Pertanika J. Trop. Agric. Sci. 18(3): 193-199(1995)

ISSN: 0126-6128

Influence of Seed Ripeness, Sarcotesta, Drying and Storage on Germinability of Papaya *(Carica papaya* L.) Seed

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Keywords: papaya, seeds, germination, fruit maturity, sarcotesta, drying

ABSTRAK

*Betik (*Carica papaya *L.) adalah buah-buahan tropikal terkenal yang dibiakkan oleh biji benih. Walau bagaimanapun, percambahan dan cara mendapatkan anak benih yang baik dalam spesis ini adalah rumit kerana keadaan biji benihnya. Sehingga kini, satu siri kajian untuk menilai kesan kematangan buah, sarkotesta dan kekeringan terhadap percambahan dan penghasilan anak benih yang baik masih diteruskan. Ciri-ciri biji benih buah betik bertukar bersama kematangan buah. Kecepatan percambahan meningkat bersama kematangan buah. Setakat ini, biji benih yang terbaik untuk percambahan dan untuk pemerolehan anak benih yang subur di dapati dari buah-buah masak atau yang terlebih masak. Kewujudan sarkotesta mengurangkan percambahan dan meningkatkan bilangan anak benih yang luar biasa. Gabungan sarkotesta dalam kesederhanaan percambahan biji benih betik atau padi tidak menghalang percambahannya. Ini bermakna bahawa halangan lebih berpunca dari sarkotesta yang tidak tersentuh bukan dari penghalang-penghalang yang diperolehi daripadanya. Mengering biji benih betik di bawah suhu berudara dan teduh, akan mengekalkan proses percambahan ke darjah yang lebih tinggi daripada bila biji benih dikeringkan di dalam oven. Penurunan kelembapan biji benih di bawah 10% yang mengurangkan percambahan, menunjukkan corak sifat yang sederhana untuk biji benih betik dibandingkan biji benih ortodok atau degil.*

ABSTRACT

Papaya (Carica papaya *L.) is a popular tropical fruit which is propagated by seed. However, germination and the procurement of good seedlings are difficult in this species due to the nature of the seed. Thus a series of studies to evaluate the influence of fruit maturity, sarcotesta and drying on germination and production of healthy seedlings was carried out. The characteristics of papaya seed change with fruit maturity. Speed of germination increases with fruit maturity. Thus, the best seed for germination and for the the procurement of healthy seedlings is obtained from ripe or over-ripe fruits. The presence of the sarcotesta reduces germination and increases the number of abnormal seedlings. Incorporation of the sarcotesta in the germination medium of papaya or rice seeds did not inhibit their germination. This suggests that inhibition is caused by the intact sarcotesta rather than inhibitors derived from it. Drying papaya seeds under shade and ambient temperature maintained germinability to a greater degree than when seeds were desiccated in ovens. The reduction of seed moisture below 10% reduced germination significantly, indicating an intermediate behaviour pattern for papaya seeds in contrast to orthodox or recalcitrant seeds.*

INTRODUCTION

Seeds are a primary source of plant propagation in agriculture, horticulture and forestry, as they are dispersal units consisting of an embryo, food reserves and protective structure (Roberts and King 1989). Seeds of most cultivated species can be dehydrated and stored under conditions of low humidity and temperatures for varying lengths of time, without loss of germinability (Ellis 1991). Such seeds are classified as orthodox types (Roberts and King 1989; Hofmann and Steiner 1989).

Another group of seeds retains high moisture contents during maturation. These seeds do not withstand desiccation and need to be stored at a high moisture content. The seed moisture content at which germinability is lost varies from species to species and according to the drying regime (Farrant *et al.* 1988). These seeds are classfied as recalcitrant and are common among tropical and subtropical perennial species (Chin and Roberts 1980; Roberts *et al.* 1984).

An intermediate category of seed has been identified (Ellis *et al.* 1990); these survive desiccation to approximately 10% moisture content, but further drying reduces germinability (Ellis 1991). Seeds of several important food crops, e.g. coffee (Ellis *et al.* 1990) are of this type.

Papaya seeds have been classified as recalcitrant (Chin *et al.* 1984; Hofmann and Steiner 1989) and more recently as the intermediate type (Ellis *et al.* 1990).

Propagation of papaya by seed is difficult due to rapid seed deterioration after harvest. This is attributed to microbial degeneration of the sarcotesta, which reduces viability (Begum *et al.* 1987), although Gherardi and Valio (1976) had reported the presence of growth-inhibiting substances in the mucilage covering the seed. However, these studies do not clearly identify the influence of fruit maturity and the presence or the sarcotesta on the germinability of papaya seeds, before and after drying. Thus three experiments were carried out with the objective of determining the importance of fruit maturity, the sarcotesta and the process of drying on the germinability of papaya.

MATERIALS AND METHODS

The experiments used seeds of commonly available papaya ecotypes in Sri Lanka, which are a mixture of the Hawaiian and Indian varieties.

Experiment 1. Influence of Fruit Maturity and the Presence of the Sarcostesta on Germination of Papaya Seeds

Seeds were removed from mature, ripe and over-ripe papayas. These stages corresponded to green fruits with a yellow tinge, with hard pink flesh (mature), yellow-green fruit with soft edible red flesh (ripe) and yellow fruit with pulpy red flesh not suitable for consumption (over-ripe) respectively.

Soon after extraction, four replicates of 100 seeds from each maturity stage were planted at a depth of 2 cm in washed river sand (diameter 0.5-0.6 mm). Similar replicates of seeds from the three maturity stages were planted in the same manner after removal of the sarcotesta by rubbing with sand. The fresh and dry weights of seed and sarcotesta were recorded. Germination and the percentage of abnormal seedlings were determined beginning from day 5 after planting, up to day 30.

Experiment 2. Effects of Drying on Storability and Germination of Papaya Seeds

Based on the results of the experiment, eight replicates, each of 600 seeds of ripe and over-ripe fruits, 50% with the sarcotesta removed as described above were dried either under partial shade at a mean ambient temperature of 28°C ± 2.6° or oven dried at 40°C ± 1.5°.

Subsamples (150 seeds) from each replicate for each of the four treatments were dried to moisture contents of 25, 10 and 5% and stored in sealed containers. Germination was determined at 0, 30 and 90 days after storage using 50 seeds per replicate.

Experiment 3. Influence of the Sarcotesta on the Germination of Papaya and Rice Seeds

Seeds obtained from ripe and over-ripe papaya fruits were divided into nine seedlots, each containing 300 seeds. The sarcotesta of seeds in each seedlot were carefully separated and placed in individual petri dishes, while the clean seeds were washed in distilled water.

Within the same maturity category, the sarcotesta from one seedlot were mixed with clean seeds of another sample, which were planted in trays and germination determined as described in Experiment 1. This was carried out on all six groups.

The sarcotesta of the remaining three seedlots were mixed with three replicates of rice seeds (variety BG 34-8), each containing 300 seeds, and planted in sand at a depth of 2 cm. Another three replicates of rice seeds were planted without mixing with the papaya sarcotesta. Control treatments of seeds with and without the sarcotesta were also maintained for comparison. Germination and numbers of abnormal seedlings were determined on day 21 after planting.

The data of all experiments were analysed statistically to determine the significance of the different treatments.

RESULTS AND DISCUSSION

The stage of maturity of papaya fruits had a significant influence on seed characteristics (Table 1). Seeds of mature unripe fruits had the lowest fresh weight. The sarcotesta accounted for 50% of fresh weight, and the seeds had a very high moisture content. Thus in comparison dry weight was low.

Fresh weight of seeds increased in ripe fruits but did not change significantly in over-ripe fruits. The weight of the sarcotesta also increased in seeds of ripe fruits, but this constituted only 45% of the seed fresh weight, and it was lower than in seeds of mature fruits. Further ripening did not change these parameters.

Seed moisture content declined with fruit maturity, and the dry weights increased, culminating in a 100-seed dry weight of 2.41 g in ripe fruits. Accumulation of photosynthates in the endosperm and loss of seed moisture are characteristic of seed maturity (Hanson 1984).

Stage of maturity and the presence of the sarcotesta had a significant impact on germination and development of abnormal seedlings (Table 2). The interaction between these two variables was significant in all samples.

Germination of seeds from mature fruits was lowest and the percentage of abnormal seedlings was the highest. In contrast, there were no differences in these parameters between seeds obtained from ripe and over-ripe fruits. This clearly shows the importance of stage of fruit maturity in determining the germinability of papaya seeds and the procurement of healthy normal seedlings. It also confirmed the unsuitability of using seed from mature but unripe fruit for the propagation of papaya. This could be attributed to incomplete development and high moisture content of the seeds, both of which affect germination and seedling development.

Germination of seeds of mature fruits was low on the 10th day, but increased significantly thereafter (Table 2), in contrast to that of the other two categories. Stage of fruit maturity had a direct impact on speed of germination. Although the number of abnormal seedlings was greater from seeds of mature fruits, the increments in number between the 10th and 30th day was similar (approximately 72%) in all seedlots. Thus development of abnormal seedlings was not affected by fruit maturity, in contrast to germination.

The presence of the sarcotesta reduced germination, and echanced the number of abnormal seedlings (Table 2). This confirms earlier reports of the detrimental effects of the sarcotesta on germination of papaya seeds (Gherardi and Valio 1976; Begum *et al.* 1987). However, the effect of the sarcotesta in reducing germination and enhancing the number of abnormal seedlings differed with fruit maturity, having a greater inhibitory effect on the germination of seeds from ripe and over-ripe fruit, while the number of abnormal seedlings was greatest in seeds of mature fruits on the 30th day. Reyes *et al.* (1980) have suggested the presence of growth inhibitors in the sarcotesta as the causal agent.

TABLE 1
Characteristics of seeds obtained from mature, ripe and over-ripe papaya

Characteristic	Mature Fruit	Ripe Fruit	Over-ripe Fruit	LSD
Fresh wt. per 100 seeds (g)	9.45	11.84	11.59	0.152
Fresh wt. of sarcotesta of 100 seeds (g)	4.81	5.42	4.99	0.029
Dry wt. per 100 seeds without sarcotesta (g)	1.15	1.94	2.41	0.008
Moisture content (%)	76.0	64.2	51.7	2.619

TABLE. 2
Influence of fruit maturity and presence of sarcotesta on germination and occurrence of abnormal seedlings in papaya

Fruit Type	Sarcotesta	Observation (Days after planting)					
		10		20		30	
		A	B	A	B	A	B*
Mature	Absent	30.1%	10.6%	42.5%	16.2%	48.2%	18.5%
	Present	24.2%	22.6%	36.0%	32.0%	42.1%	38.0%
Ripe	Absent	75.4%	8.4%	82.0%	9.5%	87.5%	10.0%
	Present	37.4%	12.5%	46.0%	17.2%	56.8%	21.0%
Over-ripe	Absent	78.2%	9.0%	84.5%	7.2%	89.0%	7.0%
	Present	39.5%	14.0%	50.2%	18.0%	57.0%	24.5%
LSD (P=0.05)	Fruit type	9.59	14.24	4.98	9.07	6.91	2.91
	Presence of Sarcotesta	2.51	8.55	1.95	2.80	1.92	4.90
	Interaction	*	*	*	*	*	*

* A - Percentage germination; B - Percentage abnormal seedlings.

The influence of the sarcotesta and method of drying on storability and germinability of papaya seeds is presented in Table 3. Seeds from ripe and over-ripe fruits were used due to the poor germinability of those from mature fruit (Table 2). The germination response was similar in both types of seed and drying significantly reduced germination, confirming the poor response of papaya seeds to desiccation (Chin *et al.* 1984). Thus the highest percentage germination was observed at a seed moisture content of 25%, irrespective of other treatments. Lowering of seed moisture to 10% reduced germination in both categories of seed, although the decrease was not excessive. In contrast, drying seeds to 5% moisture decreased germination significantly. Thus, as reported by Ellis *et al.* (1990), seeds of ripe and over-ripe papaya fruits seen to tolerate desiccation to 10% seed moisture content without considerable loss of germination. Thus, these seeds could be dried to a greater degree than most recalcitrant seeds, which lose viability at approximately 30% moisture content, thereby exhibiting intermediate characteristics, as suggested by Ellis *et al.* (1990).

The absence of the sarcotesta increased germinability significantly irrespective of fruit maturity, drying regime or seed moisture content. This confirms earlier results of the adverse effects of the sarcotesta on germination, due to the presence of inhibiting compounds (Begum *et al.* 1987). However, when compared with germination values at 25% moisture content, its effect in reducing germination is lower at reduced seed moisture contents. This indicates that drying, ecpecially to 5% seed moisture content, may deactivate the germination inhibitors. However, drying to this low seed moisture level reduced germination of all seeds significantly. Thus the beneficial impact of removing the inhibitory effect of the sarcotesta is minimal in dried seeds. Storage of seeds does not negate the adverse effect of the sarcotesta, thus illustrating the value of removing it prior to planting.

Oven drying decreases germination irrespective of fruit maturity and the presence of the sarcotesta (Table 3). This is due to the higher temperature regime, which could destroy the embryo and/or cause detrimental changes to the endosperm reserves. Drying at moderate temperatures under shade allows the process of desiccation to progress gradually, thus causing minimal changes to the seed. However, germination decreases with length of storage for both categories of seed dried to three moisture levels. The decline in germination is most significant in seeds dried to a moisture content of 5%. This again confirms the adverse effect of low moisture in papaya. The decline in germination with length of storage is greater when seeds are dried with the sarcotesta, again showing the importance of removing it.

TABLE 3
Influence of sarcotesta and drying regime on storability and germinability of papaya seed at various levels of seed moisture content

Fruit Type	Sarcotesta	Method of Drying	Storage Period (days) 0	30	90
			Germination (%)		
25% Seed Moisture					
Ripe	absent	shade	84	75	70
		oven	65	52	42
	present	shade	50	41	36
		oven	34	27	20
	LSD (P=0.05)		2.1	3.8	1.9
Over-ripe	absent	shade	85	76	70
		oven	67	55	44
	present	shade	47	44	35
		oven	36	27	21
	LSD (P=0.05)		0.9	1.13	0.7
10% Seed Moisture					
Ripe	absent	shade	74	64	61
		oven	60	47	40
	present	shade	40	32	26
		oven	30	24	20
	LSD (P= 0.05)		1.3	0.4	0.3
Over-ripe	absent	shade	76	70	65
		oven	64	57	42
	present	shade	45	40	32
		oven	35	30	24
	LSD (P = 0.05)		0.8	1.2	2.9
5% Seed Moisture					
Ripe	absent	shade	27	18	16
		oven	22	14	8
	present	shade	16	10	9
		oven	10	8	6
	LSD (P = 0.05)		0.3	1.1	0.3
Over-ripe	absent	shade	22	26	12
		oven	18	12	7
	present	shade	16	9	5
		oven	9	6	5
	LSD (P = 0.05)		0.2	0.4	0.2

The adverse effect of the sarcotesta in inhibiting seed germination of other seeds in seen in Table 4. Application of extracted sarcotesta of a similar quantity as the papaya seed of the same maturity stage or to rice seed did not reduce germination or result in abnormal seedlings. This clearly illustrates that the inhibitory effect of the sarcotesta occurs only when kept intact. Thus, the possibility that the sarcotesta acts as a barrier to germination and healthy seedling development cannot be ignored, although the presence of germination inhibitors has been reported (Begum *et al.* 1987).

CONCLUSION

Fruit maturity affects seed quality in papaya. Seed development is complete at fruit ripening and not at maturity as was observed from seed dry weight and the contribution of the sarcotesta to this parameter.

The stage of maturity, the presence of sarcotesta and drying method affected seed quality. Seeds of ripe and over-ripe fruits are most suitable for propagation purposes. As in recalcitrant seeds (e.g. Sangakkara 1993), drying under shade at ambient temperatures maintains germinability in contrast to forced desiccation in ovens. Desiccation of seeds to a moisture content of less than 10% reduces germination significantly. Length of storage also decreased germination, especially when seeds were oven-dried.

Presence of the sarcotesta, which could be considered a protective cover, significantly inhibits germination of papaya seeds and increases the number of abnormal seedlings. Thus, removal of the sarcotesta increases germination. Addition of the extracted sarcotesta was only inhibitory when left intact; this aspect requires elucidation. High rates of germination and development of healthy seedlings can be obtained by using seeds from ripe or over-ripe fruits and from which sarcotesta is removed. If desiccation is required, this process should be carried out gradually under ambient temperatures.

ACKNOWLEDGEMENTS

Gratitude is expressed to Ms N Mendis and Mr E R Piyadasa for research assistance, and Ms S N Werellagama Meegahakumbura for secretarial work. The project was partially funded by the University of Peradeniya.

TABLE 4
Influence of sarcotesta of seed from ripe and over-ripe papaya fruits on germination of rice or other papaya seeds

Seed Type	Treatment	Germination (%) at 21 Days	Abnormal Seedlings (%) 21 Days
Ripe Papaya	with sarcotesta intact	47.2	31.0
	without sarcotesta	85.6	4.5
	with sarcotesta from other seeds	80.4	5.6
	LSD (P= 0.05)	4.03	5.73
Over-ripe Papaya	with sarcotesta intact	51.7	37.6
	without sarcotesta	88.0	5.8
	with sarcotesta from other seeds	83.6	6.1
	LSD (P = 0.05)	2.77	1.84
Rice	with sarcotesta from ripe papaya seeds	91.6	4.86
	with sarcotesta from over-ripe papaya seeds	94.2	3.96
	without sarcotesta	95.1	4.22
	LSD (P = 0.05)	1.23	1.04

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(Received 27 July 1994)
(Accepted 11 January 1996)