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Effect of storage temperature and sarcotesta on seeds of papaya (*Carica papaya* L.) to sustain the viability, germination and seedling growth

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Abstract
The purpose of this study was to investigate the effect of storage temperature and sarcotesta on seeds of papaya to sustain the viability, germination and seedling growth. The experiment was carried out at College of Horticulture, Junagadh Agriculture University in Junagadh district of Gujarat during 2019. The experiment was laid out in Factorial completely randomized design with ten different treatment combinations *viz*., T1 (-4 ℃ with sarcotesta), T2 (0 ℃ with sarcotesta), T3 (4 ℃ with sarcotesta), T4 (8 ℃ with sarcotesta), T5 (Room temperature with sarcotesta), T6 (-4 ℃ without sarcotesta), T7 (0 ℃ without sarcotesta), T8 (4 ℃ without sarcotesta), T9 (8 ℃ without sarcotesta) and T10 (Room temperature without sarcotesta). The results revealed that, T10 (Room temperature without sarcotesta) showed highest germination percentage (61.00), seed vigor index length and mass (2443.78 and 76.07), shoot length (13.50), root length (26.53), seedling length (40.03), number of leaves (8.73), fresh weight (2.50) and dry weight (1.25) over all other treatments after the storage period of 1 month. T1 (-4 ℃ with sarcotesta) exhibits highest seed viability percentage (78.22) over all other treatments after the storage period of 1 month. The seed and seedling growth parameters decrease as the storage period increases.

Keywords: Temperature, sarcotesta, seed viability, vigor index

Introduction
Among the various fruit crops, papaya occupies a unique place because of its delicious and wholesome flavour, nutritional aspects, eases in cultivation, quick returns and provides more income per hectare next to banana. It has wider adoptability to diverse soil and climatic conditions. It is regarded as wonder fruit of tropics and subtropics. Due to its magnificent nutritional and medicinal values, papaya has occupied a unique place in the diet of people. It is one of the richest sources of vitamin A (2020 IU) after mango. The ripe fruits are the richest source of sugars, mineral matter, vitamin A and acts as stomachic, digestive, carminative and diuretic. While unripe fruits are used for treating gastric ulcers and other stomach related ailments and they are used for the extraction of papain, which in turn used in meat tenderization, for degumming natural silk, for pre shrinking the wool and used in pharmaceutical and other cosmetic industries. Leaves are used to fight against dengue. Seeds are used as vermifuge and roots are used as generative tonic. Papaya is a small herbaceous sparsely branched tree, with a single stem growing from 16-33 ft tall. Fruit is a large fleshy berry with numerous black seeds which contain a gelatinous layer namely sarcotesta. Propagation of papaya is universally done through seed which is the only viable option. Being a dicot, papaya tree lacks cambium which is a major drawback in carrying out the vegetative propagation and so far there is no commercially feasible vegetative propagation technique is recommended. So, the only way for commercial propagation is through seeds. The viability of seed declined rapidly with aging. Sarcotesta not only hinders the germination but also affect the normal seedling growth (Tokuhisa, 2007; Angeline and Ouma, 2008) [15, 3]. Contradictory reports are there regarding the behavior of stored papaya seeds. It has been grouped as recalcitrant by Chin *et al.* (1984) [4] and Hofmann and Steiner (1989) [9] stating that it is chilling sensitive. On the other hand, several reports says that papaya seeds are intolerant to low temperatures (Magill *et al*., 1994; Althoff and Carmona, 1999) [11, 2]. Understanding the impact of storage temperature and presence of sarcotesta on seed deterioration, could facilitate farmers to extend the storage time of papaya seeds.

Thus the main objective of this experiment is to get the ideal storage conditions for papaya seeds to reduce its deterioration and maintain its germinability.

Materials and Methods

The present experiment was carried out at College of Horticulture, Junagadh Agriculture University in Junagadh district of Gujarat during 2019. The seeds of the Papaya cv. GJP 1 were collected from Fruit Research Station, Madhadibaugh, JAU, during May.

One batch of seeds were subjected to the removal of sarcotesta by scrubbing the seeds using cotton cloth and washed with running water repeatedly. Another batch of seeds is left with intact sarcotesta. All the seeds were shade dried for three days and then they were sealed in polythene and kept at five different range of temperature for six month. The experiment was laid in Factorial completely randomized design with ten different treatment combinations *viz*., T1 (-4 ℃ with sarcotesta), T2 (0 ℃ with sarcotesta), T3 (4 ℃ with sarcotesta), T4 (8 ℃ with sarcotesta), T5 (Room temperature with sarcotesta), T6 (-4 ℃ without sarcotesta), T7 (0 ℃ without sarcotesta), T8 (4 ℃ without sarcotesta), T9 (8 ℃ without sarcotesta) and T10 (Room temperature without sarcotesta) replicated thrice. Each replication has 300 seeds. The seeds were evaluated at monthly interval for seed quality and seedling growth parameters.

Germination (%)

Seeds were sown in portrays filled with a mixture of sand, soil and FYM in the ratio of 1:1:1 at 3cm depth and kept in green house at Hi-Tech Horticulture Park, JAU in monthly interval up to 6 months. The seeds were considered as germinated when the seedlings emerge from soil surface.

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

Seed vigor index length (cm)

A combination of standard germination test with seedling length provides evaluation of seedling vigor index. Vigor index was calculated as per following formula given by Abdual-Baki and Anderson (1973) [1].

Vigor index length = Germination percentage x Seedling length (cm).

Seed vigor index mass (g)

Vigor index is determined by multiplication of germination percentage with seedling dry weight. Vigor index mass = Germination percentage x Seedling dry weight (g)

Seed viability percentage

Seeds were retrieved every month to determine the viability using tetrazolium test. The seeds were longitudinally cut and completely immersed in 0.1% tetrazolium solution. After 4-5 hours, the seeds were observed for the appearance of red color which indicates the respiratory activity of the seed. The seeds that show the respiratory activity via color change indicated as viable seed.

Shoot length (cm)

After 45 days of sowing, five normal seedlings were uprooted and cleaned with water to remove the adhered soil. Then the shoot length was recorded from collar region to tip of the seedling.

Root length (cm)

Root length of the respective five seedlings was recorded from the base of the root to the tip at 45 days of sowing.

Seedling length (cm)

The combined value of shoot length and root length was recorded as seedling length.

Number of leaves

Numbers of leaves were counted in the tagged plants and the mean is expressed as number of leaves.

Fresh weight of seedling (g)

Immediately after uprooting, the seedlings were washed and dried for ten minutes under shade. Then the fresh weight is checked in weighing balance and the average is recorded as fresh weight in grams.

Dry weight of seedling (g)

Previously uprooted plants were oven dried at 65°C in hot air oven until a constant weight was obtained. After complete drying, the weight of seedling is checked using electronic balance and the mean is expressed as dry weight in grams.

Statistical Analysis

The data is analysed for 'F' test of significance accorded to the methods described by Panse and Sukhatme, 1985 [12]. Wherever necessary, the per cent values were transformed to angular (Arc-sine) values before analysis. The critical differences (CD) were calculated at 5 per cent probability level. The data were tested for statistical significance (*). If F test is non-significant, it was indicated as NS.

Results and Discussions

Seed quality parameters

The data presented in Table-1 and Table-2, revealed that T10 (Room temperature without sarcotesta) exhibited the highest germination percentage (61.00), seed vigor index length and mass (2443.78 and 76.07) and lowest seed viability percentage (70.00) on 1 MAS. Whereas T1 (- 4℃ with sarcotesta) showed lowest germination percentage (28.00), seed vigor index length and mass (363.29 and 21.69) and highest seed viability percentage (78.22) on 1 MAS. Chilling temperature causes decrease in the activity of enzymes such as α and β amylase which are essential in the breakdown of starch during respiration in turn reduces the germinability. On the other hand seeds stored at room temperature probably favored the increase of those enzymes which positively affect the germination (Dadjo *et al*. 2019) [6]. The seed quality parameters decreases as the storage period increases for upto 6 months. Genes and Agnes (2018) [8] reported that increase in storage period resulted in the decline of ability of seeds to germinate.

The vigor index length of seed is directly proportional to germination percentage and seedling length. The vigor index mass is directly related to germination percentage and seedling dry weight. Higher the germination percentage, higher will be the vigor index and visa versa.

The results are in conformity with the findings of Ellis *et al*. (1991) [7] who opined that stored seeds performs better than fresh seeds. However these results are in contradictory to the findings of Zulhisyam *et al*. (2013) [16] who reported that seeds stored at 0 ℃ showed highest germination percentage.

Angeline and Ouma (2008) [3] had postulated that the presence of sarcotesta on papaya seed reduce germination by

preventing the infiltration of oxygen into the seeds. Sangakkara (1995) [14] stated that sarcotesta might be acting as a barrier to germination and healthy seedling development. These results are in line with the findings of Reyes *et al*. (1980) [13], Sangakkara (1995) [14], Tokuhisa *et al*. (2007) [15], Ibrahim *et al*. (2011) [10].

Table 1: Effect of storage temperature and sarcotesta on germination percentage and seed viability percentage

Treatments	Germination % (Months After Storage)						Seed viability % (Months After Storage)					
	1	2	3	4	5	6	1	3	3	4	5	6
T1: -4 ℃ with sarcotesta	28.00 (31.93)	12.33 (20.48)	1.10 (5.70)	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	78.22	74.44	68.22	61.00	56.22	51.11
T2: 0 ℃ with sarcotesta	33.00 (35.04)	14.67 (22.41)	2.23 (8.39)	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	76.67	73.11	66.44	60.33	54.00	49.11
T3: 4 ℃ with sarcotesta	38.67 (38.42)	18.00 (25.01)	4.53 (12.26)	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	74.00	70.00	64.00	58.00	51.56	47.00
T4: 8 ℃ with sarcotesta	42.00 (40.39)	37.67 (37.84)	32.00 (34.43)	26.67 (31.06)	22.00 (27.91)	17.67 (24.74)	72.00	68.56	62.33	55.33	50.00	45.11
T5: Room Temperature with sarcotesta	55.67 (48.27)	48.67 (44.23)	43.33 (41.16)	38.33 (38.23)	33.00 (35.02)	28.91 (32.50)	70.22	66.00	60.00	54.00	48.22	43.00
T6: -4 ℃ without sarcotesta	30.33 (33.40)	14.33 (22.14)	1.89 (7.65)	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	78.00	74.44	68.22	61.67	56.00	51.00
T7: 0 ℃ without sarcotesta	35.33 (36.43)	18.33 (25.30)	2.89 (9.68)	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	76.33	72.00	66.00	60.00	54.11	49.00
T8: 4 ℃ without sarcotesta	41.33 (40.00)	20.00 (26.48)	4.89 (12.67)	0.00 (4.05)	0.00 (4.05)	0.00 (4.05)	74.00	70.00	64.89	57.78	52.00	47.22
T9: 8 ℃ without sarcotesta	46.67 (43.08)	39.67 (39.02)	33.00 (35.00)	27.67 (31.70)	24.67 (29.72)	20.33 (26.73)	72.00	68.00	62.00	56.00	50.11	45.33
T10: Room Temperature without sarcotesta	61.00 (51.37)	51.33 (45.77)	44.67 (41.92)	38.67 (38.44)	35.00 (36.24)	31.22 (33.94)	70.00	66.00	60.44	53.56	48.56	42.89
Temperature (T) S.Em.±	0.411	0.431	0.401	0.160	0.271	0.319	1.060	0.960	0.941	1.056	0.949	0.798
C.D.@5%	1.164	1.218	1.133	0.451	0.767	0.901	2.998	2.715	2.661	2.988	2.684	2.257
Sarcotesta (S) S.Em.±	0.260	0.272	0.253	0.101	0.172	0.201	0.670	0.607	0.595	0.668	0.600	0.505
C.D. @5%	0.736	0.770	0.717	NS	0.485	0.570	NS	NS	NS	NS	NS	NS
T×S S.Em.±	0.582	0.609	0.567	0.226	0.384	0.451	1.499	1.357	1.330	1.494	1.342	1.128
C.D. @5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Figures in parentheses are Arc sine transformed values

Table 2: Effect of storage temperature and sarcotesta on seed vigor index length and seed vigor index mass

Treatments	SVI Length in cm (Months After Storage)						SVI Mass in gm (Months After Storage)					
	1	2	3	4	5	6	1	2	3	4	5	6
T1: -4 ℃ with sarcotesta	363.29	94.87	0.00	0.00	0.00	0.00	21.69	8.71	0.00	0.00	0.00	0.00
T2: 0 ℃ with sarcotesta	656.12	125.81	0.00	0.00	0.00	0.00	27.99	11.77	0.00	0.00	0.00	0.00
T3: 4 ℃ with sarcotesta	783.40	174.31	0.00	0.00	0.00	0.00	36.63	16.19	0.00	0.00	0.00	0.00
T4: 8 ℃ with sarcotesta	1154.82	401.11	298.17	240.00	188.71	143.77	45.12	54.39	29.89	23.74	17.40	13.06
T5: Room Temperature with sarcotesta	2132.19	608.56	434.13	401.18	313.36	258.77	67.14	55.13	47.37	38.27	29.44	23.75
T6: -4 ℃ without sarcotesta	423.36	120.40	0.00	0.00	0.00	0.00	24.21	10.43	0.00	0.00	0.00	0.00
T7: 0 ℃ without sarcotesta	753.11	172.93	0.00	0.00	0.00	0.00	30.93	15.00	0.00	0.00	0.00	0.00
T8: 4 ℃ without sarcotesta	893.19	204.30	0.00	0.00	0.00	0.00	42.15	18.18	0.00	0.00	0.00	0.00
T9: 8 ℃ without sarcotesta	1358.18	441.43	325.57	263.72	223.40	174.93	51.26	40.43	32.07	25.42	20.01	15.58
T10: Room Temperature without sarcotesta	2443.78	647.27	498.78	410.71	354.08	302.22	76.07	60.16	50.15	39.61	32.31	27.35
Temperature (T) S.Em.±	20.339	5.453	3.178	2.286	2.031	1.585	0.809	0.499	0.302	0.199	0.167	0.135
C.D.@5%	57.536	15.426	8.989	6.467	5.746	4.483	2.288	1.411	0.855	0.563	0.473	0.382
Sarcotesta (S) S.Em.±	12.863	3.449	2.010	1.446	1.285	1.002	0.512	0.315	0.191	0.126	0.106	0.085
C.D. @5%	36.389	9.756	5.685	4.090	3.634	2.835	1.447	0.892	0.541	0.356	0.299	0.242
T×S S.Em.±	28.764	7.712	4.494	3.233	2.873	2.241	1.144	0.705	0.427	0.282	0.237	0.191
C.D. @5%	81.368	NS	12.712	9.146	8.126	6.340	3.236	1.996	1.209	0.797	0.670	0.541

Seedling growth parameters

The data presented in Table-3 and Table-4, revealed that T10 (Room temperature without sarcotesta) showed the highest shoot length (13.50), root length (26.53), seedling length (40.03), number of leaves (8.73), fresh weight (2.50) and dry weight (1.25) on 1 MAS. Whereas T1 (- 4℃ with sarcotesta) showed lowest shoot length (5.10), root length (7.83), seedling length (12.93), number of leaves (6.10), fresh weight (1.55) and dry weight (0.77) on 1 MAS.

Low temperature causes injury to the seeds by restricting the metabolic activity and enzymatic actions results in lack of food supply which further affects the seedling growth, initiation of new leaves, fresh and dry weight of seedling. (Corbineau 1989) [5]. Significantly minimum shoot length, root length and seedling length was recorded in the seeds stored with sarcotesta. This may be due to the adverse effect of presence of growth inhibitors in sarcotesta. The result of root length was similar to the findings of Reyes *et al*. (1980) [13].

Table 3: Effect of storage temperature and sarcotesta on shoot length, root length and seedling length.

Treatments		Shoot Length in cm (MAS)						Root Length in cm (MAS)						Seedling Length in cm (MAS)					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
T1: -4 ℃with sarcotesta		5.10	7.67	0.00	0.00	0.00	0.00	7.83	8.93	0.00	0.00	0.00	0.00	12.93	16.60	0.00	0.00	0.00	0.00
T2: 0 ℃with sarcotesta		7.07	8.53	0.00	0.00	0.00	0.00	12.77	10.76	0.00	0.00	0.00	0.00	19.83	19.29	0.00	0.00	0.00	0.00
T3: 4 ℃with sarcotesta		9.10	9.63	0.00	0.00	0.00	0.00	11.10	12.53	0.00	0.00	0.00	0.00	20.20	22.17	0.00	0.00	0.00	0.00
T4: 8 ℃with sarcotesta		11.07	10.63	9.30	8.97	8.53	8.10	16.40	17.03	17.04	16.53	16.00	15.50	27.47	27.67	26.34	20.47	24.53	23.60
T5: Room Temperature with sarcotesta		13.17	12.50	10.00	10.43	9.47	9.10	24.99	19.53	18.97	19.10	18.07	16.50	38.27	32.03	28.97	24.60	27.53	25.60
T6: -4 ℃without sarcotesta		5.57	8.33	0.00	0.00	0.00	0.00	8.33	9.73	0.00	0.00	0.00	0.00	13.90	18.07	0.00	0.00	0.00	0.00
T7: 0 ℃without sarcotesta		7.63	9.40	0.00	0.00	0.00	0.00	13.60	11.50	0.00	0.00	0.00	0.00	21.23	20.90	0.00	0.00	0.00	0.00
T8: 4 ℃without sarcotesta		9.50	10.17	0.00	0.00	0.00	0.00	12.07	13.97	0.00	0.00	0.00	0.00	21.57	24.13	0.00	0.00	0.00	0.00
T9: 8 ℃without sarcotesta		11.60	11.10	9.61	9.50	9.03	8.57	17.47	17.97	17.60	17.10	16.50	16.13	29.07	29.07	27.21	21.60	25.53	24.70
T10: Room Temperature without sarcotesta		13.50	12.60	11.13	10.60	10.10	9.50	26.53	20.77	20.03	19.53	18.60	17.29	40.03	33.37	31.17	25.10	28.70	26.79
Temperature (T)	S.Em.±	0.045	0.112	0.069	0.036	0.036	0.045	0.225	0.231	0.055	0.053	0.030	0.125	0.142	0.134	0.086	0.075	0.055	0.143
	C.D.@5%	0.128	0.317	0.195	0.101	0.101	0.128	0.638	0.653	0.156	0.151	0.084	0.353	0.402	0.379	0.243	0.211	0.154	0.405
Sarcotesta (S)	S.Em.±	0.029	0.071	0.044	0.023	0.023	0.029	0.143	0.146	0.035	0.034	0.019	0.079	0.090	0.085	0.054	0.047	0.035	0.091
	C.D. @5%	0.081	0.200	0.124	0.064	0.064	0.081	0.403	0.413	0.098	0.095	0.053	0.223	0.254	0.240	0.154	0.134	0.090	0.256
T×S	S.Em.±	0.064	0.158	0.098	0.051	0.051	0.064	0.319	0.326	0.078	0.075	0.042	0.176	0.201	0.189	0.122	0.106	0.077	0.202
	C.D. @5%	NS	NS	0.276	0.143	0.143	0.181	NS	NS	0.220	0.213	0.119	NS	NS	NS	0.344	0.299	0.218	0.573

Table 4: Effect of storage temperature and sarcotesta on number of leaves, fresh weight and dry weight of seedling.

Treatments		Number of leaves (MAS)						Fresh weight in gm (MAS)						Dry weight in gm (MAS)					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
T1: -4 ℃with sarcotesta		6.10	5.57	0.00	0.00	0.00	0.00	1.55	1.35	0.00	0.00	0.00	0.00	0.77	0.70	0.00	0.00	0.00	0.00
T2: 0 ℃with sarcotesta		7.00	6.40	0.00	0.00	0.00	0.00	1.70	1.60	0.00	0.00	0.00	0.00	0.85	0.80	0.00	0.00	0.00	0.00
T3: 4 ℃with sarcotesta		7.37	7.03	0.00	0.00	0.00	0.00	1.90	1.80	0.00	0.00	0.00	0.00	0.95	0.90	0.00	0.00	0.00	0.00
T4: 8 ℃with sarcotesta		8.03	7.43	6.87	6.17	5.57	5.23	2.15	1.85	1.90	1.80	1.57	1.50	1.07	1.00	0.95	0.90	0.80	0.75
T5: Room Temperature with sarcotesta		8.43	8.00	7.37	6.97	6.27	6.00	2.41	2.28	2.20	2.00	1.80	1.70	1.20	1.14	1.10	1.02	0.90	0.85
T6: -4 ℃without sarcotesta		6.70	6.23	0.00	0.00	0.00	0.00	1.60	1.45	0.00	0.00	0.00	0.00	0.80	0.72	0.00	0.00	0.00	0.00
T7: 0 ℃without sarcotesta		7.17	6.57	0.00	0.00	0.00	0.00	1.75	1.66	0.00	0.00	0.00	0.00	0.87	0.83	0.00	0.00	0.00	0.00
T8: 4 ℃without sarcotesta		7.77	7.13	0.00	0.00	0.00	0.00	2.05	1.85	0.00	0.00	0.00	0.00	1.02	0.92	0.00	0.00	0.00	0.00
T9: 8 ℃without sarcotesta		8.26	7.70	7.21	6.50	6.13	5.73	2.20	2.05	1.95	1.85	1.65	1.55	1.10	1.02	0.97	0.92	0.82	0.77
T10: Room Temperature without sarcotesta		8.73	8.23	7.70	7.23	6.60	6.23	2.50	2.35	2.25	2.05	1.85	1.75	1.25	1.17	1.12	1.02	0.92	0.87
Temperature (T)	S.Em.±	0.047	0.047	0.058	0.053	0.043	0.042	0.035	0.025	0.015	0.013	0.014	0.012	0.012	0.018	0.005	0.008	0.003	0.003
	C.D.@5%	0.132	0.133	0.165	0.149	0.122	0.119	0.099	0.070	0.042	0.037	0.041	0.034	0.033	0.050	0.013	0.021	0.007	0.008
Sarcotesta (S)	S.Em.±	0.030	0.030	0.037	0.033	0.027	0.027	0.022	0.016	0.009	0.008	0.009	0.008	0.007	0.011	0.003	0.005	0.002	0.002
	C.D. @5%	0.084	0.084	0.105	0.094	0.077	0.075	0.062	0.044	NS	NS	0.026	NS	0.021	NS	0.008	NS	0.005	0.005
T×S	S.Em.±	0.066	0.067	0.083	0.074	0.061	0.059	0.049	0.035	0.021	0.018	0.020	0.017	0.017	0.025	0.007	0.011	0.004	0.004
	C.D. @5%	0.187	0.189	NS	NS	0.172	0.168	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.010	0.012

Conclusion

On the basis of present experiment, it can be concluded that papaya seeds stored without sarcotesta at room temperature was very effective in maintaining the seed quality and seedling growth parameters.

References

1. AbdulBaki, Anderson. Vigour determination in soybean seed by multiple criteria. Crop Sci 1973;13:630-633.
2. Althoff MA. Carmona R. Papaya seed conservation. Revista Brasileira de Sementes 1999;21:151-156.
3. Angeline O, Ouma G. Effect of washing and media on the germination of papaya seeds. Journal of Agricultural and Biological Science 2008;3(1):1990-6145.
4. Chin HF, Hor YL, Lassim MB. Identification of recalcitrant seeds. Seed Science and Technology. 1984;12:429-436.
5. Corbineau DC. Germination and storage of recalcitrant seeds of some tropical forest tree species. Ann. Sci. For 1989;46:89-91.
6. Dadjo C, Nyende AB, Kahia J, Assogbadjo AE. Effect of storage temperature and dormancy breaking pre-treatments on germination and early seedling growth of *Garcinia kola* (Heckel): a threatened medicinal fruit tree in Benin. Forest Science and Technology 2019;15(4):173-179.
7. Ellis RH, Hong TD, Roberts EH. Effect of storage temperature and moisture on the germination of papaya seeds. Seed Science Research 1991;1:69-72.
8. Genes F, Agnes MN. Effect of storage time and temperature on germination ability of *Escoecaria bussei*. Tanzania Journal of Science. 2018; 44(1):123-133.
9. Hofmann P, Steiner AM. An updated list of recalcitrant seeds. Landwirtschaftliche Forschung 1989;42:310-323.
10. Ibrahim H, Oladiran JA, Hssabila J. The effects of sarcotesta and storage temperature on the longevity of seeds of five papaya (*Carica papaya* L.) landraces. International Journal of Science and Nature 2011;2(4):727-732.
11. Magill W, Deighton N, Pritchard HW. Physiological and biochemical studies of seed storage parameters in *Carica papaya*. Proceedings of the Royal Society of Edinburgh Section B-Biological Sciences 1994;102:439-442.
12. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research Publication 1985, 87-89.
13. Reyes MN, Perez A, Cuevas J. Detecting endogenous growth regulators on the sarcotesta, sclerotesta, endosperm and embryo by paper chromatography on fresh and old seeds of two papaya varieties. The Journal of Agriculture of the University of Puerto Rico 1980;64(2):164-172.
14. Sangakkara UR. Influence of Seed Ripeness, Sarcotesta, Drying and Storage on Germinability of Papaya (*Carica papaya* L,) Seed. Pertanika. J Trop. Agric. Sci 1995;18(3):193-199.
15. Tokuhisa D, Dias DC, Alvarenga EM, Hilst PC, Demuner AJ. Phenolic compound inhibitors in papaya

seeds (*Carica papaya* L.). Revista Brasileira de Sementes 2007;29(3):180-188.
16. Zulhisyam AK, Seng CT, Ismail AA, Anzwanida NN, Shazani S, Jamaludin MH, *et al*. Effect of storage temperature and seed moisture contents on papaya (*Carica papaya* L.) seed viability and germination. Journal of Sustainability Science and Management 2013;8(1):87-92.