parent. The ranges for Ky 15 backcrosses were similar to those of Ky 9. However, when backcrosses were made to 'Dixieland,' a susceptible selection, the percentages of progenies in the "equal or more resistant" classes were much smaller. Outcrosses showed much the same results as backcrosses except they had larger percentages of their progenies in the resistant classes.

The crossing of selected self lines (Table 2) would seem to offer an excellent opportunity for increasing mite resistance in a population. Note that where Ky 113 was crossed with Ky 51 and Ky 45 the percentage of progenies in the "equal or more resistant" classes were 26.04% and 34.06% respectively.

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Respiratory Climacteric and Chemical Changes in the Mango Fruit, *Mangifera indica* L.[1]

Shanta Krishnamurthy[2] and H. Subramanyam,[3,4]
Central Food Technological Research Institute, Mysore-2A, India

Abstract. The parameters for optimum maturity of fruit of 'Pairi' variety mango, harvested near Mysore from 1964 to 1969, have been found to be 260 ± 20 g in weight, olive green surface color, and outgrown shoulders. In addition, pH and color of the pulp in terms of chromaticity coordinate x were useful indices. Other parameters were not consistent.

Respiration climacteric maximum was delayed in immature fruits and advanced in over-mature fruits. Fruits of optimal maturity recorded the climacteric maximum on the 9th day ± 1 at ambient storage of 26 ± 2°C and 45–65% RH. Sugar accumulation was maximum at about the time of the climacteric peak in respiration and sucrose was predominant. The chemical composition of the fruit was more or less similar over several seasons and harvests.

The mango, *Mangifera indica* native to India, is widely cultivated in tropical areas. The 'Pairi' mango, one of the popular varieties grown in southern parts of India, and also in Florida under the synonym 'Paheri', is excellent for dessert purposes (2). This fruit is gaining importance in international trade and its preservation in a fresh condition for extended periods without loss of quality becomes an urgent problem. Effective preservation in the fresh condition is governed by several factors, such as stage of maturity at harvest, handling and transport conditions, and methods and length of storage.

Physical, chemical, and physiological parameters have been examined by several research workers to define the optimum stage of maturity for harvest. The degree of maturity in mango has been correlated with physical appearance (4), starch content, sugars, specific gravity, and soluble solids (6, 13, 17). In deciduous fruits, the ratio of soluble solids to acids and to total volatile reducing substances (15) have also been recommended. The pre-climacteric minimum has been suggested to be a good index for determining the optimum stage of maturity in apples (5).

Several biochemical investigations on the growth, development and ripening of mango fruit have been reported (10, 11, 16). Maturity is known to influence the chemical composition (13, 15) and respiratory drifts (9, 14, 19) during ripening of several fruits and consequently limits storage life and consumer acceptability (13). An intensive study of factors affecting ripening behaviour have not been reported for the mango. Our purpose was to study the various parameters associated with stage of maturity at harvest and subsequently to examine variations in chemical composition and respiratory climacteric at optimal maturity as related to seasons and time of harvest.

Materials and Methods

Mango fruits were harvested from a group of trees in an orchard near Mysore. Bruised and injured fruits were discarded and sound fruits were graded into 3 groups of physiological maturity based on market practice: Group I—fruits weighing 220 ± 20 g with shoulders in line with the stem end, surface—light green; Group II—fruits weighing 260 ± 20 g with outgrown shoulders and a sunken pit at the stem end, surface—olive green; Group III—fruits weighing 300 ± 20 g with prominent shoulders and deep pit at the stem end, surface—olive green with white dots. Two hundred fruits from 4 replicates for each group were stored at ambient temperature (26 ± 2°C; 45–65% RH) in ventilated wooden crates for ripening. Periodic observations were made for spoilage due to fungi, ripening characters, and loss in weight. Ripening was judged by external appearance, odor, color, and texture of the fruit. Loss in weight was calculated on an individual basis. Respiration rates of single fruits were measured by the Pettenkoffer method. The CO_2 liberated was absorbed in 0.2 N $Ba(OH)_2$ and the excess titrated with 0.2 N HCl. CO_2-free air (1.5 liter/

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hr) was passed through the respiration chamber. Four replicates were run for each group, and the mean value taken. Consumer acceptability trials were conducted on ripe fruits at the end of the storage period by a panel of trained judges as per the hedonic rating system (1).

The flesh homogenate of 5–10 fruits was used for chemical analysis using A.O.A.C. methods (12). Soluble solids were determined on the expressed juice by means of Abbe's refractometer. The pH was measured with a Beckman pH meter using glass electrode. Total acidity of the aqueous extract of the fruit pulp was determined by titration against standard alkali and expressed as per cent anhydrous malic acid. Alcohol insoluble residue was determined after a continuous extraction of the pulp in 80% ethanol in a soxhlet extractor for 12–16 hr and the residue dried to a constant weight at 40°C. The ethanolic extract was used for sugar estimation. Sugars were determined by modified Somogyi's method (7). Non-reducing sugar was expressed as sucrose by difference (total sugars − reducing sugars × 0.95). Total nitrogen was estimated by microkjeldahl method and protein nitrogen by the colorimetric method, using Folin's reagent and expressed as total protein and true protein. Reflectance color of the fruit pulp was measured with a Photovolt Reflectance Meter with search unit 610Y and 3 tristimulus filters; amber, green, and blue. Chromaticity coordinates were calculated according to the standard formula. All estimations were done on 4 replicate samples and the mean value taken.

Fruits harvested from the second week of April to the end of May are referred to as the main season crop, since the bulk of this variety comes to market at this time. Harvests made in December–February are referred to as the off-season crop.

Studies were made on (a) optimal maturity at harvest in 1964, (b) respiratory patterns and chemical changes associated with ripening during 1964–67, and (c) seasonal variations during 1968 and 1969.

Results

Respiration. Fig. 1 shows respiratory patterns of the 3 groups of mangoes, representing different stages of maturity at harvest. Preclimacteric minimum rate of respiration appears to have covered 6 days in Group I and this period was reduced to 3 days in Group III. Respiration rate was low till 6 days in Group II. The climacteric maximum of fruits in Group I occurs on the 12th day after harvest, whereas in Groups II and III it occurs on the 9th day. The quantity of CO_2 liberated was also maximum (317 mg/kg/hr) at the climacteric peak in Group I, indicating high metabolic activity associated with the physiologically immature developmental stage. Fruits in Groups II and III liberated 220–265 mg CO_2/kg/hr at the climacteric peak, which coincided with color-break, odor development and softening—all associated with the ripening of physiologically mature fruit.

Chemical composition. There was little difference in the color of the pulp in Groups II and III. In contrast, fruits of Group I were significantly different from those of Groups II and III. The brightness of the color (Y %) of Group I was low and the value for chromaticity coordinate x was high both at the raw and ripe stages as compared with Groups II and III (Table 1). Among the chemical constituents, soluble solids were high in Group III but were similar in Groups I and II. Total sugars showed an increasing divergence from Group I to III, both at the time of harvest and in the ripe fruit (Table

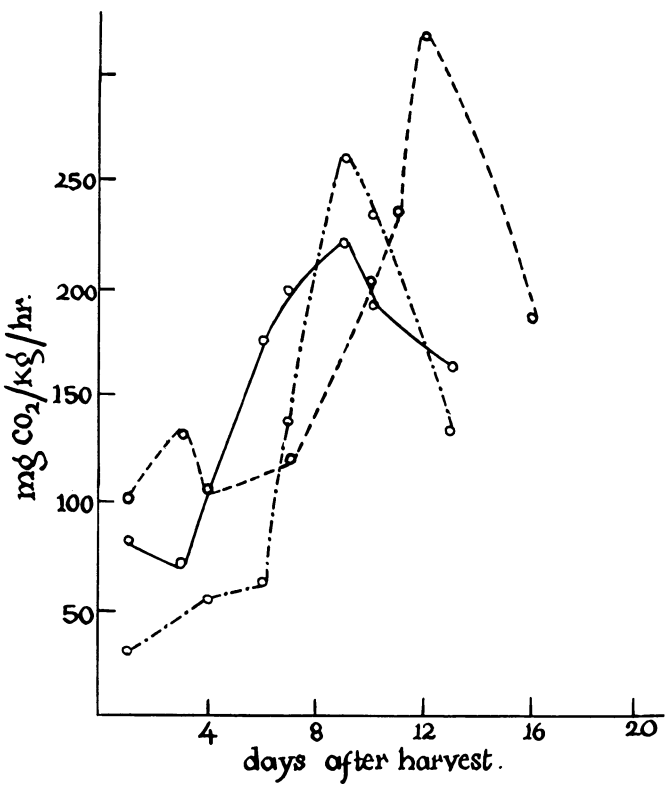

Fig. 1. Respiratory patterns of mango fruit
O — — — — — O Group I—Immature
O — . — . — . — . O Group II—Optimum maturity
O———O Group III—Advanced maturity

2). The alcohol insoluble residue increased from Group I to III in the unripe fruit, but remained more or less constant among ripe fruits. Fruits of Group I showed high acidity and low soluble solids:acid ratio in the ripe fruits. The per cent of cumulative loss in weight of fruits during storage at the climacteric peak was maximum in Group I and more or less similar in Groups II and III (Table 3).

About 85 per cent of the fruits were ripe in Groups II and III on the 13th day when the spoilage was around 16%. In Group I on the other hand, only 8% of the fruits were edible during the same period when spoilage was 31% (Table 3). Even after storage for 16 days, there were only 31% of ripe fruits in this Group and a heavy spoilage of 57% was recorded. Consumer acceptability of ripe fruits in the 3 Groups indicated that fruits of Group III were of excellent quality with respect to texture, flavor, color, and taste. Fruits of Group II were acceptable whereas those of Group I lacked characteristic flavor and were sour to the taste.

Table 1. Post-harvest behaviour of mango fruit; color of the pulp.

Group	Initial (at harvest)			Final (after 14 days)		
	Y%[a]	x[b]	y[b]	Y%[a]	x[b]	y[b]
I	26	0.58	0.45	42.5	0.51	0.41
II	27	0.46	0.44	49.5	0.36	0.41
III	29	0.46	0.45	50.0	0.39	0.43
I ∼ II	NS[c]	***	*	***	***	NS
I ∼ III	*	***	NS	***	***	NS
II ∼ III	NS	NS	*	NS	**	NS

[a]Brightness of the sample as measured by green filter.
[b]Values for x and y represent chromaticity coordinates.
[c]NS-not significant; *, **, ***-Significant at 5%, 1.0% and 0.1% respectively.

Table 2. Post-harvest behaviour of mango fruit; chemical composition (% fresh wt).

Group	Initial (at harvest)								Final[a]							
	Soluble solids	Reducing sugars	Sucrose	Total sugars	Acidity as malic	Soluble solids: acidity	pH	Alcohol insoluble residue	Soluble solids	Reducing sugars	Sucrose	Total sugars	Acidity as malic	Soluble solids: acidity	pH	Alcohol insoluble residue
I	7.0	1.5	0.3	1.8	4.3	1.6	2.2	10.7	12.0	1.9	7.6	9.9	0.5	22	4.0	2.8
II	7.0	1.7	0.2	1.9	4.3	1.6	1.9	11.3	16.5	3.4	8.5	12.3	0.2	82	4.4	3.0
III	8.0	1.8	0.9	2.7	4.5	1.8	1.9	12.9	16.0	2.5	10.1	13.1	0.2	80	4.4	2.8
I ~ II	—	NS[b]	—	NS	NS	NS	***	NS	***	***	—	*	***	***	***	NS
I ~ III	—	NS	—	*	NS	*	***	**	***	**	—	***	***	***	**	NS
II ~ III	—	NS	—	NS	NS	*	NS	*	NS	*	—	NS	*	*	NS	NS

[a]Final analysis was on 14th day of storage in Groups II and III and on 17th day in Group I.
[b]NS—not significant; *, **, ***—significant at 5%, 1.0%, and 0.1 % respectively.

Table 3. Post-harvest behaviour of mango fruit. Losses in weight, ripening behaviour, and spoilage.[a]

	Group I			Group II		Group III		I ~ II[b]	I ~ III	II ~ III[c]
	Cumulative percentage after days									
	12	14	16	9	13	9	13			
Loss in weight	12.48	14.58	—	8.38	13.38	8.13	14.09	***[d]	***	NS
Unripe	95	92	69	92	12	91	16	***	***	NS
Ripe	5	8	31	8	88	9	84	***	***	NS
Spoilage	12	31	57	3	17	2	16	***	***	NS

[a]Spoilage due to stem-end rot, lateral rot, and anthracnose caused by fungi.
[b]For statistical evaluation of ripening and spoilage, 13th day values of groups II and III were compared with 14th day values of group I.
[c]Loss in weight on the 9th day of groups II and III is compared with 12th day of group I.
[d]NS—not significant; ***—significant at 0.1% level.

Seasonal variations. Fruits belonging to Group II which was considered to have optimum maturity based on physical characters were selected for these studies. Respiratory pattern of the fruits was studied by; (a) using the same fruit throughout the ripening period and (b) different fruits selected at random. This was necessary for two reasons: 1) a few numbered fruits used for respiration study spoiled during the experimental period so that different fruits from the same lot had to be selected, and 2) studies on biochemical changes necessitated the sacrifice of the fruit after measuring the rate of respiration. The pattern of respiration as seen in Fig. 2 varied little due to method and this was classified into 4 phases —(1) pre-climacteric phase lasted till 3 days when fruits were green and firm and CO_2 was released at a low rate, (2) climacteric rise continued up to 6 days when a sudden spurt in CO_2 production was observed and fruits remained green and firm, (3) climacteric peak occurred around 9 days resulting in maximum release of CO_2 and fruits at this phase tend to break color, become soft, and develop odor, (4) senescent phase after 10 days when CO_2 release declined, attractive color developed and the fruit was soft with pronounced odor and ripe. The difference in the trends of respiration resulted from different pickings is shown in Fig. 3. The respiratory climacteric peak of fruits harvested at optimum maturity during May occurred on the 9th day after harvest, but it was advanced to 5th day in the late harvest of the same season. Off-season fruits of the December harvest showed the peak on the 12th day after harvest. A similar pattern of respiratory drifts has been recorded in several years for the main crop, except for the low respiration rate in 1964 and the second peak due to overripeness and fungal infection at the end of the storage period (Fig. 4).

Chemical composition of the fruit during ripening is presented in Table 4. The pH increased gradually from 2.4 to 4.0 during the ripening period. Reducing sugars increased from 1.7 to 4.0% whereas the total sugars increased from 2.1 to 12.7%, maximum increase occurring within 7 days after harvest, i.e., prior to the onset of the

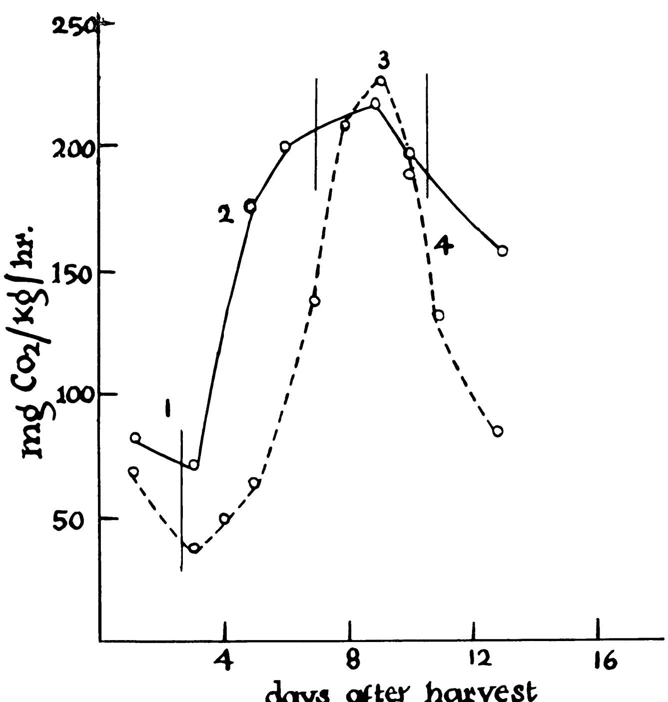

Fig. 2. Respiratory pattern of mango fruit when O————O same fruits and O – – – – O fruits at random were used. 1—Pre-climacteric; 2—Climacteric rise; 3—Climacteric peak; 4—Senescent.

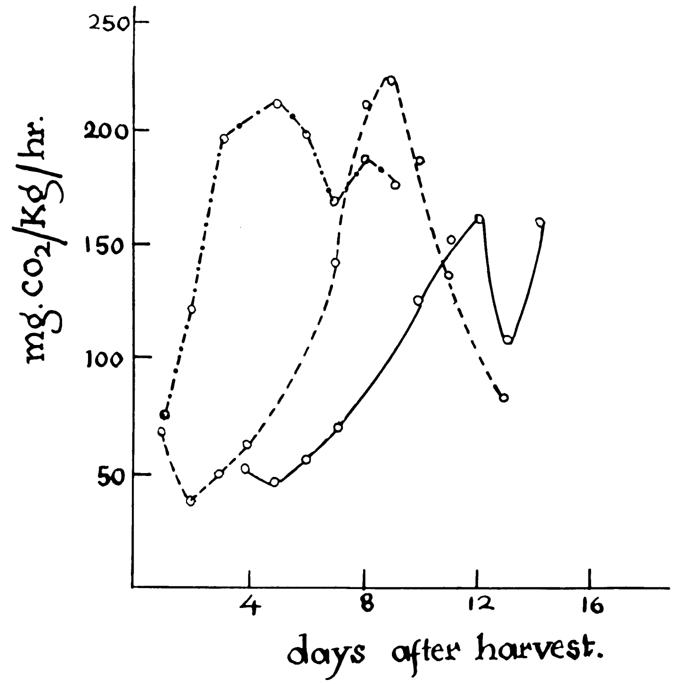

Fig. 3. Respiratory patterns of mango fruit harvested in O ___ ___ ___ ___ O May; O ___ . ___ . ___ . ___ . O June and O______ _____O December.

climacteric peak. Sucrose formed the bulk of this increase. There was little change in either total protein or true protein content.

Variation in the chemical composition among harvests of the main season and off-season for 1968 and 1969 is presented in Table 5. The harvest of June 1969 showed high sugar content and low acidity in the green fruit and there was a slight increase in the reducing sugar content at the ripe stage. The off-season crop of February 1969 showed more or less the same chemical changes as

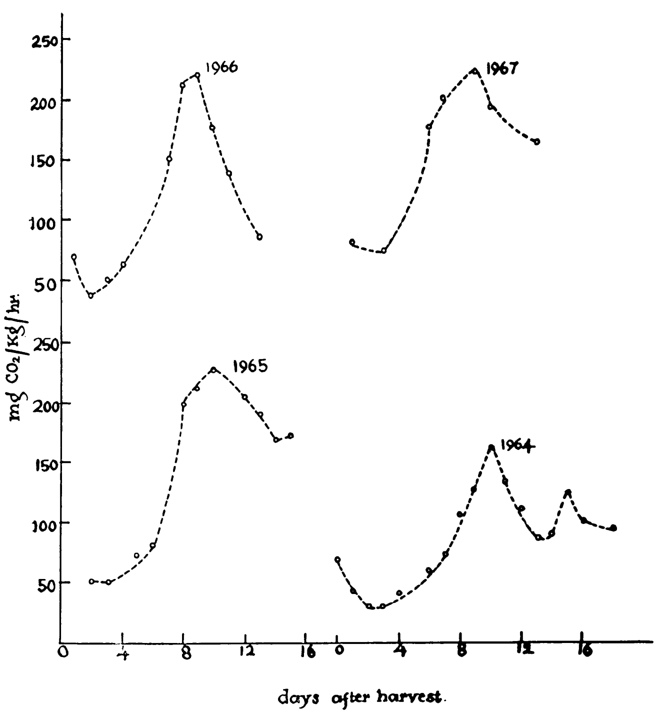

Fig. 4. Respiratory patterns of mango fruit (seasonal variation).

Table 4. Chemical changes during respiratory climacteric of mango.[a]

Days after harvest	pH	Reducing sugars	Sucrose	Total sugars	True protein	Total protein	Non-protein nitrogen (x 6.25)
1........	2.4	1.7	0.4	2.1	0.30	0.68	0.38
3........	2.5	2.7	2.2	5.0	0.37	0.80	0.43
4........	2.8	2.9	3.6	6.7	0.29	0.54	0.25
6........	3.2	3.1	5.2	8.6	0.31	0.56	0.25
7........	3.4	3.7	6.2	10.2	0.34	0.62	0.28
9........	3.7	3.8	7.2	11.4	0.38	0.58	0.20
12........	4.0	4.0	8.3	12.7	0.30	0.61	0.31

[a]The data represent the mean of 4 individual estimations.

in the fruits of the main season, but the crop of December 1968 showed high soluble solid content, high sugar content and low alcohol insoluble residue in the green fruit and low soluble solids, high acidity and reducing sugars, low ratio of soluble solids:acidity in the ripe fruit.

Discussion

The studies reported here suggest that pH and color of the pulp as determined by chromaticity coordinate x could serve as useful indices of harvest maturity for 'Pairi' mangoes. During the ripening period there was an increase in sugar content with rapid decrease in acidity. The sugar content reached the maximum around the time of climacteric peak in respiration. There was very little change in the protein content. Fruits harvested in the main season during April and May in several years showed a similar trend in chemical composition either at harvest or at the ripe stage. Late fruits harvested in June had lower acidity and higher sugar content and they ripened much earlier. Fruits of the December crop had low alcohol insoluble residue at harvest and this may be due to incomplete carbohydrate synthesis. They also had high acidity and low sugar content at the mature stage and did not ripen properly. The present findings on changes in chemical composition during ripening confirm the results of previous workers (8, 11, 18).

Respiratory trends in 3 groups also indicated that fruits in Group I showed a delay in respiratory climacteric maximum compared to those in Groups II and III. The observations made by Walford (19), Kidd and West (9), and Roux (14) in other fruits clearly indicated a delay in the occurrence of respiratory climacteric maximum in immature fruits; our observation is in full agreement with their results. The respiratory patterns of the fruit recorded at optimum maturity and the respiratory behaviour during different seasons and in different pickings indicated that the climacteric peak usually falls on the 9th day after harvest. However, the peak varies with the date of picking in the same season. Late harvests showed early climacteric, perhaps due to the over-mature condition of the fruit. Such fruits were ripe within 6–7 days. The climacteric maximum was delayed in fruits of the December crop suggesting incomplete development.

A number of workers have investigated the pattern of respiration and ripening behaviour of mango fruit of different varieties. Respiratory peak of the fruit according to Karmarkar and Joshi (8) and Leley (11) occurs 4 or 5 days after harvest and such fruits were ripe within 7 or 8 days. Burg and Burg (3) have reported the peak for 'Kent' and 'Haden' varieties of mangoes on 9th and 11th day respectively. In the present work the climacteric maximum of the 'Pairi' variety falls on the 9th day after harvest and fruits were ripe in 12–14 days. This variation

Table 5. Chemical composition of mangoes of different harvests.[a] (% fresh weight).

Date of harvest	Initial @ (at harvest)								Final £ (after 14 days)							
	Soluble solids	Reducing sugars	Sucrose	Total sugars	Acidity as malic	Soluble solids: acidity	pH	Alcohol insoluble residue	Soluble solids	Reducing sugars	Sucrose	Total sugars	Acidity as malic	Soluble solids: acidity	pH	Alcohol insoluble residue
16 –4–68	7.0	1.8	0.1	1.9	4.3	1.6	1.9	11.3	16.5	3.4	8.5	12.3	0.2	82.0	4.4	3.0
23 –5–68	6.7	2.0	0.4	2.4	3.7	1.5	3.2	12.1	14.2	2.5	9.9	12.9	0.2	71.0	4.8	2.2
13–12–68	10.0	3.2	0.1	3.3	4.7	2.1	2.9	8.1	12.0	7.3	2.8	10.1	0.7	17.1	4.1	2.1
24– 2–69	8.0	2.4	0.7	3.1	3.6	2.2	3.1	11.2	14.7	3.1	8.4	11.9	0.2	73.5	5.2	3.3
21– 4–69	7.2	1.7	0.4	2.3	3.9	1.9	2.3	12.1	15.0	5.4	7.7	13.5	0.2	75.0	5.0	2.1
22– 5–69	9.0	2.1	0.3	2.4	3.5	2.5	2.5	11.6	14.0	4.9	7.8	13.1	0.3	48.0	4.5	1.9
5– 6–69	9.0	5.0	0.6	5.6	2.2	4.1	2.7	12.9	16.0	5.4	9.7	15.6	0.1	120.0	4.8	2.5

[a]The data represents the mean of @ — 4 replicates and £ —2–4 replicates.

may be due to the varietal difference and also the climatic conditions of the place where it is grown.

Physiological maturity of the fruit as judged by physical appearance, color of the flesh, chemical composition, ripening characters, spoilage, consumer preference and respiratory patterns indicated that fruits belonging to Group I are physiologically immature and those of Group II and III are at optimum stage of maturity. Seasonal changes in respiratory pattern and chemical composition of these fruits do not show significant differences. However, fruits in Group III are available only to the extent of 20–25% of the total harvest and therefore, Group II is preferred for all practical purposes.

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