9 | 66.8 | 62.4 | 68.6 | 66.2 | 65.4 |
| Pre-cooled | | 64.8 | 67.5 | 65.9 | 61.7 | 66.7 | 65.3 |
| Semperfresh (2%) | | 62.8 | 65.0 | 68.1 | 70.9 | 69.4 | 67.2 |
| Film wrap (BDF2001) | | 65.7 | 63.6 | 63.2 | 65.3 | 63.9 | 64.4 |
| Film wrap (D955) | | 64.3 | 66.2 | 64.5 | 66.2 | 66.1 | - |
| Mean | | | | | | | |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 63.2 | 67.1 | 62.6 | 64.2 | 67.9 | 68.3 | 69.5 | 66.5 |
| Pre-cooled | | 62.3 | 63.0 | 65.1 | 65.1 | 69.0 | 71.5 | 66.0 |
| Semperfresh (2%) | | 64.3 | 62.7 | 66.6 | 65.7 | 64.5 | 70.7 | 65.7 |
| Film wrap (BDF2001) | | 64.0 | 65.3 | 65.6 | 65.9 | 66.5 | 65.8 | 65.5 |
| Film wrap (D955) | | 62.0 | 65.3 | 63.0 | 64.7 | 64.0 | 63.3 | 63.7 |
| Mean | | 63.9 | 63.8 | 64.9 | 65.8 | 66.4 | 68.1 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%          NS - Non significant

At harvest (at beginning of storage) the aril weight was 58.9 and 63.2 per cent, respectively in Bangalore and Bijapur crops.

At RT storage in Bangalore crop the aril weight increased in all the treatments during a storage period of 25 days. In untreated fruits the aril weight increased upto 70.0 per cent followed by semperfresh treated fruits with 66.0 per cent. In fruits wrapped with films D955 an BDF 2001 the aril weight was 62.0 per cent.

At 15°C the initial aril weight was 64.9 per cent and after 10 weeks of storage, it increased in all the treatments. The untreated, pre-cooled and D955 film wrapped fruits had almost same aril weight of 67.0 per cent. Lowest aril weight was recorded in BDF film wrapped fruits (66.9%).

At 8°C the weight of the aril increased with increase in storage period in all the treatments and reached the maximum value after 12 weeks of storage. Maximum aril weight of 69.0 per cent was recorded in fruits of untreated followed by those of BDF 2001 film wrapped (68.3%) semperfresh treated (66.9%), D955 film wrapped (66.5%) and pre-cooled (64.3%) treatments.

In the fruits of Bijapur crop, at RT storage the aril weight increased in all the treatments after a storage period of 25 days. Highest of 71.8 and the lowest of 65.4 per cent was recorded in semperfresh treated fruits and D955 film wrapped fruits, respectively. The untreated and BDF 2001 film wrapped fruits recorded 69.9 and 67.4 per cent aril weight, respectively.

At 15°C the increase in aril weight was minimum. The untreated and pre-cooled fruits, recorded almost same aril weight of 66.0 per cent. Highest aril weight was recorded in semperfresh treated fruits (69.4%). The BDF 2001 and D955 film wrapped fruits had 63.9 and 64 per cent aril weight, respectively after 10 weeks storage.

At 8°C after a storage period of 12 weeks, the pre-cooled fruits recorded a maximum aril weight of 71.5 per cent. The aril weight of untreated and semperfresh treated fruits were more or less the same with 69.2 and 70.7 per cent, respectively. The BDF and D955 film wrapped fruits recorded 65.8 and 63.3 per cent, respectively.

In general, the fruits of Bijapur crop showed slightly more aril weight than in the Bangalore crop at RT after 25 days of storage. However at low temperature (8 and 15°C) differences between the two crops for aril weight was negligible. No significant differences were observed in both the crops among the treatments, storage period and their interactions in all the three storage temperatures.

#### 4.2.6 Juice content

The data on the effect of treatments and storage temperature on the juice content of pomegranate grown under two climatic condition (Bangalore and Bijapur) during the year 1995 are presented in Tables 19 and 20, respectively.

In Bangalore crop, the juice content at the begining of storage was 45.7 per cent and after 25 days of storage period at RT, the juice content of the untreated fruits increased to 49.8 per cent. In semperfresh treated and BDF 2001 film wrapped fruits it remained the same (45.0%) and it slightly decreased in the D955 film wrapped fruits (44.0%).

At 15$^{o}$C, juice content at the begining of storage was 46.1 per cent. The juice content showed a slight increase in untreated fruits from 46.1 to 48.6 and in pre-cooled to 47.9 per cent. There was not much change in BDF film wrapped fruits (46.9%), but showed a slight decrease in semperfresh treated (45.7%) and D955 film wrapped fruits (44.6%) after the end of storage period.

At 8$^{o}$C at the end of storage period that is 12 weeks the juice content did not show much differences among treatments. The observed change in semperfresh treated fruits was 47.7 and 43.9 per cent in D955 film wrapped fruits.

**Table 19: Effect of treatments and storage temperature on juice content of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | | Juice content [Percent] | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 45.7 | 42.7 | 45.9 | 43.0 | 49.5 | 49.8 | 46.2 |
| Semperfresh (2%) | | 43.2 | 45.5 | 44.4 | 43.6 | 45.0 | 44.2 |
| Film wrap (BDF2001) | | 46.1 | 44.7 | 44.2 | 44.4 | 45.8 | 45.0 |
| Film wrap (D955) | | 47.9 | 45.5 | 46.2 | 47.0 | 44.0 | 46.1 |
| Mean | | 45.0 | 45.4 | 44.5 | 46.1 | 46.1 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 46.1 | 45.5 | 44.3 | 46.2 | 46.6 | 48.6 | 46.3 |
| Pre-cooled | | 43.1 | 46.6 | 46.2 | 44.6 | 47.9 | 46.7 |
| Semperfresh (2%) | | 45.6 | 47.5 | 47.7 | 48.2 | 45.7 | 46.9 |
| Film wrap (BDF2001) | | 45.6 | 43.3 | 46.9 | 46.9 | 46.9 | 45.7 |
| Film wrap (D955) | | 45.6 | 47.7 | 44.8 | 43.9 | 44.6 | 45.3 |
| Mean | | 45.1 | 46.3 | 45.7 | 46.0 | 46.8 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 45.7 | 43.6 | 42.4 | 44.0 | 46.6 | 46.6 | 46.3 | 44.8 |
| Pre-cooled | | 43.7 | 45.5 | 45.3 | 44.8 | 45.9 | 46.9 | 44.9 |
| Semperfresh (2%) | | 44.0 | 43.1 | 44.5 | 45.5 | 44.6 | 47.7 | 44.9 |
| Film wrap (BDF2001) | | 43.3 | 45.9 | 44.6 | 45.1 | 46.1 | 44.4 | 44.9 |
| Film wrap (D955) | | 47.1 | 46.3 | 43.9 | 44.6 | 43.0 | 43.9 | 44.7 |
| Mean | | 44.3 | 44.7 | 44.0 | 45.0 | 45.2 | 45.8 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%    NS - Non significant

Table 20: Effect of treatments and storage temperature on juice content of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.

| Storage in days | At harvest | 5 | 10 | 15 | 20 | 25 | Mean |
|---|---|---|---|---|---|---|---|
| | Juice content [Percent] | | | | | | |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 46.9 | 44.5 | 44.8 | 50.0 | 46.9 | 52.1 | 48.6 |
| Semperfresh (2%) | | 49.5 | 52.5 | 50.3 | 49.9 | 49.7 | 50.4 |
| Film wrap (BDF2001) | | 48.7 | 47.6 | 48.8 | 46.8 | 49.4 | 48.1 |
| Film wrap (D955) | | 46.6 | 45.7 | 49.9 | 48.8 | 45.4 | 47.4 |
| Mean | | 48.6 | 47.6 | 49.7 | 48.1 | 49.2 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 46.9 | 47.9 | 48.4 | 48.2 | 4716 | 48.9 | 48.1 |
| Pre-cooled | | 49.3 | 49.8 | 50.8 | 47.5 | 51.1 | 49.1 |
| Semperfresh (2%) | | 48.0 | 47.6 | 48.6 | 46.7 | 51.0 | 48.4 |
| Film wrap (BDF2001) | | 48.6 | 45.9 | 46.4 | 46.9 | 49.2 | 47.4 |
| Film wrap (D955) | | 46.6 | 47.0 | 47.8 | 45.6 | 45.7 | 46.6 |
| Mean | | 48.1 | 47.7 | 48.4 | 46.8 | 49.2 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 46.9 | 49.2 | 46.5 | 44.8 | 46.3 | 46.8 | 49.3 | 47.2 |
| Pre-cooled | | 46.4 | 45.2 | 47.3 | 47.0 | 47.7 | 47.6 | 46.9 |
| Semperfresh (2%) | | 47.4 | 44.6 | 48.2 | 42.8 | 44.0 | 49.7 | 46.1 |
| Film wrap (BDF2001) | | 47.3 | 45.3 | 46.4 | 44.2 | 43.1 | 46.5 | 45.5 |
| Film wrap (D955) | | 47.1 | 45.5 | 47.3 | 45.7 | 45.1 | 47.6 | 46.3 |
| Mean | | 63.9 | 63.8 | 64.9 | 65.8 | 66.4 | 68.1 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%          NS - Non significant

In the fruits of Bijapur crop, the juice content at the beginning of storage was 46.9 per cent and at RT after a storage period of 25 days, the untreated fruits recorded highest juice content of 52.1 per cent while the D955 film wrapped fruits recorded a lowest juice content of 45.4 per cent. The semperfresh treated fruits and BDF 2001 film wrapped fruits recorded 49 per cent juice content.

At 15$^{o}$C at the end of 10 weeks storage, the juice content slightly increased in all the treatments except in D955 film wrapped fruits as compared to 46.9 per cent at the beginning of storage. The pre-cooled and the semperfresh treated fruits had 51.0 per cent followed by BDF film wrapped fruits with 49.2 and untreated with 48.9 per cent.

At 8$^{o}$C the juice content after 12 weeks storage increased slightly from 46.9 to 49.3 per cent in untreated fruits, in pre-cooled to 47.6 and to 49.7 in semperfresh treated fruits. It remained almost the same in film wrapped fruits with 46.5 and 45.1 per cent in BDF 2001 and D955, respectively.

However no significant differences were observed among the treatments, storage periods and their interactions in both the crops and at all the three storage temperatures.

#### 4.2.7 Seed content

The data on the effect of treatments and storage temperature on seed content of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 21 and 22, respectively.

There was 10.6 per cent seed weight from the Bangalore harvested crop and 10.9 per cent from the Bijapur harvest crop on the initial day of storage.

At RT, the seed weight in fruits of Bangalore crop increased slightly from the initial value during 25 days storage in all the treatments. Maximum seed weight of 12.0 per cent was noticed in semperfresh treated fruits followed by BDF 2001 film wrapped (11.6%) untreated (11.1%) and D955 film wrapped (10.2%) fruits.

At 15°C the initial seed weight recorded was 11.5 per cent. During the storage period of 10 weeks, maximum seed weight of 11.2 per cent was observed in untreated fruits. The pre-cooled (9.7) and BDF film wrapped fruits (9.9) had more or less same seed per cent, while the semperfresh treated and the D955 film wrapped fruits recorded 10.0 per cent.

At 8°C after 12 weeks of storage the pre-cooled fruits had maximum seed weight of 11.9 per cent followed by D955

Table 21: Effect of treatments and storage temperature on seed content of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.

| | Seed content [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| Storage in days | At harvest | 5 | 10 | 15 | 20 | 25 | Mean |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 10.6 | 9.6 | 10.6 | 11.3 | 13.7 | 11.1 | 11.8 |
| Semperfresh (2%) | | 11.6 | 10.5 | 12.0 | 13.7 | 12.0 | 12.0 |
| Film wrap (BDF2001) | | 11.2 | 11.5 | 11.3 | 12.7 | 11.6 | 11.7 |
| Film wrap (D955) | | 10.5 | 9.6 | 10.1 | 10.0 | 10.2 | 10.1 |
| Mean | | 10.7 | 10.6 | 11.2 | 12.5 | 11.2 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 11.5 | 11.9 | 11.1 | 11.6 | 11.5 | 11.2 | 11.4 |
| Pre-cooled | | 10.8 | 9.8 | 10.2 | 11.1 | 9.7 | 10.3 |
| Semperfresh (2%) | | 11.2 | 11.1 | 11.8 | 11.5 | 10.8 | 11.3 |
| Film wrap (BDF2001) | | 10.0 | 12.0 | 11.0 | 10.1 | 9.9 | 10.6 |
| Film wrap (D955) | | 11.6 | 12.0 | 10.0 | 11.2 | 10.2 | 11.0 |
| Mean | | 11.1 | 11.2 | 10.9 | 11.1 | 10.4 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 10.6 | 11.8 | 10.6 | 11.5 | 10.1 | 11.1 | 10.9 | 11.0 |
| Pre-cooled | | 11.4 | 11.7 | 10.8 | 10.5 | 11.1 | 11.9 | 11.1 |
| Semperfresh (2%) | | 14.0 | 10.9 | 11.3 | 10.8 | 9.85 | 10.4 | 11.2 |
| Film wrap (BDF2001) | | 12.1 | 10.9 | 11.3 | 10.2 | 10.4 | 10.6 | 10.9 |
| Film wrap (D955) | | 9.7 | 10.7 | 10.6 | 10.7 | 11.2 | 11.2 | 10.7 |
| Mean | | 11.8 | 11.0 | 11.1 | 10.5 | 10.7 | 10.8 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%          NS - Non significant

**Table 22: Effect of treatments and storage temperature on seed content of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | Seed content (Percent) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 10.9 | 10.7 | 10.4 | 11.4 | 10.1 | 11.4 | 10.2 |
| Semperfresh (2%) | | 10.8 | 11.0 | 10.2 | 11.7 | 10.2 | 10.8 |
| Film wrap (BDF2001) | | 10.8 | 10.6 | 11.7 | 10.9 | 10.4 | 10.9 |
| Film wrap (D955) | | 9.5 | 10.1 | 12.7 | 11.2 | 10.8 | 10.9 |
| Mean | | 10.4 | 10.5 | 11.6 | 11.0 | 10.7 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 10.9 | 10.2 | 11.0 | 10.0 | 9.7 | 10.7 | 10.3 |
| Pre-cooled | | 11.0 | 12.6 | 10.4 | 10.0 | 12.5 | 11.3 |
| Semperfresh (2%) | | 10.7 | 11.8 | 10.8 | 10.3 | 10.4 | 10.8 |
| Film wrap (BDF2001) | | 11.0 | 9.7 | 11.0 | 9.8 | 9.9 | 10.1 |
| Film wrap (D955) | | 10.7 | 11.1 | 10.2 | 10.5 | 10.7 | 10.6 |
| Mean | | 10.7 | 11.2 | 10.5 | 10.3 | 10.8 | - |
| Treatment | | | | NS | | - | |
| Period | | | | NS | | - | |
| Interaction | | | | NS | | - | |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 10.9 | 11.1 | 10.2 | 10.0 | 10.0 | 9.6 | 10.8 | 10.3 |
| Pre-cooled | | 10.8 | 10.1 | 10.9 | 9.8 | 11.4 | 10.8 | 10.6 |
| Semperfresh (2%) | | 10.1 | 10.0 | 10.6 | 9.7 | 10.0 | 12.3 | 10.5 |
| Film wrap (BDF2001) | | 10.0 | 12.8 | 9.3 | 9.6 | 10.9 | 9.9 | 10.4 |
| Film wrap (D955) | | 10.4 | 10.7 | 10.2 | 9.9 | 10.4 | 10.9 | - |
| Mean | | 63.9 | 63.8 | 64.9 | 65.8 | 66.4 | 68.1 | - |
| Treatment | | | | NS | | - | | |
| Period | | | | NS | | - | | |
| Interaction | | | | NS | | - | | |

* - Significant at 5%  NS - Non significant

film wrapped fruits (11.2%). The untreated (10.9) semperfresh treated (10.4) and BDF 2001 film wrapped (10.6) fruits had almost same seed weight per cent.

In fruits of Bijapur crop, at RT after a storage period of 25 days, the seed weight of the untreated fruits slightly increased to 11.4 per cent as compared to the initial value whereas the seed weight of the semperfresh treated and the two film wrapped fruits remained more or less same (10.0%).

At 15$^{o}$C, maximum seed weight of 12.5 per cent was noticed in pre-cooled fruits at the end of 10 weeks storage while the minimum seed weight of 9.9 per cent was recorded in the BDF 2001 film wrapped fruits. The untreated and the D955 film wrapped fruits had equal (10.7) seed weight per cent while the semperfresh treated fruits showed 10.4 per cent.

At 8$^{o}$C after the storage period of 12 weeks, the semperfresh fruits had highest (12.3) per cent of seed weight and BDF 2001 film wrapped fruits had lowest of 9.9 per cent. The untreated, pre-cooled and D955 film wrapped fruits had equal seed weight of 10.8 per cent.

In general the seed weight of Bijapur harvested crop was lower as compared to the seed weight of Bangalore harvested crop at harvest and during storage. The seed weight more or less remained same during the storage period in both the crops in all the three storage temperatures.

No significant differences were observed in any of the treatments, storage period and the interactions for both the crops at any of the storage temperatures.

**4.2.8 Respiration**

The normal respiration rate of fruits (Bangalore crop) during storage at RT is presented in Figure 12. The respiration of untreated and wrapped fruits (Bijapur crop) during storage at RT are presented in Figure 13.

From the Figure 12 it was observed that (irrespective of growing conditions) the rate of respiration at the beginning of storage was high and it decreased gradually towards the end of storage period. The respiration at the beginning of storage was 57.0 mg $CO_2$/kg/hr. It gradually decreased to 21.6 mg $CO_2$/kg/hr on 24th day of storage.

From the Figure 13 it was observed that the respiration rate of untreated fruits on 3rd day of storage was 55 mg $CO_2$/kg/hr. It slightly increased to 60 mg $CO_2$/kg/hr on 5th day of storage and decreased gradually to 20mg $CO_2$/kg/hr on 29th day. In the wrapped fruits there was a gradual decrease in respiration rate from day 3 to 29th day of storage (56-30 and 48-24 mg $CO_2$/kg/hr in BDF 2001 and D955

Fig.12: Normal rate of respiration during storage of Pomegranate cv. Ganesh at RT (Bangalore crop)

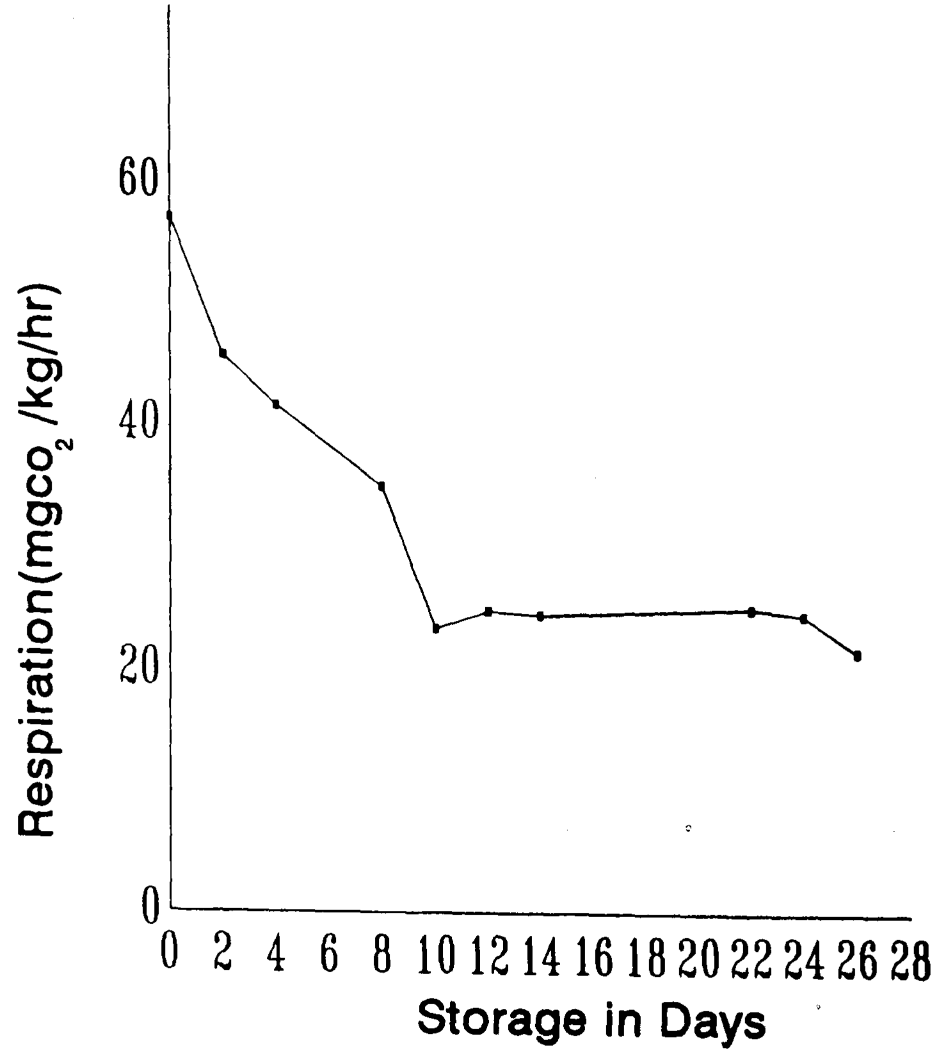
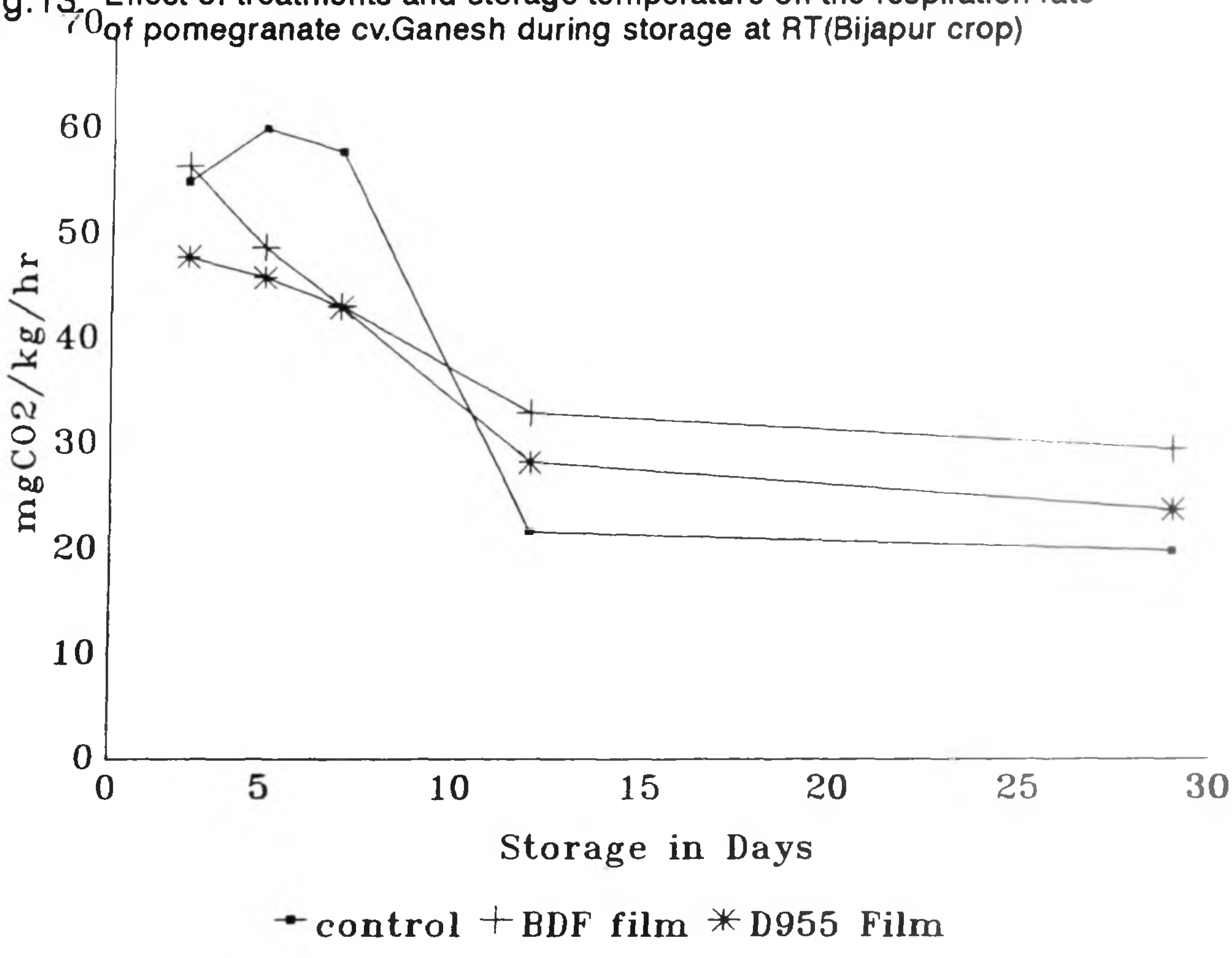


Fig.13: Effect of treatments and storage temperature on the respiration rate of pomegranate cv.Ganesh during storage at RT(Bijapur crop)



film wrapped fruits, respectively). The rate of respiration in unwrapped fruits was higher as compared to wrapped fruits during the storage period.

**4.2.9 Juice colour**

The data on the effect of treatments and storage temperature on the juice colour of pomegranate fruits grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 23 and 24, respectively.

The juice colour in fruits of Bangalore crop, at the begining of storage was 0.44 OD. At RT after 25 days of storage, the colour of the juice slightly decreased in all the treatments. The unwrapped fruits recorded 0.35 OD. The BDF 2001 film and D955 film wrapped fruits recorded juice colour of 0.36 and 0.37 OD, respectively.

At 15$^{o}$C the initial colour of the juice was 0.43 OD and after 10 weeks of storage the colour of the juice in untreated and pre-cooled fruits was 0.38 OD. The semperfresh treated fruits had 0.37 OD and the BDF 2001 film wrapped and D955 film wrapped fruits showed 0.34 and 0.41 OD, respectively.

At 8$^{o}$C after a storage period of 12 weeks, the untreated fruits had juice colour of 0.35 OD. The pre-cooled and BDF 2001 film wrapped fruits had a juice colour of 0.34 OD.

**Table 23: Effect of treatments and storage temperature on juice colour of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | Juice colour [O.D] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.44 | 0.43 | 0.36 | 0.39 | 0.32 | 0.35 | 0.37 |
| Semperfresh (2%) | | 0.42 | 0.38 | 0.36 | 0.37 | 0.35 | 0.38 |
| Film wrap (BDF2001) | | 0.34 | 0.36 | 0.35 | 0.36 | 0.36 | 0.36 |
| Film wrap (D955) | | 0.40 | 0.38 | 0.34 | 0.38 | 0.37 | 0.37 |
| Mean | | 0.41 | 0.37 | 0.36 | 0.36 | 0.36 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.43 | 0.41 | 0.40 | 0.41 | 0.37 | 0.38 | 0.39 |
| Pre-cooled | | 0.37 | 0.41 | 0.39 | 0.34 | 0.38 | 0.38 |
| Semperfresh (2%) | | 0.38 | 0.36 | 0.37 | 0.40 | 0.37 | 0.38 |
| Film wrap (BDF2001) | | 0.36 | 0.35 | 0.35 | 0.39 | 0.34 | 0.36 |
| Film wrap (D955) | | 0.36 | 0.40 | 0.42 | 0.43 | 0.41 | 0.04 |
| Mean | | 0.37 | 0.38 | 0.39 | 0.38 | 0.37 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.44 | 0.36 | 0.36 | 0.35 | 0.37 | 0.36 | 0.35 | 0.35 |
| Pre-cooled | | 0.40 | 0.36 | 0.35 | 0.34 | 0.33 | 0.34 | 0.35 |
| Semperfresh (2%) | | 0.35 | 0.38 | 0.38 | 0.37 | 0.33 | 0.32 | 0.35 |
| Film wrap (BDF2001) | | 0.33 | 0.34 | 0.38 | 0.36 | 0.36 | 0.34 | 0.35 |
| Film wrap (D955) | | 0.41 | 0.35 | 0.38 | 0.39 | 0.38 | 0.36 | 0.38 |
| Mean | | 0.37 | 0.36 | 0.37 | 0.36 | 0.35 | 0.34 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%　　　NS - Non significant

Table 24: Effect of treatments and storage temperature on juice colour of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.

| | Juice colour [O.D] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.36 | 0.36 | 0.38 | 0.33 | 0.32 | 0.37 | 0.35 |
| Semperfresh (2%) | | 0.34 | 0.36 | 0.35 | 0.33 | 0.33 | 0.34 |
| Film wrap (BDF2001) | | 0.35 | 0.36 | 0.35 | 0.36 | 0.36 | 0.35 |
| Film wrap (D955) | | 0.36 | 0.34 | 0.34 | 0.35 | 0.35 | 0.34 |
| Mean | | 0.35 | 0.36 | 0.34 | 0.34 | 0.35 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.36 | 0.35 | 0.32 | 0.35 | 0.34 | 0.31 | 0.34 |
| Pre-cooled | | 0.36 | 0.34 | 0.37 | 0.37 | 0.34 | 0.35 |
| Semperfresh (2%) | | 0.34 | 0.37 | 0.38 | 0.33 | 0.31 | 0.34 |
| Film wrap (BDF2001) | | 0.36 | 0.33 | 0.35 | 0.34 | 0.35 | 0.34 |
| Film wrap (D955) | | 0.39 | 0.36 | 0.32 | 0.37 | 0.34 | 0.35 |
| Mean | | 0.36 | 0.34 | 0.35 | 0.35 | 0.33 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.010 |
| Interaction | * | 0.023 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.36 | 0.32 | 0.35 | 0.35 | 0.33 | 0.32 | 0.33 | 0.33 |
| Pre-cooled | | 0.37 | 0.38 | 0.39 | 0.34 | 0.37 | 0.37 | 0.37 |
| Semperfresh (2%) | | 0.33 | 0.33 | 0.35 | 0.33 | 0.33 | 0.35 | 0.34 |
| Film wrap (BDF2001) | | 0.33 | 0.32 | 0.36 | 0.33 | 0.36 | 0.33 | 0.33 |
| Film wrap (D955) | | 0.39 | 0.39 | 0.37 | 0.39 | 0.35 | 0.38 | 0.37 |
| Mean | | 0.35 | 0.35 | 0.36 | 0.34 | 0.35 | 0.35 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%     NS - Non significant

The semperfresh treated fruits and D955 film wrapped fruits recorded 0.32 and 0.36 OD, respectively.

In fruits of Bijapur crop, the juice colour at the begining of storage was 0.36 OD. At RT after 25 days of storage, the untreated fruits recorded maximum juice colour of 0.37 OD while minimum juice colour of 0.33 OD was observed in semperfresh treated fruits. The BDF 2001 film wrapped and D955 film wrapped fruits recorded 0.36 and 0.35 OD, respectively.

At 15$^{o}$C after a storage of 10 weeks, the untreated and semperfresh treated fruits had a juice colour of 0.31 OD. The pre-cooled and D955 film wrapped fruits had 0.34 OD colour.

At 8$^{o}$c after a storage period of 12 weeks, the untreated and BDF 2001 film wrapped fruits had a juice colour of 0.33 OD and the D955 film wrapped fruits had 0.38 OD. The juice colour in pre-cooled and semperfresh treated fruits was 0.37 and 0.35 OD, respectively.

In general the juice colour either remained same or slightly decreased towards the end of storage irrespective of storage temperature and growing conditions.

No statistical differences were observed among the treatments and storage period in Bangalore crop at all the three storage temperatures. In Bijapur crop the differences between storage period was significant at only 15$^{o}$C and the difference at other temperatures were non significant.

**4.2.10 Rind moisture**

The effect of treatments and storage temperature on rind moisture content of pomegranate during 1994 and 1995 are presented in Tables 25 and 27, respectively for fruits of Bangalore crop and in Tables 26 and 28, respectively for Bijapur fruits. The Figures 14 and 15 represents the rind moisture content of both the crops during the years 1994 and 1995, respectively.

There was a significant decrease in the per cent rind moisture content of the unwrapped fruits as compared to the wrapped fruits in both the year at all three storage temperatures in both the crops.

In Bangalore crop during the year 1994, the rind moisture content at the begining of storage was 68.1 per cent. At RT after a storage period of 25 days the rind moisture decreased in all the treatments. The untreated fruits had the lowest moisture content of 51.4 per cent while the two film wrapped fruits had highest rind moisture of about 67.0 per cent. The semperfresh treated fruits recorded a rind moisture of 58.0 per cent.

**Table 25: Effect of treatments and storage temperature on rind moisture of pomegranate cv.Ganesh grown under Bangalore conditions during 1994.**

| | Rind moisture (Percent) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 68.1 | 67.5 | 64.8 | 60.9 | 56.6 | 51.4 | 60.2 |
| Semperfresh (2%) | | 68.1 | 70.4 | 66.3 | 66.6 | 58.0 | 65.8 |
| Film wrap (BDF2001) | | 68.2 | 67.5 | 63.4 | 67.9 | 67.3 | 66.8 |
| Film wrap (D955) | | 68.5 | 67.7 | 66.8 | 69.1 | 67.1 | 67.7 |
| Mean | | 68.0 | 67.6 | 64.3 | 65.0 | 59.4 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 2.287 |
| Period | * | 2.557 |
| Interaction | * | 5.114 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 68.1 | 69.8 | 66.1 | 68.1 | 67.2 | 64.6 | 59.8 | 65.9 |
| Pre-cooled | | 67.1 | 69.5 | 66.1 | 67.3 | 63.7 | 60.1 | 65.7 |
| Semperfresh (2%) | | 69.2 | 68.4 | 67.0 | 69.3 | 65.4 | 60.3 | 66.6 |
| Film wrap (BDF2001) | | 71.2 | 66.9 | 69.3 | 67.4 | 64.0 | 69.9 | 68.4 |
| Film wrap (D955) | | 70.0 | 70.1 | 68.3 | 69.1 | 71.8 | 68.1 | 69.5 |
| Mean | | 69.4 | 68.2 | 67.7 | 68.1 | 68.1 | 65.8 | 64.2 |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 2.249 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **14** | **Mean** |
|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | | |
| Untreated (Control) | 68.1 | 66.7 | 66.2 | 65.7 | 64.9 | 67.3 | 64.2 | 65.2 | 65.7 |
| Pre-cooled | | 68.7 | 69.0 | 67.4 | 66.9 | 67.8 | 67.5 | 65.7 | 68.5 |
| Semperfresh (2%) | | 69.6 | 65.2 | 66.8 | 66.9 | 67.2 | 64.3 | 65.7 | 66.9 |
| Film wrap (BDF2001) | | 71.3 | 69.5 | 64.4 | 68.0 | 67.5 | 68.4 | 69.6 | 68.4 |
| Film wrap (D955) | | 69.7 | 67.4 | 65.8 | 66.0 | 67.1 | 66.3 | 67.8 | 67.1 |
| Mean | | 71.2 | 67.4 | 66.0 | 66.5 | 67.3 | 66.1 | 66.1 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 2.189 |
| Interaction | NS | - |

* - Significant at 5%  NS - Non significant

Table 26: Effect of treatments and storage temperature on rind moisture of pomegranate cv.Ganesh grown under Bijapur conditions during 1994.

| | Rind moisture [Percent] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** | |
| **Treatments** | | | | | | | | |
| **At 25 ± 1°C** | | | | | | | | |
| Untreated (Control) | 68.7 | 67.8 | 67.0 | 60.8 | 55.3 | 45.4 | 59.2 | |
| Semperfresh (2%) | | 69.1 | 73.2 | 68.7 | 69.4 | 67.4 | 69.5 | |
| Film wrap (BDF2001) | | 70.7 | 70.2 | 70.3 | 72.4 | 71.5 | 71.0 | |
| Film wrap (D955) | | 69.9 | 70.7 | 69.9 | 71.6 | 72.0 | 70.8 | |
| Mean | | 69.3 | 70.3 | 67.4 | 67.2 | 64.1 | - | |
| | | | 'F' Test | CD at 5% | | | | |
| Treatment | | | * | 1.934 | | | | |
| Period | | | NS | - | | | | |
| Interaction | | | NS | - | | | | |
| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 68.7 | 70.4 | 67.3 | 67.4 | 67.3 | - | - | 67.8 |
| Pre-cooled | | 67.9 | 67.0 | 70.1 | 68.4 | - | - | 68.3 |
| Semperfresh (2%) | | 71.6 | 67.3 | 66.2 | 64.9 | - | - | 67.5 |
| Film wrap (BDF2001) | | 71.9 | 70.5 | 71.0 | 69.7 | - | - | 70.8 |
| Film wrap (D955) | | 71.7 | 71.3 | 70.6 | 70.3 | - | - | 70.9 |
| Mean | | 70.7 | 68.4 | 69.0 | 68.1 | - | - | - |
| Treatment | | | NS | - | | | | |
| Period | | | NS | - | | | | |
| Interaction | | | NS | - | | | | |
| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 68.7 | 70.4 | 68.3 | 66.0 | 66.5 | 66.9 | 61.9 | 66.6 |
| Pre-cooled | | 68.9 | 66.8 | 66.3 | 68.0 | 65.5 | 61.4 | 66.1 |
| Semperfresh (2%) | | 76.5 | 71.2 | 68.1 | 69.4 | 69.9 | 66.6 | 69.4 |
| Film wrap (BDF2001) | | 66.9 | 64.4 | 68.7 | 65.7 | 67.2 | 67.5 | 66.7 |
| Film wrap (D955) | | 71.6 | 72.0 | 71.1 | 68.8 | 67.7 | 67.7 | 69.7 |
| Mean | | 69.6 | 68.5 | 68.0 | 67.8 | 67.4 | 64.9 | - |
| Treatment | | | * | 1.547 | | | | |
| Period | | | * | 1.694 | | | | |
| Interaction | | | NS | - | | | | |

* - Significant at 5%          NS - Non significant

Table 27: Effect of treatments and storage temperature on rind moisture of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.

| | | Rind moisture [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** | |
| **Treatments** | | | | | | | | |
| **At 25 ± 1°C** | | | | | | | | |
| Untreated (Control) | 68.3 | 60.2 | 55.0 | 49.8 | 39.9 | 35.2 | 48.0 | |
| Semperfresh (2%) | | 67.4 | 65.0 | 64.8 | 58.7 | 54.3 | 62.0 | |
| Film wrap (BDF2001) | | 66.9 | 65.4 | 65.9 | 65.7 | 63.0 | 64.4 | |
| Film wrap (D955) | | 66.4 | 68.5 | 68.0 | 65.4 | 66.3 | 66.9 | |
| Mean | | 64.8 | 63.8 | 62.1 | 57.4 | 54.7 | - | |
| | | | 'F' Test | | CD at 5% | | | |
| Treatment | | | * | | 2.893 | | | |
| Period | | | * | | 3.235 | | | |
| Interaction | | | * | | 6.469 | | | |
| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** | |
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 70.2 | 68.4 | 62.7 | 61.1 | 58.8 | 52.5 | 60.7 | |
| Pre-cooled | | 70.0 | 64.7 | 64.8 | 62.4 | 53.7 | 62.8 | |
| Semperfresh (2%) | | 67.5 | 66.5 | 66.4 | 62.6 | 59.2 | 64.4 | |
| Film wrap (BDF2001) | | 66.7 | 63.1 | 65.0 | 64.2 | 63.4 | 64.5 | |
| Film wrap (D955) | | 69.0 | 63.2 | 67.0 | 64.9 | 61.8 | 64.5 | |
| Mean | | 68.3 | 63.7 | 64.8 | 62.5 | 58.1 | - | |
| Treatment | | | * | | 1.912 | | | |
| Period | | | * | | 1.912 | | | |
| Interaction | | | NS | | - | | | |
| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 68.3 | 65.6 | 66.1 | 65.8 | 64.7 | 63.4 | 57.3 | 63.8 |
| Pre-cooled | | 68.6 | 66.0 | 67.2 | 66.4 | 66.6 | 57.6 | 65.9 |
| Semperfresh (2%) | | 64.3 | 66.9 | 67.3 | 67.9 | 68.2 | 60.8 | 65.9 |
| Film wrap (BDF2001) | | 65.7 | 71.3 | 65.4 | 68.9 | 69.4 | 70.7 | 68.5 |
| Film wrap (D955) | | 70.6 | 69.2 | 72.2 | 70.8 | 68.8 | 68.0 | 70.0 |
| Mean | | 66.9 | 67.9 | 68.8 | 67.7 | 67.3 | 63.0 | - |
| Treatment | | | * | | 1.729 | | | |
| Period | | | * | | 1.894 | | | |
| Interaction | | | * | | 4.235 | | | |

* - Significant at 5%      NS - Non significant

**Table 28: Effect of treatments and storage temperature on the rind moisture of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | | Rind moisture [Percent] | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 $\pm$ 1°C** | | | | | | | |
| Untreated (Control) | 67.9 | 68.1 | 67.7 | 59.9 | 41.0 | 31.5 | 53.6 |
| Semperfresh (2%) | | 67.1 | 63.2 | 61.0 | 59.9 | 53.8 | 59.8 |
| Film wrap (BDF2001) | | 67.5 | 62.5 | 62.1 | 63.8 | 61.8 | 63.5 |
| Film wrap (D955) | | 63.4 | 66.6 | 61.1 | 65.6 | 62.6 | 63.8 |
| Mean | | 65.0 | 65.0 | 61.0 | 57.5 | 52.4 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | * | 2.595 |
| Period | * | 2.902 |
| Interaction | * | 5.803 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 $\pm$ 1°C** | | | | | | | |
| Untreated (Control) | 67.9 | 65.5 | 65.1 | 60.9 | 53.9 | 40.8 | 57.2 |
| Pre-cooled | | 64.8 | 66.5 | 65.4 | 61.8 | 46.8 | 61.6 |
| Semperfresh (2%) | | 68.8 | 66.0 | 62.6 | 61.8 | 55.1 | 62.8 |
| Film wrap (BDF2001) | | 66.2 | 69.1 | 63.8 | 65.8 | 64.5 | 65.9 |
| Film wrap (D955) | | 66.4 | 67.6 | 66.1 | 64.4 | 65.4 | 65.9 |
| Mean | | 66.3 | 65.3 | 65.9 | 61.5 | 54.5 | - |

| | | |
|---|---|---|
| Treatment | * | 1.894 |
| Period | * | 1.894 |
| Interaction | * | 4.247 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 $\pm$ 1°C** | | | | | | | | |
| Untreated (Control) | 67.9 | 66.4 | 66.2 | 66.3 | 65.7 | 59.6 | 47.8 | 62.0 |
| Pre-cooled | | 67.6 | 63.6 | 65.9 | 67.4 | 61.1 | 57.1 | 63.8 |
| Semperfresh (2%) | | 68.0 | 63.8 | 62.5 | 66.3 | 58.4 | 57.1 | 62.6 |
| Film wrap (BDF2001) | | 66.4 | 63.5 | 65.4 | 65.5 | 66.6 | 63.3 | 65.4 |
| Film wrap (D955) | | 68.0 | 64.9 | 64.6 | 67.0 | 70.3 | 63.9 | 66.4 |
| Mean | | 67.2 | 64.4 | 64.9 | 66.4 | 63.6 | 57.8 | - |

| | | |
|---|---|---|
| Treatment | * | 1.847 |
| Period | * | 2.023 |
| Interaction | * | 4.524 |

* - Significant at 5%          NS - Non significant

**Fig. 14: Effect of treatments and storage temperature on the rind moisture of Pomegranate cv. Ganesh grown under Bangalore conditions during 1994(A) and 1995(B).**

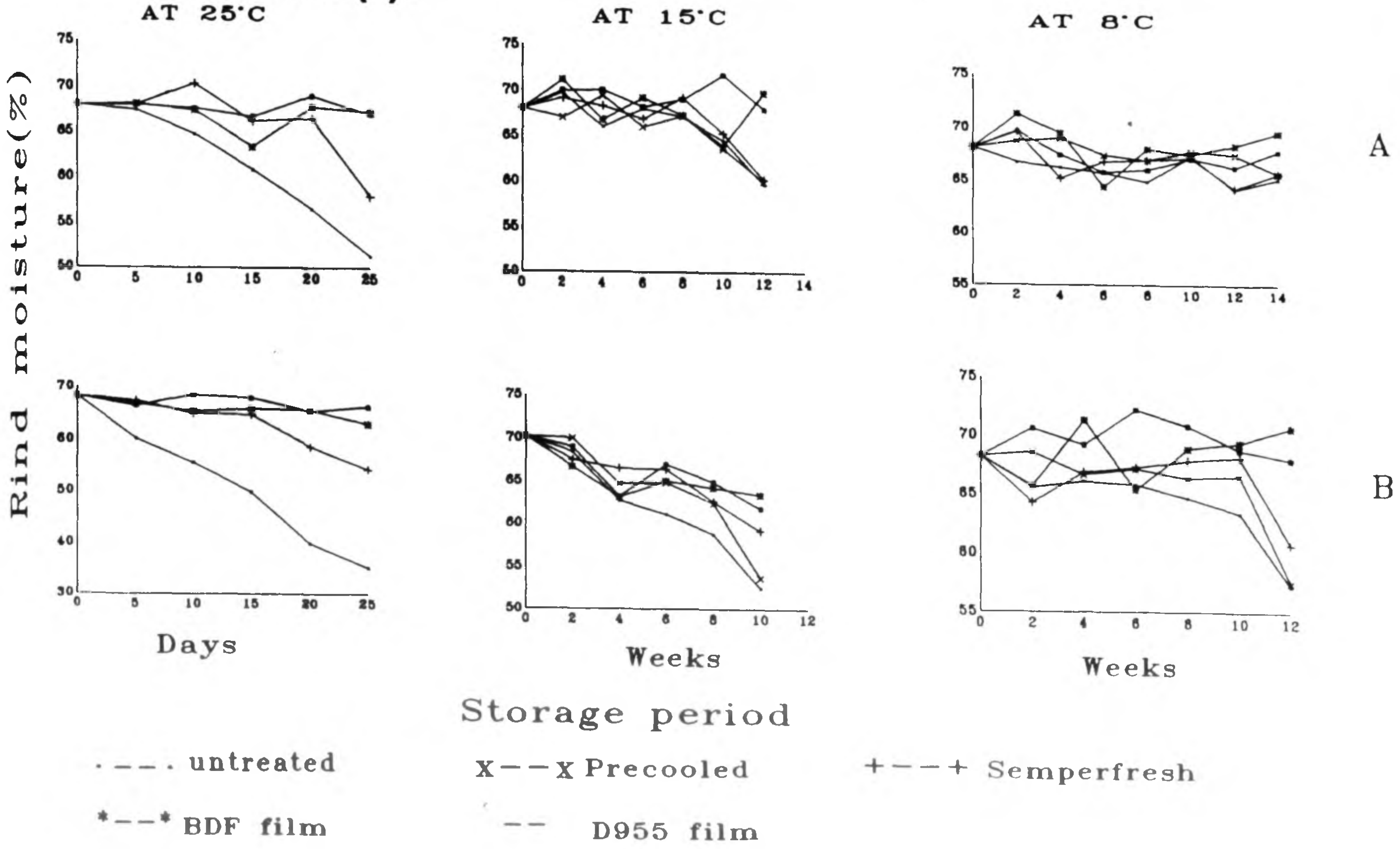
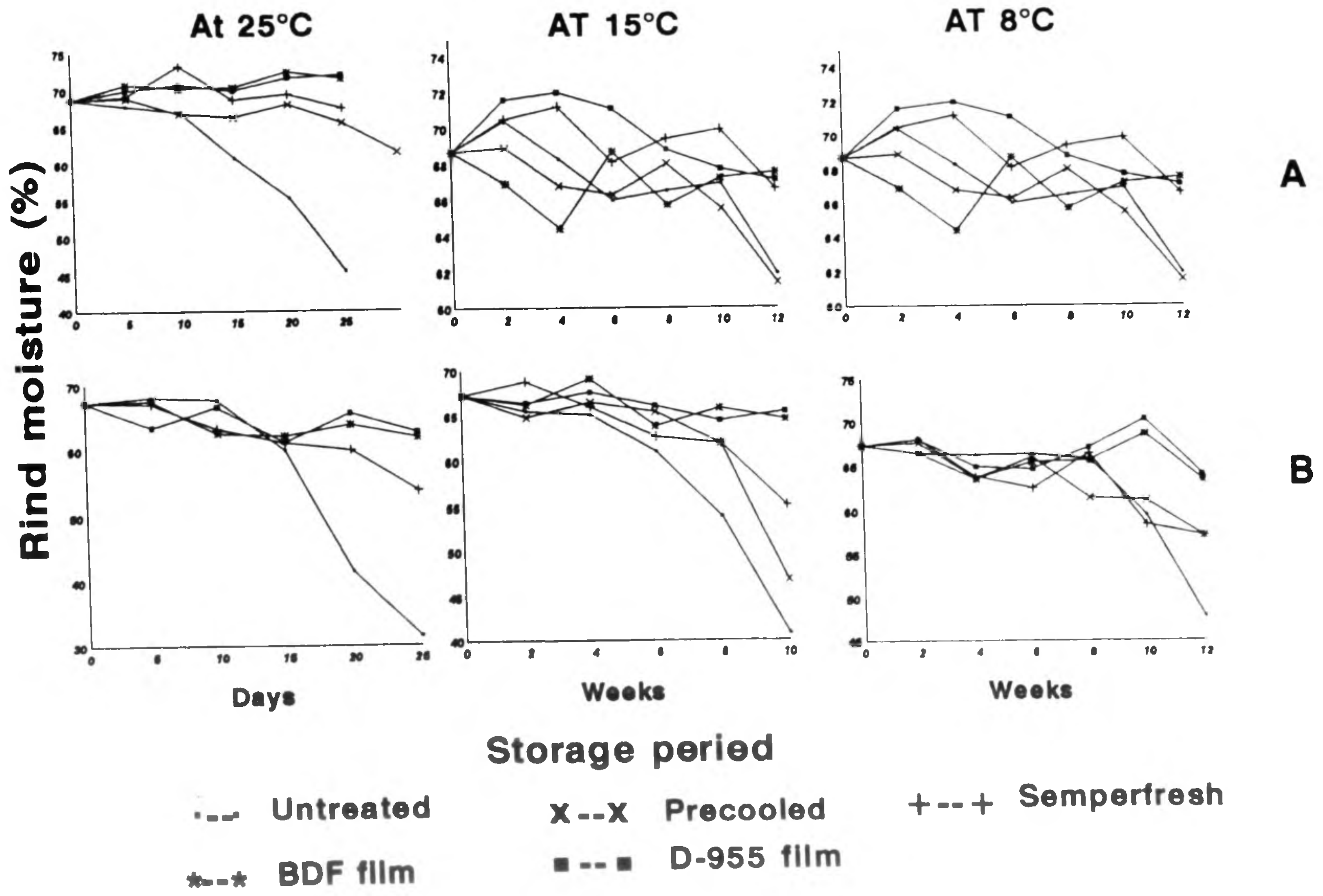


Fig. 15: Effect of treatments and storage temperature on the rind moisture of pomegranate cv.Ganesh grown under Bijapur conditions during 1994(A) and 1995(B).



At $15^{o}C$ after a storage period of 12 weeks, the rind moisture content decreased in the unwrapped fruits while it remained almost constant in wrapped fruits. Lowest rind moisture was observed in the untreated (59.8%) fruits while the BDF 2001 film wrapped fruits recorded the highest (69.9%). The pre-cooled and the semperfresh treated fruits recorded almost same rind moisture of 60.0 per cent. The D955 film wrapped fruits recorded 68.1 per cent rind moisture.

At $8^{o}C$ after a storage period of 14 weeks, the unwrapped fruits (untreated, pre-cooled and semperfresh treated fruits) recorded almost same rind moisture per cent of 65.0. The BDF 2001 film wrapped fruits had highest rind moisture of 69.6 per cent and the D955 film wrapped fruits recorded 67.8 per cent.

In the fruits of Bijapur crop (1994) the rind moisture content at the begining of storage was 68.7 per cent. At RT after a storage period of 25 days, the rind moisture content decreased in unwrapped fruits while it increased in the two wrapped fruits. The untreated fruits recorded lowest of 45.4 per cent rind moisture, while the D955 film wrapped fruits recorded highest of 72.0 per cent. The semperfresh treated and BDF 2001 film wrapped fruits had 67.4 and 71.5 per cent rind moisture, respectively.

At 15$^{o}$C after the end of 8 weeks storage, the semperfresh treated fruits had lowest rind moisture of 64.9 per cent and the D955 film wrapped fruits had highest of 70.3 per cent. The pre-cooled, untreated and BDF film wrapped fruits recorded 68.4, 67.3 and 69.7 per cent rind moisture, respectively.

At 8$^{o}$C after the end of 12 weeks storage, the two film wrapped fruits recorded almost the same rind moisture content (67.0%) while the untreated and pre-cooled fruits recorded almost same (61.5%). The semperfresh treated fruits had 66.6 per cent rind moisture.

During the year 1995 in Bangalore crop the rind moisture at the begining of storage was 68.3 per cent. At RT after 25 days storage the rind moisture decreased in all the treatments. The untreated fruits had a minimum rind moisture of 35.2 per cent while the D955 film wrapped fruits had a maximum of 66.3 per cent. The semperfresh treated and BDF 2001 film wrapped fruits recorded 54.3 and 63.0 per cent rind moisture, respectively.

At 15$^{o}$C the rind moisture at the begining of storage was 70.2 per cent and after a storage period of 10 weeks, the rind moisture decreased in all the treatments. The untreated fruits recorded a lowest of 52.5 per cent while the BDF 2001 film wrapped fruits recorded highest of 63.4 per cent. The pre-cooled, semperfresh treated and D955 film wrapped fruits recorded 53.7, 59.2 and 61.8 per cent rind moisture, respectively.

At 8$^{o}$C after end of 12 weeks storage, the untreated and pre-cooled fruits had almost same rind moisture per cent with 57.3 and 57.6, respectively. The BDF 2001 film wrapped fruits recorded 70.7 per cent. The semperfresh treated and D955 wrapped fruits had 60.8 and 68.0 per cent rind moisture, respectively.

In fruits of Bijapur crop (1995) the rind moisture at the begining of storage was 67.9 per cent. At RT after 25 days of storage, the rind moisture decreased in all the treatments. The untreated fruits recorded a lowest of 31.5 per cent while the D955 film wrapped fruits had highest rind moisture of 62.6 per cent. The semperfresh treated and BDF 2001 film wrapped fruits had 53.8 and 61.8 per cent rind moisture, respectively.

At 15$^{o}$c after the end of 10 weeks of storage, the maximum rind moisture per cent was recorded in D955 film wrapped fruits (65.4) while the untreated fruits recorded the minimum (40.8). The pre-cooled, semperfresh treated and BDF 2001 film wrapped fruits recorded 46.8, 55.1 and 64.5 per cent rind moisture, respectively.

At $8^{o}C$ after the end of 12 weeks storage, the two film wrapped fruits recorded almost same (63.0) rind moisture per cent. The untreated fruits recorded the lowest of 47.8 per cent. The semperfresh treated and pre-cooled fruits recorded the same (57.1) rind moisture per cent.

In general, the unwrapped (untreated, pre-cooled and semperfresh treated) fruits had less rind moisture content as compared to the film wrapped fruits (BDF 2001 and D955) in both the crops at all the three storage temperatures after the end of their respective storage periods in both the years. The rind moisture of unwrapped fruits was less at RT storage followed by 15 and $8^{o}C$ in both the crops and in both the years. The rind moisture between the wrapped fruits did not show much differences at the end of storage period at all the three storage temperature. The rind moisture of unwrapped fruits was lower in 1995 when kept without packing in polybags.

Statistically there were significant differences among treatments, storage periods and their interactions at RT in both the years for Bangalore crop and in Bijapur crop during the year 1995. In the year 1994 only the differences in treatments was significant for Bijapur crop.

At $15^{o}C$ (Bangalore crop) only the differences in storage period was significant in 1994 and in year 1995 along with the storage period the treatment differences also had significant results. In Bijapur crop in year 1994 no significant differences were observed but in year 1995 the differences in treatments, storage period and their interactions were found to be significant.

At 8°C in year 1994 Bangalore fruits, only the differences in storage period was significant while in fruits of Bijapur significant differences were observed among the treatments and storage periods. In the year 1995 significant differences were observed for treatments, storage periods and their interactions in both the crops.

**4.2.11 Total titratable acidity**

The data on the effect of treatments and storage temperature on titratable acidity of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 29 and 30, respectively.

The titratable acidity at the begining of storage in Bangalore crop was 0.51 per cent. At RT after a storage period of 25 days, the acidity per cent slightly decreased in all the treatments. The untreated and BDF 2001 film wrapped fruits had same acidity per cent of 0.47. The semperfresh treated fruits recorded 0.44 per cent and the D955 film wrapped fruits recorded a lowest of 0.38 per cent.

Table 29: Effect of treatments and storage temperature on titratable acidity of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.

| Storage in days | At harvest | 5 | 10 | 15 | 20 | 25 | Mean |
|---|---|---|---|---|---|---|---|
| | | Titratable acidity [Percent] | | | | | |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.51 | 0.47 | 0.47 | 0.47 | 0.41 | 0.47 | 0.46 |
| Semperfresh (2%) | | 0.44 | 0.41 | 0.41 | 0.47 | 0.44 | 0.43 |
| Film wrap (BDF2001) | | 0.44 | 0.47 | 0.44 | 0.44 | 0.47 | 0.45 |
| Film wrap (D955) | | 0.47 | 0.41 | 0.41 | 0.41 | 0.38 | 0.41 |
| Mean | | 0.45 | 0.44 | 0.43 | 0.43 | 0.44 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.47 | 0.44 | 0.44 | 0.41 | 0.38 | 0.32 | 0.40 |
| Pre-cooled | | 0.41 | 0.36 | 0.38 | 0.39 | 0.35 | 0.38 |
| Semperfresh (2%) | | 0.39 | 0.38 | 0.35 | 0.36 | 0.35 | 0.36 |
| Film wrap (BDF2001) | | 0.44 | 0.44 | 0.39 | 0.34 | 0.36 | 0.39 |
| Film wrap (D955) | | 0.44 | 0.43 | 0.37 | 0.34 | 0.31 | 0.38 |
| Mean | | 0.42 | 0.41 | 0.38 | 0.36 | 0.34 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.51 | 0.47 | 0.41 | 0.41 | 0.38 | 0.35 | 0.31 | 0.38 |
| Pre-cooled | | 0.51 | 0.51 | 0.38 | 0.32 | 0.32 | 0.32 | 0.39 |
| Semperfresh (2%) | | 0.47 | 0.41 | 0.41 | 0.35 | 0.38 | 0.35 | 0.39 |
| Film wrap (BDF2001) | | 0.38 | 0.38 | 0.38 | 0.41 | 0.41 | 0.35 | 0.38 |
| Film wrap (D955) | | 0.38 | 0.47 | 0.40 | 0.41 | 0.38 | 0.38 | 0.40 |
| Mean | | 0.44 | 0.43 | 0.39 | 0.37 | 0.36 | 0.34 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.033 |
| Interaction | * | 0.074 |

* - Significant at 5%    NS - Non significant

**Table 30: Effect of treatments and storage temperature on titratable acidity of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | Titratable acidity [Percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.40 | 0.41 | 0.41 | 0.35 | 0.41 | 0.35 | 0.38 |
| Semperfresh (2%) | | 0.38 | 0.35 | 0.36 | 0.35 | 0.35 | 0.35 |
| Film wrap (BDF2001) | | 0.41 | 0.44 | 0.41 | 0.44 | 0.38 | 0.41 |
| Film wrap (D955) | | 0.38 | 0.44 | 0.41 | 0.41 | 0.35 | 0.39 |
| Mean | | 0.39 | 0.41 | 0.38 | 0.40 | 0.35 | - |

| | **'F' Test** | **CD at 5%** |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 0.40 | 0.41 | 0.41 | 0.35 | 0.35 | 0.32 | 0.36 |
| Pre-cooled | | 0.39 | 0.41 | 0.36 | 0.41 | 0.35 | 0.38 |
| Semperfresh (2%) | | 0.38 | 0.39 | 0.38 | 0.35 | 0.31 | 0.36 |
| Film wrap (BDF2001) | | 0.41 | 0.36 | 0.35 | 0.35 | 0.31 | 0.35 |
| Film wrap (D955) | | 0.41 | 0.41 | 0.38 | 0.34 | 0.33 | 0.37 |
| Mean | | 0.40 | 0.39 | 0.36 | 0.36 | 0.32 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.034 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 0.40 | 0.41 | 0.35 | 0.36 | 0.30 | 0.31 | 0.30 | 0.33 |
| Pre-cooled | | 0.43 | 0.39 | 0.41 | 0.41 | 0.35 | 0.33 | 0.38 |
| Semperfresh (2%) | | 0.38 | 0.41 | 0.38 | 0.41 | 0.34 | 0.31 | 0.37 |
| Film wrap (BDF2001) | | 0.38 | 0.42 | 0.42 | 0.35 | 0.38 | 0.38 | 0.38 |
| Film wrap (D955) | | 0.42 | 0.45 | 0.41 | 0.38 | 0.32 | 0.30 | 0.38 |
| Mean | | 0.40 | 0.40 | 0.39 | 0.37 | 0.34 | 0.32 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.056 |
| Interaction | NS | - |

* - Significant at 5%     NS - Non significant

At $15^{o}C$ the titratable acidity at the begining of storage was 0.47 per cent and after 10 weeks of storage, the acidity of all the treatments decreased. The pre-cooled and semperfresh treated fruits recorded the same acidity percent (0.35). The untreated fruits had 0.32 per cent. The BDF 2001 film wrapped fruits recorded highest per cent of 0.36 while the D955 film wrapped fruits record a lowest of 0.31 per cent.

At $8^{o}C$ after 12 weeks of storage, the acidity slightly decreased in all the treatments. Maximum of 0.38 was observed in D955 film wrapped fruits while the minimum of 0.31 per cent was observed in the untreated fruits. The semperfresh treated and BDF 2001 film wrapped fruits recorded 0.35 per cent, while the pre-cooled fruits recorded 0.32 per cent.

In the fruits of Bijapur crop the acidity at the begining of storage was 0.40 per cent. At RT after storage period of 25 days, the acidity of all the treatments slightly decreased. The untreated, semperfresh treated and D955 film wrapped fruits recorded 0.35 per cent and the BDF 2001 film wrapped fruits had 0.38 per cent.

At $15^{o}c$ after 10 weeks of storage, the maximum acidity of 0.35 per cent was recorded in pre-cooled fruits and the minimum of 0.31 per cent was recorded in semperfresh treated and BDF 2001 film wrapped fruits. The untreated and the D955 film wrapped fruits had an acidity of 0.32 and 0.33 per cent, respectively.

At 8$^{o}$C after a storage period of 12 weeks, maximum acidity of 0.38 per cent was recorded in BDF 2001 film wrapped fruits. The untreated and D955 film wrapped fruits recorded 0.30 per cent. The acidity of pre-cooled and semperfresh treated fruits was 0.33 and 0.31 per cent, respectively.

In general it was observed that the acidity of the fruits decreased at all the three storage temperatures after their respective storage period in both the crops. The acidity of Bijapur crop at harvest and during the storage was less than the acidity of Bangalore crop. However, statistically no significant differences were observed among the treatments, storage periods and interactions at RT in both the crops. At 15$^{o}$C, the differences between the storage period was significant in only Bijapur crop. At 8$^{o}$C, the differences between the storage period was significant in both the crops.

**4.2.12 Ascorbic acid**

The data on the effect of treatments and storage temperature on the ascorbic acid content of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 31 and 32, respectively.

The ascorbic acid content at the beginning of storage in Bangalore crop was 15.1 mg/100 ml. At RT after a storage period of 25 days the acidity remained at 15.1 mg/100 ml in all the treatments except in D955 film wrapped fruits which recorded 16.2 mg/100 ml.

At 15$^{o}$C, at the begining of storage the ascorbic acid was 15.6 mg/100 ml and after a storage period of 10 weeks the ascorbic acid content slightly decreased in all the treatments. The untreated fruits recorded a minimum of 11.4 mg/100 ml while the semperfresh treated fruits recorded maximum of 15.1 mg/100 ml. The two film wrapped fruits recorded 14.9 mg/100 ml and the pre-cooled fruits recorded 13.8 mg/100 ml.

At 8$^{o}$C, after a storage period of 12 weeks, the ascorbic acid content did not change much and it ranged from 16.0 - 14.8 mg/100 ml.

In the fruits of Bijapur crop, the ascorbic acid at the begining of storage was 19.4 mg/100 ml. At RT after a storage period of 25 days, the ascorbic acid content slightly decreased in all the treatments. The BDF 2001 film wrapped fruits had maximum ascorbic acid content of

**Table 31: Effect of treatments and storage temperature on ascorbic acid content of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | | Ascorbic acid [mg/100m ml] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** | |
| **Treatments** | | | | | | | | |
| **At 25 ± 1°C** | | | | | | | | |
| Untreated (Control) | 15.1 | 14.0 | 14.9 | 12.9 | 14.9 | 15.1 | 14.4 | |
| Semperfresh (2%) | | 13.8 | 14.1 | 12.9 | 14.0 | 15.1 | 14.2 | |
| Film wrap (BDF2001) | | 13.8 | 12.9 | 15.1 | 14.0 | 15.1 | 14.2 | |
| Film wrap (D955) | | 13.8 | 15.1 | 15.1 | 16.1 | 16.2 | 15.2 | |
| Mean | | 13.9 | 14.2 | 14.0 | 14.8 | 15.6 | - | |
| | | | **'F' Test** | | **CD at 5%** | | | |
| Treatment | | | NS | | - | | | |
| Period | | | NS | | - | | | |
| Interaction | | | * | | 2.595 | | | |
| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** | |
| **Treatments** | | | | | | | | |
| **At 15 ± 1°C** | | | | | | | | |
| Untreated (Control) | 15.6 | 14.0 | 12.9 | 11.8 | 12.5 | 11.4 | 12.5 | |
| Pre-cooled | | 16.0 | 15.1 | 15.1 | 14.9 | 13.8 | 15.0 | |
| Semperfresh (2%) | | 16.0 | 16.0 | 16.9 | 14.9 | 15.1 | 15.9 | |
| Film wrap (BDF2001) | | 17.1 | 16.0 | 14.9 | 15.1 | 14.9 | 15.6 | |
| Film wrap (D955) | | 16.0 | 16.9 | 14.9 | 15.1 | 14.9 | 15.6 | |
| Mean | | 15.8 | 15.4 | 14.7 | 14.5 | 14.2 | - | |
| Treatment | | | * | | 1.110 | | | |
| Period | | | NS | | - | | | |
| Interaction | | | NS | | - | | | |
| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 15.1 | 16.2 | 14.9 | 16.8 | 15.8 | 15.1 | 14.9 | 15.6 |
| Pre-cooled | | 18.1 | 16.9 | 17.1 | 17.1 | 16.9 | 15.0 | 17.0 |
| Semperfresh (2%) | | 17.2 | 17.1 | 16.9 | 15.9 | 14.8 | 15.1 | 16.2 |
| Film wrap (BDF2001) | | 14.0 | 16.0 | 18.1 | 16.9 | 14.9 | 15.0 | 16.0 |
| Film wrap (D955) | | 16.2 | 17.1 | 18.0 | 14.9 | 16.0 | 14.8 | 16.2 |
| Mean | | 16.3 | 16.4 | 17.4 | 16.2 | 15.5 | 15.2 | - |
| Treatment | | | NS | | - | | | |
| Period | | | * | | 0.677 | | | |
| Interaction | | | * | | 1.511 | | | |

* - Significant at 5% NS - Non significant

Table 32: Effect of treatments and storage temperature on ascorbic acid content of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.

| | Ascorbic acid (mg/100m ml) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 19.4 | 16.2 | 14.9 | 16.0 | 14.9 | 15.7 | 15.5 |
| Semperfresh (2%) | | 18.3 | 16.2 | 16.2 | 15.9 | 16.6 | 16.8 |
| Film wrap (BDF2001) | | 16.2 | 17.1 | 16.2 | 15.9 | 16.7 | 16.4 |
| Film wrap (D955) | | 17.6 | 18.0 | 17.1 | 16.8 | 15.8 | 17.0 |
| Mean | | 17.1 | 16.5 | 16.3 | 16.1 | 16.2 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | * | 2.595 |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 19.4 | 19.2 | 16.8 | 15.8 | 16.4 | 16.4 | 17.0 |
| Pre-cooled | | 19.0 | 17.8 | 18.0 | 15.8 | 15.8 | 17.3 |
| Semperfresh (2%) | | 19.0 | 16.8 | 18.3 | 17.6 | 17.6 | 17.9 |
| Film wrap (BDF2001) | | 19.7 | 19.2 | 16.8 | 18.7 | 17.8 | 18.4 |
| Film wrap (D955) | | 20.3 | 18.9 | 17.6 | 16.8 | 17.6 | 18.2 |
| Mean | | 19.4 | 17.9 | 17.3 | 17.1 | 17.1 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.921 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 19.4 | 16.2 | 16.6 | 16.9 | 17.0 | 15.6 | 16.6 | 16.5 |
| Pre-cooled | | 19.0 | 17.6 | 15.6 | 15.6 | 16.6 | 15.6 | 16.7 |
| Semperfresh (2%) | | 19.4 | 19.0 | 15.6 | 17.0 | 17.0 | 16.6 | 17.4 |
| Film wrap (BDF2001) | | 19.4 | 18.7 | 18.0 | 17.0 | 16.6 | 15.6 | 17.5 |
| Film wrap (D955) | | 18.3 | 19.0 | 18.7 | 18.7 | 17.0 | 15.6 | 17.9 |
| Mean | | 18.5 | 18.2 | 16.9 | 17.0 | 16.5 | 16.0 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.974 |
| Interaction | * | 1.511 |

* - Significant at 5%    NS - Non significant

16.7 mg/100 ml and the untreated fruits had minimum of 15.7 mg/100 ml. The semperfresh treated and D955 film wrapped fruits had 16.6 and 15.8 mg ascorbic acid, respectively.

At 15$^{O}$C after the end of 10 weeks storage, the ascorbic acid content showed a slight decrease in all the treatments. The BDF 2001 film wrapped fruits recorded a maximum of 17.8 mg/100 ml while the pre-cooled fruits recorded a lowest of 15.8 mg/100 ml. The untreated fruits recorded 16.4 mg/100 ml and the semperfresh treated and D955 film wrapped fruits recorded 17.6 mg/100 ml.

At 8$^{O}$C after a storage period of 12 weeks, the ascorbic acid content decreased in all the treatments. The pre-cooled, BDF 2001 film and D955 film wrapped fruits had 15.6 mg/100 ml. The untreated and semperfresh treated fruits had 16.6 mg/100 ml.

In general the ascorbic acid slightly decreased with the increase in storage period at all the three temperatures in both the crops. The ascorbic acid content of Bijapur fruits was slightly high at harvest and during storage period than the ascorbic acid content of Bangalore harvested fruits.

Statistical differences were observed for the interaction at RT for only fruits harvested from Bangalore area. At 15$^{o}$C, in Bangalore crop the differences among the treatments was significant while in Bijapur crop the differences between storage intervals were significant. At 8$^{o}$C, the differences between the storage period was significant in both the crops.

**4.2.13 Total soluble solids (TSS)**

The data on the effect of treatments and storage temperature on the TSS of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 33 and 34, respectively.

In Bangalore crop, there was 15.7$^{o}$B TSS at the begining of storage. After the end of storage period that is 25 days at RT, the TSS of all the treatments decreased slightly. A TSS of 15.1$^{o}$B was recorded in D955 film wrapped fruits while the untreated (14.7$^{o}$B) semperfresh treated (14.1) and BDF 2001 film wrapped (14.4$^{o}$B) fruits had more or less same TSS.

At 15$^{o}$C the TSS at the begining of storage was 13.7$^{o}$Brix and after a storage period of 10 weeks it did not change and was more or less same in all the treatments in range of 13.2 to 13.9$^{o}$Brix.

At 8$^{o}$C after a storage period of 12 weeks, the TSS decreased in all the treatments from the initial value of

**Table 33: Effect of treatments and storage temperature on total soluble solids (TSS) of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | TSS [$^{o}$B] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 $\pm$ 1$^{o}$C** | | | | | | | |
| Untreated (Control) | 15.7 | 15.8 | 15.4 | 14.3 | 14.5 | 14.7 | 14.9 |
| Semperfresh (2%) | | 14.8 | 15.2 | 15.4 | 13.8 | 14.1 | 14.6 |
| Film wrap (BDF2001) | | 15.3 | 15.1 | 14.6 | 14.1 | 14.4 | 14.7 |
| Film wrap (D955) | | 15.4 | 14.5 | 14.8 | 14.7 | 15.1 | 14.9 |
| Mean | | 15.3 | 15.0 | 14.7 | 14.2 | 14.1 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 $\pm$ 1$^{o}$C** | | | | | | | |
| Untreated (Control) | 13.7 | 13.8 | 13.8 | 14.0 | 13.6 | 13.2 | 13.6 |
| Pre-cooled | | 14.1 | 14.2 | 13.9 | 13.9 | 13.7 | 13.9 |
| Semperfresh (2%) | | 13.6 | 14.4 | 13.5 | 13.1 | 13.3 | 13.5 |
| Film wrap (BDF2001) | | 14.1 | 14.2 | 14.5 | 14.5 | 13.8 | 14.2 |
| Film wrap (D955) | | 13.9 | 14.5 | 13.6 | 14.2 | 13.9 | 14.2 |
| Mean | | 13.9 | 14.2 | 13.9 | 13.8 | 13.5 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 $\pm$ 1$^{o}$C** | | | | | | | | |
| Untreated (Control) | 15.7 | 13.1 | 13.6 | 13.2 | 13.4 | 13.2 | 13.6 | 13.3 |
| Pre-cooled | | 13.5 | 13.9 | 13.9 | 13.0 | 13.1 | 13.6 | 13.5 |
| Semperfresh (2%) | | 13.4 | 13.6 | 13.3 | 13.7 | 13.9 | 13.8 | 13.6 |
| Film wrap (BDF2001) | | 14.0 | 13.2 | 14.5 | 14.1 | 14.1 | 13.8 | 13.9 |
| Film wrap (D955) | | 14.0 | 13.4 | 13.4 | 14.2 | 13.3 | 12.9 | 13.5 |
| Mean | | 13.6 | 13.5 | 13.6 | 13.6 | 13.5 | 13.5 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%        NS - Non significant

**Table 34: Effect of treatments and storage temperature on total soluble solids (TSS) of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | TSS [°B] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 14.0 | 13.9 | 13.0 | 13.1 | 13.2 | 13.1 | 13.2 |
| Semperfresh (2%) | | 13.4 | 14.0 | 13.3 | 13.1 | 13.4 | 13.4 |
| Film wrap (BDF2001) | | 14.6 | 13.9 | 13.8 | 13.2 | 13.5 | 13.8 |
| Film wrap (D955) | | 14.1 | 13.9 | 13.7 | 13.5 | 13.4 | 13.7 |
| Mean | | 14.0 | 13.7 | 13.4 | 13.2 | 13.3 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 14.0 | 12.8 | 13.3 | 13.4 | 13.4 | 12.9 | 13.1 |
| Pre-cooled | | 13.1 | 13.5 | 13.4 | 13.2 | 12.5 | 13.1 |
| Semperfresh (2%) | | 13.8 | 12.7 | 13.2 | 12.8 | 13.1 | 13.1 |
| Film wrap (BDF2001) | | 13.7 | 13.9 | 13.4 | 14.0 | 13.5 | 13.7 |
| Film wrap (D955) | | 14.2 | 15.3 | 14.3 | 13.9 | 14.0 | 14.3 |
| Mean | | 13.5 | 13.7 | 13.5 | 13.4 | 13.2 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 14.0 | 15.6 | 15.4 | 14.7 | 14.3 | 12.8 | 12.9 | 14.2 |
| Pre-cooled | | 14.4 | 14.6 | 14.3 | 13.9 | 13.2 | 14.0 | 13.0 |
| Semperfresh (2%) | | 14.4 | 14.3 | 14.0 | 13.4 | 13.6 | 14.0 | 13.9 |
| Film wrap (BDF2001) | | 14.3 | 14.7 | 14.2 | 13.7 | 13.4 | 13.5 | 13.9 |
| Film wrap (D955) | | 14.9 | 15.3 | 14.3 | 13.9 | 13.6 | 13.3 | 14.2 |
| Mean | | 14.7 | 14.8 | 14.3 | 13.8 | 13.3 | 13.5 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.478 |
| Interaction | NS | - |

* - Significant at 5%     NS - Non significant

15.7$^{O}$B. The highest TSS of 13.8$^{O}$B was observed in semperfresh treated and BDF 2001 film wrapped fruits, while the D955 film wrapped fruits had lowest TSS of 12.9$^{O}$B. The untreated and the pre-cooled fruits recorded an equal TSS of 13.6$^{O}$B.

In the fruits of Bijapur crop, the initial TSS recorded was 14.0$^{O}$Brix. At RT all the treatments showed a slight decrease after 25 days of storage. The semperfresh treated and D955 film wrapped fruits had an equal TSS of 13.4$^{O}$B while the untreated and BDF 2001 film wrapped fruits recorded 13.1 and 13.5$^{O}$B, respectively.

At 15$^{O}$C the maximum TSS of 14.0$^{O}$B was recorded in D955 film wrapped fruits while a minimum 12.5$^{O}$B was observed in pre-cooled fruits.

At 8$^{O}$C after a storage period of 12 weeks, the TSS of the pre-cooled and semperfresh treated fruits was same as the initial TSS. The TSS of the untreated fruits was 12.9$^{O}$B followed by D955 film wrapped (13.3$^{O}$B) and BDF 2001 film wrapped (13.5$^{O}$B).

In general the TSS showed a slight decrease or remained more or less same at all the three storage temperatures in both the crops. Statistical analysis showed that there was no significant differences among the treatments, between the storage period and interactions at RT and 15$^{O}$C in both the crops. At 8$^{O}$C, the differences in TSS was significant during the storage period in Bijapur crop.

**4.2.14 Reducing sugars**

The data on the effect of treatments and storage temperatures on reducing sugars of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 35 and 36, respectively.

There was 13.1 and 11.7 per cent reducing sugars from Bangalore and Bijapur crops, respectively on the initial day of storage.

At RT (Bangalore crop) after a storage period of 25 days, the reducing sugars did not change and remained more or less same in all the treatments. It ranged from 13.3 to 13.9 per cent.

At 15$^{O}$C the reducing sugars at the begining of storage was 12.0 per cent and after a storage period of 10 weeks, maximum reducing sugars of 13.2 per cent was recorded in BDF 2001 film wrapped fruits, while the untreated fruits recorded minimum of 11.8 per cent. The pre-cooled (12.4) semperfresh treated (12.6) and D955 film wrapped fruits (12.5) recorded more or less same per cent reducing sugars.

**Table 35: Effect of treatments and storage temperature on reducing sugars pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | | Reducing Sugars [percent] | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 13.1 | 13.1 | 13.4 | 13.6 | 12.8 | 13.8 | 13.5 |
| Semperfresh (2%) | | 13.2 | 14.1 | 13.7 | 13.5 | 13.3 | 13.6 |
| Film wrap (BDF2001) | | 13.4 | 13.3 | 12.2 | 13.5 | 13.3 | 13.2 |
| Film wrap (D955) | | 12.8 | 12.8 | 13.4 | 13.4 | 13.9 | 13.4 |
| Mean | | 13.4 | 13.4 | 13.2 | 13.3 | 13.6 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 12.0 | 12.9 | 12.8 | 13.1 | 12.5 | 11.8 | 12.6 |
| Pre-cooled | | 13.4 | 13.2 | 13.4 | 13.0 | 12.4 | 13.1 |
| Semperfresh (2%) | | 12.8 | 13.1 | 13.3 | 12.8 | 12.6 | 12.9 |
| Film wrap (BDF2001) | | 13.2 | 13.3 | 13.0 | 12.8 | 13.2 | 13.1 |
| Film wrap (D955) | | 13.1 | 12.8 | 13.3 | 12.4 | 12.5 | 12.8 |
| Mean | | 13.1 | 13.0 | 13.2 | 12.7 | 12.5 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | * | 0.335 |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 13.1 | 12.5 | 12.5 | 13.4 | 12.7 | 12.1 | 12.1 | 12.5 |
| Pre-cooled | | 13.3 | 13.6 | 12.6 | 12.0 | 12.2 | 11.8 | 12.7 |
| Semperfresh (2%) | | 12.3 | 13.2 | 13.3 | 12.5 | 12.7 | 13.1 | 12.8 |
| Film wrap (BDF2001) | | 12.5 | 13.2 | 13.4 | 13.1 | 12.8 | 13.0 | 13.6 |
| Film wrap (D955) | | 13.6 | 13.8 | 13.6 | 12.9 | 12.9 | 13.0 | 13.3 |
| Mean | | 12.9 | 13.3 | 13.3 | 12.8 | 12.6 | 12.6 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%    NS - Non significant

Table 36: Effect of treatments and storage temperature on reducing sugars of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.

| | Reducing Sugars [percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| Storage in days | At harvest | 5 | 10 | 15 | 20 | 25 | Mean |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 11.7 | 12.5 | 11.8 | 11.0 | 10.7 | 12.2 | 11.6 |
| Semperfresh (2%) | | 11.7 | 12.7 | 11.9 | 11.7 | 12.3 | 12.1 |
| Film wrap (BDF2001) | | 12.6 | 12.0 | 11.4 | 11.5 | 12.5 | 12.0 |
| Film wrap (D955) | | 12.0 | 13.0 | 12.0 | 11.7 | 12.0 | 12.1 |
| Mean | | 12.2 | 12.4 | 11.6 | 11.4 | 12.2 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 11.7 | 11.3 | 11.9 | 11.6 | 12.5 | 11.8 | 11.8 |
| Pre-cooled | | 11.1 | 13.1 | 11.2 | 11.6 | 12.2 | 11.8 |
| Semperfresh (2%) | | 12.0 | 11.7 | 11.3 | 12.1 | 12.0 | 11.8 |
| Film wrap (BDF2001) | | 11.6 | 12.5 | 12.3 | 12.3 | 11.4 | 12.0 |
| Film wrap (D955) | | 12.4 | 13.2 | 12.5 | 12.4 | 12.2 | 12.5 |
| Mean | | 11.7 | 12.4 | 11.8 | 12.2 | 11.9 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 11.7 | 12.3 | 12.4 | 12.2 | 12.6 | 12.5 | 12.3 | 12.4 |
| Pre-cooled | | 12.2 | 12.8 | 12.5 | 12.1 | 11.9 | 11.3 | 12.1 |
| Semperfresh (2%) | | 12.4 | 13.0 | 12.1 | 13.0 | 11.6 | 12.8 | 12.5 |
| Film wrap (BDF2001) | | 12.5 | 11.3 | 12.8 | 12.0 | 12.6 | 12.2 | 12.3 |
| Film wrap (D955) | | 12.4 | 12.3 | 12.5 | 13.0 | 12.4 | 12.2 | 12.5 |
| Mean | | 12.4 | 12.3 | 12.4 | 12.5 | 12.2 | 12.2 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%　　NS - Non significant

At 8$^{o}$C after a storage period of 12 weeks, the untreated fruits recorded 12.1 per cent and the pre-cooled fruits recorded 11.8 per cent. The semperfresh treated, BDF 2001 film wrapped and D955 film wrapped fruits recorded 13.0 per cent reducing sugars.

In the fruits of Bijapur crop, the reducing sugars at the begining of storage was 11.7 per cent. At RT after a storage period of 25 days, the reducing sugars slightly increased in all the treatments. It ranged from 12 to 12.5 per cent.

At 15$^{o}$C after a storage period of 10 weeks, the untreated fruits recorded 11.8 per cent reducing sugars and BDF 2001 film wrapped fruits recorded 11.4 per cent. The pre-cooled (12.2) semperfresh treated (12.0) and D955 film wrapped (12.2) fruits had almost same reducing sugar per cent.

At 8$^{o}$, after 12 weeks of storage, the pre-cooled fruits had minimum reducing sugars of 11.3 per cent and semperfresh treated fruits had maximum reducing sugars of 12.8 per cent. The two film wrapped fruits had 12.2 per cent reducing sugars and the untreated fruits recorded 12.3 per cent.

In general, the reducing sugars remained more or less same at all the three storage temperatures in both the crops. Out of the total sugars the reducing sugars were more and the amount of non reducing was negligible.

Statistically no differences were observed among the treatments, storage period and interactions in both the crops at all the three storage temperatures.

**4.2.15 Total sugars**

The data on the effect of treatments and storage temperature on total sugars of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 37 and 38, respectively.

There was 13.5 per cent total sugars from the Bangalore harvested crop and 12.3 per cent from the Bijapur harvested crop on the initial day of storage.

At RT, the total sugars in the fruits of Bangalore crop was more or less same as the initial value in all the treatments. It ranged from 13.2 to 13.6 per cent.

At 15$^{o}$C the initial total sugars recorded was 12.5 per cent. During the storage period of 10 weeks, maximum total sugars of 13.3 per cent was observed in untreated fruits. The pre-cooled (12.5), semperfresh treated (12.8) and D955 film wrapped fruits (12.9) had more or less same total sugars while the BDF 2001 film wrapped fruits recorded 13.2 per cent.

**Table 37: Effect of treatments and storage temperature on total sugars of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | Total Sugars [percent] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Storage in days** | **At harvest** | **5** | **10** | **15** | **20** | **25** | **Mean** |
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 13.5 | 13.9 | 14.6 | 14.0 | 14.1 | 13.6 | 14.0 |
| Semperfresh (2%) | | 13.1 | 14.5 | 13.3 | 13.4 | 13.2 | 13.5 |
| Film wrap (BDF2001) | | 13.3 | 13.4 | 13.2 | 13.4 | 13.4 | 13.3 |
| Film wrap (D955) | | 13.3 | 13.8 | 13.7 | 13.6 | 13.7 | 13.6 |
| Mean | | 13.4 | 14.1 | 13.5 | 13.6 | 13.5 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **Mean** |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 12.5 | 12.9 | 13.5 | 13.5 | 12.8 | 13.3 | 13.2 |
| Pre-cooled | | 13.5 | 13.5 | 13.5 | 12.7 | 12.5 | 13.1 |
| Semperfresh (2%) | | 13.3 | 13.6 | 12.8 | 13.4 | 12.8 | 13.2 |
| Film wrap (BDF2001) | | 13.4 | 13.5 | 13.2 | 13.2 | 13.2 | 13.3 |
| Film wrap (D955) | | 13.3 | 13.2 | 13.3 | 13.3 | 12.9 | 13.2 |
| Mean | | 13.3 | 13.5 | 13.3 | 13.1 | 12.9 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| **Storage in weeks** | **At harvest** | **2** | **4** | **6** | **8** | **10** | **12** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 13.5 | 14.2 | 13.5 | 13.5 | 12.7 | 12.6 | 12.2 | 13.1 |
| Pre-cooled | | 13.6 | 14.0 | 13.5 | 13.9 | 12.6 | 12.7 | 13.4 |
| Semperfresh (2%) | | 13.2 | 13.9 | 13.5 | 13.5 | 13.3 | 13.1 | 13.4 |
| Film wrap (BDF2001) | | 13.0 | 13.5 | 13.3 | 13.5 | 12.4 | 12.1 | 13.0 |
| Film wrap (D955) | | 13.9 | 13.9 | 13.6 | 12.7 | 13.0 | 13.2 | 13.4 |
| Mean | | 13.6 | 13.8 | 13.5 | 13.2 | 12.8 | 12.6 | - |

| | | |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5%     NS - Non significant

**Table 38: Effect of treatments and storage temperature on total sugars of pomegran cv.Ganesh grown under Bijapur conditions during 1995.**

| Storage in days | At harvest | Total Sugars [percent] 5 | 10 | 15 | 20 | 25 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 25 ± 1°C** | | | | | | | |
| Untreated (Control) | 12.3 | 13.4 | 11.9 | 12.3 | 12.4 | 13.4 | 12.7 |
| Semperfresh (2%) | | 12.7 | 13.5 | 12.4 | 12.4 | 12.8 | 12.8 |
| Film wrap (BDF2001) | | 13.5 | 12.7 | 12.9 | 12.2 | 12.4 | 12.7 |
| Film wrap (D955) | | 13.1 | 13.5 | 12.3 | 13.0 | 13.1 | 13.0 |
| Mean | | 13.2 | 12.9 | 12.5 | 12.5 | 12.9 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | Mean |
|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | |
| **At 15 ± 1°C** | | | | | | | |
| Untreated (Control) | 12.3 | 12.6 | 12.1 | 12.2 | 12.2 | 12.0 | 12.2 |
| Pre-cooled | | 12.2 | 13.2 | 13.2 | 11.9 | 12.4 | 12.6 |
| Semperfresh (2%) | | 11.7 | 12.0 | 12.5 | 13.5 | 12.9 | 12.5 |
| Film wrap (BDF2001) | | 12.8 | 13.3 | 12.4 | 13.3 | 12.6 | 12.9 |
| Film wrap (D955) | | 13.2 | 13.2 | 13.5 | 13.1 | 12.6 | 13.1 |
| Mean | | 12.5 | 12.8 | 12.8 | 12.8 | 12.5 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

| Storage in weeks | At harvest | 2 | 4 | 6 | 8 | 10 | 12 | Mean |
|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | |
| **At 8 ± 1°C** | | | | | | | | |
| Untreated (Control) | 12.3 | 12.6 | 12.6 | 12.1 | 13.4 | 13.1 | 13.0 | 12.8 |
| Pre-cooled | | 12.6 | 12.9 | 13.0 | 12.7 | 13.2 | 12.6 | 12.8 |
| Semperfresh (2%) | | 13.0 | 13.2 | 12.2 | 13.4 | 12.9 | 12.4 | 12.8 |
| Film wrap (BDF2001) | | 13.4 | 12.6 | 13.4 | 13.2 | 13.2 | 13.5 | 13.2 |
| Film wrap (D955) | | 13.0 | 12.8 | 12.8 | 13.1 | 13.1 | 13.1 | 12.8 |
| Mean | | 12.9 | 13.3 | 13.3 | 12.8 | 12.6 | 12.6 | - |

| | 'F' Test | CD at 5% |
|---|---|---|
| Treatment | NS | - |
| Period | NS | - |
| Interaction | NS | - |

* - Significant at 5% NS - Non significant

At 8$^{o}$C, after 12 weeks of storage, the D955 film wrapped fruits had maximum total sugars of 13.2 per cent followed by semperfresh treated fruits (13.1%). The untreated, pre-cooled and BDF 2001 film wrapped fruits recorded a TSS of 12.2, 12.7 and 12.1 per cent, respectively.

In fruits of Bijapur crop, at RT after a storage period of 25 days the total sugars of the untreated (13.4) and D955 film wrapped (13.1%) fruits slightly increased. The semperfresh treated and BDF 2001 film wrapped fruits recorded 12.8 and 12.4 per cent, respectively.

At 15$^{o}$C after a storage period of 10 weeks, the total sugars was more or less same as the initial value and it ranged from 12.0 to 12.9 per cent.

At 8$^{o}$C after 12 weeks of storage, maximum total sugars of 13.5 per cent was recorded in BDF 2001 film wrapped fruits. While the minimum of 12.4 per cent was recorded in semperfresh treated fruits. The untreated fruits had 13.0 per cent total sugars. The pre-cooled and D955 film wrapped fruits recorded 12.6 and 12.7 per cent, respectively.

However no statistical differences were observed among the treatments, storage period and interaction in both the crops and at all the three storage temperatures.

**4.2.16 Browning of arils**

The data on the effect of treatments and storage temperature on the brown aril of pomegranate in Bangalore and Bijapur crops during 1995 are presented in Tables 39 and 40, respectively.

Browning of arils during storage was observed irrespective of storage temperatures and post harvest treatments (Plate 8).

In Bangalore crop at RT storage the brown arils were observed in all the treatments. Percentage of brown arils varied in different treatments. The range was from 1-6 per cent during early part of storage, i.e. 5-10 days and it slightly decreased to 1-3 per cent at the end of storage i.e. 20-25 days.

At 15$^{o}$c, brown arils were observed in all the treatments during the storage. Percentage of brown arils was 2-6 per cent during 2-4 weeks storage and it slightly increased to 2 - 8 per cent towards end of storage (10 weeks).

At 8$^{o}$C, the percentage of brown arils increased towards the end of storage. During the early part (i.e. 2-4 weeks) of storage the brown arils were in range of 2-6 per cent and at the end of storage the percentage of brown arils ranged from 0.68 to 9 per cent.

**Table 39: Effect of treatments and storage temperature on brown arils of pomegranate cv.Ganesh grown under Bangalore conditions during 1995.**

| | Brown aril [percent] | | | | | |
|---|---|---|---|---|---|---|
| **Storage in days** | **5** | **10** | **20** | **25** | | |
| **Treatments** | | | | | | |
| **At 25 ± 1°C** | | | | | | |
| Untreated (Control) | 6.25 | 5.62 | 0.88 | - | | |
| Semperfresh (2%) | 2.50 | 4.45 | 0.81 | - | | |
| Film wrap (BDF2001) | 1.35 | 2.18 | 1.11 | 2.38 | | |
| Film wrap (D955) | - | 3.47 | 1.78 | 3.23 | | |
| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | |
| **Treatments** | | | | | | |
| **At 15 ± 1°C** | | | | | | |
| Untreated (Control) | 5.30 | - | 3.44 | - | 8.14 | |
| Pre-cooled | - | 6.13 | 4.79 | 1.94 | 6.14 | |
| Semperfresh (2%) | 6.47 | 5.56 | - | - | 3.81 | |
| Film wrap (BDF2001) | 3.22 | 2.23 | 1.44 | 0.65 | 2.75 | |
| Film wrap 'D955) | 3.07 | - | 0.63 | - | 4.92 | |
| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** | **12** |
| **Treatments** | | | | | | |
| **At 8 ± 1°C** | | | | | | |
| Untreated (Control) | - | 3.26 | 1.38 | - | 9.46 | 5.44 |
| Pre-cooled | - | - | 3.77 | - | 2.48 | 5.44 |
| Semperfresh (2%) | - | - | 9.52 | - | 5.57 | 3.11 |
| Film wrap (BDF2001) | 2.40 | - | - | 4.22 | 4.94 | - |
| Film wrap (D955) | 6.52 | - | 7.39 | - | - | 5.15 |

Each value is a mean of 2 fruits

**Table 40: Effect of treatments and storage temperature on brown arils of pomegranate cv.Ganesh grown under Bijapur conditions during 1995.**

| | Brown aril (percent) | | | | |
|---|---|---|---|---|---|
| **Storage in days** | **5** | **10** | **15** | **20** | **25** |
| **Treatments** | | | | | |
| **At 25 $\pm$ 1°C** | | | | | |
| Untreated (Control) | - | 6.79 | - | 5.02 | 4.02 |
| Semperfresh (2%) | 2.73 | - | - | 1.71 | 3.01 |
| Film wrap (BDF2001) | 3.81 | - | 0.89 | 1.85 | - |
| Film wrap (D955) | - | - | - | 3.72 | 17.2 |
| **Storage in weeks** | **2** | **4** | **6** | **8** | **10** |
| **Treatments** | | | | | |
| **At 15 $\pm$ 1°C** | | | | | |
| Untreated (Control) | 3.00 | - | - | 5.34 | 12.7 |
| Pre-cooled | - | 5.79 | - | 7.03 | 0.90 |
| Semperfresh (2%) | - | - | 1.91 | 0.83 | 6.18 |
| Film wrap (BDF2001) | 3.03 | - | 0.73 | 10.55 | 0.60 |
| Film wrap 'D955) | 1.64 | 1.23 | 2.18 | 3.91 | 10.52 |
| **Storage in weeks** | **2** | **6** | **8** | **10** | **12** |
| **Treatments** | | | | | |
| **At 8 $\pm$ 1°C** | | | | | |
| Untreated (Control) | - | 3.56 | 5.86 | 9.30 | 7.99 |
| Pre-cooled | 1.05 | 0.76 | 8.16 | 1.26 | 5.23 |
| Semperfresh (2%) | - | 1.45 | 8.94 | 6.92 | 5.62 |
| Film wrap (BDF2001) | - | 4.54 | 6.19 | 6.79 | 5.03 |
| Film wrap (D955) | 1.99 | 0.91 | 0.47 | 1.87 | 6.61 |

Each value is a mean of 2 fruits

**Plate 8 :** Browning in arils during storage.

a - Fresh pink arils
b - Begining of browning
c - Slightly brown arils
d - Completely brown arils


a
b
c
d
8

In Bijapur fruits at RT, percentage of brown arils varied in different treatments. The range of brown arils was from 2-7 per cent during early part of storage, i.e. 5-10 days and it slightly increased to 1-10 per cent at the end of storage i.e. 20-25 days.

At $15^{o}C$, percentage of brown arils was in range of 1-5 per cent during 2-4 weeks storage and it slightly increased to 0.83 - 13 per cent towards end of storage i.e. 8 - 10 weeks.

At $8^{o}C$, the percentage of brown arils increased towards the end of storage in all the treatments. During the early part (i.e. 2-4 weeks) of storage the brown arils were minimum of one per cent and at the end of storage the percentage of brown arils ranged from 1-9.0 per cent.

In general it was observed that the percentage of brown arils were low at the early part of storage and their per cent increased towards the end of storage period. The per cent range of brown arils was maximum at RT followed by $15^{o}C$ and $8^{o}C$. The percentage of brown arils were higher in fruits of Bijapur as compared to the fruits of Bangalore crop.

**4.2.17 Shelf life of the fruit**

The data on the effect of treatments and storage temperature on maximum shelf life of pomegranate grown around Bangalore and Bijapur conditions are presented in Tables 41 and 42 for the year 1994 and 1995, respectively.

One preliminary study in cultivar Ganesh, regarding the optimum low temperature for maximum shelf life indicated that storage at $5^{O}C$ resulted in chilling injury symptoms. Thus, the temperatures $8^{O}c$ and above was selected for storage to maintain quality and determine the shelf life of fruits grown in two different agro climate (Bangalore and Bijapur).

The physico-chemical characters showed only minimum changes during the storage of pomegranates from 25 days - 14 weeks depending on the storage temperature and post harvest treatments.

In Bangalore crop (1994) at RT maximum shelf life of fruits was 25 days. The film wrapped fruits after 25 days of storage were fresh with no brown spots. The rind was greenish yellow and were marketable upto 25 days whereas the fruits of untreated control were dull, dessicated with 30 per cent brown spot, the rind was slightly brown and such fruits were marketable only upto 15-18 days. The semperfresh treated fruits were more or less similar to untreated fruits in all the quality characters.

Table 41: Effect of treatments and storage temperature on maximum shelf life of pomegranate cv.Ganesh grown under Bangalore and Bijapur conditions during 1994

| | Bangalore Crop | | | | | Bijapur Crop | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shelf Life | | | | | Shelf Life | | | | |
| At 25 ± 1°C | 25 days | | | | | 25 days | | | | |
| | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability |
| **Treatments** | | | | | | | | | | |
| Untreated (Control) | Dull Dessicated | Slightly brown | 30 | Round | 15-18 days | Dull Dessicated | Slightly brown | 50 | Slightly round | 15-16 days |
| Semperfresh (2%) | Dull Dessicated | Slightly brown | 20 | Round | 15-18 days | Dull Dessicated | Slightly brown | 30 | Round | 15-16 days |
| Film wrap (BDF2001) | Fresh | Greenish Yellow | Absent | Round | 25 days | Fresh | Yellowish Red | Absent | Round | 25 days |
| Film wrap (D955) | Fresh | Greenish Yellow | Absent | Round | 25 days | Fresh | Yellowish Red | Absent | Round | 25 days |
| At 15 ± 1°C | 12 weeks | | | | | 8 weeks | | | | |
| Untreated (Control) | Dull Dessicated | Slightly brown | 50 | Round | 9 weeks | Dull Dessicated | Slightly brown | 40 | Slightly deformed | 6 weeks |
| Pre-cooled | Dull | Slightly | 20-25 | Round | 9 weeks | Dull Dessicated | Slightly brown | 50 | Slightly | 6 weeks |
| Semperfresh (2%) | Dull Dessicated | Yellow | 10 | Round | 10 weeks | Dull Dessicated | Yellow brown | 20 | Round | 7 weeks |
| Film wrap (BDF2001) | Fresh | Greenish Yellow | 2-3 | Round | 12 weeks | Fresh | Yellowish Red | 5-6 | Round | 8 weeks |
| Film wrap (D955) | Fresh | Greenish Yellow | 6-8 | Round | 12 weeks | Fresh | Yellowish Red | 10 | Round | 8 weeks |

Table 41: Contd....

| | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability |
|---|---|---|---|---|---|---|---|---|---|---|
| At 8 $\pm$ 1$^{o}$C | | | 14 weeks | | | | | 12 weeks | | |
| Untreated (Control) | Dull, Slightly Dessicated | Slightly brown | 20-30 | Round | 10 weeks | Dull Dessicated | Slightly brown | 40 | Slightly deformed | 8 weeks |
| Pre-cooled | Dull Slightly Dessicated | Slightly brown | 20 | Round | 10 weeks | Dull Dessicated | Slightly brown | 50 | Round | 10 weeks |
| Semperfresh (2%) | Dull Slightly Fresh | Yellow | 4-5 | Round | 12 weeks | Dull Dessicated | Yellow | 4-5 | Round | 10 weeks |
| Film wrap (BDF2001) | Fresh | Greenish Yellow | Absent | Round | 14 weeks | Fresh | Yellowish Red | Absent | Round | 12 weeks |
| Film wrap (D955) | Fresh | Greenish Yellow | Absent | Round | 14 weeks | Fresh | Yellowish Red | 1-2 | Round | 12 weeks |

Table 42: Effect of treatments and storage temperatures on maximum shelf life of pomegranate cv.Ganesh grown under Bangalore and Bijapur conditions during 1995

| | Bangalore Crop | | | | | Bijapur Crop | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shelf Life | | | | | Shelf Life | | | | |
| At 25 ± 1°C | 25 days | | | | | 25 days | | | | |
| | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability |
| **Treatments** | | | | | | | | | | |
| Untreated (Control) | Dull Dessicated hard | Completely brown | 40 | Deformed | 12 days | Dull Dessicated Hard | Completely brown | 40 | Deformed | 10 days |
| Semperfresh (2%) | Dull Dessicated | Slightly brown | 20 | Slightly | 12 days | Dull Dessicated | Completely brown | 25-30 | Deformed | 10 days |
| Film wrap (BDF2001) | Fresh | Greenish Yellow | Absent | Round | 25 days | Fresh | Yellowish Red | 6-8 | Round | 25 days |
| Film wrap (D955) | Fresh | Greenish Yellow | Absent | Round | 25 days | Fresh | Yellowish Red | 8-10 | Round | 25 days |
| At 15 ± 1°C | 10 weeks | | | | | 10 Weeks | | | | |
| Untreated (Control) | Dull Dessicated hard | Completely brown | 30 | Deformed | 7 Weeks | Dull Dessicated hard | Completely brown | 40 | Deformed | 5 Weeks |
| Pre-cooled | Dull Dessicated Hard | Completely brown | 20 | Deformed | 7 Weeks | Dull Dessicated hard | Completely brown | 30 | Deformed | 5 Weeks |
| Semperfresh (2%) | Dull Dessicated | Slightly brown | 20 | Slightly Deformed | 7 Weeks | Dull Dessicated | Slightly brown | 20 | Deformed | 5-6 Weeks |
| Film wrap (BDF2001) | Fresh | Greenish Yellow | 6-8 | Round | 10 Weeks | Slightly Dull | Yellowish | 20 | Round | 9 weeks |
| Film wrap (D955) | Fresh | Greenish Yellow | 10 | Round | 10 weeks | Slightly Dull | Yellowish | 20 | Round | 9 weeks |

Table 42: Contd...

| | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability | Freshness | Rind colour | Percent brown spots on rind | Shape of the fruit | Marketability |
|---|---|---|---|---|---|---|---|---|---|---|
| At 8 $\pm$ 1$^{o}$C | | | 12 weeks | | | | | 12 weeks | | |
| Untreated (Control) | Dull, Dessicated hard | Slightly brown | 20 | Deformed | 8 Weeks | Dull Dessicated hard | Dark brown | 20 | Deformed | 6-7 weeks |
| Pre-cooled | Dull Dessicated | Slightly brown | 20 | Slightly deformed | 8 weeks | Dull Dessicated hard | Slightly brown | 20 | Deformed | 6-7 weeks |
| Semperfresh (2%) | Dull Slightly Fresh | Yellow | 20 | Slightly deformed | 8 Weeks | Dull Dessicated | Slightly brown | 10 | Slightly deformed | 7-8 weeks |
| Film wrap (BDF2001) | Fresh | Greenish Yellow | Absent | Round | 10 Weeks | Fresh | Yellowish Red | Absent | Round | 12 weeks |
| Film wrap (D955) | Fresh | Greenish Yellow | Absent | Round | 12 Weeks | Fresh | Yellowish Red | Absent | Round | 12 Weeks |

**Plates 9,10,11:** Unwrapped (untreated control) and wrapped fruits (BANGALORE CROP) without packing in polybags after 25 days of storage at RT (25 $\pm$ 1$^{o}$C)

9 Unwrapped and wrapped fruits with shrink film intact.

10 Unwrapped (dessicated) and wrapped fruits with film removed showing the freshness of the wrapped fruits.

11 Cut fruits of unwrapped showing dessicated thin shrunken rind and thick fresh rind in wrapped fruits.


9


10


11

At 15$^{o}$C, the maximum shelf life was 12 weeks. Again the film wrapped fruits were fresh with greenish yellow rind and marketable upto 12 weeks. The unwrapped fruits were dull, dessicated and slightly brown coloured after 12 weeks and marketable only upto 9-10 weeks.

At 8$^{o}$C, the maximum shelf life was 14 weeks. The untreated and pre-cooled fruits were dull, slightly dessicated with slight brown rind and marketable only upto 10 weeks. The semperfresh treated fruits were dull, slightly fresh with yellow rind and marketable upto 10 weeks. The fruits of film wrapped treatment were fresh and marketable upto 14 weeks.

In the fruits of Bijapur crop (1994), the maximum shelf life at RT was 25 days. The film wrapped fruits had better quality retention than the unwrapped fruits and were marketable upto 25 days. The unwrapped fruits were marketable upto 15-16 days.

At 15$^{o}$C the maximum shelf life was only 8 weeks. The untreated and pre-cooled fruits were dull, dessicated, slightly deformed and marketable upto 6 weeks, while the semperfresh were slightly better and marketable upto 7 weeks. The wrapped fruits had the best qualities and were marketable upto 8 weeks.

**Plates 12,13, 14:** Unwrapped (untreated control) and wrapped fruits (BIJAPUR CROP) without packing in polybags after 25 days of storage at RT ($25 \pm 1^oC$)

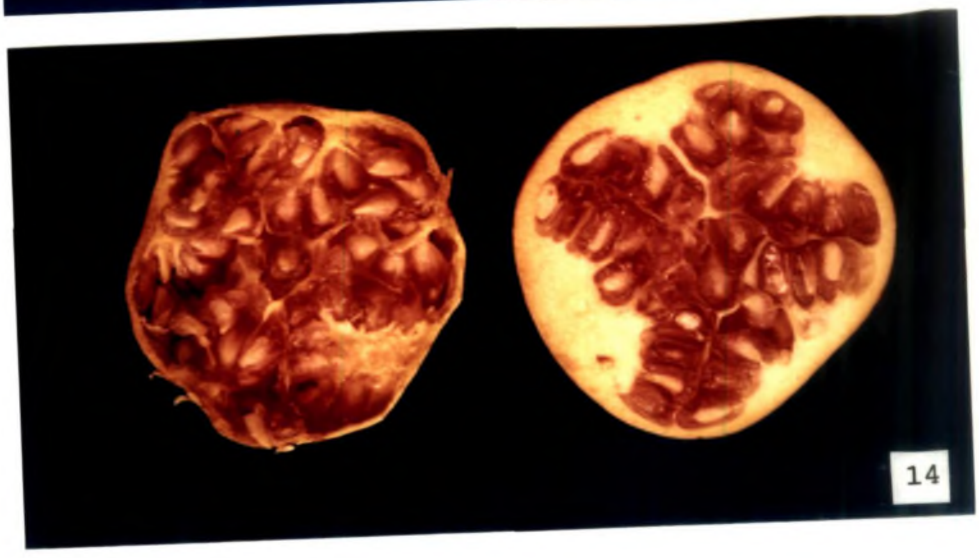
12 Unwrapped and wrapped fruits with shrink film intact.

13 Unwrapped (dessicated) and wrapped fruits with film removed showing the freshness of the wrapped fruits.

14 Cut fruits of unwrapped showing dessicated thin shrunken rind and thick fresh rind in wrapped fruits.

12

13

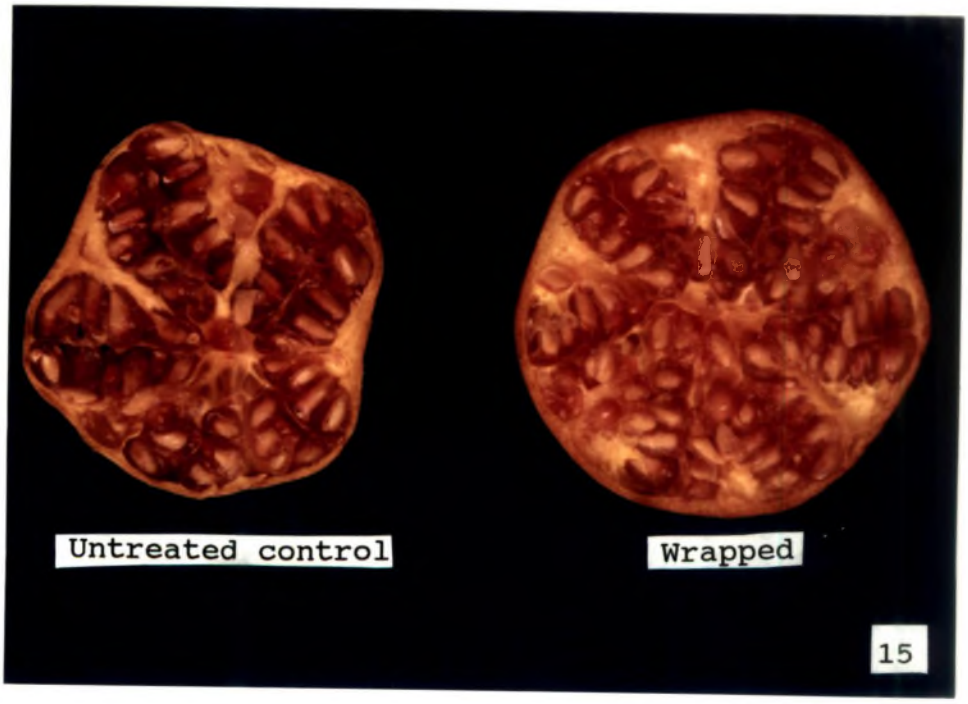


14

**Plate 15:** Cut fruits of unwrapped (untreated control) and wrapped fruits (BIJAPUR CROP) without packing in polybags after 10 weeks of storage at LT ($15 \pm 1^{o}C$)

a - Unwrapped control fruits showing the dessicated thin rind and deformation of fruits.

b - Wrapped fruits showing the thick rind.


Untreated control
Wrapped
15

**Plates 16,17, 18:** Unwrapped (untreated control) and wrapped fruits (BANGALORE CROP) without packing in polybags after 12 weeks of storage at LT ($8 \pm 1^{o}C$)

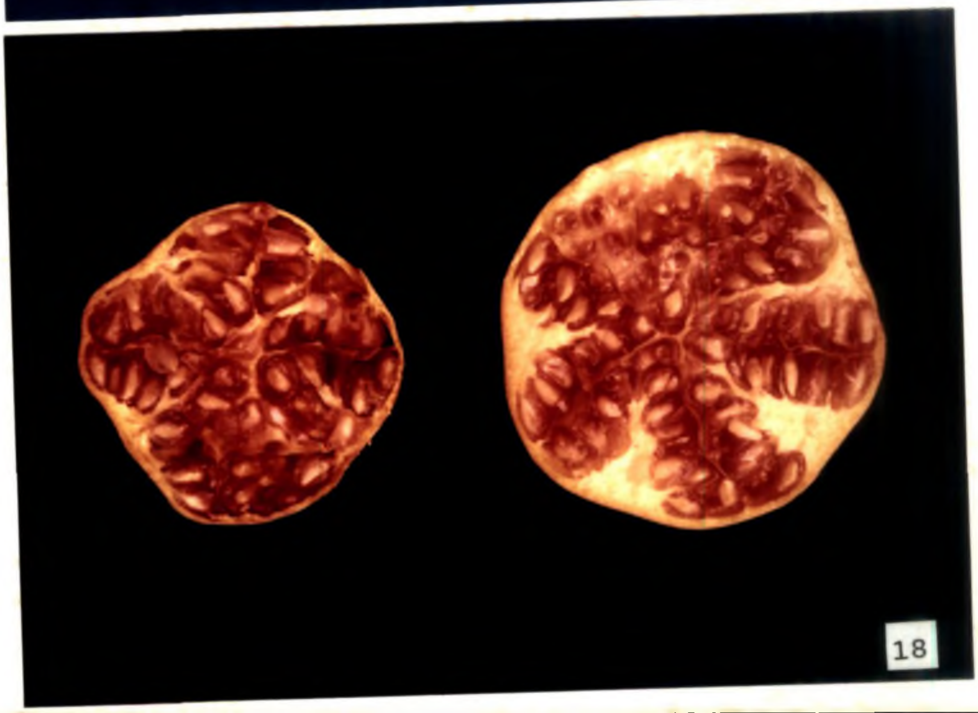
16 Unwrapped and wrapped fruits with shrink film intact.

17 Unwrapped (dessicated) and wrapped fruits with film removed showing the freshness of the wrapped fruits.

18 Cut fruits of unwrapped showing dessicated thin shrunken rind and thick fresh rind in wrapped fruits.


16


17


18

At $8^{o}C$ the maximum shelf life was 12 weeks. The untreated fruits did not retain their freshness, were slightly deformed and marketable upto 8 weeks. The pre-cooled and semperfresh treated fruits were slightly better and saleability was upto 10 weeks. The wrapped fruits were marketable upto 12 weeks with good shelf life qualities.

During the year 1995 in Bangalore crop at RT the maximum shelf life was 25 days. the untreated fruits were dull, dessicated, hard, deformed with completely brown rind and thus were marketable only upto 12 days. The semperfresh treated fruits were slightly deformed, dull, dessicated and marketable again upto 12 days. The wrapped fruits remained fresh with greenish yellow rind with no brown spots and were marketable upto 25 days (Plates 9, 10 and 11).

At $15^{o}C$ the maximum shelf life was 10 weeks. The unwrapped fruits did not retain the shelf life qualities, lost their freshness, lost their shape and were marketable upto only 7 weeks. The wrapped fruits were acceptable upto 10 weeks.

At $8^{o}C$ the maximum shelf life was 12 weeks and again the unwrapped fruit did not maintain the acceptable shelf life characters upto 12 weeks and marketable only upto 8 weeks whereas the wrapped fruits were fresh and marketable upto 12 weeks (Plates 16, 17 and 18).

In the fruits of Bijapur crop (1995) at RT the maximum shelf life was 25 days. The unwrapped fruits were completely deformed, dessicated, hard, and marketable only upto 10 days. The wrapped fruits were fresh maintained their shape and yellowish red rind colour and were marketable upto 25 days (Plates 12, 13, and 14).

At 15$^{o}$C the maximum shelf life was 10 weeks, the unwrapped fruits were dull, dessicated, hard, deformed and marketable only upto 5-6 weeks. While the wrapped fruits were slightly dull with yellow rind and were acceptable only upto 9 weeks (Plate 15).

At 8$^{o}$C the maximum shelf life was 12 weeks. The untreated and pre-cooled fruits were dull, dessicated and marketable only upto 6-7 weeks and the semperfresh treated fruits were marketable upto 7-8 weeks. The wrapped fruits were fresh and acceptable upto 12 weeks.

In general at RT storage the maximum shelf life was 25 days. The unwrapped fruits during 1994 were marketable upto 15-18 days (Bangalore crop) and upto 15 days in 1995. The wrapped fruits were highly acceptable upto 25 days. At 15$^{o}$C, the maximum shelf life ranged from 8-12 weeks. The untreated and pre-cooled fruits were not acceptable while the semperfresh treated fruits were slightly acceptable. The wrapped fruits were highly acceptable. At 8$^{o}$C the maximum shelf life was 12 - 14 weeks. The untreated and pre-cooled fruits were not acceptable in both the years. The semperfresh treated fruits were slightly acceptable and the wrapped fruits were highly acceptable.

**4.2.18 Spoilage**

The data on the effect of treatments and storage temperature on cumulative spoilage of pomegranate grown around Bangalore and Bijapur conditions during the year 1994 and 1995 are presented in Table 43.

In Bangalore crop (1994) at RT, during early part of a storage period, i.e. 15 days, spoilage was observed in only untreated fruits and after 25 days of storage the spoilage percentage varied in different treatments. The range was from 8.3 to 22.2 per cent.

At 15$^{o}$C after 6 weeks of storage, only the pre-cooled (6.6%) fruits had spoiled and after a storage period of 12 weeks spoilage was seen in all the treatments. Maximum spoilage was observed in D955 film wrapped fruits (33.3%), while minimum of 13.3 per cent was observed in semperfresh treated fruits. The pre-cooled, untreated and BDF 2001 film wrapped fruits had spoilage of 25.0 per cent.

At 8$^{o}$C after 6 weeks of storage, the fruits were not spoiled in any of the treatments. After 14 weeks, the pre-

**Table 43: Effect of treatments and storage temperature on spoilage of pomegranate cv. Ganesh grown under Bangalore and Bijapur conditions during 1994 and 1995.**

| | Cumulative Spoilage per cent | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1994 | | | | | | 1995 | | | | | |
| Storage Temperature | 25 ± 1 | | 15 ± 1 | | 8 ± 1 | | 25 ± 1 | | 15 ± 1 | | 8 ± 1 | |
| Storage Period | 15 (Days) | 25 | 6 (Weeks) | 12 | 6 (Weeks) | 14 | 15 (Days) | 25 | 6 (Weeks) | 12 | 6 (Weeks) | 14 |
| **BANGALORE CROP** | | | | | | | | | | | | |
| Untreated (Control) | 8.33 | 22.22 | - | 25.00 | - | 20.00 | 4.76 | 13.33 | 11.11 | 22.22 | 5.5 | 16.66 |
| Pre-cooled | - | - | 6.66 | 25.00 | - | 6.66 | - | - | 6.66 | 20.44 | - | 16.66 |
| Semperfresh (2%) | - | 8.33 | - | 13.33 | - | 20.00 | - | 16.66 | 11.11 | 26.66 | - | 13.33 |
| Film wrap (BDF 2001) | - | 8.33 | - | 25.00 | - | 20.00 | - | 12.50 | - | 16.66 | - | 16.66 |
| Film warp (D955) | - | 16.66 | - | 33.33 | - | 26.66 | 4.16 | 14.28 | - | 33.33 | - | 25.00 |
| | 1994 | | | | | | 1995 | | | | | |
| Storage Temperature | 25 ± 1 | | 15 ± 1 | | 8 ± 1 | | 25 ± 1 | | 15 ± 1 | | 8 ± 1 | |
| Storage Period | 15 (Days) | 25 | 6 (Weeks) | 8 | 6 (Weeks) | 10 | 15 (Days) | 25 | 6 (Weeks) | 10 | 6 (Weeks) | 12 |
| **BIJAPUR CROP** | | | | | | | | | | | | |
| Untreated (Control) | 22.22 | 33.33 | 16.66 | 27.77 | 8.33 | 20.00 | 13.33 | 26.66 | 16.66 | 33.33 | 6.66 | 13.33 |
| Pre-cooled | - | - | 5.55 | 26.66 | 5.55 | 20.00 | - | - | 8.33 | 25.00 | 6.66 | 13.33 |
| Semperfresh (2%) | 16.66 | 25.00 | 6.66 | 16.66 | - | 19.04 | 16.66 | 25.00 | 16.66 | 33.33 | - | 16.66 |
| Film wrap (BDF 2001) | - | 16.66 | - | 20.83 | - | 19.04 | - | 20.00 | - | 20.00 | - | 20.00 |
| Film warp (D9 5) | - | 25.00 | 5.55 | 23.80 | 5.55 | 21.77 | - | 13.33 | - | 33.33 | 6.66 | 26.16 |

- Means that no spoilage was observed

cooled fruits had minimum (6.6%) spoilage and D955 film wrapped fruits had maximum spoilage of 26.6 per cent. Twenty per cent spoilage was recorded in other treatments.

In fruits of Bijapur crop (1994), at RT during the early part of storage (15 days), the unwrapped fruits showed spoilage while the wrapped fruits did not spoil. At the end of 25 days storage all the treatments had spoiled fruits. Maximum spoilage of 33.3 per cent was recorded in untreated fruits and minimum of 16.6 per cent was recorded in BDF 2001 film wrapped fruits.

At 15°C after 6 weeks storage, the spoilage of fruits was in range of 5.5 to 16.6 per cent and after 8 weeks of storage, it ranged from 16.6 to 27.7 percent.

At 8°C after 6 weeks storage, maximum spoilage was 8.34 per cent (untreated) and the minimum was 5.5 per cent (pre-cooled and D955 film wrap). After 10 weeks storage the spoilage of fruits was more or less same in all the treatments in the range of 19 - 20 per cent.

During the year 1995 (Bangalore crop) minimum spoilage of 4.1 per cent (untreated) was recorded at end of 15 days storage at RT. After 25 days of storage the spoilage was observed in all the treatments and it varied from 12.5 to 16.6 per cent.

At $15^{o}C$ only the unwrapped fruits showed 6-11 per cent spoilage after 6 weeks of storage. And after 10 weeks of storage all the treatments had spoiled fruits. Maximum spoilage of 33.3 was observed in D955 film wrapped fruits and the BDF 2001 film wrapped fruits had minimum of 16.6 per cent.

At $8^{o}C$ after 6 weeks of storage only the untreated fruits had 5 per cent spoiled fruits and after 12 weeks of storage all the treatments showed spoilage in the range of 13.3 to 25.0 per cent.

In fruits of Bijapur crop (1995) at RT after 15 days of storage only the unwrapped fruits had 13-16 per cent spoiled fruits while the wrapped fruits did not show spoilage. After 25 days of storage, maximum spoilage recorded was upto 26.6 per cent (untreated). The D955 film wrapped fruits had minimum spoilage (13.30) per cent.

At $15^{o}C$ after 6 weeks storage again the spoilage was observed only in unwrapped fruits in the range of 8.3 to 16.6 per cent. After 10 weeks storage the spoilage of fruits was in the range of 20-33.3 per cent.

At $8^{o}C$ minimum spoilage of 6.6 per cent was recorded at the end of 6 weeks storage. After 12 weeks of storage the D955 film wrapped fruits showed highest spoilage with

26.1 per cent and in other treatments it varied from 13.3 - 20 per cent.

In general, spoilage of fruits varied in different treatments and at different storage temperature after their respective storage periods. The spoilage of fruits during the mid storage period was minimum or nil in wrapped fruits while the unwrapped fruits showed little spoilage and towards the end of storage spoilage of wrapped fruits was more or less same as the unwrapped.

The spoilage of fruits from Bijapur crop was more than the spoilage in fruits of Bangalore crop at all the three storage temperatures in both the years. At LT the spoilage of fruits at 15°C was more than at 8°C during both the years.

**4.2.19 Sensory evaluation**

The data on the effect of treatments and storage temperature on sensory characters of pomegranate grown around Bangalore and Bijapur conditions during the year 1995 are presented in Tables 44 and 45, respectively.

In Bangalore crop after a storage period of 25 days at RT the untreated fruits had a very dried appearance (1.83) with acceptable aril colour, poor taste- and juice and hence scored lower score (1.83). The two film wrapped fruits had good-appearance, colour of aril, taste and juice content.

Table 44: Effect of treatments and storage temperature on sensory characters of pomegranate cv. Ganesh ground under Bangalore conditions during 1995

| Treatments | Freshness | Colour of Aril | Taste | Juicyness |
|---|---|---|---|---|
| | After 25 days storage | | | |
| **At 25 ± 1°C** | | | | |
| Untreated (Control) | 1.83 | 3.00 | 2.83 | 2.16 |
| Semperfresh (2%) | 2.50 | 3.33 | 3.16 | 2.20 |
| Film wrap (BDF2001) | 3.66 | 3.83 | 3.83 | 3.66 |
| Film wrap (D955) | 4.00 | 4.00 | 4.16 | 3.83 |
| 'F' test | * | * | * | * |
| CD at 5% | 0.82 | 0.45 | 0.74 | 0.62 |
| | After 10 weeks storage | | | |
| **At 15 ± 1°C** | | | | |
| Untreated (Control) | 2.00 | 2.50 | 2.33 | 2.00 |
| Pre-cooled | 2.50 | 2.66 | 2.83 | 2.33 |
| Semperfresh (2%) | 2.50 | 3.41 | 3.16 | 2.83 |
| Film wrap (BDF2001) | 3.66 | 3.50 | 3.16 | 3.16 |
| Film wrap (D955) | 3.66 | 3.50 | 3.41 | 3.58 |
| 'F' test | * | * | * | * |
| CD at 5% | 0.61 | 0.71 | - | 0.56 |
| | After 12 weeks storage | | | |
| **At 8 ± 1°C** | | | | |
| Untreated (Control) | 2.58 | 3.00 | 3.50 | 2.66 |
| Pre-cooled | 2.83 | 3.00 | 3.66 | 3.00 |
| Semperfresh (2%) | 3.16 | 3.16 | 3.75 | 3.16 |
| Film wrap (BDF2001) | 4.33 | 3.41 | 3.75 | 3.58 |
| Film wrap (D955) | 4.50 | 4.00 | 3.91 | 4.00 |
| 'F' test | * | * | * | * |
| CD at 5% | 0.48 | 0.55 | - | 0.57 |

**Table 45: Effect of treatments and storage temperature on sensory characters of pomegranate cv. Ganesh ground under Bijapur conditions during 1995**

| Treatments | Freshness | Colour of Aril | Taste | Juicyness |
|---|---|---|---|---|
| | **After 25 days storage** | | | |
| **At 25 ± 1°C** | | | | |
| Untreated (Control) | 1.00 | 3.50 | 2.50 | 2.50 |
| Semperfresh (2%) | 2.50 | 2.33 | 3.41 | 3.50 |
| Film wrap (BDF2001) | 3.83 | 4.16 | 3.50 | 3.83 |
| Film wrap (D955) | 4.50 | 4.50 | 3.58 | 4.00 |
| 'F' test | * | * | NS | NS |
| CD at 5% | 0.51 | 0.81 | - | - |
| | **After 10 weeks storage** | | | |
| **At 15 ± 1°C** | | | | |
| Untreated (Control) | 1.16 | 2.33 | 2.50 | 2.33 |
| Pre-cooled | 1.83 | 2.58 | 2.66 | 2.50 |
| Semperfresh (2%) | 1.83 | 2.58 | 3.16 | 2.91 |
| Film wrap (BDF2001) | 3.83 | 3.25 | 3.41 | 3.58 |
| Film wrap (D955) | 4.58 | 3.91 | 3.50 | 3.66 |
| 'F' test | * | * | * | * |
| CD at 5% | 0.59 | 0.70 | 0.57 | 0.71 |
| | **After 12 weeks storage** | | | |
| **At 8 ± 1°C** | | | | |
| Untreated (Control) | 2.83 | 3.25 | 3.16 | 3.08 |
| Pre-cooled | 2.00 | 3.33 | 3.25 | 3.25 |
| Semperfresh (2%) | 2.66 | 3.83 | 3.50 | 3.66 |
| Film wrap (BDF2001) | 3.75 | 4.00 | 3.66 | 4.00 |
| Film wrap (D955) | 4.50 | 4.08 | 3.83 | 4.00 |
| 'F' test | * | NS | NS | NS |
| CD at 5% | 0.49 | - | - | - |

At $15^{o}C$ after a storage period of 10 weeks, the BDF 2001 film wrapped and D955 film wrapped fruits had more or less same scores for all the sensory characters (Freshness, colour of aril, taste, juiciness). Between the semperfresh treated and pre-cooled fruits the scores were more or less same (2.5). The untreated fruits had lowest score (2.0) for all the characters.

At $8^{o}C$ after the end of 12 weeks storage period, the D955 film wrapped fruits had maximum scores (4.5) for all the characters while the untreated fruits had minimum scores (2.5).

Statistical differences between the treatments were significant for freshness, colour of aril, taste and juiciness at RT. At 15 and $8^{o}C$ the freshness, colour of aril and juiciness were significant.

In the fruits of Bijapur crop, at RT the untreated fruits had lowest score (1.0) for all the characters with dried appearance, poor taste - and juice. The BDF 2001 film wrapped and D955 film wrapped fruits had more or less same scores for all the characters with good appearance, taste and juice.

At $15^{o}C$ the differences in scores between the untreated, pre-cooled and semperfresh treated was more or less same.

**Plate 19:** Film wrapped fruits (BANGALORE CROP) after 12 weeks of storage at LT ($8 \pm 1^{o}C$) showing the thick rind, fresh pink aril and freshness which scored best sensory characters.


19

The film wrapped fruits had higher scores as compared to the unwrapped fruits. The wrapped fruits had good appearance, taste and juice.

At $8^{O}C$, the film wrapped fruits had maximum scores for freshness, colour of aril, taste and juiciness and the unwrapped fruits had minimum scores.

Statistical differences between the treatments were significant for freshness, colour of aril, taste and juiciness at $15^{O}C$, while at RT only freshness and colour of aril had significant differences. At $8^{O}C$ only the freshness was found to have significant differences.

In general, the film wrapped fruits had good appearence, colour of aril (Plate 19), taste and juice while the unwrapped fruits had poor appearence, acceptable colour of aril, taste and juice.

## 4.3 HISTOLOGY OF FRUITS

The pomegranate being a non-climateric fruit does not undergo much changes during storage. A very much noticeable change is in its form. The fruits during storage irrespective of temperatures maintained lose their weight, reduce in rind thickness and become deformed/shrunk. The results on the histological study of pomegranate rind and aril during growth and storage, for the crops grown under Bangalore and Bijapur conditions are presented.

**SECTION OF THE RIND TESTED WITH PERIODIC SCHIFF'S ACID (PAS) REAGENT DURING GROWTH AND STORAGE IN BANGALORE CROP (PLATES FROM 20-27)**

**Plate 20:** At fruitset stage to show the General structure x 80

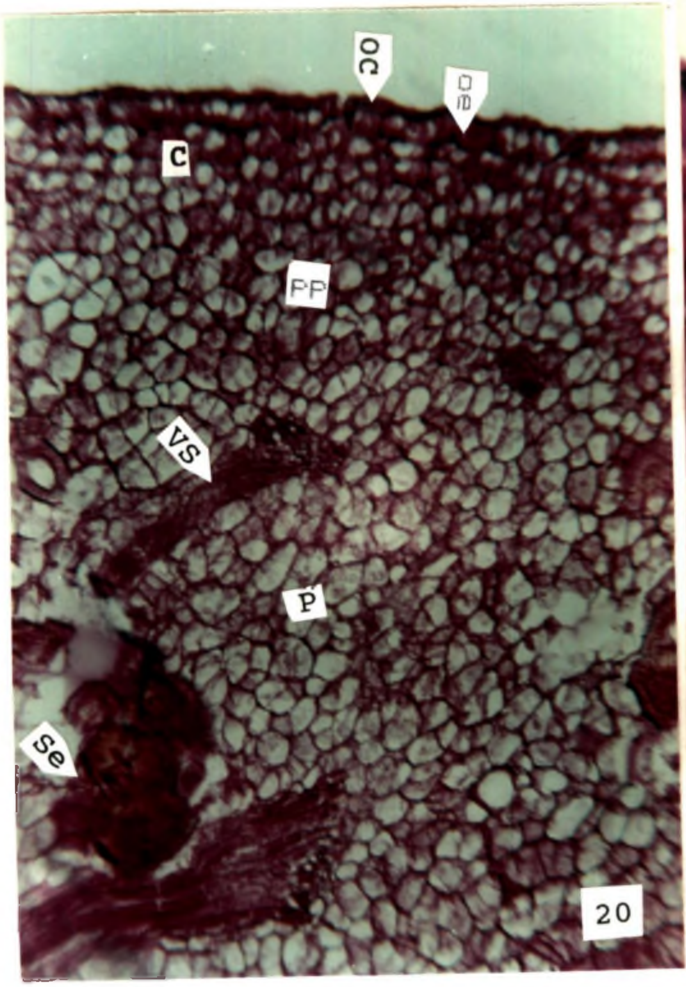
C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
P - Parenchyma
PP - Parenchyma cells proximal to outer epidermis
Se - Sclereids
Vs - Vascular strands

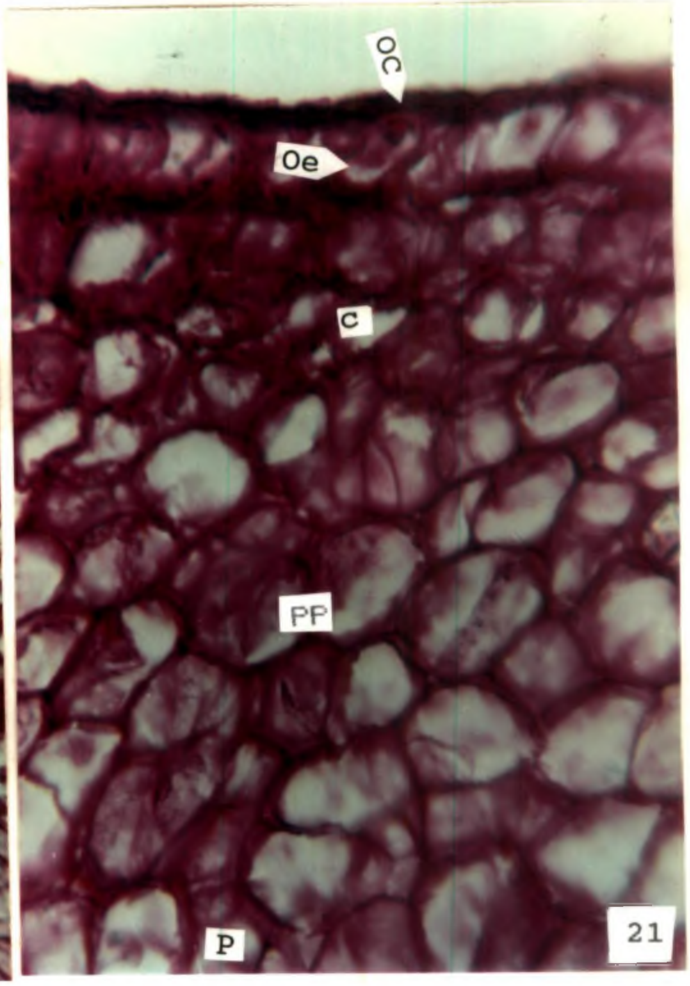
**Plate 21:** At fruitset stage to show the General structure x 250

C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
P - Parenchyma
Note the lack of starch grains

**Plate 22:** At 60th day after fruitset to show increase in size of the cells x 250

C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
PP - Parenchyma cell proximal to outer epidermis


OC
C
PP
VS
P
Se
20


OC
Oe
C
PP
P
21

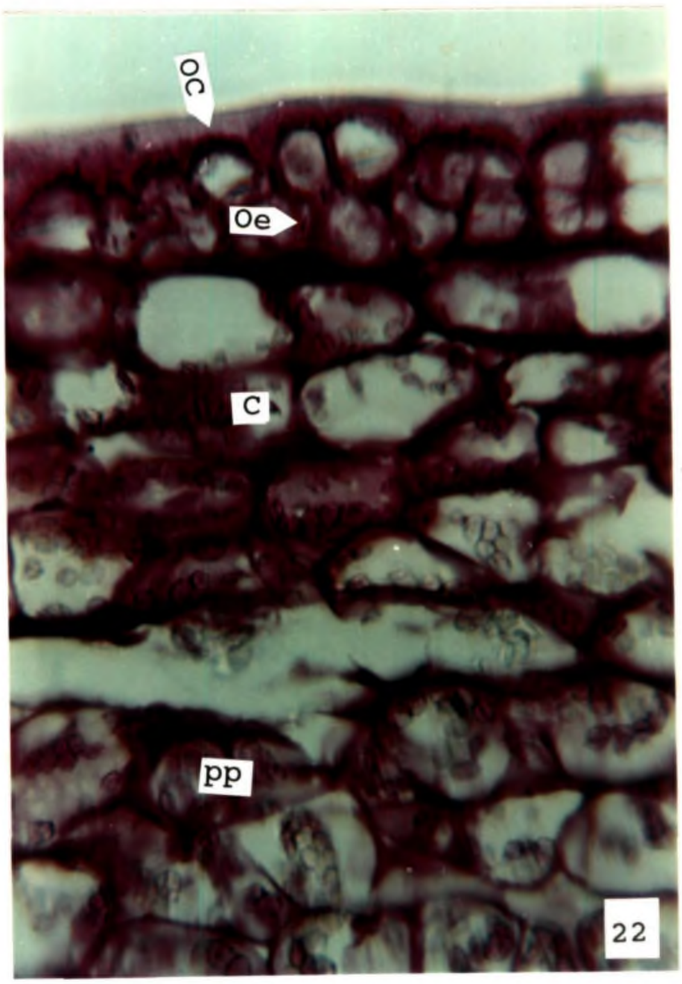

OC
Oe
C
pp
22

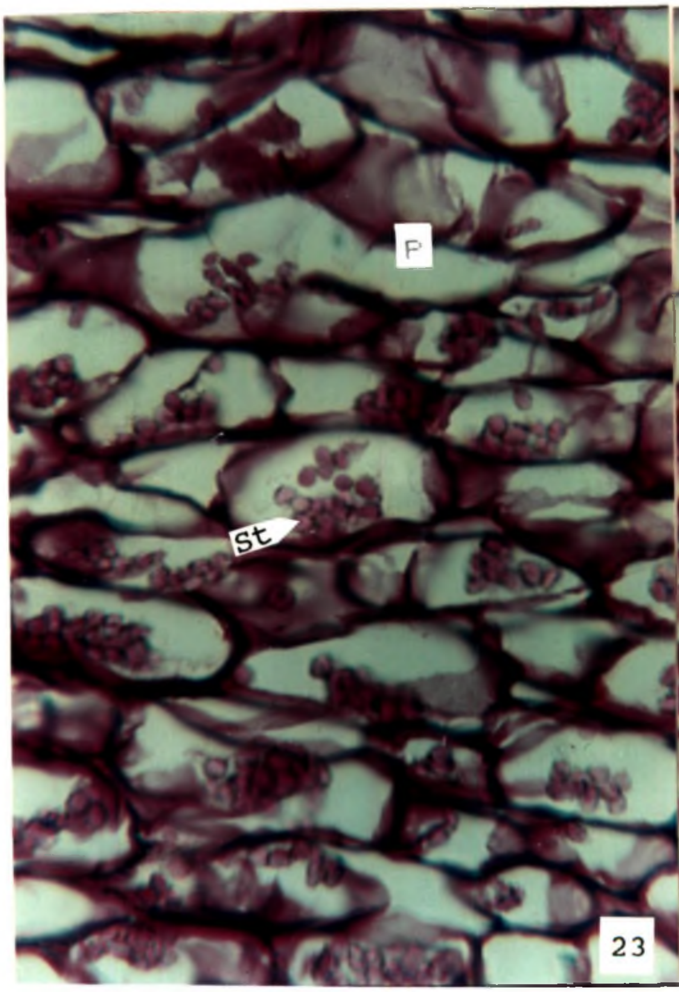
**Plate 23:** At 60th day after fruitset to show the accumulation of starch (St) grains in the parenchyma (P) cells x 250

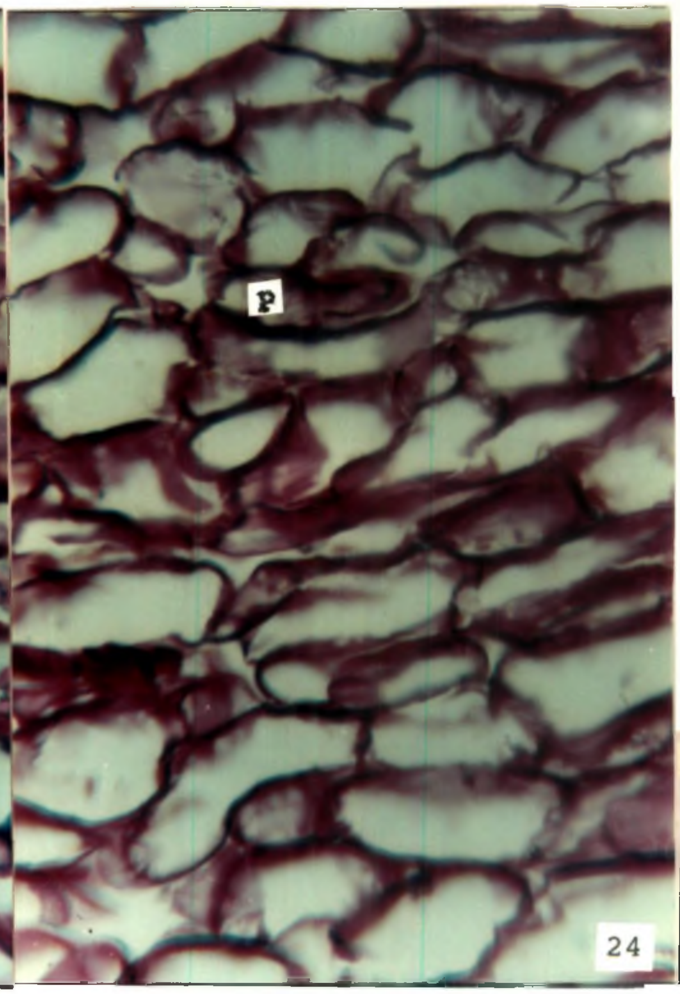
**Plate 24:** From the untreated control fruits after 15 days of storage at RT showing the disappearance of starch (St) grains in the parenchyma (P) cells x 250

Note the tangential compression of the Parenchyma (P) cells.

**Plate 25:** From the untreated control fruits after 25 days of storage at RT showing the severe compression of the parenchyma (P) cells x 250.

Note the complete disappearance of the starch (St) grains in the parenchyma (P) cells.


P
St
23


P
24

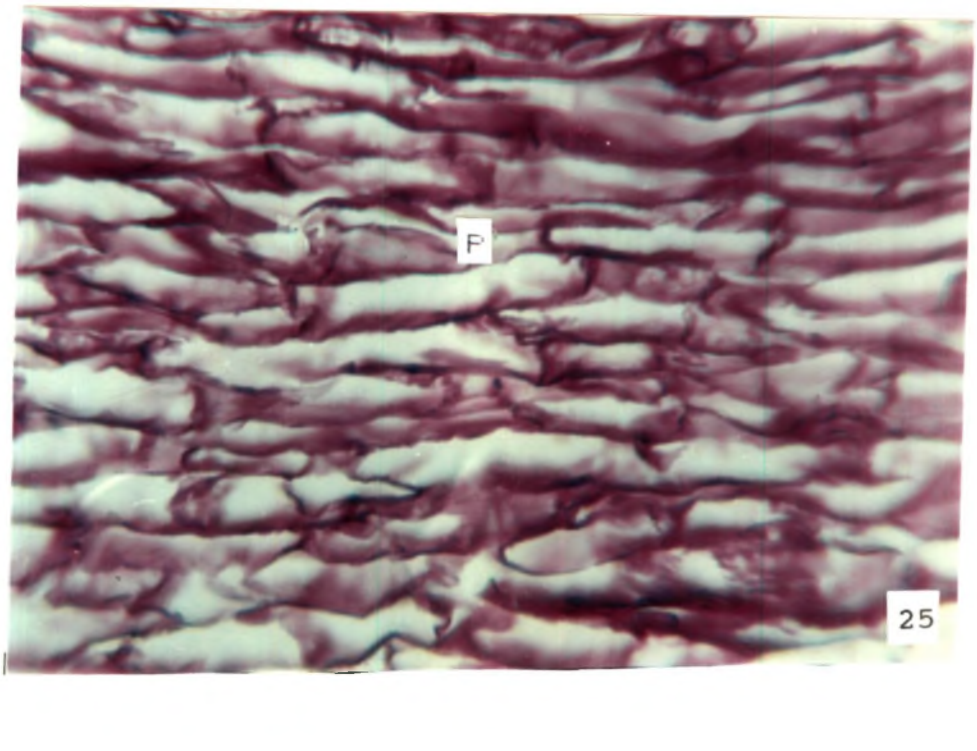
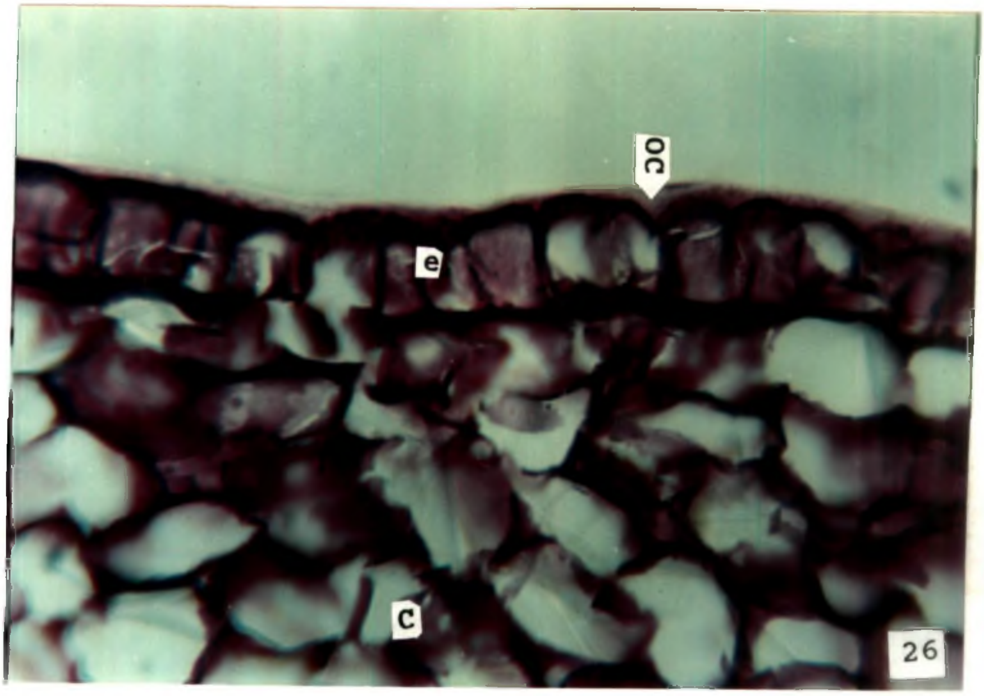
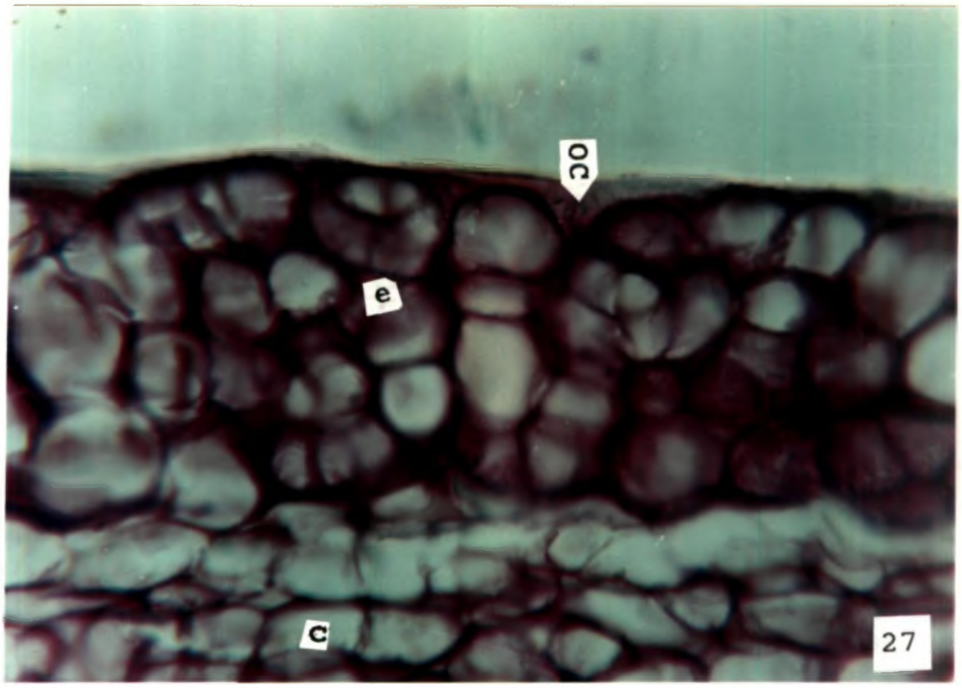

P
25

**Plate 26:** From the semperfresh (2%) treated fruits after 15 days of storage at RT showing a little compression of collenchyma (C) cells x 250

Note the single layered epidermis.

**Plate 27:** From the film wrapped fruits after 25 days of storage at RT showing the pericrinal division of epidermal (e) cells x 250.


oc
e
c
26


oc
e
c
27

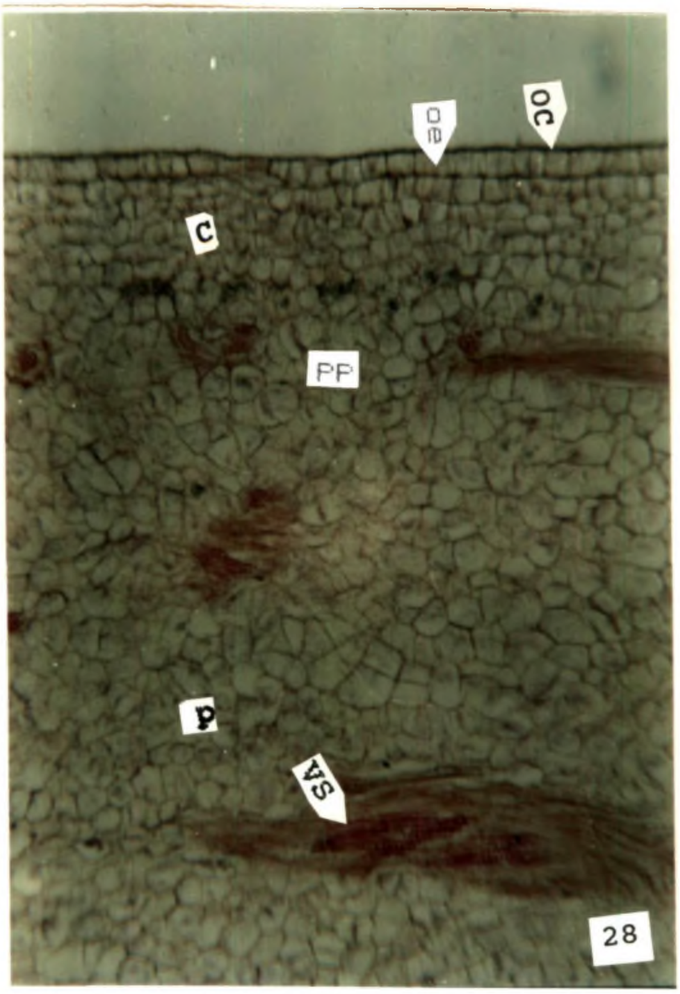
**SECTION OF THE RIND TESTED WITH METHYL GREEN PYROMINE (MGP) DURING GROWTH AND STORAGE IN BANGALORE CROP (PLATES FROM 28-35)**

**Plate 28:** At fruitset stage to show the General structure x 80

C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
P - Parenchyma
PP - Parenchyma cells proximal to outer epidermis
Vs - Vascular strands

**Plate 29:** At harvest showing the increase in size of the cells x 80

C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
P - Parenchyma
PP - Parenchyma cell proximal to outer epidermis
Vs - Vascular strands


oe
oc
C
PP
P
VS
28

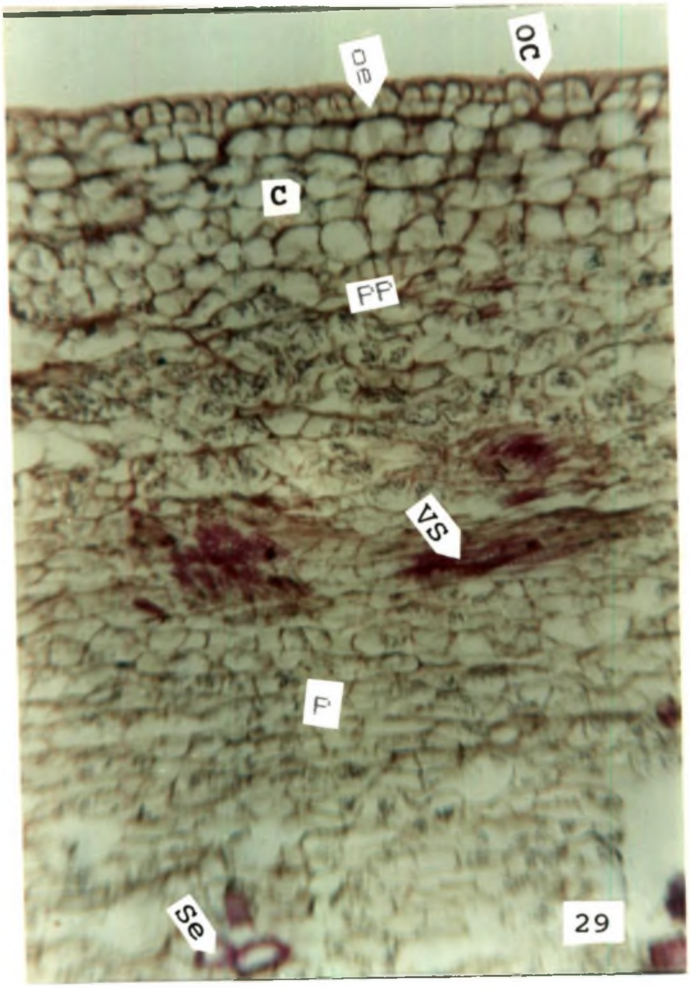
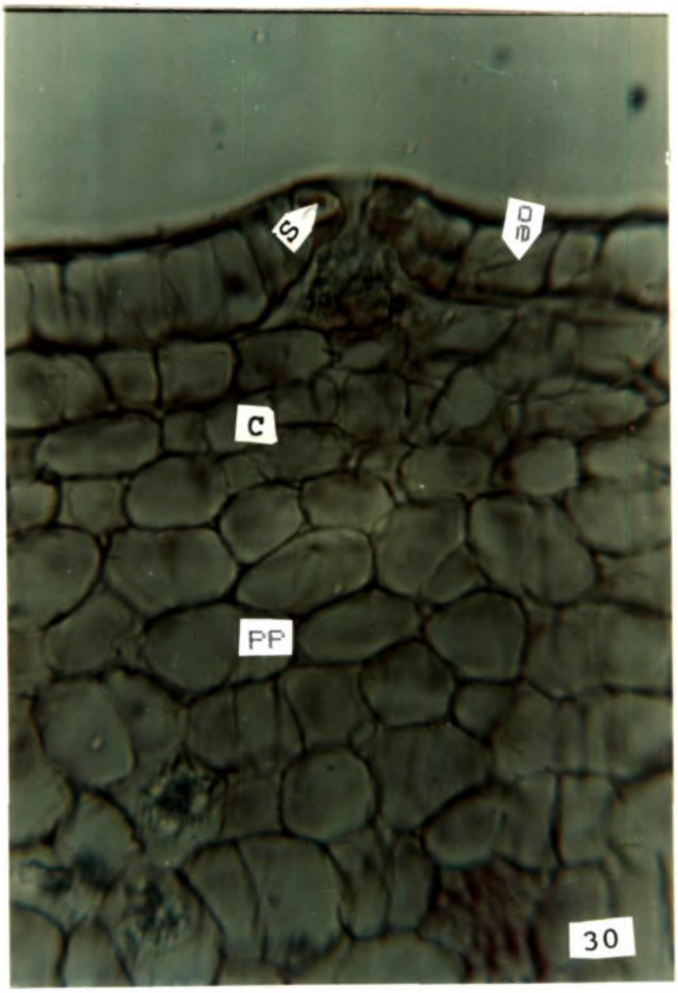

oe
oc
C
PP
P
VS
Se
29

**Plate 30:** At fruitset stage showing the single layered epidermis (e) and stomata (S) x 250

**Plate 31:** At harvest showing the 2-3 layered epidermis (e) x 250

C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
S - Stomata


s
c
PP
30

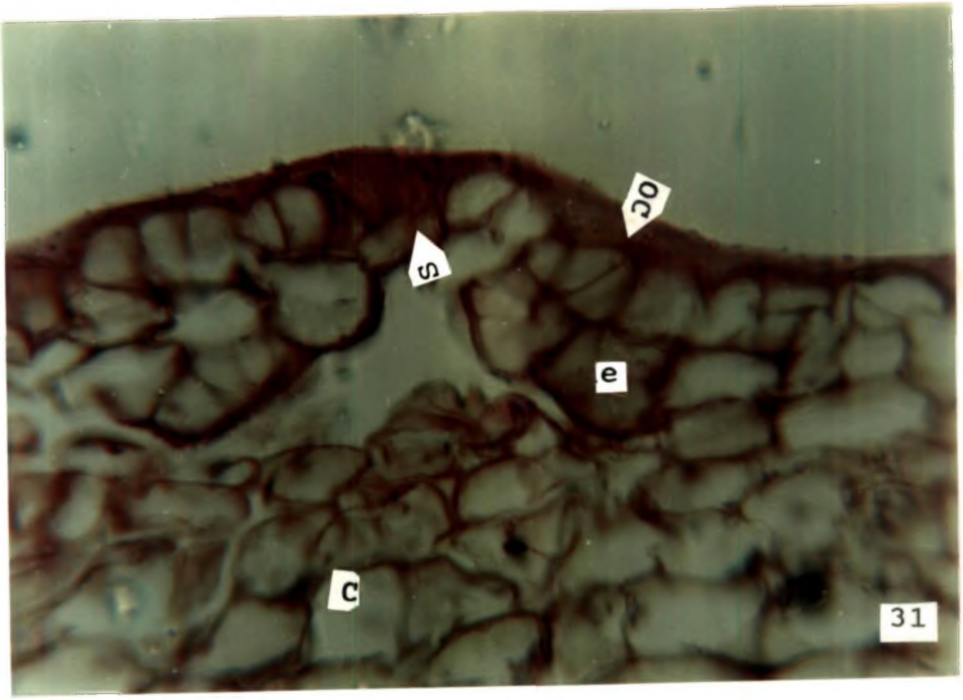
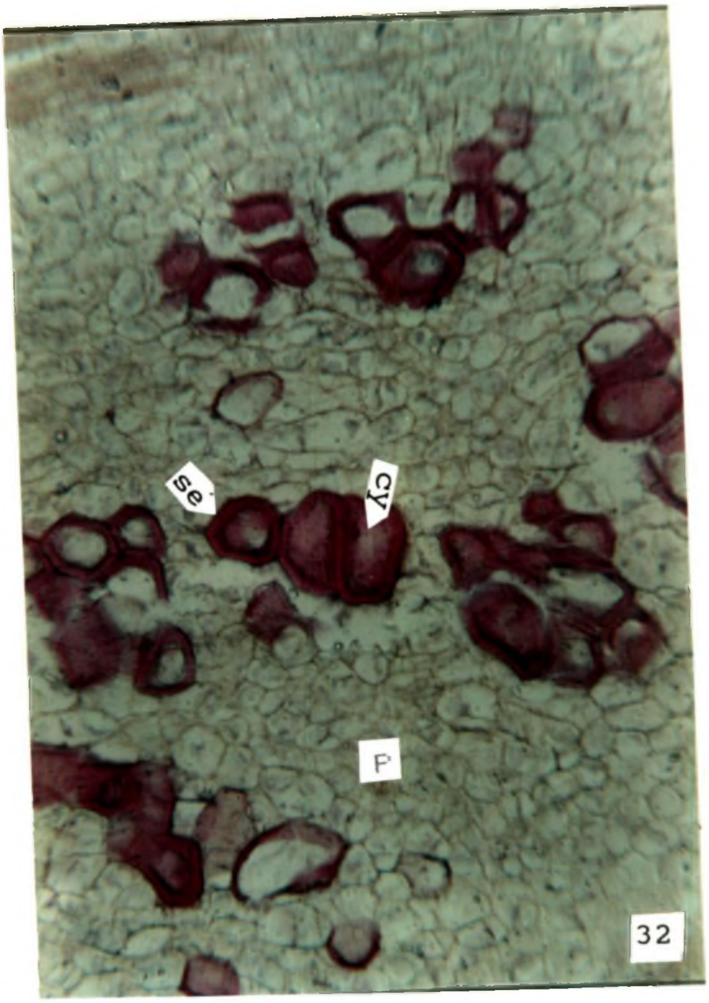

s
e
c
31

**Plate 32:** At fruitset stage showing the sclereids (Se) of different shapes and size scattered in parenchyma (P) cells x 80

**Plate 33:** At fruitset stage showing the magnified sclereid (Se) cells with cytoplasm (Cy) x 250.


se
cy
P
32

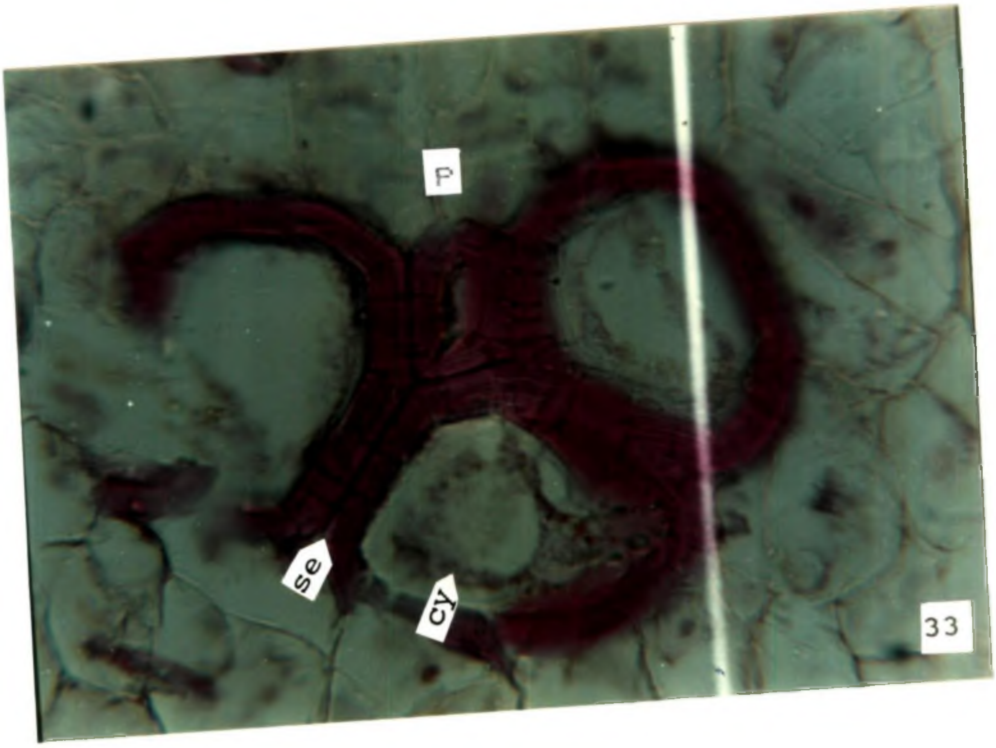
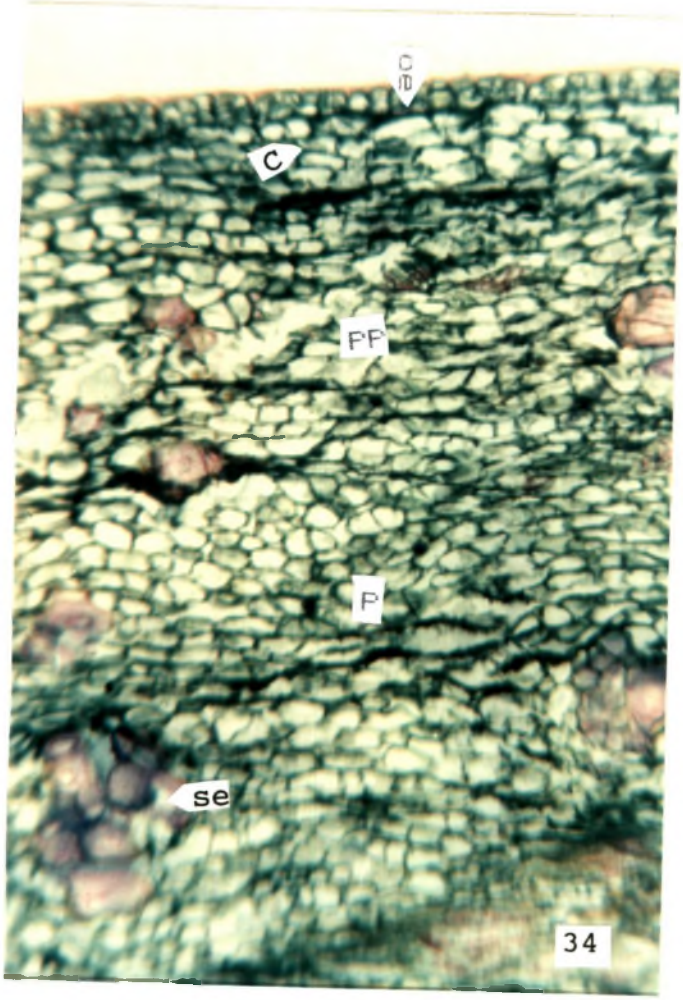
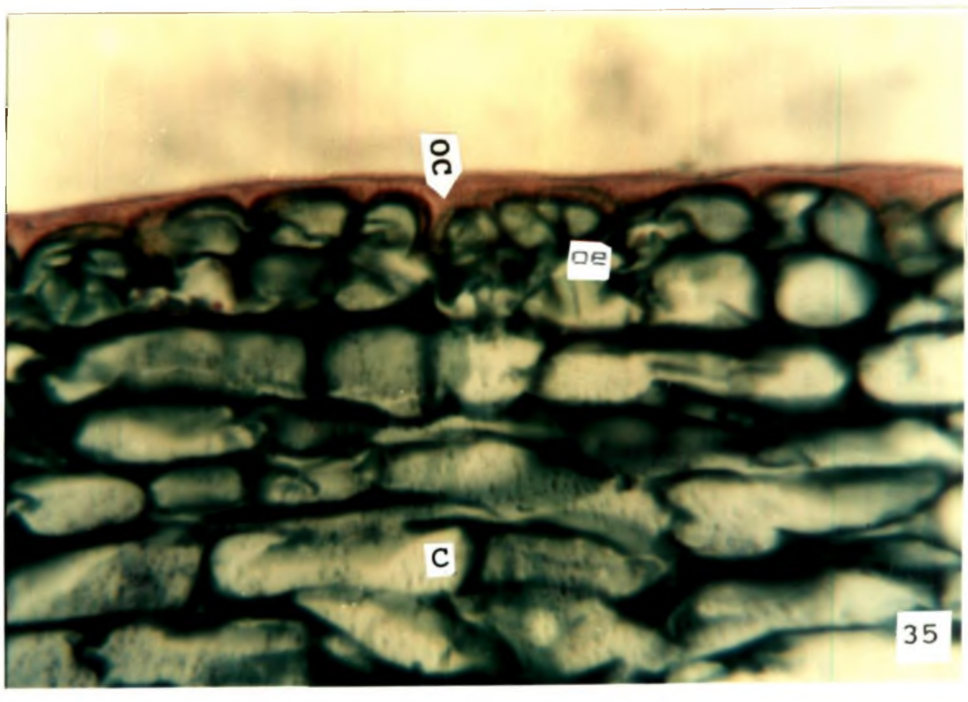

P
se
cy
33

**Plate 34:** From untreated control fruits after 15 days of storage at RT showing the compression of cells in all the layers x 80.

**Plate 35:** From untreated control fruits after 15 days of storage at RT showing the compression of cells in collenchyma (C) cells x 250.

OC - Outer cuticle
Oe - Outer epidermis


c
pp
p
se
34


oe
c
35

**4.3.1 General structure of the rind**

It was observed that the structure of pomegranate rind in general consists of a outer epidermis embedded in a thick cuticle. Beneath it lies the layer of collenchymatous cells and the parenchyma cells which have thinner walls than the collenchyma cells. In the parenchyma cells are scattered the lignified living stone cells (sclereids) of different shapes present either singly or in groups, and the vascular bundles which are radially arranged (Plates 20, 21 and 28).

The data on the structural dimensions of the rind during growth and storage for Bangalore and Bijapur crops are presented in Tables 46 and 47, respectively.

**4.3.2 Outer epidermis**

The histology of the rind on the day of fruit set (Stage 1) from the crop grown under Bangalore conditions showed that the epidermis was a single layered structure (Plate 30) with 27.50 um thickness. The cells were spherical in shape (Plates 20, 21 and 28).

On 30th day after fruit set (stage 5) the thickness of the epidermis increased to 31.16 um and the cells remained spherical. At 60 days after fruit set (stage 7) the epidermis was 38.50 um thick. After 90 days of growth (stage 9) the rind epidermis was 44.00 um and at harvest (stage 10) its thickness increased to 54.00 um and appeared to be a 2-3 layered structure (Plate 31). For the crop grown under Bijapur conditions the thickness of epidermis was 18.70 um at fruit set (stage 1) and it gradually increased to 48.40 um at harvest (stage 10).

At the begining of storage, the fruits harvested from Bangalore conditions had a epidermal thickness of 54.00 um. After 15 days of storage, the epidermal thickness of the rind decreased in untreated control (43.83 um) and semperfresh (44.00 um) treatments, whereas it slightly increased in the film wrapped (BDF 2001 = 55 um and D955 = 52.35 um) ones. At 25 days after storage, the thickness of the epidermis further decreased to 30.75 um and 33.00 um in untreated and semperfresh treated fruits, respectively. The epidermis of the wrapped fruits divided periclinally to form 5-6 layered structure with increased cell activity and reached a thickness of 65 um (Plate 27).

The stored fruits harvested from Bijapur conditions also showed similar changes in the epidermis in all the treatments studied. On 15th day of storage, the untreated control and semperfresh treated fruits had the epidermal thickness decreased to 44.00 um and 46.00 um, respectively which was slightly less than the initial thickeness (48.40 um). The wrapped fruits had an increased epidermal thickness (BDF 2001 = 48.00 and D955 = 62.70 um).

Table 46: Changes in structural dimensions (um) in the rind of pomegranate cv. Ganesh during growth and storage (Bangalore crop)

| Characters | Cuticle thickness | | Epidermal thickness | | Collenchyma Length | | Collenchyma Breadth | | Parenchyama Length | | Parenchyama Breadth | | No.of Collenchyma cells/10 ocular | | No.of parenchyma cels per 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x |
| **GROWTH STAGES** | | | | | | | | | | | | | | | | |
| 1 | - | 2.75 | - | 27.50 | 11.25 | 24.75 | 7.50 | 20.62 | 15.00 | 41.25 | 22.00 | 30.25 | 6.00 | 2.25 | 8.25 | 2.50 |
| 5 | - | 5.50 | - | 31.16 | 15.00 | 30.80 | 11.25 | 24.70 | 18.75 | 48.00 | 28.10 | 44.00 | 6.25 | 2.25 | 7.00 | 2.50 |
| 7 | - | 9.62 | - | 38.50 | 22.50 | 38.50 | 16.50 | 33.00 | 27.00 | 57.90 | 30.00 | 50.60 | 7.50 | 2.00 | 6.25 | 1.50 |
| 9 | - | 11.91 | - | 44.00 | 30.00 | 42.65 | 25.00 | 40.00 | 45.00 | 66.00 | 33.75 | 52.75 | 6.50 | 2.00 | 5.50 | 2.00 |
| 10 | - | 19.25 | - | 45.83 | 30.00 | 57.50 | 30.00 | 44.00 | 51.00 | 74.50 | 45.00 | 52.80 | 6.25 | 2.00 | 5.25 | 2.00 |
| **STORAGE AFTER 15 DAYS** | | | | | | | | | | | | | | | | |
| **Treatments** | | | | | | | | | | | | | | | | |
| Untreated (Control) | - | 17.16 | - | 43.83 | 30.00 | 44.80 | 24.75 | 41.80 | 38.00 | 58.20 | 27.00 | 32.35 | 8.66 | 3.00 | 9.00 | 2.80 |
| Semperfresh (2%) | - | 18.50 | - | 44.00 | 30.00 | 45.25 | 27.00 | 41.25 | 45.00 | 61.60 | 22.00 | 34.90 | 8.14 | 2.50 | 8.50 | 2.50 |
| Film wrap (BDF 2001) | - | 19.25 | - | 5 .00 | 33.75 | 53.62 | 36.00 | 44.25 | 60.00 | 67.10 | 45.00 | 44.00 | 7.60 | 2.00 | 7.25 | 2.00 |
| Film wrap D955) | - | 19.25 | - | 52.35 | 33.75 | 53.62 | 38.75 | 44.25 | 60.00 | 71.00 | 45.00 | 44.00 | 7.60 | 2.00 | 7.75 | 2.00 |
| **STORGE AFTER 25 DAYS** | | | | | | | | | | | | | | | | |
| **Treatments** | | | | | | | | | | | | | | | | |
| Untreated (Control) | - | 11.00 | - | 30.75 | 30.00 | 38.50 | 15.00 | 16.50 | 30.00 | 40.00 | 7.50 | 16.50 | 9.00 | 3.20 | 10.40 | 3.80 |
| Semperfresh (2%) | - | 11.00 | - | 33.00 | 30.00 | 39.87 | 15.00 | 22.00 | 30.00 | 58.00 | 15.00 | 30.25 | 8.40 | 2.80 | 8.80 | 2.70 |
| Film wrap (BDF 2001) | - | 14.00 | - | 65.00 | 30.00 | 50.60 | 24.00 | 33.00 | 30.00 | 66.00 | 38.40 | 44.00 | 7.60 | 2.20 | 7.50 | 2.00 |
| FILM wrap D955) | - | 14.00 | - | 65.83 | 33.75 | 50.60 | 27.00 | 32.30 | 45.00 | 68.75 | 45.00 | 44.00 | 7.60 | 2.20 | 7.75 | 2.00 |

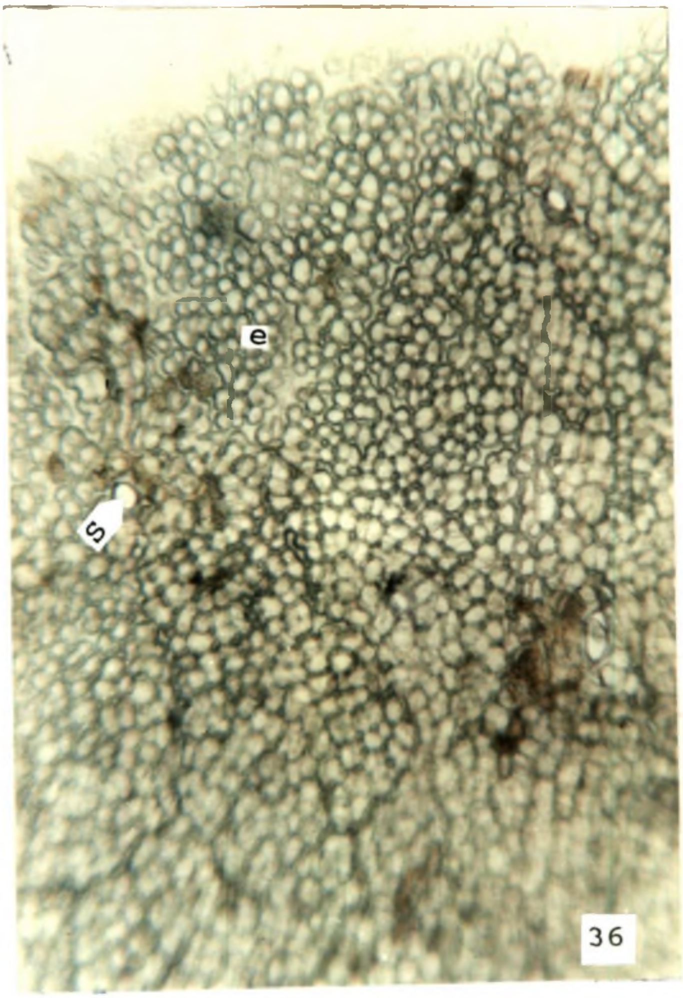
**Table 47: Changes in structural dimensions (um) in the rind of pomegranate cv. Ganesh during growth and storage (Bijapur crop)**

| Characters | Cuticle thickness | | Epidermal thickness | | Collenchyma Length | | Collenchyma Breadth | | Parenchyama Length | | Parenchyama Breadth | | No.of Collenchyma cells/10 ocular | | No.of parenchyma cels per 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x | 10x | 40x |
| **GROWTH STAGES** | | | | | | | | | | | | | | | | |
| 1 | - | 3.50 | - | 18.70 | 21.00 | 19.80 | 12.00 | 22.00 | 27.50 | 30.00 | 21.00 | 27.50 | 5.75 | 3.00 | 9.80 | 2.60 |
| 5 | - | 8.25 | - | 38.75 | 24.00 | 27.50 | 15.00 | 24.00 | 45.00 | 45.75 | 27.50 | 30.00 | 8.40 | 2.60 | 8.00 | 2.00 |
| 7 | - | 11.00 | - | 42.94 | 30.00 | 44.00 | 24.00 | 35.20 | 52.50 | 55.00 | 38.50 | 45.37 | 7.00 | 2.00 | 7.50 | 2.00 |
| 9 | - | 11.00 | - | 44.00 | 39.00 | 52.25 | 39.00 | 39.60 | 54.00 | 68.75 | 48.00 | 49.50 | 7.20 | 2.00 | 6.8 | 1.80 |
| 10 | - | 16.50 | - | 48.40 | 48.00 | 61.50 | 45.00 | 44.00 | 60.00 | 74.25 | 48.25 | 55.00 | 1.80 | 1.80 | 6.11 | 1.20 |
| **STORAGE AFTER 15 DAYS** | | | | | | | | | | | | | | | | |
| **Treatments** | | | | | | | | | | | | | | | | |
| Untreated (Control) | - | 11.00 | - | 44.00 | 42.00 | 57.20 | 27.00 | 25.70 | 54.00 | 63.80 | 30.00 | 36.30 | 7.71 | 2.28 | 8.14 | 2.00 |
| Semperfresh (2%) | - | 11.00 | - | 46.00 | 48.00 | 58.50 | 22.50 | 35.20 | 51.00 | 67.10 | 30.00 | 36.30 | 7.50 | 3.00 | 6.25 | 2.00 |
| Film wrap (BDF 2001) | - | 16.50 | - | 48.00 | 48.00 | 59.40 | 30.00 | 38.50 | 57.00 | 70.40 | 33.00 | 44.00 | 7.37 | 2.72 | 6.25 | 2.00 |
| Film wrap (D95 ) | - | 16.50 | - | 62.70 | 45.00 | 58.20 | 37.50 | 38.50 | 54.00 | 70.40 | 33.00 | 44.00 | 6.00 | 2.14 | 6.00 | 2.00 |
| **STORGE AFTER 25 DAYS** | | | | | | | | | | | | | | | | |
| **Treatments** | | | | | | | | | | | | | | | | |
| Untreated (Control) | - | 10.00 | - | 41.80 | 42.00 | 56.30 | 15.00 | 22.00 | 52.50 | 63.80 | 18.75 | 27.50 | 9.14 | 3.44 | 9.00 | 4.00 |
| Semperfresh (2%) | - | 11.00 | - | 39.60 | 48.00 | 56.30 | 22.50 | 27.50 | 51.00 | 66.00 | 27.50 | 24.75 | 9.00 | 3.50 | 8.14 | 2.85 |
| Film wrap (BDF 2001) | - | 13.20 | - | 61.60 | 48.00 | 55.00 | 30.00 | 34.10 | 55.00 | 64.70 | 30.00 | 44.00 | 7.71 | 2.22 | 6.60 | 2.00 |
| FILM wrap (D9 5) | - | 12.37 | - | 68.20 | 45. 0 | 5.00 | 32.50 | 33.78 | 54.70 | 61.40 | 30.00 | 44.00 | 7.67 | 2.47 | 6.60 | 2.50 |

**SURFACE VIEW OF THE RIND EPIDERMIS IN BANGLAORE CROP (PLATES FROM 36 TO 43)**

**Plate 36:** At harvest (begining of storage) showing the stomata (*S*) scattered in the epidermis (e) x 80.

**Plate 37:** At harvest (begining of storage) showing the magnified stomata (*S*) and the epidermal (e) cells x 250.


e
s
36

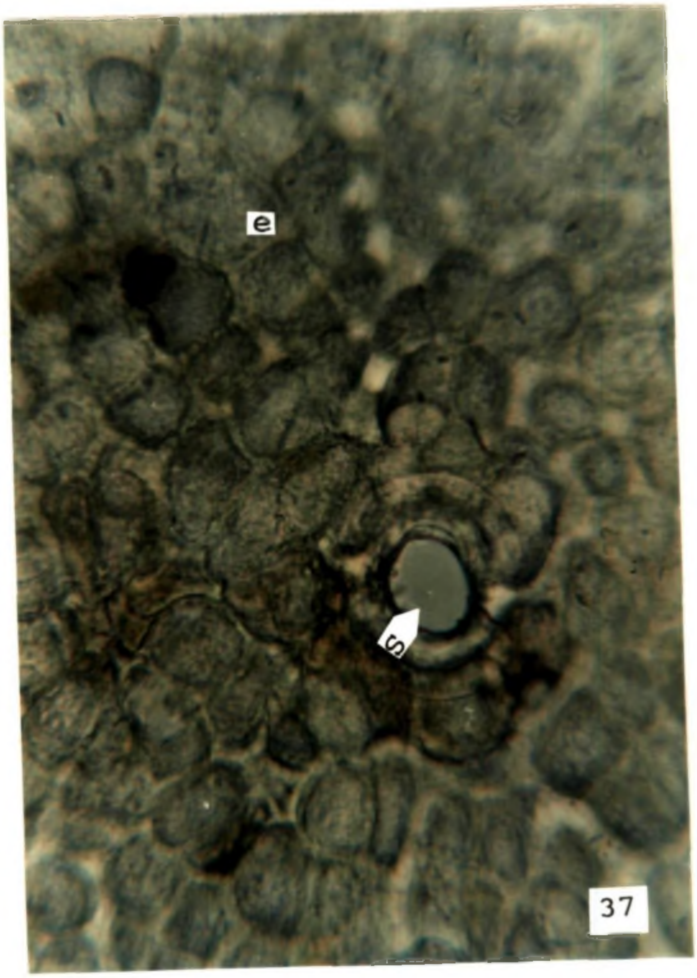
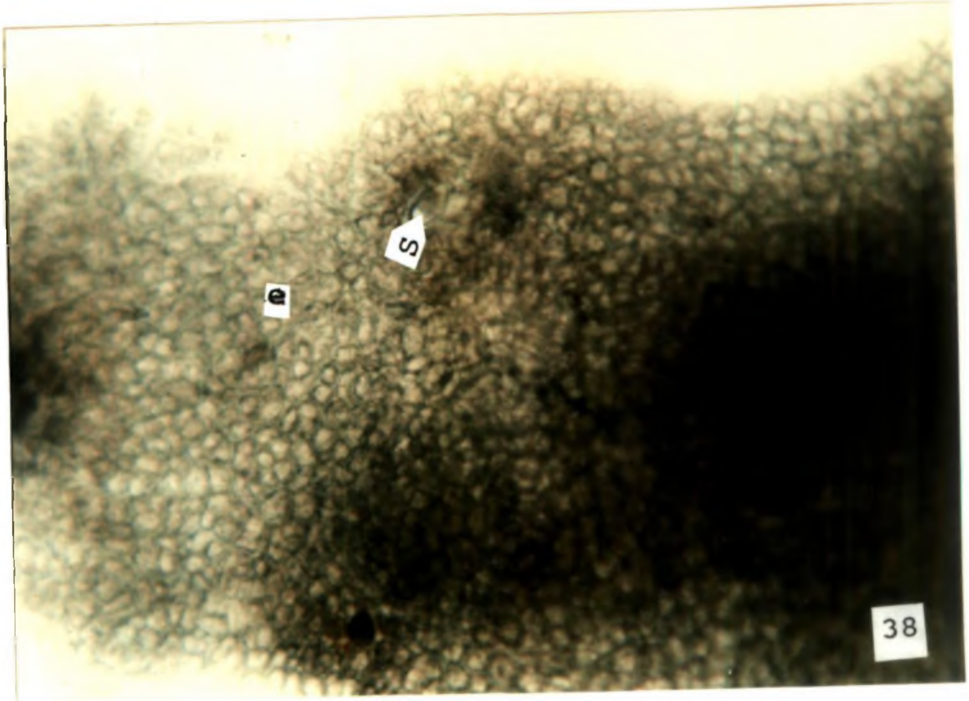

e
s
37

**Plate 38:** From untreated control fruits after 25 days of storage at RT showing high accumulation of brown substance in the epidermal (e) cells surrounding the stomata (S) x 80

**Plate 39:** From semperfresh treated (2%) fruits after 25 days of storage at RT showing low accumulation of brown substance in the epidermal (e) cells surrounding the stomata (S) x 80.


s
e
38

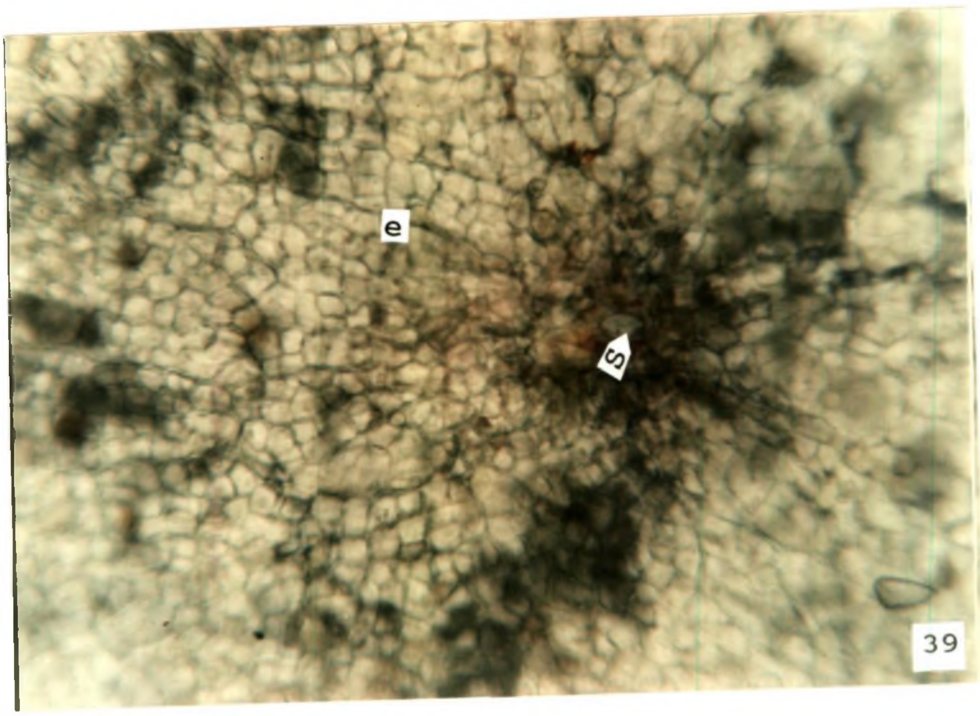
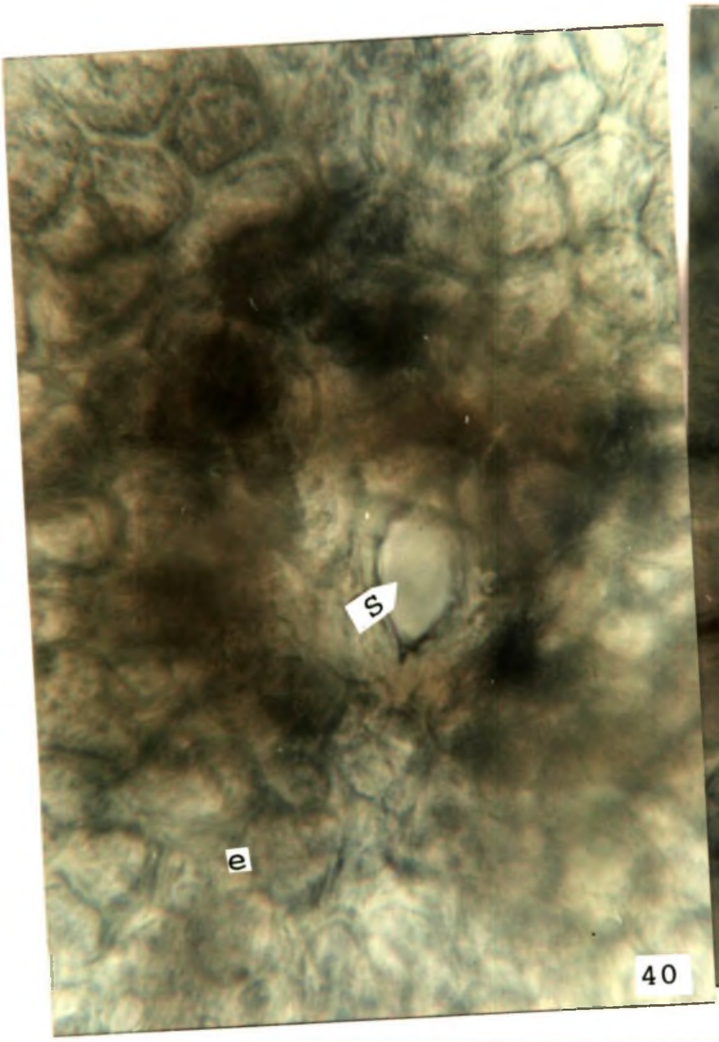

e
s
39

**Plate 40:** From untreated control fruits after 25 days of storage at RT showing high accumulation of brown substance in the epidermal (e) cells surrounding the stomata (S) x 250

**Plate 41:** From semperfresh treated (2%) fruits after 25 days of storage at RT showing low accumulation of brown substance in the epidermal (e) cells surrounding the stomata (S) x 250

**Plate 42:** From film wrapped fruits after 25 days of storage at RT showing minimum accumulation of brown substance in the epidermal (e) cells surrounding the stomata (S) x 250.


S
e
40

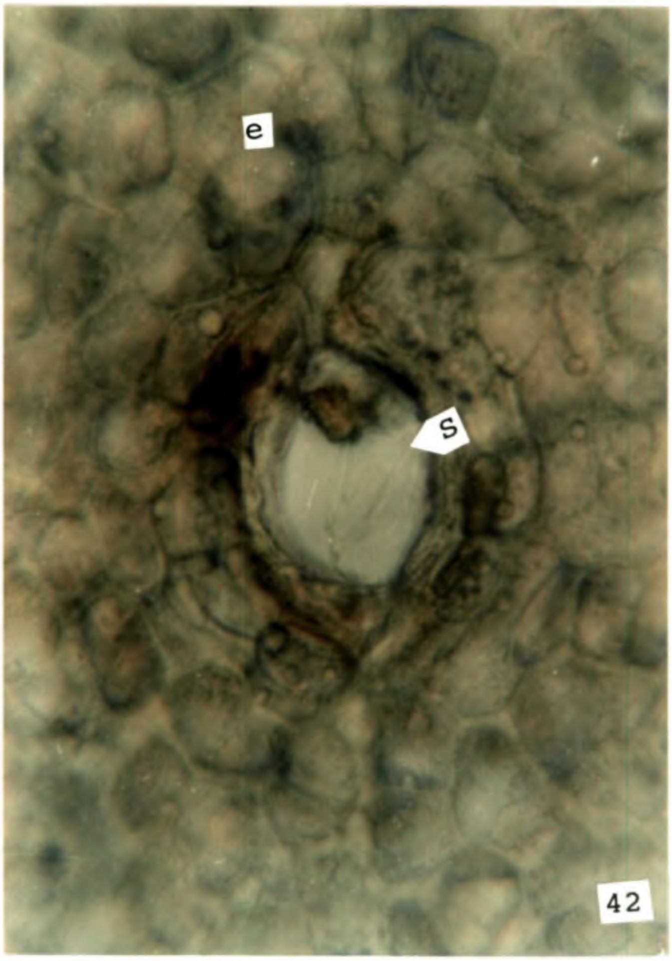
e
S
41

e
S
42

**Plate 43:** From film wrapped fruits after 25 days of storage at RT showing the pericrinal division of the epidermal (e) cells with almost nil accumulation of brown substance x 250.

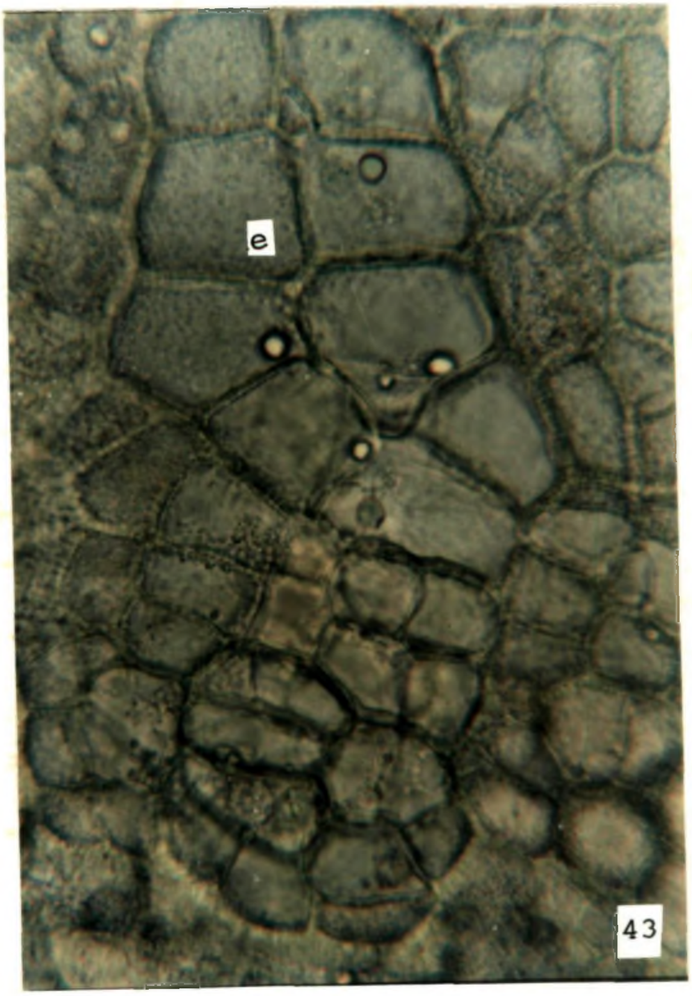

e
43

**Table 48: Histological and histochemical changes in the rind of pomegranate cv. Ganesh during development (Bangalore crop)**

| Days after fruit set | At fruitset | 30 | 60 | 90 | At harvest |
|---|---|---|---|---|---|
| Structures | | | | | |
| Outer epidermis thickness | Single layer 27.50 um | Increased to 31.16 um | Increased to 38.50 um | Increased to 44.00 um | Increased to 54.00 um appeared to be a 2 layered structure |
| Outer cuticle thickness | 2.75 um | Increased to 5.50 um | Incrased to 9.62 um | Increased to 11.91 um | Increased to 19.25 um |
| Collenchyma Cells | | | | | |
| Number of Layers | 3.4 | 6-7 | 8-7 | 9-11 | 9-11 |
| Cell shape | Spherical | Spherical | Spherical to oval | Oval | Oval to cylindrical |
| Cell length | 24.75 um | 30.80 um | 38.50 um | 42.65 um | 57.50 um |
| Cell breadth | 20.62 um | 24.70 um | 33.00 um | 44.00 um | 44.00 um |
| Parenchyama Proximal to outer epidermis | Similar to Parenchyma Cells | Similar to rind at fruit set | Similar to rind at fruit set | Partially look like collenchyma with a slight thickening at thier outer corners | Similar to rind at 90th day after fruit set |
| Other Parenchyma Cells | | | | | |
| Cell shape | Spherical | Spherical to oval | Spherical to oval | Oval to polygonal | Oval to polygonal |
| Cell length | 41.25 um | 48.00 um | 57.90 um | 66.00 um | 74.50 |
| Cell breadth | 30.25 um | 44.00 um | 50.60 um | 52.25 um | 52.80 |
| Vascular strands | Many and Scattered in Parenchyma | Similar to rind at fruit set | Similar to rind at fruit set | Similar to rind at fruit set | Similar to rind at fruit set |
| Sclereids | Varying in number size and shape | Similar to rind at fruit set | Similar to rind at fruit set | Similar to rind at fruit set | Similar to rind at fruit set |
| Inner epidermis | Similar to Parenchyma cells | Similar to rind at fruit set | Similar to rind at fruit set | Cells with slightly thinner walls | Simialr to rind at 90 days after set |
| Inner cuticle | Thinner than outer cuticle | Similar to rind at fruit set | Similar to rind at fruit set | Similar to rind at set | Similar to rind at fruit set |
| Starch grains | Absent | Similar to rind at fruit set | Accumulated | Accumulated | Accumulated |
| Number per cell | - | | 12-15 | 10-12 | 6-10 |
| Shape | - | | Spherical | No changes | No changes |
| Diameter | - | | 8-11 um | No changes | No changes |

**Table 49: Histological and histochemical changes in the rind of pomgranate cv. Ganesh during storage (Bangalore crop).**

| | | 15 days after storage | | | 25 days after storage | | |
|---|---|---|---|---|---|---|---|
| Structures | At harvest | Control | Semperfresh | Film wrapped | Control | Semperfresh | Film wrapped |
| Outer epidermis thickness | 45.83 um | Decreased to 43.83 um | Decreased to 44.00 um | Increased to 55.00 um (BDF2001) and 52.35 um (D955) | Further decreased to 30.75 um | Further decreased to 30.75 um | Pericrinal division making it a 2-3-layered structure increased to 55.00 um in both the films |
| Outer cuticle thickness | 19.25 um | Decreased to 17.16 um | Decreased to 18.00 um | Remained unchanged | Frurther decreased to 11.00 um | Same as in control | Same as in control |
| Collenchyma Cells | | | | | | | |
| Number of Layers | 9-11 | 9-11 | 9-11 | 9-11 | 9-11 | 9-11 | 9-11 |
| Cell shape | Oval to cylindrical | Ovaly to cylindrical | Oval to cylindrical | Oval to cylindrical | Cylindrical | Almost cylindrical | Almost cylindrical |
| Cell length | 57.50 um | Decreased to 44.80 um | Decreased to 45.25 um | Decreased to 53.62 um | Further decreased to 38.50 um | Further decreased to 39.87 um | Further decreased to 50.60 um in both films |
| Cell breadth | 44.00 um | Decreased to 41.80 um | Decreased to 41.25 um | Decreased to 44.25 um | | | |
| Parenchyama Proximal to outer epidermis | Looked like Collenchyma cells with slight thicke-ning at their outer corners | Slight increase in thickening | Same as in control | Same as control | Thickening of corner more prominent | Same as in control | Same as in control |
| Other Parenchyma Cells | | | | | | | |
| Cell shape | Oval to polygonal | Oval to polygonal | Oval to polygonal | Oval to polygonal | Oval to elongated | Oval to slightly elonglted | Oval to slightly elongated |
| Cell length | 74.50 um | Decreased to 58.20 um | Decreased to 61.60 um | Decreased to 67.10 um (BDF2001) and 71.00 D955) | Further decreased to 44.00 | Further decreased to to 58.00 | Further decreased to 66.000 um (BDF2001) and 68.75 um (D955) |
| Cell breadth | 52.80 um | Decreased to 32.25 um | Decreased to 34.90 um | Decreased to 44.00 um in both the films | Further decreased to 16.50 | Further decreased to 30.25 | Further decreased to 44.00 um in both the the films. |
| Sclereids | With cytoplasm many in number irregular in shape and size | No changes | Same as in control | Same as in control | Some Sclerids lost their lumen and looked broken | Some sclerids lost their lumen | Same as in control |
| Inner cuiticle | Very thin when compared to outer cuticle | No changes | Same as in control | Same as in control | Looked very thin or absent | Same as in control | Same as in control |
| Starch grains | | | | | | | |
| Number per cell | 8-10 per cell | Grains disappered | Same as in control | Same as in control | Grains disappeared | Same as in control | Same as in control |
| Any other changes compression of cells | - | Large | Medium | Very low | Severe | High | Low |
| Accumulation of brown substances | - | - | - | - | Intense | Maximum | Minimum |

After 25 days of storage, the thickness of the epidermis further decreased in unwrapped fruits (41.80 um and 39.60 um, respectively in untreated and semperfresh treatments) while it increased slightly in wrapped fruits (61.60 and 68.20 um in BDF 2001 and D955, respectively).

### 4.3.3 Outer cuticle

The cuticle from the crop grown under Bangalore conditions measured 2.75 um thickness at fruit set. On 30th day after fruit set (stage 5) it increased to 5.5 um, while it was 9.62 um thick on 60th day after fruit set. Its thickness further increased to 11.91 um on 90th day (stage 9) of growth and reached a thickness of 19.25 um at harvest.

The cuticle thickness from the crop grown under Bijapur conditions increased from 5.5 um at fruit set to 16.50 um at harvest.

The thickness of the cuticle before storage (Bangalore crop) was 19.25 um. At 15 days after storage, the thickness of the unwrapped fruits decreased to 17.16 um in untreated control and 18.50 um in semperfresh treated fruits. In the wrapped fruits it remained almost unchanged. After 25 days of storage, the cuticle thickness decreased to 11.00 um in untreated and semperfresh treated fruits. The cuticle thickness of wrapped fruits was 14.00 um.

In the fruits selected from Bijapur area the initial cuticle thickness was 16.50m. On 15th day storage the untreated and semperfresh treatments showed decreased cuticular (both at 11 um) thickness while the wrapped fruits did not show any noticeable changes.

After 25 days of storage, the cuticle thickness of unwrapped fruits did not change much and in wrapped fruits it decreased very slightly (13.20 in BDF 2001 and in 12.37 D955). However, the cuticle thickness from Bangalore chosen crop was higher than Bijapur crop at harvest.

### 4.3.4 Collenchyma cells

Beneath the epidermis there was 3-4 layers of collenchyma and the cells had a breadth of 20.62 um and length of 24.75 um at fruit set stage (stage 1) in Bangalore crop. The cells were spherical in outline. The cells were smaller in size and then increased due to the enlargement of cells concomitant with the fruit growth.

By 30th day after fruit set (stage 5) the collenchyma layers increased to 6-7 and the cells had a length of 30.80 um with a width of 24.70 um. The cells were spherical to oval in cross section. On 60th day after fruit set (stage 7) the number of collenchymatous layers increased to 8 - 10. The cells had a length of 38.50 um and 33.00 um breadth. The cells remained spherical to oval (Plate 22). At

90 days of growth (stage 9), the collenchyma was 9 - 11 layered with oval cells. The length and breadth measured was 42.65 and 40.00 um, respectively. At harvest, the collenchyma remained 9-11 layered with oval to cylindrical cells. The cells had a length and breadth of 57.50 and 44.00 um, respectively.

The length and breadth of collenchyma cells (Bijapur crop) at fruit set (stage 1) was 19.8 um and 22.00 um, respectively and it later increased to 61.50 and 44.00 um at harvest (stage 10). The cell size also increased with the growth of the fruit.

During storage of 15 days, the length and breadth of collenchyma cells decreased in all the treatments in both the crops.

In Bangalore crop, maximum decrease was observed in untreated (length being 44.80 and 41.80 um breadth) followed by semperfresh treated fruits (length and breadth being 45.25 and 41.25 um, respectively). In the wrapped fruits the collenchyma had 53.62 um length and 44.25 um breadth.

Twenty five days after storage the length and breadth of collenchyma cells further reduced to 38.50 and 16.50 um, respectively, in untreated whereas in semperfresh treated fruits they were 39.87 and 22.00 um, respectively. The two wrapped fruits had equal length (50.60 um) while their breadth were 33.00 um (BDF 2001) and 32.30 um (D955). The cell size decreased in unwrapped fruits while it almost unchanged in the wrapped fruits. In the untreated fruits the cells were cylindrical and they looked almost cylindrical in semperfresh and wrapped fruits.

The crop from Bijapur area also showed similar changes during storage. At 15 days after storage the decreased length of collenchyma cells was 57.20, 58.50, 59.40 and 58.20 um in untreated, semperfresh, BDF 2001 and D955 film wrapped fruits, respectively. The breadth of both the wrapped fruits was equal (38.50 um) while it was lowest in untreated control (25.70 um) and 35.20 um in semperfresh treatment. The cell size decreased in all the treatments.

After 25 days of storage, the length of collenchyma cells in unwrapped fruits (control and semperfresh) was 56.30 um while it was 55.00 um in wrapped fruits. The breadth of the cells was 22.00 (untreated), 27.50 (semperfresh), 33.78 (D955) and 34.10 (BDF 2001). The size of the cells further decreased in all the treatments.

The collenchyma cells had thicker cell walls than the parenchyma cells at all the stages of growth and during storage period of 25 days in both the crops. However, the thickening from the crop under Bijapur conditions appeared slightly less than that of the crop under Bangalore conditions.

#### 4.3.5 Parenchyma cells proximal to outer epidermis

The parenchyma cells proximal to outer epidermis had thicker cell wall than the inner parenchyma cells at all the stages of growth and during storage in both the crops. At fruit set (Bangalore crop) these cells were similar to parenchyma cells. From 90 days of growth (stage 9) upto harvest the cells contiguous to collenchyma partially looked like collenchyma with a slight thickening at their outer corners.

At 15 days of storage, the parenchyma cells proximal to outer epidermis showed slight increase in thickening in all the treatments. After 25 days of storage, the thickening of the corners was more prominent.

Similar changes were observed for the crop under Bijapur conditions.

#### 4.3.6 Other parenchyma cells

The parenchyma cells from the crop grown under Bangalore conditions measured the length and breadth of 41.25 and 30.25 um, respectively at fruit set. The cells were spherical in outline. On 30th day after fruit set (stage 5) the length and breadth measured was 48.00 and 44.00 um, respectively. The cells had the length and breadth of 57.90

and 50.60 um, respectively on 60th day of growth (stage 7). The cells were spherical to oval. At 90 days of growth, the parenchyma cells were oval to polygonal and measured to a length of 66.00 um and 52.25 um breadth. At harvest they had a length and breadth of 74.50 um and 52.80 um, respectively. The size of the cells increased from fruit set upto harvest (Plate 29).

From the crop growth under Bijapur conditions, the length and breath of parenchyma cells increased from 30.00 um and 27.50 um, respectively at fruit set (stage 1) to 74.25 and 55.00 um at harvest (stage 10). The cells were spherical to oval in shape. The size of the parenchyma cells also increased with the progress in growth stages.

During storage at 15 days, the length and breadth of parenchyma cells decreased in all the treatments (Bangalore crop). Maximum decrease was noticed from the untreated fruits (58.20 and 32.25 um, respectively) and then in the semperfresh fruits (61.60 and 34.90 um, respectively). The breadth of both the wrapped fruits remained almost the same (44 um) although the length slightly varied (67.10 and 71.00 um in BDF 2001 and D955 films, respectively). The cell size decreased in unwrapped fruit while it was constant in wrapped fruits. After 25 days of storage, the cell size further decreased in unwrapped fruits. The length and breadth decreased to 44.00 and 16.50 um in untreated and to 58.00 and 30.25 um in semperfresh fruits, respectively. The breadth of parenchyma in both the wrapped fruits remained 44.00 um while their lengths were 66.00 um (BDF 2001) and 68.75 um (D955).

The fruits harvested from the Bijapur conditions, after 15 days of storage showed decreased length and breadth of parenchyma cells in all the treatments. The length of cells in untreated and semperfresh treated fruits were 63.80 um and 67.10 um, respectively and their breadth was same (36.30 um). However, the length (70.40 um) and breadth (44.00 um) of both the wrapped fruits was almost same.

At 25 days after storage, the length of parenchyma cells decreased in all the treatments (63.80, 66.00, 64.70 and 61.40 um in untreated, semperfresh BDF 2001 and D955 film wrapped fruits, respectively). The breadth decreased only in unwrapped fruits (27.50 and 24.75 um and in untreated and semperfresh, respectively), while it remained almost the same in wrapped fruits (44.00 um). The size of the cells further decreased in all the treatments.

The size of both collenchyma - and parenchyma cells at the begining of storage was larger in Bijapur harvested crop than the Bangalore harvested crop and experienced more compression during storage in the former.

### 4.3.7 Vascular strands

The vascular strands irrespective of growing conditions were many and scattered in the parenchyma. They looked smaller in size at fruit set and increased in size with the growth of the fruit. However, the changes did not appear significantly either during growth or during storage.

### 4.3.8 Sclereids

Irrespective of growing conditions the sclereids varying in number, were very irregular in shape and size (Plate 32) and varied greatly in extent of the thickening and lignification, so that some possessed a very narrow lumen and a heavily thickened wall while others had a larger lumen and comparatively thinner wall. The smallest sclereid measured 3.0 um while the largest measured about 104 um (Plate 33). The sclereids did not show any change during growth. But after 25 days of storage, although not a regular feature, some sclereid cells lost their cytoplasm and looked broken in all the treatments.

### 4.3.9 Inner epidermis

The cells in the inner epidermis of the rind at fruit set (stage 1) were similar to parenchyma cells in both the crops. At 90 days after growth (Bangalore crop) the cells in the inner epidermis showed slightly thinner walls compared to other parenchymal cells. At harvest similar cells were noticed. At storage the change of inner epidermal cells were similar to the changes in other parenchyma cells.

### 4.3.10 Inner cuticle

The cuticle of the inner epidermis was very thin as compared to the outer cuticle at all the stages of growth and also during storage of fruits in both the crops.

### 4.3.11 Accumulation of starch grains

The rind on the day of fruit set (stage 1) and on 30th day after fruit set (stage 5) did not show any accumulation of starch grains in the crop under Bangalore conditions (Plate 44). On 60th day after fruit set (stage 7) accumulation of starch grains was noticed (Plates 23 and 45). The number of grains per cell on an average was 12-15 approximately. The grains were more concentrated in the parenchyma cells near the inner epidermis (Plate 47). The outer epidermis had no starch accumulation while the parenchyma proximal to outer epidermis had small quantities accumulated (Plate 46). The stone cells and the vascular bundles were devoid of starch accumulation while the cells near the vascular bundles had very little starch compared to other parenchyma cells. The grains ranged from 8 to 11 um diameter and were spherical in shape. The number of starch grains per cell decreased to 10-12 at 90 days of growth (stage 9) and at harvest the cells had about 8-10 grains.

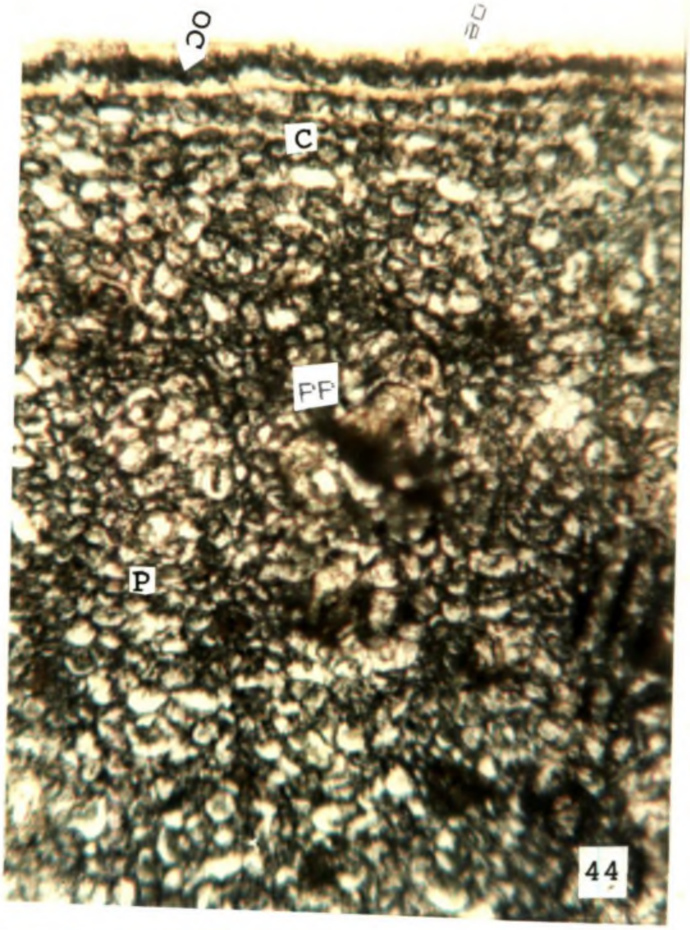
**SECTION OF THE RIND TESTED WITH IODINE SOLUTION FOR STARCH IN BANGLAORE CROP (PLATES FROM 44-48)**

**Plate 44:** At fruitset stage to show the lack of starch (St) accumulation x 80

C - Collenchyma cells
OC - Outer cuticle
Oe - Outer epidermis
P - Parenchyma

**Plate 45:** At 60 days after fruitset showing the starch (St) accumulation in parenchyma cells proximal to outer epidermis (PP) x 80.

C - Collenchyma
OC - Outer cuticle
Oe - Outer epidermis


C
PF
P
44

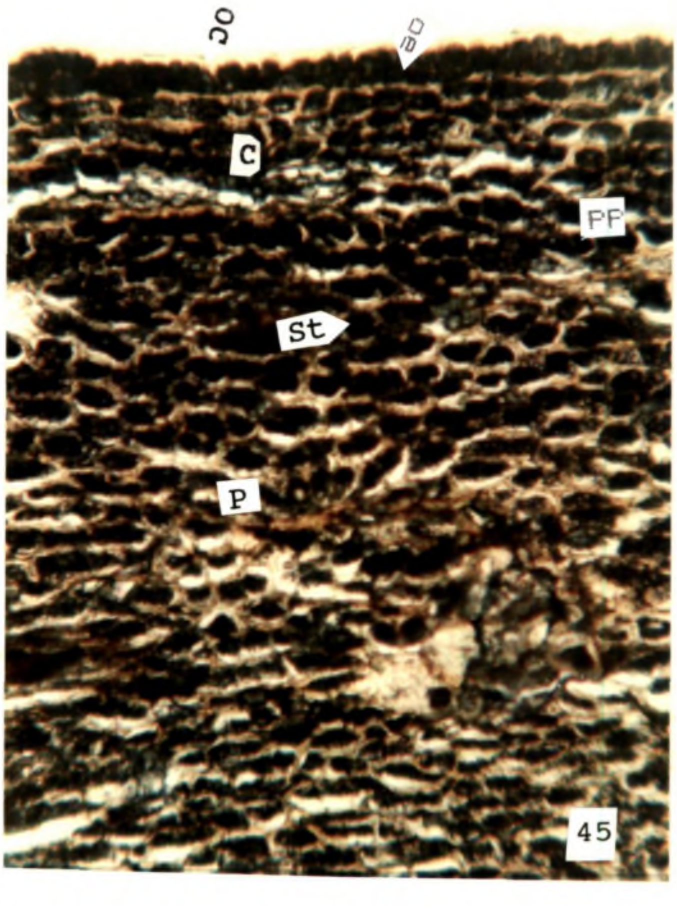
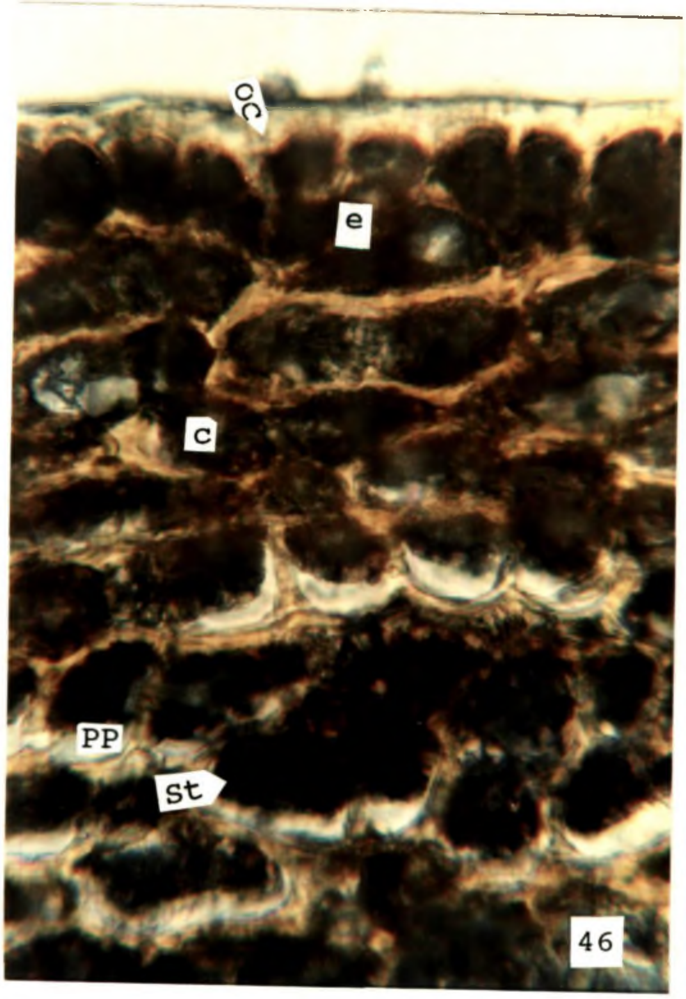

C
PF
St
P
45

**Plate 46:** At 60 days after fruitset showing the accumulation of starch (St) in the parenchyma cells proximal to outer epidermis (PP) x 250.

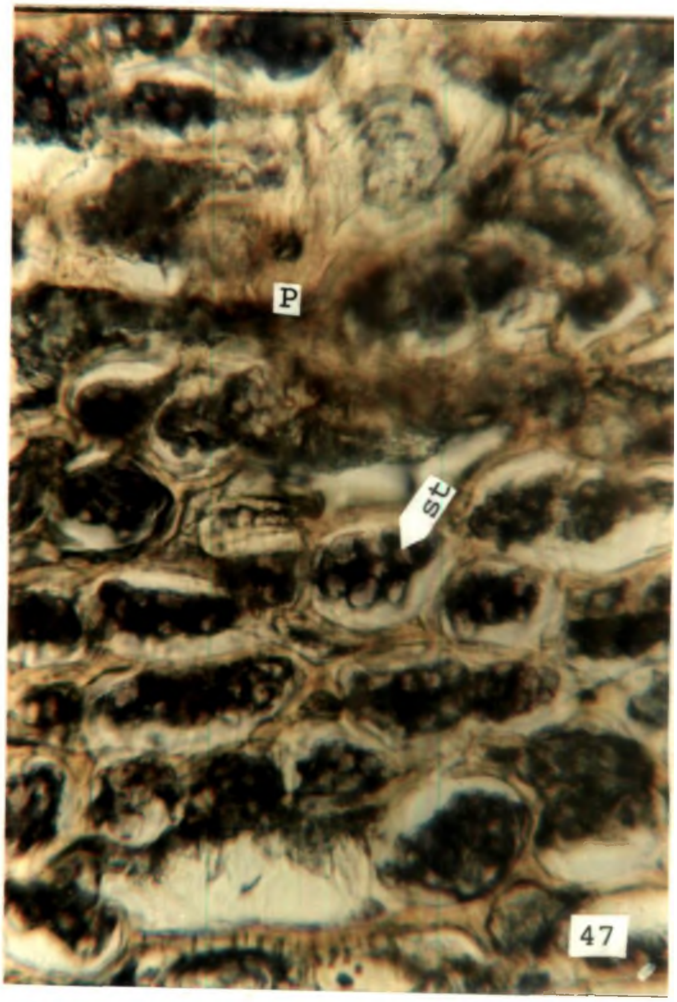
OC - Outer cuticle
Oe - Outer epidermis
The starch grains are absent in the collenchyma (C) cells.

**Plate 47:** At 60 days after fruitset showing the accumulation of starch (St) in the Parenchyma (P) cells x 250.

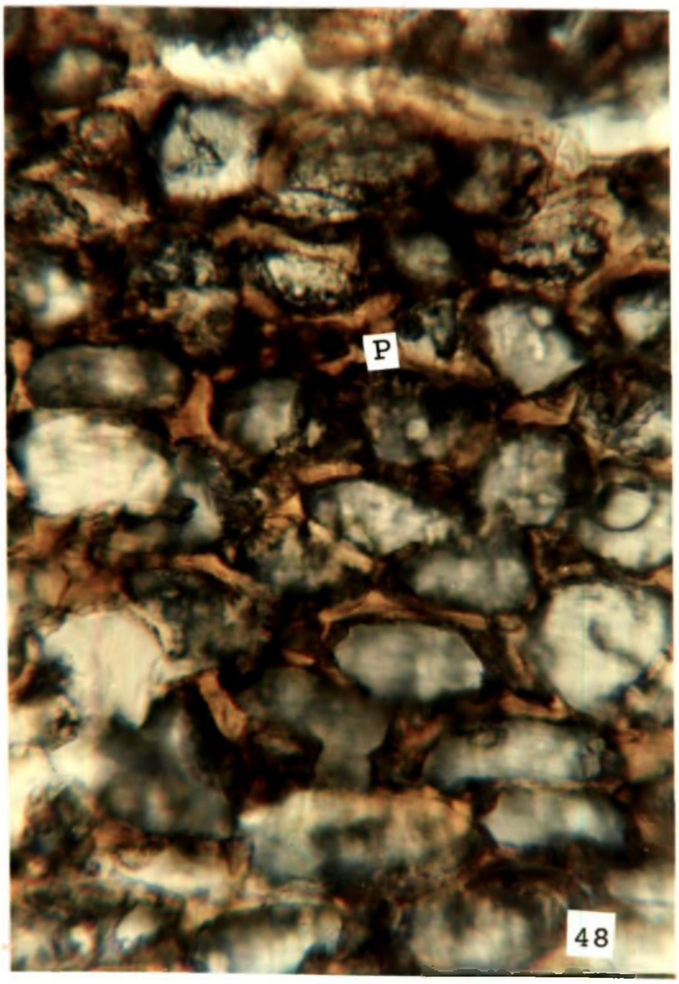
**Plate 48:** After 15 days of storage at RT showing the disappearance of the accumulated starch (St) in the parenchyma (P) cells x 250.



cc
e
c
PP
st
46

P
st
47

P
48

The starch accumulation in the crop grown under Bijapur conditions was seen at stage 7 (the diameter of the fruit being 82.52 mm).

At 15 days after storage the starch accumulated initially gradually disappeared in all the layers (Plate 24 and 48) and in all the treatments in both the crops. After 30 days of storage the starch grains did not reappear and were completely lost.

**4.3.12 Other changes**

**Compression of the cells**

The decrease in length, breadth and size of both the types of cells clearly indicated the tangential compression of cells. Maximum compression was observed in unwrapped fruits while it was comparably low in wrapped fruits. On 15th day of storage the untreated fruits showed large compression (Plates 34 and 35) while it was medium in the semperfresh treated fruits. The compression in film wrapped fruits was very low.

After 25 days of storage, the compression of cells increased in all the treatments. Severe compression was observed in untreated fruits (Plate 25) followed by semperfresh treated (Plate 26) and wrapped fruits. The increase in lateral shrinkage made the cells look more elongated. The size of collenchyma and parenchyma cells at the beginning of storage was larger in Bijapur harvested crop than in the Bangalore harvested crop and experienced more compression during storage in the former.

#### 4.3.13 Surface view of epidermis

The results on the study of surface view of epidermis at harvest and during storage are represented only for Bangalore harvested crop.

The epidermis at harvest showed the healthier cells with stomata of different size scattered (Plates 36 and 37). After 25 days of storage at room temperature in case of untreated fruits, a few stomato were closed and a few remained open. The cells had an accumulation of black depositions which are found to be phenolics or tannins from the preliminary studies. The epidermal cells surrounding the stomata had more of such depositions than the other cells.

The wrapped fruits had less accumulation of black bodies (Plate 42) than the untreated (Plates 38 and 40) fruits and showed increased division (Plate 43) of epidermal cells which is supposed to be congenial for fungal growth.

The accumulation of phenolics in the skin coated fruits (semperfresh 2%) was less (Plates 39 and 40) than the untreated fruits but more than that of the wrapped fruits. Untreated fruits which had lost much of their weight during storage had very much shrunken cells in the surface view also.

### 4.3.14 Aril histology

The edible portion of the pomegranate are the juicy fresh arils, although the occurence of brown discoloured arils is a regular feature which increases with storage.

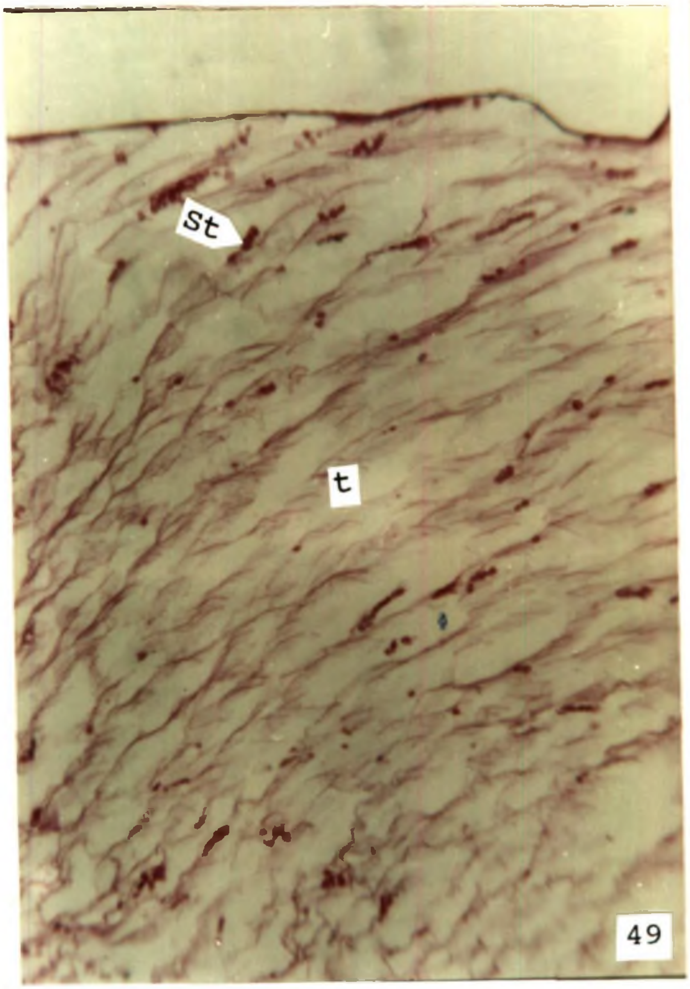
The fleshy pink aril at harvest (Plate 49) showed that it had fleshy testa cells intact and it had a few starch granules scattered. The sectioning of brown arils showed that the testa cells were distorted with the loss of the starch granules (Plate 50). With the increase in intensity of brown colour the tissues became more deformed (Plate 51). The deposition of certain unidentified black bodies could also be noticed.

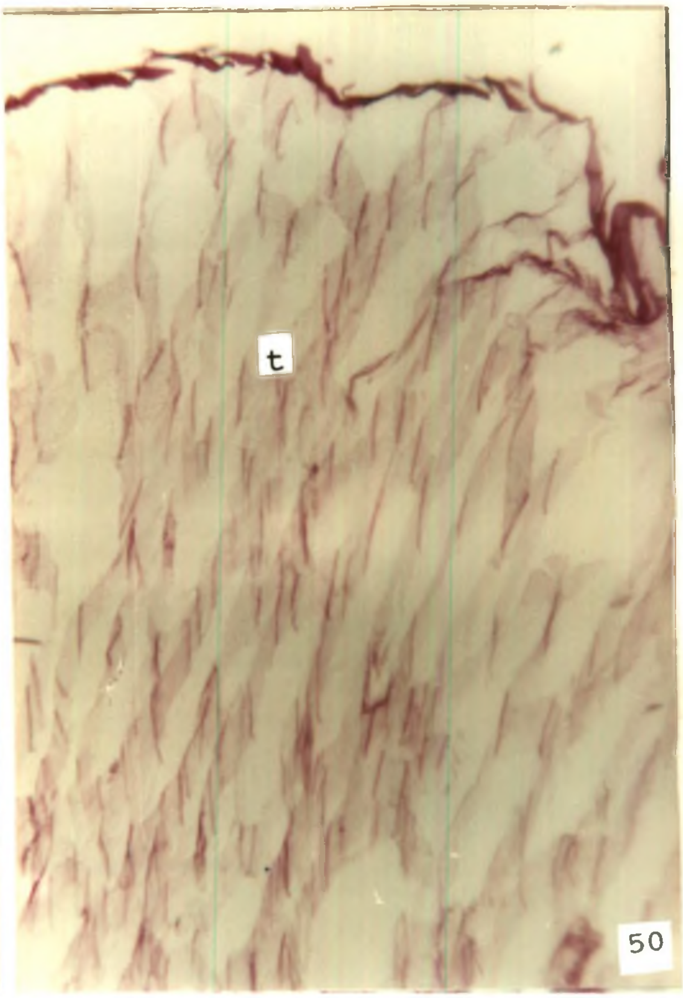
**SECTION OF THE ARIL TESTED WITH PAS IN BANGALORE CROP x 80 (PLATES FROM 49-51)**

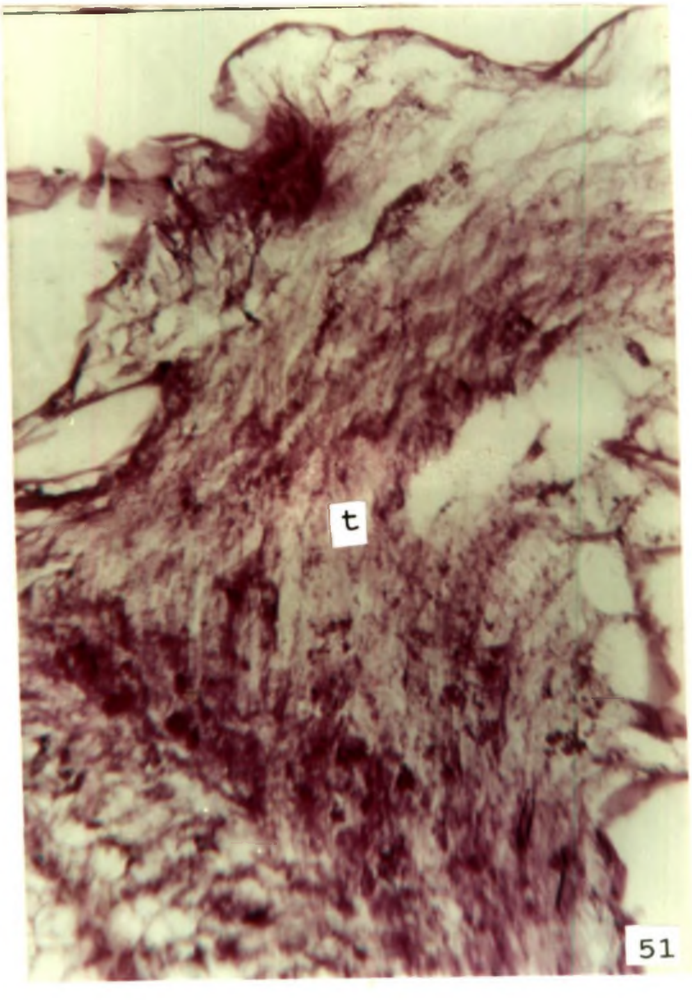
**Plate 49:** From a good (fresh pink) aril showing the insoluble polysaccharides in the form of starch (St) grains in the freshy testa (t).

**Plate 50:** From a slightly discoloured (light brown) aril showing the disappearance of starch (St) grains in a slightly distorted testa (t).

**Plate 51:** From a completely discoloured (black) aril showing the disappearance of starch (St) grains and the highly distorted cells of the testa (t).


st
t
49


t
50


t
51

# DISCUSSION

# DISCUSSION

The investigation on growth of pomegranate to study the growth pattern of cv. Ganesh grown under two different climatic conditions (Bangalore crop with mean maximum and minimum temperatures of 30.5$^{o}$C and 19.7$^{o}$C, respectively with 45.8 per cent relative humidity and Bijapur crop with mean maximum and minimum temperatures of 35.8 - and 23.4$^{o}$C, respectively with 39.9 per cent relative humidity) and storage are discussed.

## 5.1 FRUIT GROWTH AND DEVELOPMENT

### 5.1.1 Length and breadth

The length and breadth of the fruit increased continuously from fruit set to maturity under the two growing conditions. The length at fruit set was 3.9 and 3.7 cms in Bangalore - and Bijapur crops, respectively and at harvest it increased to 14.6 and 14.9 cms in Bangalore and Bijapur crops, respectively. Similarly the breadth of the fruit increased from 1.4 (Bangalore crop) and 1.5 (Bijapur crop) at fruit set to 8.5 cm and 9.6 cm at harvest in Bangalore and Bijapur crops, respectively.

The results obtained in the present study are in agreement with the studies of Dash (1983) in pomegranate variety 'Jyothi', where the length and diameter of the fruit increased continuously from fruit set to maturity. Arie *et al.* (1984) observed similar results in 'wonderful' variety of pomegranate. Similar work has been reported by Fouad *et al.* (1979) and Prasanna Kumar (1986) in cultivar 'Ganesh'.

The length of the fruit was more as compared to breadth of the fruit during growth in fruits of both the growing regions. According to Prasanna Kumar (1986) and Dash (1983) the length of the pomegranate fruit was more than the breadth during early stages and during the later period the increase in breadth was more pronounced. However Hittalmani and Rao (1976) reported the length of the fruit to be slightly more than the diameter through out the growth period of lime. Gulhane and Gupta (1979) reported the length and diameter of the guava fruit to be equal at the end of development. The length and breadth of Bijapur fruits was slightly more than that of Bangalore fruits towards harvest. This differences could be due to the variation in climatic conditions during the growing period.

The increase in length and breadth of the fruit during growth was due to the increased cell activity (cell division and cell enlargement).

**5.1.2 Fresh weight**

The fresh weight of the fruit grown under two different climatic conditions continued to increase from fruit set (3.9 and 3.5 g in Bangalore and Bijapur fruits, respectively) till harvest (295.4 and 365.5 g).

The pattern of fruit growth showed a linear curve in Cv. 'Ganesh'. Similar observations has been made by Shulman *et al.* (1984) who reported that fruits of pomegranate variety 'Mule's Head' had simple sigmoid growth curve where as variety 'wonderful' had a linear growth. The results of the present study are in confirmation with those of Dash (1983); Prasanna Kumar (1986) and Kumar and Purohit (1989). The gradual increase in fresh weight was also reported by Khodade *et al.* (1990); Fouad *et al.* (1979) in pomegranate and in mango by Pandey *et al.* (1973) and Wang and Shiesh (1990).

During the period extending from fruit set to maturity the growth rate was slow upto 4th stage followed by a high rate of growth upto 8th stage, which reached the maximum thereafterwards till it reached harvest maturity. Dash (1983) reported in variety Jyothi, fruit weight increased greatly during the second fortnight and again during sixth fortnight with decreased weights during other periods. Josan *et al.* (1979) also observed similar trend in pomegranate under Punjab conditions. Kumar and Purohit (1989) reported an alternated increase in fresh weight. But

Arie *et al*. (1984) observed a constant rate of fresh weight increase in fruits of 'wonderful' variety of pomegranate throughout the growing season. This is in conformity with our observation. The fruits collected at different stages of maturity under Bijapur conditions based on size also showed a linear curve with maximum growth at harvest.

According to Bollard (1970) the increase in fresh weight can be attributed to an increase in both the cell size and inter cellular spaces in the flesh, which resulted in the maximum possible accumulation of food substances. Ingrid Roth (1977) is of the opinion that fruit development is initiated by cell division which is later followed by cell enlargement. The period of cell division may be short and eventually restricted to parenthesis time, while cell enlargement is always of greatest importance. Some fruits enlarge 200 to 300 times of their original size and cell volume increased to the same extent. Westwood *et al*. (1967) are of the opinion that the combined growth resulting from cell division, cell enlargement and air space formation results in a general sigmoidal curve when fruit volume or weight is plotted as a function of time.

In the present study, a continuous increase in fresh weight from fruit set to maturity was a result of both cell division and cell enlargement. The weight of the fruit in

Bijapur conditions was higher at harvest than the Bangalore crop. This may be due to the higher temperature prevailing in Bijapur. Similar differences in fruit weight between higher and cooler regions has been reported by Shulman *et al.* (1984) a cvs. 'wonderful' and 'Mule's Head' during the growing period.

### 5.1.3 Volume

The volume of the fruit increased continuously with advancement in growth under two conditions. The increase in volume continuously has been reported by Dash (1983) in cv. Jyothi, Prasanna Kumar (1986) in cvs. Ganesh, Bassein seedless, Alandi and Kabul yellow, Khodade *et al.* (1990) in selection P-23 and by Fouad *et al.*(1979) in cv. Manfaloti. Pandey *et al.* (1993) and Wang and Shiesh (1990) reported the increase in volume in mango fruits and in guava fruits it was reported by Gulhane and Gupta (1974). The fruit volume at fruit set was 4.4 (Bangalore crop) and 4.1(Bijapur crop) and at harvest it increased to 310 and 400 ml in Bangalore and Bijapur crops, respectively.

At harvest the volume of fruit was more than the weight of fruit under both the conditions which is further confirmed by reduced specific gravity of the fruit. The greater increase in volume at harvest may largely be due to cell enlargement with reduced cell division and formation of air spaces.

### 5.1.4 Specific gravity

The specific gravity of the fruit increased during early stages of fruit growth and then gradually declined towards maturity under both the growing conditions. The declining specific gravity was also reported by Prasanna Kumar (1986); Khodade *et al.* (1990) in pomegranate fruits and in guava and lime by Tripathy and Gangwar (1971) and Hittalmani and Rao (1976), respectively. Mazumdar (1976) reported the increase in specific gravity with growth in mango fruits.

The specific gravity at fruit set was 0.89 and 0.90 g/cc in Bangalore and Bijapur fruits, respectively and at harvest the specific gravity was 0.96 (Bangalore crop) and 0.91 gcc (Bijapur crop). The decrease in specific gravity towards maturity may be due to development of air spaces created by cell enlargement.

### 5.1.5 Thickness of the rind

In the present study of pomegranate cv. Ganesh, rind thickness during growth of fruit gradually declined under both the growing conditions. The decrease in rind thickness towards harvest was also reported by Dash (1983) and Prasanna Kumar (1986) in pomegranate fruit and in lime fruit by Hittalmani and Rao (1976). The rind thickness at fruit set was 0.60 (Bangalore crop) and 0.42 mm (Bijapur crop). It decreased to 0.38 and 0.30 mm in Bangalore and Bijapur crops, respectively at harvest. The thickness of the rind of fruits collected from Bijapur area was lower (0.30) than the fruits collected from Bangalore area at harvest (0.38). The climatic factors like temperature, relative remedity may influence its development as the temperature (mean) around Bijapur conditions are higher than the Bangalore conditions. The high temperature might cause more loss of moisture, resulting in reduced rind thickness as reported by Saad (1990). He further reported the growth of the rind in pomegranate fruits to be slower in fruits exposed to sunlight than those in shade. Malhotra *et al.* (1983) reported the rind thickness to vary among cultivars. Cheema *et al.* 1954 reported that sudden abrupt change in soil moisture availability around maturity caused cracking of fruits, probably due to influxe of moisture in aril, there might be a reduction in the thickness of rind and aging process in rind has already started. The slower increase in rind weight towards maturity also suggests that rind thickness reduced at maturity.

### 5.1.6 Firmness

Firmness of the fruit slightly reduced from fruit set to maturity with some fluctuations in between during the growing period under both the going conditions. The decrease in firmness of guava was reported by Yusof and Mohamad (1987) and they further reported that to decrease in density of fruit. The firmness of the fruits at fruit set was 14.9 (Bangalore crop) and 13.2kg/$cm^2$ (Bijapur crop) and at harvest the firmness decreased to 13.7 - and 11.9 kg/$cm^2$, respectively The observed decrease in firmness in the pomegranate during growth may be due to cell enlargement creating air spaces with a corresponding decrease in specific gravity.

The firmness of the fruit at harvest was lower (10.97) under Bijapur conditions than in fruits grown under Bangalore conditions (13.92 kg/$cm^2$). This may be due to the fact that loss of moisture in the rind due to high temperature causes brittleness of the rind and a reduction in firmness due to loss of elasticity of cells. This is further supported by a reduction in rind thickness.

### 5.1.7 Fresh weight of rind and aril

In the present study, the fresh weigh of rind and arils increased continuously till maturity in both the crops. The fresh weight of aril at stage 2 was 0.4 (Bangalore crop) - and 0.7 g (Bijapur crop) and the weight increased to 190.7 and 248.6 g in Bangalore and Bijapur crops, respectively at harvest. Similarly the fresh weight of the rind at stage 2 was 4.6 (Bangalore crop) - and 4.8 g (Bijapur crop) and it increased to 97.1 and 116.7 g, respectively in Bangalore and Bijapur crops at harvest. During earlier days of growth (i.e. upto stage 4) the weight of the rind was higher than the aril weight. At stage 5 their weights were more or less the same. After the subsequent stages aril weight was more than the rind weight apparently due to the enlargement of arils and accumulation of juice in them. Similar changes were reported by Prasanna Kumar (1986) Kumar and Purohit (1989) in cv. 'Ganesh' while Dash (1983) reported the weight of rind and aril to be equal upto end of first month from fruit set followed by higher weight of aril with continued growth of pomegranate in cv. Jyothi.

The continuous increase in weight of rind and pulp in lime was reported by Hittalmani and Rao (1976).

During the growth of pomegranate fruit cv. Ganesh arils constituted about half of the fruits weight. Shulman *et al.* (1984) reported that the arils grew continuously during fruit development. At the beginning of the fruit development the seed consisted mainly of a soft seed, later the seed stopped growing and hardened while the juicy tissue (aril) continued to grow. They concluded that the pomegranate seeds resemble the development of drupe type fruits, but the aril grows continuously following a single sigmoid growth curve. The growing arils may draw moisture from the rind which might cause the reduction in weight of rind than the arils.

**5.1.8 Juice and seed content**

There was no extractable juice and seed content in fruits upto 5th stage of development under both the conditions of growth. Shulman *et al.* (1984) also reported that it was possible to sqeeze juice from mid July (flowering Mid April) in pomegranate and from sixth fortnight after fruit set in lime by Hittalmani and Rao (1976).

The juice and seed content of the fruit increased with advancement in maturity in both the crops (Bangalore and Bijapur). Maximum juice content was observed around harvesting period of the fruit. The juice content of the fruit increased from 22.5 ml to 122.5 ml at harvest in Bangalore crop and in Bijapur crop the juice content increased from 46.0 ml to 165.0 ml towards harvest. The seed weight was 28.9 and 38.8 g in Bangalore and Bijapur crops, respectively at harvest. These results are in agreement with those reported by Kumar and Purohit 1989; Khodade *et al.* (1990) and Shulman *et al.* (1984) in different cultivars of pomegranate. The increase in juice content of the fruit was a result of increased fleshly aril portion of seeds with continuous growth.

The juice content of the fruit from Bijapur area was higher (165 ml) than the juice in Bangalore harvested crop

(122.5). This may be due to the differences in climatic conditions. Shulman *et al.* (1984) reported the juice content in cv. 'Mule's Head' to be 35 - and 40 per cent and in cv. 'wonderful' to be 40 - and 45 per cent in the coastal and dry Betshean regions, respectively. Malhotra *et al.* (1983) reported the juice percentage to vary in cvs of pomegranate.

### 5.1.9 Respiration

The respiration rate of developing pomegranate fruit showed a maximum peak at the second stage of growth (i.e., after 5 days of fruit set in Bangalore crop and at a fruit diameter of 8.17 cm in Bijapur crop) and this was followed by a gradual decrease till the harvesting stage (47 and 113mg $CO_2$/kg/hr in Bangalore and Bijapur crops, respectively). Similar observations were made by Arie *et al.* (1984) in pomegranate cv. 'wonderful' during development. Shulman *et al.* (1984) also observed a peak in respiration rate during mid May which corresponds to early growth period. They also reported a gradual decline at the harvesting period. In banana respiration was high during early growth period followed by a decrease as the fruit reached maturity (Munasque, 1987).

### 5.1.10 Juice colour

The colour of the juice measured from 75 days after set (stage 8) showed an increase from 0.35 to 0.46 towards harvest (Bangalore crop). Gil *et al.* (1995) also reported the juice colour to increase with ripening. According to Dash (1983) the colour of aril visually observed from fruit initiation till maturity changed from wetery white to deep pink.

The colour intensity in the juice grown around Bijapur area was slightly low (0.30 OD) than in the juice of Bangalore crop (0.46 OD) at harvest. But no clear conclusions can be made since the colour of the arils in individual fruits vary. Kriventson and Arendth (1981) observed that the anthocyanins which give colour to the juice varied from 765 -200 mg/100 in intensively and pale coloured juices. Shulman *et al.* (1984) reported the colour of juice to vary in cultivar and growing conditions. He further reported that the accumulation of anthocyanins was enhanced at lower mean temperature and thus fruits in the coastal area were highly coloured. Gil *et al.* (1995) further reported the pigments to be smaller in those fruits with reddish skin than in yellow skined fruits.

**5.1.11 Moisture content of the rind and aril**

The moisture content of both rind and aril in crops under two conditions fluctuated highly during the development of the fruit. However, the rind moisture of the fruit slightly reduced at maturity (66.2 - and 60.4 per cent in Bangalore and Bijapur crops, respectively) as compared to the moisture content of rind at fruit set (69.6 and 61.8 per cent in Bangalore and Bijapur crops, respectively). The decrease in moisture content of the rind was also reported by Dash (1983). According to Gulhane and Gupta (1974) the moisture content in the developing guava fruits showed fluctuations in distinct growth stages. The decrease in the moisture content of rind at maturity may be due to removal of water by the increased solute concentrations in arils for osmotically balancing the sap concentration. And it might also be due to the influence of environmental conditions or the physiological status of the fruit. The moisture content of the rind in the crop grown under Bijapur at harvest was slightly lower (60.4%) than the moisture content of rind in Bangalore crop (66.60%). This may be due to the climatic variations influencing the growth of crop. Dash (1983) reported the moisture content of both rind and aril to vary in different cropping seasons.

The moisture content of the aril also showed fluctuations during its growth. It increased upto stage 5 and in later stages it gradually declined in both the crops. At harvest (80.2 and 82.0% in Bangalore and Bijapur crops, respectively) the moisture content of fruit slightly showed a reduced value than that at stage 2 (82.4 and 93.7% in

Bangalore and Bijapur crops, respectively). The decrease moisture content of aril may be due to higher accumulation of soluble solids at harvest. Dash (1983) reported an increase moisture content of arils at maturity. In sapota fruits Lakshminarayana and Subramanya (1966) reported a declining moisture content at the approach of fruit maturity.

**5.1.12 Titratable acidity**

There was a gradual increase in acidity upto stage 7 (i.e., 60 days of fruit set in Bangalore crop and at fruit diameter of 82.52 mm in Bijapur crop) followed by a decrease with the attainment of maturity. This observation is in confirmation with Prasanna Kumar (1986). According to Dash (1983); Arie *et al.* (1984) and Kumar and Purohit (1989) there was only a gradual decline in acidity during the growth in different cultivars of pomegranate. But in guava fruits, Gulhane and Gupta (1974) observed a gradual decrease upto 60 days after fruit set and then a gradual increase upto harvest (150 days after fruit set). The acidity of Bangalore fruit on 15th day of growth (stage 4) was 0.49 per cent and in Bijapur crop the acidity at stage 4 was 0.33 per cent. The acidity in fruits harvested from Bijapur was slightly low (0.35%) than the acidity of Bangalore crop (0.43%) at harvest and also during many stages of development of the fruit. Shulman *et al.* (1984) also reported that in cultivars 'wonderful' and 'Mule's Head' grown in two climatic conditions like the coastal plain and the valley region, the development of acidity in the same cultivar varied with the climatic conditions. This may be explained by the advanced ripening in fruits grown in a warmer valley and also due to low level of acid production at higher temperatures.

**5.1.13 Ascorbic acid**

The ascorbic acid content gradually increased during the development of the fruits under the two climatic conditions. Similar results on increase in ascorbic acid was reported by Dash (1983) in pomegranate cv. Jyothi and in mango by Gangwar and Tripathy (1973). During development of guava fruits ascorbic acid content showed an increase upto 120 days (Yusof and Mohamad, 1987; Gulhane and Gupta 1974).

Higher ascorbic acid content was observed in crop of Bijapur (17.9 mg/100 ml juice) at harvest as compared to Bangalore crop (13.7 mg/100 ml). This may be due to variations in the climatic conditions during the growth period.

**5.1.14 Total soluble solids (TSS)**

The TSS of the fruit measured at different stages of development in both the growing conditions showed an increase with increase in maturity of the fruit. Maximum accumulation of 16.7 and 17.2$^{O}$B was observed at harvest in fruits of Bangalore and Bijapur crops, respectively. Dash (1983) also reported the TSS to increase with ripening in cv. 'Jyothi' grown under Bangalore conditions.

The TSS of the fruit grown around Bijapur area was slightly higher than the TSS of crop under Bangalore conditions at harvest. The higher TSS according to Shulman *et al.* (1984) who observed differences of 14 to 15 per cent in 'Mule's Head' and 13 to 14 per cent in variety 'wonderful' grown in two different regions was due to advanced ripening with prevailing higher temperature in the valley region.

Sayed *et al.* (1988) also recorded TSS ranging from 9.1 to 15.2 per cent in variety 'Ycd-1'. The increase in TSS during maturation of fruit was also reported by Kumar and Purohit, 1989; Prasanna Kumar (1986) and TSS of upto 17.70 per cent was reported by Khodade *et al.* (1990) in pomegranate Sel-P.23 fruits. Raturi and Hiwale (1991) reported that the fruits got from Hastabhahar crop had highest TSS (17.94%) Arie *et al.* (1984) reported that in 'wonderful' variety of pomegranate the TSS was 15 when fruits appeared to be ripe in terms of quality under California conditions.

**5.1.15 Reducing - and total sugars**

Both the reducing -and total sugars increased continuously during fruit development and more so during ripening stages (i.e., 90-105 days of growth in Bangalore crop and at a fruit diameter of 82.52 mm to 113.07 mm in Bijapur crop). The increase in total sugars was maximum of 14.3 per cent in Bijapur crop as compared to Bangalore crop (11.0%) at harvest. Similarly the reducing sugars at harvest was 13.0 (Bijapur crop) and 11.0 per cent (Bangalore crop). The reducing sugars constituted more than 90 per cent of the total sugars probably because reducing sugars comprising of glucose and fructose was more than sucrose. This observation is supported by the report of Lee *et al.* (1974) that glucose and fructose are present in equal amounts in young fruits and only glucose at maturity.

The continuous increase in reducing - and total sugars were also reported by Lee *et al.* (1974); Khodade *et al.* (1990); Prasanna Kumar (1986) and Dash (1983) in different varieties of pomegranate.

The variations in the sugar contents between the two crops (Bangalore and Bijapur) may be due to differences in climatic conditions which are known to exert a profound influence upon the chemical composition of fruits and according to Nitsch (1955) in fruit growth studies it will not be possible to follow the chemical changes in the same fruit, but it is necessary to sample periodically a certain number of comparable fruits as the fruit development spreads over considerable period of time during which the weather often changes.

The increase in sugars towards maturity was reported by Gangwar and Tripathy (1973); Laxminarayana (1973); Pandey *et al.* (1979), Mazumdar (1976) in different mango varieties and in fruits of guava by Gulhane and Gupta (1974) and Yusof and Mohammed (1987).

**5.1.16 Maturity and harvesting**

The pomegranate fruit cv. Ganesh required about 105-110 days from fruit set i.e., after 10-12 days of anthesis to reach the stage of harvest maturity under Bangalore conditions and fruits under Bijapur conditions were harvested at their maximum size and optimum maturity of the fruit was decided by the physical indices like decrease in specific gravity, constant length and breadth of the fruit, reddish yellow colour of the rind with waxy shining surface, opening of calyx, uniformly deep red coloured soft and juicy arils, sweetness, freshness and by hearing to the specific sound when pressed by fingers and by the chemical characters like constant TSS, high sugar and low acid content. According to Shulman *et al.* (1984); Dash (1983) and Josan *et al.* (1979) the fruits reached harvest maturity 120 days after anthesis in different pomegranate cultivars. This difference can be attributed to differences in cultivar and the growing conditions.

**5.2 STORAGE OF FRUITS**

An investigation was made on the storage behavior of pomegranate cv.Ganesh, grown under two agroclimatic conditions (Bangalore and Bijapur) with the objective of retaining the freshness and extend the shelf life. The effect of precooling of the fruits, treating with 2 per cent semperfresh and wrapping in two types of shrink films namely, BDF 2001 and D955 and storing at 25, 15 and 8°C along with untreated control fruits on their shelf life and quality was studied. The quality of the fruit was determined by various physico-chemical parameters during different intervals of storage at different storage temperatures and sensory evaluation of the fruits at the end of storage.

The results obtained indicated that pomegranate being a non climateric fruit, harvested at ready to eat stage showed minimum changes in physico-chemical parameters during storage at both, room (25°C) and low temperatures of 15 and 8°C. The main problem during storage of pomegranate was to retain the harvest quality and freshness.

### 5.2.1 Physiological losses in weight (PLW)

During the year 1994 there was a slight increase in per cent PLW of fruits during 25 days of storage at RT in both the crops and at 15 and 8$^{o}$C after their maximum storage periods. The rate of increase was high at RT followed by 15 and 8$^{o}$C.

During the year 1995 there was a considerable increase in per cent PLW of fruits. The PLW of fruits in 1994 was very low than in year 1995. This was mainly due to packing of fruits in 100 gauge poly bags during storage kept in ventilated card board cartons. But during 1995 the fruits not packed in poly bags during storage exhibited a very high PLW per cent. Reduction in weight loss when kept in poly bags either at room temperature or at low temperature was reported in different fruits by Pota *et al.* (1981) and Joshua and Sathiamorthy (1993). Again the rate of increase in PLW (1995) was high at RT followed by 15 and 8$^{o}$C. Heikal (1968) reported high PLW at higher temperatures. Reduced weight loss in fruits at LT can be attributed to low temperature and high humidity which reduced the rate of moisture loss. The differences observed among the different treatments indicated a very high PLW in untreated control fruits as compared to other treatments at all the three temperatures and in both the crops. This was followed by pre-cooled and semperfresh treated fruits. Irrespective of crops, storage conditions, and storage temperatures, the film wrapped fruits showed less PLW as compared to unwrapped fruits (untreated, pre-cooled and semperfresh treatments). The beneficial effects of shrink wrapping in minimising the weight losses was also reported by Shivananda (1993).

In mango, Andres (1984) reported least weight loss percentage when stored in fully sealed plastic bags. The reduction in weight loss by wrapping with film can be attributed to the reason that the film acts as a barrier for moisture loss and also creates high humidity around the fruit thereby retarding the moisture loss. In present study, it was seen that PLW of film wrapped fruits at 25°C was slightly higher than the film wrapped fruit of LT (15°C) and minimum at 8°C. The combined effect of tissue paper wrapping and storing at low temperature in reducing weight loss was reported by Heikal (1966) in pomegranates. Thus maintenance of low temperature and high relative humidity along with wrapping is beneficial in reducing PLW to maximum extent. Kader *et al.* (1984) reported in pomegranate fruits, weight loss increased with storage temperature and duration. It was also seen that the PLW of the Bijapur crop was slightly higher than PLW of the Bangalore crop in both the years at all three temperatures at the end of storage period, particularly in untreated control fruits. This could be due to lesser rind thickness and higher moisture loss during storage of the Bijapur fruits.

This was further confirmed in the histological studies wherein the thickness of cuticle and epidermic as measured under ocular was lower than that of Bangalore fruits. According to Padule and Keskar (1989) in pomegranate fruits post harvest losses in weight were primarily due to the weight losses in rind tissues. pomegranate fruits are succesptible to water loss and should therefore be kept under 95% or higher relative humidity.

Precooling of fruits to lower temperature did not reduce the PLW and it showed more or less same PLW per cent as that of untreated control.

Semperfresh a skin coating chemical is known to reduce water loss in the different fruits by way of partially blocking the lenticells present on the skin. But in pomegranate the effect was not observed, perhaps, their apparently tough skin has numerous openings that permit free water vapour movement (Elyatem and Kader, 1984). In mango fruits waxing increased the shelf life and prevented the weight loss significantly (Joarder, 1980). However Onur and Arie (1986) observed maximum weight loss with waxol treatment under ordinary storage conditions.

**5.2.2 Rind weight**

At room temperature storage, rind weight decreased significantly from initial rind weight in untreated and semperfresh treated fruits as the storage period increased, during both the years and in both the crops. In film wrapped fruits it remained more or less the same. This was mainly due to more moisture loss from the rind tissue of unwrapped fruits where as in wrapped fruits this loss was controlled as indicated by low PLW.

The decrease in rind weight was more in 1995 than in 1994 in both the crops at the end of storage period because of the fact that in 1995, the fruits were not packed in poly bags. Similarly at 15 and 8$^{o}$C storage also, the rind weight showed a slight decrease towards the end of storage in both the crops in the unwrapped fruits while the wrapped fruits showed more or less constant rind weight.

The decrease in rind weight was higher at RT than at LT. This may be attributed to more loss of moisture from rind tissues due to higher temperature at RT and maintenance of less relative humidity in the storage atmosphere as compared to low temperature storage. The rind weight of Bijapur crop was slightly lower than the rind weight of Bangalore crop in the freshly harvested fruits which was an inherent feature of this crop. Further during storage, the loss of moisture being higher, the rind weight decreased more than that in Bangalore crop. The unwrapped fruits lost their shape and shrivelled due to reduction in rind weight and decrease in rind thickness.

Pota *et al.* (1981) showed that pomegranate fruits placed in plastic basket and held at room temperature for one week showed severe shrivelling and according to Shivananda (1993) fruits kept without wrapping showed desiccated appearance and were remarketable after 10 days of storage. Kader *et al.* (1984) reported that weight loss increased with storage temperature and duration of storage primarily due to loss of moisture from rind tissues. Saxena *et al.* (1987) reported that pomegranate fruits stored at low temperature of 0 - and 4.5$^{o}$C at 80-86 per cent RH did not undergo any shrinkage or spoilage for seven months. Koksal (1989) observed skin dehydration by storing fruits at ambient conditions.

**5.2.3 Rind Thickness**

The rind thickness at all the three temperatures decreased in all the treatments in both the years, in both the crops. The rind thickness of all the treatments in year 1994 was slightly higher than in the year 1995 because in 1994 the fruits were packed in poly bags and lost less moisture from their rind tissues. Irrespective of crops the decrease in rind thickness was more in untreated fruits than the decrease in wrapped fruits because they were completely unprotected from moisture loss by any post harvest treatment. Next to follow it was the pre-cooled and semperfresh treated fruits. The rind thickness of both the wrapped fruits either remained same or slightly decreased and between them not much differences were observed. The rind thickness of Bijapur crop was slightly lower than that of Bangalore crop at the beginning storage and also throughout the storage period. This is because of differences in the climatic conditions during the growth and development of the fruit where the temperature in Bijapur are generally higher than in Bangalore. Irrespective the treatment, higher decrease in thickness of rind was observed at RT followed 15 and $8^{o}C$.

The histological sections of rind of untreated fruits during storage further showed that the cells were highly shrunken causing higher reduction in rind thickness as compared to rind of film wrapped fruits. Koksal (1984) reported skin dehydration by storing fruits at ambient conditions. Shivananda (1993) also reported reduction in rind thickness of pomegranate when stored at RT and LT.

### 5.2.4 Firmness

There was a decrease in the firmness of fruits of both Bangalore and Bijapur area with increase in storage period at all the three storage temperatures. The decrease in firmness of the fruits may be due to the loss of cementing material or loss of elasticity of cells in the rind.

In Bangalore crop, the firmness of the fruit at the beginning of storage was 12.8 $Kg/cm^2$. It decreased to a range of 9.6-12.5 $KG/cm^2$ (RT) and 9.5-11.2 $KG/cm^2$ ($8^oC$) after 25 days and 12 weeks storage, respectively. AT $15^oC$ it varied from 7.6-10.7 $Kg/cm^2$ after 10 weeks of storage as compared to initial firmness of 13.1 $Kg/cm^2$. In the fruits of Bijapur the firmness on the day of storage was 12.3 $Kg/cm^2$. The decrease was in the range of 10.1-11.9 (RT), 8.2-11.9 ($15^oC$) and 8.0-9.9 ($8^oC$) $Kg/cm^2$ at the end of 25 days, 10 and 12 weeks of storage, respectively. No statistical differences were observed at RT storage in both the crops. At $15^oC$ differences (Bangalore crop) in firmness was significant during different storage periods. At $8^oC$ the Bijapur crop showed significant differences among different storage periods. The decreases in firmness of fruits were less at LT storage as compared to RT storage, perhaps due to more retention of moisture in fruits at LT storage. The fruits of Bijapur showed less firmness as compared to fruits of Bangalore crop. This may be due to more loss of moisture and thinner rind in Bijapur fruits.

It could be concluded that, the measurement of firmness of the rind during storage could not indicate clearly the freshness of the fruit as it was observed that unwrapped fruits, even though with tough rind and desiccated appearance showed the same firmness reading as that of the film wrapped fruit which had fresh appearance with soft rind. *Shivananda (1993) reported a decrease in firmness of* fruits at LT and RT. According to Ketsa *et al.* (1992) there was no difference in firmness between wrapped and non wrapped fruits.

**5.2.5 Aril Weight**

During the storage period there was a slight increase in the aril weight of unwrapped fruits while the wrapped fruits showed more or less same aril weight as at the beginning of storage at all the three storage temperatures in both the crops. However, the observed increase in aril weight did not show any statistical differences. Since the per cent and weight was calculated based on whole fruit weight, the increase in aril weight might be related to the decrease in the peel weight because of more moisture loss. Due to the same reason the aril weight in wrapped fruits did not alter much since less moisture loss was observed in the whole fruit resulting in maintenance of fruit weight. Shivananda (1993) also observed an increase aril weight in pomegranate fruits of control treatment at RT.

At 15$^{o}$C and 8$^{o}$C the increase in aril weight of fruits was less than at 25$^{o}$C again because of less moisture loss from the rind tissues at LT. The aril weight of fruits varied differently from the two growing conditions. In different cultivars of pomegranate aril weight at harvest was reported to vary from 52.3 per cent to 68.3 per cent according to Sood *et al.* (1982).

**5.2.6 Juice content**

There was a slight increase in juice content in fruits of all the treatments during storage of pomegranate at all the three temperatures and in both the crops. However the statistical analysis of the observed increase did not show any significant differences in both the crops.

The fruits of untreated control and semperfresh treatment showed a higher increase in juice content at the end of storage as compared to wrapped fruits irrespective of storage conditions. The increase in juice content can be correlated with the reduction in rind thickness resulting in its reduced weight due to dessication. Higher increase in juice content was observed at RT than at LT. The juice content of Bijapur fruits was slightly more than that in fruits of Bangalore crop at harvest and also during storage. Cemeroglu *et al.* (1988) reported the juice yield to vary from 29-60 per cent in different cultivars of pomegranate while Sayed *et al.* (1985) recorded 74.8 per cent juice in cv. Ycd-1.

**5.2.7 Seed content**

Seed content although increased slightly did not show any significant differences. This was also true at all the three storage temperature in both the crops. The increase in seed weight can be correlated with increased aril and juice content during storage due to reduction in rind weight and rind thickness.

Studies made by Malhotra *et al.* (1983) and El-nnemr *et al.* (1990) in different cultivars of pomegranate fruits at harvest indicated 14 to 22 per cent and 12 per cent seed weight, respectively, Shivananda (1993) reported an increase in seed weight during storage at room temperature and low temperature.

**5.2.8 Respiration of Pomegranate**

The rate of respiration was high at the beginning of storage and it gradually decreased towards the end of storage period. There was no climateric peak in respiration after harvest. The decrease in rate of respiration towards the end may be due to the less metabolic in the fruit.

The rate of respiration decreased in both the unwrapped and wrapped fruits with the increase in storage period. The rate of respiration in unwrapped fruits was higher as compared to wrapped fruit during early part of storage and during the later part the rate of respiration in wrapped fruits was higher than the unwrapped fruits. This may be due to low PLW rate of wrapped fruits. Shivananda (1993) reported a higher respiration rate of unwrapped fruits during storage at RT and LT than those of wrapped fruits.

### 5.2.9 Juice Colour

Colour as measured by changes in optical density (OD) of the juice in both the crops gradually decreased towards the end of the storage period at all the three temperatures. An increase in colour intensity of the juice upto and after harvest in 'wonderful' pomegranate was reported by Arie and or (1984). However the decrease in juice colour from the Bijapur crop was slightly lower than that of the Bangalore crop at all the temperatures of storage. In Bangalore crop the juice colour was in range of 0.35-0.37 (RT), 0.34-0.41 (15) and 0.32-0.36 (8$^{o}$C) after 25 days, 10 and 12 weeks, respectively after storage. In Bijapur crop the juice colour varied from 0.33-0.37 (RT) 0.31-0.35 (15$^{o}$C) and 0.33-0.38 (8$^{o}$C) after 25 days,10 and 12 weeks of storage, respectively. Statistically no difference were observed at RT and 8$^{o}$C. At 15$^{o}$C storage colour intensity showed a significant differences for Bijapur fruits at different storage periods. Elyatem and Kader (1984) observed no changes in juice colour when pomegranate fruits were exposed to exogenous ethylene treatment. Kader *et al.* (1984) observed an increase in colour intensity of the juice during maturation and ripening of pomegranate. The present results are in agreement with the studies of Shivananda (1993) who also reported a decline in the colour of juice towards the end of storage at RT and LT.

**5.2.10 Rind moisture content**

There was a significant decrease in the moisture content of rind of unwrapped (untreated pre-cooled and semperfresh treated) fruits in both the crops at all the three storage temperatures in both the years. The rind moisture in wrapped fruits remained more or less the same.

In Bangalore crop (1994) the initial rind moisture was 68.1 per cent and it decreased to a range of 51.4 to 67.8 at RT after 25 days of storage and at $15^{o}$ and $8^{o}C$ it varied from 59.8-69.9 and 65.2-66.9 per cent, respectively after their storage periods of 12 and 14 weeks. In fruits of Bijapur (1994) in initial rind moisture was 68.7 per cent and it varied in a range of 45.4-72.0 (RT), 64.9-70.3 ($15^{o}C$) and 61.4-67.5 ($8^{o}C$) after 25 days, 8 and 12 weeks storage, respectively.

Statistically the differences among treatments and storage period was significant in Bangalore crop and for only treatments in Bijapur crop at RT storage. At $15^{o}C$, the differences were non significant in Bijapur crop and significant in Bangalore crop during different storage periods. At $8^{o}C$, the storage periods was significant in both the crops and among treatment in Bijapur crop.

In the year 1995 when the fruits were not packed in poly bags the loss of rind moisture increased as compared to the 1994 data in both the crops at all the three storage temperatures. Maximum decrease in moisture was observed in unwrapped fruits. The moisture of the wrapped fruits remained more or less same.

In Bangalore crop (1995) the initial rind moisture was 68.3 per cent. It decreased in different treatments in a range of 35.2 to 66.3 (RT) and 57.3-70.7 (8$^{o}$C) at the end of their respective storage period. At 15$^{o}$C it varied from 52.5-63.4 per cent as against 70.0 per cent at the start of storage. In fruits of Bijapur crop the initial moisture of rind was 67.3 per cent and it varied from 31.5-62.6 (RT). 40.8 to 65.4 (15$^{o}$C) and 47.8-63.9 (8$^{o}$C) per cent after 25 days, 10 and 12 weeks of storage, respectively. Statistically these differences were significant at all the three storage temperatures in both the crops.

The decrease in rind moisture of unwrapped fruits was because of more loss of moisture from their rind tissues as seen in increased PLW and higher decrease in rind thickness at all three temperatures. The shrinkage or the deformed shape of pomegranate in unwrapped fruits during storage was also the cause for the decrease in rind moisture.

The retention of rind moisture in wrapped fruits irrespective of crops could be due to the protection by a moisture barrier film which created a humid atmosphere inside the film. This is also evident by the lower decrease in PLW and rind thickness of wrapped fruits irrespective storage temperatures. This is further supported from the histological studies that the shrinkage of tissue cells in wrapped fruits was less as compared to the unwrapped fruits.

The unwrapped fruits of Bijapur crop showed a higher decrease in rind moisture probably due to its lesser rind thickness. This is further evident from higher PLW and higher decrease in rind thickness of Bijapur fruits irrespective of temperatures and year. However between the wrapped fruits of both the crops the rind moisture was more or less same.

Maximum rind moisture decrease was observed in untreated fruits followed by pre-cooled fruits irrespective of growing area and temperatures of storage. This was because they were completely unprotected as compared to semperfresh treated fruits.

### 5.2.11 Titratable Acidity

There was a considerable reduction in titratable acidity of the fruits in all the treatments and at storage temperatures of 25, 15 and 8$^{o}$C in both the crops. The results obtained are in conformity with the observations made by Kader *et al.* (1984); Koksal (1989) and Padule and Keskar (1989) in different cultivars of pomegranate.

The acidity on the initial day of storage was 0.51 in Bangalore crop and it decreased in a range of 0.38-0.44 per cent at RT and 0.31-0.38 per cent at $8^{o}C$ after 25 days and 12 weeks storage, respectively. At $15^{o}C$ the variation was 0.31-0.36 per cent as compared with the initial value of 0.47 per cent. In Bijapur crop, the acidity at the beginning of storage (at harvest) was 0.40 per cent and after 25 days of storage the decrease varied from 0.35-0.38 per cent. The decrease in acidity was in the range of 0.31-0.35 and 0.30-0.38 per cent at 15 and $8^{o}C$, respectively after 10 and 12 weeks of storage. Statistically no differences were observed at RT storage in both the crops. At LT storage the differences between the storage intervals was significant.

Arie and OR (1984) and Elyatem and Kader (1984) observed insignificant changes in titratable acidity after harvest in 'wonderful' pomegranate cultivar while Shivananda (1993) reported significant changes in cv. 'Ganesh'.

The reduction in acidity may be due to the activities of carboxylase and like enzymes which are closely associated with the Respiration rate and also due to the utilization of acids during respiration.

The acidity of the Bijapur fruits was slightly lower the the acidity of Bangalore fruits at harvest and during storage irrespective of storage temperature. Shulman *et al.* (1984) reported the acidity to vary with different variety and different growing conditions.

**5.2.12 Ascorbic acid**

There was an insignificant increase in ascorbic acid content at RT storage at the end of 25 days storage in both the crops. At LT storage a slight decrease was noticed towards the end of storage in both the crops. A slight decrease in ascorbic acid content of pomegranate was also reported by Heikal (1966)

The ascorbic acid in fruits of Bangalore crop at the beginning of storage was 5.12 mg/100 ml and decreased to a range of 15.0-14.8 mg/100 at RT and 8$^{o}$C after 25 days and 12 weeks of storage, respectively. At 15$^{o}$C the decrease varied from 15.1-11.4 mg/100 ml as compared to initial value of 15.6 m/100 ml. In fruits of Bijapur crop the ascorbic acid at the beginning of storage was 19.4. The decrease was in the range of 16.7-15.7 at RT, 1.8-15.8 at 15$^{o}$C and 16.6-15.6 at 8$^{o}$C after25 days, 10 and 12 weeks of storage, respectively.

The results were non significant among the treatments and storage period at RT in both the crops. At 15$^{o}$C the differences among the treatments in Bangalore crop and among the storage periods in Bijapur crop were found to be significant. At 8°C the differences between the storage period were significant in both the crops.

Koksal (1989) reported significant losses in vitamin C content in pomegranate fruits (cv. GokBaghe) at higher temperature but at 1°C storage retention was better.

The decrease in ascorbic acid content during storage may be due to oxidative reduction of ascorbic acid in presence of molecular oxygen by ascorbic acid oxidase (Shivananda, 1993). The ascorbic acid in the Bijapur fruits was slightly higher than in the Bangalore crop at harvest and during storage. These variation may be attributed to the different agro climates during growth. A ascorbic acid content as low as 5.60 to 7.72 mg/100g was reported by Sood *et al.* (1982) while Sayed *et al.* (1986) recorded as high as 15 mg/100g in pomegranate fruits.

### 5.2.13 Total Soluble Solids (TSS)

There was a slight decrease in TSS content of fruits in all the treatments with an increase in storage period in both the crops at RT. Similarly at 15 and 8°C the TSS decreased at the end of their storage periods. However significant differences were not observed at RT and 15°C in both the crops. At 8°C the differences in storage interval was significant in Bijapur crop only.

Initial TSS content was 15.7°B in Bangalore crop and it varied to a range of 13.6-14.6°B after 25 days at RT and to 13.8-12.9°B after 12 weeks at 8°C.

Padule and Keskar (1989) reported a decrease in TSS in 'Ganesh' cultivar during storage, while Koksal (1989) showed an increase in TSS content in cv. Gok Baghe and Shivananda (1993) in cv. Ganesh at RT and LT storage. This increase in TSS was attributed by them to loss of moisture resulting in concentration of the TSS. But Arie and OR (1984) found that optimum maturity for commercial harvest in pomegranate cultivar 'wonderful' fruits was fixed when TSS of 15 per cent was attained and there was no further change after harvest. A TSS as low as 9.8 to 12.3 per cent and as high as 17-19 per cent in different pomegranate cultivars was reported by Malhotra *et al.* (1982) and Shi (1991).

### 5.2.14 Reducing Sugars

There were minimum changes in reducing sugars at RT storage in both the crops after the end of storage period (25 days). But at 15°C the reducing sugars slightly increased in both the crops. At 8°C the reducing sugars either decreased or increased. The reducing sugars at RT was in the range of 13.3 to 13.9 per cent in Bangalore crop and 12.0-12.5 per cent in Bijapur crop after the end of 25 days storage. AT 15$^{o}$C after a storage period of 10 weeks the Bangalore crop had reducing sugars in the range of 11.8-13.2 per cent and 11.8-12.2 per cent in Bijapur crop. AT 8$^{o}$C it was in range of 11.8-13.1 per cent (Bangalore crop) and 11.3-12.8 per cent (Bijapur crop). Statistically no differences among the treatments and storage periods were observed at all the three storage temperatures in both the crops.

Padule and Keskar (1989) reported an increased reducing sugar content in pomegranate fruits at ambient storage conditions. However, Shivananda (1993) reported a decreased reducing sugars at storage in RT and LT. Sood *et al.* (1982) reported the reducing sugars to vary from 5.6-7.53 per cent. In the present study the reducing sugars constituted a major portion of the total sugars. Malhotra *et al.* (1983) reported the reducing sugars the vary from 5.7 to 10.2 per cent and the reducing sugars constituted about 90 per cent of total sugars and attributed it to be a genetic characteristic of the fruit.

**5.2.15 Total Sugars**

The total sugars at RT storage slightly decreased or remained more or less the same as found at the beginning of storage i.e., 13.5 and 12.3 per cent in Bangalore and

Bijapur fruits, respectively. At the end of 25 days storage the total sugars were in the range of 13.2-13.6 per cent (Bangalore crop) and 12.4-13.4 per cent (Bijapur crop) at RT storage.

At 15$^{o}$C the total sugars slightly increased or remained more or less the same depending on the treatments. These were 12.5-13.2 per cent in Bangalore crop and 12.0-12.9 per cent in Bijapur crop after 10 weeks of storage. AT 8$^{o}$C the total sugars decreased with increased storage period in both the crops. However, the differences in total sugars among the treatments, storage period and interactions were non significant at all the three storage temperatures in both the crops.

Shivananda (1993) reported a significant increase in the total sugar content at room temperature while it was not significant at low temperature storage.

**5.2.16 Browning of arils**

Browning of arils during storage was observed irrespective of storage temperatures and post harvest treatments in both the crops and the per cent of browning varied in different treatments. Browning of arils was observed from 5 days of storage to 12 weeks of storage either at RT or LT in both the crops in different treatments. The percentage of browning (Bangalore crop) was more in the untreated control both at RT and LT storage. The percentage brown arils varied from 0.5 to 9 depending on the treatments and storage temperatures. Similarly in fruits of Bijapur crop, higher percentage of browning was observed in untreated fruits at both RT and LT storage and varied from 0.5 to 10 per cent. The percentage of brown arils were more in Bijapur fruits than in Bangalore fruits at all the three storage temperatures. The percentages of brown arils increased towards the end of storage period at LT. However, in the present investigation a close correlation of browning with the temperature of storage could not be seen.

In the portion of the fruit where brown arils were present the firmness of the rind reduced significantly. Histological study of brown arils showed that the cells of testa had distorted with accumulation of certain brown bodies.

**5.2.17 Shelf life of pomegranate**

One preliminary study in cultivar 'Ganesh' regarding the optimum low temperature for maximum shelf life indicated that storage at 5$^{\circ}$C resulted in chilling injury symptoms and it has to be stored at higher than 8$^{\circ}$C for longer shelf life. Besides 8$^{\circ}$C storage, comparative shelf life was also determined at 15 and 25$^{\circ}$C.

Elyatem *et al.* (1984) have reported that fruits could be stored at $0^{o}C$ for 2 months but according to Kader *et al.* (1984) the minimum safe temperature was more than $10^{o}C$ for longer storage.

In the present study it was observed that the maximum shelf life of pomegranate fruits varied from 25 days to 14 weeks depending on the temperature of storage and post harvest treatments. In Bangalore crop at RT storage maximum shelf life was 25 days when the fruits were individually wrapped with shrink film. The unwrapped fruits packed in poly bags (1994) were marketable upto 15-18 days whereas the unwrapped fruits without packing in poly bags were acceptable only upto 12 days only. Effect of polythene film covering for enhancing the shelf life of sapota fruits was also reported by Joshua and Sathiamorthy (1993). Film wrapping of fruits could successfully retain the harvest freshness upto 25 days with or without keeping in poly bags.

Similar observations were made in fruits of Bijapur crop also in case of wrapped fruits. But unwrapped fruits either packed in polybags or not were marketable only upto 10-12 days.

Non packed fruits stored at $28^{o}C$ had a higher storage life of 2-3 days as compared to 5 days for packaged fruits (Maharaj and Sankat, 1990).

The effect of treatments on shelf life also showed variations at 15$^{o}$C. Maximum shelf life of Bangalore crop varied from 10-12 weeks for wrapped fruits where as the unwrapped fruits when packed in poly bags were marketable for 9 weeks and without packing in poly bags they were marketable upto 7 weeks only. Since the fruits in the year 1995 were not packed in poly bags marketability of the fruits slightly reduced for unwrapped fruits. The film wrapped fruits either packed in poly bags or not shelf life almost remained the same, but the appearance of the fruits without poly bags was slightly dull but not desiccated, hard or deformed.

In Bijapur fruits the maximum shelf life varied from 8-9 weeks for wrapped fruits and from 5-7 weeks for unwrapped fruits. The untreated fruits not packed in poly bags had very hard and deformed or misshaped fruits.

At 8$^{o}$C the maximum shelf life was 12 to 14 weeks depending on the treatments. The unwrapped fruits of Bangalore crop were marketable upto 8-10 weeks. In Bijapur crop the marketability of unwrapped fruits was for 6-8 weeks. In the wrapped fruits the differences in marketability between the Bangalore and Bijapur crops was negligible at all the three storage temperatures.

In general the fruits without film wrap could be kept for 10-15 days at RT, for 6-7 weeks at 15$^{o}$C and for 8-10 weeks at 8$^{o}$C. The film wrapped fruits could be stored for 25 days at RT, for 10 weeks at 15 and for 12 weeks at 8$^{o}$C. The crop harvested from Bangalore conditions could be kept for longer period than the fruits of Bijapur. The sensory attributes of Bangalore crop was better as compared to Bijapur crop, especially at LT.

The best temperature for storage of pomegranate cv. 'Ganesh' was determined as 8$^{o}$C, where in the fruits maintained good sensory characters and acceptability. Among the post harvest treatments, individual shrink film wrapping was found to be the best treatment for retaining the freshness of the fruit.

**5.2.18 Spoilage of fruits**

There was considerable variations with regard to the spoilage of pomegranate fruits in different treatments and at different storage temperatures after their respective storage period.

In Bangalore crop during 1994 at RT storage, the cumulative spoilage of fruits after 15 days of storage was seen only in untreated control fruits. But at the end of storage that is after 25 days, spoilage percentage in untreated was maximum (22.2 per cent) as compared to wrapped fruits (8.33 and 16.6 per cent in BDF 2001 and D055 films, respectively). Similarly at $15^{o}C$ and $8^{o}C$, there was no spoilage upto 6th week of storage and at the end of 12 and 14 weeks spoilage of fruits varied from 20-30 per cent, respectively depending upon the treatments. Film wrap D955 showed higher per cent of spoilage as compared to BDF2001.

During the year 1995, Similar observations were made at both RT and LT. At RT, maximum spoilage was recorded in semperfresh treated fruits (16.6 %) while minimum of 12.5 per cent was recorded in BDF 2001 film wrapped fruits. AT LT (15 and $8^{o}C$) the spoilage of fruits varied from 20-25 per cent after 10 and12 weeks of storage, respectively depending on the treatments.

In Bijapur crop (1994) at RT storage after 15 days spoilage was observed in all the treatments varying from 16-20 per cent which enhanced during 25 days storage to 20-30 per cent. At LT storage spoilage upto 5 per cent was seen on 6th week storage itself and it increased upto 20 per cent at the end of 8 to 10 weeks of storage. During 1995, similar observations were made at both RT and LT storage.

At both RT and LT storage the spoilage of fruit was more in Bijapur crop as compared to Bangalore crop may be because of more loss of moisture in the former. The untreated fruits showed more spoilage than other treatments during early storage period. Towards the end of storage more spoilage was observed in wrapped fruits. This may be due to higher condensation of moisture creating higher RH inside the films favouring development of fungi. But without film wrapping the fruits were extremely shriveled and deformed, especially when packed without poly bags (1995). The higher percentage spoilage of unwrapped fruits at RT may be due to influence of higher temperature and minimum spoilage of wrapped fruits could be due to retention of freshness. The spoilage of fruits is mainly due to fungi *Aspergillus niger* and *Aspergillus flavus* (Padule and Keskar, 1989). Shivananda (1993) reported minimum spoilage of wrapped pomegranate fruits at LT storage than at RT.

**5.2.19 Sensory evaluation**

Among the post harvest treatments used for retaining the quality and extending the shelf life, individual shrink film wrapping was found to be the best. The overall performance of fruits wrapped with film was found to be highly satisfactory in maintaining harvest freshness which imparted good appearance, colour of arils, taste and juice at all the three storage temperatures, at the end of storage period which was 25 days at RT, 8-12 weeks at 15$^{o}$C and 12-14 weeks at 8$^{o}$C., Similar advantageous effects of film wrapping of fruits was reported by Miller in different fruits while Shivananda (1993) further reported that at both RT and LT storage, fruits kept without wrapping showed desiccated appearance while the wrapped fruits were fresh. In the present study also untreated control fruits had a desiccated, deformed, unacceptable appearance with good aril colour, acceptable taste and flavor. The fruits lost glossiness and freshness at all the three temperatures in both crops. The reason was mainly due to maximum moisture loss as they were completely unprotected and without any post harvest treatments.

The pre-cooled fruits were on par with untreated fruits in sensory evaluation. The semperfresh treated fruits had a slightly better characters as compared to untreated and pre-cooled fruits. The scoring for appearing of fruits from Bijapur was less than that of Bangalore fruits.

The score for appearance was significant at all the three temperatures in both the crops. Among the other sensory characters the differences between the two crops were negligible. The fruits held at 8°C had better sensory characters for both the crops, followed by those stored at 15 and 25°C.

**5.3 HISTOLOGY OF FRUITS**

The pomegranate fruit being a non climacteric fruit does not undergo much changes during storage (Shulman, 1984). A very much noticeable change is in its form or PLW. The fruits during storage irrespective of temperature maintained, lose their weight (Kader *et al.* 1984) reduce in rind thickness and become deformed/shrunk. According to Padule and Keskar (1989) in pomegranate the loss in weight of fruit is primarily due to the weight loss in rind tissues. Elyaten and Kader (1984) reported that pomegranates are succesptible to water loss because their apparently tough skin has numerous openings that permit free water vapour movement. Shivananda (1993) reported that although the rind of pomegranate desiccated during storage, the quality of aril inside was good, fleshy and acceptable.

An attempt to study the histology of rind and aril showed that the general structure of pomegranate rind observed irrespective of growing conditions are similar to that reported by Griffiths (1935).

The rind comprises of an outer epidermis with a few stomata and beneath it are rows of collenchymatous cells. The tissue then consists of a thin walled parenchyma through which run fibrovascular strands. The inner epidermis separates the aril containing zone from the rind.

In the parenchyma are scattered numerous sclerenchymatous cells (stone cells, sclereids). The outer epidermis consists of cutinised outer wall and the collenchymatous tissue shows occasional intercellular spaces which neither contain stone cells nor fibrovascular strands. The sclereids occur singly and/or in groups with very irregular shape and size. Some of the parenchymatous cells contains 6-14 starch grains.

**5.3.1 Outer epidermis**

On the day of fruit set, the epidermis of the rind from Bangalore and Bijapur grown crops had a thickness of 27.50 and 18.70 um, respectively. As the fruit grew, the thickness increased and at harvest however the crop from Bijapur area had a slightly thicker epidermis (48.40 um) than Bangalore grown crop (45.83 um). This differences may be due to the differences in weather/climate and the growing conditions. According to Rotaru *et al.* (1989) the different varieties of apple had some features in common but there were differences between varietal groups and even between varieties within the varietal groups.

The histology of the rind grown from the two different conditions revealed that the thickness of the epidermis in the unwrapped fruits reduced after 15 days of storage while that of the wrapped fruits increased slightly. After 25 days of storage, this behavior was more pronounced. The decrease in epidermal thickness can be attributed to rapid loss of moisture from these unprotected fruits. The increase in epidermal thickness of wrapped fruits could be because of the periclinal division of cells making it a 2-3 layered structure. Further, the moisture loss from the wrapped fruits was low creating high humidity atmosphere inside the film and hence the weight loss of rind was minimum as also seen in two PLW percent during storage.

The thickness of epidermis of Bijapur crop was more than that of Bangalore crop after 30 days of storage in all the treatments. According to Ketsa (1990) Knieowaan tangerines with thick peel when stored at ambient temperature had significantly greater peel fresh weight, peel thickness and number of stomata than those of the thin peel tangerines. They suggested that the thickness of flavedo and number of stomata to be the factors affecting weight loss.

**5.3.2 Outer cuticle**

The cuticle thickness increased with advancement in maturity of both the crops and reached 19.25 um (Bangalore crop) and 16.50 um (Bijapur crop). But the thickness of cuticle from Bijapur crop (16.50 um) was slightly lower than that of the Bangalore crop (19.25) at harvest. It may be because of the factor that the rind thickness of Bijapur (0.35 cm) crop at harvest was less than that of the Bangalore crop (0.40 cm) by way of more moisture loss in the presence of thinner cuticle. Also the slight higher mean maximum temperature of 35.8$^{o}$C prevailing in Bijapur conditions (Appendix II) might have caused more water loss from rind resulting in low rind thickness at harvest.

Miller (1982) reported a good correlation between the development of cuticle and general fruit growth. Rosenquist and Morrison (1989) reported that the cultivar, sun exposure and irrigation rates are the factors affecting accumulation of cuticle on grape berries.

The thickness of the cuticle at the beginning of storage was 19.25 in Bangalore crop and 16.50 um in Bijapur crop. After 15 days of storage the cuticular thickness decreased slightly in unwrapped fruits in both the crops while it remained almost the same in wrapped fruits. But after 25 days of storage the cuticle thickness decreased in all the treatments from the crops grown under both the conditions. However, the thickness of cuticle was slightly higher in Bangalore crop than that of Bijapur crop in all the treatments.

Shantha Krishnamurthy and Joshi (1989) reported that the epicarp of the mature Alphonso mango fruit had a thick waxy cuticle which became thinner during ripening when fruits were stored at 30$^{o}$C for 15 days. The decrease in cuticle also is a factor in causing reduction in peel thickness and for shrinkage of cells again due to loss of moisture from the cells.

### 5.3.3 Collenchyma cells

The length and breadth of collenchyma cells in the rind increased with the growth of fruit irrespective of growing conditions. The size of the cells increased from fruit set to the harvest period because of the enlargement of cells concomitant with the growth of the fruit. This is further supported by the fact that there is a linear increase in length, breadth and weight of the fruit during growth and development as reported by many workers and also in the present study on growth (Tables 1 and 2). The length of collenchyma cells (61.50 um) from the crop under Bijapur conditions at harvest was slightly higher than that of the cells from the Bangalore harvested crop (57.50 um).

The length and breadth of collenchyma cells decreased in all the treatments in the crops grown from both the areas after 15 - and 25 days of storage. The size of the cells decreased with progression in storage period causing the lateral compression of cells. The decrease was due to loss of firmness in the rind with loss of freshness and elasticity of cells.

### 5.3.4 Parenchyma cells

The length and breadth of parenchyma cells in the rind increased with the growth of the fruit irrespective of growing condition. Similarly the size of the cells increased from fruit set to the harvest period because of the enlargement of cells concomitant with the growth of the fruit.

The breadth (55.00 um) of parenchyma cells from the crop under Bijapur conditions at harvest was slightly higher than that of the crop under Bangalore conditions (52.80 um). The size of the cells was slightly larger in Bijapur crop than that of the Bangalore crop at harvest. This larger size of cells might have provided larger surface area to lose more moisture and thus causing a higher reduction in rind thickness making the fruit very hard.

The size of parenchyma cells was smaller in Bijapur grown crop than that in the crop grown under Bangalore conditions during the storage period of 15 and 25 days due to more loss of moisture through the tissues.

### 5.3.5 Starch grains

The accumulation of starch grains started at stage 7 (on 60th day after fruit set) in Bangalore crop and at stage 6 (fruit diameter of 67.72 mm) in Bijapur crop during growth. Saini *et al.* (1972) observed in a histochemical study of Dashehari and Chausa varieties of mango that the starch grains were major cell constituents of mesocarp after 60 days of fruit set and their number per cell increased upto maturity which might be accounted for increase in fruit weight. However in pomegranate rind, the starch number decreased with maturity and at harvest the cells had 8 to 10 grains. This may be due to its non climacteric nature, where the fruits start ripening on the tree itself. Tissue samples of apple cv. Jongold harvested from intervals May-September and studied showed that the starch content was higher and decreased at a lower rate in the outer part of flesh than the inner and middle parts below the skin. The cell contents (mainly starch) were lost after 15 days of storage in all the treatments and did not reappear on 25th day of storage. The degrading of starch reserves in mango mesocarp cells during 15 days storage was reported by Shantha Krishnamurthy and Joshi (1989). The loss of starch grains during storage was due to the deposition of hemicellulose, phenolics and tannins by the utilization of starch for thickening of the cell corners during storage period.

**5.3.6 Compression of cells**

The length, breadth and size of both the types of cells decreased in all the treatments after 15 days of storage. At 25 days after storage the decrease further was more. The decrease in size of the cells caused the lateral compression of cells. Severe shrinkage was observed in untreated fruits probably because they were unprotected and lost most of their rind weight due to higher moisture loss as reported by many workers. This is further confirmed by the data available on the increase in PLW percent, higher reduction - in rind weight, rind thickness and rind moisture loss during storage. The compression of semperfresh treated fruits was slightly less than that of the untreated. Between the wrapped fruits not much differences were noticed both by histological and non-histological studies. In the film wrapped fruits, the moisture loss from the rind was low because of the high humidity created inside the cover as reported by many workers. Hence the compression of cells was minimum.

The size of both the types of cells was smaller in Bijapur grown crop than that in the crop grown under Bangalore condition during the storage period of 15 and 25 days. This indicates that the cells from Bijapur crop had shrunk more as compared to those from Bangalore crop. This may be due to their large cell size which might have provided more surface area for the higher loss of moisture and thus reducing the cell size. This result is further supported by more reduction in rind thickness and moisture loss under storage studies.

### 5.3.7 Surface view of epidermis

The epidermis, from the surface view at harvest, showed the healthier cells with stomata scattered. At room temperature storage, few stomata were closed and few remained open after 25 days of storage in all the treatments. The epidermal cells in untreated control were more shrunken than those of wrapped fruits which may be again due to loss of more rind weight. According to Barsy *et al.* (1989) who studied aging in Golden Delicious apples during 7 months of storage, the cells of the skin were healthy whereas flesh cells had already begun to age.

The cells had accumulated certain brown depositions/ substances which are probably phenolics or tannins. The epidermal cells surrounding the stomata had larger depositions than other cells Griffiths (1935) also reported the sections of dried rind material to exhibit bright yellow plates and mass of tannins filling the cells. However, the fruits wrapped had less accumulation of such brown subustances than the unwrapped fruits. The accumulation of phenolics in the skin coated fruits (semperfresh 2%) was less than that of the untreated fruits but more than the wrapped fruits. In the fruits of control the accumulation of black bodies was higher as compared to other treatments.

The stomata of the stored fruits although few in number kept open, appeared to have been compressed in all the treatments. Fruits from several plantain and cooking banana cultivars assessed for their stomatal size and densities were related to weight loss during the post harvest period by Burdon *et al.*(1994). They reported that there was no correlation between weight loss and the density or the size of the stomata on the fruit peel. But according to Collin and Folliol (1990) who examined the epidermis of plantains before and after storage, reported that in fruits kept at 100 per cent RH the stomata closed indicating that stomatal closure alone was not a reliable guide to moisture stress within the fruit. Ketsa (1990) reported the number of stomata to be a major factor affecting weight loss.

### 5.3.8 Aril histology

In the present study, the occurence of the brown discoloured aril was a regular feature which increased with storage. The juicy pink arils at harvest had fleshy testa cells intact and a few starch grains scattered in the testa. In slightly brown discoloured arils the cells were distorted and lost their integrity and in a completely brown colourded aril this behaviour was more pronounced. The starch grains were also lost. Parikh *et al.* (1990) reported that the cells in the pulp of mango fruit were large and parenchymatous in nature and lost their integrity at ripe stage due to cell hydrolysis. They also reported starch degradation during ripening.

Mortenego de Carrillo (1988) reported a continuous division in the cells of parenchyma and external epidermis during growth of pummelo and the aril originated from a thickening of the apex of the funiculus. He suggested that all the processes occuring during fruit development influenced the final fruit shape and organoleptic characters. The deposition of certain unknown black bodies was noticed in testa cells. Fruits might have discoloured following mechanical injury and enzymatic browning of tissues which has been attributed to tannins (Weaver *et al.*, 1980). Barsy reported only the fragments of membranes to remain in the flesh of apples after 7 months of storage.

# SUMMARY

## SUMMARY

The investigations on growth, development and storage of pomegranate fruit cv. 'Ganesh' grown in two agroclimatic conditions (Bangalore and Bijapur with maximum mean temperatures of 30.5$^{o}$C and 35.8$^{o}$C with 45.8 and 39.9 per cent RH, respectively) during the years 1994 and 1995 were made. This study included (i) the pattern of growth and development of the fruit in two regions namely Bangalore and Bijapur (ii) determination of optimum low temperature for storage of 'Ganesh' cultivar of pomegranate (iii) study on shelf life and quality of fruits stored at 8, 15, and 25$^{o}$C and (iv) study on the histological changes in the fruits during growth, development and storage.

The salient findings are as follows:

**6.1 CHANGES DURING FRUIT GROWTH AND DEVELOPMENT**

1. The fresh weight, length, breadth and volume of the fruit increased with increase in growth of the fruit grown under two conditions. The length (14.6 cm) of the fruit was more than the breadth (8.5 cm) at the harvesting stage. The weight of the fruit was lower (295.4 g and 365 g in Bangalore and Bijapur crop, respectively) than the volume (310.0 and 400.0 ml) towards maturity. The length (14.9 cm), breadth (9.6 cm)

fresh weight, and volume i.e. size of the Bijapur fruit was slightly more than the fruits of Bangalore crop during most of the growth stages.

2. The specific gravity showed an increase during the mid growing period followed by a decline towards maturity. The specific gravity of Bijapur fruits (0.91 g/cc) was slightly less than those of the Bangalore fruits (0.96 g/cc) towards harvest.

3. The rind thickness of pomegranate fruits declined from 0.60 to 0.38 mm (Bangalore crop) and from 0.42 to 0.30 mm towards maturity. The rind thickness of Bijapur fruits (0.30 mm) was lesser than in the fruits of Bangalore crop (0.38 mm).

4. The rind weight increased from 4.6 - 97.1 g (Bangalore crop) and 4.8 - 116.7 g (Bijapur crop) with increase in growth of the fruit. The aril weight which constituted more than 50 per cent of the fruit also showed an increase from 0.4 - 190.7 g (Bangalore crop) and 0.7 - 248.6 g (Bijapur crop) at harvest. Maximum aril weight was seen towards maturity. During early part of growth the rind weight was more than the aril weight and during later stages of growth the aril weight was more. The aril weight of Bijapur fruits (248.6 g) was more than

the aril weight of Bangalore crop (190.7 g) during most of the growth stages.

5. The firmness of the fruit slightly reduced (from 14.9 - 13.7 kg/cm$^2$ and from 13.2 - 11.9 kg/cm$^2$ in Bangalore and Bijapur crops, respectively) from fruit set to maturity with some fluctuations during the growing periods.

6. The juice could not be extracted upto 5th stage of fruit development (i.e. 45th day after fruit set in Bangalore crop and a fruit diameter of 67.72 mm in Bijapur crop). Thereafter, the juice and the seed content increased with advancement in maturity. Maximum juice content (122.5 and 165.0 ml in Bangalore and Bijapur crop, respectively) was observed around harvesting period. The juice content of the fruit of Bijapur (165.0 ml) was higher than the juice content in Bangalore fruits (122.5 ml) at all the stages of growth. The juice colour increased with increase in growth of fruits of both the crops.

7. Rate of respiration increased and reached a peak (during stage 2, i.e. 5 days after fruit set in Bangalore crop and when fruit attained a diameter of 8.17 mm in Bijapur crop) followed by a gradual decline at the harvesting period (47 and 113 mg $CO_2$/kg/hr in Bangalore and Bijapur crop, respectively).

8. The moisture content of the rind decreased slightly towards maturity in both the crops. The moisture content of the rind in Bijapur crop (60.4%) was slightly lower than the moisture content of the rind in Bangalore crop (66.2%) during most of the growth stages.

9. The acidity of the fruit gradually decreased as the fruit attained maturity. The acidity content of the fruits from Bijapur (0.35%) was lower than the fruits from Bangalore (0.43%) crop during many stages of development.

10. The ascorbic acid content of the fruit gradually increased during the development of fruits of both the crops (13.9 and 17.9 mg/100 ml at harvest in Bangalore and Bijapur crop, respectively).

11. The TSS measured at different stages of development showed an increase with increase in maturity of the fruit of both the crops. The TSS of the Bijapur crop (17.2$^{o}$B) was slightly higher than the TSS of fruits of Bangalore crop (16.7$^{o}$B).

12. Both the reducing - and total sugars increased continuously during fruit development and more so during ripening stages. Both the sugars were high in fruits of Bijapur crop (13.0 and 14.3%) than in the fruits of

Bangalore crop (10.0 and 11.0%) at all the growth stages. Reducing sugars constituted a major portion of the total sugars.

13. Under Bangalore conditions the fruits reached harvest maturity 105-110 days after fruit set at which stage the fruit had low specific gravity, maximum length, breadth and volume and bright greenish yellow rind with waxy shining surface and looked fresh. Under Bijapur conditions the fruits were harvested at their maximum size and optimum maturity of the fruit was decided by the physical indices like decrease in specific gravity, reddish yellow colour of the rind with waxy shining surface, opening of calyx, uniformly deep red coloured soft and juicy arils and by chemical characters like constant TSS content.

**6.2 CHANGES DURING STORAGE OF FRUITS**

Based on preliminary hints fruits have to be stored at temperatures above 8$^{o}$C for retention of better quality and long storage since at 5$^{o}$C or below fruits developed the symptoms of chilling injury.

Physico-chemical changes during storage are as follows:

1. During the year 1994 when the fruits were packed in polybags there was a slight increase in per cent PLW in both the film wrapped and unwrapped fruits at 25, 15 and

$8^{o}C$ storage in both the crops. When the fruits were not packed in polybags (during 1995) there was a significant increase in PLW in all the treatments and at all the three temperatures of storage in both the crops. Per cent PLW increased with increase in storage temperature as seen at 8, 15 and $25^{o}C$. Untreated fruits showed maximum PLW while the wrapped fruits showed minimum PLW at all the storage temperatures in both the crops. Precooling of fruits prior to storage and treatment of fruits with 2 per cent semperfresh, a skin coating, were not effective in reducing PLW per cent in pomegranate fruits. The PLW in fruits of Bijapur crop was slightly higher than that in fruits of Bangalore crop irrespective of storage conditions.

2. The rind weight of unwrapped fruits decreased with the increase in storage time at both RT and LT, but in wrapped fruits there was not much change in rind weight. When fruits were packed in polybags the decrease in rind weight of unwrapped fruits was reduced as compared to fruits not packed in polybags. The decrease in rind weight was higher at RT than at LT storage. The decrease in rind weight of Bijapur crop was slightly higher than that in Bangalore crop at both RT and LT storage.

3. The rind thickness decreased in both unwrapped (from 0.40 - 0.14 mm in untreated control) and wrapped (from 0.40 - 0.32 mm in BDF 2001, Bangalore crop) fruits at RT and LT (from 0.40 - 0.20 in untreated and to 0.32 mm in wrapped fruits in Bangalore crop at $8^{o}C$). Packing in polybags reduced the decrease of rind thickness. Fruits of Bijapur crop (0.35 - 0.12 at RT) showed more decrease of rind thickness as compared to fruits of Bangalore crop.

4. There was no statistical differences observed in firmness of the fruits. The measurement of firmness of the rind during storage could not be taken as an indication of freshness of the fruit.

5. The aril weight of the fruits slightly increased (from 58.9 - 70.0% in Bangalore crop) during storage period at RT (63.2 - 71.8% in Bijapur crop) and LT (58.9 - 69.0 in Bangalore crop and from 63.2 - 71.5% in Bijapur crop at $8^{o}C$) in both the unwrapped and wrapped fruits of both the crops.

6. During storage the juice content showed a slight increase in unwrapped and wrapped fruits at RT (from 45.7 - 49.8 in Bangalore crop and from 46.9 - 52.1% in Bijapur crop) and LT (from 45.7 - 47.7 and from 46.9 - 49.7% in Bangalore and Bijapur crops, respectively at

$8^{o}C$) but unwrapped fruits showed a higher increase than that in the wrapped fruits.

7. The seed weight of the fruit did not show any change on account of storage temperature or wrapping of the fruit.

8. There was no post harvest climacteric peak in respiration of the fruit as the rate showed a enhanced decline during storage.

9. The juice colour of the fruit slightly decreased with increase in storage period at RT and at LT in both wrapped and unwrapped fruits of both the crops.

10. The rind moisture content of the fruit decreased in all the treatments at both RT and LT storage. This decrease was less in fruits packed in polybags and also in fruits wrapped with the film. The loss of rind moisture was higher in fruits of Bijapur than in the fruits of Bangalore crop at both RT and LT storage.

11. There was a considerable reduction in titratable acidity of the fruits of both RT (from 0.51 to 0.38 and from 0.40 to 0.35 per cent in Bangalore and Bijapur crops, respectively) and LT (from 0.51 to 0.31 in Bangalore crop and from 0.40 to 0.30 per cent in Bijapur crop at $8^{o}C$) storage in both the crops in all the treatments. The acidity of Bijapur fruits was slightly lower during

the storage period in both wrapped and unwrapped fruits at RT and LT.

12. There was a slight decrease in ascorbic acid content at LT and at RT there were not much of a change in both the crops at the end of the storage period. The ascorbic acid content in the fruits of Bijapur crop (19.4 to 14.9 at $25^{o}C$ and to 15.6 mg/100 ml at $8^{o}C$) was higher at the beginning and also during the storage than that of Bangalore crop (15.1 at 25 and to 14.9 at $8^{o}C$) in both wrapped and unwrapped fruits.

13. The change in TSS was negligible during storage both at RT and LT, in both the crops and in both wrapped and unwrapped fruits.

14. Reducing sugar content did not show significant changes both at RT and LT storage in both wrapped and unwrapped fruits of both the crops. Reducing sugars constituted the bulk of the total sugars.

15. Browning of arils was observed from 5th day of storage upto 12 weeks at all the storage temperatures in both the crops in fruits of different treatments. The percentage of browning was more in the unwrapped fruits both at RT and LT storage. Browning of arils was more in

fruits of Bijapur crop than the Bangalore crop. There was no correlation of browning with the temperature of storage.

16. The spoilage of fruits was seen only in untreated fruit during early part of storage and towards the end of storage it increased in all the treatments. More spoilage of fruits was observed (i) when they were packed in polybag ii) in wrapped fruits held at LT and iii) in unwrapped fruits at RT storage.

17. Among the post harvest treatments used for retaining the quality and extending the shelf life, individual shrink film wrapping was found to have best sensory characters. Fruits of Bijapur crop scored less for sensory characters.

18. The fruits at 8$^{o}$C showed the best shelf life and quality followed by fruits held at 15$^{o}$C and 25$^{o}$C. The fruits of Bangalore crop (15-18 days for unwrapped fruits at RT and 8-9 weeks at LT storage) had better shelf life than the fruits of Bijapur crop (10-12 days for unwrapped fruits at RT and 6-7 weeks at LT storage). The shelf life for wrapped fruits did not show much variations between the crops and it extended upto 12 weeks at LT (8$^{o}$C).

Thus the best temperature for storage of pomegranate cv. 'Ganesh' was determined as $8^{o}C$ wherein the fruits maintained good sensory characters and acceptibility. Among the post harvest treatments individual shrink film wrapping was found to be the best treatment for retaining the freshness of the fruit.

**6.3 HISTOLOGICAL CHANGES DURING GROWTH AND STORAGE**

1. In general, irrespective of the growing conditions the histology of rind comprises of outer epidermis with a few stomata and beneath it are rows of collenchymatous cells. The tissue then consists of a thin-walled parenchyma through which run fibrovascular strands. In the parenchyma are scattered numerous sclerenchymatous cells. The collenchymatous tissue shows occasional intercellular spaces which neither contain stone cells nor fibrovascular strands. The sclereids occur singly and/or in groups with very irregular shape and size.

2. As the fruit grew the epidermis and cuticle thickness increased in both the crops. The thickness of the cuticle in Bijapur crop was slightly lower than the Bangalore crop at harvest, while it was vice versa in the thickness of epidermis.

3. Similarly the length and breadth of both collenchyma and parenchyma cells increased with growth of the fruit. The

cell size also increased with growth. The cells in the rind of Bijapur crop were slightly larger in size at harvest.

4. The accumulation of starch grains was observed at 7th stage (60 days after fruit set in Bangalore crop and at a fruit diamter of 67.72 mm in Bijapur crop). In pomegranate rind, the starch grain number decreased gradually with maturity.

5. After storage of 25 days the thickness of the epidermis in the unwrapped fruits (untreated and semperfresh) decreased while that of the wrapped fruits slightly increased in both the crops. The wrapped fruits showed periclinal division in the epidermal cells during storage of 25 days in both the crops.

6. After 25 days of storage the cuticle thickness decreased in all the treatments in both the crops.

7. The length and breadth of both collenchyma and parenchyma cells decreased in all the treatments in both the crops after 25 days of storage and more so in crop of Bijapur.

8. Due to the decrease in length and breadth of cells, compression of tissues was observed during storage of 25 days. The lateral compression of cells was more in

unwrapped fruits when compared to the wrapped fruits in both the crops. It was severe in untreated followed by semperfresh and wrapped fruits in both the crops after 25 days storage. The shrinkage of cells from Bijapur crop was slightly more than that of the Bangalore crop.

9. The starch grains disappeared in the rind cells during the storage of fruits for 25 days.

10. In the surface view the epidermis of rind at harvest showed the healthier cells, but after 25 days of storage the cells showed certain brown depositions. The fruits wrapped had less accumulation of brown substances than the unwrapped fruits. The accumulation of the brown substance in semperfresh was less than that in untreated and more than that in wrapped fruit.

11. The juicy pink arils at harvest had fleshy testa cells intact and a few starch grains scattered in them. With storage, the aril became slightly discoloured and brown, became distorted and lost the cell integrity and the starch grains. The testa cells of a completely discoloured aril had depositions of certain unknown substances along with cell distortion.

Pomegranate fruits grown under Bangalore conditions can be harvested around 105-160 days after fruitset and fruits from Bijapur area can be harvested when they attain their maximum size and develop reddish yellow colour of the rind with waxy shining surface. The fruits harvested at this stage and shrink filmwrapped could be stored upto 12 weeks at 8 $\pm$ 1$^{o}$C, upto 10 weeks at 15 $\pm$ 1$^{o}$C and upto 25 days at 25 $\pm$ 1$^{o}$C. Fruits stored at 8 $\pm$ 1$^{o}$C showed the best quality followed by the fruits held at 15 and 25$^{o}$C. Packing the wrapped fruits in polybags can extend the shelflife further by two more weeks at LT. Wrapping of fruits in shrink film helped retention of freshness and quality. The histology of rind sections also revealed that the tissues of shrink wrapped fruits were intact as compared to the non wrapped fruits which had the severely deformed or compressed cells.

Further, studies on the use of different types of shrink wrap material indegenously available can be tried.

# REFERENCES

**REFERENCES**


Al-kahtani, M.A., 1992. Intercultivar differences in quality and post harvest life of pomegranate as influenced by partial drying. *J. American Soc. Hort. Sci.*, **117**(1): 100-104.

Amerine, M.A., Pangborn, R.M. and Roessler, E.B., 1965. Principles of sensory evaluation of food. Academic Press London.

*Andres, D.S., 1984. Modified atomsphere using plastic bags for storing mango. *CLSU Scientific J.*, **5**(2): 45.

Anonymous, 1984. Pomegranate special. Horticulture Information Service. Monthyl Bulletin, Feb.

Arie, R.B., Segal, N. and Sylvia Guelfet Roich, 1984. The maturation and ripening of the 'wonderful' pomegranate. *J. American Soc. Hort. Sci.*, **109**(6): 898-902.

Arie, R.B. and Or, E., 1986. The development and control of husk scald on 'Wonderful' pomegranate fruit during storage. *J. American Soc. Hort. Sci.*, **111**(31): 359-99.

Asaphgoor, 1967. The history of pomegranate in the Holyland. *Economy Botany*, **21**: 215-30.

Bacha, M.A. and Ibrahim, I.M., 1979. Effect of pinolene on splitting, yield and fruit quality on 'Banati' and 'Manfuloti' pomegranate trees. *Egyptian J. Hort.*, **6**(2): 135-140.

Barsy, T.De., Deltour, R. and Bronchart, T., 1989. Ultrastrucutral and microstereological study of aging in golden delicious apples during storage. *Acta Horticulturae*, No.258-379-87.

Bollard, E.G., 1970. The physiology and nutrition of developing fruits. Vol.1, Ed. Hulme, P.A. Academic Press, London, 387-420.

Bourdon, J.N., 1994. An examination of the stomata of the fruits of plantains and cooking banana. *J. Hort. Sci.*, **69**(1): 81-88.

Bourdon, J.N., Moore, K.G. and Wainwright, H. 1993. Post harvest water loss of plantain and cooking banana fruits. *Acta Horticulturae*, No.**343**: 307-308.

*Cemeroglu, B., Artik, N. and Yunculer, O., 1988. Studies on pomegranate juice. *Nar Suyn iizerinde arastirmalor*, **12**(3): 322-334.

Cheema, G.S., Bhat, S.S. and Naik, K.C., 1954. Commercial fruits of India. Mcmillan and Co.Ltd., Madras.

*Chongrak, K., 1981. Studies on fruit maturity of mango (*Mangifera indica* L.) cv. Duncan. *Bangkok.*, 15p.

Collin, M.N. and Folliol, M., 1990. Anatomical characters of epidermis of plantain in relation to storage technique. *Fruits*, **45**(1): 9-16.

Conn, H.J., 1936. Biological stains. *Comm. On Standardization of Biological Stains*, Geneva. New York 3d ed.

Dash, D.K., 1983. Growth dynamics, flowering and fruit development in pomegranate (*Punica granatum* L.) selection G.K.V.K.1 and its propogation by cuttings. Unpublished thesis submitted to the University of Agricultural Sciences, Bangalore.

Dastermirov, B.P. and Babaev, K.Z., 1969. Pomegranate cultivation in South Dagesten. *Sub. trop. Kul'tury*, **5**: 149-150.

Dong, Y.C. and Yang, L.X., 1994. Tiepitian, a large variety of pomegranate with long storability. *J. Fruit Sci.*, **11**(4): 260.

Du, C.T., Wang, P.L. and Francis, F.J., 1975. Anthocyanins of pomegranate. *J. Fd. Sci.*, **40**(2): 417-18.

*Elnnemr, S.K., Ismail, I.A. and Ragab, H., 1990. Chemical composition of juice and seeds of pomegranate fruit. *Nahrung*, **34**(7): 601-606.

Elyatem, S.E. and Kader, A.A., 1984. Post harvest physiology and storage behaviour of pomegranate fruits. *Scientia Horituclutürae*, **24**(3/4): 287-289.

Eris, A. and Turkben, C., 1989. Changes of some quality factors during cold storage of different table grapes grown in Turkey. *Acta Horticulturae,* **258**: pp.413-419.

Evreinoff, 1949. The pomegranate fruits. *Doutre Mer.*, **4**: 161-170.

*Ewaidah, E.H., 1987. Nutrient composition of 'Taifi' pomegranate fragments and their suitability for the production of jam. *Arab Gulf J. Scientific Res.*, **5**(3): 367-78.

Fisher, R.A., 1963, Statistical methods for Research Workers.14. Edn. Hefmer.

*Fouad, M.M., Barakat, M.R. and El-yeazal, S.A., 1979, Comparative studies on fruit growth and development of De ha Grenouliere and 'Manfaloti' cultivars (pomegranate) under Giza conditions. *Cairo*, 23p. *Research Bulletin*. Faculty of Agriculture. Aimshems University, **1090**: 21.

Gafizov, G.K., 1991. Development of the proportions of component parts of the fruit in pomegranate *Subtropicheskie - Kul'tury*, No.**4**: 105-106.

Gangawar, B.H. and Tripathi, R.S., 1973. A study on physicochemical changes during growth, maturity and ripening in mango. *The Punjab Hort. J.*, **13**(4): 230.

George, J.B. and Marriott, J., 1985, The effect of some storage conditions on the storage life of plantains. *Acta. Horticulturae*, **158**: 439-447.

Gil, M.I., Garcia, V.C., Arles, F. and Thomas, B.F.A., 1995. Changes in pomegranate juice pigmentation during ripening. *J. Sci. Fd. Agric.*, **68**(1): 77-81.

*Godara, R.K., Godara, N.R., Jitender Kumar and Surinder Kumar, 1989. Quality assessment of pomegranate cultivars. *Research and Development Reporter*, **6**(1): 76-80.

Griffiths, E., 1935. The structure of pomegranate rind. *Quart. J. Pharma.*, **8**: 622-630.

Gulhane, A.R. and Gupta, P.K., 1974. Physico-chemical changes in developing Lucknow 49 Guava fruits. *Haryana J. Hort. Sci.*, **3**(3/4): 134-139.

Heikal, E.K., 1991. Improving fruit growth and development of 'Manfaloti' pomegranate trees grown on sandy soil. *Annals Agric. Sci.*, **29**(2): 967-79.

*Heikal, H.A., Ismail, M.M. and El-man moudy, L.T., 1966. Studies on storage of pomegranates. *Agric.Res. Rev. cairio.*, **44**(3): 86-96.

Hewelt, E.W., Banks, N.H., Dixon, J., Perry, H.L. and Tian, M.S., 1989. Shelf life extension of apples with polymeric films. *Acta Horticulturae*, No.**258**: 273.

Hittalamani, S.V. and Rao, M.M., 1976. Studies on changes in physical parameters of the developing kagzi lime fruit. *South Indian Hort.*, **24**(4): 122-26.

*Ibrahim, A.M.F., Attia, M.M., Attala, A.M., Hussein, .A.M., and El-Kobbia, A.M. 1985. Studies on fruit set and physiochemical properties of fruits of some pomegranate varieties grown in Alexandria. *J. Agric. Resh.*, **11**(383): 98.

Jagpat, D.B., Desai, U.T. and Kale, P.W., 1992. Assessment of pomegranate germplasm for important fruit physico-chemical characters. *J. Maharastra Agri. Univ.*, **17**(3): 399-401.

Jensen, W.A., 1962. Botonical Histochemistry - Principles and Practices. W.H.Freeman and Co. San Fransisco.

*Ji-Zl., Zhang-ZQ., Wang, Y. and Li-x.P., 1994. Low temperature storage and chilling injury of mangoes. *Acta Horticulturae Sinica*, **21**(2): 111-116.

*Joarder, G.K., 1980. Preservation of mango at cold temperature. *Bangladesh J. Agric.*, **5**(3): 145-52.

Josan, J.S., Jawanda, J.S. and Uppal, D.K., 1979b. Studies on floral biology of pomegranate. III. Mode of pollination, fruit development and fruit cracking. *The Punjab Hort. J.*, **19**(3&4): 134-38.

Joshua, P. and Sathiamoorthy, S., 1993. Storage of sapota fruits in polythene bags. *South Indian Hort.*, **41**(6): 368-369.

Kader, A.A., Chordas, A. and Elyatem, S., 1984. Responses of pomegranate to ethylene treatment and storage temperature. *Calif. Agr.*, **38**(7-8): 14-15.

Kanwar, Z.S., 1977. Use of certain preservative chemicals for controlling soft rot of pomegranate fruits caused by *Rhizopus*. *Haryana J. Hort. Sci.*, **6**(3/4): 140-44.

Kanwar, Z.S. and Thakur, D.P., 1972. Controlling postharvest soft rot of pomegranate fruits by treatment of packing straw. *Sci. Cult.*, **38**(10): 450-52.

Kennard, W.C., 1955. Development of the fruit, seed and embryo of the Paheri mango. *Bot. Gaz.*, **117**: 28-32.

Kesta, S., 1990. Weight loss of tangerines as affected by peel thickness. *Tropical Sci.*, **30**(1): 73-76.

Kesta, S., Raksritong, T. and Subhadrabandhu, S., 1992. Effect of PVC film wrapping and temperature on storage life and quality of 'Nam dok Mai' mango fruits on ripening. International symposium on tropical fruit. *Thailand Acta Horticulturae*. No.321: 756-763.

Khodade, H.S., Wavhal, K.N. and Kale, P.N., 1990. Physico-chemical changes during growth and development of pomegranate fruit. *Indian J. Hort.*, **47**(1): 21-27.

Koksal, A.I., 1989. Research on the storage of pomegranate (cv. GokBahge) under different conditions. *Acta. Horticultuare*, No.**258**: 295-302.

Kriventson, V.I. and Arendth, N.K., 1981. Anthocyanins of pomegranate juice. *Trudy Gosudarstvennogo* Nikitskgo *Botanicheskogo sada*, **83**: 110-116.

Kumar, B.P., 1986. Studies on growth and deelopment of pomegranate (*Punica grantum* L.) fruit and seed with special references to hard and soft seededness. M.Sc. Thesis, U.A.S, Bangalore.

Kumar, B.P. and Purohit, P.G., 1989. Studies on fruit growth and development in pomegranate. *J. Maharastra agric Univ.*, **14**(2): 187-89.

Lakshminaryana, S., 1973. Respiration and ripening patterns in the life cycle of the mango fruits. *J. Hort. Sci.*, **48**: 227-33.

Lakshminarayana, S. and Subramanyam, H., 1966. Physical, chemical and physicological changes in Sapota fruit during development and ripening. *J. Fd. Sci., Technol.*, **3**: 14.

*Lee, S.W., Kim, K.S. and Kim, S.D., 1974. Studies on changes in the composition of pomegranate fruit during maturation. (1) changes in sugar, organic acids, amino acids and the respiration rate. *J. Korean Soc. Hort. Sci.*, **15**(1): 57-64.

Leena Borah, 1990. Studies on the extraction, clarification and storage of pomegranate juice. Thesis submitted to Mysore University, CFTRI.

Leopold, A.C., 1964. Plant growth and development. McGraw Hill Publication in Biological Sciences. 270-81.

Liang, C.C. and Ching, Y.D., 1991. Selection of elite pomegranate. *J. Fruit Sci.*, **8**(1): 59-60.

Lloyd, R.M.S. and Pentzer, M.S., 1974. Handling, transportation and storage of fruits and vegetales. In: Postharvest Biotechnology of fruits, AVI Publishing company, Connecticut, 2: 264.

Lutz, B.M. and Harden brug, R.C., 1968. The commercial storage of fruits, vegetables and florist and nursery stocks. Agric. Hand Book. No.66: pp.94.

Maharaj, R. and Sankat, C.K., 1990. The shelf life of bread fruit stored under ambient and refrigerated conditions. *Acta. Horticulturae*, No.**269**: 411-24.

Malhotra, V.K., Khajuria, M.N. and Jawanada, J.S., 1983. Studies on physico-chemical characteristics of pomegranate cvs. *The Punjab Hort. J.*, **23**(3&4): 153-61.

Martin, J.T. and Juniper, R.M., 1970. The cuticles of plants. Edward Arnold, Edinburg, pp.71.

Mazumdar, B.C., 1976. Comparative fruit development of three mango varieties in West Bengal. *Indian Agriculturist*, **20**(3): 163.

Miller, R.H., 1982. Apple fruit cuticles and the occurence of pores and transcuticular canals. *Ann. Bot.*, **50**: 355-371.

Miller, W.R. and Risse, L.A., 1988. Recent research on film wrapping of fresh produce in Florida. *In Sixth International Citrus Congress*. Isreal, 6-11 March. Vol.3.

Misra, R.S., Srivastava, R.P. and Kuksal, R.P., 1983. Evaluation of some pomegranate cvs. for valley areas of Garhwal Hills. *Prog. Hort.*, **15**(1-2): 24-26.

Montenegro de Carrillo, N., 1988. Study of the anatomy, growth and development of granadilla (*Passiflora quadrangularis* L.) fruit. *Agronomia colombiana*, **5**(1-2): 75-82.

Mukherjee, P.K. 1958. Storage of pomegranates (*Punica granatum L.) Sci. Cult.*, **24**: 94.

*Munasque, V.S., 1987. Developmental physiology and ripening behaviour of 'senorita' banana fruits. *College*, Laguna, 60 leaves.

*Nanthchai, P., 1982. Fruit morphology and development in mango. Laguna, p. 92-95.

Nath, N. and Randhawa, G.S., 1959. Studies on floral biology in the pomegranate. III. *Indian J. Hort.*, **14**(3): 136-40.

*Nerd, A., 1965. Anthocyanins in pomegranate juice. M.Sc. thesis. The Hebrew University.

Nitsch, J.P., 1955. Physiology of fruit growth. *Ann. Rev. Plant Physiol*, **4**: 199-236.

*Ohmiya, A. and Kakirchi, N., 1990. Quantitative and morphological studies on starch of apple fruits during development *J. Japanese Soc. Hort. Sci.*, **59**(2): 417-423.

Onur, C. and Ve.Ari, H., 1986, Nar meyvelerimin Bazi Kalite Ozelliklerine. Mamlama Ve adi Depoda Muhafaza Sureshimin etkileri. *Derim.*, **2**(3): 129-138.

Padule, D.N. and Keskar, B.G., 1989. Studies on post harvest treatments for increasing the shelf life of pomegranate fruits. *Maharashtra J. Hort.*, **4**(2): 73-76.

Pandey, R.M., Rao, M.M. and Singh, R.N., 1973. Biochemical changes in the developing mango fruit cv. Dashehari. *Prog. Hort.*, **5**(4): 47-49.

Parikh, H.R., Nair, G.M. and Modi, V.V., 1990. Some structural changes during ripening of mangoes by abscisic acid treatment. Annals Bot., **65**: 121-127.

Passam, H.C., 1982. Storage of some local and introduced mango cultivars grown in Trinidad. *Scientia Horticulturae*, **16**(2): 141-77.

Patil, A.V., Naik, V.B. and Divate, M.R., 1978. Promising muskat pomegranate (*Punica grantum* L.) selections from Kolhar region of Maharashtra State. *Indian J. Hort.*, **35**(2): 81-84.

*Patil, A.V., Rane, D.N. and Sanghavi, K.V., 1977. Studies on growth habit of some Russian pomegranate varieties under Rahuri conditions. *Agric and Agro Industries J.*, **10**(6): 9-10.

Perring, M.A., 1989. Apple fruit composition quality in relation to fruit chemical composition. *Acta. Horticulturae*, No.**258**: 365-72.

*Pota, S., Kesta, S. and Thongtham, M.L.C., 1987. Effect of packaging material and temperature on quality and storage life of pomegranate fruits. *Kesetsart J. Natur. Sci.*, **21**(4): 328-33.

Purohit, A.G., 1986. Soft seedness of commercial pomegranate varieties. *Indian J. Agri. Sci.*, **55**(5): 367-368.

Ramana, K.V.R., Aravindaprasad, B., Krishnaprasad, C.A. and Patwardhan, M.V., 1984. Temperature storage and the ripening behaviour of Alphonso. *Indian Food Packer*, **12**(4): 96-98.

Ranganna, S., 1977. *Mannual of analysis of fruit and vegetables products*. Tata Mc Graw Hill Publishing Co., New Delhi.

Raturi, G.B. and Hiwale, S.S. 1991. Regulation of cropping in pomegranate under rainfed conditions. *Indian J. Hort.*, **48**(1): 13-15.

Rosenquist, J.K. and Morrison, J.C., 1989. Some factors affecting cuticle and wax accumulation on grape berries. *American J. Enology and viticulture.*, **40**(4): 241-44.

*Rotaru, G.I., Matienko, B.T. and Turova, A.V., 1989. Anatomical features of the pericarp in some local apple varieties. *Seriya Biologicheskikhi Khimi Cheskikh Nauk*, No.1: 20-27.

Roth and Lindorf, 1972. Fruits of Angosperms. *Gebruedar Borntraagu*, Berlin, pp.461.

*Saad, F.A., 1990. Studies on the phenomenal cracking of pomegranate cv. Taifi fruits in Saudi Arabia. General study of fruit growth and cracking. *Alexandria J. Agric. Resh.*, **33**(2): 127-35.

Sadasivam, R., Subramanian, T.M. and Raman, N.V., 1972. Polythene package ensure better storage of sathgudi fruit. *Indian Farm.*, **22**(1): 32.

Saini, S.S., Singh, R.N. and Pallwal, G.S., 1972, Growth and development of mango fruit. II. Anatomy. *Indian J. Hort.*, **29**: 5-15.

Salunkhe, D.K. and Desai, B.B., 1986. Low temperature storage of pomegranate fruits. In: Post harvest biotechnology of fruits. AVI Publishing Company. Inc. Westport, **2**: 65-67.

Saxena, A.K., Manan, J.K. and Berry, S.K., 1987. Pomegranate post harvest technology chemistry and Processing. *C.F.T.R.I.*, 43-59.

Sayed, S. Seemanthini Ramadas, Nanjan, K. and Muthuswami, 1985. YCD-1 Pomegranate. *South Indian Hort.*, **33**(1): 452.

Shaikh, I.A., Arshad, M., Aslam, M., Ali, F.N. and Ekteshmuddin, A.F.M., 1991. Extension of shelf life of banana with wax emulsion. *Pakistan J Scientific and Industrial Research*, **34**(9): 362-64.

Shanmugavelu, 1987. Harvest, marketing and storage of fruits. In Production Technology of fruit crops. pg.125-39. SBA Publication Calcutta, India.

Shanthakrishnamurthy and Joshi, S.S., 1989. Studies on low temperature storge of Alphonso mango. *J. Fd. Sci. Technol.*, **26**: 177-180.

Shekar, B.V., 1979. Studies on diseases of pomegrante. M.Sc. thesis submitted to Mahatma Phule Agrucultural University, Rahuri, pp.85-88.

*Shi, C.D., 1991. Taishan Dahongshiliou, a top quality pomegranate cv. *China Fruits.*, No.4, 27.

Shivananda, C.T., 1992. Studies on storage of pomegranate. M.Sc. Thesis submitted University of Agricultural Sciences, Bangalore.

Shulman, Y., Fainberstein, L. and Lavee, S., 1984. Pomegranate fruit development and maturity. *J. Hort. Sci.*, **59**(2): 265-74.

Singh, R.R., Singh, H.K. and Chauhan, K.S., 1988. Efect of NPK on physico-chemical composition of pomegranate fruits cv. Local selection. *Prog. Hort.*, **20**(1-2): 77-79.

Sood, D.R., Dhindsa, K.S. and Wagle, D.S., 1984. Studies on the nutritive value of pomegranate. *Haryana J. Hort. Sci.*, **11**(3/4): 175-78.

Sonawane, G.S., Utika, P.G. and Shindu, A.A., 1986. Evaluation of chemicals in preventing post harvest fungal rots of pomegranate. *Maharastra J. Hort.*, **3**(1): 152-56.

Srivastava, M.P. and Tandon, R.N., 1979. Aspagillus rot of pomegranate. *Indian Phytopathol*, **24**: 172.

Sulladmath, U.K., Rao, M.M. and Advani, M.R., 1979. Studies on the pattern of growth of developing 'Kalipatti', Sapota fruit. *J. Maharastra Agril Univ.*, **4**(1): 55-60.

Susamma Philip, 1979. Aspergillus rot of pomegranate fruits. *Indian Phytopathol.*, **32**: 332.

Swarus, D.H., 1990. The effects of pre-storage conditions and storage temperature on the keeping quality of queen pineapple under simulated sea freight condition. *Inligntings bulletin.*, No.**220**:: 15-17.

*Treglazova, N.V. and Fataliev, A.T., 1989. The effect of treatment with calcium chloride on pomegranate fruit storage. *Sadovo-dstvoi vinogradarstvo*, No.9: 25-27.

Tripathy and Gangwar, 1971. Biochemical changes as indices of maturity in Guava (*Psidium guajava L.) Prog. Hort.*, **3**: 17.

Wang, T.T. and Shiesh, C.C., 1990. Fruit growth development and maturity indices of 'Irwin' mango in Taiwan. *Acta. Horticulturae*, No.269, 189-96.

*Weaver, C.M. and Charley, H., 1980. Localization of dopamine in banana. *Home Economics Research Journal*, **8**(3): 200-202.

Westwood, M.N., 1967. Cell size, number and fruit density of apples related to fruit size position in cluster and thinning method. *Proc. American Soc. Hort., Sci.*, **91**: 51-62.

Yusof, S. and Mohamad, S., 1987. Physico-chemical changes in guava during development and maturation. *J. Sci. Fd. Agric.*, **38**(1): 31-39.

Zeilinski, Q.B., 1955. Modern systematic pomology, W.M.C., Brown Co. Iowa. pp.296.

*** Original not seen**

# APPENDICES

# APPENDIX - I

**Mateorologicl data during development of pomegranate cv. 'Ganesh' under Bangalore conditions (1995)**

| Months | Maximum temperature (°C) | Minimum temperature (°C) | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|
| February | 30.5 | 16.8 | 39.8 | - |
| March | 32.5 | 19.0 | 28.2 | 50.5 |
| April | 33.7 | 20.4 | 41.4 | 23.5 |
| May | 31.0 | 21.3 | 40.0 | 73.4 |
| June | 28.0 | 21.2 | 60.9 | 34.3 |
| July | 27.8 | 20.1 | 65.0 | 120.4 |

# APPENDIX - II

**Mateorologicl data during development of pomegranate cv. 'Ganesh' under Bijapur conditions (1995)**

| Months | Maximum temperature (°C) | Minimum temperature (°C) | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|
| February | 34.0 | 19.4 | 31 | - |
| March | 36.4 | 22.2 | 31 | 6 |
| April | 39.1 | 24.5 | 28 | 10 |
| May | 37.7 | 23.9 | 37 | 39 |
| June | 36.4 | 23.7 | 49 | 72 |
| July | 31.1 | 27.7 | 63.5 | 85 |
| August | 32.5 | 22.4 | 58.7 | 71 |