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Mutational effects of gamma irradiation on biochemical parameters of Papaya cv. Arka Prabhath mutant lines

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Abstract
Papaya is a important tropical crop because of tasty flavor, fruit pulp content, its nutritional value and antioxidant properties but needs improvement in resistance to virus, shelf life and fruit quality. Papaya seeds were treated with various doses of gamma radiation to study the mutational influence on the shelf life and fruit quality. The highest reducing sugars were recorded in $R_{10}P_{20}$ (3.40%), $R_{15}P_{19}$ (3.95%) and $R_{18}P_{19}$ (3.00%), R_3P_{19} (3.85%) and R_1P_{13} (3.90%) whereas lowest reducing sugars were observed in $R_{16}P_{18}$ (3.80%) and $R_{17}P_{18}$ (3.30%). In M_4 selected mutant lines, the highest reducing sugars were recorded in R_6P_3 (4.15%) and $R_{17}P_4$ (3.50%), whereas the lowest reducing sugars recorded in R_7P_2 (4.50%). The highest total sugars were recorded in $R_{10}P_{20}$ (9.11%), whereas lowest total sugars was observed in $R_{16}P_{18}$ and $R_{17}P_{18}$ (4.68%). In M_2 selected mutant lines, the highest total sugars was observed R_2P_9 (12.03%), $R_{20}P_{10}$ (10.79%) and R_1P_7 (10.30%) whereas, the lowest total sugars% was recorded in $R_{19}P_{12}$ (6.31%) and $R_{19}P_{21}$ (6.5%). In M_4 selected mutant lines, the highest total sugars% was observed in $R_{18}P_5$ (11.83%), $R_{14}P_{10}$ (11.30%) $R_{11}P_5$ (10.19) whereas the lowest total sugar percent was recorded in R_6P_3 (5.98%) and R_7P_2 (6.20%). The highest titratable acidity were recorded in $R_{18}P_{19}$ (0.42%), R_4P_{17} (0.77%), R_1P_{13} (0.81%), $R_{19}P_{21}$ (0.61%), $R_{14}P_{10}$ (1.77%) and $R_{17}P_4$ (0.74%), whereas the lowest titratable acidity content was recorded in $R_{17}P_{14}$ (0.16%) and control with 0.17%. the highest ascorbic acid were recorded in $R_{14}P_{19}$ (59.99 mg/100 g), $R_{14}P_{15}$ and $R_{13}P_{19}$ (54.99 mg/100 g) and lowest ascorbic acid content was observed in $R_{11}P_{19}$ and $R_{15}P_{19}$ (26.66 mg/100 g). These mutant lines were selected and forwarded to next generation for future mutational studies.

Keywords: Gamma irradiation, Arka Prabhath, total sugars, titratable acidity, ascorbic acid

Introduction
The economically important fruit crop Papaya (*Carica papaya* L.) belongs to Caricaceae family. Have higher commercial importance due to its productivity, high nutritive value, diverse industrial uses and medicinal value, availability around the year (Azad *et al*., 2012) [1]. Papaya, a formerly exotic as well as rare fruit, is now available at most times of the year. Papaya grows in tropical climatic conditions and are also famous as papaws, pawpaws, fruit of angels and tree melon. It is a climacteric fleshy fruit characterized by fast ripening after harvest. It is mainly a best tropical fruit and originated from Mexico to Panama (Nakasone and Paull, 1998) [8]. Majority of papaya fruits growing areas are stuck between 30ºN to the 45ºS latitude of the equator. It is also grown successfully as sub-tropical fruit also. It requires warmness throughout the year and temperature range below 12 to 14 °C eventually reduces fruit maturation and adversely affects fruit production. An ideal temperature is between 21 to 33 °C (Villegas, 1997) [13]. It is a highly water-logging sensitive crop, hence well-drained soils are essential for healthy high yielding plants (Marler *et al*., 1993) [7]. It is a small, arborescent, fast-growing, sparsely branched tree along with a single stem and leaves confined to top of trunk.
Generally papaya crop is melon-like, oval to almost round, to some extent pyriform, or extended club-shaped, 6 - 20 inch long and 4 - 8 inch thick; weighs up to 9 kg. Semi-wild plants bears minuscule fruits 1 to 6 inch long. The waxy fruit skin and thin - moderately tough. The white latex is rich when fruit is green and hard. The entire area under papaya cultivation has been observed to be in increasing order in the recent years but the production

has not revealed a consequent raise. This may be due to loss caused by different diseases driven by fungi, mycoplasma, bacteria, viruses and phytoplasma. Post-harvest sufferers are higher (40-70%) in papaya mainly due to its perishable nature, which leads to rapid ripening (short shelf-life) and affected by papaya ring spot virus (PRSV).

The mutational breeding is one among various approaches in order to create variations through novel recombination by involving both chemical as well as physical mutagens. Pusa Nanha (earlier mutant dwarf) an ultra dwarf dioecious variety was released by ICAR-IARI, New Delhi, through mutationl breeding involving gamma irradiation (Ram, 1984) [6]. Hence, the similar approach can also be used for the development of gynodioecious types, as there will be a chance of getting a dwarf stature mutant with the tolerance/resistance for the Papaya Ring Spot Virus (PRSV), good yield, quality and prolonged shelf life. Fruit ripening and softening both are the prominent traits that determine the post-harvest shelf life of perishable climacteric fruits. Post-harvest losses can reach 70% in the all developing countries only because of lack of post-harvest infrastructures in order to store and retail all commodities. A vary wide variety of approaches from application of plant growth regulators to delaying fruit ripening, storage in controlled atmospheres and breeding/genetic engineering the prominent lines used to control the fruit ripening and softening (Santosh *et al.*, 2010) [10]. Keeping this information as a baseline, the present study aims at improving fruit quality constraints, post-harvest losses, with current special reference to shelf life and post-harvest quality.

Materials and Methods

The present investigation aims at improving fruit quality constraints, post-harvest losses, with current special reference to shelf life and post-harvest quality in papaya cv. Arka Prabhath was carried out at the Indian Council of Agricultural Research - Indian Institute of Horticultural Research (ICAR-IIHR), Bengalore-560089 during 2020-2022. Arka Prabhath is an highly developed hybrid derivative from cross between (Arka Surya x Tainung-1) x Local Dwarf developed from ICAR- IIHR. It is gynodioecious natured, with large sized fruits weighing 900-1200 g and smooth skin. The fruit pulp is eye-catching deep pink color with good shelf quality and higher TSS (13-14˚B). The seeds extracted from ripen fruits of papaya cv. 'Arka Prabhath' derived from controlled pollination were used in this experiment.

The seeds of Arka Prabhath were treated with different doses of gamma rays. For seed treatment (100 seeds/ treatment) healthy seeds of uniform size were used. These papaya seeds were kept in 0.2 mm thick polyethylene bags and the sealed bags were exposed to different doses of gamma irradiation (50 Gy, 100 Gy, 250 Gy, 500 Gy and 750 Gy) along with temperature and exposure time range (Smitha *et al*., 2022) [11]. Morphological parameters like vigor with medium dwarf stature, early flowering at short plant height ranging 50- 60 cm above the ground, good trunk circumference, variations in leaf color, maximum fruit set, higher fruit weight and higher yield (Smitha *et al*., 2022) [12]. The fruits were harvested at breaker stage for quality analysis and post-harvest shelf life among the selected mutant lines. The harvested fruits from selected mutant lines were stored in cold storage at 20˚c setup available at Department of Post-harvest Technology and Agricultural Engineering, ICAR-IIHR, Hesaraghatt, Bengaluru-89. Fruits were analyzed in order to study biochemical changes once they reached full ripe stage. The fruit pulp was filled in LDPE bags and frozen at – 20 °C until needed for biochemical analysis. Sugars present in papaya samples were estimated, following the procedure given by Lane and Eynon as described by Ranganna (1986) [9] with slight modifications.

Reducing sugars (%)

Preparation of sample: 10 gram of pulp were homogenized with 25-50 ml distilled water in 100 ml test tube, volume made up 150 ml in a volumetric flask using distilled water. Then filtered the solution with Whatman No. 1 filter paper and filtrate was utilized for the analysis. Procedure: 10 ml of Fehling's solution [Fehling's A (5 ml) + Fehling's B (5 ml)] with 25 - 50 ml of distilled water was taken in an conical flask, boiled and titrated against filtrate sample with methylene blue as a indicator. The titration end point was brick red color.

$$\text{Reducing sugars (\%)} = \frac{\text{Factor} \times \text{Volume made up}}{\text{Titre value} \times \text{weight of sample}} \times 100$$

Total sugars (%): Preparation of sample: Twenty-five milliliter of filtrate (obtained for estimation of reducing sugar) hydrolysed with ten ml of 1:1 Hcl for 24 hours at room temperature. All sugars in the sample were converted to the reducing sugars. The hydrolysed sample then neutralized by 20% NaOH and volume made up to 50 ml using distilled water (Fig 1).

Procedure: 10 ml of Fehling's solution [Fehling's A (5 ml) + Fehling's B (5 ml)] with 25 - 50 ml of distilled water taken in conical flask, boiled and titrated with sample by methylene blue as indicator. The titration end point was brick red color.

$$\text{Total sugars (\%)} = \frac{2 \times \text{Factor} \times \text{Volume made up}}{\text{Titre value} \times \text{weight of the sample}} \times 100$$

Titratable acidity (%)

The samples titratable acidity were estimated using visual titration methods (Ranganna, 1986) [9] as narrated below (Fig 2):

Sample Preparation: 5 gram of sample taken in 50 ml test tube and little quantity of distilled water added. The pulp sample was homogenized by sample homogenizer and made up to 50 ml with distilled water, aliquot was used for further estimation analysis. Procedure: Five ml of filtrate taken in conical flask added 5 ml of distilled water and titrated with 0.1N NaOH solution with 1-2 drops of phenolphthalein as indicator. Formation of pink color was obtained as titration end point. Then acidity was calculated as follows below:

$$\text{Titratable Acidity (\%)} = \frac{\text{Titre value} \times \text{0.1 N NaOH} \times \text{Volume made up} \times \text{Equivalent weight of citric acid}}{\text{Volume of sample taken for titration} \times \text{Weight of sample} \times 1000} \times 100$$

Ascorbic acid (mg/100 g)

The Ascorbic acid amount of papaya samples were estimated by 2, 6-dichlorophenol indophenol visual titration technique as given by Ranganna (1986) [9] with slight modifications (oxalic acid was used instead of meta-phosphoric acid) (Fig 3). Preparation of 2, 6-dichlorophenol indophenol dye solution**:** In beaker, 50 mg of sodium salt of 2, 6-dichlorophenol indophenol dye with 42 mg of sodium bicarbonate dissolved in 150 ml boiled distilled water. Volume made upto 200 ml using distilled water. Oxalic acid (0.4%): Oxalic acid (4 g) dissolved in 100 ml distilled water and volume made up to 1000 ml using distilled water. Standard ascorbic acid: L-ascorbic acid (100 mg) dissolved in small quantity of 0.4% oxalic acid in 100 ml volumetric flask then volume made up using oxalic acid. Ten ml of this solution diluted to 100 ml by oxalic acid. Thus, standard ascorbic acid contains 0.1 mg of ascorbic acid per each ml of solution. Standardization of dye: 5 ml of standard ascorbic acid solution and 5 ml of 0.4% oxalic acid taken in conical flask and titrated against the dye solution. The titration end point was light pinkish color which persisted lastly for 10 seconds. The dye factor then calculated as,

$$\text{Dye factor} = \frac{0.5}{\text{titre value}}$$

Preparation of the sample: 5 gram of the pulp was homogenized with the help of a homogenizer using 0.4 per cent oxalic acid. The volume was then made up to 50 ml with 0.4% oxalic acid. The solution was filtered using Whatman No.1 filter paper and the filtrate was used for estimation. Procedure: Five ml of filtered pulp sample and 5ml 0.4% oxalic acid taken in conical flask and titrated with standard dye solution. The titrated end point was light pinkish color, persisted atleast 10 seconds.

$$\text{Ascorbic acid (mg /100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume taken} \times \text{weight of the sample}} \times 10$$

The biochemical observations were statistically analyzed using completely randomized design at the probability of 0.01.

Results

Reducing sugar (%)

The datas pertaining to the reducing sugar influenced with the effect of gamma radiation among the selected mutant lines in all M_1, M_2 and M_4 population resulted significant differences between them. In M_1 selected mutant lines, the highest reducing sugars were recorded in $R_{10}P_{20}$ (3.40%), $R_{15}P_{19}$ (3.95%) and $R_{18}P_{19}$ (3.00%), whereas lowest reducing sugars were observed in $R_{16}P_{18}$ (3.80%) and $R_{17}P_{18}$ (3.30%) (Table 1). In M_2 selected mutant lines, the highest reducing sugars was observed in R_3P_{19} (3.85%) and R_1P_{13} (3.90%), whereas, the lowest reducing sugars were recorded in R_4P_{17} (3.75%) (Table 2). In M_4 selected mutant lines, the highest reducing sugars were recorded in R_6P_3 (4.15%) and $R_{17}P_4$ (3.50%), whereas the lowest reducing sugars recorded in R_7P_2 (4.50%) (Table 3). The results pertaining to $M_1$and M_2 were shown to be significant whereas M_4 mutants results shown to be not significantly higher than control fruits.

Total Sugar (%)

The data pertaining to total sugar influenced with the effect of gamma radiation among the selected mutant lines in all M_1, M_2 and M_4 population resulted significant differences between them. In M_1 selected mutant lines, the highest total sugars were recorded in $R_{10}P_{20}$ (9.11%), whereas lowest total sugars was observed in $R_{16}P_{18}$ and $R_{17}P_{18}$ (4.68%) (Table 1). In M_2 selected mutant lines, the highest total sugars was observed R_2P_9 (12.03%), $R_{20}P_{10}$ (10.79%) and R_1P_7 (10.30%) (Table 2) whereas, the lowest total sugars% was recorded in $R_{19}P_{12}$ (6.31%) and $R_{19}P_{21}$ (6.5%). In M_4 selected mutant lines, the highest total sugars% was observed in $R_{18}P_5$ (11.83%), $R_{14}P_{10}$ (11.30%) and $R_{11}P_5$ (10.19) whereas the lowest total sugar percent was recorded in R_6P_3 (5.98%) and R_7P_2 (6.20%) (Table 3). The results of total sugars obtained from all M_1, M_2 and M_4 population were not significantly higher than controls.

Titratable acidity (%)

The data pertaining to titratable acidity influenced with the effect of gamma radiation among the selected mutant lines in all M_1, M_2 and M_4 population resulted significant differences between them. In M_x selected mutant lines, the highest titratable acidity were recorded in $R_{18}P_{19}$ (0.42%), R_4P_{17} (0.77%), R_1P_{13} (0.81%), $R_{19}P_{21}$ (0.61%), $R_{14}P_{10}$ (1.77%) and $R_{17}P_4$ (0.74%), whereas the lowest titratable acidity content was recorded in $R_{17}P_{14}$ (0.16%) and control with 0.17%. These results were significantly higher than the control non-mutagenized Arka Prabhath (Table 4, 5, 6).

Ascorbic acid (mg/100 g)

The data pertaining to ascorbic acid influenced with the effect of gamma radiation among the selected mutant lines in all M_1, M_2 and M_4 population resulted significant differences between them. In M_1 selected mutant lines, the highest ascorbic acid were recorded in $R_{14}P_{19}$ (59.99 mg/100 g), $R_{14}P_{15}$ and $R_{13}P_{19}$ (54.99 mg/100 g) and lowest ascorbic acid content was observed in $R_{11}P_{19}$ and $R_{15}P_{19}$ (26.66 mg/100 g) (Table 4). In M_2 selected mutant lines, the highest ascorbic acid content was noted in $R_{20}P_{10}$ (81.66 mg/100 g) and R_5P_{13} (78.33 mg/100 g) whereas lowest ascorbic acid was recorded in $R_{18}P_{20}$ and $R_{19}P_{12}$ (26.66 mg/100 g) (Table 5). In M_4 selected mutant lines, the highest ascorbic acid was observed in R_7P_2 (134.99 mg/100 g) and R_6P_3 (116.66 mg/100 g) whereas lowest ascorbic acid was recorded in control (39.95mg/100 g) and Red lady (41.90 mg/100 g) (Table 6). The above obtained results from all generation selected mutant lines were varied among the mutants and significantly higher than control.

Fig 1: Total Soluble Sugar estimation – blue color turns to copper red on addition of sample through titration thus estimating total sugar amount in the sample

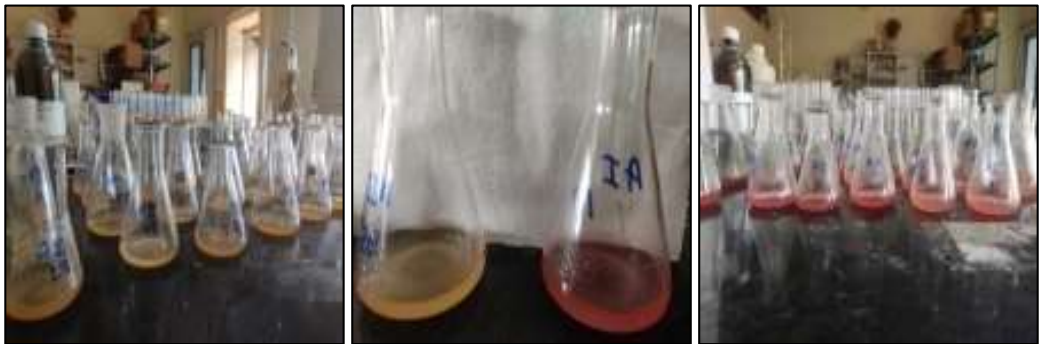

Fig 2: Estimation of Titratable acidity- color turns to pink on addition of phenolphthalein indicator

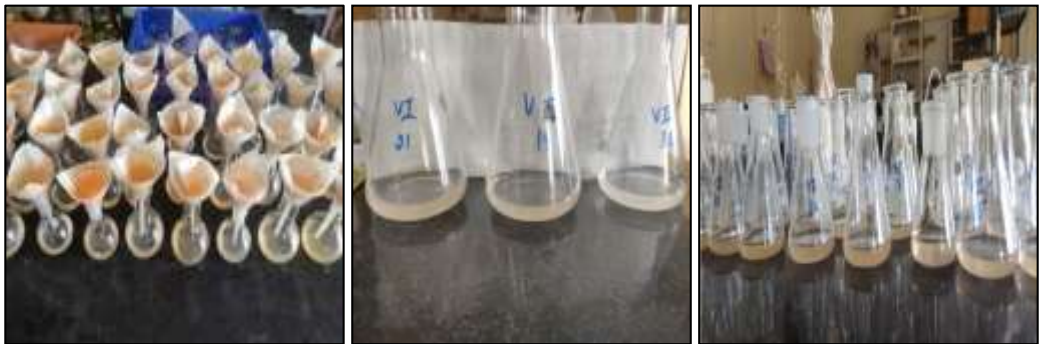

Fig 3: Estimation of Ascorbic acid- color turns to light pink color on addition of 2, 6-dichlorophenol indophenol dye

Table 1: Effect of gamma irradiation on Reducing and Total sugars (%) of M_1 population of Papaya cv Arka Prabath

M_1 Treatments	Reducing sugars (%)			Total sugars (%)		
	R_1	R_2	Mean	R_1	R_2	Mean
Control	4.3	3.9	4.10	7.65	6.98	7.32
Red Lady	4.2	3.9	4.05	8.56	9.12	8.84
$R_{10}P_{20}$	3.6	3.2	3.40	7.50	10.71	9.11
$R_{11}P_{19}$	2.9	3	2.95	6.94	6.13	6.54
$R_{12}P_{12}$	3.5	4.6	4.05	6.94	5.84	6.39
$R_{12}P_{14}$	5.3	3.6	4.45	6.87	4.86	5.86
$R_{12}P_{17}$	4.8	3.9	4.35	7.38	5.53	6.46
$R_{13}P_{19}$	3.9	4.3	3.10	5.61	4.26	4.94
$R_{14}P_{15}$	3.5	3.3	3.90	6.09	6.03	6.06
$R_{14}P_{19}$	3.2	4.8	3.00	6.21	6.15	6.18
$R_{15}P_{11}$	4.3	3.9	4.10	6.13	6.01	6.07
$R_{15}P_{19}$	4.2	3.7	3.95	6.40	6.70	6.55
$R_{15}P_{20}$	3.8	3.2	3.50	4.88	6.15	5.52
$R_{16}P_{14}$	3.6	3.3	3.95	4.80	5.60	5.20
$R_{16}P_{18}$	3.4	4.2	3.80	4.36	5.00	4.68
$R_{17}P_{14}$	3.5	3.3	3.40	5.10	7.62	6.36
$R_{17}P_{18}$	2.6	3.3	3.45	4.36	5.00	4.68
$R_{18}P_{19}$	2.2	3.8	3.00	5.36	5.68	5.52
SeM±			0.34			0.67
CD @ 1%			1.02			1.98
F test			*			*

Table 2: Effect of gamma irradiation on Reducing and Total sugars (%) of M_2 population of Papaya cv Arka Prabath

M_2 Treatments	Reducing sugars (%)			Total sugars (%)		
	R_1	R_2	Mean	R_1	R_2	Mean
Control	4.3	3.9	4.10	7.65	6.98	7.32
Red Lady	4.2	3.7	3.95	8.56	9.12	8.84
$R_{18}P_{20}$	4.9	3.5	4.20	5.79	5.97	5.88
$R_{19}P_{12}$	4.6	3.5	4.05	6.27	6.36	6.31
$R_{19}P_{21}$	4.2	4.2	4.20	6.53	6.47	6.50
$R_{20}P_{10}$	2.4	4.9	3.65	9.87	11.72	10.79
R_1P_7	2.6	4.6	3.60	9.82	10.78	10.30
R_1P_{13}	3.6	4.2	3.90	7.16	8.97	8.06
R_2P_9	3.5	2.4	2.95	11.03	13.02	12.03
R_3P_{19}	5.1	2.6	3.85	7.35	10.47	8.91
R_4P_{17}	3.9	3.6	3.75	6.47	7.10	6.78
R_5P_{13}	3.8	3.1	3.45	8.64	8.89	8.76
SeM±			0.68			0.69
CD @ 1%			1.98			2.12
F test			*			*

Table 3: Effect of gamma irradiation on Reducing and Total sugars (%) of M_4 population of Papaya cv Arka Prabath

M_4 Treatments	Reducing sugars (%)			Total sugars (%)		
	R_1	R_2	Mean	R_1	R_2	Mean
Control	4.3	3.9	4.10	7.65	6.98	7.32
Red Lady	4.2	3.7	3.95	8.56	9.12	8.84
R_6P_3	4.1	4.2	4.15	5.79	5.97	5.98
R_6P_{18}	3.7	3.5	3.60	6.27	6.36	6.81
R_7P_2	3.9	5.1	4.50	6.53	6.47	6.20
$R_{11}P_5$	3.9	3.9	3.90	9.87	11.72	10.19
$R_{14}P_{10}$	4.26	3.8	4.03	9.82	10.78	11.30
$R_{17}P_4$	2.9	4.1	3.50	7.16	8.97	8.86
$R_{18}P_5$	3.4	3.7	3.55	11.03	13.02	11.83
$R_{19}P_{10}$	3.5	3.9	3.70	7.35	10.47	8.91
$R_{21}P_{15}$	3.5	3.9	3.70	6.47	7.10	6.67
$R_{25}P_{14}$	4.2	4.26	4.23	8.64	8.89	8.56
SeM±			0.29			0.49
CD @ 1%			1.89			2.02
F test			NS			*

Table 4: Effect of gamma irradiation on Titratable acidity and Ascorbic acid of M_1 population of Papaya cv Arka Prabath

M_1 Treatments	Titratable acidity (%)			Ascorbic acid (mg/100 g)		
	R_1	R_2	Mean	R_1	R_2	Mean
Control	0.18	0.16	0.17	39.64	40.25	39.95
Red Lady	0.11	0.13	0.12	42.13	41.66	41.90
$R_{10}P_{20}$	0.19	0.26	0.23	46.66	50.00	48.33
$R_{11}P_{19}$	0.39	0.39	0.39	26.66	26.66	26.66
$R_{12}P_{12}$	0.19	0.26	0.23	76.66	26.66	51.66
$R_{12}P_{14}$	0.19	0.26	0.23	53.33	30.00	41.66
$R_{12}P_{17}$	0.32	0.19	0.26	43.33	26.66	35.00
$R_{13}P_{19}$	0.32	0.26	0.29	36.66	73.33	54.99
$R_{14}P_{15}$	0.26	0.19	0.23	69.99	40.00	54.99
$R_{14}P_{19}$	0.52	0.19	0.35	69.99	50.00	59.99
$R_{15}P_{11}$	0.32	0.26	0.29	43.33	43.33	43.33
$R_{15}P_{19}$	0.26	0.32	0.29	26.66	26.66	26.66
$R_{15}P_{20}$	0.32	0.26	0.29	36.66	33.33	35.00
$R_{16}P_{14}$	0.19	0.26	0.23	46.66	40.00	43.33
$R_{16}P_{18}$	0.19	0.26	0.23	36.66	30.00	33.33
$R_{17}P_{14}$	0.19	0.13	0.16	33.33	46.66	40.00
$R_{17}P_{18}$	0.19	0.19	0.19	26.66	43.33	35.00
$R_{18}P_{19}$	0.13	0.71	0.42	26.66	66.66	46.66
SeM±			0.08			10.63
CD @ 1%			0.25			31.58
F test			*			*

Table 5: Effect of gamma irradiation on Titratable acidity and Ascorbic acid of M_2 population of Papaya cv Arka Prabath

M_2 Treatments	Titratable acidity (%)			Ascorbic acid (mg/100 g)		
	R_1	R_2	Mean	R_1	R_2	Mean
Control	0.18	0.16	0.17	39.64	40.25	39.95
Red Lady	0.11	0.13	0.12	42.13	41.66	41.90
$R_{18}P_{20}$	0.19	0.19	0.19	23.33	30.00	26.66
$R_{19}P_{12}$	0.26	0.26	0.26	26.66	26.66	26.66
$R_{19}P_{21}$	0.84	0.39	0.61	69.99	83.33	76.66
$R_{20}P_{10}$	0.32	0.32	0.32	79.99	83.33	81.66
R_1P_7	0.32	0.19	0.26	66.66	76.66	71.66
R_1P_{13}	0.52	1.16	0.84	56.66	86.66	71.66
R_2P_9	0.26	0.52	0.39	76.66	76.66	76.66
R_3P_{19}	0.26	0.39	0.32	40.00	79.99	59.99
R_4P_{17}	0.90	0.64	0.77	40.00	83.32	61.66
R_5P_{13}	0.19	0.52	0.35	79.99	76.66	78.33
SeM±			0.14			9.92
CD @ 1%			0.42			30.56
F test			*			*

Table 6: Effect of gamma irradiation on Titratable acidity and Ascorbic acid of M_4 population of Papaya cv Arka Prabath

M_4 Treatments	Titratable acidity (%)			Ascorbic acid (mg/100 g)		
	R_1	R_2	Mean	R_1	R_2	Mean
Control	0.18	0.16	0.17	39.64	40.25	39.95
Red Lady	0.11	0.13	0.12	42.13	41.66	41.90
R_6P_3	0.45	0.25	0.35	109.99	123.32	116.66
R_6P_{18}	0.38	0.32	0.35	86.66	79.99	83.33
R_7P_2	0.25	0.25	0.26	136.65	133.32	134.99
$R_{11}P_5$	0.19	0.32	0.26	119.99	103.32	111.66
$R_{14}P_{10}$	0.51	3.02	1.77	99.99	103.32	101.66
$R_{17}P_4$	0.90	0.57	0.74	103.32	103.32	103.32
$R_{18}P_5$	0.19	0.38	0.29	109.99	99.99	104.99
$R_{19}P_{10}$	0.25	0.32	0.29	79.99	126.65	103.32
$R_{21}P_{15}$	0.19	0.25	0.23	96.66	69.99	83.33
$R_{25}P_{14}$	0.25	0.32	0.29	66.66	53.33	59.99
SeM±			0.37			8.77
CD @ 1%			1.14			27.01
F test			*			*

Discussion

The good fruit quality is noticed widely by sugar amount in pulp. During the earlier stages of the fruit development, glucose is main sugar. The sucrose content increases during the ripening process. Desai and Wagh (1995) [3] reported that sugar is major components of papaya and its amount varies depending on cultivars. They also reported that while extracting the sugars in papaya, activity of the enzyme invertase declines amount of the non-reducing sugars meanwhile raises the amount of reducing sugar.

The total soluble-solids amount of papaya leads to raise in ripening and softening stage and varies between 6 – 19% depended upon cultivars. However, the soluble-solids amount in mature fruits should be least 11.5% to meet the market quality. The highest suitability percentages of papaya varieties that has 87.4% with 12% of total soluble solids as recorded by Zaman *et al*., 2006 [14].

The titratable acidity declines during ripening stage in papaya which is natural occurrence. This might be reason of rapid utilization of acids in fruits during the respiration process as a substrate as reported by Gupta *et al*., 1979 [4]. In the study on quality of guava and papaya fruit pulp by Jain *et al*., 2011 [15], reported that pulps are influenced by blending ratio and storage period. They reported 12.4°brix TSS with 69.44 mg/100 g of ascorbic acid and 0.316 percent of titratable acidic content.

Ascorbic acid is one of the prominent nutritive values, prone for degradation upon oxidation compared with other nutrients during the storage of papaya fruits. Vitamin C content is directly involved in various metabolic process in growth control, division of cells and cell wall expansion in vegetables. The amount of decrease in Vitamin C during ripening occurs while conversion of dehydroascorbic acids to diketogulonic acids during oxidation. Lee and Kader, 2000 [5] reported that ascorbic acid contents of fruit decreases as storage duration increases, but it is a contradictory report to the results obtained as ascorbic acid contents remains with enhanced shelf life. De Figueiredo *et al*., 2014 [2], results showed that vitamin C contents was significantly lesser in radiated fruit in examined days and noted a positive correlation among Vitamin C content and fruit maturation process.

The shelf life studies, post-harvest analysis and biochemical parameters among all selected 36 mutant lines from different treatments and M_x generations, 10 mutants were forwarded to study molecular cloning and characterization. Based on the enhanced shelf life, quality fruit storage, pulp thickness, highest TSS, less post-harvest loss in weight in the fruit pulp ten mutant lines were forwarded. In order to study the sequence variations, Single Nucleotide Polymorphisms and nucleotide insertions and deletions in fruit ripening genes *viz*., ACC-oxidase, ACC-synthase and ETR-1. Cloning and sanger sequencing were carried out for

following mutants; $R_{12}P_{17,}$ $R_{14}P_{15}$, $R_{16}P_{18}$, $R_{17}P_{14}$, R_1P_7, R_5P_{13}, R_7P_2, $R_{19}P_{10}$, $R_{21}P_{15}$ and $R_{25}P_{14}$.

Conclusion

Papaya is a nutritionally important tropical fruit crop for tastier flavor, more pulp content and antioxidantal properties. The aim of the experiment was to improve quality, shelf life in order to minimize fruit post-harvest losses of papaya cv. Arka Prabhath. The enhanced shelf life and post-harvest quality parameters were studied among mutant lines from M_1 generation. The improvement in fruit quality can be achieved due to induction of gamma radiation which intern induces hormones which are responsible for the improvement to fruit quality. Based on the observations, enhanced shelf life and good fruit quality in storage, less post-harvest loss in weight, good fruit cavity index, length and width, good pulp thickness and TSS were recorded among the mutant lines compared to control (non-mtagenized Arka Prabhath) and Red lady. Mutational studies were also carried out to know morphological, physiological, biochemical and molecular characterization of selected mutants in order to carry forward to next generation.

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