Effect of different plant growth regulators and packaging materials on shelf-life of Mandarin (*Citrus reticulata* Blanco)

THESIS

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Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

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(Post Harvest Management)

By

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College of Horticulture

Mandsaur (MP)

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CERTIFICATE - I

This is to certify that thesis entitled, **"Effect of different plant growth regulators and packaging materials on shelf-life of Mandarin (*Citrus reticulata* Blanco)"**, submitted in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture (Post Harvest Management)**, of the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) is a record of the bonafide research work carried out by **Mr. RAHUL PIPPAL**, ID. NO. RH/MS/1237/2009, under my guidance and supervision. The subject of the thesis, have been approved by the Student's Advisory Committee and the Director of Instruction

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by him.

(Er. Rajesh Gupta)
Chairman of the Advisory Committee

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CERTIFICATE II

This is to certify that thesis the entitled **"Effect of different plant growth regulators and packaging materials on shelf-life of Mandarin (*Citrus reticulata* Blanco)"** submitted by **Mr. RAHUL PIPPAL**, ID. NO. RH/MS/1237/2009, to the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture in the department of Post Harvest Management** has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.

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Place – Mandsaur

Date - **(Rahul Pippal)**

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ABBREVIATIONS USE IN TEXT

%	:	Percentage
/	:	Per
@	:	At the rate of
°F	:	Degree farenhite
^0C	:	Degree Celsius
2,4-D	:	2,4- dichlorophenoxy acetic acid
ANOVA	:	Analysis of variance
CD	:	Critical Difference
$CaCl_2$	:	Calcium chloride
CFB	:	Corrugated fibre box
cm	:	Centimeter
CO_2	:	Carbon di - oxide
CRD	:	Completely Randomized Design
cv.	:	Cultivar
Df	:	Degree of Freedom
DAS	:	Days after storage
et.al	:	and others
Fig.	:	Figure
ft.	:	Feet
g	:	Gram
GA_3	:	Gibbralic acid
h	:	Hour
ha	:	Hectare
HDEP	:	High density polyethylene
i.e.	:	That is
IARI	:	Indian Agricultural Research Institute
Kg	:	Kilogram
Km	:	Kilometer
LDPE	:	Low density polyethylene
LLDPE	:	Linear low density polyethylene
M.P.	:	Madhya Pradesh
M.S.S.	:	Mean Sum of Square
MAP	:	Modified atmospheric packaging

Mg	:	Milligram
min	:	Minute
ml	:	Milliliter
MT	:	Metric tonne
NaCl	:	Sodium chloride
NHB	:	National Horticultural Board
No.	:	Number
NS	:	Non - significant
O_2	:	Oxygen
PLW	:	Physiological loss in weight
ppm	:	Parts per million
PVC	:	Polyvinylchloride
R.V.S.K.V.V.	:	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
RH	:	Relative humidity
S.Em.	:	Standard Error of Mean
SS	:	Sum of square
SSC	:	Soluble solids content
TSS	:	Total soluble solids
USDA	:	United State Development and Agriculture
Viz.	:	(Videlicet) Namely

CHAPTER - I
INTRODUCTION

1.1 Area, production and productivity of mandarin

Mandarin (*Citrus reticulata* Blanco) is one of most popular fruits grown in tropical and sub-tropical regions of India, which belongs to the family Rutaceae. It is native to tropical and subtropical region of South-East Asia, It is the very important fruit crop, second only to banana. The loose skinned oranges, belonging to the specie *Citrus reticulata* Blanco are commonly known as mandarins. Though mandarin and tangerines are names used more or less interchangeably to designate the whole group but tangerine is applied more strictly to those varieties producing deep orange or scarlet fruits. These two groups are differentiated only on the basis of color of the fruit. The Dancy and Beauty tangerine can be termed as mandarins from the horticultural standpoint. There are six distinct groups of mandarin oranges i.e., King, Satsuma, Mandarin, Tangerine, Mandarin-lime and Mitis groups (Niaz, 2004). The different countries have given the mandarins indigenous names, in Philippines all mandarin oranges are called Naranjita and in Spain the nomenclature is Mandarina.

An evergreen tree growing up to 4.5 m (14 ft) by 3 m (9 ft). The flowers are hermaphrodite and are pollinated by Apomictic insects. The plant is self-fertile. The plant prefers medium (loamy) and heavy (clay) soils and requires well-drained soil. The plant prefers acid, neutral and basic (alkaline) soils and can grow in very acid and very alkaline soils. It cannot grow in the shade. It requires moist soil, Due to its wider adaptability in diverse soils and agro-climatic regions, it has gained more popularity among the fruit growers. It is cultivated on large scale in different parts of the world. In India, this crop has been confined to the states of Maharastra, Madhya Pradesh, Tamil Nadu, Rajasthan, Assam and Tripura. Major mandarin producing areas in Madhya Pradesh are Chhindwara, Mandsaur, Betul, Ujjain and Shajapur. Area, production and productivity of mandarin for the year 2010 have been shown in Table 1.1.

Table 1.1 Area, production and productivity of mandarin

	India	M.P.
Area (ha)	2,85,490	38,300
Production (MT)	20,84,000	6,77,800
Productivity (MT/ha)	7.3	17.7

Source: NHB, 2010

1.2 Nutritional value

The physico-chemical composition of mandarin varies widely with cultivars, stage of maturity and season. The general nutritional contents of mandarin have been shown in Table 1.2.

Table 1.2 Nutritional contents of mandarin

S. No.	Constituent	Range
1	Moisture	82.6-90.2 g
2	Ash	0.29-0.54 g
3	Crude fat	0.05-0.32 g
4	Crude protein	0.61-0.215 g
5	Crude fiber	0.3-0.7 g
6	Carotene	0.013-0.175 mg
7	Ascorbic acid	13.3-54.4 mg
8	Thiamine	0.048-0.128 mg
9	Riboflavin	0.014-0.041 mg
10	Niacin	0.199-0.38 mg
11	Calcium	25.0-46.8 mg
12	Phosphorus	11.7-23.4 mg
13	Iron	0.17-0.62 mg

Source: Morton, 1987

1.3 Medicinal value

Mandarins are eaten to allay fever and catarrh. The roasted pulp is prepared as a poultice for skin diseases. The fresh peel is rubbed on acne. Whole mandarins are much useful because of its protopectin, bioflavonoids and inositol (related to vitamin B). Mandarin contains a significant amount of the vitamin-like glucoside, hesperidin, and 75-80% of it in the albedo, rag and pulp. An infusion of the immature fruit is taken to relieve stomach and intestinal complaints. Mandarin flower water made in Italy and France as cologne is bitter and considered antispasmodic and sedative. A decoction of the dried leaves and flowers is given in Italy as an antispasmodic, cardiac sedative, antiemetic, digestive and remedy for flatulence. The inner bark, macerated and infused in wine is taken as a tonic and carminative. A vinous decoction of husked orange seeds is prescribed for urinary ailments in China and the juice of fresh mandarin leaves or a decoction of the dried leaves may be taken as a carminative or emmenagogue or applied on sores and ulcers. Mandarin seed extract is given as a treatment for malaria in Ecuador, but it is known to cause respiratory depression and a strong contraction of the spleen.

1.4 Seasonal availability

Mandarin is a winter season crop. Generally, mandarins are harvested in 32-36 weeks after the fruit is set; otherwise there is every possibility of shriveling of fruits and heavy drops. The colour of the rind also indicates the time of harvesting of the fruits. The maturity of harvested fruits has an important role on shelf life, quality and market price. Hence, certain standards of maturity must be kept in mind while harvesting the fruits. However, the most commonly used measures to access maturity for harvesting the Mandarin is peel colour. Fruits are considered mature, if they have a yellow orange colour on 25% or more of the fruit surface. States like Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Tripura, the harvesting of mandarin is undertaken twice a year. In Karnataka, the season of harvesting is December to February (summer crop), and June to August (Monsoon) crop. While in Madhya Pradesh, both the harvesting seasons are of very short duration i.e., November to December (I season) and January to February (II season). In Maharashtra, the first harvesting commences in third week of October and lasts till the end of January/February (Ambia season), the period of second harvesting is from February to mid May (Mrug Bahar). Similarly, in Tamil Nadu, the main season commences in November and lasts up to January/February, the period of second season namely ‘off season’ is from July to September. In Tripura, the duration of first season is from November to January and second season is from December to February. In rest of the Mandarin producing states, the harvesting of fruits is done only once in a year, as in Assam (October to February), Haryana and Punjab (November to March), Meghalaya (November to February), Mizoram (November to

January), Nagaland and West Bengal (November to January) and Rajasthan (January to April).

1.5 Regional significance

Mandarin is a seasonal fruit. It is available from mid October to January end in Malwa region of Madhya Pradesh. If we use appropriate packaging materials and suitable chemicals for storing of the fresh fruits, we can increase the shelf-life of mandarin. They can be transported to local and short distant markets with minimum physiological loss in weight. Major producing states and important characters of mandarin variety have been shown in Table 1.3.

1.6 Ripening and storage

Mandarin is a non-climacteric fruit and does not show respiratory climacteric phenomena coupled with steep rise in ethylene production. Respiration is affected by temperature, humidity, air movement, atmospheric gases and pathogenic infections coming from orchard and handling practices. Citrus rind/peel is prone to damage to oil cells. The peel colour improved with advancement of maturity (Sonkar and Ladania, 1995).

Table 1.3 Major producing states and important characters of mandarin variety

S. No.	Variety	State	Important Characters
1	Khasi Orange	Assam and Meghalaya	Fruits globose to oblate, surface smooth, colour orange-yellow to bright orange, rind thin with very little adherence, segments usually 10, pulp vesicles uniformly orange, texture coarse, juice abundant with well-blended flavour.
2	Coorg Orange	Karnataka	Fruits oblate, colour bright yellow and uniform, rind medium thick with little adherence, segments usually between 9 to 11, pulp yellow with fine texture and abundant juice.
3	Kinnow Orange	Punjab and Haryana	The fruit is medium-size somewhat oblate in shape, rind moderately thick, adherence with the pulp quite strong, thick mesocarp, easily peelable surface, smooth and glossy,

			fruit colour yellowish orange at full maturity, segments 9 to 10, firm, pulp yellowish orange, very juicy somewhat acidic. The variety is cold resistant.
4	Darjeeling Orange	West Bengal and Sikkim	Fruits are comparatively smaller in size somewhat flat in shape, colour yellowish to orange when fully ripe, rind thin, adherence little, juice abundant and sweet flavour.
5	Nagpur Oranges	Maharashtra, Tamil Nadu, Bihar and Madhya Pradesh	Fruits are yellowish green to orange, oblate, rind thin, fine texture and good flavour and taste. Size is medium and the skin is easily peelable.

Source: Tiwari, R.K. (2009)

Fruit colour retained greenness of buttons in Nagur mandarin with 2,4-D treatment (Ladania and Sonkar, 1996). Recommended storage condition of mandarin has been shown in Table 1.4.

Table 1.4 Recommended storage condition of mandarin

S. No.	Temperature (°C)	Relative Humidity (%)	Duration (weeks)	References
1	6-7	85-90	6-8	Jadho *et al.* (2008)
2	0	90	5-6	Liu (2009)
3	15	85-90	4	Liu *et al.* (2005a)
4	6-7	90-95	6-8	Ladaniya (2004)

Prasad *et al*. (2000) recorded minimum PLW in fruits packed in PE bags with cushioning at room temperature (4.1%) and at low temperature (2.8%). Raghav and Gupta (2003) found that individually wrapped fruit could be stored for 84 days maintaining acceptable eating quality and less PLW (4%) as compared to 40 days with 37.0% PLW in unwrapped fruits under ambient condition. Randhwa *et al.* (2000) found that shelf-life of all the wrapped fruits increased many folds with HDEP unipackaging.

1.7 Packaging and transportation

Market value of citrus fruits is controlled by its quality, which is dependent on its external and internal characteristics. Improvement of quality is one of the main factors in increasing sales (Kitagawa and Kawada, 1992). The packaging of mandarin is required for efficient handling and marketing, better eye appeal and better shelf life by reducing mechanical damage and water loss. The proper packaging protects the fruits from pilferage, dirt, and physiological and pathological deterioration during further handling. Efficient packaging of mandarin in uniform size reduces the need for repeated weighing and can facilitate handling, stacking, loading, unloading, better storage, long transportation, transshipment and marketing. The use of traditional baskets, sacks, boxes and trays to carry the produce to the market is very much common, as a packaging material. These are locally fabricated, low cost and made out of cane and bamboo, dried grass, palm leaves and teak leaves.

For shorter distances, mandarins are generally transported as head load, while within a radius of 10-20 Km, the bullock cart/tractor trolley are commonly used. Other means of transportation of fruits to the nearby markets are auto rickshaw and mini lorry. For carrying the fruits to the distance more than 100 Km, the use of trucks/railways are found to be the most convenient mode of transport due to its easy approach from the orchards to the market. In the trucks sometimes excessive pressure is exerted on the fruits due to faulty stacking and also do not possess temperature regulating devices. Therefore, it is essential to design and develop suitable transport system to overcome such defects. For long distance transportation and for export purposes it advisable that refrigerated vans is used, to reduce the post harvest losses.

1.8 Criteria and objectives

Mandarin becomes ready for harvesting from mid October to January end in the Malwa region of Madhya Pradesh. The produce remains in the market for short period. Huge harvest of produce during peak harvesting season creates glut and the growers are compelled to sell it in the local or nearby markets at throwaway rates. Owing to restricted duration of availability, perishable nature and glut during harvesting time, the fruit demands the need of packaging & storage for proper transportation to the distant markets. Packaging and storage is also required for value addition increased shelf life. Hence, mandarin packaging using various packaging materials, storage and value addition is a solution to benefit the farmer of the Malwa region of Madhya Pradesh.

There are certain chemicals, which reduce the ethylene production (respiration rate) and growth of micro-organisms so as to increase the shelf life of mandarin. Different packaging materials have different effect of the storage of mandarin.

Therefore, keeping these points in view a study on packaging and storage of mandarin is planned with the following objectives.

1. To see the effect of different plant growth regulators on physico-chemical characteristics of mandarin
2. To study the shelf-life of mandarin by use of different packaging materials
3. To study the interaction effect of plant growth regulators and packaging materials on shelf-life of mandarin

CHAPTER - II
REVIEW OF LITERATURE

Packaging and chemical treatment of mandarin is the most important for transportation and storage as it ensures the product in good condition. The main objective of packaging and chemical treatment is to reduce the physico-chemical losses and increase shelf life of mandarin. It minimizes the chances of insect and mold infestation by maintaining required moisture level in the commodity. It is also required for transportaion and storage of mandarin. Not much attention is paid to varieties, pre-treatments and packaging materials for increasing shelf-life of mandarin. Lots of work has been done by different workers in India and abroad on storage of mandarin in relation to method of packaging, pre-treatment, storage etc. The present chapter deals with the review of work carried out by various researchers.

2.1 Effect of plant growth regulators on physico-chemical properties of mandarin

Bhullar *et al.* (1981*)* conducted a study to extend the shelf life of kinnow fruits and found that the PLW and T.S.S. increased with the length of the storage period. No fruit rotting was observed after 3 weeks of storage in 2,4-D (50 ppm) treated fruits and without 2,4-D (50-100 ppm) gave better retention of juice during storage. Acidity, on the other hand decreased as the storage period progressed.

Ferguson *et al.* (1982) studied the effect of post harvest GA_3 + 2,4-D dip treatments on peel quality and decay during grape storage. Grape fruit were stored for 12 weeks at 60°F. They found that GA_3 + 2,4-D treated fruit had significantly less over ripe colour, greater puncture strength and less decay than controls.

Tatl and Ozguven (1999) studied the growth regulator treatments on the storage of Valencia in which they treated Valencia orange fruits with 0 or 200 ppm 2,4-D in the first year of study. In the second year, the following treatments were applied after harvest: 0, 100, 200 or 400 ppm 2,4-D; 200 ppm 2,4-D + 100 ppm GA_3; or 400 ppm 2,4-D + 100 ppm GA_3. The fruits were wrapped in paper and put in cardboard boxes, then placed in a cold store at 4^0C and 85-90% RH for 5 months. Fruit quality criteria, such as juice content (%), acidity (%), pH, TSS (%) and physiological and pathological losses were determined at monthly intervals during storage. Results showed that 200 ppm 2,4-D + and the 2,4-D + GA_3 treatments were the most effective for keeping the green button and reducing fruit rotting

Choudhary and Dhaka (2005) conducted a study on wax emulsion (prepared from carnauba wax; at 3, 6, 9 and 12%), gibberellic acid (GA_3 at 100, 200 and 300 ppm) and their combinations to prolong the shelf life of kinnow mandarin (*Citrus nobilis x C. deliciosa*). Appreciable results were observed during physico-chemical analysis of treated fruits on the 28^{th} day of storage. The minimum physiological loss in weight (17.97%) and spoilage percentage (13.90%) were recorded in fruits treated with 9% wax emulsion + 200 ppm GA_3. This treatment also recorded the highest organoleptic score (7.5/10), which indicated that the treated fruits were acceptable after 28 days of storage.

Jadhao *et al.* (2007) studied the effect of GA_3 on storage of kagzi lime in which they stored the kagzi lime fruits under room condition, packed in 100 gauged ventilated polyethylene bags and kept open with various chemical treatments viz. GA_3 50 ppm, GA_3 100 ppm, NaCl -1% and NaCl 2%. The fruits stored in polyethylene bags and open without chemicals treatment were considered as control. Enclosure of fruits in polyethylene bags reduced the physiological loss in weight, maintained maximum juice content, per cent acidity, ascorbic acid and minimum pH, TSS, brix/acid ratio and spoilage as compared to fruits stored in open at the end of 10 days of storage period. The fruits stored open with different treatments were spoiled completely at the end of 20 days.

Bisen and Panday (2008) investigated the efficacy of various post harvest treatments using gamma irradiation, growth retardants and coatings on quality and sensory parameters of Kagzi lime under ambient conditions. Among various treatments, pure coconut oil coating was very effective as higher TSS, acidity, vitamin C, juice content, flavour, appearance and taste were retained during storage. Pure coconut oil coated fruits maintained natural light green colour up to 24 days of storage, which was acceptable to consumers.

Jadhao *et al.* (2008) conducted an experiment in which the Nagpur mandarin fruits were stored in cold storage subjected to various chemical treatments and wax emulsion viz. without treatments, NaCl 2%, $KMnO_4$ 500 ppm, carbendazin 0.1%, waxol 6% + GA_3 500 ppm, waxol 6% + NaCl 2%, GA_3 500 ppm + NaCl 2% and carbendazin 0.1% + NaCl 2%. The fruits treated with waxol 6% + NaCl 2% recorded minimum weight loss, spoilage, pH, TSS and brix/acid ratio and the highest content of juice, titratable acidity and ascorbic acid up to 60 days in cold storage. At the end of 72 days, the fruits stored without treatments, the fruits treated with NaCl 2% and carbendazin 0.1% spoiled to the tune of 39.68, 29.99 and 32.1% respectively. The shelf life was found to be 60 days by fruits treated with NaCl 2%, carbendazin 0.1% and without chemicals (control) whereas, the fruits treated with $KMnO_4$ 500 ppm, waxol 6% + GA_3 500 ppm, waxol 6% + NaCl 2%, GA_3 500 ppm + NaCl 2% and carbendazin 0.1% + NaCl 2% could extend shelf life up to 72 days.

Bhardwaj *et al.* (2010) used nine treatment combinations consisting three levels of neem leaf extract (0, 10 and 20%) and three levels of benzyladenine (0, 50 and 100 ppm) in their experiment. Freshly fully matured and uniform fruits were packed in 0.5% perforated polyethylene bags after giving the different neem leaf extract and benzyladenine treatments and stored at room temperature. The stored fruits were examined for the physico-nutritional changes during 9, 18, 27 and 36 day of storage. The results at end of storage period revealed that the minimum losses of various physico-chemical characteristics of orange fruit were observed under dip treatment of 20% neem leaf extract combined with 100 ppm benzyladenine. Under this treatment, minimum physiological loss in weight (21.64%), fruit rotting (16.27%), minimum reduction in diameter (14.81%), minimum decrease (0.695 to 4.466%) in acidity and ascorbic acid (36.65 to 25.92 mg/100 ml juice) were recorded.

Pila *et al.* (2010) studied the physico-chemical characteristics and shelf life of tomato fruits treated with Gibberellic acid (0.1, 0.3 and 0.5%), Calcium chloride (0.5, 1 and 1.5%) and Salicylic acid (0.1, 0.2 and 0.4mM). All tested treatments indicated a significant delay in the change of weight loss, titrable acidity, total soluble solids, decaying percentage, sugar accumulation, chlorophyll degradation and carotenoids accumulation in tomato fruits of experimental set than that of the control set. Moreover, the physico-chemical analysis of tomato fruits revealed that it contain higher amount of ascorbic acid and phenolic content. The significant impact of treatment is found on the least decay percentage in the order of fruits treated with GA_3 0.1%, $CaCl_2$ 1.5% and SA 0.4mM.

2.2 Effect of packaging materials on physico-chemical properties of mandarin

McCornack (1975) determined the post harvest weight loss of most of the major citrus cultivars grown in Florida at 4 different combinations of humidity and temp. Weight loss comparisons were made monthly with Indian River-grown seedless grapefruit. Similar comparisons were made with other cvs. during their respective maturity seasons. Weight loss was approx halved in fruit held either at 40 or 70°F with 90% relative humidity (RH) rather than ambient humidity. Weight loss within each holding condition for each type of fruit showed limited variation. Storage of 'Valencia' oranges in cartons rather than mesh bags reduced weight loss at 70°F storage, but not at 40°F storage.

Ahmad *et al.* (1979) studied the effect of waxing and some lining materials on the storage life of 'Feutrell's Early' and 'Kinnow' mandarins, stored at room temperature. Waxing as well as lining materials reduced weight loss but had no effect on the physico-chemical constituents, however, ascorbic acid and citric acid decreased whereas sugars and sugar/acid ratio increased during storage. Both waxing and lining materials helped to maintain the external appearance of fruits. However, development of off-flavour was noticed in waxed fruit stored at room temperature.

Ahmad and Khan (1987) determined the effects of waxing of the fruit and of the use of cellophane for lining storage boxes on chemical quality indices and flavour scores of Feutrell's Early mandarin during storage at room conditions. Maximum changes during storage of waxed mandarins in film-lined boxes occured in ethanol contents which were followed by acetaldehyde, total soluble solids (TSS)/acid ratio, TSS and acid contents. There were comparatively greater increases in ethanol and acetaldehyde content, lesser increases in TSS and greater decreases in total solids of waxed mandarins during storage than those of unwaxed fruits stored in film lined boxes; the ratio of ethanol and acetaldehyde (E/A) of waxed mandarins was also higher. Decreases in citric acid content during storage correlated linearly to increases in the E/A ratio at the 1% level of significance indicating that citric acid metabolism was affected during storage of waxed mandarins at ordinary room conditions.

Kawada and Kitagawa (1992) reported that Sudachi (Citrus sudachi Hort. ex Shirai) in Japan production amounts to 10000 t of which 1300 t is stored, the fruits are usually served as a garnish, cut in half. They are harvested at the green stage because their aroma disappears, as they turn yellow. After harvest the fruits are cured at ambient temperature for 3-5 days then sealed in polyethylene bags and stored at 1°C for 2-3 months, or 3°C for 6 months. Pre-storage curing, conditioning and storage temperature are important for minimizing fruit injury and decay.

Sandhu (1992) studied over 10 years for mandarins cv. Kinnow in relation to fruit maturity indices, harvesting, grade specifications and packaging materials. He found that packaging in wooden crates resulted in the lowest losses from rotting and maintained fruit quality in comparison with other packaging materials.

Barua and Yamdagni (1996) reported that fruits of mandarin cv. Khasi packed in wooden boxes or corrugated paper boxes retained their firmness, weight and ascorbic acid contents better during transportation and subsequent storage than fruits packed in bamboo baskets or fertilizer bags. Fruits packed in bamboo baskets showed the greatest loss of quality in terms of decreasing ascorbic acid contents. Colour break fruits lost more moisture during transportation and storage than complete orange-yellow fruits. Acidity of fruits decreased significantly during storage, irrespective of packaging material and fruit maturity stage.

Toker and Bicici (1996) conducted a study on storage of fruits in which mandarin, orange, grapefruit and lemon fruits untreated before harvest and at packing were stored at ambient temperature for 2 months or kept for 2 or 4 months in cold storage. During storage, 16.8, 25.1 and 65.4% crop losses caused by post harvest diseases were observed under the 3 storage conditions tested, respectively. In another experiment, citrus trees were sprayed with benomyl, fosetyl-aluminium and $CuSO_4.5H_2O+ZnSO_4.6H_2O$ + hydrated lime to control post harvest diseases 1-1.5 months before harvest. In addition, adding fosetyl-aluminium, sodium-phenylphenate, 2,4-D isopropyl-ester to water and spraying benomyl and imazalil to water-wax were tested for control of post harvest diseases during packing. Some lemon fruits were wrapped in biphenyl-emitting paper. A combination of pre-harvest fungicide treatments with treatment during packing gave the best disease control.

Tugwell and Chvyl (1996) reported that Valencia oranges and lemons packed in carton liners were of fresh appearance after 12 weeks of storage, losing <1% weight compared with 9% from non-lined packages. Imperial mandarins packed in plastic liners and held at 5°C had a storage life of only 4 weeks due to loss of flavour. Lemons and mandarins packed in plastic liners were held at 20°C to determine if freshness could be maintained during local marketing conditions.

Saucedo-Veloz *et al.* (1997) reported that harvested Dancy mandarin fruits were individually wrapped in polyolefin film or polyvinylchloride (PVC) film or not wrapped (controls). The fruits were stored in commercial conditions (20 plus or minus 2^0C; 50-60% RH) for 12 days (controls) or 20 days (wrapped fruits), or in cold storage (5 or 10^0C) for 4-8 weeks. Water loss was higher from control fruits than from wrapped fruits (4-6 times higher at 20^0C, 6-7 times at 10^0C and 7-9 times higher at 5^0C). The firmness of control fruits was lower than that of wrapped fruits (4 times lower at 10^0C and 2 times lower at 5^0C). Wrapped fruits had significantly lower levels of internal percentage CO_2 and ethanol levels in juice than control fruits. No off-flavours or undesirable aromas were detected. Wrapping had no effect on internal quality (soluble solids content (SSC), titratable acidity or the SSC:acidity ratio). The results show that film-wrapped Dancy mandarins can be kept in cold storage for up to 8 weeks; the best results were obtained with storage at 5^0C, 85-90% RH.

Peretz *et al.* (1998) found in their study that high humidity packaging extended the life of different types of easily peeled citrus fruit. Thiabendazole and imazalil succeeded in maintaining low levels of decay in the high humidity packaged fruits. Sealed Nova and Ora mandarins after 4 weeks storage at 5°C followed by 1 week at

20°C, remai ned firm and lost very little weight (0.6-1% in comparison with 6.7% in the control).

Sonkar and Ladaniya (1999) evaluated that heat-shrinkable (50 mm) low density polyethylene (LDPE) and stretch-cling (15 mm) linear low density polyethylene (LLDPE) films for individual wrapping of Nagpur mandarin fruits to extend their shelf life under refrigerated storage conditions (6-7°C and 90-95% RH). Wrapping fruits reduced water loss drastically (1-2%) in both the films compared with non-wrapped fruits (13.29%) at the end of refrigerated storage (60 days), followed by a 2-day holding period in ambient conditions. Colour development was not adversely affected either by heat-shrinkable (LDPE) or stretch cling film (LLDPE). Respiration rate was low in film-wrapped fruits. Fruit firmness decreased in wrapped fruits, but not in controls. Flavour and overall acceptability scores were highest in stretch-cling film-wrapped fruits at the end of storage.

Kumar *et al.* (2000) conducted a study on shelf life of kinnow (a hybrid mandarin) in which they harvested the fruits at full ripe stage, packed in paper and polyethylene lined cardboard boxes, and weight and decay losses were recorded at weekly interval. Fruits with individual paper wrapper and paper lining were also kept in modified atmosphere storage. Physiological loss in weight (PLW) increased with increasing period of storage in all the treatments. The minimum PLW (3.0%) was observed in fruits wrapped individually in polyethylene, followed by fruits packed in polyethylene lined boxes (3.6%) after 70 days of storage. However, fruits packed in modified atmosphere storage with individual paper wrapping and paper lining also showed significantly less PLW than the control. Maximum PLW was observed in individual paper wrapped fruits kept in cardboard boxes. There was no decay loss in any of the treatments up to 49 days of storage. Polyethylene packed fruits had more decay loss compared to fruits kept in newspaper and cardboard boxes. The total soluble solid content increased with increasing period of storage in all the treatments, the highest increase being observed in fruits packed individually in newspaper. Ascorbic acid decreased with increasing period of storage in all treatments.

Akram *et al.* (2001) evaluated the effect of washing on the shelf life of damaged citrus fruit quality. The unwashed fruits had higher weight loss than washed fruits and all the sealed fruits had lower weight loss than unwrapped fruit. Sealed and washed fruits maintained the initial deformation and firmness and had good appearance while the unwashed and unwrapped fruits became softer. The total soluble solids (TSS) were not affected by washing and sealing but the unwrapped fruits had lower acidity and higher TSS/acid ratio than in sealed fruits. Higher O_2 and lower CO_2 contents were recorded in washed and sealed fruit bags than in unwashed and sealed fruit bags.

D'Aquino *et al.* (2001) studied the feasibility of improving the post harvest keeping quality of Malvasio mandarins, a late ripening cultivar, with the application of three different plastic films (least permeable, medium permeability and perforated), in order to allow marketing of the produce in summer months, when no other mandarins are available on the market. The perforated film had a slight and negligible influence on the quality maintenance of mandarins. The permeable films preserved the visual appearance and prevent weight losses, and in particular the medium permeable film that inhibited ageing and losses of overall quality in mandarins during storage at different temperature.

Ladaniya (2001) reported that fruits packed without polyethylene liner lost more juice and ascorbic acid and had more firmness, TSS and acidity content. Appearance and flavour score was highest after 30 days in degreened fruit treated with Sta-fresh 451 wax and packed in vented polyethylene lined CFB boxes.

Glahan (2004) studied the influences of packaging materials and O_2:CO_2 gases on quality and storage life of tangerine (*Citrus reticulate* Blanco) and found that TSS content of tangerine increased whereas titrable acidity content gradually decreased corresponding to the storage time increased. The packaging materials, PE bag had more pronounce effect on quality and storage life of tangerine than LDPE and PP bags which contrary LDPE and PP bags had greater effects than PE bag on fresh weight loss color changing of rind, pulp and taste. The tangerine stored in PE bag as follows: + O_2:CO_2 0:0, 5:5, 5:10, 10:15 and 10:20 PSI that provided the longest storage life for 63 days whereas the shortest storage life for 14 days which were obtained from LDPE and PP bag + O_2:CO_2 at any flow rates and showed significantly difference.

Rana *et al.* (2002) studied the shelf life of Kinnow mandarin fruits packed in card board boxes covered with polyethylene under various storage conditions (i.e. paper as the lining material, paper lining with modified atmosphere storage, individual paper wrapping with or without modified atmosphere storage, polyethylene sheet lining, and individual polyethylene packaging). After 77 days of storage, fruits stored in polyethylene bags had the lowest physiological weight loss (4.0%) while those packed using paper lining as a cushioning material recorded the greatest physiological weight loss (20.6%).

Thakur *et al.* (2002) conducted an experiment with Kinnow in which the fruits were given a post harvest dip in 0.1% Bavistin solution for 5 min, and varying number of fruits were packed in low density polyethylene (LDPE) bags of 150 gauge thickness. The fruits were stored under ambient, evaporative cool chamber and cold storage conditions to compare the efficacy of different treatments and storage conditions in retaining fruit quality during prolonged storage. Fruits stored under ambient conditions remained in marketable condition up to 8 weeks, whereas, fruits from the other storage systems were in marketable condition even after 10 weeks. Bavistin treatment followed by packaging of fruits in LDPE bags was effective in retaining fruit quality during storage and the best results were obtained when four fruits were packed in a unit.

Keditsu *et al*. (2003) conducted an experiment on fruits of 'Khasi' mandarin. Fruits were treated with various combinations of modified packaging (polyethylene bags, perforated bags, $KMnO_4$ + polyethylene bags) and low temperature treatments (4-5^{0}C and 0-1^{0}C) and stored. Colour development increased total soluble solids and total sugars increased marginally but declined towards later part of storage while fruit weight, juice content and ascorbic acid decreased with storage period. Fruits from polyethylene bag + $KMnO_4$ and 4-5^{0}C treatments were found to be better than fruits from other treatments.

Hussain *et al.* (2004) investigated the effect of Uni-Packaging treatments on the shelf life of citrus fruits. Different treatments were polyethylene bags of 0.0254 mm, 0.0508 mm thickness and control. The result showed that the uni-packaging had no significant effect on the pH of citrus fruit. Weight loss increased significantly as storage increased. Maximum weight loss was observed in control and minimum weight loss in thick packaging (0.0508 mm). The T.S.S increased during storage but individual packaging had non-significant effect on the T.S.S. ascorbic acid decreased from 1.59-0.63% during storage. The organoleptic properties evaluation revealed that individual packaging had significant effect on the external appearance, taste and texture. Thick packagings perform significant effect in prolonging the shelf life of citrus fruit.

Ahmad *et al.* (2005) reported a continuous increase in PLW of fruits during storage in all treatments and storage conditions. However, application of Bavistin (0.05%) + PE packaging of four fruits in a unit proved to be an efficient treatment in reducing weight loss followed by Sta-Fresh 960 (100%). The ascorbic acid contents registered a gradual decline with the advancement in storage period in all treatments and storage systems. Packaging of four fruits in one PE bag after 0.05% Bavistin treatment followed by 100% wax emulsion recorded maximum retention of ascorbic acid content as compared to other treatments at the end of storage.

Mahajan *et al.* (2005) conducted an experiment with freshly harvested Kinnow fruits (*Citrus reticulata*) treated with citrashine wax, calcium chloride ($CaCl_2$ 2%) and Bavistin (500 ppm) and thereafter the fruits were packed in corrugated fibre board cartons and stored in commercial cold storage at 2-3.5ºC and 90-95% RH. The control fruits were kept untreated under same conditions. Results indicated that wax-coated fruits could be stored up to 60 days in cold storage without loss of quality. However, control fruits developed shriveling and slight off-flavour after 45 days of storage.

Choi *et al.* (2006a) conducted a study to find out the feasibility of the MAP method to *Tangor* preservation. For this purpose, the effect of carbon dioxide absorbent treatment in MAP inquire into prolonged shelf-life and maintain quality during storage periods in Citrus *Tangor*. Packaging material for carbon dioxide control was a low density polyethylene film of 0.03 mm thickness or a mixed CaO carbon dioxide film. Fruits were packaged as sealed, single fruit per 3 fruit packages, and a 3 kg package. The packaging film of mixed CaO was better than the control during long-term storage. It is suggested that the film of mixed CaO in MAP treatments was the better treatment to improve the fruit shelf life and freshness in the most cases of fruit storage.

Choi *et al.* (2006b) designed their research to select a packaging material to improve quality and extend fruit freshness in modified atmospheres. Fruits (*Citrus unshiu*) were packaged in film with different whole levels as bored percentage of plastic surface of 1, 3, 5%, and then stored at 4°C or 8°C in storage room. Some physical and chemical analyses were conducted which were taken at different intervals of storage and shelf life period. The most successful results regarding storage of *Citrus unshiu* were obtained from PE package material with individual sealing and bored 3% of film surface containing holes.

Marcilla *et al.* (2006) reported the effect of different storage temperatures (5, 15, 20 and 25ºC) on the flavour of cv. Valencia Late Frost oranges stored for up to one month. Samples were instrumentally analysed every week for titratable acidity, soluble solid content, maturity index, and ethanol and acetaldehyde contents. In addition, four sensory attributes were assessed by 20 taste panellists i.e. acidity, maturity index, off-flavours and orange-like flavour. This showed that the presence of off-flavours reduced the orange-like flavour perceived, but affected neither the acidity nor the maturity index. The higher temperatures reduced the orange-like flavour and increased the presence of off-flavours over storage.

Hammash and Assi (2007) conducted a study in which the oranges were subjected to four treatments: without wrapping or waxing, with wrapping or waxing, all placed at 4°C and 90-95 % relative humidity, and wrapping placed under room conditions (13-19°C), for three months. Stored oranges were analyzed at 0 days after 45 days, and after 90 days of storage to evaluate fruit weight loss, fruit albedo firmness, total soluble solids, total titratable acidity, and ascorbic acid.

Massignan and Lovino (2007) studied post harvest and packaging techniques for citrus fruits. Cold storage effects and over ripening were evaluated on the quality of orange cv. Valencia Late. Hot water treatment and yeast treatment were applied on Valencia Late, Washington Navel and Tarocco for the quality evaluation after the cold storage and after the shelf life. The cold treatment at 1^0C for 14 days and then the ozone and the ETOH treatments and the controlled atmosphere were applied to organic Clementine to preserve the quality during the shelf life.

Jadhao *et al.* (2008) conducted an experiment, which deals with the storage of kagzi lime in perforated polyethylene and non-perforated polypropylene bags of 100, 200 and 300 gauges and with different treatments, chemicals and wax emulsion. The fruits stored in 200 gauged perforated polypropylene bags recorded minimum pH, TSS, brix/acid ratio and maximum content of acidity and ascorbic acid at the end of 70 days in cold storage condition. Among different chemicals and wax emulsion, waxol 6% + captan 0.1% recorded minimum pH, TSS, brix/acid ratio and maximum content of acidity and ascorbic acid at the end of 30 days in case of CS and 20 days in cold storage. However, it revealed that, fruits packed in 200 gauge perforated polypropylene and polyethylene bags exhibited shelf life up to 70 by slowed down bio-chemical changes.

Ramin and Khoshbakhat (2008) investigated the potential of 30 µm thickness High Density Polyethylene (HDPE) bags with, 1x40, 2x40, 3x40 micro-perforations and no-bags (control) for maintaining the quality of “Key” acid lime fruits during storage. The influence of storage temperatures (10 and 20°C) and storage periods (5 and 10 weeks) was also evaluated.

Shein *et al.* (2008) found that the application of food grade wax not only reduces water loss from the fruit but also improves the appearance of the fruit. They also reported that low temperature storage is the most effective method to maintain quality and extend shelf life of the fruit mandarin orange (*Citrus reticulata* Blanco cv. ’Sai Nam Peung’).

Zade *et al.* (2008) reported that the storage life can be increased by several means like storing at low temperature (cold storage), use of fungicides, application of growth regulators and various chemical treatments have been reported to increase the shelf life of Nagpur mandarin. They concluded that fruits treated with 2% Sesamum oil and stored at 5ºC temperature in cold storage resulted in minimum physiological loss in fruit weight up to 45 days. The palatability and fruit quality of Nagpur mandarin were found better during the storage period.

Marcilla *et al.* (2009) studied the relationship between physico-chemical parameters (weight loss, rind gloss, juice yield, soluble solids content, titratable acidity, maturity index, and ethanol and acetaldehyde content) and sensory attributes (acidity, sensory maturity index, off-flavor and mandarin like-flavor) of "Clemenules" mandarins was studied in relation to coating treatments and cold storage duration. Fruit were uncoated (control) or treated with two commercial water-based waxes, both with the same wax composition (polyethylene wax and shellac) but two different total solids concentrations (70 and 100 g/kg). Fruit were stored at 5 ºC and 90% relative humidity for 12, 22, 32, 42, 52 or 62 days, plus 7 days at 20 ºC to simulate shelf life marketing conditions. Physico-chemical quality was well preserved throughout storage, especially in fruit coated with 70 g/kg total solids water wax. Fruit from this treatment had the lowest weight loss and the greatest rind gloss. Mandarin-like flavor decreased throughout the storage period, which was highly related with ethanol build-up. Partial least square regression analysis showed that in general the correlation between sensory attributes and instrumental measurements was high.

CHAPTER- III

MATERIALS AND METHODS

Materials and methods used for the present study are described under the following sub-sections.

3.1 Location

An investigation entitled, "**Effect of different plant growth regulators and packaging materials on shelf-life of mandarin (*Citrus reticulata* Blanco*)***" was conducted at the Department of Post Harvest Management, College of Horticulture, Mandsaur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior during 2010-2011.

3.2 Experimental details

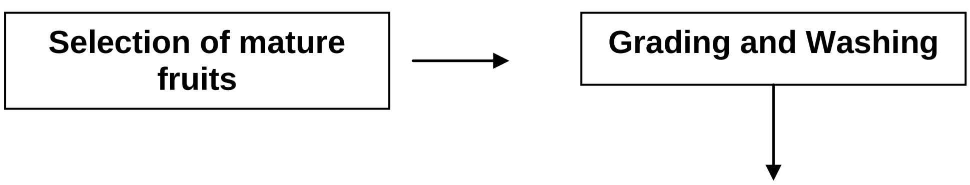
For different treatment combinations, one level of variety, five levels of pre-treatments and four levels of methods of packaging were used. Thus, in the present investigation a total of 20 treatment combinations on storage were made. The experimental details and various treatment combinations are presented in Table 3.1, Table 3.2 and Plate 3.1.

3.3 Materials

3.3.1 Raw materials

Evenly sized, uniform and fully matured fruits of mandarin cv. Nagpur were harvested from the field of a farmer Shri Rajendra Patidar of Jaora, Ratlam (M.P.) and brought to the laboratory for the purpose of experiment.

A sample of 2 kg mandarin fruits/pack was weighed before packaging and storage. For a single replication 40 kg fruits were used in the experiment. Thus for three replications a total of 120 kg mandarin was used for the experiment.



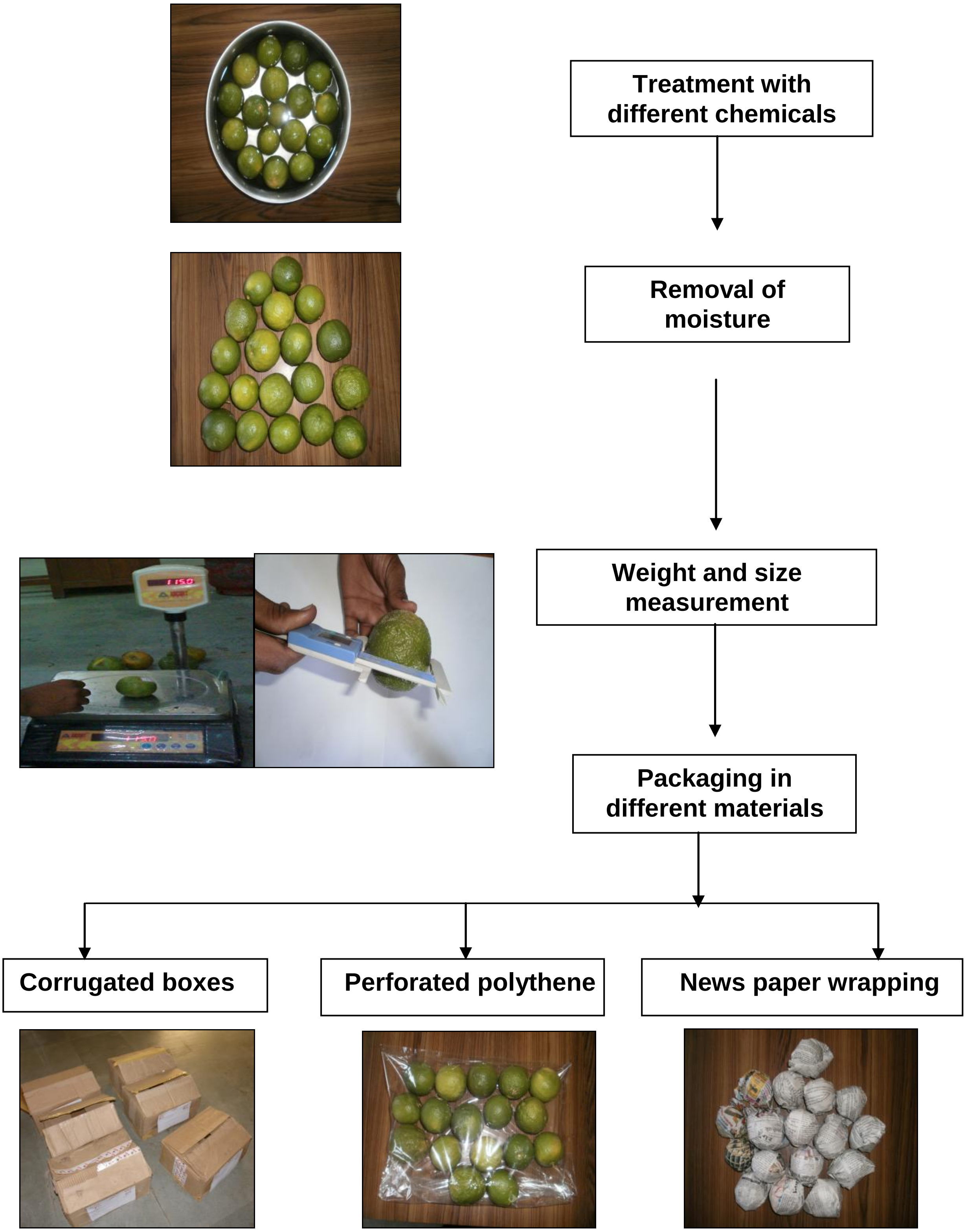


Plate 3.1: Flow chart of preparation for mandarin storage

Table 3.1 Experimental details

Name of crop	Mandarin (*Citrus reticulata* Blanco)
Variety	Nagpur

Pre-treatment	1. Untreated (Without any chemical treatment) (T_0)
	2. Dipping in 2,4-D 50 ppm (T_1)
	3. Dipping in 2,4-D 100 ppm (T_2)
	4. Dipping in GA_3 50 ppm (T_3)
	5. Dipping in GA_3 100 ppm (T_4)
Packaging materials	1. Untreated (Without any packaging material) (P_0)
	2. Corrugated fiber box (P_1)
	3. Perforated polythene (P_2)
	4. Individual wrapping with newspaper (P_3)
Total No. of treatment combinations	20
No. of replications	3
Quantity of fruits per pack	2 kg
Total number of treatments	20 x 3 = 60
Experimental design	Factorial CRD
Observations recorded at	0, 5th, 10th, 15th and 20th day of storage

Table 3.2 various treatment combinations

S. No.	Treatment combinations		Symbols
	Pre-treatment	Packaging material	
1	Untreated (Without any chemical treatment)	Without packaging	T_0P_0
2	Dipping in 2,4-D 50 ppm solution for one h	Without packaging	T_1P_0
3	Dipping in 2,4-D 100 ppm solution for five min	Without packaging	T_2P_0
4	Dipping in GA_3 50 ppm solution for five min	Without packaging	T_3P_0
5	Dipping in GA_3 100 ppm solution for five min	Without packaging	T_4P_0
6	Untreated (Without any chemical treatment)	Corrugated boxes	T_0P_1
7	Dipping in 2,4-D 50 ppm solution for five min	Corrugated boxes	T_1P_1
8	Dipping in 2,4-D 100 ppm solution for five min	Corrugated boxes	T_2P_1
9	Dipping in GA_3 50 ppm solution for five min	Corrugated boxes	T_3P_1
10	Dipping in GA_3 100 ppm solution for five min	Corrugated boxes	T_4P_1
11	Untreated (Without any chemical treatment)	Perforated polythene	T_0P_2
12	Dipping in 2,4-D 50 ppm solution for five min	Perforated polythene	T_1P_2
13	Dipping in 2,4-D 100 ppm solution for five min	Perforated polythene	T_2P_2
14	Dipping in GA_3 50 ppm solution for five min	Perforated polythene	T_3P_2
15	Dipping in GA_3 100 ppm solution for five min	Perforated polythene	T_4P_2
16	Without any pre-treatment	Newspaper wrapping	T_0P_3
17	Dipping in 2,4-D 50 ppm solution for five min	Newspaper wrapping	T_1P_3
18	Dipping in 2,4-D 100 ppm solution for five min	Newspaper wrapping	T_2P_3
19	Dipping in GA_3 50 ppm solution for five min	Newspaper wrapping	T_3P_3
20	Dipping in GA_3 100 ppm solution for five min	Newspaper wrapping	T_4P_3

3.3.2 Ingredients

Chemicals (T_1: 2,4-D 50 ppm, T_2: 2,4-D 100 ppm, T_3: GA_3 50 ppm, T_4: GA_3 100 ppm), alcohol and distilled water.

3.3.3 Packaging materials

Corrugated boxes (35 cm x 20 cm x 20cm), perforated polythene (35 cm x 25 cm) with diameter of perforation 2.5 mm, newspaper (30 cm x 25 cm) and brown tap were used for the preparation of samples for storage.

3.3.4 Other instruments

For the purpose of weighing an electric balance made by Ascort Digital was used. The maximum capacity of balance was 5 kg (SHC-12, Crown - made in India) with least count 0.5 g, vernier calipers (Omega, made in Japan) with least count 0.01 cm, and Abbe refractometer (Fuzhou, made in China), Inch tape were used in the experiment.

3.4 Methods

3.4.1 Selection of fruits

Greenish and fully matured mandarin fruits were selected for preparation of samples for storage. Damaged, diseased, and immature fruits were sorted out.

3.4.2 Washing

Selected fruits were washed with the help of running tap water.

3.4.3 Preparation of chemical solution

For preparation of 50 and 100 ppm 2,4-D solution, 0.5 and 1 g crystals of 2,4-D were dissolved in 10 ml of alcohol respectively. Thereafter, 1 litre of distilled water was added to it. Similarly, for 50 and 100 ppm GA_3 solution, 0.5 and 1 g crystals of GA_3 were dissolved in 10 ml of alcohol respectively. Thereafter, 1 litre of distilled water was added to it.

3.4.4 Method of pre-treatment

The washed fruits were dipped in above prepared chemical solutions for five minutes.

3.4.5 Removing of moisture

After pre-treatment the fruits were dried at room temperature for one h.

3.4.6 Methods of packaging

After moisture removal the mandarin fruits were packed in different packaging material (corrugated boxes, perforated polythene and newspaper) @ 2 kg/pack.

3.4.7 Storage

After packaging the fruits were stored at ambient room temperature (16-22°C) and relative humidity (66-80%). The details of room temperature and relative humidity fluctuations during the course of investigation are given in Appendix-I. The treated fruits were subjected to various physico-chemical observations at 0, 5^{th}, 10^{th}, 15^{th} and 20^{th} day of storage as described in succeeding sub-sections.

3.5 Observations

The study of physical, chemical and organoleptic parameters at 0, 5^{th}, 10^{th}, 15^{th} and 20^{th} day of storage constituted the part of observation. Various observations were recorded during the study as shown in Table 3.3.

Table 3.3 Observations recorded during the study

Fresh fruits	Physical characteristics	Appearance Fruit size (L x W cm) Individual fruit weight (g) Moisture content (%) Number of fruits/kg
	Chemical characteristics	Acidity (%) Ascorbic acid (mg/100ml) Reducing sugars (%) Total sugars (%) T.S.S. (^{0}Brix)
Chemically treated and packaged fruits	Physical characteristics	Appearance Fruit size (L x W cm) Individual fruit weight (g) Physiological loss in weight (%) Rotting (%) Shrinkage ratio

	Chemical characteristics	Acidity (%) Ascorbic acid (mg/100ml) Reducing sugars (%) Total sugars (%) T.S.S.(^{0}Brix)
	Organoleptic characteristics	Colour Flavour Texture Overall acceptability

3.6 Methodology used for observations

The details of the techniques used for recording the observations at different intervals during the storage are given below.

3.6.1 Physical characteristics of fresh and stored mandarin

3.6.1.1 Appearance

Mandarin fruit visually analyzed before and after the treatment on 5th, 10th, 15th and 20th day of storage. Any colour change in samples was noted. Color of fruit was categorized in three categories i.e. greenish, yellowish green, yellowish, brownish yellow.

3.6.1.2 Fruit size

For determination of fruit size, three fruits in each treatment was marked and labeled. The diameter of labeled fruits was measured with the help of inch tape prior to storage. Their diameter was measured on 0, 5th, 10th, 15th and 20th day of storage. Reduction in diameter was expressed on percentage basis (on the basis of original diameter of fruits).

$$\text{Reduction in size (\%)} = \frac{\text{Initial diameter - Final diameter}}{\text{Initial diameter}} \times 100$$

3.6.1.3 Weight of the individual fruit

Weight of the five fruits was taken on the top pan of electric balance individually and the average weight was recorded in gm.

3.6.1.4 Moisture content

Moisture content was determined by standard official methods of analysis. This involves drying the desired material to a constant weight at suitable temperature and calculating moisture as the loss in weight of the dried samples. The percentage moisture content was calculated as loss in weight of the original fruit.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where, W_1 = Initial weight, g

W_2 = Final weight after drying sample, g

3.6.1.5 Physiological loss in weight

For determination of physiological loss in weight (PLW), 1kg fruits from each treatment were marked and labeled. The marked and labeled fruits in each treatment were weighed prior to storage. Their weight was determined on 0, 5th, 10th, 15th and 20th days of storage. PLW was expressed on percent basis (on the basis of original weight of fruit).

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

3.6.1.6 Rotting

Rotten fruits were visually counted out from total number of fruits in each treatment at an interval on 0, 5th, 10th, 15th and 20th day of storage. Rotting was expressed on percentage basis.

$$\text{Rotting (\%)} = \frac{\text{Rotten fruits}}{\text{Total fruits}} \times 100$$

3.6.1.7 Shrinkage ratio

For determination of shrinkage ratio, four fruits in each treatment was marked and labeled. Volume of the labeled fruits was taken prior to storage. Volume was taken on 5th, 10th, 15th and 20th day of storage. Reduction in volume was expressed on percentage basis (on the basis of original volume of the fruit).

$$\text{Shrinkage ratio} = \frac{\text{Final volume}}{\text{Initial volume}}$$

3.6.2 Organoleptic characteristics of fresh and stored mandarin

The mandarin fruit is stored over a period of 20 days were subjected to organoleptic evaluation by a panel of six judges following hedonic rating tests as described by Ranganna (1978). The mandarin fruits were evaluated for colour, taste, flavour, texture and overall acceptability. The characters with mean scores of zero or more out of 10 marks were considered acceptable.

3.6.2.1 Colour

The colour of the mandarin fruits was judge by visual method. For this a panel of six judges was chosen who examined the fruit and score given by them was averaged. All the fruits in a given replication were judged. The fruits were placed in four categories/ranks depending upon marks allotted to them at the storage intervals. The following ranges were fixed for various categories. The scoring was done by following pattern as shown in Table 3.4.

Table 3.4 Sensory score for colour

S. No.	Category	Marks/Range
1	Greenish	7.5-10.0
2	Yellowish green	5.0-7.49
3	Yellowish	2.50-4.99
4	Brownish yellow	< 2.49

3.6.2.2 Texture

The texture of fruits was judged by a panel of six judges using the thumb and nail (thumb and finger) method. All four fruits in a given replication were judged. The fruits were placed into four categories/ranks depending upon the marks allotted to them at the storage interval. The scoring was done by following pattern as shown in Table 3.5.

Table 3.5 Sensory score for texture

S. No.	Category	Marks/Range
1	Firm	7.5-10.0
2	Moderately firm	5.0-7.49
3	Soft	2.50-4.99
4	Very soft	< 2.49

3.6.2.3 Flavour and overall acceptability

The flavour and overall acceptability of stored fruits were evaluated by a panel of six judges on the basis of smell and blend of the fruit juice. The scoring was done by following pattern as shown in Table 3.6.

Table 3.6 Sensory score for flavour and overall acceptability

S. No.	Category	Marks/Range
1	Excellent	7.5-10.0
2	Very good	5.0-7.49
3	Good	2.50-4.99
4	Poor	< 2.49

3.6.3 Chemical characteristics of fresh and stored mandarin

3.6.3.1 Acidity

Acidity was determined by diluting the known weight of fresh juice of mandarin fruit sample (sample was weight and ground well with a pestle and mortar) and titrating the sample against standard 0.1 NaOH using phenolphthalein as the indicator. Appearance of light pink colour denotes the end point. The acidity was calculated by using following formula and expressed in percent.

$$\text{Acidity (\%)} = \frac{1 \times \text{Equivalent weight of acid} \times \text{Normality of NaOH} \times \text{Titer}}{\quad} \times 100$$

10 x Weight of sample

3.6.3.2 Ascorbic acid

The ascorbic acid content of fresh and stored fruits was determined by diluting the known quantity of the fruit juice with 4% metaphosphoric acid and filtered through filter paper and titrating with 2, 6-dichlorophenol indophenol dye solution (A.O.A.C., 1960) until the stable faint pink colour was obtained.

Standardization of 2, 6-dichlorophenol indophenol dye solution was done by titrating it against standard ascorbic acid solution. For this purpose 100 mg of ascorbic acid was dissolved in 4% metaphosphoric acid and the volume was made to 100 ml from this 10 ml of ascorbic acid solution was used for titration. The result was calculated by the following formula and expressed in mg ascorbic acid (vitamin C) per 100 ml of fruit juice.

$$\text{Ascorbic acid (mg/100 ml)} = \frac{\text{Titer x dye equivalent X dilution}}{\text{Weight of sample}} \text{ X 100}$$

3.6.3.3 Reducing sugars

Reducing sugar of fresh and stored fruits was estimated by dinitro salicylic acid method. A sample of 100 ml was taken and sugar extracted with hot 80% ethanol twice (5 ml each time). Supernatant was collected and evaporated by keeping it on a water bath at 80°C then 10 ml of water was added to dissolve the sugars. From which, 0.05 ml of the extract was taken in the test tube and volume was made up to 3 ml with distilled water. To this 3 ml of DNS reagent was added. The content were treated in boiling water bath for 5 min when the contents of the tube were still warm, 1 ml of 40% Rochelle salt solution was added, cooled to room temperature and absorbance was measured at 510 nm. The amount of sugars present in the sample was compared against standard curve prepared from different concentration of glucose. The reducing sugars content was expressed in percentage basis.

3.6.3.4 Total sugars

For estimation of total sugar content, 100 ml of sample was weighed and sugar was extracted with hot 80% ethanol, twice (5 ml each time). Supernatant was collected and evaporated by keeping it on a water bath at 80°C. Total sugars was determined by using anthrone reagent method. To 0.5 ml of this supernatant (100 times diluted), 5 ml of anthrone reagent was added then heated for 10 to15 min in a water bath, cooled to room temperature and absorbance was measured at (620 nm). The amount of sugars present in the sample was compared against standard curve prepared from glucose. The total sugars content was expressed in percentage basis.

3.6.3.5 Total soluble solids (TSS)

The total soluble solids content was measured at room temperature with the help of Abbe refractometer (Fuzhou, made in China). For this purpose a drop of fruit juice is placed on the prism of refractometer and values obtained were corrected at 20°Brix.

3.7 Environmental conditions

3.7.1 Temperature

Ambient temperature was determined with the help of minimum and maximum thermometer (Zeal -Made in England, Capacity - 0^{o}C to 50^{o}C).

3.7.2 Relative humidity

Relative humidity was measured through digital hygrometer (make Vista Biocell Pvt. Ltd. New Delhi, INDIA). Dry bulb and wet bulb temperatures were also used to calculate the relative humidity with the help of psychometric chart.

3.8 STATISTICAL ANALYSIS

To test the significance of variation in the data obtained, the analysis of variance technique was adopted as suggested by Fisher (1950) for Completely Randomized Design. Significance of the difference in the treatment effect was tested through “F” test.

CHAPTER- IV
RESULTS

The results of the present investigation entitled **"Effect of different plant growth regulators and packaging materials on shelf-life of mandarin (*Citrus reticulata* Blanco)"** have been presented in this chapter. The data pertaining to various parameters were subjected to statistical analysis. In support of tabular representation of data, a few bar diagrams have also been inserted for better understanding. The further analysis of the data is given in Appendix II to XVI.

4.1 Physical characteristics of fresh mandarin

The average fruit appearance, fruit size, individual fruit weight, moisture content and no. of fruits/kg, length & width, colour, taste, flavour and texture was measured and has been shown in Table 4.1.

Table 4.1 Physical characteristics of fresh mandarin

S. No.	Characteristics	Value
1	Appearance	9.5
2	Fruit size (L x W cm)	14.72 x 12.28
3	Individual fruit weight (g)	192
4	Moisture content (%)	92
5	Number of fruits/kg	7

4.2 Organoleptic characteristics of fresh mandarin

The average fruit colour, flavour, texture and overall acceptability was measured and has been shown in Table 4.2.

4.3 Chemicals characteristics of fresh mandarin

Chemical characteristics of fresh mandarin viz., acidity, ascorbic acid, reducing sugars, total sugars and total soluble solids were determined shown in Table 4.3.

Table 4.2 Organoleptic characteristics of fresh mandarin

S. No.	Characteristics	Value
1	Colour	9.5
2	Flavour	9.2
3	Texture	9.3
4	Overall acceptability	9.8

Table 4.3 Chemicals characteristics of fresh mandarin

S. No.	Characteristics	Value
1	Acidity (%)	0.89
2	Ascorbic acid (mg/100ml)	17.4
3	Reducing sugars (%)	3.26
4	Total sugars (%)	10.3
5	T.S.S. (^{0}Brix)	7.4

4.4 Physical Parameters of stored mandarin

Data of physical characteristics of stored mandarin viz. appearance**,** fruit size, individual fruit weight, physiological loss in weight, rotting and shrinkage ratio were determined and are presented in Table 4.4 to 4.9 and analysis of variance for these characteristics is given in Appendices II to VII. The results obtained with regard to various physical characteristics are discussed in following sub-sections:

4.4.1 Appearance

The results pertaining to the appearance of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.4 and Fig. 4.1. The analysis of variance is given in Appendix-II.

4.4.1.1 Effect of chemicals

An examination of Table 4.4 reveals that the pre-treatments affected the appearance of mandarin. The minimum appearance (4.95) was recorded in treatment T_0, and the maximum (5.64) was recorded in T_2 after twenty days of storage.

4.4.1.2 Effect of packaging materials

Appearance of stored mandarin was significantly affected by packaging methods. The maximum appearance (5.42) was recorded in P_1 and minimum (4.91) in P_0 after twenty days of storage.

4.4.1.3 Combined effect of chemicals and packaging materials

The appearance of stored mandarin significantly affected by treatments combination of packaging methods and pre-treatments. The maximum appearance (6.19) was obtained in T_2P_1 and minimum (4.79) in T_0P_0 after twenty days of storage.

4.4.2 Reduction in fruit size (%)

The results pertaining to the reduction in fruit size (length x width) of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.5 and Fig. 4.2 (a & b). The analysis of variance is given in Appendix-IIIa & IIIb.

4.4.2.1 Effect of chemicals

An examination of Table 4.5 reveals that the pre-treatments significantly affected the reduction in size (length x width) of mandarin. The minimum reduction in size (13.55 x 13.25%) was recorded in treatment T_2 and the maximum (14.59 x 14.30%) was recorded in T_0 after twenty days of storage.

4.4.2.2 Effect of packaging materials

Fruit size of stored mandarin was significantly affected by packaging methods. The maximum reduction in size (14.52 x 14.22%) was recorded in P_0 and minimum (13.47 x 13.17%) in P_2 after twenty days of storage.

Table 4.4 Effect of pre-treatments, packaging materials and their combination on appearance of mandarin

Pre-treatments	Storage days			
	5^{th} day	10^{th} day	15^{th} day	20^{th} day
Chemicals				
T_0	7.49	6.46	5.56	4.95
T_1	7.80	6.74	5.85	5.24
T_2	8.20	7.15	6.25	**5.64**
T_3	7.62	6.58	5.66	5.05
T_4	7.59	6.56	5.66	5.05
S.Em±	0.0344	0.0327	0.0323	0.0326
CD at $_{5\%}$	0.0982	0.0935	0.0923	0.0933
Packaging materials				
P_0	7.46	6.42	5.52	4.91
P_1	7.98	6.94	6.03	**5.42**
P_2	7.74	6.69	5.79	5.18
P_3	7.77	6.73	5.84	5.23
S.Em±	0.0307	0.0293	0.0289	0.0292
CD at $_{5\%}$	0.0878	0.0836	0.0825	0.0835
Interaction T x P				
T_0 P_0	7.32	6.30	5.40	4.79
T_0 P_1	7.72	6.70	5.80	5.19
T_0 P_2	7.45	6.40	5.50	4.89
T_0 P_3	7.45	6.43	5.53	4.92
T_1 P_0	7.46	6.43	5.53	4.92
T_1 P_1	7.82	6.77	5.87	5.26
T_1 P_2	7.89	6.87	5.97	5.36
T_1 P_3	8.02	6.90	6.03	5.42
T_2 P_0	7.55	6.47	5.57	4.96
T_2 P_1	8.76	7.70	6.80	**6.19**
T_2 P_2	8.22	7.17	6.27	5.66
T_2 P_3	8.27	7.27	6.37	5.76
T_3 P_0	7.51	6.47	5.57	4.96
T_3 P_1	7.89	6.87	5.93	5.29
T_3 P_2	7.52	6.47	5.53	4.96
T_3 P_3	7.55	6.50	5.60	4.99
T_4 P_0	7.48	6.43	5.53	4.92
T_4 P_1	7.72	6.67	5.77	5.16
T_4 P_2	7.61	6.57	5.67	5.06
T_4 P_3	7.57	6.57	5.67	5.06
S.Em±	0.0653	0.0646	0.0654	0.0687
CD at $_{5\%}$	0.1866	0.1845	0.1869	0.1964

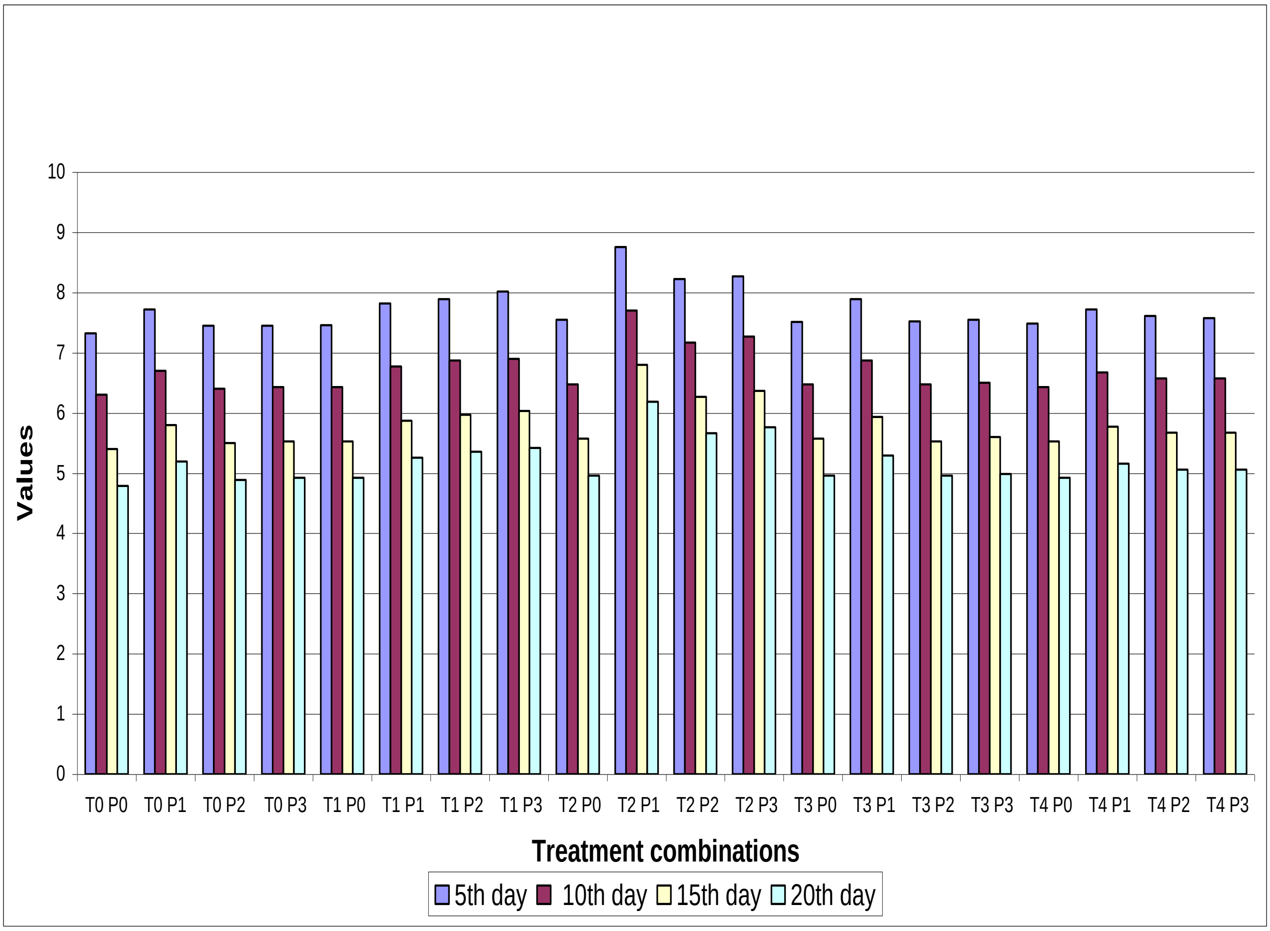


Fig. 4.1 Combined effect of pre-treatments and packaging materials on appearance of mandarin

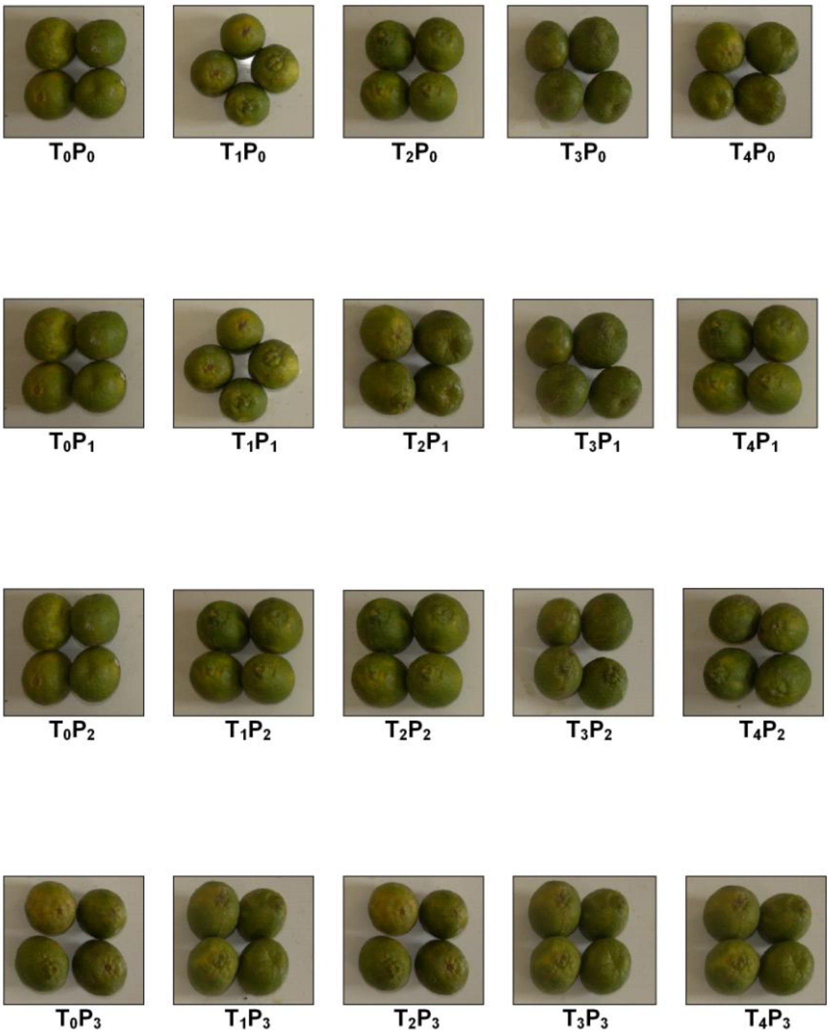


Plate 4.1: Various treatment combinations on 10 th day of storage

Table 4.5 Effect of pre-treatments, packaging materials and their combination on reduction of fruit size (length x width) (%) of mandarin

Pre-treatments	Storage days							
	5th day		10th day		15th day		20th day	
	Length	Width	Length	Width	Length	Width	Length	Width
Chemicals								
T_0	11.30	11.01	12.67	12.37	13.96	13.66	14.59	14.30
T_1	10.70	10.40	12.06	11.76	13.35	13.05	14.00	13.70
T_2	10.25	9.95	11.61	11.31	12.88	12.58	**13.55**	**13.25**
T_3	10.58	10.28	11.94	11.64	13.22	12.92	13.87	13.57
T_4	10.59	10.29	11.91	11.61	13.21	12.94	13.88	13.58
S.Em±	0.027	0.0265	0.034	0.0337	0.030	0.0295	0.027	0.0267
CD at 5%	0.077	0.0757	0.097	0.0963	0.086	0.0843	0.077	0.0762
Packaging materials								
P_0	11.22	10.92	12.55	12.25	13.87	13.57	14.52	14.22
P_1	10.67	10.37	12.03	11.73	13.30	13.00	13.97	13.67
P_2	10.18	9.88	11.54	11.24	12.83	12.53	**13.47**	**13.17**
P_3	10.67	10.37	12.03	11.73	13.29	13.01	13.95	13.65
S.Em±	0.0240	0.0237	0.0303	0.0301	0.0270	0.0264	0.0241	0.0238
CD at 5%	0.0686	0.0677	0.0876	0.0861	0.0772	0.0754	0.0690	0.0681
Interaction T x P								
$T_0 P_0$	11.81	11.52	13.18	12.88	14.47	14.17	15.11	14.82
$T_0 P_1$	11.11	10.81	12.47	12.17	13.76	13.46	14.41	14.11
$T_0 P_2$	10.99	10.69	12.35	12.05	13.64	13.34	14.29	13.99
$T_0 P_3$	11.30	11.00	12.66	12.36	13.95	13.65	14.56	14.26
$T_1 P_0$	11.03	10.73	12.39	12.09	13.68	13.38	14.33	14.03
$T_1 P_1$	11.02	10.72	12.38	12.08	13.67	13.37	14.32	14.02
$T_1 P_2$	10.04	9.74	11.40	11.10	12.69	12.39	13.34	13.04
$T_1 P_3$	10.69	10.39	12.05	11.75	13.34	13.04	13.99	13.69
$T_2 P_0$	11.03	10.73	12.39	12.09	13.68	13.38	14.33	14.03
$T_2 P_1$	10.15	9.85	11.51	11.21	12.71	12.41	13.45	13.15
$T_2 P_2$	9.65	9.35	10.99	10.71	12.30	12.00	**12.95**	**12.65**
$T_2 P_3$	10.17	9.87	11.53	11.23	12.82	12.52	13.47	13.17
$T_3 P_0$	11.10	10.80	12.46	12.16	13.75	13.45	14.40	14.10
$T_3 P_1$	10.53	10.23	11.89	11.59	13.18	12.88	13.83	13.53
$T_3 P_2$	10.11	9.81	11.47	11.17	12.76	12.46	13.38	13.08
$T_3 P_3$	10.58	10.28	11.94	11.64	13.20	12.90	13.88	13.58
$T_4 P_0$	11.10	10.80	12.30	12.00	13.75	13.45	14.40	14.10
$T_4 P_1$	10.53	10.23	11.89	11.59	13.18	12.88	13.83	13.53
$T_4 P_2$	10.11	9.81	11.47	11.17	12.76	12.46	13.41	13.11
$T_4 P_3$	10.60	10.30	11.96	11.66	13.13	12.95	13.86	13.56
S.Em±	0.054	0.0529	0.068	0.0674	0.060	0.0590	0.054	0.0533
CD at 5%	0.153	0.1513	0.194	0.1926	0.173	0.1686	0.154	0.1523

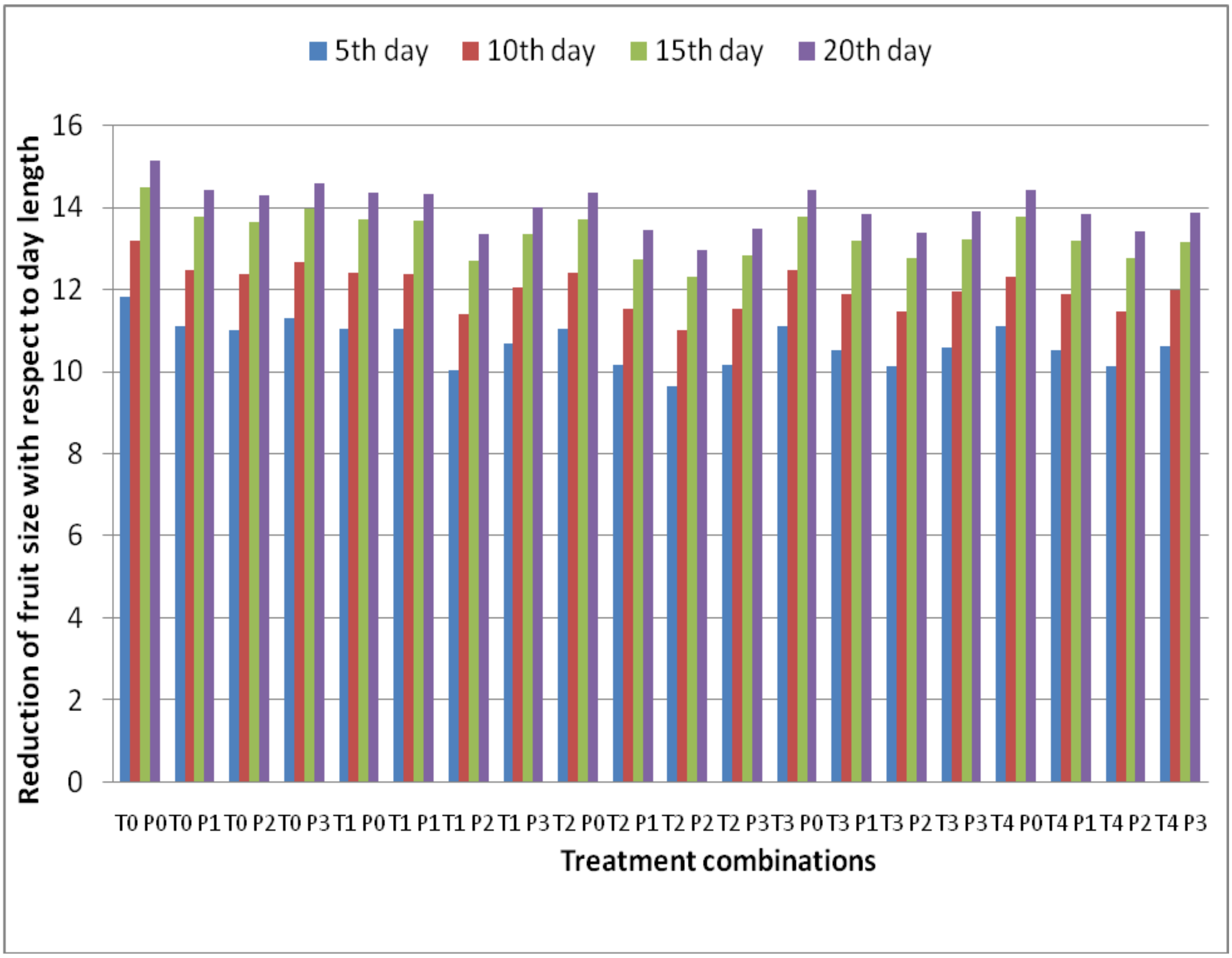


Fig. 4.2(a) Combined effect of pre-treatments and packaging materials on reduction of fruit size of mandarin with respect to day length

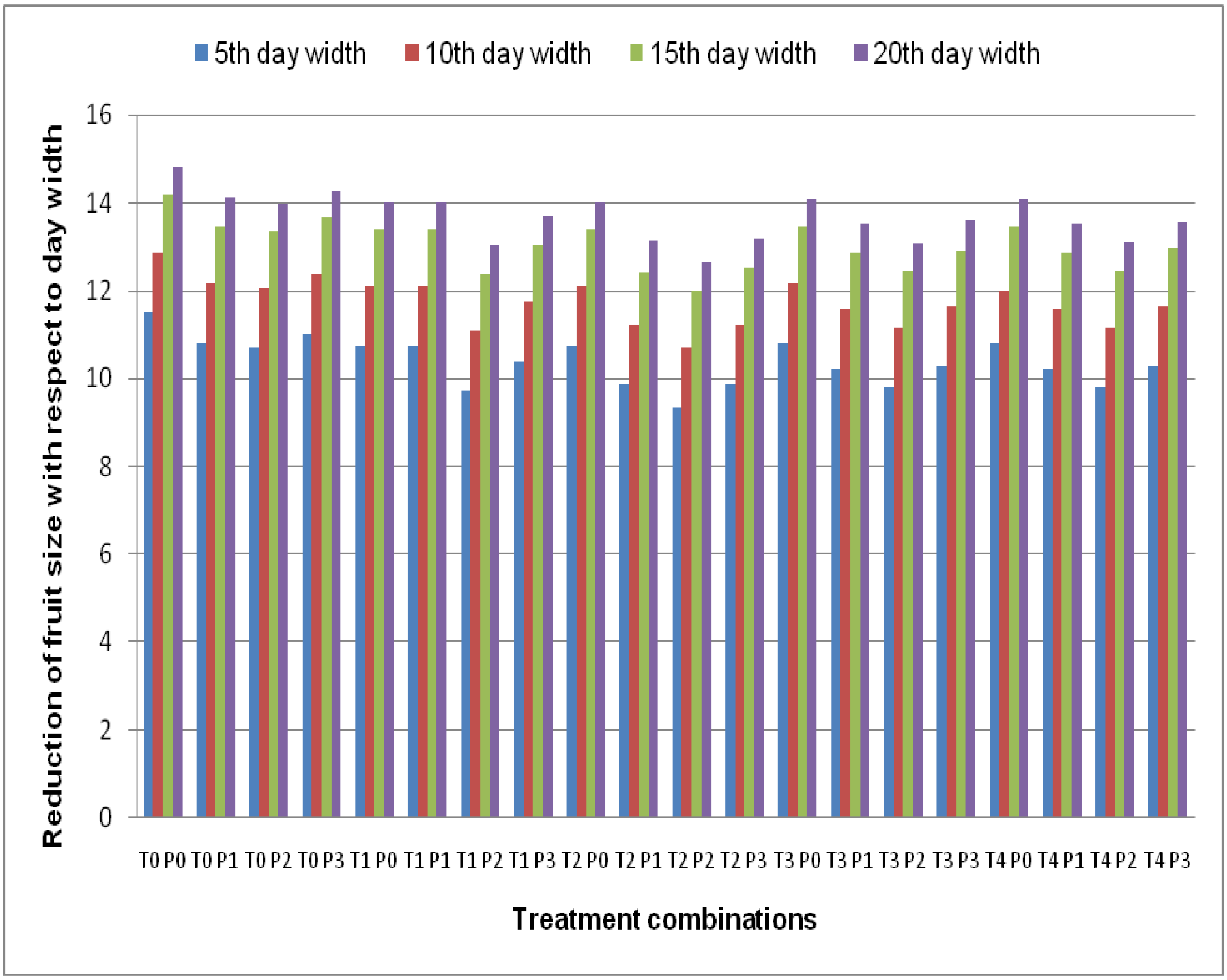


Fig. 4.2(b) Combined effect of pre-treatments and packaging materials on reduction of fruit size of mandarin with respect to day width

4.4.2.3 Combined effect of chemicals and packaging materials

The reduction in size of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum size (15.11 x 14.82%) was obtained in T_0P_0 and minimum (12.95 x 12.65%) in T_1P_1 after twenty days of storage.

4.4.3 Individual fruit weight (g)

The results pertaining to the individual fruit weight of of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.6 and Fig. 4.3. The analysis of variance is given in Appendix-IV.

4.4.3.1 Effect of chemicals

An examination of Table 4.6 reveals that the pre-treatments significantly affected the individual fruit weight of mandarin. The minimum Individual fruit weight (160.19%) was recorded in treatment T_0 and the maximum (162.05%) was recorded in T_2 after twenty days of storage.

4.4.3.2 Effect of packaging materials

Individual fruit weight of stored mandarin was significantly affected by packaging methods. The maximum Individual fruit weight (162.20 g) was recorded in P_2 and minimum (160.18 g) in P_0 after twenty days of storage.

4.4.3.3 Combined effect of chemicals and packaging materials

The individual fruit weight of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum individual fruit weight (162.8 g) was obtained in T_2P_2 and minimum (159.4 g) in T_0P_0 after twenty days of storage.

Table 4.6 Effect of pre-treatments, packaging materials and their combination on individual fruit weight (g) of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	182.30	173.24	165.15	160.19
T_1	183.48	174.21	166.50	161.38
T_2	184.34	175.34	167.68	**162.05**
T_3	183.70	174.58	166.63	161.52
T_4	183.69	174.67	166.42	161.74
S.Em±	0.0511	0.0897	0.0290	0.0289
CD at 5%	0.1461	0.2563	0.0828	0.0825
Packaging materials				
P_0	182.48	173.70	165.57	160.18
P_1	183.54	174.11	166.40	161.56
P_2	184.46	175.49	167.48	**162.20**
P_3	183.54	174.34	166.46	161.57
S.Em±	0.0457	0.0802	0.0259	0.0258
CD at 5%	0.1307	0.2292	0.0741	0.0738
Interaction T x P				
$T_0 P_0$	181.32	172.13	164.21	159.40
$T_0 P_1$	182.68	173.58	165.78	160.52
$T_0 P_2$	182.88	174.22	165.38	160.48
$T_0 P_3$	182.32	173.03	165.23	160.34
$T_1 P_0$	182.83	173.50	165.23	160.33
$T_1 P_1$	182.87	173.45	166.32	161.42
$T_1 P_2$	184.73	175.62	167.82	162.02
$T_1 P_3$	183.50	174.25	166.65	161.76
$T_2 P_0$	182.83	175.58	166.78	160.59
$T_2 P_1$	184.53	174.09	167.62	162.73
$T_2 P_2$	185.50	176.45	168.65	**162.81**
$T_2 P_3$	184.50	175.25	167.65	162.13
$T_3 P_0$	182.70	173.61	165.81	160.05
$T_3 P_1$	183.80	174.72	166.22	161.33
$T_3 P_2$	184.60	175.58	167.78	162.74
$T_3 P_3$	183.70	174.42	166.70	161.82
$T_4 P_0$	182.70	173.66	165.82	160.51
$T_4 P_1$	183.80	174.71	166.05	161.82
$T_4 P_2$	184.60	175.56	167.76	162.72
$T_4 P_3$	183.67	174.74	166.05	161.80
S.Em±	0.1022	0.1793	0.0579	0.05395
CD at 5%	0.2922	0.5126	0.1656	0.15422

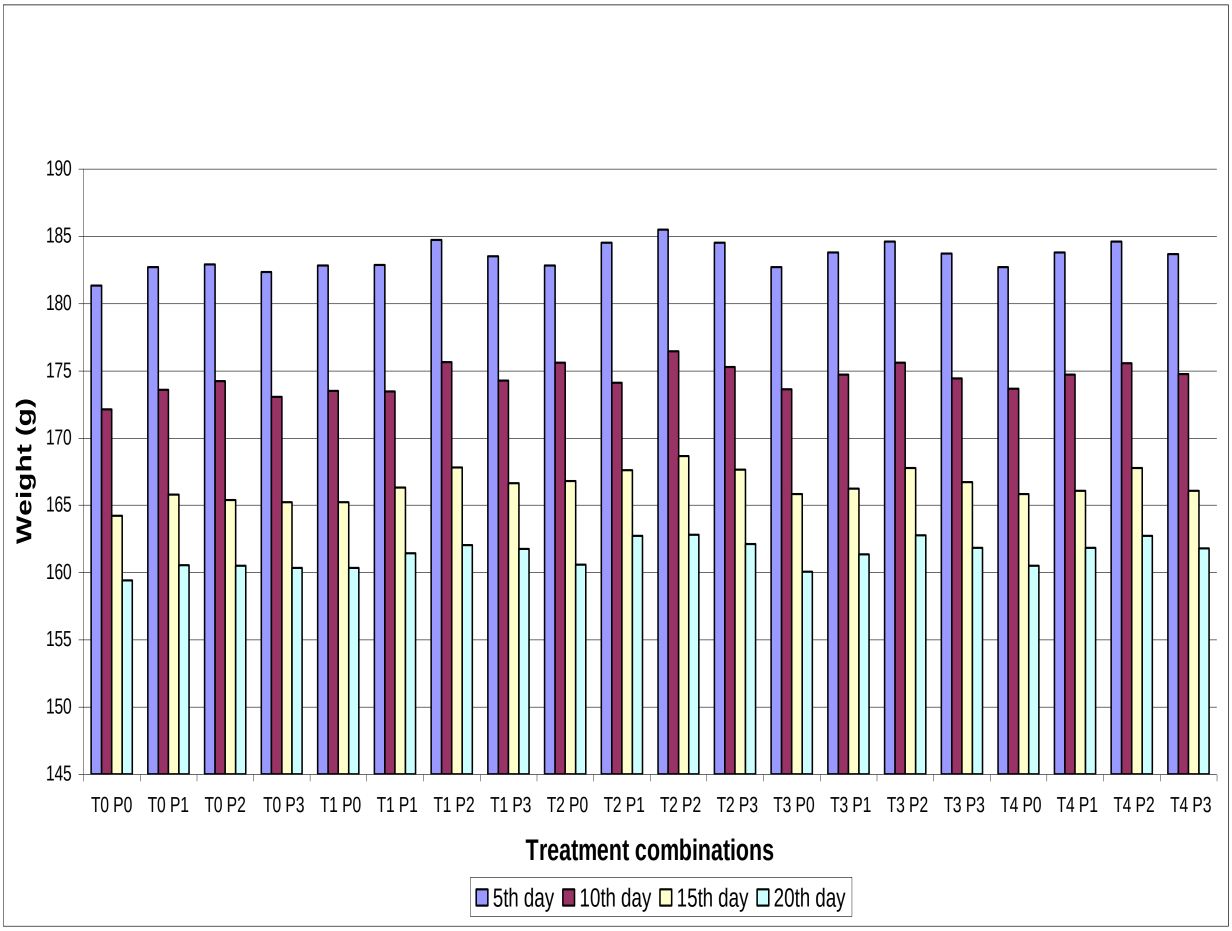


Fig. 4.3 Combined effect of pre-treatments and packaging materials on individual fruit weight (g) of mandarin

4.4.4 Physiological loss in weight (%)

The results pertaining to the physiological loss in weight of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.7 and Fig. 4.4. The analysis of variance is given in Appendix-V.

4.4.4.1 Effect of chemicals

An examination of Table 4.7 reveals that the pre-treatments significantly affected the physiological loss in weight of mandarin. The minimum physiological loss in weight (15.59%) was recorded in treatment T_2 and the maximum (16.57%) was recorded in T_0 after twenty days of storage.

4.4.4.2 Effect of packaging materials

Physiological loss in weight of stored mandarin was significantly affected by packaging methods. The maximum physiological loss in weight (16.58%) was recorded in P_0 and minimum (15.55%) in P_2 after twenty days of storage.

4.4.4.3 Combined effect of chemicals and packaging materials

The physiological loss in weight of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum physiological loss in weight (16.98%) was obtained in T_0P_0 and minimum (15.20%) in T_2P_2 after twenty days of storage.

4.4.5 Rotting (%)

The results pertaining to the rotting (%) of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4. 8 and Fig. 4.5. The analysis of variance is given in Appendix-VI.

Table 4.7 Effect of pre-treatments, packaging materials and their combination on physiological loss in weight (%) of mandarin

Pre-treatments	Storage days			
	5th day	**10th day**	**15th day**	**20th day**
Chemicals				
T_0	5.05	9.77	13.98	16.57
T_1	4.44	9.27	13.28	15.95
T_2	3.99	8.68	12.67	**15.59**
T_3	4.32	9.07	13.21	15.89
T_4	4.33	9.03	13.32	15.78
S.Em±	0.0266	0.0467	0.0151	0.0141
CD at $_{5\%}$	0.0761	0.1335	0.0431	0.0402
Packaging materials				
P_0	4.96	9.53	13.77	16.58
P_1	4.41	9.32	13.33	15.85
P_2	3.93	8.60	12.77	**15.55**
P_3	4.41	9.20	13.30	15.85
S.Em±	0.0238	0.0418	0.0135	0.0126
CD at $_{5\%}$	0.0681	0.1194	0.0386	0.0359
Interaction T x P				
T_0 P_0	5.56	10.35	14.48	16.98
T_0 P_1	4.85	9.59	13.66	16.40
T_0 P_2	4.75	9.26	13.86	16.42
T_0 P_3	5.04	9.88	13.94	16.49
T_1 P_0	4.77	9.64	13.94	16.49
T_1 P_1	4.76	9.66	13.38	15.93
T_1 P_2	3.78	8.53	12.59	15.61
T_1 P_3	4.43	9.24	13.20	15.75
T_2 P_0	4.77	8.55	13.14	16.36
T_2 P_1	3.89	9.33	12.70	15.24
T_2 P_2	3.39	8.10	12.16	**15.20**
T_2 P_3	3.91	8.72	12.68	15.56
T_3 P_0	4.84	9.58	13.64	16.64
T_3 P_1	4.27	9.00	13.43	15.97
T_3 P_2	3.85	8.55	12.61	15.24
T_3 P_3	4.32	9.16	13.18	15.72
T_4 P_0	4.84	9.55	13.64	16.40
T_4 P_1	4.27	9.01	13.51	15.72
T_4 P_2	3.85	8.56	12.63	15.25
T_4 P_3	4.34	8.99	13.52	15.73
S.Em±	0.0533	0.0934	0.0302	0.0281
CD at $_{5\%}$	0.1522	0.2670	0.0862	0.0803

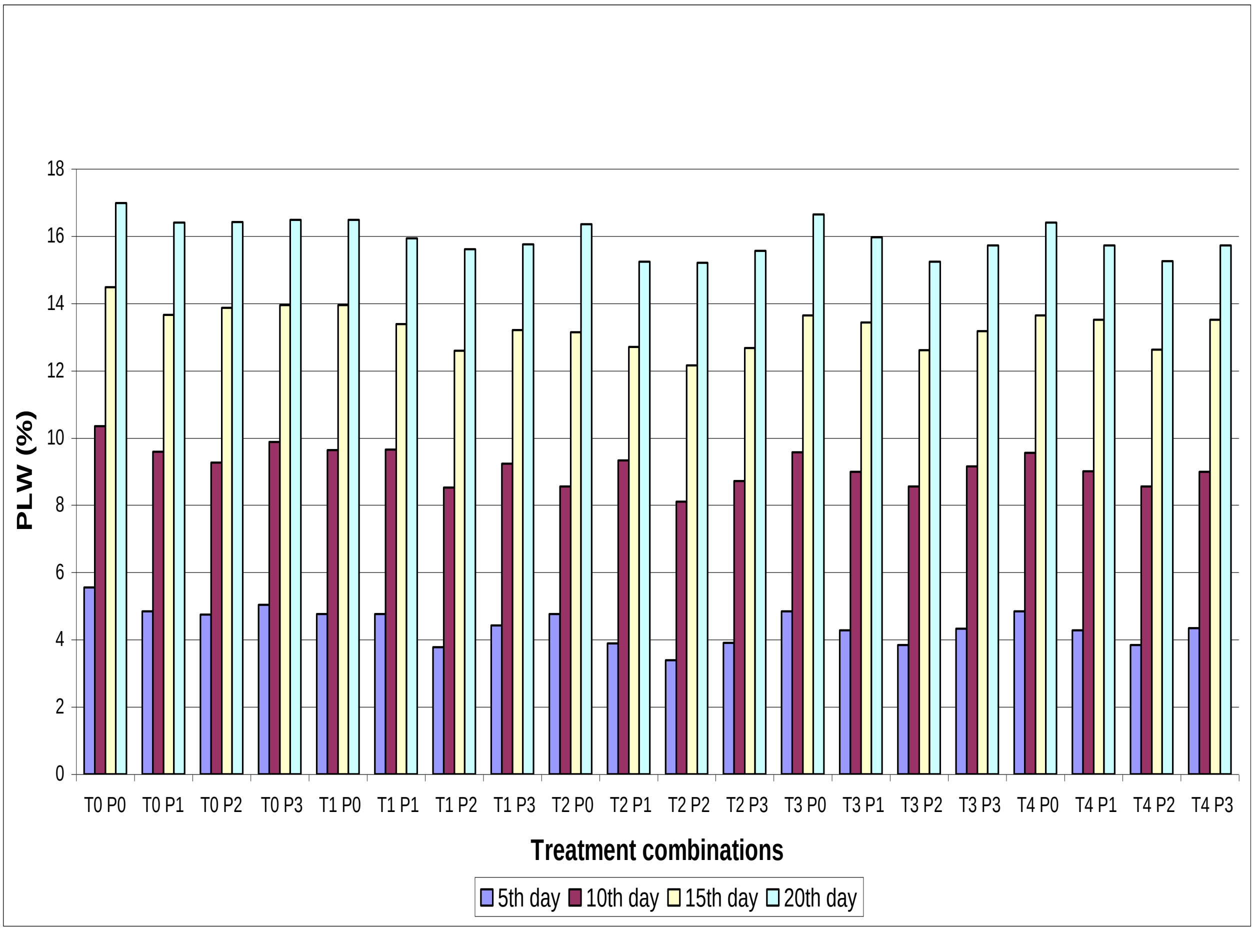


Fig. 4.4 Combined effect of pre-treatments and packaging materials on physiological loss in weight (%) of mandarin

Table 4.8 Effect of pre-treatments, packaging materials and their combination on rotting (%) of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	0	0	7.79	11.58
T_1	0	0	7.08	10.95
T_2	0	0	6.47	**10.60**
T_3	0	0	7.01	10.87
T_4	0	0	7.12	10.76
S.Em±	0	0	0.0148	0.0148
CD at 5%	0	0	0.0423	0.0422
Packaging materials				
P_0	0	0	7.57	11.58
P_1	0	0	7.13	10.85
P_2	0	0	6.58	**10.53**
P_3	0	0	7.10	10.85
S.Em±	0	0	0.0132	0.0132
CD at 5%	0	0	0.0379	0.0377
Interaction T x P				
$T_0 P_0$	0	0	8.28	11.97
$T_0 P_1$	0	0	7.46	11.39
$T_0 P_2$	0	0	7.69	11.44
$T_0 P_3$	0	0	7.74	11.48
$T_1 P_0$	0	0	7.74	11.49
$T_1 P_1$	0	0	7.18	10.92
$T_1 P_2$	0	0	6.39	10.61
$T_1 P_3$	0	0	7.00	10.75
$T_2 P_0$	0	0	6.94	11.35
$T_2 P_1$	0	0	6.50	10.24
$T_2 P_2$	0	0	5.96	**10.14**
$T_2 P_3$	0	0	6.48	10.55
$T_3 P_0$	0	0	7.44	11.64
$T_3 P_1$	0	0	7.23	10.90
$T_3 P_2$	0	0	6.41	10.18
$T_3 P_3$	0	0	6.98	10.71
$T_4 P_0$	0	0	7.44	11.40
$T_4 P_1$	0	0	7.31	10.71
$T_4 P_2$	0	0	6.43	10.19
$T_4 P_3$	0	0	7.32	10.72
S.Em±	0	0	0.0296	0.0318
CD at 5%	0	0	0.0846	0.0908

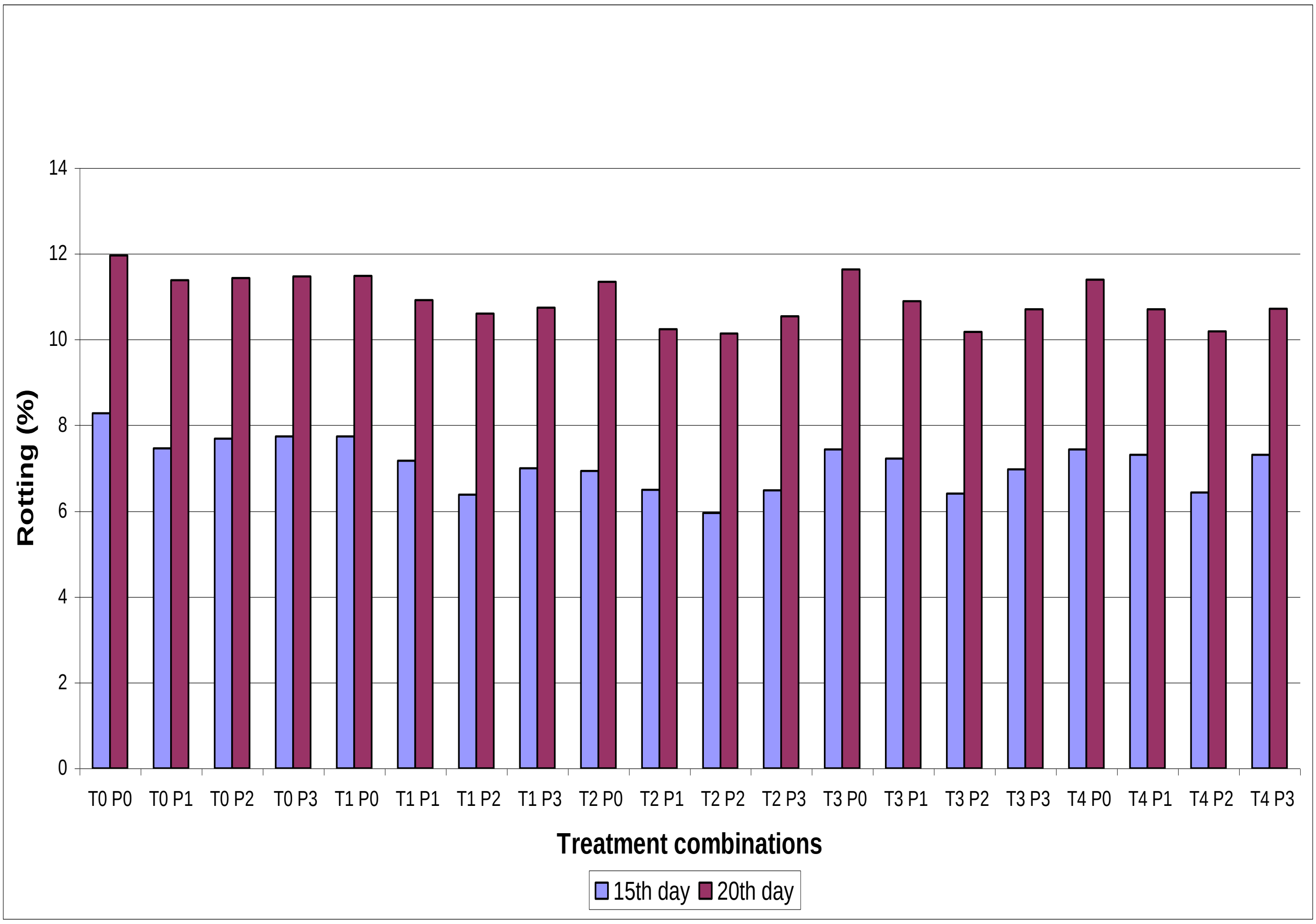


Fig. 4.5 Combined effect of pre-treatments and packaging materials on rotting (%) of mandarin

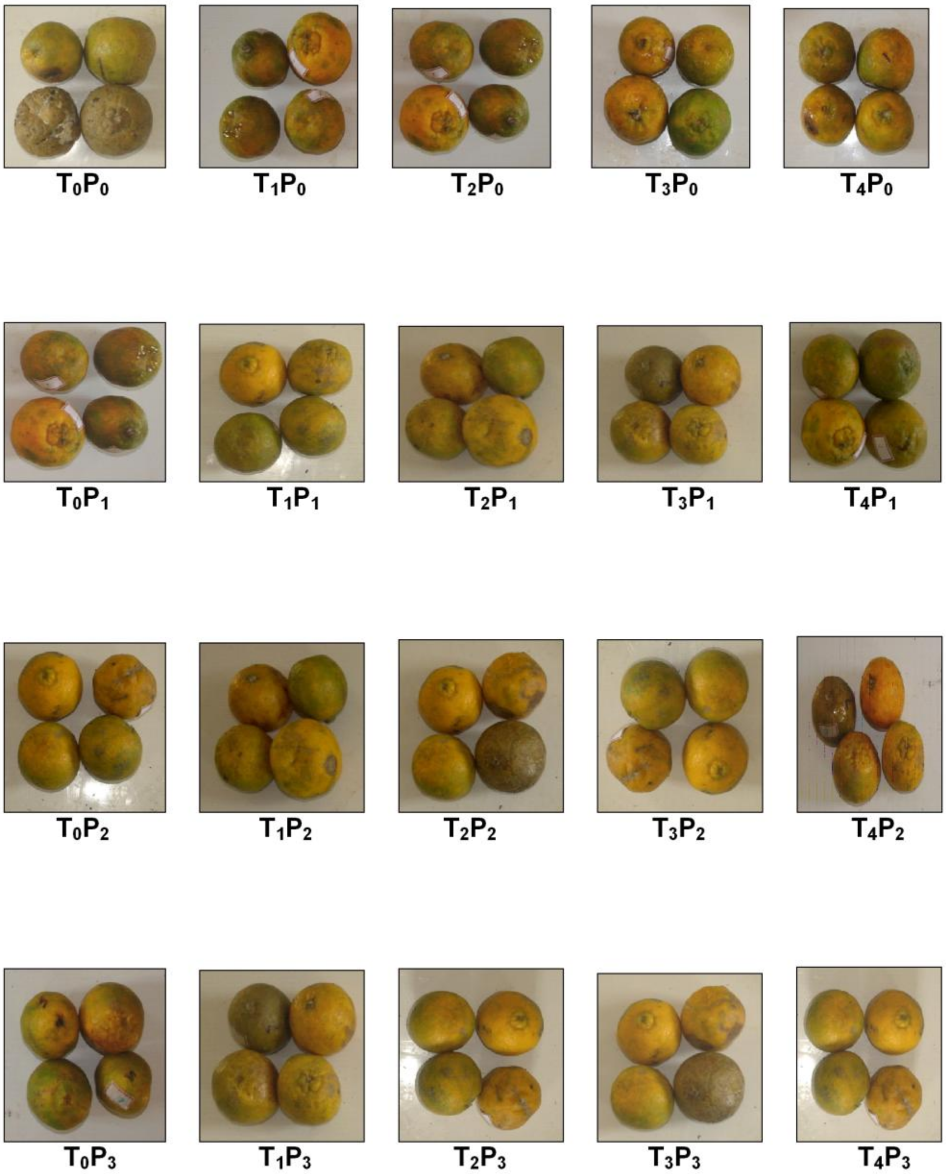


Plate 4.2: Various treatment combinations on 20 th day of storage

4.4.5.1 Effect of chemicals

An examination of Table 4.8 reveals that the pre-treatments significantly affected the rotting of mandarin. The minimum rotting (10.60%) was recorded in treatment T_2 and the maximum (11.58%) was recorded in T_0 after twenty days of storage.

4.4.5.2 Effect of packaging materials

Rotting of stored mandarin was significantly affected by packaging methods. The maximum rotting (11.58%) was recorded in P_0 and minimum (10.53%) in P_2 after twenty days of storage.

4.4.5.3 Combined effect of chemicals and packaging materials

The rotting of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum rotting (11.97%) was obtained in T_0P_0 and minimum (10.14%) in T_2P_2 after twenty days of storage.

4.4.6 Shrinkage ratio

The results pertaining to the shrinkage ratio of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.9 and Fig. 4.6. The analysis of variance is given in Appendix-VII.

4.4.6.1 Effect of chemicals

An examination of Table 4.9 reveals that the pre-treatments significantly affected the shrinkage ratio of mandarin. The maximum shrinkage ratio (1:0.843) was recorded in treatment T_0 and the minimum (1:0.853) was recorded in T_2 after twenty days of storage.

4.4.6.2 Effect of packaging materials

Shrinkage ratio of stored mandarin was significantly affected by packaging methods. The maximum shrinkage ratio (1:0.853) was recorded in P_2 and minimum (1:0.843) in P_0 after twenty days of storage.

Table 4.9 Effect of pre-treatments, packaging materials and their combination on shrinkage ratio of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	0.959	0.912	0.869	0.843
T_1	0.966	0.917	0.876	0.849
T_2	0.970	0.923	0.883	**0.853**
T_3	0.967	0.919	0.877	0.850
T_4	0.967	0.919	0.876	0.851
S.Em±	0.00027	0.00047	0.00015	0.00044
CD at 5%	0.00041	0.00135	0.00044	0.00041
Packaging materials				
P_0	0.960	0.914	0.871	0.843
P_1	0.966	0.916	0.876	0.850
P_2	0.971	0.924	0.881	**0.853**
P_3	0.966	0.918	0.876	0.850
S.Em±	0.00024	0.00042	0.00121	0.00039
CD at 5%	0.00036	0.00121	0.00039	0.00036
Interaction T x P				
$T_0 P_0$	0.954	0.906	0.864	0.839
$T_0 P_1$	0.961	0.914	0.873	0.845
$T_0 P_2$	0.963	0.917	0.870	0.845
$T_0 P_3$	0.960	0.911	0.870	0.844
$T_1 P_0$	0.962	0.913	0.870	0.844
$T_1 P_1$	0.962	0.913	0.875	0.850
$T_1 P_2$	0.972	0.924	0.883	0.853
$T_1 P_3$	0.966	0.917	0.877	0.851
$T_2 P_0$	0.962	0.924	0.878	0.845
$T_2 P_1$	0.971	0.916	0.882	0.856
$T_2 P_2$	0.976	0.929	0.888	**0.857**
$T_2 P_3$	0.971	0.922	0.882	0.853
$T_3 P_0$	0.962	0.914	0.873	0.842
$T_3 P_1$	0.967	0.920	0.875	0.849
$T_3 P_2$	0.972	0.924	0.883	0.857
$T_3 P_3$	0.967	0.918	0.877	0.852
$T_4 P_0$	0.962	0.914	0.873	0.845
$T_4 P_1$	0.967	0.920	0.874	0.852
$T_4 P_2$	0.972	0.924	0.883	0.856
$T_4 P_3$	0.967	0.920	0.874	0.852
S.Em±	0.00054	0.00094	0.00030	0.00028
CD at 5%	0.00081	0.00270	0.00087	0.00081

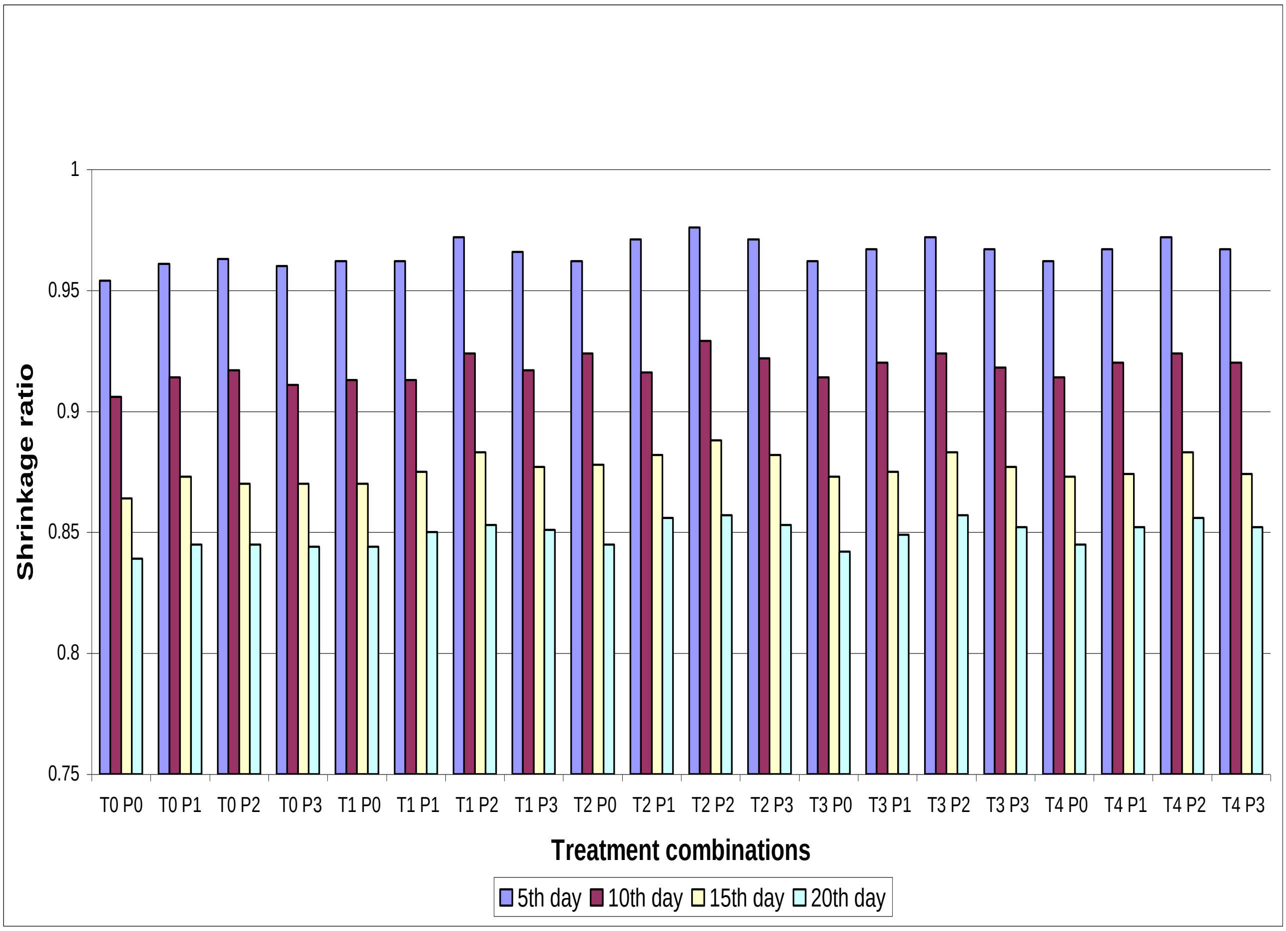


Fig. 4.6 Combined effect of pre-treatments and packaging materials on shrinkage ratio of mandarin

4.4.6.3 Combined effect of chemicals and packaging materials

The shrinkage ratio of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum (1:0.857) shrinkage ratio was obtained in T_0P_0 and minimum (1:0.839) in T_2P_2 after twenty days of storage.

4.5 Chemical characteristics of stored mandarin

Chemicals characteristics of stored mandarin viz. acidity, ascorbic acid, reducing sugars, total sugars and T.S.S. were determined and data presented in Table 4.10 to 4.14 and analysis of variance for these characteristics is given in Appendices VIII to XII. The results obtained with regard to various chemicals characteristics are discussed in following sub sections:

4.5.1 Acidity (%)

The results pertaining to the acidity of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.10 and Fig. 4.7. The analysis of variance is given in Appendix- VIII.

4.5.1.1 Effect of chemicals

An examination of Table 4.10 reveals that the pre-treatments significantly affected the acidity of mandarin. The minimum acidity (0.598%) was recorded in treatment T_0 and the maximum (0.613%) was recorded in T_2 after twenty days of storage.

4.5.1.2 Effect of packaging materials

Acidity of stored mandarin was significantly affected by packaging methods. The maximum acidity (0.614%) was recorded in P_2 and minimum (0.596%) in P_0 after twenty days of storage.

4.5.1.3 Combined effect of chemicals and packaging materials

The acidity of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum (0.624%) acidity was obtained in T_2P_2 and minimum (0.581%) in T_0P_0 after twenty days of storage.

Table 4.10 Effect of pre-treatments, packaging materials and their combination on acidity (%) of mandarin

Pre-treatments	Storage days			
	5^{th} day	10^{th} day	15^{th} day	20^{th} day
Chemicals				
T_0	0.838	0.748	0.668	0.598
T_1	0.849	0.759	0.679	0.609
T_2	0.853	0.764	0.686	**0.613**
T_3	0.847	0.757	0.677	0.608
T_4	0.846	0.756	0.676	0.606
S.Em±	0.00192	0.00193	0.00234	0.00198
CD at $_{5\%}$	0.00547	0.00553	0.00670	0.00567
Packaging materials				
P_0	0.836	0.746	0.666	0.596
P_1	0.849	0.759	0.679	0.609
P_2	0.853	0.764	0.686	**0.614**
P_3	0.849	0.759	0.679	0.609
S.Em±	0.00171	0.00173	0.00210	0.00178
CD at $_{5\%}$	0.00490	0.00494	0.00599	0.00507
Interaction T x P				
$T_0 P_0$	0.821	0.731	0.651	0.581
$T_0 P_1$	0.845	0.755	0.675	0.605
$T_0 P_2$	0.847	0.757	0.677	0.607
$T_0 P_3$	0.840	0.750	0.670	0.600
$T_1 P_0$	0.839	0.749	0.669	0.599
$T_1 P_1$	0.854	0.764	0.684	0.614
$T_1 P_2$	0.853	0.763	0.683	0.613
$T_1 P_3$	0.849	0.759	0.679	0.609
$T_2 P_0$	0.838	0.748	0.668	0.598
$T_2 P_1$	0.856	0.766	0.686	0.616
$T_2 P_2$	0.864	0.776	0.706	**0.624**
$T_2 P_3$	0.855	0.765	0.685	0.615
$T_3 P_0$	0.837	0.747	0.667	0.597
$T_3 P_1$	0.845	0.755	0.675	0.605
$T_3 P_2$	0.856	0.767	0.687	0.621
$T_3 P_3$	0.849	0.759	0.679	0.609
$T_4 P_0$	0.844	0.754	0.674	0.604
$T_4 P_1$	0.845	0.755	0.675	0.605
$T_4 P_2$	0.846	0.756	0.676	0.606
$T_4 P_3$	0.850	0.760	0.680	0.610
S.Em±	0.0038	0.0039	0.0047	0.0040
CD at $_{5\%}$	0.0109	0.0111	0.0134	0.0113

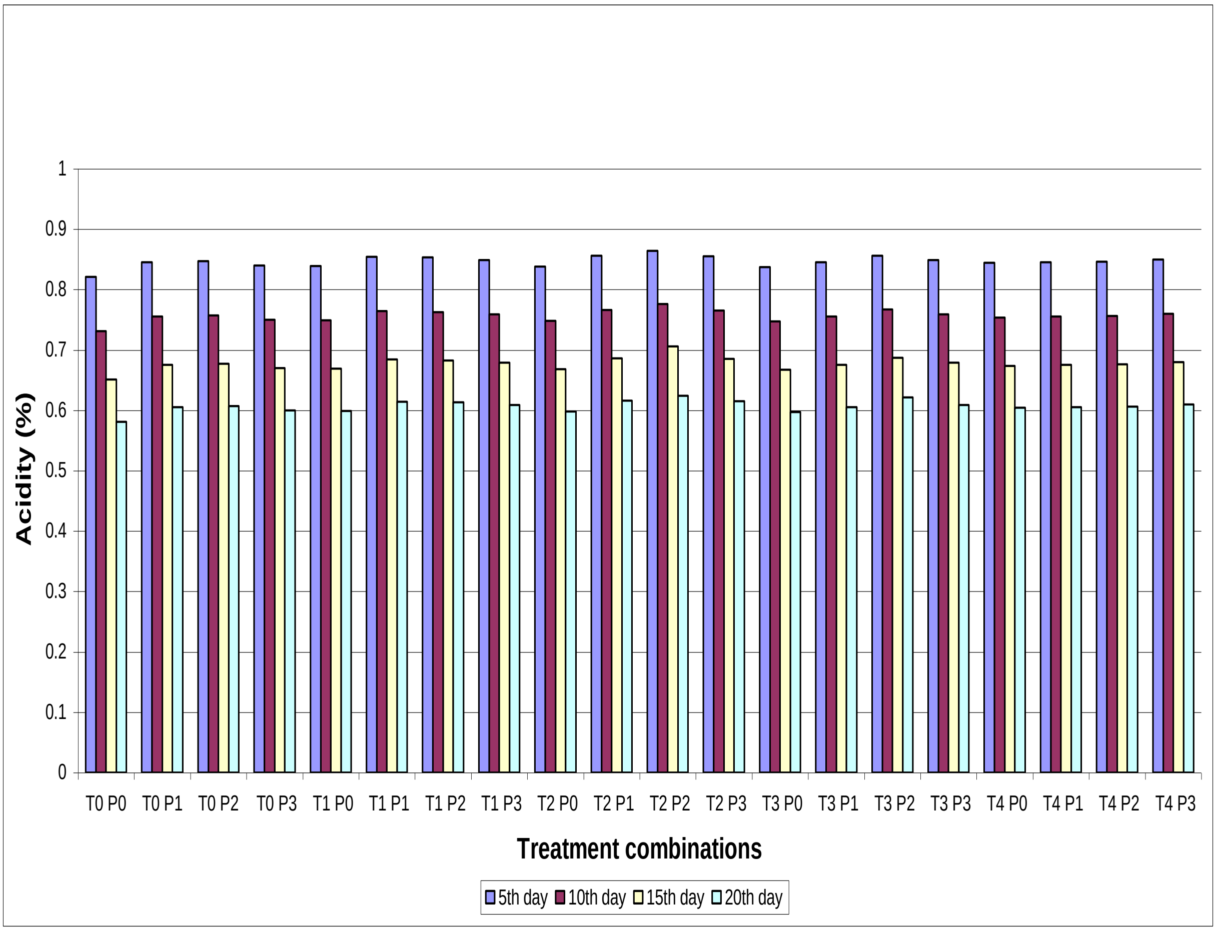


Fig. 4.7 Combined effect of pre-treatments and packaging materials on acidity (%) of mandarin

4.5.2 Ascorbic acid (mg/100 ml juice)

The results pertaining to the ascorbic acid of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.11 and Fig. 4.8. The analysis of variance is given in Appendix-IX.

4.5.2.1 Effect of chemicals

An examination of Table 4.11 reveals that the pre-treatments significantly affected the ascorbic acid of mandarin. The minimum ascorbic acid (12.45 mg/100 ml juice) was recorded in treatment T_0 and the maximum (13.13 mg/100 ml juice) was recorded in T_2 after twenty days of storage.

4.5.2.2 Effect of packaging materials

Ascorbic acid of stored mandarin was significantly affected by packaging methods. The maximum acidity (13.17 mg/100 ml juice) was recorded in P_1 and minimum (11.87 mg/100 ml juice) in P_0 after twenty days of storage.

4.5.2.3 Combined effect of chemicals and packaging materials

The ascorbic acid of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum (14.17 mg/100 ml juice) ascorbic acid was obtained in T_2P_1 and minimum (11.87 mg/100 ml juice) in T_0P_0 after twenty days of storage.

4.5.3 TSS (^{0} Brix)

The results pertaining to the TSS (^{0} Brix) of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.12 and Fig. 4.9. The analysis of variance is given in Appendix-X.

Table 4.11 Effect of pre-treatments, packaging materials and their combination on ascorbic acid (mg/100 ml juice) of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	15.68	14.38	13.28	12.45
T_1	15.91	14.62	13.51	12.67
T_2	16.35	15.03	13.95	**13.13**
T_3	15.73	14.43	13.33	12.49
T_4	15.72	14.43	13.32	12.49
S.Em±	0.0376	0.0369	0.0342	0.0271
CD at $_{5\%}$	0.1076	0.1055	0.0976	0.0776
Packaging materials				
P_0	15.10	13.80	12.70	11.87
P_1	16.40	15.10	14.00	**13.17**
P_2	15.70	14.40	13.30	12.50
P_3	15.50	14.20	13.10	12.27
S.Em±	15.63	14.33	13.23	12.40
CD at $_{5\%}$	16.40	15.13	14.00	13.13
Interaction T x P				
$T_0 P_0$	15.10	13.80	12.70	11.87
$T_0 P_1$	16.40	15.10	14.00	13.17
$T_0 P_2$	15.70	14.40	13.30	12.50
$T_0 P_3$	15.50	14.20	13.10	12.27
$T_1 P_0$	15.63	14.33	13.23	12.40
$T_1 P_1$	16.40	15.13	14.00	13.13
$T_1 P_2$	15.83	14.53	13.43	12.60
$T_1 P_3$	15.77	14.47	13.37	12.53
$T_2 P_0$	15.50	14.20	13.10	12.27
$T_2 P_1$	17.40	16.10	15.00	**14.17**
$T_2 P_2$	16.30	14.97	13.90	13.10
$T_2 P_3$	16.20	14.83	13.80	12.97
$T_3 P_0$	15.63	14.33	13.23	12.40
$T_3 P_1$	16.13	14.83	13.73	12.90
$T_3 P_2$	15.43	14.13	13.03	12.20
$T_3 P_3$	15.30	14.00	12.90	12.07
$T_4 P_0$	15.70	14.40	13.30	12.43
$T_4 P_1$	16.37	15.10	13.97	13.13
$T_4 P_2$	15.43	14.13	13.03	12.20
$T_4 P_3$	15.37	14.07	12.97	12.20
S.Em±	0.075	0.074	0.068	0.054
CD at $_{5\%}$	0.215	0.211	0.195	0.155

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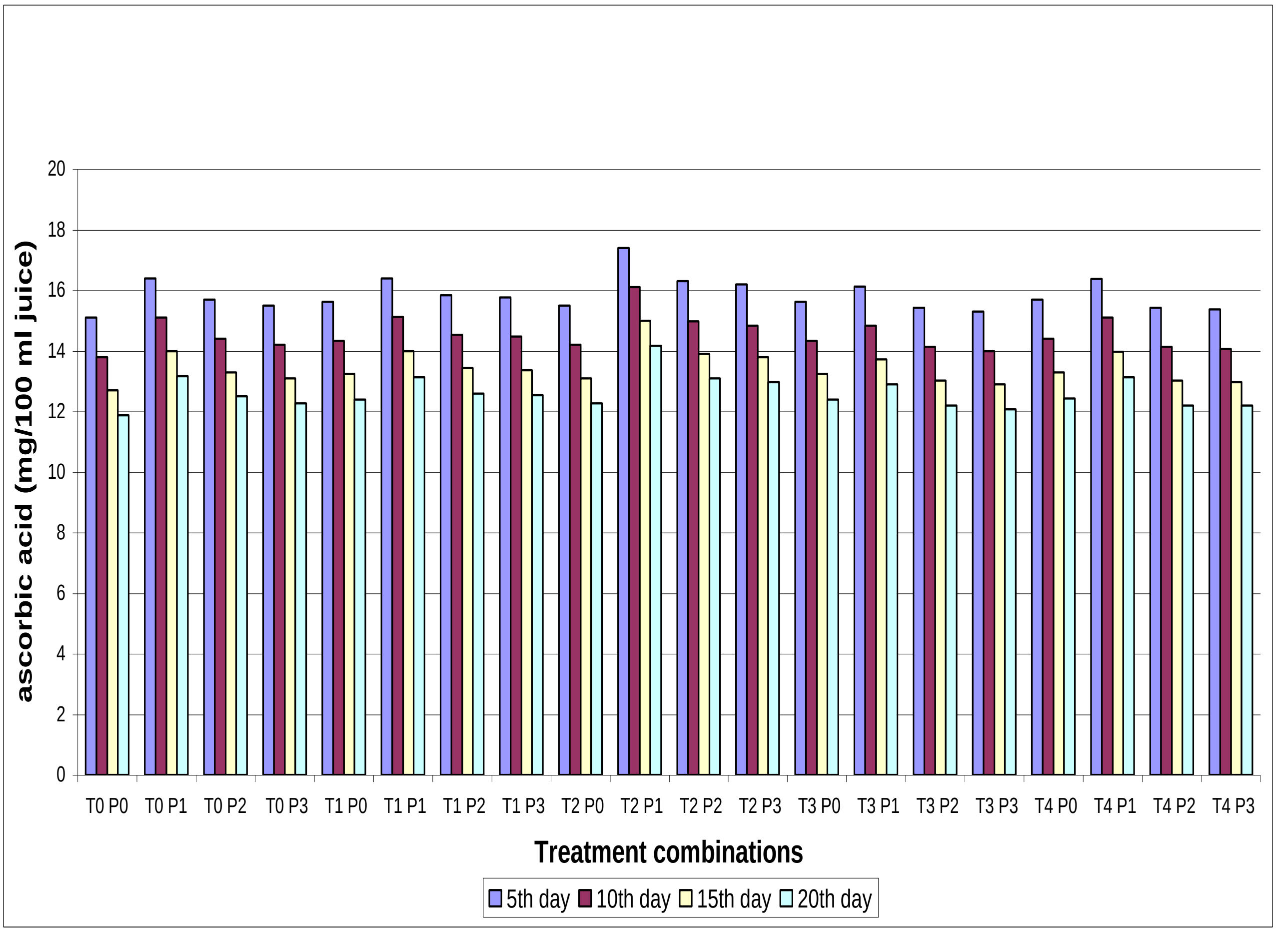

Fig. 4.8 Combined effect of pre-treatments and packaging materials on ascorbic acid (mg/100 ml juice) of mandarin

Table 4.12 Effect of pre-treatments, packaging materials and their combination on TSS (^{0} Brix) of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	9.31	10.67	11.96	12.60
T_1	8.70	10.06	11.35	12.00
T_2	8.25	9.61	10.88	**11.55**
T_3	8.58	9.94	11.22	11.87
T_4	8.59	9.91	11.24	11.88
S.Em±	0.0265	0.0337	0.0295	0.0267
CD at 5%	0.0757	0.0963	0.0843	0.0762
Packaging materials				
P_0	9.22	10.55	11.87	12.52
P_1	8.67	10.03	11.30	11.97
P_2	8.18	9.54	10.83	**11.47**
P_3	8.67	10.03	11.31	11.95
S.Em±	0.0237	0.0301	0.0264	0.0238
CD at 5%	0.0677	0.0861	0.0754	0.0681
Interaction T x P				
T_0 P_0	9.82	11.18	12.47	13.12
T_0 P_1	9.11	10.47	11.76	12.41
T_0 P_2	8.99	10.35	11.64	12.29
T_0 P_3	9.30	10.66	11.95	12.56
T_1 P_0	9.03	10.39	11.68	12.33
T_1 P_1	9.02	10.38	11.67	12.32
T_1 P_2	8.04	9.40	10.69	11.34
T_1 P_3	8.69	10.05	11.34	11.99
T_2 P_0	9.03	10.39	11.68	12.33
T_2 P_1	8.15	9.51	10.71	11.45
T_2 P_2	7.65	9.01	10.30	**10.95**
T_2 P_3	8.17	9.53	10.82	11.47
T_3 P_0	9.10	10.46	11.75	12.40
T_3 P_1	8.53	9.89	11.18	11.83
T_3 P_2	8.11	9.47	10.76	11.38
T_3 P_3	8.58	9.94	11.20	11.88
T_4 P_0	9.10	10.30	11.75	12.40
T_4 P_1	8.53	9.89	11.18	11.83
T_4 P_2	8.11	9.47	10.76	11.41
T_4 P_3	8.60	9.96	11.25	11.86
S.Em±	0.0529	0.0674	0.0590	0.0533
CD at 5%	0.1513	0.1926	0.1686	0.1523

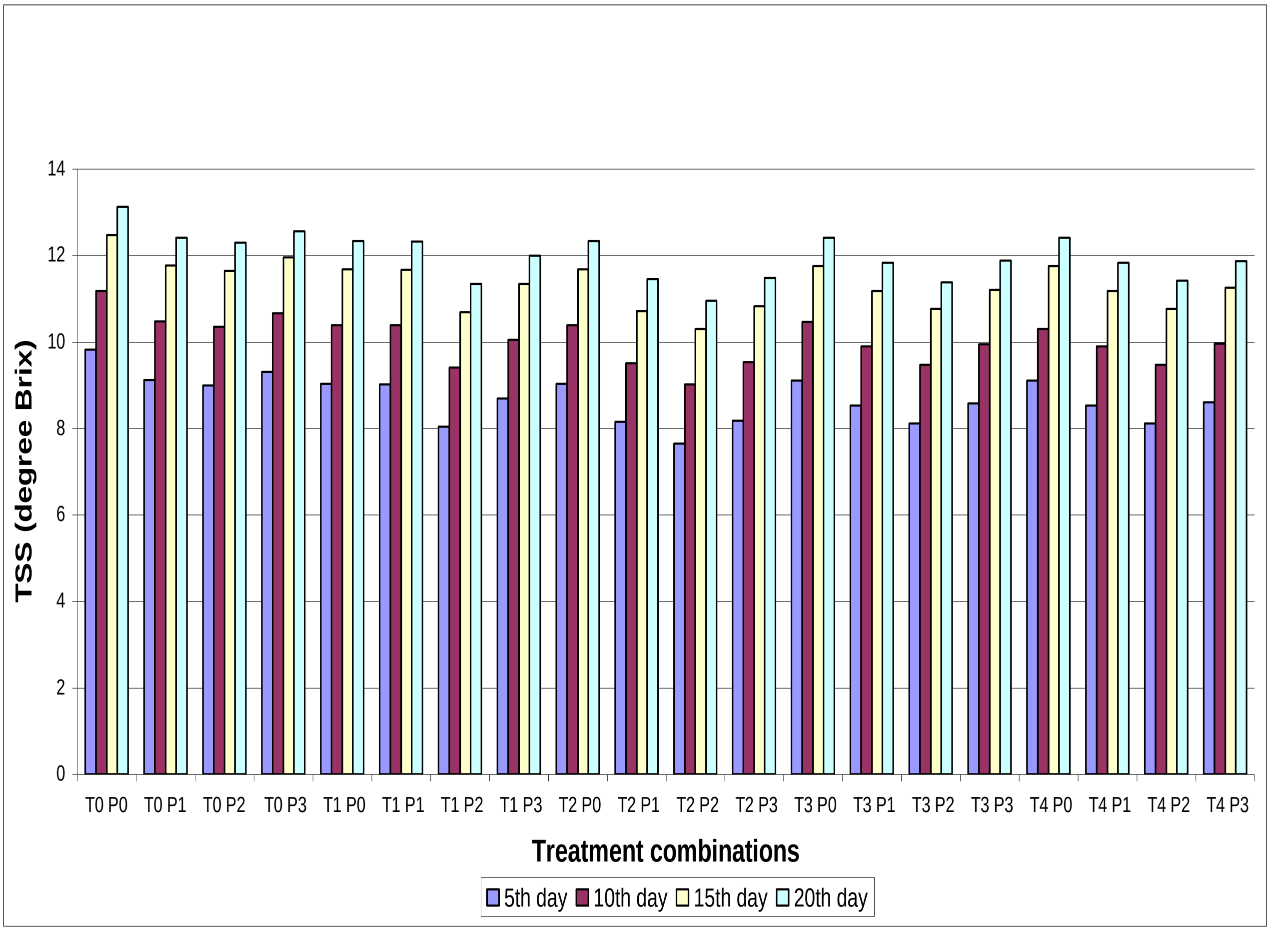

Fig. 4.9 Combined effect of pre-treatments and packaging materials on TSS (^{0}Brix) of mandarin

4.5.3.1 Effect of chemicals

An examination of Table 4.12 reveals that the pre-treatments significantly affected the TSS (^{0} Brix) of mandarin. The minimum TSS (11.55^0 Brix) was recorded in treatment T_2 and the maximum (12.60^0 Brix) was recorded in T_0 after twenty days of storage.

4.5.3.2 Effect of packaging materials

TSS (^{0} Brix) of stored mandarin was significantly affected by packaging methods. The maximum TSS (12.52^0 Brix) was recorded in P_0 and minimum (11.47^0 Brix) in P_2 after twenty days of storage.

4.5.3.3 Combined effect of chemicals and packaging materials

The TSS (^{0} Brix) of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum (13.12^0 Brix) TSS (^{0} Brix) was obtained in T_0P_0 and minimum (10.95^0 Brix) in T_2P_2 after twenty days of storage.

4.5.4 Reducing sugars (%)

The results pertaining to the reducing sugars of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.13 and Fig. 4.10. The analysis of variance is given in Appendix-XI.

4.5.4.1 Effect of chemicals

An examination of Table 4.13 reveals that the pre-treatments significantly affected the reducing sugars of mandarin. The minimum reducing sugars (4.79%) was recorded in treatment T_2 and the maximum (5.13%) was recorded in T_0 after twenty days of storage.

4.5.4.2 Effect of packaging materials

Reducing sugars of stored mandarin was significantly affected by packaging methods. The maximum reducing sugars (5.06%) was recorded in P_0 and minimum (4.91%) in P_2 after twenty days of storage.

Table 4.13 Effect of pre-treatments, packaging materials and their combination on reducing sugars (%) of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	3.55	4.23	4.73	5.13
T_1	3.40	4.03	4.53	4.93
T_2	3.32	3.97	4.39	**4.79**
T_3	3.43	4.08	4.58	4.98
T_4	3.37	4.02	4.57	4.97
S.Em±	0.0475	0.0482	0.0476	0.1360
CD at 5%	0.1356	0.1378	0.1360	0.1356
Packaging materials				
P_0	3.50	4.15	4.65	5.06
P_1	3.38	4.05	4.51	4.91
P_2	3.32	3.95	4.45	**4.85**
P_3	3.46	4.11	4.63	5.03
S.Em±	0.0425	0.0431	0.0426	0.0424
CD at 5%	0.1215	0.1232	0.1217	0.1213
Interaction T x P				
$T_0 P_0$	3.68	4.35	4.85	5.28
$T_0 P_1$	3.57	4.25	4.75	5.15
$T_0 P_2$	3.42	4.07	4.57	4.97
$T_0 P_3$	3.55	4.23	4.73	5.13
$T_1 P_0$	3.49	4.14	4.64	5.04
$T_1 P_1$	3.27	3.92	4.42	4.82
$T_1 P_2$	3.36	3.94	4.44	4.84
$T_1 P_3$	3.47	4.12	4.62	5.02
$T_2 P_0$	3.23	3.88	4.38	4.78
$T_2 P_1$	3.35	4.08	4.37	4.77
$T_2 P_2$	3.16	3.74	4.24	**4.64**
$T_2 P_3$	3.54	4.19	4.56	4.96
$T_3 P_0$	3.56	4.21	4.71	5.11
$T_3 P_1$	3.39	4.04	4.54	4.94
$T_3 P_2$	3.34	3.99	4.49	4.89
$T_3 P_3$	3.45	4.10	4.60	5.00
$T_4 P_0$	3.55	4.20	4.70	5.10
$T_4 P_1$	3.33	3.98	4.48	4.88
$T_4 P_2$	3.34	3.99	4.49	4.89
$T_4 P_3$	3.27	3.92	4.62	5.02
S.Em±	0.0950	0.0964	0.0952	0.0949
CD at 5%	0.2716	0.2756	0.2721	0.2712

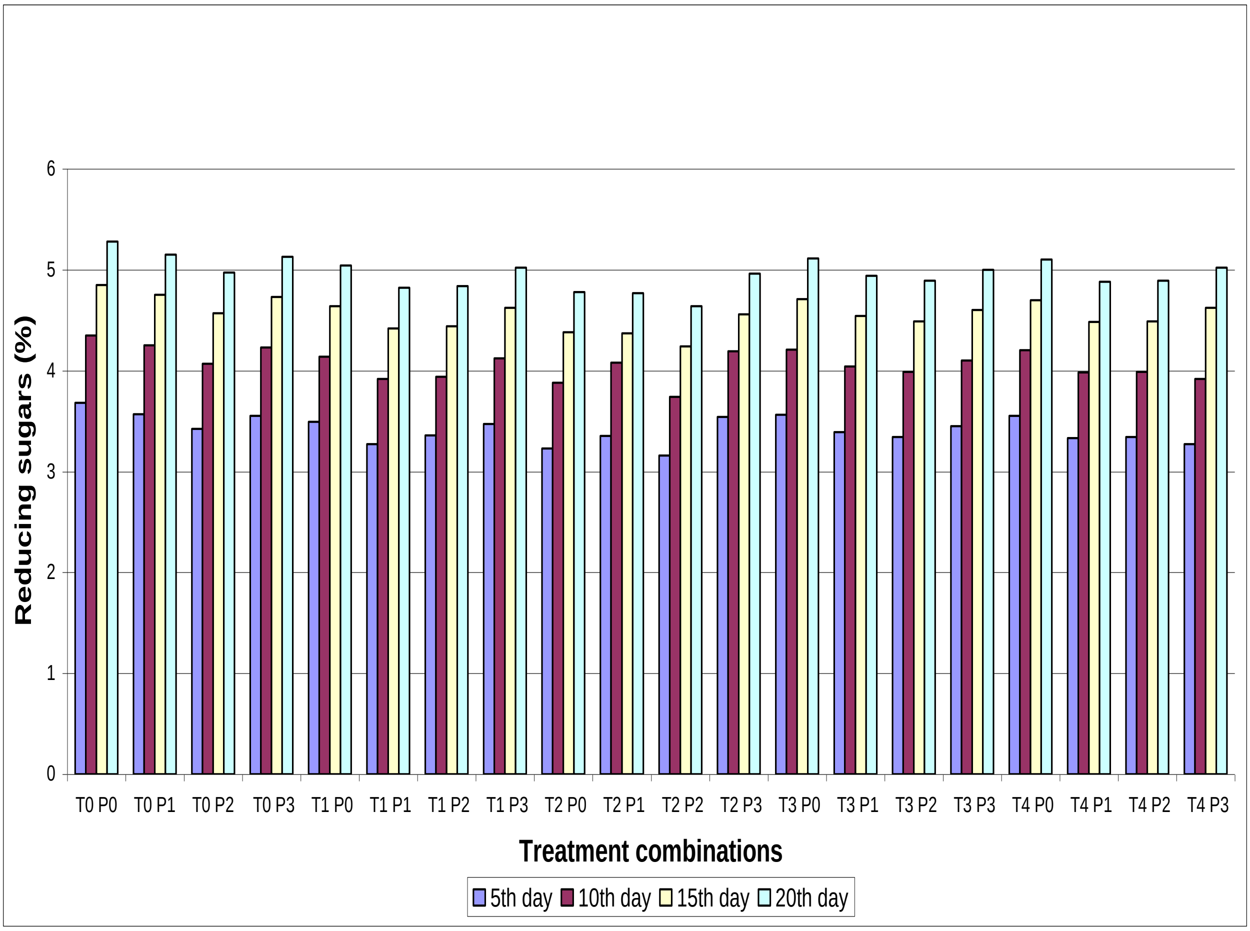

Fig. 4.10 Combined effect of pre-treatments and packaging materials on reducing sugars (%) of mandarin

4.5.4.3 Combined effect of chemicals and packaging materials

The reducing sugars of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum (5.28%) reducing sugars was obtained in T_0P_0 and minimum (%) (4.64) in T_2P_2 after twenty days of storage.

4.5.5 Total sugars (%)

The results pertaining to the total sugars of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.14 and Fig. 4.11. The analysis of variance is given in Appendix-XII.

4.5.5.1 Effect of chemicals

An examination of Table 4.14 reveals that the pre-treatments significantly affected the total sugars of mandarin. The maximum total sugars (9.95%) was recorded in treatment T_0 and the minimum (9.72%) was recorded in T_2 after twenty days of storage.

4.5.5.2 Effect of packaging materials

Total sugars of stored mandarin was significantly affected by packaging methods. The minimum total sugars (9.72%) was recorded in P_2 and maximum (9.90%) in P_0 after twenty days of storage.

4.5.5.3 Combined effect of chemicals and packaging materials

The total sugars of stored mandarin did not significantly affected by treatment combination of packaging methods and pre-treatments. The minimum (9.56%) total sugars was obtained in T_2P_2 and maximum (10.80%) in T_0P_0 after twenty days of storage.

Table 4.14 Effect of pre-treatments, packaging materials and their combination on total sugars (%) of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	8.05	8.85	9.46	9.95
T_1	7.90	8.70	9.30	9.80
T_2	7.83	8.62	9.22	**9.72**
T_3	7.93	8.73	9.33	9.83
T_4	7.87	8.67	9.27	9.77
S.Em±	0.047	0.048	0.047	0.047
CD at 5%	0.136	0.136	0.136	0.136
Packaging materials				
P_0	8.00	8.80	9.41	9.90
P_1	7.88	8.68	9.28	9.78
P_2	7.83	8.62	9.22	**9.72**
P_3	7.96	8.76	9.36	9.86
S.Em±	0.0425	0.0425	0.0424	0.1212
CD at 5%	0.1214	0.1215	0.1212	0.1214
Interaction T x P				
$T_0 P_0$	8.18	8.98	9.61	10.08
$T_0 P_1$	8.07	8.87	9.47	9.97
$T_0 P_2$	7.92	8.72	9.32	9.82
$T_0 P_3$	8.05	8.85	9.45	9.95
$T_1 P_0$	7.99	8.79	9.39	9.89
$T_1 P_1$	7.77	8.57	9.17	9.67
$T_1 P_2$	7.86	8.66	9.26	9.76
$T_1 P_3$	7.97	8.77	9.37	9.87
$T_2 P_0$	7.73	8.53	9.13	9.63
$T_2 P_1$	7.85	8.65	9.25	**9.75**
$T_2 P_2$	7.69	8.46	9.06	9.56
$T_2 P_3$	8.04	8.84	9.44	9.94
$T_3 P_0$	8.06	8.86	9.46	9.95
$T_3 P_1$	7.89	8.69	9.29	9.79
$T_3 P_2$	7.84	8.64	9.24	9.74
$T_3 P_3$	7.95	8.75	9.35	9.85
$T_4 P_0$	8.05	8.85	9.45	9.95
$T_4 P_1$	7.83	8.63	9.23	9.73
$T_4 P_2$	7.84	8.64	9.24	9.74
$T_4 P_3$	7.77	8.57	9.17	9.67
S.Em±	0.0949	0.0950	0.0948	0.0950
CD at 5%	0.2713	0.2716	0.2711	0.2714

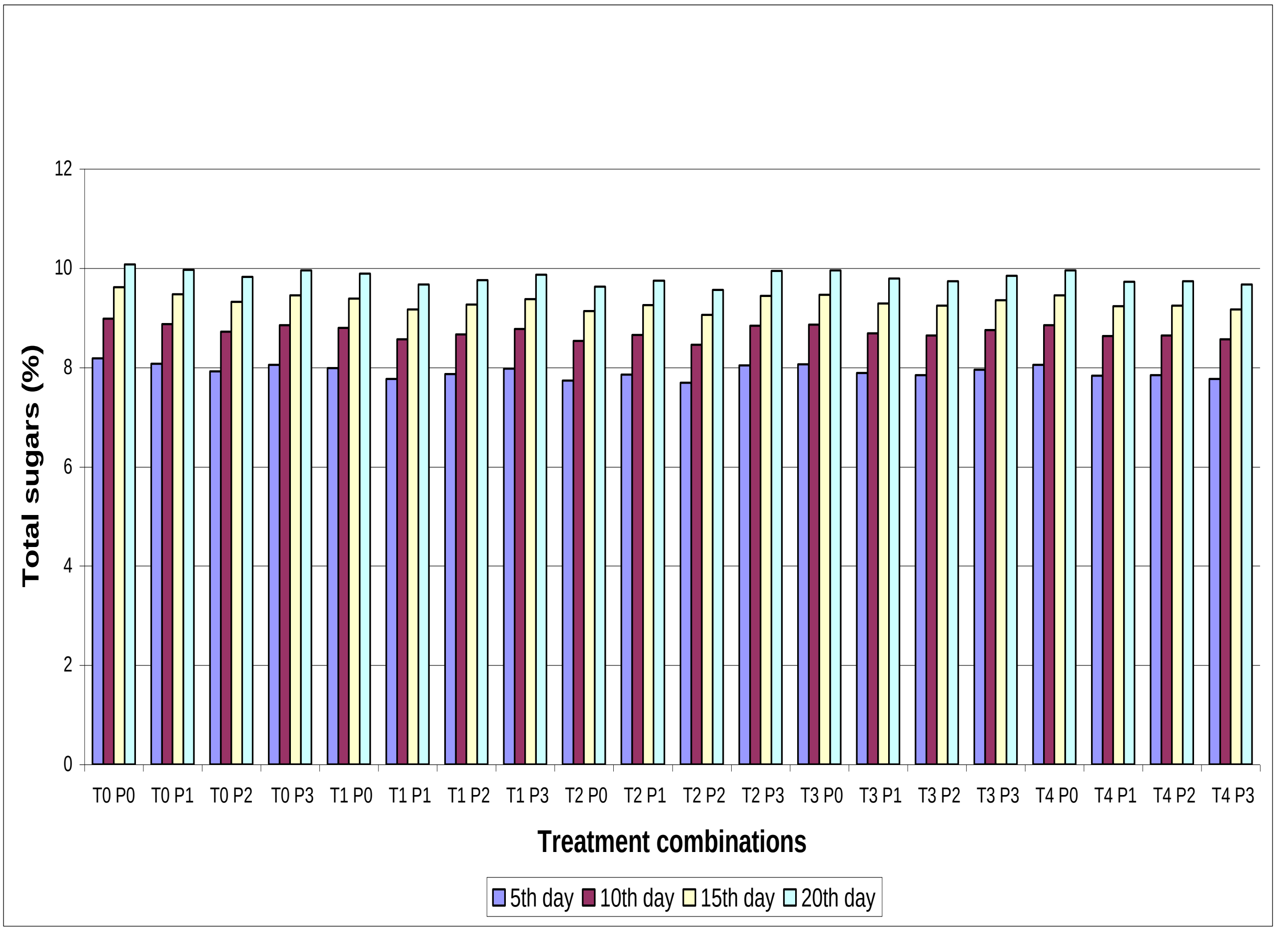

Fig. 4.11 Combined effect of pre-treatments and packaging materials on total sugars (%) of mandarin

4.6 Organoleptic Characteristics of stored mandarin.

Organoleptic characteristics of stored mandarin viz. colour, flavour, texture and overall acceptability were determined and presented in Table 4.15 to 4.47 and analysis of variance for these characteristics is given in Appendices XIII to XVI. The results obtained with regard to various organoleptic characteristics are discussed in following sub sections:

4.6.1 Colour

The results pertaining to the colour of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.15 and Fig. 4.12. The analysis of variance is given in Appendix- XIII.

4.6.1.1 Effect of chemicals

An examination of Table 4.15 reveals that the pre-treatments significantly affected the colour of mandarin. The minimum value for colour (3.02) was recorded in treatment T_0, and the maximum (3.71) was recorded in T_2 after twenty days of storage.

4.6.1.2 Effect of packaging materials

Colour of stored mandarin was significantly affected by packaging methods. The maximum value for colour (3.50) was recorded in P_1 and minimum (2.99) in P_0 after twenty days of storage.

4.6.1.3 Combined effect of chemicals and packaging materials

The colour of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum value for colour (4.24) was obtained in T_2P_2 and minimum (2.87) in T_0P_0 after twenty days of storage.

Table 4.15 Effect of pre-treatments, packaging materials and their combination on colour of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	7.99	6.95	4.45	3.02
T_1	8.30	7.24	4.74	3.33
T_2	8.70	7.65	5.14	**3.71**
T_3	8.12	7.08	4.57	3.15
T_4	8.09	7.06	4.55	3.13
S.Em±	0.0344	0.0333	0.0323	0.0326
CD at 5%	0.0982	0.0953	0.0923	0.0931
Packaging materials				
P_0	7.96	6.91	4.41	2.99
P_1	8.48	7.45	4.93	**3.50**
P_2	8.24	7.19	4.68	3.27
P_3	8.27	7.23	4.73	3.30
S.Em±	0.0307	0.0298	0.0289	0.0291
CD at 5%	0.0878	0.0852	0.0825	0.0833
Interaction T x P				
$T_0 P_0$	7.82	6.80	4.29	2.87
$T_0 P_1$	8.22	7.20	4.69	3.27
$T_0 P_2$	7.95	6.90	4.39	2.97
$T_0 P_3$	7.95	6.90	4.42	2.97
$T_1 P_0$	7.96	6.90	4.42	3.00
$T_1 P_1$	8.32	7.27	4.76	3.34
$T_1 P_2$	8.39	7.37	4.86	3.46
$T_1 P_3$	8.52	7.43	4.92	3.50
$T_2 P_0$	8.05	6.97	4.46	3.04
$T_2 P_1$	9.26	8.23	5.69	**4.24**
$T_2 P_2$	8.72	7.67	5.16	3.74
$T_2 P_3$	8.77	7.73	5.26	3.84
$T_3 P_0$	8.01	6.97	4.46	3.04
$T_3 P_1$	8.39	7.37	4.86	3.44
$T_3 P_2$	8.02	6.97	4.46	3.04
$T_3 P_3$	8.05	7.00	4.49	3.07
$T_4 P_0$	7.98	6.93	4.42	3.00
$T_4 P_1$	8.22	7.17	4.66	3.24
$T_4 P_2$	8.11	7.07	4.56	3.14
$T_4 P_3$	8.07	7.07	4.56	3.14
S.Em±	0.0687	0.0667	0.0646	0.0652
CD at 5%	0.1964	0.1906	0.1845	0.1863

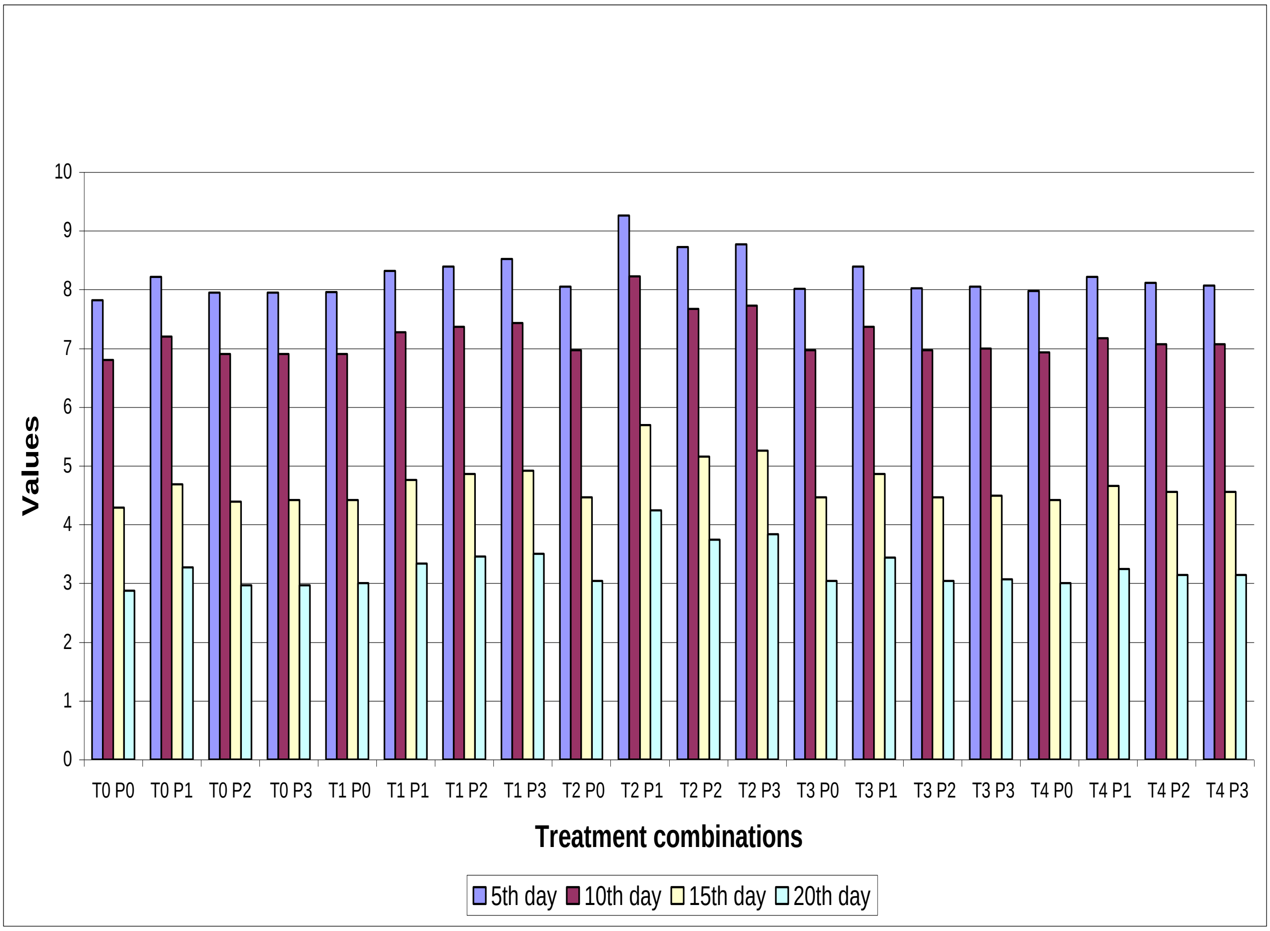

Fig. 4.12 Combined effect of pre-treatments and packaging materials on colour of mandarin

4.6.2 Flavour

The results pertaining to the flavour of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.16 and Fig. 4.13. The analysis of variance is given in Appendix-XIV.

4.6.2.1 Effect of chemicals

An examination of Table 4.16 reveals that the pre-treatments significantly affected the flavour of mandarin. The minimum flavour (3.28) was recorded in treatment T_0, and the maximum (3.98) was recorded in T_2 after twenty days of storage.

4.6.2.2 Effect of packaging materials

Flavour of stored mandarin was significantly affected by packaging methods. The maximum value for flavour (3.76) was recorded in P_1 and minimum (3.24) in P_0 after twenty days of storage.

4.6.2.3 Combined effect of chemicals and packaging materials

The flavour of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum value for flavour (4.52) was obtained in T_2P_1 and minimum (3.12) in T_0P_0 after twenty days of storage.

4.6.3 Texture

The results pertaining to the texture of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.17 and Fig. 4.14. The analysis of variance is given in Appendix-XV.

4.6.3.1 Effect of chemicals

An examination of Table 4.17 reveals that the pre-treatments significantly affected the texture of mandarin. The minimum value for texture (4.94) was recorded in treatment T_0 and the maximum (5.64) was recorded in T_2 after twenty days of storage.

Table 4.16 Effect of pre-treatments, packaging materials and their combination on flavour of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	8.24	7.21	4.69	3.28
T_1	8.55	7.50	4.99	3.57
T_2	8.95	7.90	5.39	**3.98**
T_3	8.37	7.33	4.82	3.40
T_4	8.34	7.31	4.80	3.38
S.Em±	0.0344	0.0323	0.0316	0.0314
CD at $_{5\%}$	0.0982	0.0923	0.0903	0.0898
Packaging materials				
P_0	8.21	7.17	4.65	3.24
P_1	8.73	7.69	5.18	**3.76**
P_2	8.49	7.44	4.93	3.52
P_3	8.52	7.49	4.98	3.56
S.Em±	0.0307	0.0289	0.0282	0.0281
CD at $_{5\%}$	0.0878	0.0825	0.0807	0.0803
Interaction T x P				
T_0 P_0	8.07	7.05	4.50	3.12
T_0 P_1	8.47	7.45	4.94	3.52
T_0 P_2	8.20	7.15	4.64	3.22
T_0 P_3	8.20	7.18	4.67	3.25
T_1 P_0	8.21	7.18	4.67	3.25
T_1 P_1	8.57	7.52	5.01	3.59
T_1 P_2	8.64	7.62	5.11	3.69
T_1 P_3	8.77	7.68	5.17	3.75
T_2 P_0	8.30	7.22	4.71	3.29
T_2 P_1	9.51	8.45	5.95	**4.52**
T_2 P_2	8.97	7.92	5.41	4.02
T_2 P_3	9.02	8.02	5.51	4.09
T_3 P_0	8.26	7.22	4.71	3.29
T_3 P_1	8.64	7.62	5.11	3.69
T_3 P_2	8.27	7.22	4.71	3.29
T_3 P_3	8.30	7.25	4.74	3.32
T_4 P_0	8.23	7.18	4.67	3.25
T_4 P_1	8.47	7.42	4.91	3.49
T_4 P_2	8.36	7.32	4.81	3.39
T_4 P_3	8.32	7.32	4.81	3.39
S.Em±	0.0687	0.0646	0.0632	0.0628
CD at $_{5\%}$	0.1964	0.1845	0.1805	0.1795

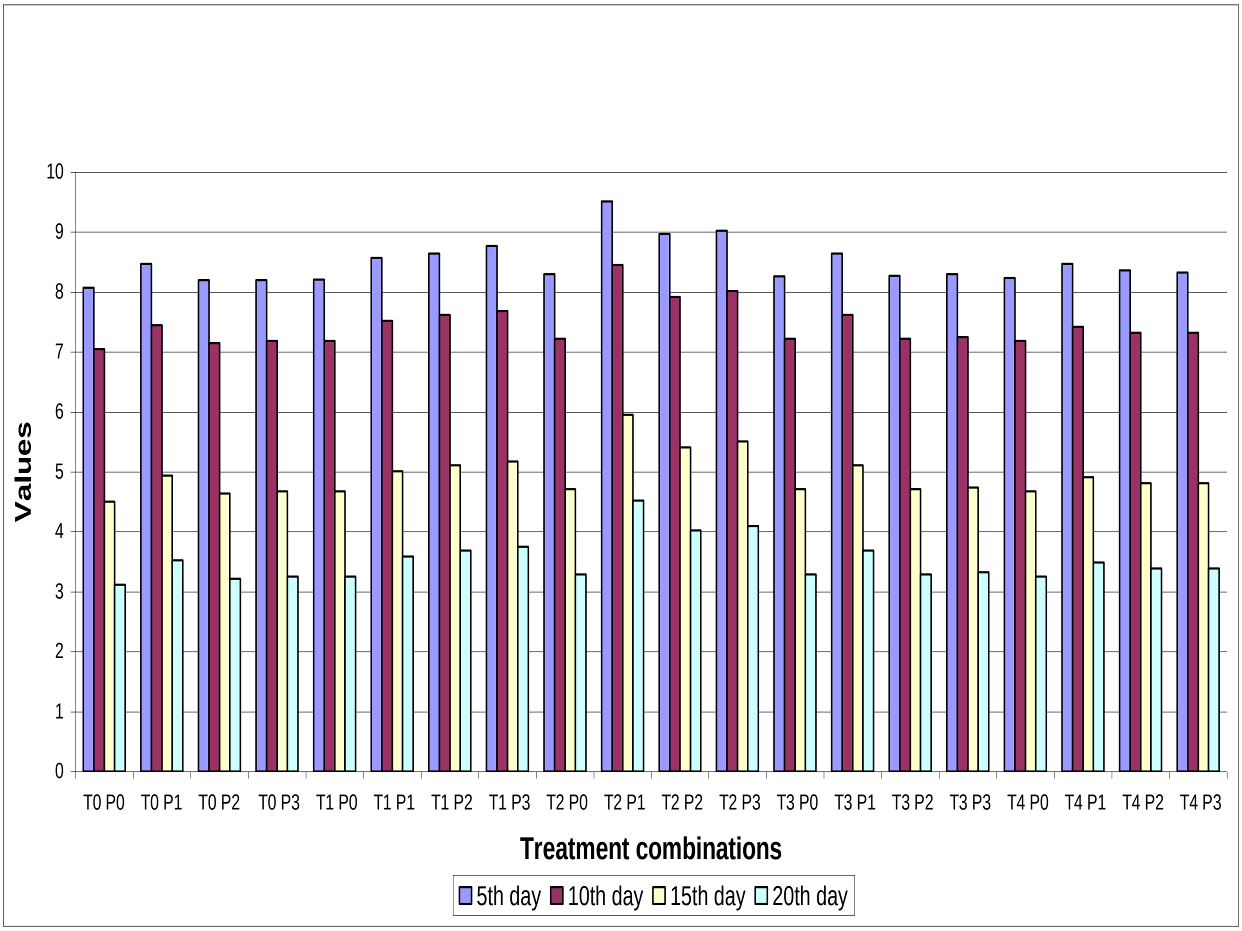

Fig. 4.13 Combined effect of pre-treatments and packaging materials on flavour of mandarin

Table 4.17 Effect of pre-treatments, packaging materials and their combination on texture of mandarin

Pre-treatments	Storage days			
	5th day	10th day	15th day	20th day
Chemicals				
T_0	8.16	6.92	5.97	4.94
T_1	8.47	7.21	6.31	5.24
T_2	8.87	7.61	6.68	**5.64**
T_3	8.29	7.04	6.14	5.07
T_4	8.26	7.02	6.12	5.05
S.Em±	0.0344	0.0323	0.0410	0.0337
CD at $_{5\%}$	0.0982	0.0923	0.1171	0.0963
Packaging materials				
P_0	8.13	6.88	5.91	4.90
P_1	8.65	7.40	6.50	**5.43**
P_2	8.41	7.15	6.25	5.18
P_3	8.44	7.20	6.30	5.23
S.Em±	0.0307	0.0289	0.0366	0.0301
CD at $_{5\%}$	0.0878	0.0825	0.1047	0.0861
Interaction T x P				
T_0 P_0	7.99	6.76	5.65	4.74
T_0 P_1	8.39	7.16	6.26	5.19
T_0 P_2	8.12	6.86	5.96	4.89
T_0 P_3	8.12	6.89	5.99	4.92
T_1 P_0	8.13	6.89	5.99	4.92
T_1 P_1	8.49	7.23	6.33	5.26
T_1 P_2	8.56	7.33	6.43	5.36
T_1 P_3	8.69	7.39	6.49	5.42
T_2 P_0	8.22	6.93	5.89	4.96
T_2 P_1	9.43	8.16	7.26	**6.19**
T_2 P_2	8.89	7.63	6.73	5.66
T_2 P_3	8.94	7.73	6.83	5.76
T_3 P_0	8.18	6.93	6.03	4.96
T_3 P_1	8.56	7.33	6.43	5.36
T_3 P_2	8.19	6.93	6.03	4.96
T_3 P_3	8.22	6.96	6.06	4.99
T_4 P_0	8.15	6.89	5.99	4.92
T_4 P_1	8.39	7.13	6.23	5.16
T_4 P_2	8.28	7.03	6.13	5.06
T_4 P_3	8.24	7.03	6.13	5.06
S.Em±	0.0687	0.0646	0.0819	0.0674
CD at $_{5\%}$	0.1964	0.1845	0.2341	0.1926

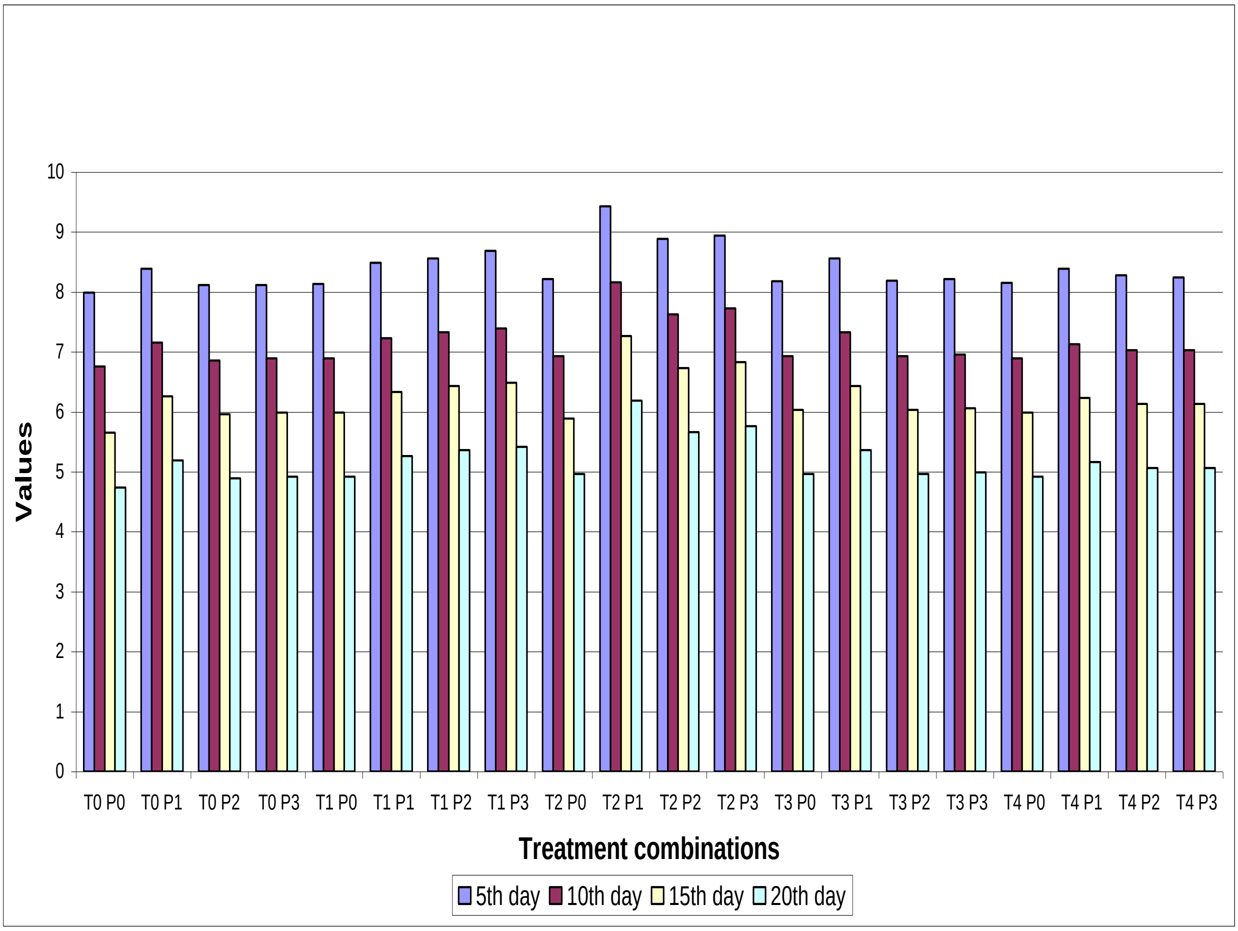

Fig. 4.14 Combined effect of pre-treatments and packaging materials on texture of mandarin

4.6.3.2 Effect of packaging materials

Texture of stored mandarin was significantly affected by packaging methods. The maximum value for texture (5.43) was recorded in P_1 and minimum (4.90) in P_0 after twenty days of storage.

4.6.3.3 Combined effect of chemicals and packaging materials

The Texture of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum value for texture (6.19) was obtained in T_2P_1 and minimum (4.74) in T_0P_0 after twenty days of storage.

4.6.4Overall acceptability

The results pertaining to the overall acceptability of mandarin affected by different pre-treatments, packaging methods and their combinations during the entire period of storage are presented in Table 4.18 and Fig. 4.15. The analysis of variance is given in Appendix-XVI.

4.6.4.1 Effect of chemicals

An examination of Table 4.18 reveals that the pre-treatments significantly affected the overall acceptability of mandarin. The minimum value for overall acceptability (3.73) was recorded in treatment T_0 and the maximum (4.40) was recorded in T_2 after twenty days of storage.

4.6.4.2 Effect of packaging materials

Overall acceptability of stored mandarin was significantly affected by packaging methods. The maximum value for overall acceptability (4.21) was recorded in P_1 and minimum (3.69) in P_0 after twenty days of storage.

4.6.4.3 Combined effect of chemicals and packaging materials

The overall acceptability of stored mandarin significantly affected by treatment combination of packaging methods and pre-treatments. The maximum value for overall acceptability (4.97) was obtained in T_2P_1 and minimum (3.57) in T_0P_0 after twenty days of storage.

Table 4.18 Effect of pre-treatments, packaging materials and their combination on overall acceptability of mandarin

Pre-treatments	**Storage days**			
	5^{th} day	**10^{th} day**	**15^{th} day**	**20^{th} day**
T_0	8.39	7.46	5.05	3.73
T_1	8.70	7.75	5.34	4.02
T_2	9.10	8.17	5.73	**4.40**
T_3	8.52	7.58	5.17	3.85
T_4	8.49	7.56	5.15	3.83
S.Em±	0.0344	0.0310	0.0318	0.0315
CD at $_{5\%}$	0.0982	0.0885	0.0910	0.0901
Packaging materials				
P_0	8.36	7.42	5.01	3.69
P_1	8.88	7.95	5.52	**4.21**
P_2	8.64	7.70	5.28	3.96
P_3	8.67	7.74	5.33	4.00
S.Em±	0.0307	0.0277	0.0285	0.0282
CD at $_{5\%}$	0.0878	0.0791	0.0814	0.0806
Interaction T x P				
T_0 P_0	8.22	7.30	4.89	3.57
T_0 P_1	8.62	7.70	5.29	3.97
T_0 P_2	8.35	7.40	4.99	3.67
T_0 P_3	8.35	7.43	5.02	3.70
T_1 P_0	8.36	7.43	5.02	3.70
T_1 P_1	8.72	7.77	5.36	4.04
T_1 P_2	8.79	7.87	5.46	4.14
T_1 P_3	8.92	7.93	5.52	4.20
T_2 P_0	8.45	7.47	5.06	3.74
T_2 P_1	9.66	8.73	6.26	**4.97**
T_2 P_2	9.12	8.20	5.76	4.40
T_2 P_3	9.17	8.27	5.86	4.49
T_3 P_0	8.41	7.47	5.06	3.74
T_3 P_1	8.79	7.87	5.46	4.14
T_3 P_2	8.42	7.47	5.06	3.74
T_3 P_3	8.45	7.50	5.09	3.77
T_4 P_0	8.38	7.43	5.02	3.70
T_4 P_1	8.62	7.67	5.26	3.94
T_4 P_2	8.51	7.57	5.16	3.84
T_4 P_3	8.47	7.57	5.16	3.84
S.Em±	0.0687	0.0619	0.0637	0.0630
CD at $_{5\%}$	0.1964	0.1770	0.1820	0.1801

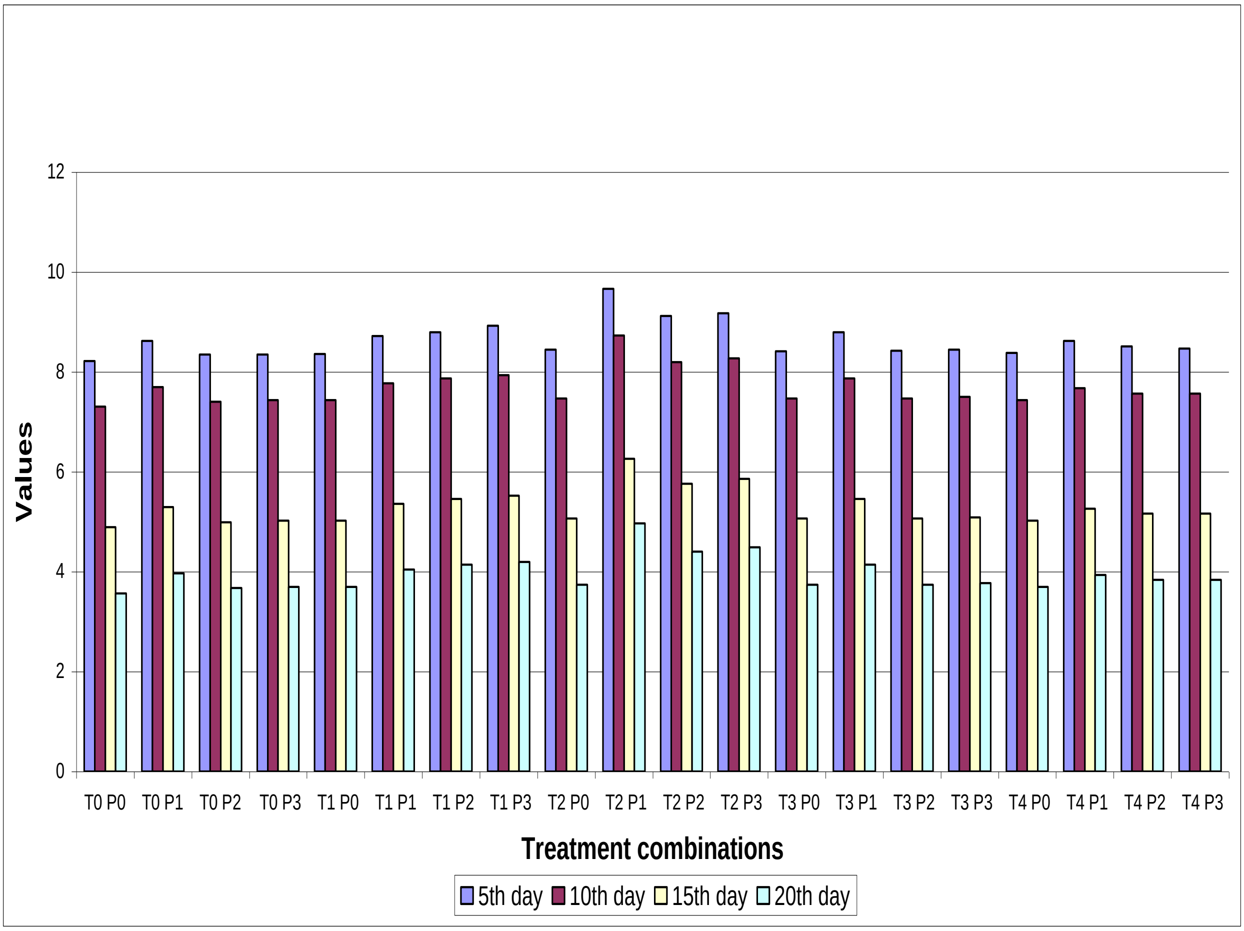

Fig. 4.15 Combined effect of pre-treatments and packaging materials on overall acceptability of mandarin

Chapter V

DISCUSSION

Result of the experiment entitled **"Effect of different plant growth regulators and packaging materials on shelf-life of mandarin (*Citrus reticulata* Blanco)"** presented in the preceding chapter revealed that the treatment with plant growth regulators, packaging materials and their combinations significantly affected various physico-chemical parameters of mandarin fruits during the storage period. The salient features of the result obtained are discussed in this chapter.

5.1 Physical characteristics of stored mandarin

5.1.1 Appearance

Appearance is one of the most important quality parameter because it attracts the eyes of consumer and thus influences the market price. It is evident from the present study that appearance was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20^{th} day (Table 4.4).

The different chemical treatments affected appearance very significantly. The chemically treated fruit showed gradual decrease in appearance value up to 20^{th} day of storage. On 20^{th} day of storage the maximum flavour value was found in 2,4-D 100 (T_2) ppm as compared to minimum in control (T_0). The reason for lower appearance value with control was due to increase in ripening, rotting and shrinkage at the end of storage, which is, minimize with application of 2,4-D.

The appearance values were significantly affected by different packaging materials throughout the storage period. The appearance values gradually decreased up to 20^{th} day of storage in all the treatments. The corrugated boxes (P_1) showed higher appearance values at the end of storage period as compared to control (P_0) and other treatments.

All the interactions between different chemicals and packaging materials were found significant. The maximum value of appearance at the end of storage was obtained in 2,4-D 100 ppm + corrugated boxes (T_2P_1) whereas the minimum value was obtained in control (T_0P_0). The present findings are supported by Tatl and Ozguven (1999), and Tugwell and Chvyl (1996).

5.1.2 Reduction in fruit size

The result indicates that fruit size in terms of length X width decreased with the advancement of storage period upto 20th day of storage. However, the reduction in size was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.5).

The results of the present investigation indicated that the minimum reduction in fruit size was recorded in fruits, which was treated with 2,4-D 100 ppm (T_2) whereas, maximum reduction in fruit size was recorded in control (T_0).

Use of various packaging materials significantly reduces the rate of reduction in size of fruits during storage. The minimum reduction in size was recorded in corrugated boxes (P_1) treatment whereas maximum reduction in fruit size was recorded in control (P_0). However, P_1 and P_3 treatments used in the present investigation are effective in control of reduction of fruit size during storage.

The data further indicated that combined application of chemicals and packaging materials treatments were quite effective in preventing the reduction in fruit size. On 20th day of storage the minimum reduction in fruit size in 2,4-D 100 ppm + Corrugated boxes (T_2P_1) treatment as compared to the maximum in control (T_0P_0). The present findings are supported by Jadhao *et al.* (2007) and Rana *et al.* (2002).

5.1.3 Individual fruit weight

Individual fruit weight of mandarin during storage is characterized by the weight of mandarin at different days of storage. It is an important parameter because it governs the physical quality of the fruits. Any loss in weight of fruit is likely to reduce the quality of product drastically. Therefore, one of the main objectives of any post harvest treatment should be to maintain the fruit weight. It is evident from the present study that individual fruit weight of mandarin significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.6).

As far as the effect of individual chemical treatment is concerned, the maximum individual fruit weight was recorded in 2,4-D 100 ppm (T_2) followed by GA_3

100 ppm (T_4) as compared to minimum in control (T_0) at the end of the storage period i.e. 20^{th} day of storage.

As far as the effect of individual packaging treatments is concerned, the maximum individual fruit weight was recorded in polythene bag (P_2) followed by corrugated boxes (P_1) and newspaper wrapping (P_3) as compared to the minimum in control (P_0) at the end of storage period i.e. 20^{th} day.

When all the individual treatments were combined their effect was found to be slightly more prominent as compared to the individual effect. Combined application of 2,4-D 100 ppm with perforated polythene (T_2P_2) resulted in maximum individual fruit weight as compared to minimum in control (T_0P_0) at the end of storage period i.e. 20^{th} day.

Thus, it is clear from the present results that role of chemicals and packaging material is crucial in maintaining individual fruit weight. A possible explanation for maintain individual fruit weight in the mandarin fruits obtained in the present study could be that perforated polythene or corrugated boxes provide better protective cover as compared to newspaper wrapping which perhaps helps in maintain individual fruit weight of mandarin. The present findings are supported by Bhullar *et al.* (1981*),* Choudhary and Dhaka (2005), Jadhao *et al.* (2007), Tugwell and Chvyl (1996) and Rana *et al.* (2002).

5.1.4 Physiological loss in weight (PLW)

Physiological loss in weight during storage is characterized by reduction in fruit weight by the way of loss of moisture through evaporation and/or transpiration. It is the most important parameter because it governs the post harvest quality of the fruits. Any loss in weight of fruit is likely to reduce the quality of product drastically. Therefore, one of the main objectives of any post harvest treatment should be to reduce the physiological loss in weight. It is evident from the present study that loss in weight was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20^{th} day (Table 4.7).

As far as the effect of individual chemical treatment is concerned, the minimum PLW was recorded in 2,4-D 100 ppm (T_2) followed by GA_3 100 ppm (T_4) as compared to maximum in control (T_0) at the end of the storage period i.e. 20^{th} day of storage.

As far as the effect of individual packaging treatments is concerned, the minimum PLW was recorded in polythene bag (P_2) followed by corrugated boxes (P_1) and newspaper wrapping (P_3) as compared to the maximum in control (P_0) at the end of storage period i.e. 20th day.

When all the individual treatments were combined their effect was found to be slightly more prominent as compared to the individual effect. Combined application of 2,4-D 100 ppm with perforated polythene (T_2P_2) resulted in minimum PLW as compared to maximum in control (T_0P_0) at the end of storage period i.e. 20th day.

Thus, it is clear from the present results that role of chemicals and packaging material is crucial in minimizing PLW. A possible explanation for lower PLW in the mandarin fruits obtained in the present study could be that perforated polythene or corrugated boxes provide better protective cover as compared to newspaper wrapping which perhaps helps in lower PLW of mandarin fruits. Alternatively these packaging materials (perforated polythene/corrugated boxes/ newspaper wrapping) might have lowered the temperature surrounding the fruits thereby reducing evapo-transpiration of the fruits, thus might helped in lowering PLW of fruits packed in perforated polythene as against the fruits packed in newspaper wrapping. The present findings are supported by Bhullar *et al.* (1981*),* Choudhary and Dhaka (2005), Jadhao *et al.* (2007), Tugwell and Chvyl (1996) and Rana *et al.* (2002).

5.1.5 Rotting

Rotting of the fruit is another important fruit quality parameter and occurrence of rotting adversely affects the shelf-life of fruits. Rotting caused due to infection by fungus, mainly *Rhizopus* makes the fruit soft and affected fruits develop bad odour**.**

Rotting of fruits increased with the advancement of storage period. Thus, elimination and/or reduction of rotting during storage are crucially important for preserving the good quality of fruits. In the present investigation, application of different chemicals and packaging material alone or in combination allowed minimum rotting during storage (Table 4.8).

As far as the effect of individual chemical treatment is concerned, the minimum rotting was recorded in 2,4-D 100 ppm (T_2) as compared to maximum in control (T_0) at the end of the storage period i.e. 20th day.

Among the effects of individual treatments, minimum rotting was recorded in perforated polythene (P_2) treatment as compared to maximum in control (P_0) at 20th

day after storage. The beneficial effect of polythene bag and corrugated boxes packaging on rotting of fruits over newspaper wrapping treatment may be attributed to the limited exposure of fruits to the micro flora and atmospheric oxygen in this packaging material.

The combined application of different chemicals and packaging materials had significant effect on rotting of fruits up to 20^{th} day of storage. However, among all the treatments attempted in the present investigation, the minimum rotting was recorded in 2,4-D 100 ppm with Perforated polythene (T_2P_2), where, the maximum in control (T_0P_0).

The effectiveness of combined application of different chemicals and packaging materials might be due to fact that packaging restricts the levels of ethylene generation by reducing the oxygen levels in the polyethylene bag and decreased the rate of rotting which might have preserved the fruits by maintaining their texture and carbohydrate levels. The combined applications of seal packaging and 2,4-D 100 ppm have been found to control the rotting by several workers Bhullar *et al.* (1981*),* Ferguson e*t al.* (1982), Tatl and Ozguven (1999), Choudhary and Dhaka (2005), Jadhao *et al.* (2007) and Jadhao *et al.* (2008).

5.1.6 Shrinkage ratio

The result indicates that shrinkage ratio in terms of volume of the fruit decreased with the advancement of storage period upto 20^{th} day of storage. However, the reduction in volume of the fruit was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20^{th} day (Table 4.9).

The results of the present investigation indicate that the maximum shrinkage ratio was recorded in fruits, which was treated with 2,4-D 100 ppm (T_2) whereas, minimum shrinkage ratio was recorded in control (T_0).

Use of various packaging materials in packaging significantly reduces the rate of reduction in volume of the fruit during storage. The maximum shrinkage ratio was recorded in corrugated boxes (P_1) treatment whereas minimum shrinkage ratio was recorded in control (P_0).

The data further indicated that combined application of chemicals and packaging materials treatments were quite effective in preventing the reduction in volume of the fruit. On 20^{th} day of storage the maximum shrinkage ratio in 2,4-D 100 ppm + Corrugated boxes (T_2P_1) treatment as compared to the minimum in control (T_0P_0). The present findings are supported by Jadhao *et al.* (2008).

5.2 Chemical characteristics of stored mandarin

5.2.1 Acidity

Acidity is an important parameter of fruit quality. Therefore, maintenance of acidity of fruits during storage assumes specially significance. The acidity content of fruits decreased with the advancement of storage period. However, various chemical and packaging material treatments significantly affected the rate of decrease in acidity content of fruits. It is evident from the present study that acidity was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.10)

As far as the effect of individual chemical treatment is concerned, the maximum acidity was recorded in 2,4-D 100 ppm (T_2) followed by 2,4-D 50 ppm (T_1) as compared to maximum in control (T_0) at the end of the storage period i.e. 20th day of storage.

As far as the effect of individual packaging treatments is concerned, perforated polythene (P_2) recorded maximum acidity as compared to control (P_0). It might be due to less oxidation of organic acids in perforated polythene bags.

When all the individual treatments were combined their effect was found to be significant. Combined application of 2,4-D 100 ppm with Perforated polythene (T_2P_2) resulted in maximum acidity as compared to maximum in control (T_0P_0) at the end of storage period i.e. 20th day.

The present findings are supported by Bhullar *et al.* (1981*),* Tatl and Ozguven (1999), Jadhao *et al.* (2008), Ahmad *et al.* (1979), Ahmad and Khan (1987) and Ladaniya (2001).

5.2.2 Ascorbic acid

Among various chemical parameter, ascorbic acid or vitamin ‘C’ is very important qualitative parameter of mandarin fruits. Minimum loss of ascorbic acid from mandarin fruits during storage is therefore most importance. In the present study, ascorbic acid content in mandarin fruit was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.11).

The ascorbic acid content of fruits decreased with advancement of storage period. However, various chemical and packaging materials used in the present study helped in reducing the loss of vitamin 'C' during storage fruits.

The decrease in ascorbic acid during storage is probably due to the process of oxidation of ascorbic acid to dehydroascorbic acid by enzyme ascorbic-nase (Das and Desh, 1967).

Among the individual treatment, on 20^{th} day of storage minimum loss of ascorbic acid during storage was recorded in 2,4-D 100 ppm (T_2) however, the maximum loss in ascorbic acid was recorded in control (T_0).

As far as the effect of individual packaging treatments is concerned, corrugated boxes recorded maximum ascorbic acid as compared to control (P_0). It might be due to less oxidation of organic acids in perforated polythene bags (P_2).

The reduction in the loss of vitamin 'C' content of mandarin fruits due to various chemical and packaging materials treatment as obtained in present study may be due to reduction in the rate of evapo-transpiration, which normally results in volatile dissipation of ascorbic acid during storage.

The combined effect of chemical and packaging materials was found to be significant. The control (T_0P_0) showed lower retention of ascorbic acid while the higher retention of ascorbic acid content of fruits was observed in 2,4-D 100 ppm + corrugated boxes (T_2P_1). The present findings are supported by Ahmad *et al.* (1979), Ahmad and Khan (1987) and Ladaniya (2001).

5.2.3 Total soluble solids

It is clear from the data that TSS content of fruits was increased with advancement of storage period. The minimum rate of increase in TSS of fruits during storage period is desirable for preservation of good fruit quality. It is evident from the present study that total soluble solids was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20^{th} day (Table 4.12).

Different chemicals significantly lowered the increase in total soluble solids content of fruits during the storage period. On 20^{th} day of storage the minimum TSS was observed in 2,4-D 50 ppm (T_1) as compared to maximum in control (T_0).

As expected, the increase in total soluble solids content of fruits was significantly lowered by packaging material during the entire period of storage. On

20th day of storage the minimum TSS was observed in perforated polythene (P_2) as compared to maximum in control (P_0).

The interaction effect of chemical and packaging materials was found to be significant during the storage period. The minimum TSS content was observed in 2,4-D 50 ppm + perforated polythene (T_2P_2) on 20th day of storage, however it was maximum in control (T_0P_0). Deka (1990) reported that the rate of increase in TSS was slower in perforated polythene as compared to no packaging.

The increase in TSS with advancement of storage may be accounted to the moisture loss, hydrolysis of polysaccharides and concentration of juice as a result of dehydration. The present findings are supported by Jadhao *et al.* (2008).

5.2.4 Reducing sugars

It is clear from the data that reducing sugars of fruits was increased with advancement of storage period. The minimum rate of increase in reducing sugars of fruits during storage period is desirable for preservation of good fruit quality.

The increase in total soluble solids content of fruits was significantly lowered by different chemicals during the storage period (Table 4.13). On 20th day of storage the minimum content of reducing sugars was observed in 2,4-D 100 ppm (T_2) as compared to maximum in control (T_0).

As expected, the increase in reducing sugars content of fruits was significantly lowered by packaging materials during the entire period of storage. On 20th day of storage the minimum content of reducing sugars was observed in perforated polythene (P_2) as compared to maximum in control (P_0).

The interaction effect of chemical and packaging materials was found to be non-significant during the storage period. The minimum content of reducing sugars was observed in 2,4-D 100 ppm + perforated polythene (T_2P_2) on 20th day of storage, however it was maximum in control (T_0P_0).

The effectiveness of application of different chemicals, packaging materials and their combination might be due to fact that some acids being converted into sugars during respiration conversion of starch (polysaccharides) into sugars (monosaccharide). The present findings are supported by Ahmad *et al.* (1979), Ahmad and Khan (1987) and Ladaniya (2001).

4.2.5 Total sugars

It is clear from the data that a total sugar of fruits was increased with advancement of storage period. The minimum rate of increase in total sugars of fruits during storage period is desirable for preservation of good fruit quality.

Different chemicals significantly lowered the increase in total soluble solids content of fruits during the storage period (Table 4.14). On 20th day of storage the minimum content of total sugars was observed in 2,4-D 100 (T_2) ppm as compared to maximum in control (T_0).

As expected, the increase in total sugars content of fruits was significantly lowered by packaging material during the entire period of storage (Table 4.14). On 20th day of storage the minimum content of total sugars was observed in perforated polythene (P_2) as compared to minimum in control (P_0).

The interaction effect of chemical and packaging materials was found to be non-significant during the storage period. The minimum content of total sugars was observed in 2,4-D 100 ppm + perforated polythene (T_2P_2) on 20th day of storage, however it was maximum in control (T_0P_0).

The effectiveness of application of different chemicals, packaging materials and their combination might be due to fact that some acids being converted into sugars during respiration conversion of starch (polysaccharides) into sugars (monosaccharide). The present findings are supported by Ahmad *et al.* (1979), Ahmad and Khan (1987) and Ladaniya (2001).

5.3 Organoleptic characteristics of stored mandarin

5.3.1 Colour

Fruit colour is an important quality parameter because it attracts the eyes of consumer and thus influences the market price. The treatment with chemicals, packaging materials and their combination had pronounced effect on change in colour of fruits. It is evident from the present study that colour was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.15).

The data presented in the table 4.15 indicated that use of chemical 2,4-D 100 ppm (T_2) resulted slower rate of colour change followed by 2,4-D 50 ppm (T_1) whereas quick deterioration in colour of fruit was recorded in control (T_0). The retention of colour of fruit due to different chemicals 2,4-D 50 ppm and 2,4-D 100 ppm as compared to control may be due to inhibition of chlorophyll conversion into carotenoids, lycopene and β –carotene.

The fruits, without packaging, showed quick deterioration in colour of fruits, whereas, corrugated boxes (P_1), perforated polythene (P_2) and newspaper (P_3) packed fruits showed slower rate of colour change during storage. On 20th day of storage, the maximum colour value was recorded in corrugated boxes (P_1) followed by newspaper (P_3) and perforated polythene (P_2) treatment as compared to minimum in control (P_0). A possible reason for retention of colour during storage by different packaging material could be that packaging materials form a cover over the fruits leading to reduction in oxygen concentration. As a result, the respiration in fruits may slow down due to which the degeneration of colour in treated fruits is reduced. Packaging materials prevent the fruits from the direct sunrays, which may also result in less fading of colour.

The combined application of chemical and packaging materials has significant effect on this aspect. The fruit treated with 2,4-D 100 ppm + corrugated boxes (T_2P_1) showed maximum colour value as compared to minimum in control (T_0P_0). The better retention of colour due to various chemical and packaging treatments with might be because of mutual complementary effect of these treatments. The present findings are supported by the result obtained by the Siddiqui *et al*. (1997) and Mandhyan (1999).

5.3.2 Flavour

The flavour of fruits is an important quality of mandarin. It is judged on the basis of smell and blend of the fruit. The treatment with chemicals and packaging materials had pronounced effect on flavour of fruits. It is evident from the present study that flavour was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.16).

The different chemical treatments affected flavour very significantly. The chemical treated fruit showed higher flavour value up to 20th day of storage. On 20th day of storage the maximum flavour value was in 2,4-D 100 ppm (T_2) as compared to minimum in control (T_0). The reason for lower flavour value was due to increase in ripening at the end of storage.

The flavour values were significantly affected by different packaging material throughout the storage period. The flavour values were higher up to 20th day of storage but it decreased at the end of storage. The corrugated boxes (P_1) showed higher flavour values at the end of storage period as compared to lower in control (P_0).

All the interactions between different chemicals and packaging materials were found insignificant. The maximum value of flavour at the end of storage was in 2,4-D 100 ppm + corrugated boxes (T_2P_1) whereas the minimum value was obtained in control (T_0P_0). The present findings are supported by Sonkar and Ladaniya (1999).

5.3.3 Texture

Like fruit colour, the flavour also forms part of visual appearance attributes affecting the marketability of fruits. In the present investigation, the texture of mandarin fruits during storage was significantly affected by various treatments of packaging. It is evident from the present study that texture was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20th day (Table 4.17).

The different chemical treatments affected texture very significantly. The texture of fruit decreased with the advancement of storage period up to 20th day of storage (Table 4.17). On 20th day of storage the maximum texture value was in 2,4-D 100 ppm (T_2) as compared to minimum in control (T_0).

The different packaging material affected texture very significantly. The texture of fruit decreased with the advancement of storage period up to 20th day of storage. On 20th day of storage the maximum texture value was in corrugated boxes (P_1) as compared to minimum in control (P_0).

The effect of various chemical and packaging materials treatments was found to be significant. On 20th day the highest value of texture was recorded in 2,4-D 100 ppm + corrugated boxes (T_2P_1) as compared to minimum in control (T_0P_0). The higher retention of texture in corrugated boxes over the control may be due to the fact that packaging prevents the direct evapo-transpiration and lowered the physiological loss in weight. The present findings are supported by Sonkar and Ladaniya (1999) and Ladaniya (2001).

5.3.4 Overall acceptability

Overall acceptability is the total organoleptic quality of the fruit. In the present investigation, the overall acceptability of mandarin fruits during storage was significantly affected by various treatments of packaging. It is evident from the present study that overall acceptability was significantly affected by different chemicals, packaging materials and their combinations throughout the storage period up to 20^{th} day (Table 4.18).

The different chemical treatments affected overall acceptability very significantly. The overall acceptability of fruit decreased with the advancement of storage period up to 20^{th} day of storage. On 20^{th} day of storage the maximum overall acceptability value was in 2,4-D 100 ppm (T_2) as compared to minimum in control (T_0).

The different packaging material affected overall acceptability very significantly. The overall acceptability of fruit decreased with the advancement of storage period up to 20^{th} day of storage. On 20^{th} day of storage the maximum overall acceptability value was in corrugated boxes (P_1) as compared to minimum in control (P_0).

The effect of various chemical and packaging materials treatments was found to be significant. On 20^{th} day the highest value of overall acceptability was recorded in 2,4-D 100 ppm + corrugated boxes (T_2P_1) as compared to minimum in control (T_0P_0). The present findings are supported by Choudhary and Dhaka (2005), Sonkar and Ladaniya (1999).

CHAPTER-VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

The experiment entitled "**Effect of different plant growth regulators and packaging materials on shelf-life of mandarin (*Citrus reticulata* Blanco)**" was conducted at the Department of Post Harvest Management, College of Horticulture, Mandsaur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya Gwalior (M.P.) during the year 2010-2011.

The experiment was conducted from 14th October, 2010 to 2nd November 2010 at room temperature ranging from 5 to 29°C and relative humidity varied from 16 to 87 percent. Twenty treatment combinations consisting of four types of chemical (2,4-D 50 ppm, 2,4-D 100 ppm, GA_3 50 ppm, and GA_3 100 ppm) and three types of packaging materials (Corrugated boxes, perforated polythene and newspaper) and their combinations were used in the study. Only interaction effect of chemical and packaging materials on various physico-chemical parameters of mandarin during the storage has been highlighted.

I. The maximum value of appearance (6.19) at the end of storage was obtained in 2,4-D 100 ppm + corrugated boxes whereas the minimum value (4.79) was obtained in control treatment on 20th day of storage.

II. The minimum reduction in fruit size (11.85% in length & 11.15% in width) was obtained in 2,4-D 100 ppm + Corrugated boxes treatment as compared to the maximum (10.88% in length & 12.88% in width) in control on 20th day of storage.

III. The maximum individual fruit weight (162.8%) was recorded in 2,4-D 100 ppm with perforated polythene as compared to minimum (159.4%) in control on 20th day of storage.

IV. The maximum physiological loss in weight (16.98%) was obtained in control as compared to minimum (15.20%) in 2,4-D 100 ppm with perforated polythene on 20th day of storage.

V. The maximum rotting (11.97%) was found in control whereas minimum rotting (10.14%) was found in 2,4-D 100 ppm with perforated polythene on 20th day of storage.

VI. The maximum shrinkage ratio (1:0.857) was recorded in 2,4-D 100 ppm with perforated polythene and GA_3 50 ppm with perforated polythene as compared to minimum (1:0.839) in control on 20th day of storage.

VII. The maximum acidity (0.624%) was obtained in 2,4-D 100 ppm with perforated polythene whereas minimum acidity (0.581%) was obtained in control on 20th day of storage.

VIII. The maximum ascorbic acid (14.17 mg/100 ml juice) was obtained in 2,4-D 100 ppm with corrugated boxes as compared to minimum (11.87 mg/100 ml juice) in control on 20th day of storage.

IX. The maximum (13.12^{0} Brix) TSS was obtained in control whereas minimum (10.95^{0} Brix) in 2,4-D 100 ppm with perforated polythene in control on 20th day of storage.

X. The maximum reducing sugars (5.28%) was obtained in control as compared to minimum (4.64%) in 2,4-D 100 ppm with perforated polythene on 20th day of storage.

XI. The minimum total sugars (9.56%) was obtained in 2,4-D 100 ppm with perforated polythene whereas maximum total sugars (10.80%) was obtained in control on 20th day of storage.

XII. The maximum value for colour (4.24) was obtained in 2,4-D 100 ppm with corrugated boxes whereas minimum (2.87) in control on 20^{th} day of storage.

XIII. The maximum value for flavour (4.52) was obtained in 2,4-D 100 ppm with corrugated boxes whereas minimum (3.12) in control on 20^{th} day of storage.

XIV. The maximum value for texture (6.19) was obtained in 2,4-D 100 ppm with corrugated boxes whereas minimum (4.74) in control on 20^{th} day of storage.

XV. The maximum value for overall acceptability (4.97) was obtained in 2,4-D 100 ppm with corrugated boxes and minimum (3.57) in control on 20^{th} day of storage.

6.2 CONCLUSIONS

On the basis of results obtained in the present investigation it can be concluded that application of various chemicals either alone or in combination with different packaging materials may be used for extending post-harvest shelf life of mandarin during storage. Out of four types of chemicals (2,4-D 50 ppm, 2,4-D 100 ppm, GA_3 50 ppm, and GA_3 100 ppm), 2,4-D 100 ppm was found to be more beneficial followed by 2,4-D 50 ppm as compared to GA_3 50 ppm, and GA_3 100 ppm. In case of packaging materials out of three levels (corrugated boxes, perforated polythene and newspaper), the perforated polythene was found to be more beneficial followed by corrugated boxes as compared to newspaper.

The combined application of 2,4-D 100 ppm with perforated polythene (P_2T_2) proved to be best post harvest treatment for storage of mandarin from the point of reduction in size (length & width), physiological loss in weight (PLW) (%), rotting. Further, this treatment also maintained the fruit quality in terms of total soluble solids (TSS), acidity, reducing sugars and total sugars content during storage on 20^{th} day of storage.

Therefore, it may be recommended that before transportation, growers and retailers shall pack the mandarin fruits in perforated polythene with 2.5 mm holes and also No. of hole in a pack after the chemical treatment with 2,4-D 100 ppm. Thereafter thé mandarin fruits can be stored at ambient room temperature for prolonging the shelf life upto 20^{th} day of storage.

6.3 SUGGESTIONS FOR FURTHER WORK

The following suggestions are made for further work on the basis of present study:

1. Experiment should be done with other chemical treatments and packaging materials.
2. Experiment should be done with other variety for finding the best combination of chemicals and packaging materials.

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Appendix I

Agro-meteorological parameters recorded during the period of storage

Date	Temperature (^0C)		Relative Humidity (%)	Rainfall (mm)
	Min.	Max.		
14/10/10	27.07	28.35	24.5	Nil
15/10/10	25.91	28.02	16.85	Nil
16/10/10	25.15	25.04	28	Nil
17/10/10	20.62	23.32	18.14	Nil
18/10/10	17.1	23.34	64.85	Nil
19/10/10	10	26.45	44.85	Nil
20/10/10	9.77	27.75	51	Nil
21/10/10	12.2	29.14	72.57	Nil
22/10/10	11.34	25.4	87.14	Nil
23/10/10	10.05	26.74	64.28	Nil
24/10/10	7.85	23.75	75.42	Nil
25/10/10	4.91	23.14	54.14	Nil
26/10/10	4.9	22.55	64	Nil
27/10/10	6.24	27.4	42.4	Nil
28/10/10	11.84	29.31	31.14	Nil
29/10/10	12.78	29.51	46	Nil
30/10/10	11.84	29.07	50.23	Nil
31/10/10	10.68	25.41	45.12	Nil
01/11/10	15.7	29.55	36.85	Nil
02/11/10	18.84	29.67	45.28	Nil

Source: Meteorological Observatory, College of Horticulture, Mandsaur

Appendix- II Analysis of variance of appearance

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	2.04	0.68	47.99	2.06	0.69	53.42	2.02	0.67	53.81	1.97	0.66	51.48
T	4	3.81	0.95	67.28	3.58	0.89	69.73	3.64	0.91	72.82	3.64	0.91	71.14
T X P	12	1.35	0.11	7.93	1.39	0.12	9.03	1.43	0.12	9.53	1.40	0.12	9.15
Error	40	0.57	0.01		0.51	0.01		0.50	0.01		0.51	0.01	
Total	59	7.77			7.54			7.59			7.53		

*Significant at 5 percent level of significance

Appendix- III(a) Analysis of variance of length

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	8.05	2.68	310.77	7.63	2.54	184.79	8.13	2.71	247.70	8.17	2.72	311.49
T	4	7.10	1.78	205.78	7.30	1.83	132.63	7.49	1.87	170.99	7.01	1.75	200.43
T X P	12	1.00	0.08	9.62	1.07	0.09	6.48	1.05	0.09	8.01	0.99	0.08	9.39
Error	40	0.35	0.01		0.55	0.01		0.44	0.01		0.35	0.01	
Total	59	16.49			16.56			17.11			16.52		

* Significant at 5 percent level of significance

Appendix- III(b) Analysis of variance of width

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	8.10	2.70	321.07	7.59	2.53	185.69	8.11	2.70	259.01	8.22	2.74	321.69
T	4	7.17	1.79	213.04	7.27	1.82	133.35	7.41	1.85	177.50	7.07	1.77	207.44
T X P	12	0.99	0.08	9.85	1.06	0.09	6.49	1.05	0.09	8.38	0.98	0.08	9.61
Error	40	0.34	0.01		0.54	0.01		0.42	0.01		0.34	0.01	
Total	59	16.60			16.46			17.00			16.62		

*Significant at 5 percent level of significance

Appendix- IV Analysis of variance of individual fruit weight

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	29.63	9.88	314.93	26.44	8.81	314.93	27.50	9.17	314.93	31.74	10.58	314.93
T	4	26.70	6.68	212.89	28.48	7.12	212.89	38.70	9.67	212.89	24.19	6.05	212.89
T X P	12	3.75	0.31	9.97	9.84	0.82	9.97	5.84	0.49	9.97	4.00	0.33	9.97
Error	40	1.25	0.031		3.86	0.096		0.40	0.010		0.35	0.009	
Total	59	61.34			68.63			72.45			60.28		

* Significant at 5 percent level of significance

Appendix- V Analysis of variance of physiological loss in weight

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	8.10	2.70	321.07	7.00	2.33	321.07	7.37	2.46	321.07	8.96	2.99	321.07
T	4	7.17	1.79	213.04	7.92	1.98	213.04	10.61	2.65	213.04	6.86	1.72	213.04
T X P	12	0.99	0.08	9.85	2.69	0.22	9.85	1.65	0.14	9.85	1.25	0.10	9.85
Error	40	0.34	0.008		1.08	0.03		0.11	0.003		0.11	0.003	
Total	59	16.60			18.69			19.75			17.19		

*****Significant at 5 percent level of significance

Appendix- VI Analysis of variance of rotting

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	8.10	2.70	321.07	7.00	2.33	86.46	7.37	2.46	934.51	9.00	3.00	988.99
T	4	7.17	1.79	213.04	7.92	1.98	73.35	10.61	2.65	1008.71	6.89	1.72	567.64
T X P	12	0.99	0.08	9.85	2.69	0.22	8.31	1.65	0.14	52.35	1.26	0.10	34.58
Error	40	0.34	0.01		1.08	0.03		0.11	0.00		0.12	0.00	
Total	59	16.60			18.69			19.75			17.27		

* Significant at 5 percent level of significance

Appendix- VII Analysis of variance of shrinkage ratio

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	0.00082	0.00027	0.30	0.00073	0.00024	0.30	0.0008	0.0003	0.30	0.00088	0.00029	0.30
T	4	0.00074	0.00018	0.21	0.00079	0.00020	0.21	0.0011	0.0003	0.21	0.00067	0.00017	0.21
T X P	12	0.00010	0.00001	0.01	0.00027	0.00002	0.01	0.0002	0.0000	0.01	0.00011	0.00001	0.01
Error	40	0.00003	0.0009		0.00011	0.00027		0.0000	0.00028		0.00001	0.00024	
Total	59	0.00170			0.00190			0.0020			0.00167		

* Significant at 5 percent level of significance

Appendix-VIII Analysis of variance of acidity

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	0.0025	0.00084	18.97	0.0027	0.00089	18.92	0.0026	0.00088	19.52	0.0026	0.00088	19.52
T	4	0.0014	0.00035	8.05	0.0014	0.00036	7.56	0.0015	0.00037	8.35	0.0015	0.00037	8.35
T X P	12	0.0009	0.00007	1.62	0.0010	0.00008	1.71	0.0009	0.00008	1.73	0.0009	0.00008	1.73
Error	40	0.0018	0.00004		0.0019	0.00005		0.0018	0.00005		0.0018	0.00005	
Total	59	0.0065			0.0070			0.0069			0.0069		

*Significant at 5 percent level of significance

Appendix-IX Analysis of variance of ascorbic acid

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	9.77	3.26	191.57	10.16	3.39	207.43	9.77	3.26	232.62	9.57	3.19	361.13
T	4	4.23	1.06	62.17	3.92	0.98	60.04	4.23	1.06	75.49	4.25	1.06	120.42
T X P	12	2.55	0.21	12.50	2.47	0.21	12.60	2.55	0.21	15.18	2.53	0.21	23.91
Error	40	0.68	0.02		0.65	0.02		0.56	0.01		0.35	0.01	
Total	59	17.23			17.21			17.11			16.71		

* Significant at 5 percent level of significance

Appendix- X Analysis of variance of TSS

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	8.10	2.70	321.07	7.59	2.53	185.69	8.11	2.70	259.01	8.22	2.74	321.69
T	4	7.17	1.79	213.04	7.27	1.82	133.35	7.41	1.85	177.50	7.07	1.77	207.44
T X P	12	0.99	0.08	9.85	1.06	0.09	6.49	1.05	0.09	8.38	0.98	0.08	9.61
Error	40	0.34	0.01		0.54	0.01		0.42	0.01		0.34	0.01	
Total	59	16.60			16.46			17.00			16.62		

*Significant at 5 percent level of significance

Appendix- XI Analysis of variance of reducing sugars

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	0.28	0.09	3.43	0.37	0.12	3.43	0.43	0.14	3.43	0.45	0.15	3.43
T	4	0.37	0.09	3.40	0.45	0.11	3.40	0.70	0.17	3.40	0.72	0.18	3.40
T X P	12	0.38	0.03	1.17	0.44	0.04	1.17	0.15	0.01	1.17	0.15	0.01	1.17
Error	40	1.08	0.03		1.12	0.03		1.09	0.03		1.08	0.03	
Total	59	2.11			2.39			2.37			2.40		

*Significant at 5 percent level of significance

Appendix- XII Analysis of variance of total sugars

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	0.265	0.088	3.263	0.278	0.093	3.432	0.275	0.092	3.392	0.300	0.100	3.648
T	4	0.353	0.088	3.268	0.373	0.093	3.446	0.368	0.092	3.406	0.399	0.100	3.639
T X P	12	0.371	0.031	1.144	0.380	0.032	1.170	0.377	0.031	1.164	0.395	0.033	1.199
Error	40	1.081	0.027		1.082	0.027		1.081	0.027		1.098	0.027	
Total	59	2.070			2.112			2.101			2.192		

*Significant at 5 percent level of significance

Appendix- XIII Analysis of variance of colour

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	2.04	0.68	47.99	2.16	0.72	47.99	2.06	0.69	47.99	2.01	0.67	47.99
T	4	3.81	0.95	67.28	3.63	0.91	67.28	3.59	0.90	67.28	3.56	0.89	67.28
T X P	12	1.35	0.11	7.93	1.49	0.12	7.93	1.42	0.12	7.93	1.39	0.12	7.93
Error	40	0.57	0.014		0.53	0.013		0.50	0.013		0.51	0.013	
Total	59	7.77			7.81			7.57			7.47		

* Significant at 5 percent level of significance

Appendix-XIV Analysis of variance of flavour

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	2.04	0.68	47.99	2.06	0.69	55.05	2.15	0.72	59.93	2.06	0.69	58.14
T	4	3.81	0.95	67.28	3.59	0.90	71.78	3.68	0.92	76.96	3.68	0.92	77.75
T X P	12	1.35	0.11	7.93	1.42	0.12	9.44	1.42	0.12	9.86	1.42	0.12	10.02
Error	40	0.57	0.01		0.50	0.01		0.48	0.01		0.47	0.01	
Total	59	7.77			7.57			7.73			7.64		

* Significant at 5 percent level of significance

Appendix- XV Analysis of variance of texture

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	2.04	0.68	47.99	2.06	0.69	47.99	2.70	0.90	47.99	2.15	0.72	47.99
T	4	3.81	0.95	67.28	3.59	0.90	67.28	3.56	0.89	67.28	3.66	0.92	67.28
T X P	12	1.35	0.11	7.93	1.42	0.12	7.93	1.68	0.14	7.93	1.38	0.12	7.93
Error	40	0.57	0.014		0.50	0.013		0.81	0.020		0.55	0.014	
Total	59	7.77			7.57			8.74			7.74		

* Significant at 5 percent level of significance

Appendix- XVI Analysis of variance of overall acceptability

ANOVA		5 DAS			10 DAS			15 DAS			20 DAS		
S.V	**Df**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**Fcal**
P	3	2.04	0.68	47.99	2.11	0.70	61.23	2.02	0.67	55.25	2.06	0.69	57.51
T	4	3.81	0.95	67.28	3.77	0.94	82.01	3.50	0.87	71.90	3.38	0.85	71.02
T X P	12	1.35	0.11	7.93	1.48	0.12	10.76	1.36	0.11	9.29	1.40	0.12	9.76
Error	40	0.57	0.01		0.46	0.01		0.49	0.01		0.48	0.01	
Total	59	7.77			7.83			7.36			7.31		

* Significant at 5 percent level of significance

VITA

The author **Rahul Pippal** was born on 05 November 1985 in Morena, (M.P.). He passed his higher secondary school certificate examination with first division in 2003, from V.C.H.S. School Morena, (M.P.). He was admitted for B.Sc (Horti) in 2004 in Jawaharlal Nehru Krishi Vishwa Vidyalaya, K.N.K. College of Horticulture Mandsaur, (M.P.), and secured his degree with on O.C.G.A. 6.85 out of 10.00 scales in 2009.

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(RAHUL PIPPAL)