STANDARDIZATION OF HARVEST MATURITY FOR LOW CHILL CULTIVARS OF PEACH [*Prunus persica* (L.) Batsch] UNDER MID HILL CONDITIONS OF HIMACHAL PRADESH

Thesis

by

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(H-2012-23-M)

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CERTIFICATE - I

This is to certify that the thesis titled **"Standardization of harvest maturity for low chill cultivars of peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh",** submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) Fruit Science** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Mr. Lalit Narayan Mishra (H-2012-23-M)** son of Sh. R P Mishra under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni, Solan
Dated: July, 2020

(Dr. Vishal S. Rana)
Chairman, Advisory Committee

CERTIFICATE - II

This is to certify that the thesis titled, **"Standardization of harest maturity for low chill cultivars of peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh** submitted by **Mr Lalit Narayan Mishra (H-2012-23-M)** son of Shri R P Mishra to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173230 India in partial fulfilment of the requirements for the degree of **Master of Science (Horticulture) Fruit Science** in the discipline of **Horticultural Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Chapter-1

INTRODUCTION

Peach (*Prunus persica* (L.) Batsch) is an important fruit crop in the temperate regions of the world. Peaches are considered good source of vitamins and minerals. The peaches are commercially cultivated in areas lying between 10^{o} to 49^{o} N and 18^{o} to 45^{o} S latitudes in the world (Kumar *et al.,* 2010). The performance of peach is quite good under mid-hill conditions of the Himalayas. With the advent of crop improvement programs, affords have been made to develop peach cultivars with relatively less chilling requirement which are suitable for mid and foot hill elevations. The subsequent evolution of low chilling cultivars paved the way for peach cultivation in subtropical areas. The low chilling cultivars have a relatively short development period and can be grown in the subtropical areas experiencing winter chilling of 400-1000hrs.

The total peach production in the world is 24.66 million MT in an area of 1.52 millions ha (Anonymous, 2018a). It is cultivated on a large scale in China, Europe, Spain, Italy, USA and Iran. The area under peach cultivation in India is 18,000 ha and total production is 1,23,000 MT (Anonymous, 2019). It is grown mainly in Jammu and Kashmir, Himachal Pradesh, Punjab, Uttarakhand, Nilgiri hills, Jharkhand and north eastern states (Kahlon *et al*., 1992 and Josan *et al*., 2009). In Himachal Pradesh, it is cultivated in an area of 5,090 ha with an annual production of 7,292 MT (Anonymous, 2018b). Recently, some commercial cultivars of peach have shown decline in production in the mid-hills of Himachal Pradesh, mainly due to the changing climate. The introduction and cultivation of low-chill peach cultivars in the subtropical plain areas of northern India have extended their scope for cultivation in the mid-hill conditions under changing climatic scenario.

Peach is the most preferred and legendary fruit among stone fruits and is grown under low temperature in hilly areas of the temperate world. Due to exciting colors and high texture, peaches are generally valued for their fresh and canned fruits. Now the peach has become pride to poor and marginal hilly farmers of sub mountainous and plains areas of northern India and southern hills. It is also cultivated in irrigated arid and plateau ecosystem (Jana, 2015). The peaches have performed well at an altitude ranging between 600-2000m above mean sea level. The peach production has shown a declining trend in the recent years

due to several factors like diseases, overdependence on selective cultivars and global warming (Singh *et al.,* 2014). With the advances in breeding efforts, low chilling peach cultivars have been developed and their cultivation has been extended from temperate regions to subtropical world (Kuden *et al.,* 2004).

Physico-chemical changes that occur during fruit growth and development serve as indications to judge the stage of maturity (Biswas and Roy, 1985). Peaches like other stone fruits are perishable and have short post harvest shelf life at normal atmosphere. They are subjected to softening immediately after harvest. It is a delicate crop and well known for its poor shelf life. Due to perishable nature, it does not stand during long transportation and sustains considerable transit losses. Due to lack of knowledge about physico-chemical changes and maturity indices, the crop is harvested at improper stage of maturity which affects the quality and storage life of the fruit. The maturity standards also vary from cultivar to cultivar and the agro-climatic conditions (Badiyala and Awasthi, 1990).

Peaches harvested at immature stage of maturity may fail to ripen properly or may ripen abnormally. The immature fruits soften slowly and never reach the desired melting texture of fully mature fruit. Green ground colour of immature fruit may also persists. The immature fruits lack a fully developed surface cuticle and are more susceptible to water loss than the properly matured fruits. These fruits do not acquire adequate flavours and acceptance. The peach consumption has been facing a constant drop due to the poor textural and flavor characteristics of some recently selected cultivars (Crisosto *et al.,* 1994). However, the decline in market demand has not affected the fruit supply, causing a substantial surplus in production and a consequent drop in the return to producers (Bianchi *et al.,* 2017). Hence, the major focus have been to prolong the shelf life of fruits for distant markets due to perishable nature of the fruit. Consequently, new cultivars, such as the stony-hard varieties, have been selected due to their better storage characteristics and organoleptic attributes. Furthermore, harvesting of fruits before physiological maturity affects the aroma at consumption (Infante *et al.,* 2012).

The over mature fruits on the other hand have shorter postharvest life and subject to rapid softening as they are already approaching a senescent stage at harvest. Such fruits are partially ripened and are highly susceptible to mechanical injury and pathological spoilages. The major bottleneck in commercial peach cultivation is its limited postharvest life. It has a shelf-life of 3-5 days under ordinary environmental conditions (Tonini and Tura, 1998).

Keeping in view the scope of cultivating low chill peach cultivars in mid-hills of Himachal Pradesh under the changing climatic scenario, the proposed investigation was undertaken with following objectives:

i) To standardize the harvest maturity for low chill cultivars of peach under mid hill conditions

ii) To study the effect of harvest maturity on the quality and storage behaviour of peach

Chapter-2

REVIEW OF LITERATURE

The fruit maturity at harvest is the most important factor that determines fruit quality and storage-life. Immature fruits are subject to shrivelling and mechanical damage, and impart inferior flavour quality after ripening. Overripe fruits are likely to become soft and mealy with insipid flavour soon after harvest. Fruits picked either too early or too late are more susceptible to postharvest physiological disorders than the fruits picked at right stage of maturity (Kader, 1999). The peach is highly perishable fruit and therefore, requires immediate harvesting at maturity. However, the degree of picking maturity for peach depends on the cultivars. The relevant literature pertaining to harvest maturity and the associated physico-chemical changes has been reviewed under the following heads.

2.1 CHANGES DURING FRUIT GROWTH AND DEVELOPMENT

The life of a fruit begins with initiation of fruit bud which after fertilization is ultimately converted into the fruit. The growth of peach exhibits a double sigmoid curve with three rapid growth periods and two lag phases of growth. The first one is very rapid and continue until the pit begins to harden. In the second stage, the growth of flesh is slow as seed develops and the seed coat hardens. In the last stage the growth, the fruit again increases. The young fruit just formed goes through a period of rapid cell division and growth.

Khajuria *et al* (1986) assessed eight cultivars of peach viz., Sharbati Red, Chakli, Khurmani, Ranjit Bagh Early, Matchless, Honey Sweet, Safeda and Jewel under Punjab conditions and observed maximum fruit weight in Sharbati Red and minimum in Chakli. Gautam *et al.* (1986) reported optimum harvest maturity of peach cvs. July Elberta and Shimazu Hakuto attained fruit weight of 73.90 g and 81.70 g, respectively.

Solanki *et al.* (1988) reported that Saharanpur Prabhat as an early ripening, sweet, yellowish to pinkish blush; medium in size round in shape with good taste having good keeping quality. The fruit ripened during 3rd week of April i.e. about 4-6 days earlier than the Flordasun.

Sherman and Lyrene (1989) evaluated the performance of Flordacrest peach in Florida and observed that it was having attractive fruits with yellow flesh and ripened after

Flordaking and before June Gold in Northern Florida. Anderson and Sherman (1990) reported Flordadawn peach as the earliest ripening peach with commercial potential in the United States. Flordasun had attractive fruits with yellow flesh and ripened before Flordaking in Northern Florida.

Chanana *et al* (1992) evaluated some low chilling peach introductions for their suitability in Punjab plains and concluded that the two introductions TA-170 and 5-2 were suitable for cultivation in the area because of early ripening, superior quality and better finnness of the fruit. The fruit firmness at maturity was maximum in TA-170 (15.20 lbs $inch^2$) and and minimum in Flordasun (10.10 lbs/$inch^2$).

Maness *et al.* (1992) studied the variability in mesocarp firmness of peach fruit at 4 harvesting stages. They observed that average mesocarp firmness decreased with advancement of fruit maturity and internal variation in firmness for the middle and outer mesocarp regions was found highly cultivar dependent. Firmness decreased longitudinally from the stem end to the blossom end and latitudinally from the suture to the cheeks.

Fruit mass increased by 2-10g day^{-1} as the fruit approached harvest date. There was also an increase in sugar and flavour components in peach fruits (Rizzolo *et al.*, 1993; Bassi *et al.*, 1995).

Badiyala and Lakhanpal (1994) assessed the relative performance of ten year old low chilling peach cultivars viz, Bonita, Early Amber, Flordared, Flordasun and Shan-i-Punjab under Paonta valley of Himachal Pradesh and recorded maximum fruit weight and fruit size in Shan-i-Punjab and minimum in Early Amber..

Prerak and Kaul (2002) studied the growth and development of peach cultivars namely; Pratap, Flordasun and Shan-i-Punjab in Sri Ganganagar, Rajasthan and found that the fruit exhibited a double sigmoid curve. The entire growth period of the fruits was divided into 3 distinct phases, i.e. rapid growth (10 to 40 days after fruit set phase I), slow growth (40 to 60 DAF; phase II), and a period of final swell with faster growth from 60 to 80 DAF, followed by a depressed growth till ripening (phase III). At the time of harvest, the maximum fruit weight was recorded in Pratap and the minimum in Shan-i- Punjab. The pulp weight varied from 92.32 g in Shan-e- Punjab to 120.44 g in Pratap and the stone weight ranged from 1.08 g in Shan-i- Punjab to 1.89 g in Pratap. The pulp/stone ratio was found minimum in Pratap and maximum in Flordasun. The total soluble solids content varied from 13.4 in

Shan-i- Punjab to 13.8 ^{0} B in Flordasun. The total titratable acidity was minimum in Flordasun and maximum in Pratap. The total TSS/acidity ratio varied from 21.26 in Shan-i-Punjab to 23.44 in Flordasun.

Park and Kim (2002) observed that flesh firmness decreased and the soluble solids contents increased with fruit maturity in two nectarine cultivars viz., Subong and Cheonhong. The variation in acidity was attributed to fruit maturity which did not show a specific trend. The titratable acidity also varied between Flordasun and Pratap cvs. of peach at ripening stage (Bhatnagar and Kaul, 2002).

Haji *et al.* (2004) measured the time courses in fruit weight, ground colour of skin, flesh firmness, sugar content, titratable acidity and ethylene evolution rate during growth, maturation and senescence of four peach cultivars. In the melting-type cultivars namely; 'Akatsuki', 'Kushigatahakuto' and 'Nagasawahakuho', the increase in fruit size, changes in ground colour, rise in sugar content and reduction in titratable acidity gradually proceeded after full bloom. Whereas, in Kushigatahakuto the softening proceeded fruit enlargement indicating completion of ground colour changes, and the rapid rise in sugar content. In contrast, 'Nagasawahakuho' showed a slow and late softening after attaining the full size, accumulating near maximum sugar level and loss of ground colour.

Lescourret and Genard (2005) reported that the proportion of total fruit mass in terms of fruit size consisting of fruit flesh, dry matter content of the flesh and the concentrations of sucrose, glucose, fructose and sorbitol in the flesh can be used to calculate a sweetness index as quality traits for peach.

2.2 HARVEST MATURITY INDICES

Peaches should be harvested after the attainment of harvest maturity. The peaches do not mature uniformly therefore, several pickings are needed to harvest good-quality fruits based on ground color, size, and suture. A large number of maturity indices, such as days after full bloom (DAFB), calendar date, fruit size, firmness, sense of touch, pit discoloration, freeness of pit, taste, ground color, sugar, acidity, starch, sugar-to-acid ratio, and multiple linear regression analysis, have been used to judge optimum maturity (Chapman *et al*., 1991; Liverani *et al*. 1991;Joshan and Chauhan, 1982; Kumar and Chitkara, 1983; Smith, 1985; Sistrunk and Rom, 1976 and Delwiche, 1987).

Deshpande and Salunkhe (1964) proposed the use of soluble solids to acid ratio as a reliable index of peach maturity for harvest, whereas, Sidwell (1961) found that the eating quality of Elberta peaches could be determined on the basis of chlorophyll content (0.06-18 mg/g fresh weight). Visaglie and Eksteen (1981) also reported that color, flesh, firmness and the total soluble solids content of juice could be used as reliable maturity indices. The onset of softening coincides with an increase in red fruit color about 100 days after fruit set, when the respiration rate and ethylene production reach a maximum (Amoros *et al.*1989). Various quality characteristics of peach fruits have also been found to be related to maturity (Robertson *et al.*, 1992). Ground color, texture, TSS/acid ratio, and titratable acidity of peach were found to be good maturity indices (Moris *et al*., 1978). The days required from flowering to maturity vary in different cultivars, ranging from 78-100 days after full bloom to up to 127 days (Gangwar and Tripathi, 1972; Dhuria *et al*., 1978; Chander and Khajuria, 1982; Kinge, 1993; Deshpande and Salunkhe, 1964).

Romani and Jennings (1971) reported that as the fruit matures and ripens, colour changes from green to red or yellow. The development of red color in nectarines and peaches depends on exposure to light. Further the postion of fruits on the tree influences its degree of red colouration (Mitchell *et al*., 1979; Ryall and Pentzer; 1982 and Kader and Mitchell, 1989b).

Gangawar and Tripathi (1972) reported that peach fruits are ready to harvest after attaining 98 days of full bloom. Panwar and Kaul (1973) studied the developmental stage in Sharbati Safeda, Sharbati Red and Saharanpur No. 6 varieties of peach. They reported that the development starts in the first week of March and was rapid next 22 days, after which slow development took place for 56 days, followed by a rapid growth for 21 days. The fruits were ready to harvest after attaining these developmental stages.

Teskey and Shoemaker (1972) reported different stages of peach fruit maturity for different purposes viz., hard for long distance export market, firm for long distance export and domestic market, firm-ripe for short distance export market, tree-ripe for short distance local market and soft-ripe for ready consumption and processing purpose.

Garg *et al.* (1975) reported optimum harvest maturity with fruit firmness reading in Crawfords Early and Golden Bush peaches recording 6.5 lb/inch^2 and 15.0 lb/inch^2, respectively. In Elberta peach, Dhuria *et al.* (1978) reported 2.04 kg/cm^2 pressure at maturity. Early season peach, plum and nectarine varieties were usually less firmer than the late season

varieties. However, flesh firmness alone was not found to be the satisfactory maturity index because flesh firmness for a given variety varied according to fruit size, climatic conditions, and cultural practices (McDonald and Delwiche, 1983; Delwiche, 1987 and Kader and Mitchell, 1989a).

Dhuria *et al.* (1978) in a study conducted at Solan (HP) reported 127 days after full bloom as picking maturity of Elberta peach, when all the physico-chemical characteristics attained more or less the optimum values for commercial uses.

Chander and Khajuria (1981) studied fruit length, diameter, weight, volume, specific gravity, firmness, TSS content, total sugars, acidity and TSS/acid ratio as maturity indices for peaches under Punjab conditions. They reported that fruit firmness is a good index of picking maturity. Bhargava *et al.* (1986) observed that the most appropriate time for harvesting peach cv. July Elberta in Solan region of Himachal Pradesh was found to be 12-14 July.

Sherman *et al.* (1982) reported that the fruits of Flordaprince were round with little or no tip, pubescent and semi cling with little separation of the flesh at the pit when soft ripe. Flesh was flavourful, melting, yellow and firm but slightly coarse in texture. Red blush covers about 80 per cent of the surface, dark red stripes over a yellow ground colour.

Biswas and Roy (1985) reported that the external appearance of fruit along with physico-chemical changes that occur during fruit growth and development serve as indices to judge the stage of fruit maturity.

Mehrotra *et al.* (1988) studied the performance of some peach cultivars under Patiala conditions of Punjab and recorded highest TSS content in Sharbati and least in Flordasun. The titratable acidity ranged from 0.80 per cent in Shan-i-Punjab as maximum to 0.38 per cent in Sharbati as minimum.

Flesh firmness decreased during the maturation and ripening. The peach fruit harvested at 10 - 12 pounds-force firmness at picking will ripen after harvest and attain better quality than those of 12 to 15 lbs/ $inch^2$ (Kader and Mitchell, 1989a and Kader and Mitchell, 1989b). Badiyala and Awasthi (1990) stated that the maturity standards for peach harvest vary from cultivar to cultivar and the agro-climatic conditions.

Kurnaz and Kaska (1991) observed that the green ground and flesh colour of the fruit was gradually replaced with the yellow color as stage III began in peach cv. Springtime. The

intensity of red skin coloration increased until maturation but decreased towards fruit ripening.

Badiyala (1993) studied the changes in physico-chemical characteristics of peach cv. Flordared for assessment of fruit maturity and recorded that fruits reached maturity at 102 days after fruit set. This corresponded to the fruit firmness of 6.4 lb/inch ^{2}. Bassi *et al.* (1995) reported that fruit ground colour was a better indicator of the ripening potential with a linear relationship between greenness at harvest and firmness at storage.

Crisosto (1994) reviewed different maturity indices for nectarine, plum and peach fruit. The ripening of peaches and nectarines and storage associated changes transform a mature fruit into eatable stage. They reported that ground colour is the most practical and reliable method for determining maturity. Fruit firmness was also found to an excellent indicator of maturity but the combination of ground colour and fruit firmness proved better than a single index to assess stone fruit maturity. The soluble solids content varied significantly among orchard trees and therefore, was not regarded as a reliable indicator of fruit maturity. They further opined that development of new technologies like near infrared, magnetic resonance, light transmittance and sound detection may lead to an ideal, non-destructive and reliable maturity index for the aforesaid fruits.

Krewer *et al.* (1994) observed that external fruit appearance was attractive with 40-90 per cent red blush over a bright yellow ground colour in nectarine cv. Sunsplash at maturity. According to Andersen and Sherman (1995), fruit colour was excellent with 80-90 per cent red blush over a yellow ground colour in 'Suncoast' nectarine.

Bassi *et al.* (1995) recorded increase in fruit size especially the diameter of nectarine cvs. Maria Aurelia and Red Gold. In Red Gold peach, the proportion of fruits having more than 21 cm diameter increased up to the third sampling date which was considered appropriate during ripening at 3 to 4 days interval. Andersen and Sherman (1995) observed that 'Suncoast' nectarine fruit ripened during the first week of May after a development period of 75-80 days in northern Florida with average fruit diameter of 6 cm and weighing more than 100g.

Ravaglia *et al*. (1996) assessed the fruit colour in peach/nectarine cultivars, harvested at 3- 5 day intervals and stored for one or two weeks at 0 ^{0}C, followed by 1 day at room temperature. They concluded that on the basis of changes in firmness and colour, fruits pass

through three ripening stages each requiring different postharvest treatments. While, Singh *et al* (1997) classified peach cultivars on the basis of fruit weight into three groups viz., small (30.2 g to 32.2 g), medium (50.5 g to 64.3 g) and heavy (76.3 g to 81.3 g).

Ozelkok *et al.* (1996) observed that flesh firmness and soluble solids were the best practical methods for adjudging harvest maturity in nectarine cvs. Nectared-6 and Independence of 14-15 lb with a minimum TSS of 11 per cent was suitable for determining minimum acceptable maturity. Singh and Arora (1998) picked the fruits of peach cvs. Saharanpur Prabhat and Flordasun at 3 days intervals from 61 days after petal fall to 70 days after petal fall. They reported that the fruits attained their optimum size and qualitative characteristics on 67^{th} days after petal fall. At this stage, the total sugars contents were recorded to be 13.37 per cent and 11.82 per cent in Saharanpur Prabhat and Flordasun cultivars, respectively.

Barbosa *et al.* (1999) showed that the fruits of Douradao cultivar of peach ripened at 105 days from full bloom to harvest in Itupeva. Ou and Song (1999) noticed that low chill peaches required 67 days from full flowering to reach maturity.

Josan *et al.* (1999) evaluated low chilling peaches viz. Flordasun, Pratap, Prabhat, Shan-i-Punjab, Flordared and Sharbati under arid-irrigated regions of Punjab for their flowering behaviour, fruit yield and quality attributes. They recorded highest fruit yield in Flordasun followed by Shan-i-Punjab and lowest in Sharbati. The maximum fruit weight was recorded in Pratap and minimum in Flordasun. Fruit length was recorded maximum in Shan-i-Punjab and minimum in Flordasun whereas, maximum fruit breadth was recorded in Pratap and minimum in Flordasun.

Sherman and Lyrene (2000) developed UF 2000 peach and reported that fruits produced were of high quality with deep orange colour and bright red blush covering 50-70 per cent of the surface with yellow clingstone flesh. Kher and Dorjay (2001) studied fruit weight of three peach cultivars and recorded that Flordasun produced fruits with medium weight (56.95 g) whereas, Shan-i-Punjab (80.86 g) and Flordared (72.94 g) produced comparatively heavier fruits.

Bhatnagar and Kaul (2002) reported that the ideal maturity standards for Pratap, Flordasun and Shan-i-Punjab cultivars of peaches for table purpose were fixed on the basis of total soluble solids, pulp: stone ratio, skin colour and sugar:acid ratio.

Babu and Yadav (2002) reported that average fruit weight increased by 2-4 g/day during final stage of ripening. They did not reported any significant improvement in fruit yield at 82days after fruit set in peach cv. Shan-i-Punjab. They advised that this peach variety should be harvested at 82-86 days after fruit set.

Neelam and Ishtiaq (2002) evaluated 15 peach cultivars and observed maximum fruit length, fruit diameter and fruit weight in cv. Loring. ShyiKuan . Ou and Wen (2003) observed Spring Honey peach as an early ripening, low acid, large-fruited, white, melting flesh peach cultivar for lowland sub-tropical environments of Taiwan. They also reported that fruits were very large, ovate and sweet, medium textured and firm but melting, white flesh with red-purple (25%) coloration.

Kanwar *et al.* (2002) evaluated the low chill peach cvs. FIordaGrande, Flordaglo, Flordaprince, EarliGrande, ValleGrande, TropicBeauty, TropicSnow and TropicSweet in Punjab and found that ValleGrande had the highest fruit weight (88.8 g) followed by EarliGrande (87.2 g) and the lowest in TropicSweet (67.3 g). The highest diameter was also recorded in ValleGrande (5.6 cm) followed by Earligrande (5.2 cm) and the lowest in TropicSweet (4.7 cm). The fruit firmness was also recorded highest in ValleGrande (11.77 lb/inch^2) and lowest in TropicSweet (10.32 lb/inch^2).

Yang *et al.* (2004) found that Chunming cultivar of peach matured in 60 days after full bloom. Fallahi *et al.* (2009) noticed that nectarine cvs. Diamond June and Honey Kist were the earliest to harvest and needed 110 and 114 days between full bloom and harvest, respectively.

Kuden *et al.* (2004) explored the possibility of growing peach under sub-tropical conditions of Turkey and North Cyprus. They observed that in Adana, Francoise variety ripened earlier than other varieties which was followed by Maycrest and Early Maycrest. However, it was observed that Francoise and Maycrest ripen 14 and 12 days earlier in Adana than in Turkmenkoy. Francoise (106.43 g) and Early Maycrest (103.75 g) gave bigger sized fruits in Adana while Maycrest (107.50 g) and Springcrest (99.50 g) bagged better sized fruits in Turkmenkoy.

Tandon (2006) evaluated peach cultivars under Solan (Nauni) conditions and recorded heaviest fruit (36.92 g) in Early Amber and lightest (12.92 g) in Jewel. Fruit firmness varied from 1.05 kg/cm^2 (Jewel) to 1.20 kg/cm^2 (Gold Prince).Patel *et al.* (2007)

studied the performance of low chilling peach cultivars viz. TA-170, Flordasun, Shan-i-Punjab and Meghalaya Local under mid hills of Meghalaya and observed that TA-170, Flordasun and Shan-i-Punjab cvs. matured early in the last week of April to the first week of May while Meghalaya Local matured in second week of June. The maximum yield fruit weight, fruit length, fruit diameter and pulp.stone ratio were recorded in TA-170.

Josan *et al.* (2009) studied the performance of some low chilling peach cultivars viz. EarliGrande, Flordaprince, Pratap, Prabhat and Shan-i-Punjab under North Indian conditions. and recorded observations on the flowering behaviour, fruit yield and quality attributes. The fruit yield was observed to be maximum (59.67 kg/tree) in Shan-i-Punjab and minimum (34.17 kg/tree) in Flordaprince. Maximum fruit weight (75.50 g) was recorded in Shan-i-Punjab. The cultivars EarliGrande, Flordaprince, Prabhat and Pratap were observed to be the earliest (last week of April) to reach maturity while, Shan-i-Punjab matured during the first week of May

Singh *et al.* (2009) studied the suitability of low chilling peach cultivars for irrigated arid ecosystem and recorded that the fruits of EarliGrande were heaviest in weight (85.5 g) followed by Prabhat (75.5 g) and Shan-i-Punjab (72.5 g). Maximum sized fruits were recorded in Shan-i-Punjab (5.68 x 5.10 cm^2), Prabhat (5.50 x 5.32 cm^2) and least in Flordasun (4.62 x 4.4 cm^2).

Sun *et al*. (2010) studied maturity indices for different peach cultivars Zaohongfeitao, an early season cultivar of peach which matured in late July with large attractive fruits, weighing about 333.5 g, with around 80 per cent fruit surface covered with pinkish blush. The total soluble solids content were 15.20 per cent with sweet flavor and excellent eating quality. While, Wenyuan, flat peach cultivar had large fruit size, weighing 175.7 g on average, having deep blush on the 80 per cent surface with a soft melting flesh containing a soluble solids content of 17.4 per cent. Jinqiuta cultivar, another large fruited cultivar, weighing 285 g on average with soluble solids content of 17.50 per cent.

Babu *et al.* (2011) investigated maturity indices in low chill peach orchards grown at 1000 m above mean sea level. They picked the fruits at weekly interval from 7 weeks after fruit set to 13 weeks after set for standardization of harvest maturity in peach cvs. namely; TA-170, Flordasun and Shan-i-Punjab. They observed that TA-170 attained maturity within 11 weeks after fruit set, while, Flordasun and Shan-i-Punjab attained maturity within 12 weeks after fruit set. They also highlighted the importance of maturity indices in peach and

identified different stages of maturity viz., hard, firm, firm-ripe, tree-ripe and soft ripe. They further reported that the fruits of 'Flordasun' and 'Shan-i-Punjab' cvs. harvested 12 weeks after fruit set secured good score in terms of quality. Hence, it was advisable to harvest the fruits of peach cultivar 'TA-170' at 11 weeks after fruit set whereas, 'Flordasun' and 'Shan-i-Punjab' at 12 weeks after fruitset under mid-hill altitude of Meghalaya.

Chaurasiya and Mishra (2017) recorded higher reducing sugars in the variety Shan-i-Punjab and highest total sugars were found in Early Grand peach. The cultivar Punjab Red (Nectarine) gave higher yield per tree followed by Pratap and Early Grand. It was concluded that vigorous and spreading type peach cv. Punjab Red (Nectarine) was the best performer followed by Pratap and Shan-i-Punjab under northern hill zone Chhattisgarh for commercial cultivation.

2.3 CHANGES DURING FRUIT RIPENING

The time of harvest profoundly affects the storage condition. The peach maturity studies have focused on identifying the points when fruits come into acceptable flavour qualities with long term storage. Peach harvesting coincides with the prevailing high seasonal temperatures which accelerate ripening process during marketing, but it declines to half with each reduction of 5.6°C from. 21.1°C. After picking, the fruits should immediately be stored under cool conditions. Peaches ripen with good flavor and aroma at temperatures above 15°C but with undesirable flavor at 1.0°C. There is internal breakdown instead of ripening at 4.4°C (Teskey and Shoemaker, 1972).

Park and Ko (1986) studied the physiological changes during post-harvest ripening of peach cv. Okubu. The total pectin content of peaches decreased slightly but there was a marked increase in water-soluble pectin after 6 days of ripening. Peaches held at room temperature for 2 days after harvest and cold storage for 4 days at 5^{o}Cwere firmer than those held for 6 days at room temperature. Polygalacturonase activity increased during ripening. There was considerable weight loss from peaches during ripening. Eating quality of peaches was highest at 6 days after post-harvest ripening.

Gupta and Jawandha (2010) studied the effect of picking maturity on the storage performance of ‘Earli Grande’ peaches. The fruits for storage were harvested at three stages i.e. before, during and after predictable optimum harvest stage and kept in cold store (0-20^{o}C, 85-90 % RH for a period of 21 days and at ambient conditions (28-30 ^{o}C, 65-70% RH)

for 72 h. The fruits were evaluated for quality parameters at harvest and after 7, 14 and 21 days of storage. The post-cold storage shelf-life was studied after 3 days to assess the market behaviour of fruits. The fruit quality parameters changed according to stage of harvest. An increase in the spoilage, physiological loss in weight, TSS: acid ratio and anthocyanins were noticed with the advancement of maturity and storage period. There was a gradual decrease in reducing sugars of the fruits picked after optimum maturity with increase in storage period. Fruits harvested at optimum stage retained maximum TSS:acid ratio and palatability rating after 3 days storage at ambient temperature. The results also revealed that peach fruits harvested at optimum stage can be stored with post-storage shelf life of 3 days at ambient temperature.

Hong *et al.* (2012) examined the changes in the quality characteristics of unripe peach Jangachi made from different cultivars during storage at room temperature for 60 days. The unripe peach Jangachi-showed decline in pH of pulps and soaking solutions of all varieties during storage. Soluble solids contents decreased during storage in all varieties, both in pulps and soaking solutions. Among Hunter's colour values, L values decreased, a values increased, and b values decreased during storage in all varieties.

Kan *et al*. (2013) studied the modifications in cell wall ultrastructure, cell wall polysaccharides, and the activities of some enzymes involved in cell wall degradation during the development and ripening of 'Honey' peach fruit from Stage I (very immature) to Stage V (over-ripe). The results indicated a decrease in fruit firmness accompanied by an increase in ethylene production during peach ripening. Major changes in cell wall structure included degradation of the middle lamella and the eventual disruption of the primary cell wall.

Ullah *et al.* (2013) studied the effect of harvest location and cultivars on peach fruit softening and quality during ripening at ambient conditions (30±1°C, 60-65% RH). The fruit harvested from Sillanwali exhibited significantly higher ethylene production, respiration rate , ascorbic acid contents, activities of ripening enzyme and significantly lower fruit firmness, ground colour (1.65 score), soluble solid contents and total phenolic contents as compared to fruit harvested from Soan Valley. The Peach cv. Early Grand exhibited significantly higher ethylene production and respiration rate as compared to Flordaking. The harvest locations and cultivars had significant influences on the physico-chemical attributes including activities of various fruit softening and antioxidative enzymes in peach fruit.

Pérez-López *et al.* (2014) reported that the fruits harvested with 50 per cent yellow surface colour (M_2) showed a higher respiration rate than fruits harvested at green (M_1) and (M_3) yellow state. The faster M_2 respiration rate was related to the fruit's climacteric behavior with the consequent development of the characteristic color of a fully ripe fruit after two days of storage. The fresh weight loss in the three maturity stages studied was not more than 9 per cent after 5 days of storage without severe wilting symptoms. It was concluded from the study that various properties of peach exhibited a strong dependence on the degree of maturity at harvest and the rate of senescence progression.

Khan *et al.*(2016) analyzed the ripening behaviour of different peach cultivars during ripening by evaluating their physiological parameters namely; weight loss, respiration rate and ethylene production, physical (fruit firmness) and biochemical parameters viz.; Total soluble solids, titratable acidity, SSC:TA ratio, ascorbic acid, total sugars, reducing sugars, non-reducing sugars, total carotenoids, antioxidant activity and total phenolics. The fruits of five different peach cultivars were collected from two districts and were kept at ambient conditions in laboratory for five days. The fruits were evaluated for various physico-chemical attributes during ripening period. The results revealed significant variations in fruit quality of all cultivars during ripening at ambient conditions. At day-5 of ripening, cultivar '8-A' exhibited maximum SSC; whereas, lowest SSC was measured in 'Flordaking'. Maximum ascorbic acid content and total sugars were observed in '5-A' fruit at ripening day 5; while, maximum total antioxidant, total phenolic content and total carotenoids content were noted in cultivar 'Tex-6A-69'. Maximum fruit firmness was recorded in cultivars '5-A'. Per cent physiological loss in fruit weight was lower in cv. '8-A'. It was also noticed that cultivars '8-A' and 'Tex-6A-69' had the best physico-chemical properties and better eating quality after 4 days ripening at ambient condition.

Karagiannis *et al.* (2016) studied the quality characteristics in peach cv. June Gold at different elevations. They concluded that soluble solids concentration and fruit firmness at commercial harvest stage were unaffected by altitude. Peach grown at high-altitude environment displayed higher levels of pigmentation and specific antioxidant-related activity in their skin at the commercial harvest stage.

Guizani *et al.* (2019) studied the physiological behaviors and fruit quality changes in five peach cultivars during three ripening stages in a semi-arid climate. Fruit quality, sugar and organic acids profile as well as bioactive compounds and antioxidant activities were

investigated in exocarp and mesocarp during three ripening stages (1, 2 and 3). The results showed a signifcant diference in chlorophyll content and assimilation rate among cultivars. In addition, signifcant differences were noticed in total phenol contents among cultivars during stage 1. During ripening, there was a signifcant rise in sugar and soluble solids content and a decrease in citric and malic acids in addition to titratable acidity. Phenolic compounds decreased during ripening. The results indicated that fruit in stage 1 was more abundant in organic acid and phenolic compounds, while fruit in stage 3 was less firm and had best color.

Jiang *et al.* (2020) studied the mechanism that determines the texture of peach flesh in two cultivars viz., hard melting flesh Xiahui 8 and stony hard Xiacui. They observed 57 proteins in Xiacui and 171 proteins in Xiahui 8 which were involved in cellular activities such as sugar metabolism, membrane structure, and cell-cycle control. The results exhibited new light on proteomic differences and protein interactions during the metabolism of ethylene, amino acids, sugars, and carbohydrates in cultivars with varied texture phenotypes; and the underlying mechanisms of peach fruit ripening.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled "**Standardization of harvest maturity for low chill cultivars of Peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh**" was carried out in experimental block of the Department of Fruit Science during the year 2014. The material used and methodologies adopted to accomplish the studies have been detailed below:

3.1 EXPERIMENTAL SITE

The experiment was laid out at an elevation of 1260 m above mean sea level with latitude of 30º 50' North and longitude of 77º11'30" East. The location of experimental field falls under sub-temperate, sub-humid and mid-hill agro-climatic zone of Himachal Pradesh. The average annual rainfall of the area is about 100-130 cm and the major amount of which is received during July to September. Summer is moderately hot during May-June, while winter is severe during December-January.

3.2 EXPERIMENTAL DETAILS

The experiment was laid out on 10 years old plants of four commercial low chill cultivars namely; Tropic Sweet, Early Grande, Florida Prince and Pratap. These plants were planted at a spacing 4.5m × 4.5 m and trained on open center system. The trees were selected on the basis of uniform vigor. The whole program of study was divided into two experiments.

3.3 EXPERIMENT-I: STANDARDIZATION OF HARVEST MATURITY FOR LOW-CHILL CULTIVARS OF PEACH

The fruits samples were taken on seven harvesting dates at 3 days intervals starting from10 days before and 10 days after the anticipated date of harvest and were analyzed for different physico-chemical analyses. The experiment was laid out in a Randomized Block Design with 7 treatments and each treatment was replicated thrice.

Table 3.1. Treatment details

Treatment	Harvest Dates
D_1	May 06th , 2014
D_2	May 09th , 2014
D_3	May 12th , 2014
D_4	May 15th , 2014
D_5	May 18th , 2014
D_6	May 21th , 2014
D_7	May 24th , 2014

3.3.1 OBSERVATIONS RECORDED

3.3.1.1 Fruit size

The size of the fruit was expressed in terms of length and diameter. The length and diameter of the fruits were measured with the help of Digital Vernier caliper and were expressed in millimeter. The length of the fruit was determined by measuring the length between the calyx and styler end of the fruits. The diameter was measured in two perpendicular directions at the center of the fruit and the average value was considered.

3.3.1.2 Fruit weight

The weight of five fruits from each harvest was recorded on electronic top pan balance and average fruit weight was expressed as gram (g).

3.3.1.3 Fruit skin colour

The surface colour of the fruit was observed by comparing it with the colour chart of the Royal Horticultural Society, Londan.

3.3.1.4 Fruit firmness

The fruit firmness was measured with the help of Pressure tester or Penetrometer (Magness-Taylor Pressure Tester), which recorded the pressure required to force plunger of 8 mm diameter into the flesh of fruit. The reading was taken on opposite sides of each fruit and results were expressed in lb/inch^2.

3.3.1.5 Pulp stone ratio

Five fresh fruits in each replication were weighed and the stone from these fruits were removed, washed under tap water, dried to remove excess water and finally weighed. The pulp to stone ratio was worked out by dividing the weight of flesh by the weight of stone.

3.3.1.6 Total soluble solids

The total soluble solids content in fruit were determined by Erma hand refractrometer (0-32º Brix). The refractrometer was calibrated with distilled water before use and a few drops of fruit juice were placed on the prism and the reading was recorded. A temperature correction was applied when it was above or below 20ºC (AOAC, 1984). The total soluble solids were expressed as per cent.

3.3.1.7 Titratable acidity

Ten gram of fruit sample was crushed and taken in a 100 ml volumetric flask. The volume was made up by adding distilled water. After filtration, 10 ml of the filtrate was taken in a separate conical flask and titrated against 0.1 N sodium hydroxide using phenolphthalein as an indicator. The end point was determined by the appearance of a faint pink colour (Ranganna, 1986).

The titratable acidity was calculated on the basis of 0.1 N NaOH equivalents to 0.0067 g anhydrous malic acid and by using the following formula suggested by AOAC (1984).

$$\textbf{Titratable acidity(\%)} = \frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Volume made} \times \text{equivalent weight of acid}}{\text{Weight of sample} \times \text{volume of sample taken} \times 1000} \times 100$$

3.3.1.8 Sugars

Twenty five grams of fruit pulp was thoroughly homogenized with distilled water in an electric blender and volume was made to 250 ml in volumetric flask and filtered through Whatman No. 4 filter paper. Five milliliters of lead acetate (45%) solution was added to it and kept for 10 minutes to remove the impurities. Excess of lead acetate was removed from the sample by using a sufficient quantity of potassium oxalate (22%) and then filtered through

Whatman No. 4 filter paper. From this clear filtrate, 50 ml was separated for the estimation of total sugars and rest was used for estimation of reducing sugars.

3.3.1.8.1 Total sugars

Already separated 50 ml clarified solution was hydrolyzed by adding 5 ml of concentrated hydrochloric acid and leaving it overnight. The excess of hydrochloric acid was neutralized by 10 per cent sodium hydroxide solution. The total sugars were estimated by titrating a boiling mixture of 5 ml each of Fehling solution A and Fehling solution B against aliquot using methylene blue as an indicator. The end point was noted after obtaining the brick red colour and total sugars were expressed as per centage of fresh weight of fruit pulp and calculated as per formula given below (AOAC, 1984).

$$\text{Total sugar (\%)} = \frac{\text{*Factor} \times \text{Dilution} \times \text{Dilution}}{\text{Titre value} \times \text{Weight or Volume of sample taken}} \times 100$$

*Factor = 0.05

3.3.1.8. 2 Reducing sugars

The remaining unhydrolysed deleaded and clarified solution after adding lead acetate and potassium oxalate apart from total sugars estimation was titrated against boiling mixture of 5 ml each of Fehling solution A and Fehling solution B using methylene blue as an indicator (AOAC, 1984). Reducing sugars content was expressed as per cent of fresh weight and were determined using same formula.

3.3.1.8. 3 Non-reducing sugars

The contents of non-reducing sugars were calculated by subtracting the reducing sugars content from the total sugars and multiplying the difference by standard factor 0.95. The results were expressed as per cent non-reducing sugars.

3.3.1.9 Sugar acid ratio

The ratio was obtained by dividing the corresponding value of total sugars to the titratable acid content of the fruit juice.

3.4 EXPERIMENT-II: EFFECT OF HARVEST MATURITY ON THE FRUIT QUALITY OF PEACH AFTER STORAGE AT AMBIENT TEMPERATURE

The fruits of all the four cultivars namely; Tropic Sweet, Early Grande, Florida Prince and Pratap, harvested on seven different dates were subjected to one week storage at ambient temperature. The following observations were recorded:

3.4.1 Physiological loss in weight (PLW)

Fruit weight was recorded on the day of harvest and was again recorded after one week storage on a top pan balance and expressed as g/fruit. The loss of weight during storage was expressed as per cent of the initial weight.

3.4.2 TSS content

The procedure was followed as detailed in 3.3.1.6

3.4.3 Titratable acidity

The procedure was followed as detailed in 3.3.1.7

3.4.4 TSS acid ratio

The ratio was obtained by dividing the corresponding value of total soluble solids to the titratable acid content of the fruit juice.

3.5 STATISTICAL ANALYSIS

The data obtained from these investigations were appropriately computed, tabulated and analyzed by applying Randomized Block Design (RBD). The level of significance was tested for different variable at 5 per cent level of significance (Gomez and Gomez, 1984).

Chapter-4

RESULTS AND DISCUSSION

The present study on the "**Standardization of harvest maturity for low chill cultivars of Peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh"** was conducted during 2014. The whole program of study was divided into two experiments. The results obtained during the present investigation are presented and discussed under the following subheads:

4.1 STANDARDIZATION OF OPTIMUM HARVEST MATURITY

4.1.1 Days from full bloom to harvest

Data pertaining to days from full bloom (DFFB) to harvest have been presented in Table 4.1. The full bloom dates were recorded on 12th February in Tropic Sweet, 15th February in Early Grande, 18th February in Florida Prince and 16th February in Pratap. Accordingly, the fruits were harvested from 84-102 DFFB in Tropic Sweet, 81-99 DFFB in Early Grande, 78-96 DFFB in Florida Prince and 80-98 DFFB in Pratap for standardization of harvest maturity. On the basis of physico-chemical characteristics of the fruits and storage behavior for one week at ambient temperature, 24th May for Tropic Sweet (102 DFFB), 18th May for Early Grande (93 DFFB), 15th May (87 DFFB & 89 DFFB, respectively) for both cultivars namely; Florida Prince and Pratap were found to be the optimum harvest dates.

Table 4.1. Effect of picking maturity on the Days from full bloom (DFFB) to harvest in low chill peach cultivars

Treatments	Harvest Date	Days from full bloom (DFFB)			
		Cultivars			
		Tropic Sweet	Early Grande	Florida Prince	Pratap
D_1	**May, 06**	84	81	78	80
D_2	**May, 09**	87	84	81	83
D_3	**May, 12**	90	87	84	86
D_4	**May, 15**	93	90	87	89
D_5	**May, 18**	96	93	90	92
D_6	**May, 21**	99	96	93	95
D_7	**May, 24**	102	99	96	98

According to Panwar and Kaul (1973), the peach fruit development starts in the first week of March and was rapid during next 22 days, after which slow development took place for 56 days, followed by a rapid growth for 21 days. A large number of maturity indices, such as days after full bloom (DAFB), calendar date, fruit size, firmness, sense of touch, pit discoloration, freeness of pit, taste, ground color, sugar, acidity, starch, sugar/acid ratio, and multiple linear regression analysis have been used to judge optimum harvest maturity (Chapman *et al*., 1991; Liverani *et al*., 1991; Joshan and Chauhan, 1982; Kumar and Chitkara, 1983; Smith, 1985; Sistrunk and Rom, 1976 and Delwiche, 1987).

The days required from flowering to maturity vary in different cultivars, ranging from 78-100 days after full bloom up to 127 days as reported by several researchers (Moris *et al*., 1978; Dhuria *et al*., 1978; Chander and Khajuria, 1982; Kinge, 1993). Barbosa *et al.* (1999) also reported that the fruits of Douradao cultivar of peach ripened at 105 days from full bloom to harvest. Ou and Song (1999) noticed that low chill peaches required 67 days from full flowering to reach maturity.

4.1.2 Fruit colour

The results on the effect of harvest maturity on fruit colour are presented in Table 4.2. It is evident that the fruits on different sampling dates exhibited a clear-cut difference in fruit colour development from 1st sampling to 7th sampling date. In Tropic sweet, Yellow Green Group to Orange Red Group 34 A on the 7th sampling date, in Early grande, Yellow Green Group fruit changed to Orange Red Group from 142 C to 34 A on 3rd sampling date However, in Florida Prince, the fruit colour changed from Yellow Green Group 145 B to Orange Red Group 34 A on 4th sampling dates and Pratap fruit also changed from Yellow Green Group 142 B to Orange Red Group 34 B on the 4th sampling date.

During fruit maturation and ripening, the colour changes from green to red or yellow pigments (Romani and Jennings,1971). The development of red color in nectarines and peaches also depends on exposure to light. Further the position of fruits in the tree influences its degree of red colouration (Mitchell *et al*., 1979; Ryall and Pentzer; 1982 and Kader and Mitchell, 1989b). Kurnaz and Kaska (1991) observed that the green ground and flesh colour of the fruit was gradually replaced by yellow color as stage-III began in peach cv. Springtime. The intensity of red skin coloration increased until maturation but decreased

towards fruit ripening. Bassi *et al.* (1995) also reported that fruit ground colour is a better indicator of the ripening potential with a linear relationship between greenness at harvest and firmness at storage.

Table 4.2. Effect of picking maturity on the fruit colour of low chill Peach cultivars

Treatments	Harvest Date	Fruit colour			
		Cultivars			
		Tropic Sweet	Early Grande	Florida Prince	Pratap
D_1	**May, 06**	Yellow Green Group 145 B	Yellow Green Group 142 C	Yellow Green Group 145 B	Yellow Green Group 142 B
D_2	**May, 09**	Yellow Green Group 145 C	Yellow Orange Group 20 B	Yellow Green Group 145 C	Yellow Green Group 150 C
D_3	**May, 12**	Yellow Green Group 150 B	Yellow Orange Group 23 C	Orange Red Group 34 B	Orange Red Group 33 C
D_4	**May, 15**	Yellow Green Group 151 B	Orange Red Group 33 C	Orange Red Group 34 A	Orange Red Group 34 B
D_5	**May, 18**	Orange Red Group 33 C	Orange Red Group 34 A	Orange Red Group 34 A	Orange Red Group 34 B
D_6	**May, 21**	Orange Red Group 31 B	Orange Red Group 34 A	Orange Red Group 34 A	Orange Red Group 34 B
D_7	**May, 24**	Orange Red Group 34 A	Orange Red Group 34 A	Orange Red Group 34 A	Orange Red Group 34 B

4.1.3 FRUIT SIZE

4.1.3.1 Fruit Length

The data presented in Table 4.3 revealed that the fruit length increased gradually with the advancement of maturity, but the rate of increase declined after attaining a particular maturity level depending upon the cultivars. Among different cultivars, the highest (58.67 mm) fruit length was recorded in Pratap, followed by Early Grande (55.27mm), Florida Prince (50.52mm) and Tropic Sweet (41.37mm). In Tropic Sweet, the fruit length increased up to the 7^{th} sampling date (48.42mm) at faster pace. Fruit length on 7^{th} sampling dates was found statistically at par with 6^{th} sampling date. In Early grande, the increase in fruit length was significant upto 5^{th} sampling date (58.24mm), thereafter, increase in fruit length was slower. Similarly, the cultivars, Florida Prince and Pratap exhibited significant increase in fruit length upto 4^{th} sampling dates, recording 51.27mm and 60.10 mm, respectively.

Table 4.3. Effect of picking maturity on the fruit length of different low chill Peach cultivars

Treatments	Harvest Date	Fruit length (mm)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	May, 06	36.61	47.79	47.45	53.42	46.32
D_2	May, 09	37.14	51.48	49.52	56.89	48.76
D_3	May, 12	38.06	55.35	50.18	58.91	50.63
D_4	May, 15	40.26	57.20	51.27	60.10	52.21
D_5	May, 18	41.03	58.24	51.48	60.13	52.72
D_6	May, 21	48.05	58.31	51.82	60.60	54.70
D_7	May, 24	48.42	58.50	51.91	60.62	54.86
Mean		41.37	55.27	50.52	58.67	
$CD_{(0.05)}$ Cultivar (C) : 0.80 Date of Harvesting (D) : 1.02 C X D : 2.11						

4.1.3.2 Fruit diameter

The data pertaining to fruit diameter as influenced by different sampling dates in peach cultivars are presented in Table 4.4. It was found that fruit diameter followed almost similar trend as that of fruit length. The fruit diameter increased with the advancement of maturity but the rate of increase declined at subsequent pickings, tending to level off towards the end of harvest. The fruit diameter increased at faster pace till 5th harvesting date and after that gradual increase was noticed in Tropic Sweet. The fruit diameter of Early Grande cultivar also increased rapidly was until 5th sampling date, recording 56.63 mm and tended to level off thereafter. The cultivar Florida Prince and Pratap noticed rapid increase in fruit diameter upto 4th sampling dates when these cultivars recorded 52.10 mm and 55.27 mm values for fruit diameter, respectively.

Kanwar *et al.* (2002) studied the low chill peach cvs. Florida Grande, Floridaglo, Florida prince, Early Grande, Valle Grande, Tropic Beauty, Tropic Snow and Tropic Sweet in Punjab and found that Valle Grande had the highest fruit weight (88.8 g) followed by Early Grande (87.2 g) and the lowest in Tropic Sweet (67.3 g). The highest diameter was also recorded in Valle Grande (5.6 cm) followed by Early Grande (5.2 cm) and the lowest in Tropic Sweet (4.7 cm).

Table 4.4 Effect of picking maturity on the fruit diameter of different low chill Peach cultivars

Treatments	Harvest Date	Fruit diameter (mm)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	37.55	43.38	38.02	44.47	40.86
D_2	**May, 09**	38.50	48.33	45.23	49.47	45.38
D_3	**May, 12**	39.44	53.66	49.78	54.68	49.39
D_4	**May, 15**	42.22	55.43	52.10	55.27	51.26
D_5	**May, 18**	47.60	56.63	52.11	56.35	53.17
D_6	**May, 21**	52.85	56.66	52.20	56.64	54.29
D_7	**May, 24**	53.42	56.66	53.20	56.69	54.99
Mean		44.51	52.96	48.95	53.37	
$CD_{(0.05)}$ Cultivar (C) : 0.76 Date of Harvesting (D) : 1.00 C X D : 2.00						

4.1.4 Fruit weight

The data pertaining to fruit weight was recorded on different sampling dates in peach cultivars and are presented in Table 4.5. It is evident from the data that an increase was recorded throughout the sampling period in all the cultivars but the rate of increase was not significant on a particular date of sampling depending upon the cultivars. In Tropic Sweet, the rapid increase in fruit weight was observed up to the 7th sampling date (72.10 g). In Early Grande, the fruit weight increased significantly until 5th sampling date (85.27g). However, Florida Prince and Pratap cultivars, registered significant increase in fruit weight up to the 4th sampling date, recording 74.37g and 85.24 g, respectively. Thereafter, the fruit weight followed a marginal increase.

Khajuria *et al.* (1986) assessed eight cultivars of peach viz., Sharbati Red, Chakli, Khurmani, Ranjit Bagh Early, Matchless, Honey Sweet, Safeda and Jewel under Punjab conditions and observed maximum fruit weight in Sharbati Red and minimum in Chakli. At optimum maturity, the average fruit weight in cvs. July Elberta and Shimazu Hakuto was recorded as 73.9 g and 81.7 g, respectively (Gautam *et al.*, 1986). Singh *et al.* (1997) classified peach cultivars on the basis of fruit weight into three groups viz., small (30.2 g to 32.2 g), medium (50.5 g to 64.3 g) and heavy (76.3 g to 81.3 g).

Kher and Dorjay (2001) studied fruit weight of three peach cultivars and recorded that Flordasun produced fruits with medium weight (56.95 g) whereas, Shan-i-Punjab (80.86

g) and Flordared (72.94 g) produced comparatively heavier fruits. Babu and Yadav (2002) reported that average fruit weight increased by 2-4 g/day during final stage of ripening. They did not report any significant improvement in fruit yield at 82days after fruit set in peach cv. Shan-i-Punjab. They advised that this peach variety should be harvested at 82-86 days after fruit set.

Table 4.5 Effect of picking maturity on fruit weight of different low chill Peach cultivars

Treatments	Harvest Date	Fruit weight (g)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	42.53	54.59	58.89	68.47	56.12
D_2	**May, 09**	49.05	61.05	64.83	74.05	62.25
D_3	**May, 12**	54.52	67.83	69.47	81.15	68.24
D_4	**May, 15**	59.83	79.46	74.37	85.24	74.73
D_5	**May, 18**	65.05	85.27	74.39	85.37	77.52
D_6	**May, 21**	70.60	85.37	74.48	85.49	78.99
D_7	**May, 24**	72.10	85.74	74.94	85.92	79.68
Mean		59.10	74.19	70.20	80.81	
$CD_{(0.05)}$ Cultivar (C) : 1.16 Date of Harvesting (D) : 1.54 C X D : 3.08						

4.1.5 Fruit firmness

The fruit firmness decreased gradually till 5th harvesting date and thereafter, it decreased significantly till 6th harvesting date (Table 4.6). The lowest fruit firmness (8.45 lb/inch^2) was recorded on the 7th harvesting date in Tropic Sweet. Similarly the fruit firmness declined marginally upto 5th sampling date the (9.75 lb/inch^2) in Early Grande and declined thereafter at faster pace. However the cultivars Florida Prince and Pratap registered low firmness decline upto 4th sampling dates, recording 10.03 lb/inch^2 and 10.15 lb/inch^2 fruit firmness values, respectively. A significant decline in fruit firmness was noticed after 4th sampling dates in these cultivars.

Garg *et al.* (1975) reported optimum harvest maturity reading in Crawfords Early and Golden Bush peaches with fruit firmness recording 6.5 lb/inch^2 and 15.0 lb/inch^2, respectively. In Elberta peach, Dhuria *et al.* (1978) reported 2.04 kg/cm^2 pressure at maturity. Early season peach, plum and nectarine varieties were usually less firmer than the late season varieties. However, flesh firmness alone was not found to be the satisfactory maturity index

because flesh firmness for a given variety varied according to fruit size, climatic conditions, and cultural practices (McDonald and Delwiche, 1983; Delwiche, 1987 and Kader and Mitchell, 1989a). The peach fruit harvested at 10 - 12 pounds-force firmness at picking will ripen after harvest and attain better quality than those of 12 to 15 lbs/ $inch^2$ (Kader and Mitchell, 1989a and Kader and Mitchell, 1989b). Badiyala and Awasthi (1990) stated that the maturity standards for peach harvest vary from cultivar to cultivar and the agro-climatic conditions. Chanana *et al* (1992) evaluated some low chilling peach introductions for the suitability in Punjab plains and concluded that the two introductions TA-170 and 5-2 were very suitable for cultivation in the area because of early ripening, superior quality and better finnness of the fruit. The fruit firmness at maturity was maximum in TA-170 (15.20 $lbs/inch^2$) and and minimum in Flordasun (10.10 $lbs/inch^2$).Tandon (2006) evaluated peach cultivars under Solan (Nauni) condition fruit firmness varied from 1.05 kg/cm^2 (Jewel) to 1.20 kg/cm^2 (Gold Prince).

Table 4.6 Effect of picking maturity on the fruit firmness of different low chill Peach cultivars

Treatments	Harvest Date	Fruit firmness ($lb/inch^2$)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	May, 06	10.18	10.31	10.28	10.43	10.30
D_2	May, 09	10.16	10.27	10.26	10.41	10.28
D_3	May, 12	10.09	10.19	10.21	10.31	10.20
D_4	May, 15	9.93	9.98	10.03	10.15	10.02
D_5	May, 18	9.68	9.75	9.76	9.97	9.79
D_6	May, 21	8.56	8.25	8.23	8.56	8.40
D_7	May, 24	8.45	7.89	7.25	7.78	7.84
Mean		9.58	9.52	9.43	9.66	
$CD_{(0.05)}$ Cultivar (C) : 0.15 Date of Harvesting (D) : 0.20 C X D : 0.40						

Maness *et al.* (1992) studied the variability in mesocarp firmness of peach fruit at 4 harvesting stages. They observed that average mesocarp firmness decreased with advancement of fruit maturity and internal variation in firmness for the middle and outer mesocarp regions was found highly cultivar dependent. Firmness decreased longitudinally from the stem end to the blossom end and latitudinally from the suture to the cheeks.

Kan *et al*. (2013) studied the modifications in cell wall ultrastructure, cell wall polysaccharides, and the activities of some enzymes involved in cell wall degradation during

the development and ripening of 'Honey' peach fruit from Stage I (very immature) to Stage V (over-ripe). The results indicated a decrease in fruit firmness accompanied by an increase in ethylene production during peach ripening. Major changes in cell wall structure included the degradation of middle lamella and eventual disruption of the primary cell wall.

Park and Ko (1986) studied the physiological changes during post-harvest ripening of peach cv. Okubu. The total pectin content of peaches decreased slightly but there was a marked increase in water-soluble pectin after 6 days of ripening. Peaches held at room temperature for 2 days after harvest and cold storage for 4 days at 5^{o}C were firmer than those held for 6 days at room temperature. Polygalacturonase activity increased during ripening. There was considerable weight loss from peaches during ripening. Eating quality of peaches was highest at 6 days after post-harvest ripening.

4.1.6 Pulp stone Ratio

The fruit pulp stone ratio increased rapidly in the initial harvesting dates in all the cultivars but the rate of increase was slower down with the advancing maturity (Table 4.7). However, the pulp stone ratio increased rapidly upto 7th date of sampling in Tropic Sweet, Early Grande and Florida price recording 13.07, 22.94, 18.18 values, respectively. However, the cultivar Pratap recorded significant increase in pulp stone ratio upto 6th sampling date (21.46).

Table 4.7 Effect of picking maturity on the pulp stone ratio of different low chill Peach cultivars

Treatments	Harvest Date	Fruit Pulp Stone Ratio				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	4.18	9.46	5.88	11.03	7.64
D_2	**May, 09**	6.53	13.09	8.70	11.04	9.84
D_3	**May, 12**	7.35	13.21	10.34	12.26	10.79
D_4	**May, 15**	8.81	14.05	10.72	12.56	11.54
D_5	**May, 18**	10.47	19.12	12.70	17.96	15.06
D_6	**May, 21**	12.64	20.25	15.50	21.46	17.46
D_7	**May, 24**	13.07	22.94	18.18	21.50	18.92
Mean		41.37	9.01	16.02	11.72	15.40
$CD_{(0.05)}$ Cultivar (C) : 0.21 Date of Harvesting (D) : 0.28 C X D : 0.56						

Prerak and Kaul, (2002) reported that the pulp weight varied from 92.32 g in Shan-i-Punjab to 120.44 g in Pratap. The pulp/stone ratio was found minimum in Pratap and maximum in Flordasun.

4.1.7 Total soluble solids

The data recorded on the periodic changes in total soluble solids (TSS) during fruit maturity are presented in Table 4.8. It is revealed that total soluble solids increased significantly throughout the sampling period. The highest (15.81%) TSS was recorded on 7th harvesting date in Tropic Sweet, Early Grande (13.85%), Florida Prince (13.97%) and Pratap (14.71%).

Table 4.8 Effect of picking maturity on the total soluble solids of different low chill Peach cultivars

Treatments	Harvest Date	Total soluble solids (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	10.55	11.53	10.32	11.51	10.98
D_2	**May, 09**	12.14	12.35	11.15	12.61	12.06
D_3	**May, 12**	13.78	12.68	12.69	13.32	13.12
D_4	**May, 15**	14.64	13.05	13.25	14.27	13.80
D_5	**May, 18**	15.17	13.43	13.49	14.46	14.04
D_6	**May, 21**	15.49	13.75	13.84	14.66	14.44
D_7	**May, 24**	15.81	13.85	13.97	14.71	14.59
Mean		41.37	13.94	12.95	12.62	13.65
$CD_{(0.05)}$ Cultivar (C) : 0.26 Date of Harvesting (D) : 0.35 C X D : 0.69						

Prerak and Kaul (2002) reported that the total soluble solids content varied from 13.4 ^{0}B in Shan-i- Punjab to 13.8 ^{0} B in Flordasun. The total titratable acidity was minimum in Flordasun and maximum in Pratap. The total TSS/acidity ratio varied from 21.26 in Shan-i-Punjab to 23.44 in Flordasun.

4.1.8 Total sugars

The observations pertaining total sugars content revealed that total sugars increased significantly upto 7th sampling date in Tropic Sweet, upto 5th sampling date in Early Grande and 6th sampling date in Florida Prince and Pratap cultivar (Table 4.9). The total sugars

content on the aforesaid sampling dates was found to be 11.86 per cent, 9.94 per cent, 10.38 per cent, 11.00 per cent inTropic Sweet, Early Grande, Florida Prince and Pratap, respectively.

Table 4.9 Effect of picking maturity on the total sugars of different low chill Peach cultivars

Treatments	Harvest Date	Total sugars (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	7.39	8.07	7.22	8.06	7.69
D_2	**May, 09**	8.62	8.77	7.92	8.95	8.57
D_3	**May, 12**	9.92	9.13	9.14	9.59	9.45
D_4	**May, 15**	10.69	9.53	9.67	10.42	10.08
D_5	**May, 18**	11.23	9.94	9.69	10.70	10.39
D_6	**May, 21**	11.62	10.31	10.38	11.00	10.83
D_7	**May, 24**	11.86	10.39	10.48	11.03	10.94
Mean		41.37	10.19	9.45	9.21	9.96
$CD_{(0.05)}$ Cultivar (C) : 0.18 Date of Harvesting (D) : 0.23 C X D : 0.47						

Ozelkok *et al.* (1997) observed that total sugars content was found to be best practical methods for adjudging harvest maturity in nectarine cvs. Nectared-6 and Independence with 14-15 lb/inch^2 firmness and 11.00 per cent TSS which were suitable for determining minimum acceptable maturity. Singh and Arora (1998) picked the fruits of peach cvs. Saharanpur Prabhat and Flordasun at 3 days intervals from 61 days after petal fall to 70 days after petal fall. They reported that the fruits attained their optimum size and qualitative characteristics on 67th days after petal fall. At this stage, the total sugars contents were recorded to be 13.37 per cent and 11.82 per cent in Saharanpur Prabhat and Flordasun cultivars, respectively.

4.1.9 Reducing sugars

Data pertaining to reducing sugars (Table 4.10) revealed that the reducing sugars increased significantly up to 6th harvesting date and after that no significant increase was noticed till 7th harvesting date in Tropic Sweet. The reducing sugars contents increased significantly upto 5th sampling date (7.35%) in Early Grande and 4th sampling date (7.06% and 7.60%, respectively) in Florida Prince and Pratap. The reducing sugars content almost followed similar trend as that of total sugars.

Table 4.10 Effect of picking maturity on fruit reducing sugar of different low chill Peach cultivars

Treatments	Harvest Date	Reducing sugars (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	May, 06	5.17	5.65	5.06	5.64	5.38
D_2	May, 09	6.12	6.23	5.62	6.36	6.08
D_3	May, 12	7.14	6.57	6.58	6.91	6.80
D_4	May, 15	7.80	6.95	7.06	7.60	7.35
D_5	May, 18	8.31	7.35	7.17	7.92	7.69
D_6	May, 21	8.71	7.73	7.79	8.25	8.12
D_7	May, 24	8.89	7.79	7.86	8.27	8.20
Mean		41.37	7.45	6.90	6.73	7.28
$CD_{(0.05)}$ Cultivar (C) : 0.12 Date of Harvesting (D) : 0.16 C X D : 0.33						

Ravi and Tshering (2001) found that total sugars ranged from 7.64 per cent (Flordared) to 8.35 per cent (Shan-i-Punjab). The reducing sugars were recorded to be 4.12, 4.23 and 3.66 per cent and non-reducing sugars with 3.93, 4.12 and 3.98 per cent in Flordasun, Shan-i-Punjab and Flordared, respectively.

4.1.10 Non-reducing sugars

The observations on the non-reducing sugars revealed that the non-reducing sugars increased significantly up to 7th harvesting date in Tropic Sweet and Early Grande. However, the differences between harvesting dates with respect to non-reducing sugars content did not follow any trend in increase/ decrease in Florida Prince and Pratap cultivars.

Table 4.11 Effect of picking maturity on the non-reducing sugar of different low chill Peach cultivars

Treatments	Harvest Date	Non-reducing sugars (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	May, 06	2.10	2.30	2.06	2.30	2.19
D_2	May, 09	2.37	2.42	2.18	2.47	2.36
D_3	May, 12	2.64	2.43	2.43	2.55	2.51
D_4	May, 15	2.74	2.44	2.48	2.67	2.58
D_5	May, 18	2.76	2.45	2.39	2.64	2.56
D_6	May, 21	2.77	2.45	2.47	2.61	2.58
D_7	May, 24	2.82	2.47	2.49	2.62	2.60
Mean		2.60	2.42	2.36	2.55	
$CD_{(0.05)}$ Cultivar (C) : 0.04 Date of Harvesting (D) : 0.05 C X D : 0.10						

Guizani *et al.* (2019) recorded a significant rise in sugars and soluble solids content and a decrease in citric and malic acids during ripening.

4.1.11 Titratable acidity

The data presented on the titratable acidity (Table 4.12) revealed a significant decline upto last sampling date,recording 0.65 per cent in Tropic Sweet, 0.71 per cent in Early Grande, 0.67 per cent in Florida Prince and 0.68 per cent in Pratap. Mehrotra *et al.* (1988) studied the performance of some peach cultivars under Patiala conditions and recorded that titratable acidity ranged from 0.80 per cent in Shan-i-Punjab as maximum to 0.38 per cent in Sharbati as minimum.

Table 4.12 Effect of picking maturity on the titratable acidity of different low chill Peach cultivars

Treatments	Harvest Date	Titratable acidity (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	May, 06	0.97	0.94	0.91	0.93	0.94
D_2	May, 09	0.89	0.91	0.86	0.84	0.88
D_3	May, 12	0.85	0.87	0.81	0.80	0.83
D_4	May, 15	0.83	0.77	0.72	0.74	0.77
D_5	May, 18	0.78	0.73	0.69	0.69	0.72
D_6	May, 21	0.72	0.72	0.68	0.68	0.70
D_7	May, 24	0.65	0.71	0.67	0.68	0.68
Mean		0.81	0.81	0.76	0.77	
$CD_{(0.05)}$ Cultivar (C) : 0.01 Date of Harvesting (D) : 0.02 C X D : 0.03						

4.1.12 Sugar acid ratio

The observations on the sugar acid ratio revealed that the sugar acid ratio increased rapidly till 2nd harvesting date in the all the cultivars under study and increased at slower pace thereafter (Table4.13). The highest sugar acid ratio was found on the 7th sampling dates exhibiting 18.25, 14.63, 15.64 and 16.22, respectively in cultivars Tropic Sweet, Early Grande, Florida Prince and Pratap. The increase in sugar acid ratio of different cultivar under study with the advancement of maturity may attributed to be increase in total sugars content and decrease in titratable acid content .

Table 4.13 Effect of picking maturity on fruit sugar acid ratio of different low chill Peach cultivars

Treatments	Harvest Date	Sugar acid ratio				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	May, 06	7.62	8.59	7.93	8.67	8.20
D_2	May, 09	9.69	9.64	9.21	10.65	9.80
D_3	May, 12	11.67	10.49	11.28	11.99	11.36
D_4	May, 15	12.88	12.38	13.43	14.08	13.19
D_5	May, 18	14.40	13.62	14.04	15.51	14.39
D_6	May, 21	16.14	14.32	15.26	16.18	15.48
D_7	May, 24	18.25	14.63	15.64	16.22	16.19
Mean		12.95	11.95	12.40	13.33	
$CD_{(0.05)}$ Cultivar (C) : 0.19 Date of Harvesting (D) : 0.25 C X D : 0.49						

4.2 EFFECT OF HARVEST MATURITY ON THE STORAGE BEHAVIOR OF PEACH

The fruits of all the four cultivars harvested on seven different dates at 3 days interval were subject to one week storage at ambient temperature and analyzed for physico-chemical parameters.

4.2.1 Physiological Loss in Weight

The per cent physiological loss in weight (PLW) after one week storage at ambient temperature was recorded to be the highest in fruits from earlier sampling dates in all the cultivars. The per cent PLW declined to record the lowest values on a particular date specific to the cultivar and again followed an upward trend. The data presented in Table 4.14 on physiological loss in weight revealed that the minimum per cent physiological loss in weight was recorded in 7^{th} sampling date in Tropic Sweet, 5^{th} sampling date in Early Grande and 4^{th} sampling dates in both the cultivars namely; Florida Prince and Pratap, recording 10.43%, 10.19%, 8.28% and 8.91 %, respectively.

Table 4.14 Effect of picking maturity on the physiological loss in weight (PLW) of different low chill Peach cultivars after one week storage at ambient temperature

Treatments	Harvest Date	Physiological Loss in Weight (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	12.64	10.85	14.28	11.57	12.34
D_2	**May, 09**	11.11	12.38	11.01	11.76	11.57
D_3	**May, 12**	11.29	21.18	13.74	10.24	14.11
D_4	**May, 15**	14.28	15.51	8.28	8.91	11.75
D_5	**May, 18**	13.79	10.19	12.19	9.33	11.38
D_6	**May, 21**	12.09	12.50	11.38	12.96	12.23
D_7	**May, 24**	10.43	19.23	18.18	12.83	15.17
Mean		12.23	14.55	12.72	11.09	
$CD_{(0.05)}$ Cultivar (C) : 0.21 Date of Harvesting (D) : 0.27 C X D : 0.54						

Khan *et al.* (2016) reported significant variations in fruit quality of different cultivars during ripening at ambient conditions. Maximum ascorbic acid content and total sugars were observed in '5-A' fruit at ripening day 5. Per cent physiological loss in fruit weight was lower in cv. '8-A'. It was also noticed that cultivars '8-A' and 'Tex-6A-69' had the best physico-chemical properties and better eating quality after 4 days ripening at ambient condition.

Gupta and Jawandha (2010) reported that the fruit quality parameters changed according to the stage of harvest. An increase in the spoilage, physiological loss in weight, TSS: acid ratio and anthocyanins were noticed with the advancement of maturity and storage period. There was a gradual decrease in reducing sugars of the fruits picked at optimum maturity with increase in storage period. Fruits harvested at optimum stage retained maximum TSS: acid ratio and palatability rating after 3 days storage at ambient temperature. The results also revealed that the peach fruits harvested at optimum stage can be stored with post-storage shelf life of 3 days at ambient temperature.

4.2.2 Total Soluble solids

The data recorded on the total soluble solids of peach fruits after one week storage at ambient temperature as influenced by different harvesting dates are presented in Table 4.15. It is revealed that total soluble solids increased significantly till 3rd harvesting date in Tropic

Sweet and thereafter a gradual increase was observed up to 7th harvesting date. The highest (17.39 %) total soluble solids were recorded on 7th harvesting date. Similarly, the TSS contents of other cultivars increased gradually with the advancement of picking maturity. However, the rate of increase was slower down after 5th picking date in Early Grande and 4th sampling dates in Florida Prince and Pratap. The highest TSS contents were recorded for the aforesaid cultivars on the 7th picking dates, recording 15.24%, 15.37% and 16.18% values in Early Grande, Florida Prince and Pratap, respectively.

Table 4.15 Effect of picking maturity on the total soluble solids of different low chill peach cultivars after one week storage at ambient temperature

Treatments	Harvest Date	Total soluble solids (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	11.61	12.68	11.35	12.66	12.08
D_2	**May, 09**	13.35	13.59	12.27	13.87	13.27
D_3	**May, 12**	15.16	13.95	13.96	14.65	14.43
D_4	**May, 15**	16.10	14.36	14.58	15.70	15.18
D_5	**May, 18**	16.69	14.77	14.40	15.91	15.44
D_6	**May, 21**	17.04	15.13	15.22	16.13	15.88
D_7	**May, 24**	17.39	15.24	15.37	16.18	16.04
Mean		12.23	15.33	14.24	13.88	15.01
$CD_{(0.05)}$ Cultivar (C) : 0.29 Date of Harvesting (D) : 0.38 C X D : 0.77						

Gupta and Jawandha (2010) studied the effect of picking maturity on the storage performance of 'Early Grande' Peaches. The fruits for storage were harvested at three stages i.e. before, during and after predictable optimum harvest stage and kept in cold store (0-20^{o}C, 85-90 % RH for a period of 21 days and at ambient conditions (28-30 ^{o}C, 65-70% RH) for 72 h. The fruits were evaluated for quality parameters at harvest and after 7, 14 and 21 days of storage. The post-cold storage shelf-life was studied after 3 days to assess the market behaviour of fruits. The fruit quality parameters changed according to stage of harvest. An increase in the spoilage, physiological loss in weight, TSS: acid ratio and anthocyanins were noticed with the advancement of maturity and storage period. There was a gradual decrease in reducing sugars of the fruits picked after optimum maturity with increase in storage period. Fruits harvested at optimum stage retained maximum TSS:acid ratio and palatability rating after 3 days storage at ambient temperature. The results also revealed that peach fruits

harvested at optimum stage can be stored with post-storage shelf life of 3 days at ambient temperature.

Guizani *et al.* (2019) studied the physiological behaviors and fruit quality changes in five peach cultivars during three ripening stages in a semi-arid climate. Fruit quality, sugar and organic acids profile as well as bioactive compounds and antioxidant activities were investigated in exocarp and mesocarp during three ripening stages (1, 2 and 3). The results showed a signifcant diference in chlorophyll content and assimilation rate among cultivars. In addition, signifcant differences were noticed in total phenol contents among cultivars during stage 1. During ripening, there was a signifcant rise in sugar and soluble solids content. Phenolic compounds decreased during ripening. The results indicated that fruit in stage 1 was more abundant in organic acid and phenolic compounds, while fruit in stage 3 was less firm and had best color.

4.2.3 Titratable acidity

The data presented on the titratable acidity after one week storage of fruits (Table 4.16) revealed a significant declining trend up to 7rd harvesting date in all the cultivars understudy. The lowest titratable acidity was recorded on 7th harvesting dates in Tropic Sweet (0.48 %), Early Grande (0.53 %), Florida Prince (0.50 %), and Pratap (0.50 %) .

Table 4.16. Effect of picking maturity on the titratable acidity of different low chill peach cultivars after one week storage at ambient temperature

Treatments	Harvest Date	Titratable acidity (%)				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	0.78	0.75	0.73	0.74	0.75
D_2	**May, 09**	0.70	0.72	0.69	0.66	0.69
D_3	**May, 12**	0.66	0.68	0.63	0.62	0.65
D_4	**May, 15**	0.64	0.59	0.55	0.57	0.59
D_5	**May, 18**	0.59	0.55	0.53	0.52	0.55
D_6	**May, 21**	0.54	0.54	0.51	0.51	0.53
D_7	**May, 24**	0.48	0.53	0.50	0.50	0.50
Mean		0.63	0.62	0.59	0.59	
$CD_{(0.05)}$ Cultivar (C) : 0.42 Date of Harvesting (D) : 0.55 C X D : 1.10						

Guizani *et al.* (2019) studied the physiological behaviors and fruit quality changes in five peach cultivars during three ripening stages in a semi-arid climate. Fruit quality, sugar and organic acids profile as well as bioactive compounds and antioxidant activities were investigated in exocarp and mesocarp during three ripening stages (1, 2 and 3). The results showed a significant difference in chlorophyll content and assimilation rate among cultivars. In addition, significant differences were noticed in total phenol contents among cultivars during stage 1. During ripening, there was a signifcant decrease in citric and malic acids in addition to titratable acidity.

4.2.4 TSS acid ratio

The observations on the TSS acid ratio revealed that the TSS acid ratio increased significantly upto 7th picking date in Tropic Sweet, 6th picking date in Early Grande, 4th picking date for the cultivar Florida Prince and 5th picking date for Pratap (Table 4.17). The values recorded for TSS acid ratios on these date were 36.23, 28.02, 26.51 and 30.60 for Tropic Sweet, Early Grande, Florida Prince and Pratap, respectively.

Table 4.17 Effect of picking maturity on TSS acid ratio of different Peach cultivars after one week storage at ambient storage

Treatments	Harvest Date	TSS Acid ratio				
		Cultivars				
		Tropic Sweet	Early Grande	Florida Prince	Pratap	Mean
D_1	**May, 06**	14.88	16.91	15.55	17.11	16.11
D_2	**May, 09**	19.07	18.88	17.78	21.02	19.19
D_3	**May, 12**	22.97	20.51	22.16	23.63	22.32
D_4	**May, 15**	25.16	24.34	26.51	27.54	25.89
D_5	**May, 18**	28.29	26.85	27.17	30.60	28.23
D_6	**May, 21**	31.56	28.02	29.84	31.63	30.26
D_7	**May, 24**	36.23	28.75	30.74	32.36	32.02
Mean		25.45	23.47	24.25	26.27	
$CD_{(0.05)}$ Cultivar (C) : 0.42 Date of Harvesting (D) : 0.55 C X D : 1.10						

Khan *et al.* (2016) analyzed the ripening behaviour of different peach cultivars during ripening by evaluating their physiological parameters namely, weight loss, respiration rate and ethylene production, physical (fruit firmness) and biochemical parameters viz.; Total

soluble solids, titratable acidity, SSC:TA ratio, ascorbic acid, total sugars, reducing sugars, non-reducing sugars, total carotenoids, antioxidant activity and total phenolics. The fruits of five different peach cultivars were collected from two districts and were kept at ambient conditions in laboratory for five days. The fruits were evaluated for various physico-chemical attribute during ripening period. The results revealed significant variations in fruit quality of all cultivars during ripening at ambient conditions. At day-5 of ripening, cultivar '8-A' exhibited maximum SSC; whereas, lowest SSC was measured in 'Flordaking'. Maximum ascorbic acid content and total sugar were observed in '5-A' fruit at ripening day 5; while, maximum total antioxidant, total phenolic content and total carotenoids content were noted in cultivar 'Tex-6A-69'. Maximum fruit firmness was recorded in cultivars '5-A'. Per cent physiological loss in fruit weight was lower in cv. '8-A'. It was also noticed that cultivars '8-A' and 'Tex-6A-69' had the best physico-chemical properties and better eating quality after 4 days ripening at ambient condition.

Chapter-5

SUMMARY AND CONCLUSION

The results obtained in the present investigation entitled **"Standardization of harvest maturity for low chill cultivars of Peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh"** are summarized and the conclusion drawn from the salient findings are presented hereunder:

5.1 STANDARDIZATION OF OPTIMUM HARVEST MATURITY

5.1.1 The optimum harvest maturity was attained on 24th May in Tropic Sweet, 18th May in Early Grande, 15th May in both the cultivars namely; Florida Prince and Pratap. In terms of days from full bloom (DFFB), these dates corresponded to 102, 93, 87 & 89 days for Tropic Sweet, Early Grande, Florida Prince and Pratap cultivars, respectively.

5.1.2 The observations on the effect of harvest maturity on fruit colour revealed a clear-cut difference upto to 7th picking date in Tropic sweet, 5th picking date in Early Grande and 4th picking date in Florida Prince and Pratap. Hence ,the fruit colour was regarded as reliable estimate of maturity.

5.1.3 The fruit weight increased throughout the sampling period in all the cultivars in Tropic sweet, the rapid increase in fruit weight was observed up to the 7th sampling date (72.10 g). In Early Grande, the fruit weight increased significantly until 5th sampling date (85.27g). However, Florida Prince and Pratap cultivars, registered significant increase in fruit weight up to the 4th sampling date, recording 74.37g and 85.24 g, respectively.

5.1.4 The lowest fruit firmness (8.45 lb/inch^2) was recorded on the 7th harvesting date in Tropic Sweet. However the cultivars Florida prince and Pratap registered firmness values upto 4th sampling dates, recording 10.03 lb/inch^2 and 10.15 lb/inch^2 values, respectively.

5.1.5 The fruit pulp: stone ratio increased rapidly upto 7th date of sampling in Tropic Sweet, Early Grande and Florida Prince, recording 13.07, 22.94, 18.18 values respectively. However, the cultivar Pratap recorded significant increase in pulp stone ratio upto 6th sampling date (21.46) and exhibited non significant differences with 7th sampling date.

5.1.6 The total soluble solids increased significantly throughout the sampling. The highest tota soluble solids were recorded on 7th harvesting date in Tropic Sweet (15.81 %), Early Grande (13.85%), Florida prince (13.97%) and Pratap (14.71%).

5.1.7 The observations pertaining to total sugars content revealed that total sugars increased significantly upto 7th sampling date in tropic sweet, upto 5th sampling date in Early Grande and 6th sampling date in Florida prince and Pratap cultivars .The total sugars content on the aforesaid sampling dates was found to be 11.86 per cent, 9.94 per cent, 10.38 per cent, 11.00 per cent in Tropic Sweet, Early Grande, Florida prince and Pratap, respectively. The reducing and non-reducing sugars content followed almost similar trend as that of total sugars.

5.1.8 The titratable acidity recorded a significant decline upto last sampling date ,recording 0.65 per in Tropic Sweet cent, 0.71 per cent in Early Grande, 0.67 per cent in Florida Prince and 0.68 per cent in Pratap.

5.1.9 The sugar acid ratio increased rapidly till 2nd harvesting date in all the cultivars under study and increased at slower pace thereafter. The highest sugar acid ratio was found on the 7th sampling dates exhibiting 18.25, 14.63, 15.64 and 16.22, respectively in cultivars Tropic Early Grande, Florida prince and Pratap cultivars, respectively.

5.2 EFFECT OF HARVEST MATURITY ON THE STORAGE BEHAVIOR OF PEACH

5.2.1 The per cent physiological loss in weight (PLW) after one week storage at ambient temperature (25±2°C) was recorded to be the highest in fruits from earlier sampling dates in all the cultivars. The PLW declined to record the lowest values on a particular date specific to the cultivar. The minimum per cent physiological loss in weight was recorded in 7th sampling date in Tropic sweet, 5th sampling date in Early Grande and 4th sampling date in both the cultivars namely; Florida Prince and Pratap, recording. The minimum PLW in said cultivar to be 10.43%, 10.19%, 8.28% and 8.91%, respectively.

5.2.2 The total soluble solids of peach fruits after one week storage at ambient temperature as influenced by different harvesting dates recorded. The highest TSS contents for the aforesaid cultivars on the 7th picking dates, recording 17.39%, 15.37% and 16.18% values in Tropic Sweet, Early Grande, Florida Prince and Pratap, respectively.

5.2.3 The titratable acidity after one week storage of fruits was recorded lowest on 7th harvesting date in Tropic Sweet (0.48 %), Early Grande (0.53 %), Florida Prince (0.50 %), and Pratap (0.50 %) .

5.2.4 The TSS acid ratio increased significantly upto 7th picking date in Tropic Sweet, 6th picking date in Early Grande and 4th picking date for Florida Prince and 5th picking date for Pratap. The values recorded on these date were 36.23, 28.02, 26.51 and 30.60 for Tropic Sweet, Early Grande Florida Prince and Pratap, respectively.

CONCLUSION

On the basis of physico-chemical characteristics of the fruits, 24th May for Tropic Sweet (102 DFFB), 18th May for Early Grande (93 DFFB) and 15th May (87 DFFB & 89 DFFB, respectively) for both cultivars namely; Florida Prince and Pratap were adjudged as the optimum harvest dates. The fruits harvested on these dates exhibited best storage performance after one week storage at ambient temperature. Among different maturity indices, DFFB, fruit colour, TSS and Total sugars were found to be the dependent indices of maturity for low chill cultivars under study.

The present study will help the farmers of mid-hills by suggesting the right stage of maturity for the aforesaid low-chill cultivars which are commercially grown in north Indian plains. This will also help the farmers to expand the area under peach cultivation in Himachal Pradesh as the traditional cultivars like July Elberta have shown decline in production under changing climatic scenario.

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APPENDIX – I (A)

Effect of picking maturity on Fruit length of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.699			
Variety	3	3,552.896	1,184.299	717.730	0.00000
Date of Harvesting	6	703.622	117.270	71.070	0.00000
Interaction V X D	18	220.001	12.222	7.407	0.00000
Error	54	89.103	1.650		
Total	83	4,566.321			

APPENDIX – I (B)

Effect of picking maturity on Fruit diameter of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.173			
Variety	3	1,078.072	359.357	242.648	0.00000
Date of Harvesting	6	1,954.867	325.811	219.997	0.00000
Interaction V X D	18	287.693	15.983	10.792	0.00000
Error	54	79.973	1.481		
Total	83	3,400.778			

APPENDIX – I (C)

Effect of picking maturity on Fruit weight of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.669			
Variety	3	5,223.845	1,741.282	496.323	0.00000
Date of Harvesting	6	6,012.382	1,002.064	285.621	0.00000
Interaction V X D	18	766.038	42.558	12.130	0.00000
Error	54	189.452	3.508		
Total	83	12,196.385			

APPENDIX – I (D)

Effect of picking maturity on Fruit firmness of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Variety	3	0.576	0.192	3.202	0.03036
Date of Harvesting	6	72.356	12.059	201.202	0.00000
Interaction V X D	18	2.394	0.133	2.219	0.01256
Error	54	3.237	0.060		
Total	83	78.588			

APPENDIX – I (E)

Effect of picking maturity on Fruit pulp stone ratio of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.057			
Variety	3	681.545	227.182	1,935.321	0.00000
Date of Harvesting	6	1,260.135	210.023	1,789.145	0.00000
Interaction V X D	18	67.366	3.743	31.882	0.00000
Error	54	6.339	0.117		
Total	83	2,015.441			

APPENDIX – I (F)

Effect of picking maturity on Fruit TSS of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.182			
Variety	3	23.573	7.858	44.109	0.00000
Date of Harvesting	6	128.322	21.387	120.058	0.00000
Interaction V X D	18	13.088	0.727	4.082	0.00003
Error	54	9.619	0.178		
Total	83	174.784			

APPENDIX – I (G)

Effect of picking maturity on Fruit total sugar of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.066			
Variety	3	12.797	4.266	52.309	0.00000
Date of Harvesting	6	106.100	17.683	216.849	0.00000
Interaction V X D	18	6.972	0.387	4.750	0.00000
Error	54	4.404	0.082		
Total	83	130.338			

APPENDIX – I (H)

Effect of picking maturity on Fruit reducing sugar of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.111			
Variety	3	6.897	2.299	57.683	0.00000
Date of Harvesting	6	80.971	13.495	338.583	0.00000
Interaction V X D	18	3.763	0.209	5.245	0.00000
Error	54	2.152	0.040		
Total	83	93.895			

APPENDIX – I (I)

Effect of picking maturity on Fruit Non-reducing sugar of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.001			
Variety	3	0.794	0.265	72.858	0.00000
Date of Harvesting	6	1.677	0.280	76.926	0.00000
Interaction V X D	18	0.475	0.026	7.255	0.00000
Error	54	0.196	0.004		
Total	83	3.144			

APPENDIX – I (J)

Effect of picking maturity on Fruit titratable acidity of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.001			
Variety	3	0.044	0.015	39.870	0.00000
Date of Harvesting	6	0.679	0.113	306.381	0.00000
Interaction V X D	18	0.027	0.002	4.117	0.00003
Error	54	0.020	0.000		
Total	83	0.771			

APPENDIX – I (K)

Effect of picking maturity on fruit sugar acid ratio of different low chill Peach cultivars

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.356			
Variety	3	23.075	7.692	86.090	0.00000
Date of Harvesting	6	640.724	106.787	1,195.235	0.00000
Interaction V X D	18	24.969	1.387	15.526	0.00000
Error	54	4.825	0.089		
Total	83	693.948			

APPENDIX – II (A)

Effect of picking maturity on Fruit physiological loss in weight of different low chill Peach cultivars after one week storage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.444			
Variety	3	130.849	43.616	397.523	0.00000
Date of Harvesting	6	148.463	24.744	225.519	0.00000
Interaction V X D	18	434.639	24.147	220.075	0.00000
Error	54	5.925	0.110		
Total	83	720.320			

APPENDIX – II (B)

Effect of picking maturity on Fruit TSS of different low chill peach cultivars after one week storage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.165			
Variety	3	28.457	9.486	43.304	0.00000
Date of Harvesting	6	155.373	25.896	118.219	0.00000
Interaction V X D	18	15.793	0.877	4.005	0.00004
Error	54	11.829	0.219		
Total	83	211.616			

APPENDIX – II (C)

Effect of picking maturity on fruit Titratable acidity of different Peach cultivars after one week storage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.000			
Variety	3	0.026	0.009	45.538	0.00000
Date of Harvesting	6	0.611	0.102	539.063	0.00000
Interaction V X D	18	0.019	0.001	5.595	0.00000
Error	54	0.010	0.000		
Total	83	0.666			

APPENDIX – II (D)

Effect of picking maturity on fruit tss acid ratio of different Peach cultivars after one week storage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.056			
Variety	3	97.719	32.573	72.027	0.00000
Date of Harvesting	6	2,496.086	416.014	919.915	0.00000
Interaction V X D	18	106.210	5.901	13.048	0.00000
Error	54	24.420	0.452		
Total	83	2,725.492			

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Title of Thesis	:	**"Standardization of harvest maturity for low chill cultivars of Peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh"**
Name of the Student	:	Lalit Narayan Mishra
Admission Number	:	H-2012-23-M
Major Advisor	:	Dr. Vishal S Rana
Major Field	:	Fruit Science
Minor Field(s)	:	Plant Physiology
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ABSTRACT

The present investigation entitled "Standardization of harvest maturity for low chill cultivars of Peach [*Prunus persica* (L.) Batsch] under mid hill conditions of Himachal Pradesh" were carried out at the experimental orchard of Department of Fruit Science, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) during 2014. The experiment was laid out on 10 years old plants of four commercial low chill cultivars namely; Tropic Sweet, Early Grande, Florida Prince and Pratap. These plants were planted at a spacing 4.5m × 4.5m trained on open center system. The whole program of study was split into two experiments. First experiment was laid out in Randomized Block Design to standardization of optimum harvest maturity for these cultivars. The second experiment was conducted to elucidate the relative storage performance of peach cultivars, harvested at different maturities after one week at ambient temperature. On the basis of physico-chemical characteristics of the fruits and storage behavior for one week at ambient temperature, 24th May for Tropic Sweet (102 DFFB), 18th May for Early Grande (93 DFFB), 15th May (87 DFFB & 89 DFFB, respectively) for both cultivars namely; Florida Prince and Pratap were adjudged as the optimum harvest dates .Among different maturity indices, DFFB, fruit colour, TSS and Total sugars were found to be the dependent indices of maturity for low chill cultivars understudy.

Signature of Major Advisor **Signature of the student**

Countersigned

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