EFFECT OF BAGGING ON LITCHI FRUIT cv. DEHRADUN

By

Varun Pal Singh

(J-17-M-498)

Thesis submitted to Faculty of Post Graduate Studies

in partial fulfillment of the requirement

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MASTER OF SCIENCE IN AGRICULTURE

IN

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Division of Fruit Science

Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu

Main Campus, Chatha, Jammu 180009

2021

M.Sc.

EFFECT OF BAGGING ON LITCHI FRUIT cv. DEHRADUN

Varun Pal Singh

CERTIFICATE-I

This is to certify that the thesis entitled **"Effect of bagging on litchi fruit cv. Dehradun"** submitted in partial fulfillment of the requirements for the degree of **Master of Science (Ag.) Horticulture (Fruit Science)** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is a record of bonafide research, carried out by **Mr.Varun Pal Singh**, Registration Number **J-17-M-498** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.

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We, the members of Advisory Committee of **Mr. Varun Pal Singh**, Registration Number **J-17-M-498,** a candidate for the degree of **Master of Science (Ag.) Horticulture (Fruit Science)** have gone through the manuscript of the thesis entitled **"Effect of bagging on litchi fruit cv. Dehradun"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

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Varun Pal Singh.

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ABSTRACT

Title of the Thesis	:	**Effect of bagging on litchi fruit cv. Dehradun**
Name of the Student	:	**Varun Pal Singh**
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Abstract

The present investigation entitled "Effect of bagging on litchi fruit cv. Dehradun" was carried out at Fruit nursery, Department of the Horticulture, Marallia (Miran Sahib) Jammu during 2018-19. Different bagging materials (brown paper bag, newspaper bag, muslin cloth bag, butter paper bag, laminated brown paper bag, white polypropylene bag, pink polypropylene bag) were used in combination with different time of bagging (20 days, 30 days and 40 days after fruit set). Results revealed that panicles bagged with pink polypropylene bag 40 days after fruit set showed least fruit cracking (14.02 %) and pericarp sunburn (18.85 %) whereas this treatment resulted in maximum fruit retention per panicle (54.92%) and fruit yield (78.81 kg/tree). Among the various physical parameters studied, fruit weight (21.64 g), fruit length (4.21cm), fruit breadth (3.96 cm) fruit volume (21.32 cc), specific gravity (1.02), pulp weight (15.94 g) and stone weight (3.06 g) were also found maximum in pink polypropylene bag in combination with 40 days after fruit set. Pink polypropylene bag in combination with bagging at 40 days after fruit set was also superior in terms of chemical parameters of fruits viz., total soluble solids (22.48^0 Brix), titratable acidity (0.40 %), TSS: acid ratio (56.20), ascorbic acid (24.68 mg/100g), total sugars (17.10 %), reducing sugars (12.83 %), non-reducing sugars (4.06%), anthocyanin content (54.35 mg/100g) and minimum polyphenoloxidase activity (9.0 unit/min/g).The total benefit: cost ratio was found maximum (3.74:1) with pink polypropylene bag in combination with bagging at 40 days after fruit set.3

It is thus concluded that bagging of litchi panicles with pink polypropylene bags is considered best in overall improvement of all physical and bio-chemical parameters when bagged at 40 days after fruit set in litchi cv. Dehradun

Key words: Bagging material, Time of bagging, Pink polypropylene bag, Yield, Quality, Economics

Varun Pal Singh

Signature of Major Advisor **Signature of Student**

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LIST OF ABBREVIATIONS

%	:	per cent
µg	:	Microgram
^{0}B	:	Degree Brix
^{o}C	:	Degree Celsius
A. O. A. C.	:	Association of Official Analytical Chemist
Anon.	:	Anonymous
C. D.	:	Critical Difference
Cm	:	Centimetre (s)
Kg	:	Kilogram
Cv.	:	Cultivar
DAB	:	Days after Bagging
RH	:	Relative humidity
g	:	Gram (s)
Ha	:	Hectare
HPO_3	:	Metaphosphoric acid
K	:	Potassium
Max.	:	Maximum
mg	:	Milligram (s)
Min.	:	Minimum
ml	:	Millilitre (s)
mm	:	Millimetre (s)
MSL	:	Mean Sea Level
NaOH	:	Sodium hydroxide
B: C ratio	:	Benefit : cost ratio
pH	:	Hydrogen ion concentration
R.H.	:	Relative Humidity
RCBD	:	Randomized Complete Block Design
PPO	:	Polyphenoloxidase
T.S.S.	:	Total soluble solids

Chapter-1

Introduction

CHAPTER-1

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.), belonging to the family Sapindaceae and subfamily Nepheleae has about 150 genera and 2000 species is one of the most important sub-tropical evergreen fruit crops and is believed to be originated in China. Litchi fruits are highly prized in fresh form due to their attractive red skin, semi-translucent juicy white aril, high nutritive value, strong aroma, rosy flavour which makes it an excellent thirst quencher. Litchi is generally used as table fruit and little as preserved fruits including dried litchi (litchi nuts), canned in syrup and squashes. It has specific climatic requirement and its cultivation is restricted to only few countries like China, India, Taiwan, Thailand and Vietnam etc. India is second largest producer of litchi in the world after China. In India, it is mainly grown in Bihar, West Bengal, Uttar Pradesh, Punjab, J&K and Uttrakhand, where it has a prominent position both in terms of production and productivity. In India, litchi is grown on 92,000 hectares of land with a production of 686,000 metric tons (Anonymous, 2018a) whereas, in Jammu region litchi is grown on 938 hectares of land with a production of 1964 metric tons (Anonymous, 2018b).

The litchi is a good source of nutrition (Jiang *et al.* 2006) and is one of the most important fruit with increasing demand in national and global market. The fruit is high in sugar, carbohydrates, minerals and vitamins (Marisa, 2006). Litchi pulp has a fine blend of sugars and acids which varies with cultivar and climate. Sucrose, fructose and glucose are the major sugars in litchi (Paul *et al.*, 1984; Jiang *et al.*, 2006). The Litchi fruit is rich source of vitamin C (Wall, 2006) and phenolic compounds that have antioxidant activities (Hu *et al.*, 2010). Water is the main component of litchi fruit, which account for 76 to 91% of the pulp and can be processed into juice, wine, and yoghurt (Sauco and Menini, 1989; Huang *et al.*, 2005).

Litchi can be grown on a wide range of soil types ranging from sandy loams, alluvial sand, and calcareous soil, but grown best in alluvial sandy loam soils with good drainage. It thrives well in acidic loamy soils with abundant moisture and well drained clay soils (Kunwar and Singh, 1993; Xie *et al.*,1997). For good production, litchi requires cool dry winters and warm wet summers (Menzel and Simpson,1987).

Fluctuation in temperature (Crane and Schaffer, 2004) and poor nutrition result in yield losses and poor fruit quality (Waseem *et al*., 2002).

Litchi is an evergreen, spreading tree with dense green shining foliage which grows up to a height of 10-12 meters with well distributed branches and root system. Litchi fruits are borne on multi-branched flower panicles or inflorescences. These panicles typically arise from the terminal end of branches. The fruiting and fruit quality is highly dependent on climatic condition. Litchi grown in foothills of Himalayas is available late in the season. The fruits are available from 15th May to 15th July and the shelf life varies from 3 to 5 days. During adverse climatic conditions, when continuous dry heat (40±2 ^{0}C temp and <50% RH) along with dry hot winds prevails, there is severe problem of sunburn and fruit cracking. During favourable climatic conditions, several pests mainly fruit borer, birds and bats affects the quality and yield. These factors results in considerable loss of yield as well as quality of the litchi fruits in conventional method of litchi production.

The major problems responsible for low economic potential of litchi cultivation are poor fruit set and inferior fruit quality. In recent years, the climatic aberrations such as sudden rise in the temperature and humidity, abnormal rains especially during fruit development are often experienced. It not only affects the external appearance of the fruit but also aggravates the pest physiological disorders which further added in the losses. The affected fruits gain poor price in the market and such fruits are also rejected for processing. It causes serious economic loss to litchi growers. To prevent the losses caused by biotic and abiotic factors, several good agricultural practices (GAP) are becoming popular throughout the world. Of several such alternatives pre-harvest fruit bagging has emerged as one of the best approaches in different parts of the world. In this technique, individual fruit or fruit bunch is bagged on the tree for a specific period to get desired results. It is a physical protection technique commonly applied to many fruits, which not only improves fruit visual quality by promoting fruit coloration but also enhances internal fruit quality. Bagging is commonly applied to many fruits for improving quality, colouration (Huang *et al*., 2009 and Sharma *et al*., 2014) protection from pests, extreme environmental conditions, and pesticide residues (Xu *et al*., 2010).

Fruit bagging has been found effective to improve fruit quality, reduce pest damage, bird damage, sun burning and cracking in apples (Ritenour *et al*., 1997 and

Wang *et al*., 2002), pomegranate (Abd El-Rhaman, 2010), litchi (Sanyal *et al*., 1990; Debnath and Mitra, 2008), mango (Sarker *et al.*,2009) and pear (Amarante *et al*., 2002). Pre-harvest bagging of fruit is practiced in Japan, Australia, and China in peach, apple, pear, grape, and loquat cultivation in order to optimise fruit quality by reducing physiological and pathological disorders and to improve fruit colouration to increase market value (Joyce *et al*., 1997 and Kim *et al.*, 2008). Some countries such as Mexico, Chile, and Argentina do not import apples unless they are bagged. It was, thus, hypothesized that by employing appropriate bagging to litchi fruit bunches, the physical losses and quality can be improved. Other factors which are also influenced by fruit bagging are physiological disorders, fruit nutrient concentrations, eating quality of fruits, enzymatic activities, phenolic compound concentration and antioxidant activities, aroma volatiles and fruit firmness.The date of bagging, bagging material and the duration of bagging have a profound influence in the fruit quality and other parameters. The kind of bag and its material may have a significant influence on the fruit. The type of bag recommended for one fruit may not work well for another fruit (Hong *et al.*, 1999).

Considering the importance of Dehradun cultivar in Jammu region, efforts are required to provide technological support through research and developmental programmes for the promotion of production and improved quality fruit for local marketing as well as export. Hence, the present investigation was under taken to study the effect of different type of bags and time of fruit bagging on production and quality of litchi fruits with the following objectives :

- To study the effect of different bagging material on the physico-chemical characteristics of litchi cv. Dehradun.
- To standardize the optimum time for bagging of litchi fruit crop.
- To work out the economic feasibility of bagging.

Chapter-2

Review of Literature

CHAPTER-2

REVIEW OF LITERATURE

Litchi is an important subtropical evergreen fruit with tremendous export potential and high market value. However, rapid pericarp browning, uneven surface colour, cracking, fruit drop and pericarp sunburn are the main problems that result in drop of market value. Number of researchers have explained that these problems can be reduced by applying pre-harvest bagging of different materials. Bagging is one of the Good Agriculture Practice that has the potential to improve fruit quality and colour with no negative impact on yield. Fruit bagging can improve fruit quality mainly by keeping fruit appearance and preferable colouration of fruit as reported for apples (Wang *et al.,* 2000), mangoes (Hofman *et al.,* 1997) and litchi (Tyas *et al.*, 1998). An attempt has been made to review the work done earlier on the influence of bagging material and time of bagging on litchi and other fruits.

2.1 Physical parameters

Tyas *et al*. (1998) found that bagging increased the percentage of fruits in first class, mainly because of increased visual quality of fruit from the north-east and south-west aspects in 12-year-old `Tai So' lychee trees, when enclosed in paper bags at early fruit set, at 1/2–3/4 fruit fill, and just before fruit colouring (corresponding to 80, 42 and 28 days before harvest). The percentage of second class fruits was not affected by bagging, but the percentage rejects was reduced. Thus, bagging has the potential to improve fruit quality and red colour with no negative impact on yield.

2.1.1 Fruit weight

Xiano and Cui (2000) bagged apple fruits with a plastic bag (20cm length, 16cm width with two air hole of 0.5cm at the lower ends) or with the Japanese double-layer bag in early June and bags were removed in mid October. They found that the plastic bag was better than the Japanese double-layer bag in terms of colour and appearance in apple fruits. Average fruit weight (14.9g) in apple also increased by use of the plastic bag.

Wang *et al.* (2003) studied the effect of pre-harvest bagging by using different coloured bags in litchi fruits and found that bagging improved fruit colour and the weight per fruit also increased significantly. They observed that among the different colour bags, white bag showed best results.

Debnath and Mitra (2008) studied the effect of panicle bagging in litchi fruit crop and found that both brown paper bags and newspaper bags showed an increase in fruit weight as compared to control. The maximum fruit weight was found in newspaper bag (23.20 g) as compared to control (22.51 g.)

Xu *et al.* (2008) investigated the effects of bagging date and bag type on fruit size, quality and fruit drop of carambola. Three types of bags (plastic, self-made newspaper and non-woven cloth bag) were used. The results showed that bagging with plastic bags increased average fruit weight, when bagging was carried out 10 days after full bloom.

Harhash and Al-Obeed (2010) carried out an experiment on date palm where panicles were bagged with five coloured plastic bags viz., black, white, blue, yellow and control (unbagged) four weeks after pollination in order to see the effect of bunch bagging on fruit quality. The result showed that the bunch bagging significantly increased the bunch weight, accelerated ripening and improved fruit quality compared with the control.

Kassem *et al.* (2011) bagged the bunches of date palm at the time of pollination with transparent and blue polyethylene bags. The bags were removed at three stages of fruit growth; stage one (khimri stage, 1.1-1.3 cm fruit diameter), stage two (mature stage, fruits were green) and stage three (partially-ripe, 50-60% fruits colouring) and found that polyethylene bagging resulted in significant increase in fruit weight, length, diameter, yield as well as decreased the percentage of tip cracked fruits at harvest time compared with unbagged fruits.

Nagaharshitha *et al.* (2014) conducted an experiment to study the effect of bagging on growth and development of mango (*Mangifera indica* L.) cv. Alphonso. Mango fruits were bagged with six different types of bagging materials at 60 days after fruit set. They observed that different types of bags influenced the growth and development of the mango fruit. All the treatments showed improved fruit weight over the control.

Purbey and Kumar (2015) conducted an experiment to study the effect of pre-harvest bagging on fruit quality and yield of Litchi (*Litchi chinensis* Sonn.) fruits.

They used four different types of bags (plastic bag, brown paper/ kraft paper bags, butter paper bags and muslin cloth bags) at 40 and 50 days after anthesis. The fruit weight of litchi significantly increased in all treatments and maximum fruit weight (25.12 g) was observed with white butter paper bag.

Kishore *et al*. (2016) studied the effect of pre-harvest bagging on fruit quality of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented and revealed that brown paper bag and butter paper bag were found quite effective in increasing maximum fruit weight and size.

Hossain *et al*. (2018) studied the effect of pre-harvest fruit bagging with different type of materials (brown paper bag, white paper bag, white polythene bag, black polythene bag) on post-harvest quality of guava cv. Swarupkathi and stated that among the different bagging materials of guava, maximum fruit weight (164.26 g) was obtained from white paper bag followed by white polythene bag (131.03 g) and lowest fruit weight (104.15 g) was obtained from black polythene bag.

Islam *et al*. (2019) evaluated the effect of bagging time on fruit quality and shelf life of mango (*Mangifera indica* L.) cv. Langra. Bagging increased fruit weight over control. Maximum fruit weight (329.2 g) was found in the treatment of brown paper bag at 35 days after fruit set and minimum in the polythene bag treatment (248.6 g). Bagging increased fruit weight, size over control fruits.

Araujo Neto *et al*. (2020) evaluated the interference of bagging materials (nonwoven fabric, transparent plastic bag, white plastic bag, parchment paper, Tulle fabric bag and kraft paper) on the incidence of insect larvae and the physical and chemical quality of the guava cv. Paluma in an organic system and reported higher fruit mass with parchment paper bags (164.41 g) and nonwoven fabric bags (189.00 g) and lower fruit mass value with Tulle fabric bag (138.83 g).

2.1.2 Fruit size

Wanichkul and Harach (2002) examined the effect of different pre-harvest bagging materials (white, blue, or yellow in colour) on quality of guava fruit cv. “Yen Song” and found that there was significant difference in increased in fruit size of guava.

Huang *et al*. (2004) studied the effect of pre-harvesting bagging by covering "Ruby" grapefruit with black paper bag and reported that longitudinal and transverse diameter did not differ significantly.

Xu *et al*. (2008) observed the effect of pre-harvest bagging dates and bag types on fruit growth and fruit quality of carambola and reported that there was significant increase in fruit width and length with plastic bags when bagging was carried out 10 days after full bloom.

Harhash and Al-Obeed (2010) observed the effect of bagging with five coloured plastic bags viz., black, white, blue, yellow and control (unbagged) four weeks after pollination in order to see the effect of bunch bagging on fruit quality in Succary and Khalas cultivars of date palm. The result showed that the blue colour bag significantly increased the fruit size, fruit length, and fruit diameter and thus improved fruit quality compared to control.

Kassem *et al.* (2011) observed that bagging of panicles with different coloured plastic bags four weeks after pollination showed significant increase in fruit length, diameter in date palm.

Hossain *et al*. (2018) investigated influence of pre-harvest fruit bagging on post-harvest quality of guava cv. Swarupkathi. Four different bagging materials viz. brown paper bag, white paper bag, white polythene bag, black polythene bag were included for the study and uncovered fruits were used as control treatment. Fruits were gained maximum in size (6.59 cm length, 5.86 cm diameter) under white paper bag in comparison to control (5.36 cm length, 4.95 diameter).

Islam *et al*. (2019) evaluated the effect of bagging time on fruit quality and shelf life of mango (*Mangifera indica* L.) cv. Langra. Pre-harvest fruit bagging with brown paper and white paper bag(84.85 mm and 79.27 mm respectively) gave the maximum fruit diameter over both control and polythene bag (74.13 mm) at 35 days after fruit set which is statistically similar with 45 days after fruit. The diameter of fruit was slightly decreased at 45 and 55 days after fruit set.

2.1.3 Fruit volume

Zhou and Guang (2007) observed the effect of different bagging material on fruit volume of pear and found that fruit bagged in plastic film had the fastest increased in fruit volume as compared to those without bagging.

Shah *et al.* (2020) studied the effect of pre-harvest bagging on litchi cv. Rose Scented and found that fruits bagged with pink polypropylene bags (5 % perforation), white polypropylene bags (no perforation) and white polypropylene bags (5 % perforation) 30 days before harvest showed maximum fruit volume (21.25 ml) as compared to control (19.28 ml).

2.1.4 Specific gravity

Mishra *et al.* (2017) studied that the combined application of $CaCl_2$ (2%) + k_2SO_4 (2%) + Bagging (Blue colour polythene) improved the specific gravity of guava fruit.

Asrey *et al.*(2019) conducted an experiment on fruit bagging and bag colour to access the effect on physico-chemical, nutraceutical quality and consumer acceptability of pomegranate (*Punica granatum* L.) arils and concluded that highest specific gravity (1.05 ± 0.01) was found in red and white (at par) colour bagged fruits followed by blue and control. Early maturation in red bag fruits might have induced rapid disintegration of aril tissues, which has possibly facilitated escaping of cell air and resulted in higher specific gravity.

2.1.5 Pulp weight

Senanan *et al.* (2011) concluded that pre harvesting bagging of panicles had no significant effect on the pulp weight of litchi fruit cv. Hong Huay.

Nagaharshita *et al.* (2014) examined the effect of bagging on growth and development of mango cv. “Alphonso” and found that pulp weight was significantly improved due to bagging as compared to control.

Haldanker *et al.* (2015) assessed the effect bagging at marble stage of mango cv. Alphonso which were bagged 30 days after fruit set with different types of bags (newspaper bag, brown paper bag, scurting bag, polythene bag, butter paper bag muslin cloth bag, brown paper bag with polythene coating and control) and observed that bagging with newspaper bag (206.55 g) and brown paper bag (195.21 g) improved pulp weight of mango at ripe stage as compared to control (180.62 g).

Islam *et al*. (2017) carried out an experiment on influence of pre-harvest bagging on fruit quality of mango (*Mangifera indica* L.) cv. Mallika. Observation showed brown paper bag (271.79 g) had significantly highest pulp weight over control (259.90 g)

2.1.6 Stone weight

Senanan *et al.* (2011) concluded that in litchi cv. Hong Huay pre-harvest bagging did not showed any significant effect on seed/stone weight.

Islam *et al*. (2017) conducted an experiment on influence of pre-harvest bagging on fruit quality of mango (*Mangifera indica* L.) cv. Mallika and conclude maximum stone weight (41.10 g) was recorded in the muslin cloth bag followed by white paper bag (36.84 g) and brown paper bag (32.11 g) and minimum was observed in control (39.13 g).

2.1.7 Pulp to seed ratio

Senanan *et al.* (2011) found that pre-harvest bagging on litchi cv. Hong Huay had no significant effect on pulp to seed weight.

Awad and Al-Qurashi (2012) concluded that pre-harvest bunch bagging improved flesh to seed ratio in date palm cv. Barhee.

Islam *et al*. (2017) carried out an experiment on influence of pre-harvest bagging on fruit quality of mango (*Mangifera indica* L.) cv. Mallika. Result showed that brown paper bag gave the maximum pulp stone ratio (8.46) than control (6.65). There was non-significant difference among other type of bagging material.

Tendulkar *et al.* (2019) carried out study on effect of different type of bags (newspaper bag, brown paper bag, scurting bag, plastic bag, butter paper bag, muslin cloth bag, brown paper bag with polythene coating, black polythene bag, opaque colour bag) and control (without bag) on growth and development of mango fruit cv. Alphonso and reported maximum pulp to stone ratio in fruits covered with brown paper bag (8.55) and minimum in fruits covered with black polythene bag (6.92).

2.1.8 Fruit retention per panicle

Oosthusye (2007) reported that pre-harvest bagging had no significant effect on fruit retention in litchi.

Debnath and Mitra (2008) studied the effect of bagging of panicles with different materials in litchi. Maximum fruit retention (13.80 %) was observed in panicles bagged with brown paper bags in comparison to control (13.61 %).and showed that bagging had no significant effect on fruit retention per panicle.

Yang *et al.* (2009) studied the effects of pre-harvest bagging on fruit development and fruit quality in cross-winter off-season longan cv. Chuliang and results showed that white adhesive bonded fabric bag increased fruit size and fruit retention rate.

Costa *et al.* (2017) studied effect of bagging on Red Pitaia Fruits [*Hylocereus undatus* (Haw) Brotton and Rose]. They used different bagging material viz. news paper bag, kraft paper bag, wax paper bag, non-woven bag and un bagged (control) and reported that non woven (100 %) and newspaper bag (74.59 %) were found more effective in fruit retention during fruit development in the plant.

Nakamoto and Kawabata (2013) worked on lychee fruit bagging for commercial and home growers and concluded that the bagged panicles had 55.6 % fruit retention as compared to 28.3 % on unbagged panicles.

Ghanekar (2014) studied the effect of scurting bag on growth and development of mango fruit cv. Alphonso and showed that pre-harvest bagging had significant effect on fruit retention.

Nagaharshitha *et al.* (2014) conducted an experiment to study the effect of bagging on growth and development of mango (*Mangifera indica* L.) cv. Alphonso. Mango fruits were subjected to six types of bagging treatments at 60 days after fruit set. They concluded that different types of bags influenced the growth and development of the mango fruit along with improved fruit retention over the control.

Shinde (2015) observed the effect of pre-harvest bagging on physico-chemical properties of mango cv. Kesar and found that news paper bag showed improvement in fruit retention as compared to control.

Haldankar *et al.* (2015) carried out the study to show the influence of bagging on quality of mango. They used seven different types of bags i.e. newspaper, brown paper, scruting, polythene, butter paper, muslin cloth, brown paper with polythene coating. The result showed that fruit retention was significantly improved with news paper bag (71.25 %), brown paper bag (71.67 %) and scruting bag (71.67 %) over control (66.25 %).

Tendulkar *et al.* (2019) carried out study on effect of different type of bags (newspaper bag, brown paper bag, scurting bag, plastic bag, butter paper bag, muslin cloth bag, brown paper bag with polythene coating, black polythene bag, opaque colour bag and control (without bag) on growth and development of mango fruit cv. Alphonso. Fruits were bagged at 60 days after fruit set (i.e. egg stage). The maximum fruit retention was found in fruits bagged with muslin cloth bag (96.00 %) and scurting bag (96.00 %) whereas, minimum in plastic bag (89.33 %).

2.1.9 Fruit cracking

Yang *et al.* (2009) evaluated the effects of bagging on fruit development and quality in cross-winter off-season logan (*Dimocarpus longan* lour) cv. Chuliang. Three types of bags (perforated translucent plastic bag, white adhesive bonded fabric bag and black adhesive bonded fabric bag) and one control (as unbagged) were used as treatments. Bagging treatment was done 34 days after anthesis with different materials showed significant effect on fruit cracking. Black adhersive bonded fabric bag and white adhesive-bonded fabric bags with about70 % light transmittance reduced fruit cracking incidence (5.1 % and 11.6 % respectively) as compared to control (32.8 %.).

Son and Kim (2010) investigated the effects of bagging on berry cracking during development in grape cv. Kyoho and concluded that bagging critically reduced the fruit cracking as compared to control.

Kishore *et al*. (2016) studied the effect of pre-harvest bagging materials viz., perforated transparent polyethylene bag of different colours (green , white , yellow bag, , blue), butter paper bag and brown paper bag and control on fruit quality of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. Fruits were bagged two months prior to harvest and results revealed that brown paper bag and butter paper bag were found quite effective in reducing the incidence of fruit cracking.

Nguyen *et al.* (2017) evaluated the effect of bagging time on fruit yield and quality of dragon fruit *(Hylocereus spp.*) in Vietnam. The results showed that bagging of fruit after 7 days of anthesis reduced 10-20 % fruit cracking (5.55 %), sunburn, fruit fly as compared to unbagged fruit (26.00 %).

Asrey *et al*. (2019) investigated the effect of pre harvest bagging and bag colour (white, blue and red) on physico-chemical quality and consumer acceptability of pomegranate cv. Kandhari and found that among bags, red colored bags were found most efficient in reducing fruit cracking incidence to1/3rd (66 %) over control.

2.1.10 Pericarp sun burn

Hong and Zhengming (2001) observed effect of bagging on quality of fruits of navel orange cv. Robertson. Results showed that bagging significantly improved the appearance of fruits and protected from sunburn.

Purbey and Kumar (2015) carried out their study by using four different types of bags namely plastic bag, brown paper bag, butter paper bag and muslin cloth bags on litchi fruit bunches and observed that irrespective of bagging date and type, there was significant decrease in pericarp sunburn, spotted and cracked fruits. Bright red colour was obtained with white butter paper bag with minimum spot (3.43%) as compared to unbagged fruit when bagged at 40 days after bearing.

Nguyen *et al.* (2017) studied the effect of bagging time on fruit yield and quality of dragon fruit *(Hylocereus spp.*) in Vietnam. The results showed that bagging fruits 7 days after anthesis significantly reduced pericarp sunburn (5.55%) as compared to control (27.78%).

Abdel Gawad-Nehad *et al*.(2017) conducted an experiment on impact of different bagging types on preventing sunburn injury and quality improvement of Keitt mango fruits and conclude that number of sunburned fruits per tree were decreased by all bagging types treatments as compared to control (without bag) during the two seasons.

2.2 Effect of bag material and time of bagging on chemical parameters of different fruits.

HuiJuan *et al.* (2005) concluded the influence of bagging on aroma volatiles and skin coloration of ‘Hakuho’ peach and observed that bagging can improve fruit skin colour through the reduction of chlorophyll content. They also found increased fruit flavour through the increased in aroma volatiles content bagged with orange paper bag 15 days before harvest having 80 % transmission of sunlight.

Gang and Rulin, (2009) reported that the fruit of mango cv. Zill bagged with single white bags resulted in the purple-red skin at green maturity stage and pink at full maturity stage. Single white layer bagging also tended to produce fruit with best internal quality, which had highest content of vitamin C, titratable acidity, soluble solids, glucose and fructose.

2.2.1 Total soluble solids

Hui Juan *et al. (*2005) observed the effect of pre-harvest bagging on fruit quality of litchi with single, double and triple-layers of orange paper bags at 50 days after full bloom and found higher total soluble solids and improved quality with abundant aromas in juice in fruits bagged with single-layer orange paper bags than double and triple layered orange paper bags at the full-ripe stage.

Debnath and Mitra (2008) reported that the panicles of the litchi were bagged with cellophanes paper bags, brown paper bags and news paper bags one week after fruit set and evaluated its feasibility in fruit borer management, commercial maturity regulation and quality improvement of litchi fruits and revealed that the fruits developed inside the brown paper bags were superior in quality (average, total soluble solid was 18.50^{o} Brix) in comparison to control (average total soluble solids was 18.10^{o} Brix) with no blemishes in peel and free from the risk of hazardous residues of agrochemicals.

Kim *et al.* (2008) studied the effect of bagging material on fruit colouration and quality of peach fruit and reported that fruits bagged with white coloured bags had higher soluble solid concentration.

Hongxia *et al.* (2008) carried out an experiment on two loquat cultivars, Baiyu and Ninghaibai which were bagged with one layered white paper bags having approximately 50 percent light transmission ,two layered paper bags (a black inner and a grey outer layer) and control (unbagged fruits). One-layer white paper bags were the most suitable for bagging of ‘Baiyu’ loquat fruit as it increased total soluble solids and total sugars and decreases the titratable acid in fruits.

Harhash and Al-Obeed (2010) investigated the effect of colour of bag on the date palm .Panicles were bagged with five colored plastic bags viz., black, white, blue, yellow and control (unbagged) four weeks after pollination in order to see the effect of bunch bagging on colour, yield and fruit quality. The result showed that the bunch bagging significantly increased the bunch weight, accelerated ripening and improved fruit quality compared with the control Fruit weight, soluble solids and sugar increased by 10.97g, 27.92% and 61.49%, respectively when fruits were bagged with blue polythene bag as compared to control.

Costa *et al*. (2017) investigated an experiment to study the effect of different bagging materials (newspaper bags, kraft paper bags, waxed paper bag and non-woven bags) and found that non-woven bags were most effective as compared to all other bags in increasing the total soluble solids of the Red pitaia fruits.

Prabha *et al.* (2018) carried out an experiment to study the effect of different bagging materials on physio-chemical properties of pineapple cv. Mauritius and found improved total soluble solids in paper bag (14.22 ^{0}Brix) and black plastic bag(13.49^0 Brix) as compared to unbagged fruits(12,35^0 Brix).

Shah *et al.* (2020) studied the effect of pre harvest fruit bagging on the physio-chemical properties of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented and reported highest TSS (20.20 ^{0}Brix) was reported in panicles bagged 30 days before harvest with white polypropylene bags having 5% perforation .

2.2.2 Titratable acidity

Hu *et al.* (2010) observed the effect of pre-harvest bagging on the fruit quality of litchi cultivar and results showed that bagging with sulphuric acid paper bag reduced the acidity of fruits.

Ding and Syakirah (2010) concluded that pre-harvest bagging in mango did not affect titratable acidity of mango fruit.

Ani and Miftahul (2011) suggested that bagging had no effect on the titratable acidity in the banana cv. Typica

Nagaharshitha *et al.* (2014) studied the effect of bagging on chemical properties of mango (*Mangifera indica* L.) cv. Alphonso and conclude that there was non-significant variation between different treatments in case of titratable acidity of Alphonso mango fruits at harvest and at ripe stages. At harvest, the highest acidity (3.69%) was observed in butter paper bag treatment whereas the lowest (3.61%) was recorded in control.

Wu *et al.* (2013) observed the effect of pre-harvest bagging on fruit quality in Zill mango and founded that single white bagging significantly increased the content of titratable acid.

Shah *et al. (*2020) investigated the effect of pre harvest fruit bagging on the physio-chemical properties of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented and reported that among the bagging materials used , minimum acidity (0.38%) was found in fruits bagged with white polypropylene bags (no perforation) whereas maximum acidity (0.53%) was found in unbagged fruits.

2.2.3 Ascorbic acid

Yang *et al.* (2006) studied the effect of pre-harvest bagging in longan cv. Shixia and reported that bagging enhanced the ascorbic acid content, anthocyanin and flavonoid content of the fruit as compared to control.

Watanwan *et al.* (2008) evaluated that pre harvest fruit bagging did not affect ascorbic acid and pulp colour in mango fruit.

Senanan *et al*. (2011) reported that pre harvest bagging of panicles showed not significantly effect on ascorbic acid content of litchi fruit.

Sharma *et al*. (2013) observed the effect of pre-harvest bagging with spun-bound fabric bags on colour and quality of Delicious apple. Bagging was done about a month before harvesting and removed 3-day before harvesting. Bagged apples showed fairly higher level of ascorbic acid content (28.6 mg/100pulp) at harvest than non-bagged apples.

Zhao *et al*. (2013) studied the effect of pre harvest bagging in mango fruit and reported that ascorbic acid content is increased in bag fruit than control.

Abbasi *et al*. (2014) observed the highest ascorbic acid content in guava fruit by using newspaper bag.

Nagaharshitha *et al.* (2014) studied the effect of bagging on chemical properties of mango (*Mangifera indica* L.) cv. Alphonso and conclude that Ascorbic acid was significantly varied at harvesting stage. It was observed highest in bagging treatment with plastic bag (79.43 mg/100 g) and lowest value was noticed in newspaper (78.11 mg/100 g).

Purbey and Kumar (2015) studied effect of pre-harvest bagging on fruit quality and yield of Litchi (*Litchi chinensis* Sonn.) fruits. They conclude that the bagged litchi had significantly higher level of ascorbic acid content. Fruits bagged with white butter paper bagged at 40 DAB showed higher level of ascorbic acid (64.39 mg/100 ml juice) at harvest.

2.2.4 Reducing sugar

Harhash and Al-obeed (2010) reported in date palm that highest reducing sugars was observed in blue colour bag (27.69 %) as compared to control (23.33 %).

Ni *et al*. (2010) observed in loquat fruit that sugar content increased in bagged fruit than control.

Wang and Lee (2012) suggested that the content of total sugar and reducing sugar were gradually increased at the time of pre harvest bagging in Red Fuji Apple.

Islam *et al.* (2019) reported that highest reducing sugars were recorded in brown paper bag (3.63 %) at 55 days after fruit set which is statistically identical with 45 days while the lowest was recorded in the polythene bag (1.80 %) at 45 days after fruit set of mango cv. Langra. They observed that fruits of newspaper and white paper bag exhibited the maximum reducing sugars at ripe stage in mango due to pre-harvest bagging treatments.

2.2.5 Non Reducing sugar

Harhash and Al-Obeed (2010) reported that date palm fruit bagged with blue paper bag showed the highest non reducing sugars (33.95 %) as compared to control (30.67 %).

Nagaharshitha *et al*. (2014) studied the effect of bagging on chemical properties of mango (*Mangifera indica* L.) cv. Alphonso and conclude that bagging influenced on level of non reducing sugars at harvest stage. At harvest stage, the non-reducing sugars were highest in both scurting bags and muslin cloth bag (10.32 %) while it was lowest in the brown paper bags (9.98 %).

Shah *et al.* (2020) studied the effect of pre harvest fruit bagging on the physio-chemical properties of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented and reported highest amount (1.84%) of non-reducing sugars in fruits bagged with white polypropylene bags (5% perforation) bagged 30 days before harvest.

2.2.6 Total sugar

kim *et al*. (2008) studied effects of bagging material on fruit coloration and quality of 'Janghowon Hwangdo' peach. Result showed that the effect of bag material (coated white paper, white paper, coated yellow paper, yellow paper and newspaper) on microclimate changes (light, temperature, and humidity inside the bag) and fruit quality were studied to find a suitable bag to improve the appearance of fruit skin and fruit quality. Total free sugar content of fruit did not show significant differences. Fructose content was not significantly affected by bag material, whereas the white bags tended to increase glucose content and white coated bags increased sucrose content up to 6.52%. Percent composition of free sugars was in the order of sucrose>glucose>fructose.

Harhash and Al-obeed (2010) reported that date palm fruit bagged with blue colour bag showed the highest total sugars as compared to control.

Islam *et al*., (2019) evaluated the effect of bagging time on fruit quality and shelf life of mango (*Mangifera indica* L.) cv. Langra and found that the total sugars were the highest in the white paper bag treatment (14.82 %) at 45 days after fruit set while lowest values was observed in the polythene bag treatment (10.44%).

2.2.7 TSS: acid ratio

Costa *et al.* (2017) studied the effect of different bagging material in ‘red pitaya’ fruit and result showed that non-woven and newspaper bags were more effective in improving the TSS: Acid ratio.

Senanan *et al.* (2011) examined the effect of different bagging materials on litchi fruit crop and found that bagging materials did not affect the TSS: acid ratio.

Debnath and Mitra (2008) concluded that quality of fruits improved under cellophane paper bags with respect to colour development and TSS/acid ratio.

Wanichkul and Subrungroeng (2011) observed that the highest total soluble solids and total soluble solids / titratable acidity ratio were occurred in carambola fruits bagged with brown paper bags

Jakhar and Pathak (2014) assessed that the spray of 2% $Cacl_2$ and 1% K_2SO_4 in combination with bagging was found much better in increasing the TSS/ acid ratio in mango fruit.

Shah *et al.* (2020) studied the effect of pre harvest fruit bagging on the physio-chemical properties of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented and reported highest TSS/acid ratio (58.17) in fruits bagged with white polypropylene bags (no perforation) 30 days after fruit set.

2.2.8 Anthocyanin

Ritenour *et al*. (1997) found that the fruit bagging is an effective way to promote anthocyanin synthesis and improve fruit coloration in apple.

Ju, Zhiguo (1998) studied the anthocyanin synthesis and gene expression in apples through fruit bagging. He covered the ‘Delicious' fruits with one, two, or three-layered paper bags from the early developmental stage until harvest. Fruits from one or two-layer-bag treatments accumulated certain amount of anthocyanin, but no anthocyanin and only low level of other phenolics were accumulated in fruit peel in the three-layer-bag treatment. When fruits treated with three-layered bags were exposed to light, they started to accumulate anthocyanin rapidly and anthocyanin accumulation reached maximum after 3 days of light exposure. The capability of anthocyanin synthesis in fruits remained constant during 5 months of cold storage. Results indicate that these fruits could be a useful model in the research on anthocyanin synthesis and gene expression in apples.

Hu *et al.* (2001) reported that bagging resulted in improvement in colour of litchi fruit. They used different bagging material such as cellophane paper bag, adhesive bonded fabric bag, newspaper bag and brown paper laminated bag and found that cellophane and brown paper bag promote better colouration in litchi fruit. Other benefits observed were protection of fruit from insects, bats and birds as well as delayed maturity of fruit.

Huang *et al*. (2004) studied the effect of bagging with black paper on coloration and fruit quality of ‘Ruby’ grapefruit (*Citrus paradisi* Macf.) Bagging was done in late May or early June (early bagging) or early July (late bagging), and changes in the peel and flesh colour were measured by spectrophotometer in regular intervals till harvest in late November. Bagging resulting in a light reddish orange colour during maturation period, while unbagged (control) fruits were bright yellow. The most intense colour on peel of bagged fruit occurred in late October. The peel colour of early-bagged fruit was redder (smaller hue angle) than that of late-bagged fruit compared to control.

Wu *et al.* (2010) studied the effect of bagging with four types of bags on the fruit quality of “Zill” mango and revealed that single white bag could be promising one as it significantly reduced contents of chlorophylls and carotenoids thus increase anthocyanin content, total soluble solids, Vitamin C, sucrose, fructose, glucose etc as compared to others.

Sharma *et al*. (2013) observed the effect of pre-harvest bagging (done a month before harvesting) with spun-bond fabric bags on colour and quality of Delicious apple. Results showed that bagged apples have better colour development (Hunter “a”= 52) than non bagged fruits at harvest (Hunter “a” = 38).

Liu *et al*. (2015) studied the effect of non-woven polypropylene bags of different colour to overcome the poor peach fruit colour problem and found that fruit bagged with white non-woven polypropylene accumulated the higher amount of anthocyanin content in peels of peach cv. “Hujingrilu” and “Yulu”.

Purbey and Kumar (2015) conducted an experiment on effect of pre-harvest bagging on fruit quality and yield of Litchi (*Litchi chinensis* Sonn.) fruits and found that bagging increases light sensitivity of fruit and stimulate more anthocyanin synthesis .

Asrey *et al*. (2019) investigated the effect of preharvest bagging and bag colour on physico-chemical quality and consumer acceptability of pomegranate cv. Kandhari. Fruits were covered with 15x20 cm three coloured single layer cellulosic bags 60 days after flowering. Maximum total anthocyanin content was found with red colour bagged (73.03 ±3.97 mg 100 g-1FW) fruits when harvested 150 days after anthesis.

Shah *et al.* (2020) found highest anthocyanin content (23.66mg/100g) in the peel of litchi fruits cv. Rose Scented bagged with white polypropylene bags with 5% perforation while it was lowest (21.59 mg/100g) in unbagged fruits.

2.2.9 Polyphenoloxidase

Tyas *et al.* (1998) suggested that semi-transparent cellophane bag improves the colour of litchi fruit by increasing their anthocyanin content thus inhibiting the PPO activity resulted in better colouration of fruit as compared to control.

Hu *et al.* (2001) studied that pre-harvest bagging in litchi fruit enhanced colour development, which was related with the activity of PPO enzyme. Fruit of "Feizixiao" litchi were bagged with cellophane paper, adhesive-bonded fabric, newspaper and craft paper 15 or 30 days after bloom, and de-bagged at harvest or 10 days before. Cellophane or fabric bags advanced coloration by 10 days compared with the de-bagged fruit. It is recommended that fruit should be bagged 15 days after full bloom until harvest. The effect of bagging on coloration is associated with the metabolism of phenols and flavonoids, and the activity of PPO as well.

2.3 Number of days from fruit set to harvest

Hofman *et al.* (1997) studied the effect of pre-harvest bagging on mango cv. Keitt and reported that days for ripening were shorter in bagged fruits as compared to unbagged fruits.

Debnath and Mitra (2008) studied the effect of panicle bagging in litchi and founded that transparent, semitransparent cellophane bags had advanced maturity of fruits around 12, 5 days respectively and delayed maturity of fruits in newspaper bags over 10 days.

Chonhenchob *et al*. (2011) studied preharvest bagging with wavelength selective materials to enhance development and quality of mango (*Mangifera indica* L.) cv. Nam Dok Mai and reported that mango fruit bagged with plastic bags reached maturity stage at 95 DAFB as compared to control

Teixeira *et al.* (2011) observed the effects of fruit bagging on maturity of "Fuji Suprema" apples and reported that pre-harvest bagging had advanced fruit maturity, especially in transparent micro-holed plastic bags.

Kireeti *et al*. (2016) studied the effect of bagging of mango cv. Alphonso prior to harvest .Different bagging material viz., newspaper bag, brown paper bag, scurting bag, polythene bag, butter paper bag, muslin cloth bag brown paper bag with polythene coating and control (un bagged) were used at 60 day after fruit set. Polythene bag (55 days) and brown paper bag with polythene coating (56 days) took less time to harvest fruit after bagging than fruit bagged with both news paper and brown paper bags (61 days).

2.4 Yield

Harhash and Al-Obeed (2010) studied the effect of pre-harvest bagging by using different bagging materials viz., black, white, blue and yellow colour bags in date palm. The results showed that the bunch bagging with blue colour bags was found to be effective in maintaining the high yield and quality of fruits.

Kassem *et al.* (2011) observed that bagging of date palm panicles with four different coloured plastic bags viz., black, white, blue, yellow and control (unbagged) four weeks after pollination significantly increased fruit yield and quality in date palm.

Abdel Gawad-Nehad *et al.* (2017) Studied impact of different bagging types on preventing sunburn injury and quality improvement of Keitt mango fruits of five year old trees and concluded that yield/tree increased significantly with all the different bagging types over control (without bag) during both experimental seasons of study. Bagging with Agrail green bag was found to be most superior treatment for increasing yield.

2.5 Effect of bagging on economics

Amarante *et al*. (2002) studied the effect of pre-harvest bagging on fruit quality of the pear (*Pyrus communis* L) cv. Doyenne du Comice with micro-perforated polythene bags 30 days after full bloom resulted in increased the percentage of fruit accepted for export from 27.2 – 63.2 % by improving the quality of fruits.

Faoro and Mondardo (2004) found that the fruits of the Japanese pear cultivars Housui and Nijisseiki were bagged after the thinning in order to avoid the development of russeting and protect the fruits from insects. The total cost of bagging was $ 4075.00/ha, for 110000 fruits/ha. cultivar. Nijisseiki, with brown colour fruit was double bagged at the total cost of $4188.00/ha to protect 73370 fruits/ha. The estimate cost of bagging per fruit was $ 0.06 for cv. Nijisseiki and $ 0.04 for cv. Housui. Bagging improved fruit quality resulting in high market value.

Debnath and Mitra (2008) studied the economic viability of bagging technique by comparative estimates of cost of fruit-borer control for litchi cv. Bombai. Bagging is a labour intensive method but can be possible in litchi using ladder and supporting structures. On the average, it took two man- days to bag 3 trees of 22 years-old litchi cv. Bombai (i.e., tying of around 200 bags). Total cost of bagging per hectare was ₹ 11500.00 which included labour cost of ₹ 7300.00 and cost of cellophane paper bags of ₹ 4200.00. The total cost of pesticides and cost of application for 5 sprayings were ₹ 12,500.00. There was a saving of ₹ 1000.00. by bagging over pesticide spraying for borer management in litchi. The bags are reusable thus; it will save the cost by at least 35% in the next year. Besides, the fruit developed by bagging technique were superior in visual and eating quality, free from the risk of hazardous residue of chemical pesticides and can get at least 25% more of the premium price in the market.

Nakamoto and Kawabata (2013) analysed lychee fruit bagging for commercial and home growers and found that with proper field management and a purchase price of $2.50/lb, there is potential to earn $173 per tree or $8,484 per acre with bagging compared to $69 per tree and $3,372 per acre for unbagged lychee. At $6.00/lb, growers can achieve upwards of $613 per tree or $30,026 an acre. By bagging their lychee fruit, growers can gain an estimated 2.5 to over 3 times more in returns at the stated farm gate prices. At farm gate prices at or above $1.34 per pound, bagging lychee becomes worthwhile compared to harvesting entire panicles of unbagged lychee.

Abbasi *et al.* (2014) studied the effect of different bagging materials viz., newspaper bags, perforated polyethylene bags, muslin cloth bags and netted cloth bags on guava fruit and results revealed that all bagging techniques were cost effective and fruit covered with perforated polyethylene bags exhibited maximum benefit cost ratio with better quality of fruits.

Shah *et al.* (2020) carried out an experiment to evaluate the effect of different bagging materials (white polypropylene and pink polypropylene bags) with varied perforations (0, 5 and 10%) and bagging dates (30, 35 and 45 days before harvest) on litchi cv. Rose Scented and found that bagging of 100 kg fruits was found significant and feasible with benefit: cost ratio of 3.23, when bagged 30 days before the harvest. Among the treatments used highest benefit: cost ratio (3.88) was obtained when the fruits were bagged 30 days before the harvest with white polypropylene bags having five per cent perforation.

Chapter-3

Materials and Methods

CHAPTER-3

MATERIALS AND METHODS

The details of the experimental materials used, procedures and techniques followed during the course of present investigation have been described below under appropriate headings and sub headings.

3.1 EXPERIMENTAL SITE

The present study entitled "Effect of bagging on litchi fruit cv. Dehradun" was carried out on litchi plants in Fruit Nursery, Department of Horticulture, Marallia (Miran sahib) Jammu during the year 2018-2019. The experimental location is situated in the subtropical zone at 32.73 N latitude and longitude of 74.87 E. It has an average elevation of 327 m from the mean sea level.

3.1.1 Climate and weather conditions of experimental site

In this region annual precipitation is about 1200 mm. Most of the rains are received during July to October (about 70 percent). The annual mean maximum and minimum temperature are 29.60^{0}C and 16.70^{0}C, respectively. Summer months are hot with temperature and humidity ranging from 23.50^{0}C to 35.50^{0}C and 53.0 to 73.50 percent, respectively. The winter months experience mild to severe cold conditions with average temperature ranging from 6.5^{0}C to 21.7^{0}C. December is the coldest month, when minimum temperature touches 4^{0}C. The highest temperature is recorded in the month of June (45^{0}C). The daily maximum and minimum temperature and evaporation rate rise from March onwards. The detailed meteorological data for crop season is given in appendix-I.

3.1.2 Physio-chemical soil status of experimental site

The soil sample was collected from different places of the experimental orchard with the help of soil auger at 0-90 cm depth. The collected samples were mixed thoroughly and representative samples were air dried, grounded, sieved on 2mm sieve and stored in cloth bags for subsequent analysis. The important mechanical and chemical properties of soil of experimental site are presented in table 1 as under:

TABLE 1: Physico-chemical soil status of experimental site

Properties	Values	Method employed
Mechanical composition		
1. Clay (%)	21	
2. Silt (%)	19	
3. Sand (%)	60	International pipette method (Piper,1966)
4. Textural class	Sandy clay Loam	
Chemical composition		
5. pH	6.7	1:2 soil-water suspension with Beckman glass electrode pH meter (Jackson, 1973)
6. Electrical conductivity (DS^{-1})	0.20	1:2 soil-water suspension with Systronic conductivity meter (Jackson, 1973)
7. Organic Carbon (%)	0.51	Walkley and Black method (1934)
8. Available Nitrogen (kg ha^{-1})	225.5	Alkaline potassium
9. Available Phosphorus (kg ha^{-1})	13.84	Permanganate method (Subbiah and Asija, 1956) Olsen *et al.* (1954)
10. Available Potassium (kg ha^{-1})	138.0	Ammonium acetate method (Jackson, 1973)

3.2 EXPERIMENTAL DETAILS:

The experiment was conducted at Fruit nursery, Department of Horticulture, Marallia (Miran sahib). Twenty year old litchi cv. “Dehradun” planted in square system at 10 meter distance of uniform size and vigour were selected. All the trees were maintained under uniform cultural practice before and during the course of investigation. The 24 treatment combinations were comprised of seven different bagging materials (News paper bag, Muslin cloth bag, White butter paper bag, Laminated brown paper bag, White polypropylene bag and Pink polypropylene bag) with one un-bagged (control) and three bagging time period (20 days after fruit set, 30 days after fruit set, 40 days after fruit set). Single tree were selected for each replication for bagging. The experiment was statistically laid out as per Factorial Randomised Block Design with three replications.

Treatments Combinations:

B_1T_1	B_1T_2	B_1T_3
B_2T_1	B_2T_2	B_2T_3
B_3T_1	B_3T_2	B_3T_3
B_4T_1	B_4T_2	B_4T_3
B_5T_1	B_5T_2	B_5T_3
B_6T_1	B_6T_2	B_6T_3
B_7T_1	B_7T_2	B_7T_3
B_8T_1	B_8T_2	B_8T_3

3.2.1 Bagging of panicles

The litchi panicles were bagged with different bagging material viz., news paper bag, muslin cloth bag, white butter paper bag, laminated brown paper bag, white polypropylene bag and pink polypropylene bag of 40 x 30 cm size and with 5 percent area of each bag perforated by making holes (4mm) on all bags except muslin cloth bags for proper ventilation required for fruit development.The litchi panicles were bagged at different time intervals at 20 days after fruit set, 30 days after fruit set and 40 days after fruit set. Necessary care was taken to avoid possible shock to the young fruit lets and breakage of panicles during tying of bags. Fruits were harvested at proper maturity stage from different treatments at different dates.

3.3 OBSERVATIONS RECORDED

The following observations on “Effect of bagging on litchi fruit cv. Dehradun” were recorded in due time and are discussed below.

3.3.1 PHYSICAL PARAMETERS OF FRUIT

3.3.1.1 Fruit weight

The weight of randomly selected ten fruits from each replication of all the treatments was measured with the help of electronic balance. Subsequently, the average fruit weight was calculated and expressed in gram.

3.3.1.2 Fruit length

Length of ten randomly selected fruits from each replication of all the treatments was measured using vernier calliper. Mean length was computed and expressed in centimetre.

3.3.1.3 Fruit breadth

Fruit breadth of randomly selected ten fruits from each replication of all the treatments was measured using vernier calliper. Mean breadth was calculated and expressed in centimetre.

3.3.1.4 Fruit volume

The volume of fruit was measured by water displacement method. Ten randomly selected fruits per treatment were dipped in a large jar containing water up to rim. The amount of water displaced by fruits was collected in a tray and was measured by a measuring cylinder. The average volume per fruit was determined by dividing the total volume of displaced water with number of fruits and expressed in cubic centimetre.

3.3.1.5 Specific gravity

Specific gravity was calculated by dividing the average fruit weight by average fruit volume

$$\text{Specific gravity} = \frac{\text{Average fruit weight}}{\text{Average fruit volume}}$$

3.3.1.6 Pulp weight

The weight of pulp of the representative fruits (10 fruits from each replication) was recorded by subtracting the seed weight + peel weight from total fruit weight with the help of electronic balance and average weight was calculated and expressed in gram (g).

3.3.1.7 Stone weight

The weight of stone of the representative fruits (10 fruits from each replication) was recorded by subtracting the pulp weight + peel weight from total fruit weight with the help of electronic balance and average weight was calculated and expressed in gram (g).

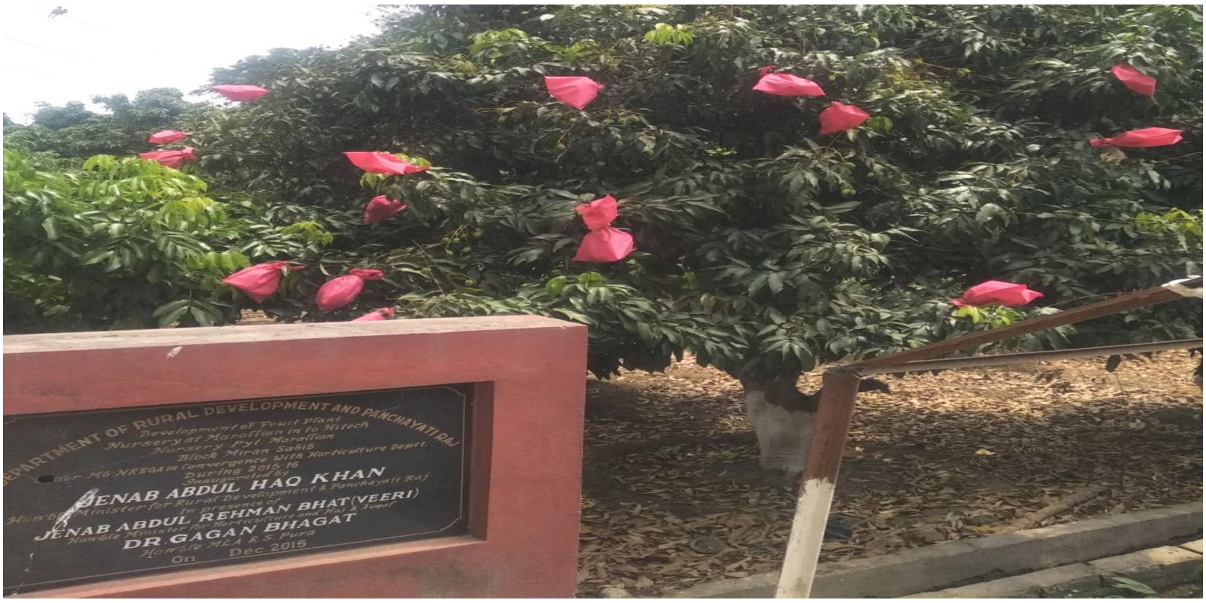

Plate 1. View of experimental site at Fruit nursery, Department of Horticulture, Miran Sahib.

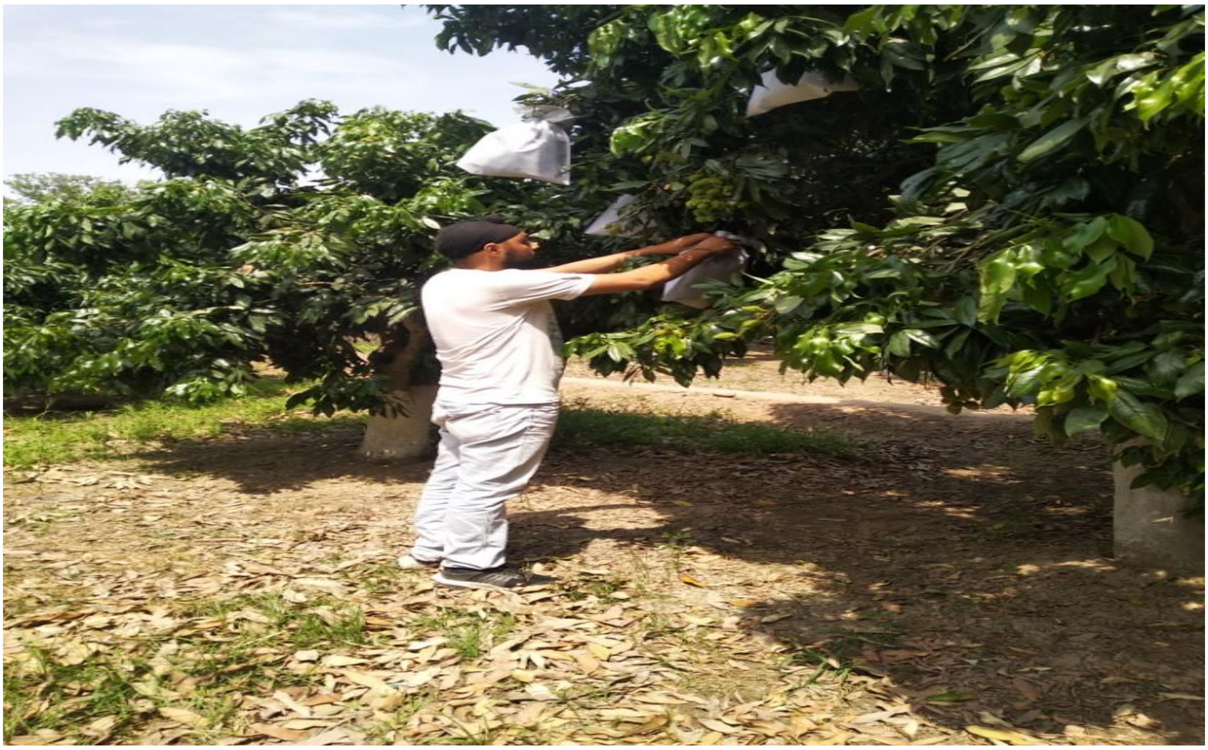

Plate 2. Bagging with white polypropylene bags

3.3.1.8 Pulp: seed ratio

Pulp to stone ratio was the ratio of pulp weight and stone weight and was calculated by the following formula:

$$\text{Pulp: seed ratio} = \frac{\text{Weight of pulp}}{\text{Weight of stone}}$$

3.3.1.9 Fruit retention per panicle

Data on fruit retention per panicle were recorded at the time of harvesting by counting the number of fruits obtained in selected panicle and percent fruit retention per panicle was calculated over the total number of fruits at the time of bagging.

3.3.1.10 Fruit cracking

Fruit cracking percentage was recorded visually by observing and counting the number of total and cracked fruits on the tagged branches and converting the differential into percentage. Fruit with even the slightest of cracks were counted as cracked fruits.

$$\text{Fruit cracking (\%)} = \frac{\text{No. of cracked fruit on tagged branch}}{\text{Total no. of fruits on tagged branch}} \times 100$$

3.3.1.11 Pericarp sunburn

Pericarp sunburn percentage was recorded visually by observing and counting the number of total and sunburn fruits on the tagged branches and converting the differential into percentage.

$$\text{Pericarp sunburn (\%)} = \frac{\text{No. of pericarp sunburn fruits on tagged branch}}{\text{Total no. of fruits on tagged branch}} \times 100$$

3.4 CHEMICAL PARAMETERS

3.4.1 Total soluble solids

The total soluble solids (TSS) of the fruit juice was recorded with the help of Erma hand refractometer (0-32^{0}Brix) according to standard procedure as given in the A.O.A.C. (1995) in terms of degree Brix (^{0}B) at room temperature. A temperature correction chart was applied when the readings were taken at a temperature other than 20^{o}C. The refractometer was calibrated with distilled water before use.

3.4.2 Titratable acidity

Titratable acidity in fresh fruit was determined by the method suggested in A.O.A.C (1995).Twenty five gram of fruit pulp was taken in waring blender, homogenized in distilled water and the volume was made 250 ml and then, filtered to through Whatman No.1 filter paper. Twenty five ml of filtrate solution was titrated against N/10 NaOH solution using phenolphthalein indicator. The results were expressed as percent malic acid.

$$\text{Acidity (\%)} = \frac{\text{Titre value} \times \text{normality of alkali} \times \text{volume made} \times \text{equivalent wt. of acid}}{\text{Volume of sample taken} \times \text{weight of sample} \times 1000} \times 100$$

3.4.3 Ascorbic acid

The ascorbic acid was determined by the method of AOAC (1995).

Reagents

Indophenols dye (0.04%): Weigh 50mg of sodium salt of 2, 6-dichlorophenol indophenols. Added 150ml hot distilled water and 42mg sodium bicarbonate.Content was cooled and volume was made to 200ml with distilled water and kept in refrigerator.

Metaphosphoric acid (3%): Dissolved 30 g metaphosphoric acid in distilled water and made volume to 1000 ml.

Standard ascorbic acid (0.1%): Dissolved 100mg ascorbic acid in 100ml of 3% MPA solution. Diluted 10ml to 100ml with Metaphosphoric acid(1ml=0.1mg ascorbic acid).

Standardization of dye: Took 5ml standard ascorbic acid and added 5ml HPO_3. Filled a microburette with dye. Titrated against dye solution to light pink colour and determined dye equivalent.

Dye equivalent =0.5/titre

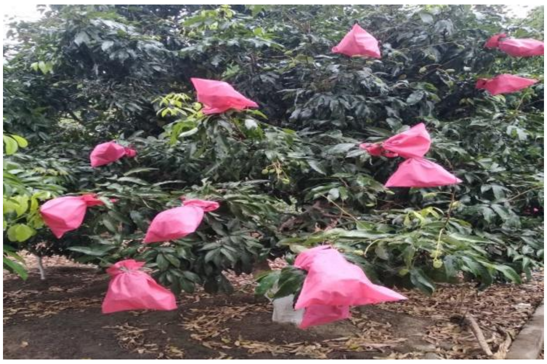

Plate 3. Bagging with Pink Polypropylene bags

Plate 4. Bagging with brown paper bags

Plate 5. Bagging with muslin cloth bag

Plate 6. Bagging with butter paper bags

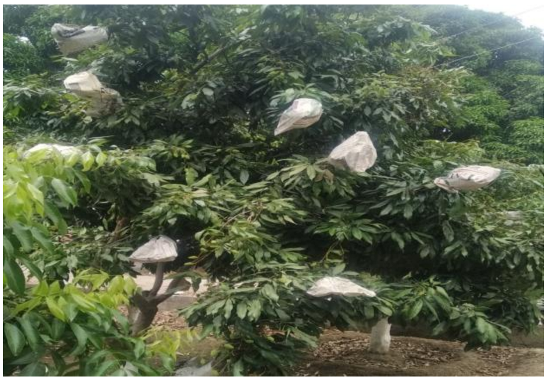

Plate 7. Bagging with Newspaper bags

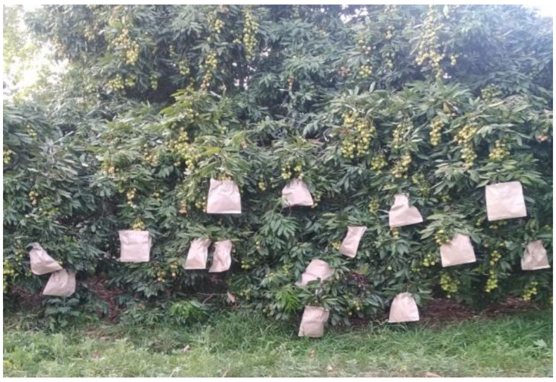

Plate 8. Bagging with Laminated brown paper bags

Procedure

Ascorbic acid was extracted from the pulp by macerating 10 g of sample with metaphosphoric acid (3 %). The extract was filter and volume made to 100 ml. 10 ml of the aliquot was titrated against standardized dye till the light pink colour appeared at end point. Results were expressed as mg /100g of fruit weight.

Calculation

$$\text{Ascorbic acid (mg/100g juice)} = \frac{\text{Titre} \times \text{dye equivalent} \times \text{dilution}}{\text{Weight of the sample (g)}} \times 100$$

3.4.4 Reducing sugars

Reducing sugars were estimated by lane and Eynon method as described by Ranganna (1995). The extract was taken and titrated against 10 ml of mixed Fehling solution (5 ml Fehling solution A + 5 ml Fehling solution B) using methylene blue as indicator. It was then boiled for two minutes, 2-3 drops of methylene blue indicator were added and titration was completed within a minute. The end point was identified when the discolouration of indicator occurred. The results were expressed as percentage of reducing sugar.

$$\text{Reducing sugar (\%)} = \frac{\text{Invert sugar (mg)} \times \text{Dilution}}{\text{Titre value} \times \text{Weight of sample} \times 1000} \times 100$$

3.4.5 Non reducing sugars

The non reducing sugar was calculated by the formula given below:

Non reducing sugar (%) = Total sugar – Reducing sugar.

3.4.6 Total sugars

Modified lane and Eynon method as described by Ranganna (1995) was used to determine total sugar content in the fruits. 50 ml filtered juice was mixed with 100 ml distilled water and neutralised with 0.1N NaOH solution using phenolphthalein as indicator and solution was allowed to stand for 10 minutes, then 8 ml of potassium oxalate solution was added the was made up to 250 ml by adding distilled water.5 ml of the extract were taken in the burette and titrated against 10ml mixed Fehling solution (5ml Fehling solution A+ 5ml Fehling solutionB) using methylene blue as indicator the end point was indicated by the decolourisation of the solution

$$\text{Total sugar (\%)} = \frac{\text{Factor for Fehling solution x Dilution}}{\text{Titre value} \times \text{Weight of sample taken}} \times 100$$

Where, factor for Fehling solution denotes the gram of invert sugar given by factor = (Titre×2.5)/100

3.4.7 TSS: Acid ratio

The TSS: acid ratio was determined by dividing total soluble solid with titratable acidity.

3.4.8 Anthocyanin content

Reagents:

Ethanolic Hcl: 95% ethanol 1.5N Hcl (85:15)

Anthocyanin content was estimated according to the method given by Ranganna (1995). 10ml of juice was taken and blended with 50ml of ethanolic Hcl and kept in a refrigerator at 4^0 C for further use. It was then filter to filter paper and volume was made to 250 ml with ethanolic acid. 2 ml of aliquot was taken in 100 ml volumetric flask and volume was made to 100ml with ethanolic Hcl, the absorbance of which was measured at 535 nm in UV- Visible Spectrophotometer.

3.4.9 Polyphenoloxidase

Polyphenoloxidase is one of the enzymes involved in the oxidation of phenolic compounds to brown pigments, the enzymes is implicated in the undesirable browning of the litchi fruit and intimately reduces their marketability.

Principle

The enzymes activity is measured as the rate of increasing absorbance calorimetrically at 410nm with the oxidation of catechol as the substrate.

Method

The PPO activity in litchi pericarp was determined using 4-methylcatechol as substrate (Jiang and Fu 1998), where the oxidation of 4-methylcatechol caused by PPO was measured at 410 nm using a Spectrophotometer. All the steps were performed at 4^0C. A 6% suspension of the previously mentioned lyophilized powder was prepared in 0.05 M phosphate buffer (pH 6.8), thoroughly mixed and allowed to

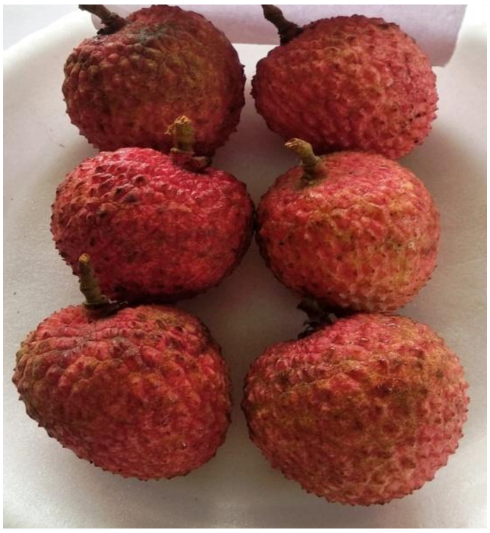

Plate 9. Fruits bagged with pink polypropylene bag 40 days after fruit set.

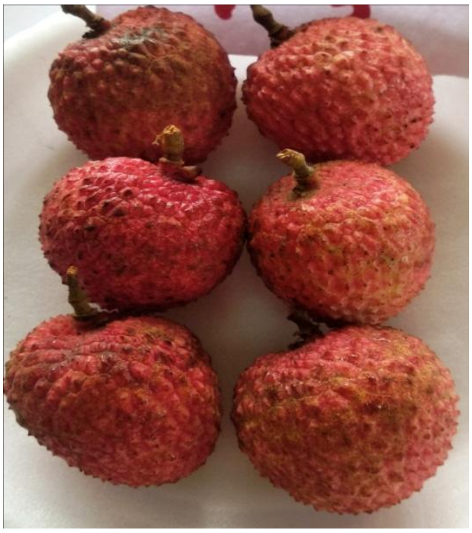

Plate 10. Fruits bagged with white polypropylene bag 40 days after fruit set.

Plate 11. Unbagged fruits bag 40 days after fruit set.

stand for 20 min. Later the suspension was centrifuged at 10,000 x g for 20 minutes (CMF 15 KR, Tigra, Poland) and the supernatant was collected. The assay was performed by mixing 0.05 M phosphate buffer (pH 6.8), 25µ L substrate (25 mM) and extract supernatant of 50 and 200µ L for "Dehradun" cultivar as the source of enzyme in a 1-ml reaction mixture, which was incubated at 25^0C for 4 min. The increase in absorbance was monitored every minute and average change in absorbance per minute was calculated. One unit of enzymatic activity was defined as the amount of enzyme which caused a change of 0.001 in absorbance/min. PPO activity was expressed as U/g of fresh pericarp weight.

3.5 Number of days from fruit set to harvest

It was calculated by counting the number of days from fruit set to harvesting.

3.6 Yield

Total number of fruits in each tree per replication was counted. The counting was made two to three times for minimizing the count error. The fruits harvested from each tree were weighed on electronic balance. The crop load removed from the tree during harvesting season was recorded as yield per tree and expressed in kg/tree.

3.7 Economics (Benefit: Cost ratio)

Gross returns:

Gross returns from litchi fruit crop per tree were obtained by multiplying the yield of litchi fruits and the price per kg obtained by the farmers.

Added returns:

Added returns from litchi fruit crop per tree were obtained by deducting gross returns from unbagged litchi (control) from gross returns obtained by different bagging materials.

Added cost:

Added cost per tree was obtained by calculating cost incurred for different types of bagging on litchi during the treatment period.

Net returns:

Net returns was calculated by deducting added cost of bagging from added returns.

Net returns = Added returns – Added cost

Benefit cost Ratio (return per rupee)

The benefit cost ratio (BCR) of an investment is the ratio of the value of all cash inflows to the cash outflows during the treatment period. It can be estimated as follows

BCR = B_t/C_t

where,

B_t = Added returns in time t

C_t = Added cost in time t

3.8 STATISTICAL ANALYSIS

The data generated during the course of study was subjected to statistical analysis as prescribed by Gomez and Gomez (1984). The per cent data were transformed and given under the parenthesis of original values.

Chapter-4

Results

CHAPTER-4

RESULTS

The present investigation entitled "Effect of bagging on litchi fruit cv. "Dehradun" was carried out at Fruit nursery, Department of Horticulture, Marallia (Miran Sahib), Jammu during 2018-19. The results emanating from the present studies are presented in this chapter with the help of appropriate tables.

4.1 Physical parameters

4.1.1 Fruit weight

The perusal of data given in Table 2 shows the increase in fruit weight as affected by different bagging materials and time of bagging. The increase in fruit weight ranged from 15.78 g to 21.64 g in various treatment combinations.

Pink polypropylene bags in combination with bagging times 40 days after fruit set exhibited maximum fruit weight (21.64 g) followed by white polypropylene bags (21.13 g) in treatment combination with 40 days after fruit set, which was significant over all treatments except muslin cloth bag while minimum fruit weight (15.78 g) was registered in unbagged fruits.

4.1.2 Fruit length

It is evident from the data presented in Table 3 that there was increase in the fruit length in all the bagging material used in combination with time that varied from 2.43 cm to 4.21 cm.

The maximum fruit length of 4.21 cm was recorded in fruits bagged with pink polypropylene bags in combination with bagging time 40 days after fruit set which was followed by white polypropylene bags 3.88 cm which showed significant increase over all treatment combinations whereas minimum fruit length (2.43 cm) was observed in control.

4.1.3 Fruit breadth

Different bagging materials and bagging time were found to have significant effect on increase in fruit breadth as shown in Table 4. The increase in fruit breadth ranged from 2.32 cm to 3.96 cm under various treatment combinations.

Maximum fruit breadth (3.96 cm) was observed in fruits bagged with pink polypropylene bags at 40 days after fruit set while minimum fruit breadth was recorded in unbagged fruits (2.32 cm).

4.1.4 Fruit volume

The data pertaining to fruit volume is presented in table 5. The increase in fruit volume varied from 15.19 cc to 21.32 cc under different treatment combinations.

The maximum fruit volume (21.32 cc) was observed in fruit bagged with pink polypropylene bags in combination with bagging time 40 days after fruit set followed by white polypropylene bag (20.87 cc) which were significantly superior over all treatments and minimum fruit volume (15.19 cc) was recorded in control.

4.1.5 Specific gravity

The perusal of the data given in the Table 6 revealed that there was non significant variation in specific gravity of litchi fruit by using different bagging materials in combination with bagging time.

4.1.6 Pulp weight

Different bagging materials and bagging time showed significant effect on pulp weight of litchi fruit (Table 7). The pulp weight of litchi fruit varied from 10.79 g to 15.94 g under various treatments.

The maximum pulp weight (15.94 g) was recorded in pink polypropylene bags in combination with bagging time 40 days after fruit set which was at par with pink polypropylene bags (15.78 g) in combination with 30 days after fruit set and minimum pulp weight of litchi (10.79 g) was recorded in control.

4.1.7 Stone weight

The data regarding the effect of different bagging materials and bagging time on stone weight of litchi fruit are represented in Table 8. The stone weight of litchi ranged from 2.86 g to 3.88 g.

The maximum stone weight of litchi fruit (3.88 g) was observed in brown paper bags followed by newspaper bags in combination with 20 days after fruit set and minimum stone weight (2.39 g) was found in laminated brown paper bag at 40 days after fruit set.

Table 2. Effect of bagging material and time of bagging after fruit set on fruit weight (g) of litchi fruit cv. Dehradun

Bagging material	Fruit weight (g)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	17.04	17.38	17.85	17.42
B_2: Newspaper bag	16.30	16.61	17.11	16.67
B_3: Muslin cloth bag	19.69	20.04	20.51	20.08
B_4: Butter paper bag	19.43	19.80	20.16	19.79
B_5: Laminated brown paper bag	17.30	17.71	18.28	17.76
B_6: White polypropylene bag	20.21	20.71	21.13	20.68
B_7: Pink polypropylene bag	20.68	21.04	21.64	21.12
B_8: Control (Unbagged)	15.78	16.02	16.27	16.02
Sub Mean	18.30	18.66	19.12	
C.D. ($P \leq 0.05$)	BM = 0.98 D = 0.31 BM xD = NS			

Table 3. Effect of bagging material and time of bagging after fruit set on fruit length (cm) of litchi fruit cv. Dehradun

Bagging material	Fruit length (cm)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	3.09	3.30	3.48	3.29
B_2: Newspaper bag	2.61	2.82	3.01	2.81
B_3: Muslin cloth bag	3.27	3.35	3.67	3.43
B_4: Butter paper bag	3.12	3.32	3.55	3.33
B_5: Laminated brown paper bag	3.00	3.19	3.35	3.18
B_6: White polypropylene bag	3.32	3.49	3.88	3.56
B_7: Pink polypropylene bag	3.74	3.98	4.21	3.97
B_8: Control (Unbagged)	2.43	2.56	2.68	2.55
Sub Mean	3.07	3.25	3.48	
C.D. ($P \leq 0.05$)	BM = 0.1 D = 0.09 BM x D = NS			

Table 4. Effect of bagging material and time of bagging after fruit set on fruit breadth (cm) of litchi fruit cv. Dehradun

Bagging material	Fruit breadth (cm)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	2.89	3.01	3.26	3.05
B_2: Newspaper bag	2.32	2.48	2.68	2.49
B_3: Muslin cloth bag	3.08	3.18	3.39	3.21
B_4: Butter paper bag	3.01	3.14	3.30	3.15
B_5: Laminated brown paper bag	2.90	3.06	3.22	3.06
B_6: White polypropylene bag	3.21	3.36	3.62	3.39
B_7: Pink polypropylene bag	3.56	3.72	3.96	3.74
B_8: Control (Unbagged)	2.32	2.41	2.52	2.41
Sub Mean	2.91	3.04	3.24	
C.D. ($P \leq 0.05$)	BM = 0.21 D = 0.08 BM x D = NS			

Table 5. Effect of bagging material and time of bagging after fruit set on fruit volume (cc) of litchi fruit cv. Dehradun

Bagging material	Fruit volume (cc)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	16.81	17.10	17.50	17.14
B_2: Newspaper bag	16.05	16.25	16.85	16.38
B_3: Muslin cloth bag	19.20	19.55	20.05	19.60
B_4: Butter paper bag	19.15	19.30	19.78	19.41
B_5: Laminated brown paper bag	17.02	17.34	17.89	17.42
B_6: White polypropylene bag	19.80	20.35	20.87	20.34
B_7: Pink polypropylene bag	20.42	20.80	21.32	20.85
B_8: Control (Unbagged)	15.19	15.32	15.49	15.33
Sub Mean	17.96	18.25	18.72	
C.D. ($P \leq 0.05$)	BM = 0.33 D = 0.2 BM x D = NS			

Table 6. Effect of bagging material and time of bagging after fruit set on specific gravity of litchi fruit cv. Dehradun

Bagging material	Specific gravity			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	1.01	1.01	1.02	1.01
B_2: Newspaper bag	1.02	1.02	1.02	1.02
B_3: Muslin cloth bag	1.03	1.03	1.02	1.03
B_4: Butter paper bag	1.01	1.03	1.02	1.02
B_5: Laminated brown paper bag	1.02	1.02	1.02	1.02
B_6: White polypropylene bag	1.02	1.02	1.01	1.02
B_7: Pink polypropylene bag	1.01	1.01	1.02	1.01
B_8: Control (Unbagged)	1.04	1.05	1.05	1.05
Sub Mean	1.02	1.02	1.02	
C.D. ($P \leq 0.05$)	BM = NS D = NS BM x D = NS			

Table 7. Effect of bagging material and time of bagging after fruit set on pulp weight (g) of litchi fruit cv. Dehradun

Bagging material	Pulp weight (g)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	11.77	11.98	12.37	12.04
B_2: Newspaper bag	11.28	11.65	11.92	11.62
B_3: Muslin cloth bag	14.50	14.53	14.83	14.62
B_4: Butter paper bag	14.38	14.55	14.83	14.59
B_5: Laminated brown paper bag	12.77	12.89	13.26	12.97
B_6: White polypropylene bag	15.08	15.10	15.25	15.14
B_7: Pink polypropylene bag	15.12	15.78	15.94	15.61
B_8: Control (Unbagged)	10.79	11.00	11.08	10.96
Sub Mean	13.21	13.44	13.69	
C.D. ($P \leq 0.05$)	BM = 0.41 D = 0.22 BM x D = NS			

Table 8. Effect of bagging material and time of bagging after fruit set on stone weight (g) of litchi fruit cv. Dehradun

Bagging material	stone weight (g)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	3.88	3.62	3.56	3.69
B_2: Newspaper bag	3.80	3.75	3.64	3.73
B_3: Muslin cloth bag	3.56	3.40	3.22	3.39
B_4: Butter paper bag	3.82	3.49	3.34	3.55
B_5: Laminated brown paper bag	2.83	2.62	2.39	2.61
B_6: White polypropylene bag	3.48	3.21	3.19	3.29
B_7: Pink polypropylene bag	3.21	3.15	3.06	3.14
B_8: Control (Unbagged)	2.86	2.80	2.79	2.82
Sub Mean	3.43	3.26	3.15	
C.D. ($P \leq 0.05$)		BM = 0.11 D = 0.17 BM x D = NS		

4.1.8 Pulp to stone ratio

The perusal of data presented in Table 9 revealed that highest pulp to stone ratio (5.55) was recorded in fruit panicles bagged with laminated brown paper bags followed by pink polypropylene bags (5.21) in combination with 40 days after fruit set and minimum value (2.97) was observed in newspaper bag at 20 days after fruit set.

4.1.9 Fruit retention per panicle

The data pertaining to the effect of different bagging materials on fruit retention per panicle is present in Table 10. The increase in fruit retention per panicle varied from 40.07 to 54.92 per cent.

It was evident from the data that significant increase in fruit retention per panicle was observed in different bagging materials. The maximum increase in fruit retention per panicle (54.92 %) was observed in pink polypropylene bag followed by white polypropylene bags (50.98 %) in combination with 40 days after fruit set whereas minimum fruit retention per panicle (40.07 %) was observed in laminated brown paper bagged at 20 days after fruit set.

4.1.10 Fruit cracking

Data given in Table 11 indicates that there was significant effect of different bagging material on fruit cracking. Minimum fruit cracking (14.02 %) was observed in pink polypropylene bags in combination with 40 days after fruit set followed by white polypropylene bags (15.04 %) which was significant over all treatments and maximum was observed in control (26.92 %) at 20 days after fruit set.

4.1.11 Pericarp Sunburn

The data pertaining to effect of different bagging materials on pericarp sunburn is presented in Table 12. The pericarp sunburn of litchi fruit varied from 18.85 to 25.31 per cent .The maximum pericarp sunburn 25.31per cent was recorded in unbagged fruits at 20 days after fruit set, where as minimum pericarp sunburn (18.85%) was recorded in pink polypropylene bagged at 40 days after fruit set.

4.2 Chemical parameters

4.2.1 Total soluble solids (^{0}Brix)

The perusal of data given in Table 13 revealed that there was significant effect of different bagging materials on T.S.S. of litchi fruits. The increases in T.S.S. of litchi fruit vary from 16.84 to 22.48 ^{0}Brix. The maximum T.S.S. (22.48 ^{0}Brix) was recorded in litchi fruits bagged with pink polypropylene bags in combination with 40 days after fruit set followed by white polypropylene bags (22.26 ^{0}Brix) in combination with 40 days after fruit set and minimum was in unbagged fruits (16.84 ^{0}Brix) .

4.2.2 Titratable acidity

It is evident from the data presented in Table 14 that there was significant effects of different bagging materials on titratable acidity of litchi fruits. The titratable acidity varied from 0.40 to 0.62%. Minimum titratable acidity (0.40 %) was recorded in litchi fruit bagged with pink polypropylene bags in combination with 40 days after fruit set and maximum (0.62%) in unbagged fruits i.e. in control.

4.2.3 Ascorbic acid

The perusal of the data given in Table 15 revealed that there was significant effect of different bagging material and bagging time on ascorbic acid of litchi fruits. The maximum ascorbic acid (25.44 mg/100g) was recorded in litchi fruit bagged with pink polypropylene bags in combination with 20 days after fruit set and minimum (19.64 mg/100g) in unbagged fruits (control) bagged at 40 days after fruit set.

4.2.4 Reducing sugars (%)

It is evident from the table 16 that different bagging material and time of bagging had a significant effect on reducing sugars (%) of litchi. The maximum reducing sugar of litchi fruit (12.83 %) was recorded in pink polypropylene bags in combination with 40 days after fruit set while reducing sugar was minimum (10.40 %) in unbagged fruits.

4.2.5 Non-reducing sugars (%)

The perusal of the data presented in table 17 revealed that non-reducing sugars was significantly affected by both factors i.e. bagging time and bagging materials. The maximum non-reducing sugars of litchi fruit (4.06 %) was recorded in pink

Table 9. Effect of bagging material and time of bagging after fruit set on pulp to stone ratio of litchi fruit cv. Dehradun

Bagging material	Pulp to stone ratio			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	3.03	3.31	3.47	3.27
B_2: Newspaper bag	2.97	3.11	3.27	3.12
B_3: Muslin cloth bag	4.74	4.27	4.61	4.54
B_4: Butter paper bag	3.82	4.17	4.44	4.14
B_5: Laminated brown paper bag	4.51	4.92	5.55	4.99
B_6: White polypropylene bag	4.33	4.70	4.78	4.60
B_7: Pink polypropylene bag	4.71	5.01	5.21	4.98
B_8: Control (Unbagged)	3.77	3.93	3.97	3.89
Sub Mean	3.99	4.18	4.41	
C.D. ($P \leq 0.05$)	BM = 0.06 D = 0.11 BM x D = NS			

Table 10. Effect of bagging material and time of bagging after fruit set on fruit retention per panicle (%) of litchi fruit cv. Dehradun

Bagging material	Fruit retention (%)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	47.38	49.09	50.85	49.11
B_2: Newspaper bag	44.04	43.78	44.32	44.05
B_3: Muslin cloth bag	43.67	44.89	45.85	44.80
B_4: Butter paper bag	44.45	44.65	45.84	44.98
B_5: Laminated brown paper bag	40.07	41.25	41.62	40.98
B_6: White polypropylene bag	46.47	48.57	50.98	48.67
B_7: Pink polypropylene bag	52.43	51.56	54.92	52.97
B_8: Control (Unbagged)	41.66	40.52	42.06	41.41
Sub Mean	45.02	45.54	47.06	
C.D. ($P \leq 0.05$)	BM = 1.02 D = 2.11 BM x D = NS			

Table11. Effect of bagging material and time of bagging after fruit set on fruit cracking (%) of litchi fruit cv. Dehradun

Bagging material	Fruit cracking (%)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	18.52 (1.27)	17.85 (1.25)	17.53 (1.24)	17.69 (1.25)
B_2: Newspaper bag	18.98 (1.28)	18.15 (1.26)	18.07 (1.26)	18.4 (1.26)
B_3: Muslin cloth bag	16.51 (1.22)	15.98 (1.20)	15.73 (1.20)	16.07 (1.20)
B_4: Butter paper bag	17.89 (1.25)	17.47 (1.24)	17.35 (1.24)	17.57 (1.24)
B_5: Laminated brown paper bag	16.76 (1.22)	16.35 (1.21)	16.12 (1.21)	16.41 (1.21)
B_6: White polypropylene bag	15.85 (1.20)	15.62 (1.19)	15.04 (1.18)	15.50 (1.19)
B_7: Pink polypropylene bag	14.82 (1.17)	14.44 (1.16)	14.02 (1.15)	14.42 (1.16)
B_8: Control (Unbagged)	26.92 (1.43)	25.75 (1.41)	26.48 (1.42)	26.38 (1.42)
Sub Mean	18.28 (1.25)	17.70 (1.24)	1.54 (1.23)	
C.D. ($P \leq 0.05$)	BM = 0.02 D = 0.01 BM x D = NS			

❖ The figures in parenthesis indicate square root transformation

Table 12. Effect of bagging material and time of bagging after fruit set on pericarp sunburn (%) of litchi fruit cv. Dehradun

Bagging material	**Pericarp sunburn (%)**			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	22.45	22.20	21.96	22.20
B_2: Newspaper bag	23.24	22.98	22.56	22.93
B_3: Muslin cloth bag	21.45	21.28	20.99	21.24
B_4: Butter paper bag	21.23	21.58	21.32	21.38
B_5: Laminated brown paper bag	23.88	24.55	24.11	24.18
B_6: White polypropylene bag	20.21	19.97	19.38	19.85
B_7: Pink polypropylene bag	19.42	19.18	18.85	19.15
B_8: Control (Unbagged)	25.31	24.52	24.02	24.62
Sub Mean	22.15	22.03	21.65	
C.D. ($P \leq 0.05$)	BM = 1.32 D = 1.95 BM x D = NS			

Table 13. Effect of bagging material and time of bagging after fruit set on TSS (^{0}Brix) of litchi fruit cv. Dehradun

Bagging material	TSS (^{0}Brix)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	18.56	18.75	18.95	18.75
B_2: Newspaper bag	17.58	17.91	18.34	17.94
B_3: Muslin cloth bag	20.08	20.24	20.32	20.21
B_4: Butter paper bag	19.07	19.23	19.54	19.28
B_5: Laminated brown paper bag	20.42	21.03	21.23	20.89
B_6: White polypropylene bag	21.04	21.16	22.26	21.49
B_7: Pink polypropylene bag	22.00	22.05	22.48	22.18
B_8: Control (Unbagged)	16.84	17.09	17.74	17.22
Sub Mean	19.45	19.68	20.11	
C.D. ($P \leq 0.05$)	BM = 0.75 D = 0.21 BM x D = NS			

Table 14. Effect of bagging material and time of bagging after fruit set on titratable acidity (%) of litchi fruit cv. Dehradun

Bagging material	Titratable acidity (%)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	0.56	0.53	0.47	0.52
B_2: Newspaper bag	0.57	0.55	0.49	0.54
B_3: Muslin cloth bag	0.51	0.49	0.42	0.47
B_4: Butter paper bag	0.55	0.53	0.46	0.51
B_5: Laminated brown paper bag	0.49	0.44	0.41	0.45
B_6: White polypropylene bag	0.50	0.49	0.46	0.48
B_7: Pink polypropylene bag	0.42	0.43	0.40	0.42
B_8: Control (Unbagged)	0.62	0.57	0.53	0.57
Sub Mean	0.53	0.50	0.46	
C.D. ($P \leq 0.05$)	BM = 0.01 D = 0.02 BM x D = NS			

Table 15. Effect of bagging material and time of bagging after fruit set on ascorbic acid (mg/100g) of litchi fruit cv. Dehradun

Bagging material	Ascorbic acid (mg/100g)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	21.85	21.22	21.07	21.38
B_2: Newspaper bag	20.75	20.12	20.04	20.30
B_3: Muslin cloth bag	23.49	23.34	23.09	23.31
B_4: Butter paper bag	22.16	22.03	21.76	21.98
B_5: Laminated brown paper bag	24.16	24.04	23.74	23.98
B_6: White polypropylene bag	24.85	24.64	24.32	24.60
B_7: Pink polypropylene bag	25.44	24.87	24.68	25.00
B_8: Control (Unbagged)	19.81	19.76	19.64	19.74
Sub Mean	22.81	22.50	22.29	
C.D. ($P \leq 0.05$)	BM = 1.09 D = 1.27 BM x D = NS			

Table 16. Effect of bagging material and time of bagging after fruit set on reducing sugars (%) of litchi fruit cv. Dehradun

Bagging material	Reducing sugars (%)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	10.97 (3.31)	11.00 (3.32)	11.04 (3.32)	11.00 (3.31)
B_2: Newspaper bag	10.66 (3.26)	10.79 (3.28)	10.88 (3.30)	10.77 (3.28)
B_3: Muslin cloth bag	11.07 (3.33)	11.33 (3.37)	11.53 (3.40)	11.31 (3.36)
B_4: Butter paper bag	11.02 (3.32)	11.28 (3.36)	11.49 (3.39)	11.26 (3.35)
B_5: Laminated brown paper bag	11.04 (3.32)	11.41 (3.38)	11.62 (3.41)	11.35 (3.37)
B_6: White polypropylene bag	12.13 (3.48)	12.32 (3.51)	12.53 (3.54)	12.32 (3.51)
B_7: Pink polypropylene bag	12.41 (3.52)	12.62 (3.55)	12.83 (3.58)	12.62 (3.55)
B_8: Control (Unbagged)	10.40 (3.22)	10.44 (3.23)	10.46 (3.23)	10.43 (3.22)
Sub Mean	11.21 (3.34)	11.39 (3.37)	11.54 (3.39)	
C.D. ($P \leq 0.05$)	BM = 0.03 D = 0.09 BM x D = NS			

❖ The figures in parenthesis indicate square root transformation

Table 17. Effect of bagging material and time of bagging after fruit set on non-reducing sugars (%) of litchi fruit cv. Dehradun

Bagging material	Non-reducing sugars (%)			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	2.52 (1.74)	2.83 (1.82)	3.08 (1.89)	2.81 (1.81)
B_2: Newspaper bag	2.41 (1.71)	2.57 (1.75)	2.71 (1.79)	2.56 (1.75)
B_3: Muslin cloth bag	3.26 (1.94)	3.37 (1.97)	3.42 (1.98)	3.35 (1.96)
B_4: Butter paper bag	3.06 (1.89)	3.12 (1.90)	3.20 (1.92)	3.12 (1.90)
B_5: Laminated brown paper bag	3.52 (2.00)	3.51 (2.00)	3.58 (2.02)	3.53 (2.00)
B_6: White polypropylene bag	3.62 (2.03)	3.71 (2.05)	3.88 (2.09)	3.73 (2.05)
B_7: Pink polypropylene bag	3.74 (2.06)	3.80 (2.07)	4.06 (2.14)	3.86 (2.09)
B_8: Control (Unbagged)	2.03 (1.59)	2.17 (1.63)	2.36 (1.69)	2.18 (1.63)
Sub Mean	3.02 (1.87)	3.13 (1.89)	3.28 (1.94)	
C.D. ($P \leq 0.05$)	BM = 0.01 D = 0.02 BM x D = NS			

❖ The figures in parenthesis indicate square root transformation

polypropylene bags in combination with 40 days after fruit set followed by white polypropylene bags (3.88 %) and minimum (2.03 %) in control.

4.2.6 Total sugars (%)

It is evident from the table 18 that different bagging material and bagging time had a significant effect on total sugars (%) of litchi. The maximum total sugars of litchi fruit (17.10 %) was recorded in pink polypropylene bags in combination with 40 days after fruit set and minimum (12.54 %) in control in combinations with 40 days after fruit set.

4.2.7 TSS: acid ratio

Data furnished in Table 19 indicates that there was a significant effect of different bagging materials and bagging time on the TSS: acid ratio on litchi fruit. The maximum TSS: acid ratio of litchi fruit (56.20) was recorded in pink polypropylene bags in combination with 40 days after fruit set whereas, it was minimum in unbagged fruits (27.16).

4.2.8 Anthocyanin (mg/100gm)

It is evident from the Table 20 that different bagging material and time of bagging had a significant effect on anthocyanin content of litchi fruit. The maximum anthocyanin content (54.35 mg/100g) of litchi fruit was observed in pink polypropylene bags in combination with 40 days after fruit set ,while it was minimum (46.21 mg/100g) in control.

4.2.9 Polyphenoloxidase (PPO) (unit/min/g)

Data given in Table 21 indicates that there was no significant effect of different bagging material on PPO activity in litchi fruit. The minimum PPO activity (9.0 unit/min/g) was observed in pink polypropylene bags in combination with 40 days after fruit set and maximum (12 unit/min/g) was recorded in control.

4.3 Number of days from fruit set to harvest

The perusal of the data presented in table 22 revealed that there was significant difference in bagging material from fruit set to harvest in litchi fruit. The minimum days from fruit set to harvest (71 days) was observed in pink polypropylene bags bagged 30 days after fruit set while it was maximum (81 days) in unbagged fruits after 30 day of fruit set.

4.4 Yield (kg/tree)

It is evident from the data presented in Table 23 that there were significant effects of different bagging materials and bagging time on yield of litchi fruits. The maximum yield of litchi fruits (78.81 kg/tree) was observed in pink polypropylene bags in combination with 40 days after fruit set followed by white polypropylene bags (75.10 kg/tree) bagged 40 day after fruit set which were significantly superior to all other treatment combinations. The minimum fruit yield (48.94 kg/tree) was recorded in control.

4.5 Economics (Benefit: Cost ratio)

Results

The cost incurred for different types of bagging on litchi is presented in table 24. The table revealed that highest expenditure of ₹ 984.37 per tree was incurred in pink and white polypropylene bagging whereas lowest of ₹ 474.37 per tree was incurred in newspaper bagging. Price per bag varies from ₹ 0.75 to ₹ 5.00 and it was found that newspaper bag was having a minimum price of ₹ 0.75 per bag whereas both white polypropylene and pink polypropylene bags were having maximum price of ₹ 5.00 per bag.

Table 25 represents cost-benefit ratio analysis of bagging in litchi fruit after 20 days of fruit set. The table revealed that average yield per tree due to the different types of bagging on litchi varies from 52.10 kg from newspaper bagging to 72.03 kg from pink polypropylene bagging. Unbagged fruits were having yield of 49.94 kg per tree. Per tree gross returns and net returns were found highest in case of pink polypropylene bagging with a value of ₹ 5042.10 and ₹ 1810.43, respectively. The net returns were worked out based on added returns and added cost of bagging. Per tree added returns due to bagging on litchi were also found highest i.e., ₹ 2794.80 in case of pink polypropylene bagging followed by white propylene bagging with ₹ 2659.00. Cost Benefit ratio 1:2.84 was found to be highest in pink polypropylene bagging and lowest of 1:1.20 was found in laminated brown paper bagging. The bagging technique was found to be highly economically viable for adoption in commercial cultivation.

Table 18. Effect of bagging material and time of bagging after fruit set on total sugars (%) of litchi fruit cv. Dehradun

Bagging material	Total sugars (%)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	13.62 (3.69)	13.98 (3.74)	14.28 (3.78)	13.96 (3.73)
B_2: Newspaper bag	13.20 (3.63)	13.49 (3.67)	13.73 (3.71)	13.47 (3.67)
B_3: Muslin cloth bag	14.50 (3.81)	14.88 (3.86)	15.13 (3.89)	14.83 (3.85)
B_4: Butter paper bag	14.24 (3.77)	14.56 (3.82)	14.86 (3.85)	14.55 (3.81)
B_5: Laminated brown paper bag	14.75 (3.84)	15.10 (3.89)	15.39 (3.92)	15.08 (3.88)
B_6: White polypropylene bag	15.94 (3.99)	16.22 (4.03)	16.61 (4.08)	16.25 (4.03)
B_7: Pink polypropylene bag	16.35 (4.04)	16.62 (4.08)	17.10 (4.14)	16.69 (4.08)
B_8: Control (Unbagged)	12.54 (3.54)	12.72 (3.57)	12.94 (3.60)	12.73 (3.57)
Sub Mean	14.39 (3.78)	14.69 (3.83)	15.00 (3.87)	
C.D. ($P \leq 0.05$)	BM = 0.07 D = 0.03 BM x D = NS			

❖ The figures in parenthesis indicate square root transformation

Table 19. Effect of bagging material and time of bagging after fruit set on TSS: acid ratio of litchi fruit cv. Dehradun

Bagging material	TSS: acid ratio			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	33.14	35.38	40.32	36.28
B_2: Newspaper bag	30.84	32.56	37.43	33.61
B_3: Muslin cloth bag	39.37	41.30	48.38	43.02
B_4: Butter paper bag	34.67	36.28	42.48	37.81
B_5: Laminated brown paper bag	41.67	47.80	51.78	47.08
B_6: White polypropylene bag	42.08	43.18	48.39	44.55
B_7: Pink polypropylene bag	52.38	51.28	56.20	53.29
B_8: Control (Unbagged)	27.16	29.98	33.47	30.20
Sub Mean	37.66	39.72	44.81	
C.D. ($P \leq 0.05$)	BM = 1.43 D = 1.75 BM x D = NS			

Table 20. Effect of bagging material and time of bagging after fruit set on anthocyanin (mg/100g) of litchi fruit cv. Dehradun

Bagging material	Anthocyanin (mg/100g)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	49.62	49.82	50.62	50.02
B_2: Newspaper bag	49.43	50.02	50.24	49.90
B_3: Muslin cloth bag	51.08	51.38	52.48	51.65
B_4: Butter paper bag	50.46	50.68	51.76	50.97
B_5: Laminated brown paper bag	49.77	49.98	50.24	50.00
B_6: White polypropylene bag	51.92	52.62	53.25	52.60
B_7: Pink polypropylene bag	52.96	54.04	54.35	53.78
B_8: Control (Unbagged)	46.21	46.42	46.64	46.42
Sub Mean	50.18	50.62	51.20	
C.D. ($P \leq 0.05$)	BM = 1.09 D = 1.22 BM x D = NS			

Table 21. Effect of bagging material and time of bagging after fruit set on polyphenoloxidase (PPO) (unit/min/g) of litchi fruit cv. Dehradun

Bagging material	Polyphenoloxidase (PPO)(unit/min/			
	Bagging days after fruit set			
	20 days	30 days	40 days	Sub Mean
B_1: Brown paper bag	11.00	10.50	11.00	10.83
B_2: Newspaper bag	11.00	12.00	11.50	11.50
B_3: Muslin cloth bag	11.00	11.50	10.00	10.83
B_4: Butter paper bag	10.50	10.50	11.00	10.67
B_5: Laminated brown paper bag	11.00	11.50	11.00	11.17
B_6: White polypropylene bag	10.50	11.00	10.50	10.67
B_7: Pink polypropylene bag	10.00	10.00	9.00	9.67
B_8: Control (Unbagged)	12.00	11.50	12.00	11.83
Sub Mean	10.88	11.06	10.75	
C.D. ($P \leq 0.05$)	BM = NS D = NS BM x D = NS			

Table 22. Effect of bagging material and time of bagging after fruit set on number of days from fruit set to harvest of litchi fruit cv. Dehradun

Bagging material	number of days from fruit set to harvest			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	74.00	75.00	78.00	75.67
B_2: Newspaper bag	74.00	76.00	78.00	76.00
B_3: Muslin cloth bag	75.00	73.00	77.00	75.00
B_4: Butter paper bag	73.00	74.00	77.00	74.67
B_5: Laminated brown paper bag	74.00	72.00	76.00	74.00
B_6: White polypropylene bag	73.00	72.00	75.00	73.33
B_7: Pink polypropylene bag	72.00	71.00	74.00	72.33
B_8: Control (Unbagged)	79.00	81.00	80.00	80.00
Sub Mean	74.25	74.25	76.88	
C.D. ($P \leq 0.05$)	BM = 0.81 D = 0.75 BM x D = NS			

Table 23. Effect of bagging material and time of bagging after fruit set on yield (kg/tree) of litchi fruit cv. Dehradun

Bagging material	Yield (kg/tree)			
	Bagging days after fruit set			
	20 days	**30 days**	**40 days**	**Sub Mean**
B_1: Brown paper bag	57.05	60.05	61.60	59.57
B_2: Newspaper bag	52.10	54.01	55.22	53.78
B_3: Muslin cloth bag	68.14	70.04	71.82	70.00
B_4: Butter paper bag	61.02	65.03	68.50	64.85
B_5: Laminated brown paper bag	57.04	59.03	61.90	59.32
B_6: White polypropylene bag	70.09	73.04	75.10	72.74
B_7: Pink polypropylene bag	72.03	75.05	78.81	75.30
B_8: Control (Unbagged)	48.94	50.09	53.45	50.83
Sub Mean	60.80	63.29	65.80	
C.D. ($P \leq 0.05$)	BM = 1.98 D = 2.44 BM x D = NS			

Table 24. Cost incurred for application of inputs and different types of bagging materials on litchi (₹/tree)

Items / Input cost on Bagging	Quantity	Price/ bag (₹)	Amount (₹)	Labour Charges			Cost of Fertilizers (Urea, DAO, MoP)	Miscellaneous charges (₹)	Total cost of bagging (Added Cost) (₹)
				Time of bagging/ tree (in hours)	Rate/labour/day (₹)	Amount (₹)			
Brown Paper Bag	120	1.00	120.00	8	325.00	325.00	29.37	30.00	504.37
Newspaper Bag	120	0.75	90.00	8	325.00	325.00	29.37	30.00	474.37
Muslin Cloth Bag	120	3.00	360.00	8	325.00	325.00	29.37	30.00	744.37
White Butter Paper Bag	120	2.00	240.00	8	325.00	325.00	29.37	30.00	624.37
Laminated brown paper bag	120	3.00	360.00	8	325.00	325.00	29.37	30.00	744.37
White polypropylene bag	120	5.00	600.00	8	325.00	325.00	29.37	30.00	984.37
Pink polypropylene bag	120	5.00	600.00	8	325.00	325.00	29.37	30.00	984.37
Control (unbagged)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	00.00	0.00

Table 25. Cost Benefit ratio analysis of bagging in litchi produce after 20 days fruit set (₹/tree)

Items / Input cost on Bagging	Average Yield (kg/tree)	Rate/kg (₹)	Gross returns (₹)	Returns fron unbagged litchi (₹) (control)	Added returns (₹)	Net returns (Added return – added cost) (₹)	B:C Ratio
Brown Paper Bag	57.05	55.00	3137.75	2247.30	890.45	386.08	1.77
Newspaper Bag	52.10	55.00	2865.50	2247.30	618.20	143.83	1.30
Muslin Cloth Bag	65.14	60.00	3908.40	2247.30	1661.10	916.73	2.23
White Butter Paper Bag	61.02	55.00	3356.10	2247.30	1108.80	484.43	1.78
Laminated brown paper bag	57.04	55.00	3137.20	2247.30	889.90	145.53	1.20
White polypropylene bag	70.09	70.00	4906.30	2247.30	2659.00	1674.63	2.70
Pink polypropylene bag	72.03	70.00	5042.10	2247.30	2794.80	1810.43	2.84
Control (unbagged)	49.94	45.00	2247.30	2247.30	0.00	0.00	

Table 26. Cost Benefit ratio analysis of bagging in litchi produce after 30 days fruit set (₹/tree)

Items / Input cost on Bagging	Average Yield (kg/tree)	Rate/kg (₹)	Gross returns (₹)	Returns from unbagged litchi (₹) (control)	Added returns (₹)	Net returns (Added return – added cost) (₹)	B:C ratio
Brown Paper Bag	60.05	60.00	3603.00	2504.50	1098.50	594.13	2.18
Newspaper Bag	54.01	60.00	3240.60	2504.50	736.10	261.73	1.55
Muslin Cloth Bag	67.04	70.00	4692.80	2504.50	2188.30	1443.93	2.94
White Butter Paper Bag	65.03	55.00	3576.65	2504.50	1072.15	447.78	1.72
Laminated brown paper bag	59.03	70.00	4132.10	2504.50	1627.60	883.23	2.19
White polypropylene bag	73.04	80.00	5843.20	2504.50	3338.70	2354.33	3.39
Pink polypropylene bag	75.05	80.00	6004.00	2504.50	3499.50	2515.13	3.56
Control (unbagged)	50.09	50.00	2504.50	2504.50	0.00		

Table 27. Cost Benefit ratio analysis of bagging in litchi produce after 40 days fruit set (₹/tree)

Items / Input cost on Bagging	Average Yield (kg/tree)	Rate/kg (₹)	Gross returns (₹)	Returns fron unbagged litchi (control) (₹)	Added returns (₹)	Net returns (Added return – added cost) (₹)	B:C ratio
Brown Paper Bag	61.60	60.00	3696.00	2622.50	1073.50	569.13	2.13
Newspaper Bag	55.22	60.00	3313.20	2622.50	690.70	216.33	1.46
Muslin Cloth Bag	70.82	70.00	4957.40	2622.50	2334.90	1590.53	3.14
White Butter Paper Bag	68.50	55.00	3767.50	2622.50	1145.00	520.63	1.83
Laminated brown paper bag	61.90	70.00	4333.00	2622.50	1710.50	966.13	2.30
White polypropylene bag	75.10	80.00	6008.00	2622.50	3385.50	2401.13	3.44
Pink polypropylene bag	78.81	80.00	6304.80	2622.50	3682.30	2697.93	3.74
Control (unbagged)	52.45	50.00	2622.50	2622.50	0.00		

Table 26 represents cost-benefit ratio analysis of bagging in litchi fruit after 30 days of fruit set. The table revealed that average yield per tree due to the different types of bagging on litchi varies from 54.01 kg from newspaper bagging to 75.05 kg from pink polypropylene bagging. Unbagged fruits were having yield of 50.09 kg per tree. Per tree gross returns and net returns were found highest in case of pink polypropylene bagging with a value of ₹ 6004.00 and ₹2515.13, respectively. The net returns were worked out based on added returns and added cost of bagging. Per tree added returns due to bagging on litchi were also found highest i.e., ₹ 3499.50 in case of pink polypropylene bagging followed by white propylene bagging with ₹ 3338.70. Cost Benefit ratio 1:3.56 was found to be highest in pink polypropylene bagging and lowest of 1:1.53 was found in newspaper bagging. The bagging technique was found to be highly economically viable for adoption in commercial cultivation.

Table 27 represents cost-benefit ratio analysis of bagging in litchi fruit after 40 days of fruit set. The table revealed that average yield per tree due to the different types of bagging on litchi varies from 55.22 kg from newspaper bagging to 78.81 kg from pink polypropylene bagging. Unbagged fruits were having yield of 52.45 kg per tree. Per tree gross returns and net returns were found highest in case of pink polypropylene bagging with a value of ₹6304.80 and ₹ 2697.93, respectively. Per tree added returns due to bagging on litchi were also found highest i.e., ₹ 3682.30 in case of pink polypropylene bagging followed by white propylene bagging with ₹ 3385.50. Cost Benefit ratio 1:3.74 was found to be highest in pink polypropylene bagging and lowest of 1:1.46 in newspaper bagging.

Chapter-5

Discussion

CHAPTER-5

DISCUSSION

During the course of the present investigation entitled "Effect of bagging on litchi fruit cv. Dehradun" many significant variations among the different bagging materials were noted. In this chapter, efforts have been made to assign reasons responsible for variations and also to establish the cause and effect relationship in the light of available scientific literature in the support of findings of present investigations under the appropriate heads.

5.1 Physical parameters

5.1.1 Fruit weight

A considerable variation was observed in fruit weight which was appreciably influenced both by bagging materials and bagging time. The maximum fruit weight (21.64 g) was recorded in fruit bagged with pink polypropylene bags bagged 40 days after fruit set and minimum was recorded in unbagged fruits (16.27 g). This trend in fruit weight might be attributed due to the favourable microclimate created inside the bagging materials which increased accumulation of assimilates leading to maximum fruit weight of fruits. These findings are in consonance with the results of Fumuro and Gamo (2001) in persimmon and Debnath and Mitra (2008) in litchi fruits.

5.1.2 Fruit length

Fruit length was significantly influenced by bagging material and dates. Maximum fruit length was observed in fruit bagged with pink polypropylene bags bagged 40 days after fruit set (4.21 cm) and minimum was found in unbagged fruits (2.43 cm). This increase in the fruit length inside the bags may be due to favourable conditions inside the bagged fruit. Similar results were reported by Omar *et al*. (2014) in date palm and Haldankar *et al*. (2015) in mango.

5.1.3 Fruit breadth

In the present investigation, it has been observed that fruit breadth was appreciably influenced by bagging material and dates table 3. Maximum fruit breadth was observed in fruit bagged with pink polypropylene bags bagged 40 days after fruit set (3.96 cm) and minimum was recorded in unbagged fruits (2.32 cm). The increase in the fruit breadth inside the bags may be due to favourable microclimate conditions inside the bag. Earlier studies made by several workers also have similar findings like Ghalib *et al.* (1988), El-Kassas *et al.* (1995) in date palm and Daniells *et al.* (1992) in banana fruits.

5.1.4 Fruit volume

Fruit volume was significantly influenced both by bagging material and time of bagging. Maximum fruit volume was observed in fruit bagged with pink polypropylene bags bagged 40 days after fruit set (21.32 cc) and was found minimum in unbagged fruits (15.19 cc). Similar findings have been obtained by Daniells *et al.* (1992) who reported that high fruit volume in banana fruits may be due to higher humidity and appropriate micro-climate inside the bags, which results in proper growth and development of fruits.

5.1.5 Specific gravity

The bagging materials and bagging time had a non-significant effect on specific gravity of litchi fruits. This non-significant difference in specific gravity in all the treatments may be due to increased or decreased fruit weight and fruit volume in same proportion. These results are in conformity with the findings of Harhash and Al-Obeed (2010) in date palm.

5.1.6 Pulp weight

Both bagging materials and bagging time significantly influenced the pulp weight of litchi fruits. Maximum pulp weight was recorded in fruits bagged 40 days after fruit set with pink polypropylene bags (15.94 g) and least was recorded in unbagged fruits (10.79 g). The increase in pulp weight may be due to more moisture level and temperature inside the bag which promotes the better development of pulp. Similar results have also been achieved by Jun Hui *et al*. (2012) in *Canarium album*, El-kassas *et al.* (1995), El-Salhy (1999) and Mcustafa (2007) in date palm fruits.

5.1.7 Stone weight

The results obtained from present investigation depicted in the table 8 reveal that the stone weight was significantly influenced by both bagging materials and bagging days used. The maximum stone weight (3.88 g) was recorded in fruits bagged with brown paper bags which was followed by butter paper bags (3.82 g) after

30 days of fruit set and minimum in laminated brown paper bag (2.39 g) tagged 40 days after fruit set. Stone weight may increase due to large size of fruits inside the bagged panicles. These results are in conformity with the findings of several workers Rabeh and Kaseem (2003) Harhash and Al-Obeed (2010), in date palm. Awad and Al-Qurashi (2012) also reported that bunch bagging increased seed weight over control in “Barhee” datepalm cultivar.

5.1.8 Pulp: Stone ratio

Pulp: stone ratio was also influenced by both bagging materials and bagging time as shown in Table 9. Data reveals that maximum pulp: stone ratio (5.55) was found in fruit bagged with laminated brown paper bags followed by pink polypropylene bags (5.21) when bagged 40 days after fruit set and minimum ratio was found in unbagged fruits (3.77). The possible reasons might be the increased fruit pulp weight inside the bagged fruits due to favourable microclimate which ultimately resulted in higher pulp: seed ratio of the fruits. The present results are in harmony with those of Harhash and Al-Obeed (2010) who also find the similar results in date palm.

5.1.9 Fruit retention

The results of present study reveal that fruit retention was significantly influenced by both bagging materials used and bagging times. Maximum fruit retention was observed in fruit bagged with pink polypropylene bags (54.92 %) 40 days after fruit set whereas, minimum retention was found in unbagged fruits (40.52 %) tagged 30 days after fruit set. This might be due to the micro climate surrounding the fruit get changed favourably by bagging which leads to more retention as abiotic factors like temperature and humidity play important role in overall growth and development of fruit. Another possible reason may also be that due to biotic factor like less incidence of pest and diseases and less natural fruit drop in the initial stage of fruit growth. These results are in line with the finding of Debnath and Mitra (2008) who reported that fruit retention per panicle was significantly increased when litchi fruits were bagged one week after fruit set. Similarly, Yang *et al.* (2009) reported that white adhesive fabric bags increases the fruit retention rate in cross winter off-season Longan cv. Chuliang. These findings are also in agreement with Ghanekar (2014) in mango.

5.1.10 Fruit cracking

Present investigation reveals a significant decrease in per cent fruit cracking which was appreciably influenced by materials and bagging time. Minimum per cent (14.02 %) of fruit cracking was observed in fruit bagged with pink polypropylene bags bagged 40 days after fruit set and maximum was recorded in unbagged fruits (26.92 %). The trend of decline in fruit cracking may be due to less moisture stress inside the bagged fruits. Similar findings had been reported by Li Juan *et al.* (2003) in grape fruit and Yang *et al.* (2009) in longan fruit.

5.1.11 Pericarp sunburn

The data pertaining to pericarp sunburn in litchi fruits presented in Table 12 shows that least pericarp sunburn (18.85%) was observed in fruit bagged with pink polypropylene bags followed by white polypropylene bags (19.38%) bagged 40 days after fruit set. whereas maximum pericarp sunburn (25.31%) was observed in unbagged fruits tagged 20 days after fruit set. The reduction in pericarp sunburn inside the bagged fruits might be due to protection of fruits from direct sun light during hot and scorching summer. These results are in consonance with the findings of Hong and Zhengming (2001) in navel orange cv. Robeston and Santos and Wamser (2006) who advocated that polypropylene bags were found to be more effective against pericarp sunburn on apple fruits epidermis.

5.2 Chemical parameters

5.2.1 Total soluble solids

A marked influence on total soluble solids was observed during the course of present investigation with preharvest bagging with different bagging materials and bagging time .The maximum amount of Total soluble solids (22.48 ^{0}Brix) recorded in fruit bagged with pink polypropylene bags followed by white polypropylene bags (22.26 ^{0}Brix) when bagged at 40 days after fruit set and minimum (16.84 ^{0}Brix) in unbagged fruits (control). The covered panicles had more total soluble solids than unbagged fruits, probably because of higher temperature inside the bags favoured the conversion of starch and other polysaccharides into sugars. The present results are in harmony with those of Harhash and Al-Obeed (2010) in date palm, Debnath and Mitra (2008) in litchi fruit, Wanichkul and Subruengroeng (2011) in carambola, Jakhar and Pathak (2014) in mango.

5.2.2 Titratable acidity

The analysed data presented in Table 14 showed that different bagging materials and their time of bagging significantly influenced the titratable acidity of litchi fruit. Among the different bagging materials used, lowest acidity percentage (0.40 %) was noticed in fruits bagged with pink polypropylene bags which was closely followed by fruit bagged with laminated brown paper bags (0.41 %) when bagged 40 day after fruit set whereas, highest (0.62 %) acidity was noted in unbagged fruits. Decrease in acidity content in bagged fruits might be due to increase in translocation of carbohydrates and increase in metabolic conversion of acid to sugars which can be explained as the harvesting of bagged as well as unbagged fruits were taken at the same date and bagging resulted in early maturation of fruits due to improved microclimate inside the covering material. These findings are in accordance with the findings of Shah *et al.* (2020) who reported that minimum acidity (0.29 %) was found in fruits bagged with white polypropylene bags in combination with 30 day before harvest whereas, maximum acidity (0.53%) was found in un bagged fruits. Jakhar and Pathak (2014) in mango and Huang *et al.* (2009) in pear also reported similar findings.

5.2.3 Ascorbic acid

Ascorbic acid content in fruits is an important quality component. The results obtained in the present investigation showed significant increase in the ascorbic acid content with pre harvest bagging of litchi fruits with different bagging materials bagged at different time. In the present study maximum ascorbic acid (25.44 mg/100g) was observed in fruits bagged with pink polypropylene bag followed by white polypropylene bags (24.85 mg/100g) in combination with 20 day after fruit set whereas, minimum ascorbic acid (19.64 mg/100g) in un bagged fruits tagged 40 days after fruit set. It might be due to the fact that there is more temperature inside the bags which helped in more activation of phytochemicals and their synergistic effect therefore, increasing the level of ascorbic acid inside the bags (Paul and Ghosh, 2012).Similar findings have also been achieved by Changqing *et al.* (2006) in longan fruits. Hong xia *et al.* (2009) concluded that single white layer bagging tended to produce fruit with highest content of vitamin C over control in Zill mango. Jun Hui *et al.* (2012) have also reported similar results in *Canarium album* fruits.

5.2.4 Reducing sugars

The data presented in Table 16 showed significant difference in reducing sugars by bagging materials and bagging time. The maximum reducing sugar (12.83 %) was recorded in fruit bagged with pink polypropylene bags in combination with 40 days after fruit set which was followed by fruit bagged with white polypropylene bags (12.53 %) and minimum (10.40 %) was recorded in unbagged fruits. The higher reducing sugar may be the due to breakdown of polysaccharides into water soluble sugars such as glucose, fructose and sucrose. The results obtained in the present investigation also get support from the findings of Hongxia *et al*. (2009) who concluded that in Zill mango the single white layer bagging tended to produce fruit with best internal quality, which had the highest content of sucrose, glucose and fructose. These findings are also in agreement with those reported by Wu *et al*. (2013) in mango.

5.2.5 Non- Reducing sugars

Data on reducing sugars was significantly affected by bagging materials and bagging time. The maximum (4.06 %) non-reducing sugar was recorded in fruit bagged with pink polypropylene bags in combination with 40 days after fruit set and minimum (2.03 %) was recorded in unbagged fruits. The higher reducing sugars might be due to the conversion of sucrose into glucose inside the bags due to higher enzymatic activity. Similar beneficial effects on non-reducing sugar have also been reported by Harhash and Al-Obeed (2010) in date palm , Wu *et al.* (2013) in mango and Shah et al.(2020) in litchi.

5.2.6 Total sugars

A marked influence on total sugar was observed during the course of present investigation. The highest (17.10 %) total sugar was recorded in fruit bagged with pink polypropylene bags at 40 days after fruit set and minimum (12.54 %) was recorded in unbagged fruits. The increase in level of total sugars inside the bagged fruits might be due to increased enzymatic activity of sucrose synthase (SS) and sucrose-phosphate synthase (SPS) due to the modified atmospheric climate/micro climate around bagged fruit. Sucrose synthase is an enzyme that plays an important role in sucrose decomposition. These results are in conformity with the results of

Harhash and Al-Obeed (2010) in date palm, Wu *et al.* (2013) and Jakhar and Pathak (2014) in mango.

5.2.7 TSS: acid ratio

From the present study, it is evident that there was significant increase in TSS: acid ratio over control. Among the different bagging materials and time of bagging maximum TSS: acid ratio (56.20) was found in fruits bagged with pink polypropylene bags bagged at 40 days after fruit set and minimum (27.16) was found in unbagged fruits. The TSS: acid ratio higher in bagged fruit might be due to higher total soluble solids and lower rate of acidity. These findings are also in agreement with those reported by Wanichkul and Subrugroeng (2011) in carambola, Ma *et al*. (2009) in peach and Shah *et al*. (2020) in litchi.

5.2.8 Anthocyanin

Fruit peel anthocyanin content suggests about the colour of fruit peel which defines the external appearance of fruit. Fruit colour is one of the basic point of attraction for the consumers. Bright and attractive colour generally improves the physical appreance of the fruit that helps to get better price in the domestic or export market. It is thus observed from present study that bagging significantly influence the anthocyanin content of fruits. Maximum anthocyanin content (54.35 mg/100g) in the peel was found in the fruit bagged with pink polypropylene bags at 40 days after fruit set which was followed by fruit bagged with white polypropylene bags (53.25 mg/100g) whereas, the minimum (46.21 mg/100g) recorded in unbagged fruits. Bagged fruits generally have high anthocyanin content as compared to unbagged ones. It is believed that bagging increase light sensitivity of fruit which stimulate anthocyanin synthesis and due to increase temperature inside the bags the anthocyanin synthesis might have got hastened at time of harvesting when the fruit mature that why bagged treatments accumulated higher anthocyanin content than the unbagged ones. The above results are in support with the findings of Tyas *et al.* (1998) in litchi, Debnath and Mitra (2008) in litchi, Ju (1998) in apple, Wu *et al.* (2013) in mango.

Wu (2004) reported that the pomegranate fruits in bag had the best colour compared to the un-bagged fruit. Saure (1998) reported that a strong inhibition of skin colour was observed when fruits were bagged on tree. This was primarily because bagging intercepts light, which is required for anthocyanin synthesis in apple fruit. The results are in conformity with the findings of Guibing *et al.* (2001) in litchi fruits and Wanichkul and Subrungroeng (2011) in carambola fruit.

5.2.9 Polyphenoloxidase (PPO)

Data pertaining to PPO activity has been shown in Table 21. All the bagging days and materials had non- significant effect on activity of polyphenoloxidase enzymes at harvest. The interaction effects also found to be non-significant for both bagging days and materials. However minimum PPO activity (9.0 unit/min/g) was observed in pink polypropylene bag when bagged 40 days after fruit set and maximum PPO activity (12.0 unit/min/g) observed in unbagged fruits. Thus bagging results in minimum PPO activity which enhance the colour development thus improve the quality of fruit. The above results are in support with the findings of Hu *et al*. (2001) who reported that bagging "Feizixiao" litchi fruit enhanced colour development, which was associated with the metabolism of phenolics and flavonoids, and the activities of polyphenoloxidase. The results are also in conformity with the findings of Zhou and Guo (2005) in grape fruits and Ni *et al.* (2010) in loquat fruit.

5.3 Number of days from fruit set to harvest

Data pertaining to number of day from fruit set to harvest has been shown in Table 22.All the bagging materials bagged at different time period had significant effect on number of days from fruit set to harvest. The minimum days from fruit set to harvest (71 days) was observed in pink polypropylene bags followed by white polypropylene bag and laminated brown paper bag (72 days) when bagged 30 days after fruit set while it took maximum time (81 days) in unbagged fruits after 30 days of fruit set. Bagging reduced time from fruit set to harvest as it provide more heat and raise the temperature of microclimate in which fruits are developing as a result more rate of transpiration, rapid ethylene production thus took less time period for ripening as compared to unbagged fruits. These results corroborated by the findings of Debnath and Mitra (2008) in litchi, Chonhenchob *et al.* (2011) in mango and Teixeira *et al*. (2011) in "Fuji Suprema" apples.

5.4 Yield

The data represented in the table 23 revealed that the yield was significantly influenced by both bagging materials used and time of bagging time. The maximum fruit yield (78.81 kg/tree) was recorded in fruit bagged with pink polypropylene bags which was followed by white polypropylene bags (75.10 kg/tree) when bagged 40 days after fruit set and least recorded in unbagged fruits (48.94 kg/tree). These findings might be due favourable condition inside the bags which increase fruit moisture contents that lead to increased fruit weight and consequently increased fruit yield. Earlier studies made by several workers also have similar findings like Harhash and Al-Obeed (2010) and Kassem *et al.* (2011) in date palm and El-Wa fa *et al.* (2014) in pomegranate fruit.

Abdel *et al*. (2017) also reported an increased fruit yield/tree with Agrail green bags over different bagging types and control. in Keitt mango fruits.

5.5 Benefit: cost ratio

Table 24 representing per tree cost incurred for bagging on litchi revealed that there is variation in the total cost of different types of bagging which is due to the variation in prices of the bags depending upon the quality. Table 25, 26 and 27 clearly represent the positive effect of different types of bagging on litchi which can be seen from the increase in per tree yield of litchi. Pink polypropylene bagging with highest gross returns, net returns and added returns in all the experiments was found to be most effective type of bagging. It was revealed from the tables that gross returns, net returns and added returns increases with the increase in time of fruit setting. The study analysed the effect of bagging in a particular time period on litchi fruit, therefore, added returns and added costs were calculated to get the best results. The net returns and cost benefit ratio was worked out based on added returns and added cost of bagging. The bagging technique was found to be highly economically viable for adoption in commercial cultivation with a highest cost benefit ratio of 1:2.84, 1:3.56 and 1:3.74, respectively after 20 days, 30 days and 40 days of fruit set due to pink polypropylene bagging. These results are in conformity with the findings of Amarante *et al.* (2002) which reported that bagging of pear fruits with micro-perforated polythene bags 30 days after full bloom increased the percentage of fruits for export purposes from 27.2 to 63.2 % by increasing the quality of fruits. Shah *et al*. (2020) also reported highest (3.88) benefit: cost ratio was obtained when the fruits were bagged 30 days before the harvest with white polypropylene bags having 5 per cent perforation. As per Sharma *et al.* (2014), bagging is a physical protection method which not only improves the appearance and colour of the fruits but also modifies the micro-environment for fruit development, which results in increasing the market value of the fruits.

Chapter-6

Summary and Conclusion

CHAPTER-6

SUMMARY AND CONCLUSION

The present investigation entitled "Effect of bagging on litchi fruit cv. "Dehradun" was carried on litchi plant in Fruit Nursery, Department of Horticulture, Marallia, (Miran Sahib) Jammu during 2018-19. The salient findings and conclusion drawn from the experiment are summarized below:

6.1 Physical parameters

6.1.1 The maximum increase in fruit weight (21.64 g) was recorded in pink polypropylene bags in combination with 40 days after fruit set and minimum (15.78 g) was recorded in control.

6.1.2 The maximum increase in fruit length (4.21 cm) was recorded in pink polypropylene bags in combination with 40 days after fruit set and minimum (2.43 cm) was recorded in unbagged fruits.

6.1.3 The maximum increase in fruit breadth (3.96 cm) was recorded in pink polypropylene bags in combination with 40 days after fruit set and minimum (2.32 cm) was recorded in control.

6.1.4 The maximum increase in fruit volume (21.32 cc) was recorded in pink polypropylene bags in combination with 40 days after fruit set and minimum (15.19 cc) was recorded in control.

6.1.5 There was no significant effect of different bagging material on specific gravity of litchi fruit.

6.1.6 The maximum increase in pulp weight (15.94 g) was recorded in pink polypropylene bags in combination with 40 days after fruit set and minimum (10.48 g) was recorded in control.

6.1.7 The maximum stone weight (3.88 g) was recorded in brown paper bags in combination with 20 days after fruit set and minimum (2.39 g) in laminated brown paper bag at 40 day after fruit set.

6.1.8 The maximum pulp to stone ratio (5.55) was observed in laminated brown paper bags in combination with 40 days after fruit set and minimum in (2.79) in news paper bag at 20 day after fruit set.

6.1.9 The maximum fruit retention per panicle (54.92 %) was observed in pink polypropylene bags in combination with 40 days after fruit set and minimum (40.07%) in laminated brown paper bagged at 20 days after fruit set.

6.1.10 The minimum fruit cracking (14.02%) was observed in pink polypropylene bags in combination with 40 days after fruit set and maximum in control (26.92%).

6.1.11 The minimum pericarp sunburn (18.85 %) was observed in pink polypropylene bags in combination with 40 days after fruit set and maximum (25.31 %) in unbagged.

6.2 Chemical parameters

6.2.1 The maximum T.S.S. (22.48 ^{0}Brix) was observed in pink polypropylene bags in combination with 40 days after fruit set and minimum in control (16.84 ^{0}Brix).

6.2.2 The minimum titratable acidity (0.40 %) was observed in pink polypropylene bags in combination with 40 days after fruit set and maximum (0.62%) in control.

6.2.3 The maximum ascorbic acid (25.44 mg/100g) was observed in pink polypropylene bags in combination with 20 days after fruit set and minimum (19.64 mg/100g) in control at 40 day after fruit set.

6.2.4 The maximum reducing sugars (12.83%) was observed in pink polypropylene bags in combination with 40 days after fruit set and minimum (10.40%) in control.

6.2.5 The maximum non-reducing sugars (4.06 %) were observed in pink polypropylene bags in combination with 40 days after fruit set and minimum (2.03 %) in control.

6.2.6 The maximum total sugars (17.10 %) were observed in pink polypropylene bags in combination with 40 days after fruit set and minimum (12.54 %) in control.

6.2.7 The maximum TSS: acid ratio (56.20) was observed in pink polypropylene bags in combination with 40 days after fruit set and minimum (27.16) in unbagged fruits.

6.2.8 Maximum anthocyanin content (54.35 mg/100g) was observed in pink polypropylene bags in combination with 40 days after fruit set and minimum (46.21 mg/100g) in control.

6.2.9 There was no significant effect of different bagging material on polyphenoloxidase enzyme activity of litchi fruit. However, the minimum activity (9 unit/min/g)) was observed in pink polypropylene bags in combination with 40 days after fruit set and maximum (12 unit/min/g) was reported in control.

6.3 Number of days from fruit set to harvest

Minimum days (71 days) from fruit set to harvest were observed in pink polypropylene bags in combination with 30 days after fruit set and maximum (81 days) was recorded in control.

6.4 Yield (kg/tree)

Maximum yield (78.81 kg/tree) was observed in pink polypropylene bags in combination with 40 days after fruit set and minimum in unbagged fruits (48.94 kg/tree).

6.5 Benefit: Cost ratio

6.5.1 The maximum net returns (₹ 2697.93) were observed in pink polypropylene bags in combination with 40 days after fruit set whereas, the minimum net returns were recorded in control.

6.5.2 The highest B: C ratio (3.74) was recorded in pink polypropylene bags in combination with 40 days after fruit set whereas, the minimum was recorded in control.

CONCLUSION

From the present study, it can be concluded that among the different bagging materials, pink polypropylene bags when bagged 40 days after fruit set is found to be superior for enhancing the quality and other parameters of litchi fruits in terms of improved fruit weight, fruit length, fruit breadth, fruit volume, specific gravity, pulp weight, fruit retention per panicle, TSS, ascorbic acid, reducing sugars, total sugars as well as on yield of litchi and reduction in fruit cracking, pericarp sunburn along with decreasing the PPO activity of litchi fruit. Bagging with pink polypropylene bags also resulted in maximum net returns and highest B: C ratio. Thus, from the present investigation, it can be concluded that for improving the colour, quality and other parameters of litchi fruit cv. Dehradun bagging with pink polypropylene bags in combinations with 40 days after fruit set is the most suitable and economically feasible material.

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Appendix

Appendix-1

Meterological data during the period of experimentation

SMW	Month & Date	Max.T (^{0}C)	Min.T (^{0}C)	RH1 (%) (Morning)	RH2 (%) (Evening)	Sun Shine (hours)	Rainfall (mm)
48	26-2 Dec	24.5	9	95	44	5.3	0
49	3-9	21.7	6.2	95	49	4.5	0
50	10-16	19.3	6.5	94	53	5.5	11.8
51	17- 23	20.7	2.9	94	39	7.2	0
52	24-31	18.8	1.7	95	39	6.3	0
1	1-7 Jan	17.6	5.4	93.3	50.4	2.3	11.0
2	8-14	18.2	5.2	92.4	49.9	4.5	5.2
3	15-21	17.4	5.4	91.7	64.4	2.9	5.4
4	22-28	16.6	4.4	93.4	53.4	6.6	41.6
5	29-4 Feb	18.3	6.0	90.4	55.4	3.8	8.8
6	5-11	18.4	8.0	91.3	57.0	4.5	59.2
7	12-18	19.2	9.4	93.6	65.9	2.8	20.6
8	19-25	20.3	8.6	91.3	58.6	5.9	67.8
9	26-4 Mar	18.0	6.3	92.3	56.6	3.9	11.2
10	5-11	22.4	8.8	91.1	49.0	6.6	0.0
11	12-18	24.3	9.1	91.3	46.1	6.6	10.8
12	19-25	25.2	10.9	91.9	51.6	4.9	14.2
13	26-1 Apr	29.1	13.5	89.0	44.4	6.5	0.0
14	2-8	33.4	15.9	80.9	37.1	8.5	0.0
15	9-15	33.8	17.8	81.4	38.7	6.4	7.2
16	16-22	30.2	17.1	77.1	43.4	7.6	26.8
17	23-29	37.1	17.9	57.6	22.9	9.1	8.4
18	30-6 May	36.6	18.3	42.4	18.7	9.9	0.0
19	7-13	38.5	19.6	47.9	23.9	8.6	0.0
20	14-20	34.9	20.9	58.6	32.0	5.8	0.6
21	21-27	37.1	21.1	58.3	28.6	7.7	5.0
22	28-3 Jun	43.1	21.7	46.4	24.6	9.2	0.0
23	4-10	41.9	24.2	47.0	26.7	8.7	0.0
24	11-17	41.1	23.7	51.0	29.1	7.6	11.6

25	18-24	36.7	23.9	52.7	38.1	6.7	8.8
26	25-1 July	41.7	25.4	51.9	20.7	9.4	3.8
27	2-8	38.9	27.5	66.7	46.9	5.6	13.2
28	9-15	32.9	25.2	88.0	63.4	3.7	94.8
29	16-22	34.4	26.3	79.0	59.7	5.6	1.2
30	23-29	32.3	26.1	90.1	72.9	2.7	170.6
31	30-5 Aug	32.7	26.2	86.0	67.7	5.7	50.2
32	6-12	34.1	27.2	87.3	70.0	5.7	23.0
33	13-19	32.7	26.2	86.0	67.7	5.7	131.1
34	20-26	34.6	25.8	84.4	58.3	8.9	9.4
35	27-2 Sep	35.2	26.7	87.7	61.0	7.8	2.0
36	3-9	34.6	25.6	85.4	61.9	6.3	9.0
37	10-16	35.0	25.9	87.0	63.4	4.9	3.0
38	17-23	32.2	23.0	89.4	61.1	6.7	62.8
39	24-30	29.7	23.1	93.1	75.9	2.7	93.4
40	1-7 Oct	28.8	18.8	88.6	64.6	5.4	21.4
41	8-14	30.5	18.6	86.4	52.1	8.1	0.0
42	15-21	29.2	17.3	87.3	51.6	5.9	9.2
43	22-28	29.3	14.5	84.6	43.6	8.9	0.0
44	29-4 Nov	28.0	15.8	89.9	52.3	5.2	0.0
45	5-11	25.4	13.0	83.1	52.0	5.6	51.8
46	12-18	24.0	13.4	89.9	61.7	3.5	2.8
47	19-25	22.4	12.4	92.6	63.3	4.0	0.8
48	26-2 Dec	21.9	9.8	93.1	52.1	4.9	22.0
49	3-9	22.4	6.4	90.3	45.6	6.9	0.0
50	10-16	16.7	7.8	93.7	72.7	2.5	82.6
51	17- 23	14.2	8.4	93.7	77.4	2.3	1.2
52	24-31	10.5	6.6	90.6	78.0	0.4	0.0

Vita

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Bachelor's Degree	**:**	**B.Sc. (Hons.) Agriculture**
University and Year of award	**:**	Sher-e-Kashmir University of Agriculture Sciences and Technology of Jammu, 2018
OGPA	**:**	7.37/10.00
Master's Degree	**:**	**M.Sc. (Ag.) Horticulture (Fruit Science)**
OGPA	**:**	7.53/10.00

CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the external examiner and the advisory committee have been duly incorporated in the thesis entitled **"Effect of bagging on litchi fruit cv. Dehradun"** submitted by **Mr. Varun Pal Singh,** Registration No. **J-17-M-498.**

29/3/21

Dr. Kiran Kour
Major Advisor & Chairman
Advisory Committee

Place: Jammu

Date:

29/03/2021

Head
Division of Fruit Science