INFLUENCE OF DEGREE OF FRUIT MATURITY ON SEED GERMINATION, SEEDLING VIGOUR AND STORABILITY OF SANDAL (*SANTALUM ALBUM*)

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MANONMANI, V. & VANANGAMUDI, K. 2001. Influence of degree of fruit maturity on seed germination, seedling vigour and storability of sandal (*Santalum album*). Sandal (*Santalum album*) is an important tree in India both economically and culturally. The study was aimed at deciphering the differences in germinability, seedling vigour and storability of seed obtained from fruits harvested at different stages of maturity. The fruit characteristics, namely, 100 fruit weight, fruit moisture content, 100 seed weight, seed length and seed breadth were closely related to the level of fruit maturity. The green fruits were not able to germinate while 29.0, 68.2 and 73.2% of greenish red, reddish brown and black fruits germinated. The brown fruits recorded the lowest percentage of reduction in germination after 14 months of storage. Seedling length, dry matter production, vigour index and oil content were also highest for the black fruits. The results strongly support the collection of sandal fruits when they are black in colour.

Key words: *Santalum album* - fruit maturity - seed germination - seedling vigour - storability

MANONMANI, V. & VANANGAMUDI, K. 2001. Pengaruh darjah kematangan buah terhadap percambahan biji benih, kecergasan anak benih dan penyimpanan cendana (*Santalum album*). Cendana (*Santalum album*) merupakan pokok yang penting dari segi ekonomi dan kebudayaan di India. Kajian ini bertujuan untuk mentaksirkan perbezaan dalam percambahan, kecergasan anak benih dan penyimpanan biji benih yang diperoleh daripada buah yang dipetik pada tahap kematangan yang berbeza. Ciri-ciri buah iaitu berat 100 biji buah, kandungan lembapan buah, berat 100 biji benih, panjang biji benih dan lebar biji benih berkait rapat dengan tahap kematangan buah. Buah yang berwarna hijau tidak bercambah manakala 29.0, 68.2 dan 73.2% daripada

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buah-buah yang berwarna merah kehijauan, coklat kemerahan dan hitam didapati bercambah. Buah berwarna coklat mencatatkan peratusan penurunan percambahan yang paling rendah selepas 14 bulan dalam penyimpanan. Panjang anak benih, pengeluaran bahan kering, indeks kecergasan dan kandungan minyak juga didapati paling tinggi dalam buah berwarna hitam. Keputusan ini menunjukkan bahawa buah cendana hendaklah dikutip apabila ia berwarna hitam.

Introduction

Sandal is valued in India both economically and culturally for its fragrant heartwood and its oil which contains santalol. Both the wood and the oil are also credited with diaphoretic, diuretic and expectorant properties (Chopra *et al.*1958). Estimation of optimum time for collecting seed, pre-treatment and the way to store seed safely have not been extensively studied for sandal. In sandal, the criterion usually used in the field to determine degree of maturity is the fruit colour. The main reason is because other indices offer no advantage over this easily observed attribute (Bonner 1974). In actual fact colour of mature fruit, germination percentage, seedling dry matter as well as root and hypocotyl length of seedlings are the best criteria to determine the maturity stage (Oliver 1974, Rietveld 1978). Colour changes have been recommended as an indicator of ripeness in oaks (Bonner 1974), green ash (*Fraxinus pennsylvanica*) (Bonner 1973), black cherry (*Prunus serotina*) and yellow popular (*Liviodendron tulipifera*) fruits (Bonner 1975). A study was formulated with an objective to determine the differences in germinability and seedling vigour of sandal seeds extracted from fruits at different stages of maturity. The seeds were also tested to delineate the relationship between fruit maturity and storability.

Materials and methods

Sandal fruits were collected from the plus trees at Forest College and Research Institute, Mettupalayam and sorted into different maturity stages based on their colour, namely, green, greenish red, reddish brown, black and black but shrivelled fruits which are over matured. Immediately after collection, the fruits were cleaned to remove other plant and floral parts. The weight of fruits were measured from four replications of 100 fruits and the moisture content was determined by using low constant temperature method (ISTA 1993). Following these, seeds were extracted by depulping. Seeds were then shade dried before being sun dried to 12% moisture content. Four replications of 25 seeds each were measured for length and breadth using dial calipers.

Seeds were subjected to germination test in sand medium by sowing four replications of 25 seeds each. Twenty eight days after sowing, counts were made and germination was expressed as percentage of seeds which produced normal seedlings (ISTA 1993). Ten random seedlings were then measured for root and shoot length. The vigour index (VI) was derived from the formula by Abdul-Baki & Anderson (1973).

VI = Percentage germination × Seedling length (cm)

where seedling length is the sum of root and shoot length.

Fifty seeds selected at random were pre-washed thrice with water and soaked in 50 ml deionised water for 12 h at room temperature and decanted. Electrical conductivity of the seed leachate was read in an Elico type CM 82 conductivity bridge with cell constant of one and expressed as dS m^{-1} (Presley 1958). The oil extraction process was carried out in Soxhlet apparatus as per the AOAC (1960) procedure.

$$\text{Oil content in \%} = \frac{\text{Weight of oil (g)}}{\text{Weight of seed (g)}} \times 100$$

The seeds extracted from the five maturity stages were packed in cloth bags and stored under ambient conditions. Seed samples were drawn at bimonthly intervals until the 14th month and evaluated for moisture content, 100 seed weight (dry basis), germination, root length, shoot length, dry matter production, vigour index, electrical conductivity and oil content. The data obtained from the studies were statistically analysed to find out the 'F' test of significance (Panse & Sukhatme 1967).

Results and discussion

The fruit characteristics, namely, 100 fruit weight, fruit moisture content, 100 seed weight, seed length and seed breadth were closely related to the fruit maturity levels (Table 1). The 100 fruit weight increased from 43.28 g in the green stage to 70.44 g in the black stage. The over matured fruits recorded 40.48 g. All the stages tested recorded over 59% fruit moisture content except for over matured fruits, which recorded only 44.9%. The 100 seed weight increased from 14.60 g (green stage) to 17.46 g (black stage). Over matured fruits recorded the lowest weight of 14.06 g. Seed length ranged from 7.18 mm (green stage) to 7.68 mm (black stage). Over matured fruits recorded only 6.78 mm. Not much variation was recorded for seed breadth in all the stages of fruit maturity.

Table 1 Influence of degree of fruit maturity on fruit and seed attributes in sandal

Fruit maturity	100 fruit weight (g)	Fruit moisture content (%)	100 seed weight (g)	Seed length (mm)	Seed breadth (mm)
Green	43.28	59.5	14.60	7.18	6.30
Greenish red	49.82	59.5	15.04	7.54	6.32
Reddish brown	50.64	59.4	16.14	7.56	6.30
Black	70.44	59.8	17.46	7.68	6.46
Over mature	40.48	44.9	14.06	6.78	6.37
SED	0.33	0.19	0.15	0.03	0.005
CD (p = 0.05)	0.70	0.39	0.32	0.07	0.009

Fruit maturity stage is of paramount importance for seed germination and seedling vigour (Table 2). The green fruits were not able to germinate while 29.0, 68.2 and 73.2% of greenish red, reddish brown and black fruits respectively germinated. Only 29.2% of over matured fruits germinated. Root length (7.12 cm), shoot length (10.18 cm), dry matter production (0.021 g seedling^{-1}), vigour index (1267) and oil content (56.2%) were highest in the black fruits. Over matured fruits recorded the highest electrical conductivity of 0.140.

Table 2 Influence of degree of fruit maturity on seed germination, seedling attributes and biochemical parameters in sandal

Fruit maturity	Germination (%)	Root length (cm)	Shoot length (cm)	Dry matter production (g seedling^{-1})	Vigour index	Electrical conductivity (dS m^{-1})	Oil content (%)
Green	0.0 (0.0)	0.00	0.00	0.000	0	0.116	39.0
Greenish red	29.0 (32.6)	5.92	7.54	0.014	390	0.119	50.8
Reddish brown	68.2 (55.7)	6.90	10.00	0.019	1152	0.119	54.6
Black	73.2 (58.8)	7.12	10.18	0.021	1267	0.116	56.2
Over mature	29.2 (32.7)	5.08	6.10	0.011	326	0.140	52.2
SED	0.34	0.05	0.06	0.0002	10	0.004	0.5
CD (p = 0.05)	0.72	0.10	0.13	0.0005	20	0.008	1.1

Figures in parentheses indicate arc sin transformed values.

Moisture content and 100 seed weight during storage consistently decreased with storage period. The percentage decrease values of 100 seed weight over 14 months were 23.7, 24.4, 26.0, 24.5 and 37.2 in green, greenish red, reddish brown, black and over mature stages respectively (Table 3).

The initial germination percentage was highest in the black stage (58.2%) (Table 3). There was a complete loss of germination after 14 months of storage in the over matured, greenish red and green fruits, whereas black fruits recorded 5.4% germination.

Root and shoot length, dry matter production as well as vigour index were also initially highest in the black stage (Tables 5 & 6). However, as with germination, these parameters also decreased over storage period. Electrical conductivity, which increased with storage period, was highest in the over matured stage. The black stage recorded the highest oil content initially (55.6%) and after 14 months of storage (39.8%) followed by the reddish brown stage (50.2 & 35.0% respectively) (Table 7).

The increased fruit and seed characteristics in the black stage such as fruit weight, seed weight, length and breadth as well as seed germination can be attributed to maximum accumulation of storage food reserves (drying oil chiefly composed

Table 3 Influence of degree of fruit maturity on moisture content and 100 seed weight of sandal seeds in storage

Fruit maturity	Moisture content (%) Months of storage									100 seed weight (g) Months of storage								
	0	2	4	6	8	10	12	14	Mean	0	2	4	6	8	10	12	14	Mean
Green	15.36	15.40	14.50	13.82	13.16	12.46	11.74	10.66	13.39	14.92	14.36	14.06	13.70	13.22	12.60	12.28	11.38	13.32
Greenish red	14.30	14.44	14.16	13.84	12.92	12.22	11.70	10.74	13.04	15.08	14.84	14.44	14.42	13.94	13.20	11.90	11.40	13.32
Reddish brown	13.44	13.46	13.40	12.62	11.88	11.22	10.40	9.84	12.09	16.12	16.02	15.36	14.86	14.60	14.08	13.12	11.92	14.51
Black	12.20	11.72	12.02	11.16	10.70	9.88	9.22	8.96	10.73	17.62	17.52	16.70	16.30	14.80	14.40	13.80	13.20	15.54
Over mature	13.60	13.52	13.54	12.62	12.32	11.54	10.62	10.04	12.23	14.36	13.40	12.30	11.50	11.00	10.02	9.24	9.02	11.36
Mean	13.78	13.71	13.52	12.81	12.28	11.46	10.74	10.05		15.62	15.23	14.57	14.16	12.97	12.86	12.07	11.38	
		M	P	MP							M	P	MP					
SED		0.05	0.06	0.15							0.24	0.30	-					
CD (p = 0.05)		0.10	0.13	0.29							0.47	0.60	NS					

M = Maturity stage; P = Period of storage

Table 4 Influence of degree of fruit maturity on germination and root length of sandal seeds in storage

Fruit maturity	Germination (%) Months of storage									Root length (cm) Months of storage								
	0	2	4	6	8	10	12	14	Mean	0	2	4	6	8	10	12	14	Mean
Green	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greenish red	32.4 (34.7)	38.2 (38.2)	38.8 (38.5)	36.8 (37.3)	18.2 (25.3)	10.4 (18.7)	1.2 (6.2)	0.0 (0.0)	22.0 (24.9)	5.14	5.54	5.54	5.32	5.04	4.60	2.16	0.00	4.17
Reddish brown	57.4 (49.3)	67.6 (55.3)	68.8 (56.0)	62.0 (51.9)	33.4 (35.3)	20.4 (26.8)	13.2 (21.3)	1.4 (6.7)	40.5 (37.8)	6.56	6.90	6.98	6.76	6.12	5.30	4.56	3.08	5.78
Black	58.2 (49.7)	75.6 (60.4)	77.0 (61.3)	67.6 (55.3)	38.8 (38.5)	27.4 (31.6)	15.0 (22.8)	5.4 (13.4)	45.6 (41.6)	6.74	7.16	7.60	7.24	6.98	6.08	5.42	3.90	6.39
Over mature	43.0 (40.9)	44.0 (41.6)	44.2 (41.7)	40.8 (39.7)	19.6 (26.3)	10.8 (19.1)	0.0 (0.0)	0.0 (0.0)	25.3 (26.2)	5.04	5.16	5.16	5.10	4.22	3.84	0.00	0.00	3.57
Mean	38.2 (34.9)	45.1 (39.1)	45.8 (39.5)	41.4 (36.9)	22.0 (25.1)	13.8 (19.3)	5.9 (10.1)	1.4 (4.0)		4.69	4.95	5.06	4.88	4.47	3.96	2.43	1.39	
			M	P	MP							M	P	MP				
SED			0.16	0.21	0.46							0.02	0.03	0.07				
CD (p = 0.05)			0.32	0.41	0.92							0.05	0.06	0.13				

M = Maturity stage; P = Period of storage

Table 5 Influence of degree of fruit maturity on shoot length and dry matter production of sandal seeds in storage

Fruit maturity	Shoot length (cm) Months of storage									Dry matter production (g seedling^{-1}) Months of storage								
	0	2	4	6	8	10	12	14	Mean	0	2	4	6	8	10	12	14	Mean
Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Greenish red	6.06	6.32	6.90	6.80	6.32	5.26	3.12	0.00	5.10	0.014	0.014	0.014	0.013	0.012	0.011	0.011	0.009	0.013
Reddish brown	8.14	8.46	8.92	8.80	8.62	7.30	6.30	4.32	7.61	0.016	0.016	0.015	0.015	0.013	0.012	0.011	0.010	0.014
Black	8.80	9.12	10.30	10.30	10.26	9.82	8.42	6.28	9.16	0.016	0.016	0.016	0.015	0.014	0.013	0.012	0.011	0.015
Over mature	6.14	6.38	6.84	6.24	5.78	5.18	0.00	0.00	4.57	0.013	0.013	0.013	0.012	0.012	0.011	0.008	0.007	0.012
Mean	5.83	6.06	6.59	6.43	6.20	5.51	3.57	2.12		0.012	0.012	0.012	0.011	0.011	0.009	0.009	0.008	
		M	P	MP							M	P	MP					
SED		0.03	0.03	0.08							0.00004	0.00005	0.00012					
CD (p = 0.05)		0.05	0.07	0.15							0.00008	0.00011	0.00024					

M = Maturity stage; P = Period of storage

Table 6 Influence of degree of fruit maturity on vigour index and electrical conductivity of sandal seeds in storage

Fruit maturity	Vigour index Months of storage									Electrical conductivity (dS m^{-1}) Months of storage								
	0	2	4	6	8	10	12	14	Mean	0	2	4	6	8	10	12	14	Mean
Green	0	0	0	0	0	0	0	0	0	0.118	0.119	0.121	0.129	0.135	0.153	0.163	0.187	0.141
Greenish Red	363	454	483	446	207	102	6	0	258	0.119	0.121	0.124	0.131	0.139	0.148	0.157	0.170	0.139
Reddish Brown	844	1040	1094	965	492	257	143	11	606	0.116	0.117	0.118	0.122	0.127	0.196	0.207	0.220	0.153
Black	904	1231	1375	1186	669	436	208	55	758	0.117	0.118	0.122	0.131	0.134	0.139	0.147	0.153	0.133
Over mature	494	508	527	463	196	98	0	0	286	0.138	0.138	0.147	0.158	0.176	0.221	0.294	0.371	0.205
Mean	521	646	696	612	313	179	71	13		0.122	0.123	0.126	0.134	0.142	0.171	0.194	0.220	
		M	P	MP							M	P	MP					
SED		3	4	9							0.0007	0.0009	0.0022					
CD (p = 0.05)		6	8	18							0.0015	0.0019	0.0043					

M = Maturity stage; P = Period of storage

Table 7 Influence of degree of fruit maturity on oil content (%) of sandal seed in storage

Fruit maturity	Oil content (%) Months of storage 0	2	4	6	8	10	12	14	Mean
Green	38.00	38.20	36.00	33.80	30.80	28.40	27.40	26.00	32.33
Greenish red	50.20	50.50	48.80	47.00	42.80	40.40	35.40	35.00	43.76
Reddish brown	53.00	53.10	51.20	49.20	46.60	42.60	39.40	38.40	46.69
Black	55.60	56.30	53.60	51.80	49.80	44.40	41.40	39.80	49.09
Over mature	51.20	51.00	48.80	46.40	41.80	34.80	28.60	28.40	41.38
Mean	49.60	49.82	47.68	45.64	42.36	38.12	34.44	33.52	
		M	P	MP					
SED		0.20	0.25	0.56					
CD (p = 0.05)		0.39	0.50	1.12					

of polyunsaturated fatty acids) during development and maturation of seed as reported in neem (*Azadirachta indica*) by Sivasamy (1991). Arisman and Powell (1986) reported that seeds from brown cones in *Pinus merkusii* recorded higher germination than green cones. Change in fruit colour can be recommended as a visual index for ripeness in neem (Sivasamy 1991, Bharathi *et al.* 1996), *Ailanthus excelsa* (Ramakrishnan 1988) and *Casuarina equisetifolia* (Kajamaideen *et al.*1990). A colour change from green to light brown in the acorns of white oak (*Quercus alba*) and dark red brown in shumard oak (*Q. shumardii*) was found to be a good maturity indicator (Bonner 1976).

It is also documented that the more mature the seeds are when harvested, the greater are their vigour and potential for establishment (Ching & Ching 1962, Pollock & Roos 1972). The degree of fruit maturity plays a paramount role in maintaining shelf life of tree seeds (Bonner 1976). Physiologically immature seeds deteriorated faster in storage than ripe and mature seeds (Harrington 1970, Stein *et al.* 1974). The faster deterioration of seeds in immature fruits is ascribed to the poor formation and accumulation of certain biochemical compounds (e.g., free fatty acids, free amino acids and sugars) essential for preserving viability until the final stages of seed ripening (Suszka 1978). Over mature fruits do not store well mainly because storage fungi leading to rapid deterioration easily attack these seeds (Srimathi & Nagaveni 1995).

The results of the present investigation are in strong support of collecting sandal seeds from black fruits in terms of good initial germination and best seed storability.

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