Indian Journal of Agricultural Sciences **83** (9): 928–32, September 2013/Article

Papaya (*Carica papaya*) seed quality as influenced by stage of fruit harvest, postharvest ripening and seed extraction

H S YOGEESHA[1], C VASUGI[2], SOMASHEKHAR[3], K BHANUPRAKASH[4] and L B NAIK[5]

Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bangalore, Karnataka 560 089

Received: 22 December 2011; Revised accepted: 12 April 2013

ABSTRACT

Role of fruit maturity, postharvest ripening and seed extraction techniques on seed quality of papaya (*Carica papaya* L.) cv. Surya was studied. The seeds extracted from ¾th ripe fruits onwards showed significantly higher 100 seed weight, germination and vigour compared to the seeds from early harvested fruits. However, half ripe fruits showed good germination and vigour when they were kept for postharvest ripening for 6 days. The best stage of fruit harvest for obtaining best quality seed was when the ¾th of the fruit skin turned yellow. The seeds from these fruits not only gave better germination and vigour but also showed better storability compared to the seeds extracted from the fruits of early harvested. Fermentation for 24-48 hr was found ideal for easy removal of sarcotesta, the mucilage surrounding the seed surface, without affecting the quality of the seed.

Key words: Papaya, Postharvest ripening, Seed extraction, Seed quality, Stage of fruit harvest

Poor, delayed and irregular germination is a common problem experienced by the papaya growers and nursery men and it is attributed to many factors. The factors such as stage of fruit maturity at harvest, postharvest ripening and seed extraction techniques are known to affect seed quality especially in crops with fleshy fruits. It is reported that in crops like capsicum (Vidigal *et al.* 2009), tomato (Yogeesha *et al*. 2006), egg plant (Yogeesha *et al.* 2008a) and cucumber (Medeiros *et al.* 2010) the seeds continue to develop physiologically even after complete fruit maturity. Hence, in such crops it is recommended to keep the harvested fruits for some days for postharvest ripening before seed is extracted. Seed extraction in fleshy fruits is a cumbersome process as it involves scooping seeds manually from fleshy fruits and then washing in water for removal of fruit debris. In some crops like tomato, papaya and cucumber, the removal of mucilage (sarcotesta) covering the seed coat is essential. Removal of mucilage is accomplished easily in case of tomato and cucumber by fermentation for 1 or 2 days. In papaya, removal of mucilage is done immediately after extraction by rubbing the seeds by hands or using cloth or wire mesh vigorously as the mucilage does not break easily. There is a possibility of seed getting damaged due to vigorous rubbing. Hence, it is a tedious process. There is a need to develop a technique, like in tomato and cucumber for easy separation of seeds from sarcotesta. The information on the effect of fruit maturity and seed extraction on seed quality is either scanty or not available in this crop. Hence, this study was conducted to determine the right stage of fruit maturity, maturity index, postharvest ripening requirement and to develop an easy method of seed extraction to get better quality seeds of papaya.

MATERIALS AND METHODS

Papaya (*Carica papaya* L.) cv. Surya, a gynodioecious variety with a medium fruit size and red flesh, was grown at Central Horticultural Experimentation Station, Hirehalli, Tumkur during 2009-2011. The recommended agronomic practices were followed to raise the crop and the crop was completely free from papaya ring spot virus, a serious disease which affects not only fruit yield but seed quality also. The plant population consisted of female and hermaphrodites in 1:1 ratio. Only hermaphrodite plants were selected for the study as the fruits in these plants produce plenty of seeds without hand pollination.

The fruits of different maturity stages, viz. green immature, green mature (skin slightly turning yellow), ¼ ripe (¼ of skin turned yellow), ½ ripe (½ of skin turned yellow), ¾ ripe (¾ of skin turned yellow) and full ripe (skin completely yellow) stages, were harvested from

[1] Principal Scientist (e mail: hsy@iihr.ernet.in), [4] Senior Scientist (e mail: kbp@iihr.ernet.in), [2] Senior Scientist (e mail: vasuc@iihr.ernet.in), [5] Principal Scientist (e mail: lbnaik@iihr.ernet.in); [3] Subject Matter Specialist (e mail: somuvd@rediffmail.com), KVK, Hirehalli, Tumkur, Karnataka

hermaphrodite plants at peak harvesting period. The flowering in papaya is acropetal in nature. In majority of plants the first formed flower from each leaf axil set the fruit as a result the basal fruits were older to fruits formed at upper position of the plant. The immature fruits were those with deep green skin. As the fruits enter maturity, the fruit skin started turning to light green and the flesh inside the fruit turning to red and seeds changing from white to black. This stage was considered as mature green stage for our study and the fruits just above these fruits on the plant were considered as immature fruits.

Immediately after the harvest, the fruits of various maturity stages except in immature and fully ripe fruits were divided separately into two sets. One set of fruit was used for immediate seed extraction and the other set was kept in well aerated room condition till they attained full ripe stage, the stage at which skin became completely yellow and flesh became soft, and then seeds were extracted. In case of immature and fully ripe fruits seeds were extracted immediately after harvest. Seed extraction was done manually by scooping the seeds from cut fruits. The seeds collected from fruits of different maturity stages except green immature stage were subjected for fermentation for one day. The sarcotesta was removed by rubbing the seeds with coarse cotton cloth and then washed thoroughly in running water. The seeds which floated in water were removed as they were chaffy and the sinkers were dried in shade by spreading over the nylon net in a thin layer till they attained 8-10% moisture content. The seeds collected from immature fruits were dried as such without removing sarcotesta as it was not possible to remove it without damaging the embryo. The shade dried seeds were further dried to 6-7% moisture content over silica gel and packed in sealed moisture proof aluminum poly pouches and kept at 15^0C till they were used for evaluation. Further, a part of the dried seeds of different maturity stages were packed in butter paper bags and kept in room conditions for 8 months and then seeds were evaluated for seed quality.

The observations such as days to full ripening in fruits kept for ripening after harvest, fruit skin color, flesh color, seed color, 100 seed weight, per cent seed germination, first count, seedling length and seedling dry weight were recorded in the fruits of different maturity stages. Seedling vigour index I was computed by multiplying germination percentage with seedling length and seedling vigour index II by multiplying germination percentage with seedling dry weight. Germination test was conducted using rolled paper method with 400 seeds in 4 replications of 100 seed each. The ideal temperature of 32°C for 8 hr and 20°C for 16 hr (Yogeesha *et al.* 2007) was used for incubating the seeds. First count was recorded on 15^{th} day and final count on 20^{th} day. In the experiment on seed extraction techniques, the seeds collected from full ripe fruits were subjected for different extraction techniques, viz. immediate extraction, extraction after 24 hr fermentation and extraction after 48 hr fermentation. In case of immediate extraction, as soon as the seeds were scooped from fruits, the sarcotesta was removed by rubbing the seeds with coarse cotton cloth without damaging the seed coat and then washed thoroughly in running water. In case of fermentation treatments the seeds were soaked in little quantity of water in a plastic bucket and kept for fermentation. After fermentation for prescribed duration, the sarcotesta was removed and drying was done as described earlier under the experiment on fruit maturity. The seeds were evaluated for quality as mentioned above, immediately after extraction and also after 8 months of storage under ambient conditions.

The data were analysed using ANOVA technique for Completely Randomized Design and means were compared using Least Significant Difference at 0.01 probability (Gomez and Gomez 1984). To know the effect of post harvest ripening over immediate extraction, paired mean comparison using Student's t- test was done for means of post harvest ripening

Table 1 Fruit and seed characteristics at different stages of maturity in papaya cv. Surya

Stage of fruit extraction	Stage of seed extraction	Skin color	Flesh color	Flesh firmness	Seed color
Immature fruits	Immediate	green	white	firm	white
Mature green	Immediate	light green	turning to red	firm	turning to black
Mature green	Full ripe (after 13 days of harvest)	complete yellow	deep red	soft	medium black
1/4 ripe	Immediate	1/4 yellow	light red	firm	light black
1/4 ripe	Full ripe (after 8 days of harvest)	complete yellow	deep red	soft	medium black
1/2 ripe	Immediate	1/2 yellow	red	soft inner layer	medium black
1/2 ripe	Full ripe (after 6 days of harvest)	complete yellow	deep red	soft	dark black
3/4 ripe	Immediate	3/4 yellow	deep red	half of the flesh soft	dark black
3/4 ripe	Full ripe (after 4 days of harvest)	complete yellow	deep red	soft	dark black
Full ripe	Full ripe	complete yellow	deep red	soft	dark black

and immediate extraction of various stages of maturity excluding immature and ripe stages.

RESULTS AND DISCUSSION

Stage of fruit harvest and postharvest ripening

The immature fruits with deep green skin had white flesh with white seed. The sarcotesta was not fully formed and without watery fluid. The mature green fruits had flesh colour turning from white to red and also seed turning from white to black. About 50% of the seeds were still white but the sarcotesta had the characteristic watery fluid at this stage. Majority of the seeds became black when these fruits were kept for full ripening. At ¼ ripe, the fruits had light red firm flesh and seeds with fully formed sarcotesta. However, at this stage also few seeds were white in color and they changed to black upon ripening for 8 days. As the fruits matured further the colour intensity of flesh and seed increased. In half ripe fruits, the inner most layer of the flesh became deep red and little soft with medium black seeds. The deep pink flesh became further soft at ¾ ripe stage with dark black seeds. At full ripe stage the flesh became very soft. In case of incomplete ripe fruits of different maturity stages the skin colour changed to yellow and flesh colour to deep red with flesh turning to soft after postharvest ripening (Table 1). However, the skin colour was dull in mature, ¼ and ½ ripe fruits when compared to natural ripening on the plant itself. Number of days taken for complete ripening was 12, 8, 6 and 4 days for mature, ¼ ripe, ½ ripe and ¾ ripe fruits, respectively.

The 100 seed weight of dried seeds was lowest in seeds of green immature fruits (0.934 g) and it steadily increased as the fruits aged (Table 2). The highest 100 seed weight (1.523g) was recorded in seeds extracted from fruits of ¾ ripe stage and it was on par with seeds extracted from full ripe fruits and seeds from ½ and ¾ ripe fruits extracted after postharvest ripening and significantly superior over other fruit maturity stages. This indicated that seeds attained maximum dry matter at ¾ ripe stage of maturity and remained constant thereafter. Postharvest ripening of ½ ripe fruits resulted in increase of 100 seed weight that was on par with the seeds from ¾ ripe stage.

There was no germination in seeds extracted from immature fruits. Seeds from mature green fruits showed very low germination (12%) but seeds extracted from mature green fruits kept for postharvest-ripening showed marked increase in germination (59%) and it was on par with seeds from ¼ ripe fruits. As the fruits ripened either on plant or by postharvest ripening there was a steady increase in germination till ¾ ripe (90.7%) and there after remained same. Similar trend was noticed with respect to seedling length, seedling dry weight and vigour index I and II. With respect to speed of germination as reflected in first count, seeds extracted from ¾ ripe stage onwards showed rapid germination. Seeds from ½ ripe fruits kept for postharvest ripening also showed rapid germination compared to seeds extracted immediately after harvest though the final germination was almost same (Table 2). This corroborates the findings of Sangakkara (1995) who observed the highest germination and vigour in papaya seeds obtained from ripe fruits and which was on par with over-ripe fruits. This study clearly shows the importance of stage of fruit maturity in obtaining good quality of papaya seeds. The seeds attained maximum seed weight at ¾ ripe stage and this could be considered as the stage of physiological maturity. Mean comparison of post harvest ripening versus immediate extraction showed a significant positive effect of post harvest ripening on all seed quality parameters except for seedling length (Table 3). This showed that seed continues to develop even after fruit maturity like other fleshy fruits, viz. capsicum (Vidigal *et al.* 2009), tomato (Yogeesha *et al.* 2006), egg plant (Yogeesha *et al.* 2008a) and cucumber (Medeiros *et al.* 2010). These results clearly indicate that for better seed

Table 2 Seed quality as influenced by stage of fruit harvest and seed extraction in papaya cv. Surya

Stage of fruit harvest and seed extraction	100 seed wt (g)	First count (%)	Final germination (%)	Seedling length (cm)	Vigour index I	Seedling dry wt (mg)	Vigour index II
Immature fruits- Immediate extraction	0.934	0.0	0.0	0.00	0.00	0.00	0.00
Mature green- Immediate extraction	1.117	2.0	12.0	3.20	41	0.57	6.80
Mature green -extracted after full ripe	1.221	29.3	58.0	11.40	663	2.07	119.7
1/4 ripe -immediate extraction	1.251	33.3	62.7	12.80	799	2.77	173.4
1/4 ripe - extraction at full ripe	1.222	51.3	68.7	13.67	942	3.17	218.7
1/2 ripe -immediate extraction	1.276	46.7	74.7	13.60	1012	2.97	220.9
1/2 ripe - extraction at full ripe	1.452	77.3	78.7	13.67	1081	3.23	265.7
3/4 ripe -immediate extraction	1.523	77.3	90.7	14.13	1280	3.17	292.8
3/4 ripe - extraction at full ripe	1.376	81.3	88.0	14.37	1264	3.37	279.7
Full ripe	1.439	87.3	91.3	18.13	1657	3.50	319.9
LSD (0.01)	0.092	14.7	9.6	3.54	293	0.71	68.0
SEm±	0.031	3.68	2.40	0.89	73.3	0.18	17.0

Table 3 Effect of post harvest ripening on seed quality in papaya cv. Surya

Stage of fruit harvest and seed extraction	100-seed wt (g)	First count (%)	Germination (%)	Seedling length (cm)	Vigour index-I	Seedling dry wt (mg)	Vigour index II
Immediate extraction	1.292	51.5	57.2	35.25	2057	13.98	951.6
Extraction after post harvest ripening	1.312	72.5	82.9	35.42	3029	16.26	1380.6
"t" value (0.05)	NS	3.6	3.5	NS	3.03	3.94	4.13

quality papaya fruits should be harvested between ¾ and full ripe stage and be kept for 3-4 days or till the flesh become soft before seed is extracted. Retaining fruits on the plant till they attain full ripe stage is not advisable as the fruits may get damaged by birds and other animal pests and also difficult to handle such fruits at harvesting time.

Seed extraction

Significant differences between immediate extraction and fermentation methods were found for seed germination and vigour as expressed in first count. However there was no difference between 24 and 48 hr fermentation. The final germination was 86.3. 93.0 and 92.8% respectively, in immediate extraction, 24 hr fermentation and 48 hr fermentation methods. The sarcotesta could be removed easily when the seeds were subjected for 24 or 48 hr fermentation; 48 hr fermentation was better than 24 hr fermentation for removal of sarcotesta (Fig 1). The seeds obtained from different extraction methods stored for 8 months under ambient condition in paper cover showed no significant difference among the treatments with respect to seed germination and vigour as expressed in terms of first count (Fig 2).

Papaya seed is rubbed against rough surface like wire mesh or sand or rough cloth to break the sarcotesta surrounding the seed surface. It is not only tedious and time consuming process but may also damage seed if great force is applied while rubbing. Fermentation method is widely followed in tomato and cucumber for the removal of mucilage around the seeds. Water is not added in these crops as the fruits contain sufficient juice and that helps in fermentation. In case of papaya some quantity of water is required as the fruit does not contain juice. There is no danger of seed germination during the fermentation process as papaya seeds have initial dormancy and also require specific temperature for germination (Yogeesha *et al.* 2007). This fermentation helps in easy breakdown of sarcotesta and hence, quick removal of sarcotesta with little force while rubbing is possible. Higher germination in fermentation treatments in the present study may be due to leaching of germination inhibitors during fermentation. There was no difference in 8 months old seeds among extraction treatments (Fig 2) as the seeds lose dormancy with ageing (Yogeesha *et al.* 2008b). This study shows that fermentation method can be employed for quick and easy removal of papaya seed sarcotesta without affecting the seed quality.

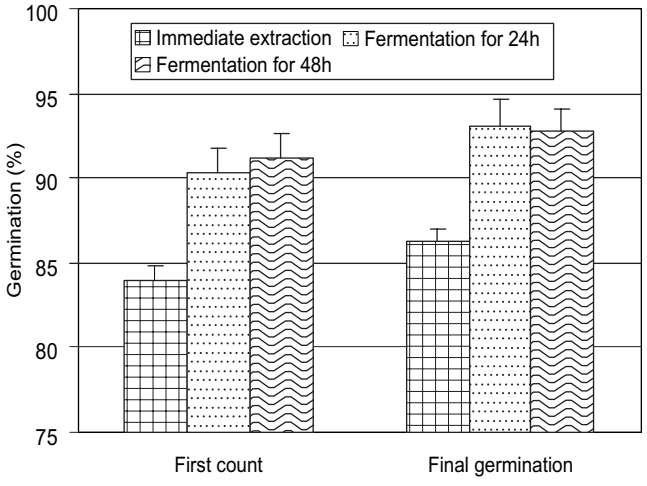

Fig 1 Effect of seed extraction technique on seed germination in cv Surya (initial)

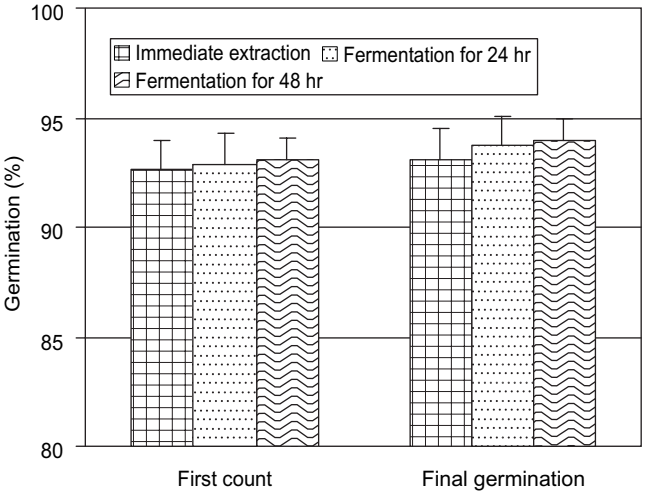

Fig 2 Effect of seed extration technique on seed germination in papaya cv Surya after 8 months storage under ambient condition

Storage behaviour of seeds extracted from different maturity stages

Seed quality evaluation of 8 months old seeds stored under ambient conditions showed similar trend as that of

Table 4 Seed quality as influenced by stage of fruit harvest and seed extraction in papaya cv. Surya after 8 months of storage under ambient conditions

Stage of fruit harvest and seed extraction	First count (%)	Germination (%)	Germination length (cm)	Vigour index I	Seedling dry wt (mg)	Vigour index II
Immature fruits- Immediate extraction						
Mature green- Immediate extraction	4.0	10.7	7.93	85	0.50	28.1
Mature green -extracted after full ripe	52.0	74.0	13.53	1000	3.70	244.7
1/4 ripe -immediate extraction	48.7	53.3	13.30	710	2.67	199.7
1/4 ripe - extraction at full ripe	76.7	82.7	15.80	1306	4.13	278.6
1/2 ripe -immediate extraction	68.7	74.0	15.03	1112	3.70	272.1
1/2 ripe - extraction at full ripe	75.3	86.7	16.87	1463	3.63	314.7
3/4 ripe -immediate extraction	84.7	90.7	17.83	1617	4.53	365.8
3/4 ripe - extraction at full ripe	90.0	90.0	18.30	1645	4.50	333.1
Full ripe	92.7	93.3	18.23	1702	4.67	370.7
LSD (0.01)	9.6	10.4	1.83	199	0.52	58.0
SEm ±	2.4	2.6	0.44	49	0.13	14.2

fresh seeds (Table 4). Seeds from ¾ ripe fruits and fully ripe fruits showed better germination (90.7%) and seedling vigour (1617 and 365.8 vigour index I and vigour index II, respectively) compared to the seeds extracted from ½ ripe and early stages of fruit maturity. However, the seeds extracted from postharvest ripened fruits resulted in better seed quality than seeds obtained from immediate extraction. Similar results were reported in watermelon (Nerson 2002), chilli (Pandita and Shantha Nagarajan 2001) and tomato (Demir and Samit 2001). Only the seeds extracted from over ripe firm tomato fruits maintained high germination during 22 months storage period (Yogeesha *et al.* 2006).This shows that physiologically fully developed seeds deteriorate slowly in storage than seeds extracted before physiological maturity.

From the study, it can be concluded that the best stage of fruit harvest for obtaining best quality seed was when the ¾th of the fruit skin turned yellow as the seeds from these fruits not only gave better germination and vigour but also showed better storability compared to the seeds from fruits of early stages of maturity. Fermentation for 24-48 hr was found ideal for easy removal of sarcotesta surrounding the seed surface, without affecting the quality of the seed.

REFERENCES

Demir I and Samit Y. 2001. Quality of tomato seeds as affected by fruit maturity at harvest and seed extraction method. *Gartenbauwissenschaft* **66**(4): 199–202.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agriculture Research*. USA: John Wiley & Sons, New York.

Medeiros M A, de Grangeiro L C, Torres S B and Freitas A V L. 2010. Physiological maturity in gherkin (*Cucumis anguria* L.) seeds. *Revista Brasileira de Sementes* **32** (3): 17–24. (http://dx.doi.org/10.1590/S0101-31222010000300002)

Nerson H. 2002. Effects of seed maturity, extraction practices and storage duration on germinability in watermelon. *Scientia Horticulturae* **93**: 245–56. (http://dx.doi.org/10.1016/S0304-4238(01)00332-6)

Pandita V K and Shantha Nagarajan. 2001. Fruit maturity and post harvest ripening affecting chilli seed quality and field emergence. *Seed Research* **29**(1): 21–3.

Sangakkara U R. 1995. Influence of seed ripeness, sarcotesta, drying and storage on germinability of papaya *(Carica papaya* L.) seed. *Pertanika Journal of Tropical Agricultural Sciences* **18**(3): 193–9.

Vidigal D S, Dias D C F S, Pinho E R V and von Dias L A S. 2009. Sweet pepper seed quality and leaf-protein activity in relation to fruit maturation and post-harvest storage. *Seed Science and Technology* **37**(1): 192–201. (http://www.ingentaconnect.com/content/ista/sst/2009/00000037/00000001/art00021)

Yogeesha H S, Prakash K B and Naik L B. 2006. Stage of fruit maturity on seed quality during storage in tomato (*Lycopersicon esculentum* Mill.). *Seed Research* **34**(1): 74–6.

Yogeesha H S, Bhanuprakash K and Naik L B. 2007. Effect of temperature and chemical pre-treatment on seed germination in papaya (*Carica papaya*). *Indian Journal of Agricultural Sciences* **77**(10): 689–91. (<http://epubs.icar.org.in/ojs-2.3.1-2/index.php/IJAgS/article/view/3445>)

Yogeesha H S, Singh T H and Naik L B. 2008a. Seed germination in relation to seed development in eggplant (*Solanum melongena*). *Indian Journal of Agricultural Sciences* **78**(12): 1010–2. (<http://epubs.icar.org.in/ejournal/index.php/IJAgS/article/view/9968>)

Yogeesha H S, Bhanuprakash K and Naik L B. 2008b. Seed storability in three varieties of papaya in relation to seed moisture, packaging material and storage temperature. *Seed Science & Technology* **36**(3): 721–9.