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Effect of Different Seed Storage Methods and Period on Seed Germination of Jackfruit (*Artocarpus heterophyllus* Lam.) under Konkan Coastal Region of Maharashtra

M. S. GAWANKAR[1]*, P. M. HALDANKAR[2], P. C. HALDAVANEKAR[1], B. R. SALVI[2], M. M. BURONDKAR[2], C. D. PAWAR[2] and B. M. JAMADAGNI[3]

[1]College of Horticulture, Dr. B.S. Konkan Krishi Vidyapeeth, Mulde - 416 520, Sindhudurg, Maharashtra, India
[2]Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli - 415 712, Maharashtra, India
[3]Agricultural Research Station, Dr. B.S. Konkan Krishi Vidyapeeth, Mulde - 416 520, Sindhudurg, Maharashtra, India

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Jackfruit (*Artocarpus heterophyllus* Lam.) seeds are used for raising the rootstock for softwood grafting. Availability of seeds throughout the year is a major hurdle in raising rootstock for grafting. Jackfruit seeds are recalcitrant by nature and hence they lose viability on drying or exposure to chilling temperature and are difficult to store for longer periods. Hence, an investigation on seed viability of jackfruit and methods to prolong it under artificial storage conditions was conducted during the year 2017 and 2018 at College of Horticulture, Mulde, Sindhudurg under Konkan coastal region of Maharashtra. The experiment was carried out in a factorial randomised block design with two distinct treatments namely eight seed storage methods and six storage periods in all possible combinations with two replications. Significantly the highest germination percentage (93%) was observed in treatment where seeds were stored in a screw cap plastic bottle for a period of 150 days followed by storing the seeds in a polybag and keeping it in a screw cap plastic bottle for 150 days recorded 91% germination. The data revealed that fast deterioration in germinability was observed in the treatment where seeds were kept under ambient conditions (at room temperature 32°C). Seeds stored in an earthen pot buried in the soil had already germinated at 90, 120 and 150 days of storage and attained 50% germination at the earliest (17.25 days), exhibited a span of 17.25 to 27.75 days in all the treatments of storage period. Thus, the study revealed that jackfruit seeds can be effectively stored in wide mouth screw cap plastic bottles or in polybags of 300 gauge with a screw cap plastic bottle for a period of 150 days.

(***Key words:*** *Ambient temperature, Recalcitrant seeds, Seed germination, Storage method)*

The coastal warm and humid climate of the Konkan region of Maharashtra is favourable for the cultivation of rainfed horticultural crops. Among different rainfed horticultural crops grown in the coastal region, Jackfruit (*Artocarpus heterophyllus* Lam.) has a great potential to bring cultivable wasteland under cultivation in the Konkan region. The recalcitrant nature of jackfruit seeds and their non-availability play an important role in limiting the rapid multiplication of the crop by grafting. The seeds of jackfruit are large in size and lose water slowly during storage. When the moisture content in the seeds decreases below the critical level, the seeds lose viability. The information on longevity and seed storage of this crop for plant propagation is sparsely available.

Assured supply of seeds during the lean period can be achieved only from the seed stock held in storage (Umarani *et al*., 2015). Hence, efficient storage of recalcitrant seeds is indispensable to ensure a continuous and cost-effective supply of rootstock seedlings, which is a prerequisite for the success of any massive nursery programme. Hence, the present study was carried out to understand the effect of different storage methods on jackfruit seed germination and its viability in the coastal Konkan region of Maharashtra.

MATERIALS AND METHODS

The experiment was conducted during 2017 and 2018 at the College of Horticulture, Dr. B.S. Konkan Krishi Vidyapeeth, Mulde, Sindhudurg located in the coastal part of the Konkan region of Maharashtra at 6°2´ N latitude, 73°42´ E longitude and at 17 m elevation above mean sea level. The region receives an annual rainfall of 3000 mm most of which occurs during the monsoon months of June to September. The minimum temperature ranges from 12°C to 24°C and maximum

**Corresponding author:* E-mail: gawankarms@yahoo.co.in

temperature from 26°C to 38°C. The average relative humidity at this location is 80%. The experiment consists of eight storage methods and six storage periods in a factorial randomised block design with two replications.

In this experiment eight seed storage methods, namely, C_1: Screw cap plastic bottle (transparent, 2.5 kg capacity), C_2: Polybag - 300 gauge (transparent, 25 × 40 cm) + Screw cap plastic bottle (transparent, 2.5 kg capacity), C_3: Polybag - 300 gauge (transparent, 25 × 40 cm), C_4: Earthen pot (5.0 L capacity), C_5: Earthen pot (5.0 L capacity) buried in soil, C_6: Coating with fresh cow dung slurry, drying and stored in polybag (transparent, 25 × 40 cm, 300 gauge), C_7: Coating with mud slurry, drying and stored in polybag (transparent, 25 × 40 cm, 300 gauge) and C_8: control (seeds were kept on paper and exposed to ambient air) and six storage period *viz*., 15 days (S_1), 30 days (S_2), 60 days (S_3), 90 days (S_4), 120 days (S_5) and 150 days (S_6) in all possible combinations were studied. In each treatment hundred seeds per replication was taken for the study.

Fresh seeds from ripe soft flesh type fruits were collected, de-pulped and washed to remove perianth and aril. Healthy seeds weighing more than 3 g were treated with carbendazim (50% WP @ 2 g L^{-1}) for 5 minutes and further kept for surface drying under shade for three hours to remove moisture. Such seeds were used for the different treatments (Doijode, 2001). The seeds were stored in respective containers after taking initial weight by providing sufficient air space and sealed thereafter. Except in the case of treatment, C_5, in all other treatments, the seeds were stored at ambient room temperature (32 ± 2°C). After completion of the storage period of 15, 30, 60, 90, 120 and 150 days, the seeds were sown in the black polythene bags (200 gauge and size 15 × 20 cm) containing soil + farmyard manure (FYM) in 3:1 proportion. Polybags were kept in the polyhouse for raising the seedlings and watering was done immediately after sowing of the seeds. Then after everyday, light irrigation was given till the emergence of the seedling. After completion of germination, irrigation was given every alternate day.

Germination was recorded at every alternate day from the first emergence until no further seeds germinated. Observations on germination percentage, days required for germination, days required for 50% germination and germination period were recorded. Germination percentage was calculated by dividing the total number of germinated seeds by the total number of seeds sown and multiplied by 100 as given below.

$$\text{Germination percentage (\%)} = \frac{\text{(No. of seeds germinated)}}{\text{(Total number of seeds sown)}} \text{ X } 100 \quad (1)$$

The days taken for the first germination were calculated from the date of sowing up to germination of the first seedling. The days taken for 50% germination were calculated from the date of sowing upto 50% germination of seedlings. The germination period was taken as the period of days between the first germination to germination of the last seed. For statistical analysis, the data of percentage was transformed to arcsine $\sqrt{(100/X)}$ and actual percentages are shown. Experimental data were analysed using the statistical package SAS version 9.01.

RESULTS AND DISCUSSION

Germination

The data on the effect of different storage methods, storage period and their interaction effect on germination percentage is presented in Table 1.

Effect of storage methods on seed germination

During the first year (2017) significantly the highest germination percentage (83.08%) was recorded in treatment C_1 (Screw cap plastic bottle) and it was at par with treatment C_5 (78.42%). Treatment C_2 and C_3 recorded 66.37 and 54.50% seed germination, respectively. While treatment C_4 (34.83%), C_7 (32.00%) and treatment C_8 (31.33%) were at par with each other. Significantly the lowest germination percentage (20.50%) was recorded in treatment C_6 (Coating with fresh cow dung slurry, drying and stored in poly bag). During the second year also (2018), significantly the highest germination per cent (76.33 %) was recorded in the treatment C_1 (Screw cap plastic bottle) and it was at par with the treatment C5 (74.42 %). Treatment C_7 (48.50 %) and treatment C_2 (45.00 %) were at par with each other. Similarly, treatment C_4 recorded 36.33% germination while treatment C_3 recorded 35.67% germination and both were at par with each other while treatment C_8 recorded 29.83% germination. Significantly, the lowest germination (15.50 %) was recorded in treatment C_6 (Coating with fresh cow dung slurry, drying and stored in poly bag).

Table 1. *Effect of storage methods and storage period on germination percentage (%) of jackfruit seeds*

C x S	2017							2018							Pooled						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)
C_1	90.00 (72.15)	68.00 (55.59)	81.50 (64.58)	83.00 (65.65)	82.00 (65.03)	94.00 (75.87)	83.08 (66.48)	79.50 (63.28)	64.00 (53.16)	73.50 (59.10)	72.00 (58.06)	77.00 (61.39)	92.00 (73.70)	76.33 (61.44)	84.75 (67.71)	66.00 (54.38)	77.50 (61.84)	77.50 (61.85)	79.50 (63.21)	93.00 (74.78)	79.71 (63.96)
C_2	80.50 (63.94)	-	-	86.00 (68.04)	7.00 (15.19)	92.00 (73.60)	66.37 (55.19)	78.50 (62.50)	4.50 (12.23)	7.00 (15.31)	77.50 (61.72)	13.00 (21.08)	89.50 (71.10)	45.00 (40.65)	79.50 (63.22)	4.50 (12.23)	7.00 (15.31)	81.75 (64.88)	10.00 (18.14)	90.75 (72.35)	53.55 (46.47)
C_3	54.50 (47.63)	-	-	-	-	-	54.50 (47.63)	55.00 (47.89)	40.50 (39.53)	11.50 (19.72)	-	-	-	35.67 (35.71)	54.75 (47.76)	40.50 (39.53)	11.50 (19.72)	-	-	-	40.38 (38.69)
C_4	66.00 (54.51)	30.00 (33.19)	8.50 (16.95)	-	-	-	34.83 (34.88)	62.50 (52.33)	35.50 (36.52)	11.00 (19.35)	-	-	-	36.33 (36.07)	64.25 (53.42)	32.75 (34.85)	9.75 (18.15)	-	-	-	35.58 (35.47)
C_5	84.50 (67.15)	63.50 (52.99)	74.00 (59.99)	89.50 (71.75)	76.50 (61.02)	82.50 (65.32)	78.42 (63.03)	74.50 (59.80)	60.50 (51.09)	75.50 (60.39)	84.50 (67.15)	76.00 (60.67)	75.50 (60.34)	74.42 (59.91)	79.50 (63.48)	62.00 (52.04)	74.75 (60.19)	87.00 (69.45)	76.25 (60.84)	79.00 (62.83)	76.42 (61.47)
C_6	38.50 (38.34)	2.50 (8.64)	-	-	-	-	20.50 (23.49)	36.50 (37.00)	5.50 (13.55)	4.50 (12.08)	-	-	-	15.50 (20.87)	37.50 (37.67)	4.00 (11.10)	4.50 (12.08)	-	-	-	17.50 (21.92)
C_7	32.00 (34.45)	-	-	-	-	-	32.00 (34.45)	48.50 (44.14)	-	-	-	-	-	48.50 (44.14)	40.25 (39.30)	-	-	-	-	-	40.25 (39.30)
C_8	55.00 (47.87)	29.50 (32.80)	9.50 (17.95)	-	-	-	31.33 (32.87)	51.50 (45.86)	28.50 (32.12)	9.50 (17.95)	-	-	-	29.83 (31.98)	53.25 (46.87)	29.00 (32.46)	9.50 (17.95)	-	-	-	30.58 (32.42)
Mean (S)	62.63 (53.25)	38.70 (36.64)	43.38 (39.86)	86.17 (68.48)	55.17 (47.08)	89.50 (71.60)		60.81 (51.60)	34.14 (34.03)	27.50 (29.13)	78.00 (62.31)	55.33 (47.71)	85.67 (68.38)		61.72 (52.43)	36.04 (35.12)	33.27 (33.03)	82.08 (65.39)	55.25 (47.40)	87.58 (69.99)	
	Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction		
S. Em ±	1.76		2.34		3.42			1.21		1.48		2.49			1.03		1.30		2.94		
CD at 5 %	5.11		6.83		9.98			3.49		4.28		7.20			2.92		3.67		8.34		

Figures in parenthesis are arcsine transformed values

C_1 - Screw cap plastic bottle

C_2 - Polybag - 300 gauge + Screw cap plastic bottle

C_3 - Polybag - 300 gauge

C_4 - Earthen pot

C_5 - Earthen pot buried in soil

C_6 - Coating with fresh cowdung slurry, drying and stored in poly bag

C_7 - Coating with mud slurry, drying and stored in poly bag

C_8 - Storing under open condition at ambient temp. (Control)

S_1 - 15 days

S_2 - 30 days

S_3 - 60 days

S_4 - 90 days

S_5 - 120 days

S_6 - 150 days

Effect of storage period on seed germination

During the first year, the highest germination of 89.50% was recorded in treatment S_6 (150 days) but was at par with treatment S_4 (86.17 %). The germination in the treatments S_1, S_5 and S_3 were 62.63, 55.17 and 43.38%, respectively, while significantly the lowest germination percentage (38.70 %) was recorded in the treatment S_2 (30 days). During the second year also treatment S_6 (150 days) recorded significantly highest germination percentage (85.67%) followed by treatment S_4 (78.00%), S_1 (60.81%), S_5 (55.33 %) and treatment S_2 (34.14 %). Significantly lowest germination percentage (27.50 %) was noticed in treatment S_3 (60 days).

Interaction effect of storage methods and storage period on seed germination

During the first year, treatment C_1S_6 recorded significantly the highest germination percentage (94.00%) and was at par with treatment C_2S_6 (73.60%), C_1S_1 (90.00%), C_5S_4 (89.50%), C_2S_4 (86.00%) and C_2S_1 (80.50 %). Treatment C_6S_2 recorded significantly the lowest germination percentage (2.50%). During the second year, treatment C_1S_6 recorded significantly the highest germination percentage (92.00%) followed by and at par with treatment C_2S_6 (89.50%) and C_5S_4 (84.5 %). Treatment C_6S_3 recorded significantly the lowest germination percentage (4.50%).

From pooled results, it is clear that keeping the seeds at ambient temperature conditions is an obvious practice in any crop. The data in this respect revealed that there was a fast deterioration in germinability when seeds were stored under ambient conditions. A maximum of 53.25% germination was noticed at 15 days storage period and it declined to 9.5% at 60 days. Thereafter no germination was noticed in this treatment. Warrier (2009) explained the storage problem of jackfruit seeds and suggested that ambient temperature (25 ± 2°C) conditions were not conducive for the storage of jackfruit seeds for more than three weeks. Similarly, Panggabean (1979) observed 80 to 86% seed germination of jackfruit seeds after 22 days of storage. Coating the seeds with mud is a conventional practice of seed preservation. In the current investigation this practice gave 40.25% germination at 30 days storage period. In the further course of storage, germination was not at all observed.

In this investigation coating seeds with cow dung was found to be unsuccessful in maintaining germinability. At 15 days storage, there was 37.50% germination under this condition. However, at 30 and 60 days, it remained 4 to 4.5%. Preserving seeds in the earthen pot was found to be better in comparison with cow dung coating, mud coating and storage under ambient temperature. The seed could be stored with germination of 32.75% up to 30 days which declined rapidly reaching 9.75% at 60 days of storage. Beyond this period of storage, no germination was noticed. Girija and Srinivasan (2000) observed no germination of mango stones after six weeks of storage in mud pot.

Keeping the seeds in polybag is thought to be useful for prolonging the viability. However, in the current investigation also the germination percentage went down rapidly from 54.75% at 15 days to 11.50% at 60 days. Results of the investigation are in line with the findings of Sheela (2007) who got short longevity for 110 days of jackfruit seeds under storage in polythene bags at room temperature. However, Krishnasamy (1990) observed 100% germination after 6 weeks when jackfruit seeds were stored in 700 gauge thick polythene containers. Anandalakshmi *et al*. (2005) stored non-desiccated seeds in various containers, namely, polybag (150, 200 and 250 gauge), polybag with two pores (200 gauge), cloth bag, paper bag and plastic container at 20°C and after five months observed that irrespective of thickness and presence of pores, storage of seeds in polybags was able to prolong the seed viability of *Syzigium cuminii* seeds.

Thus, the usual practice of storing the seed is ineffective in maintaining germination beyond 60 days. In an attempt to store the seeds in a screw cap plastic bottle, success was noticed in maintaining the germinability of jackfruit seeds even after 150 days. The value of germination percentage was 84.75% at 15 days. It declined slightly and remained in the range of 66 to 79% upto 120 days. Importantly seeds under such conditions showed as high as 93% germination at 150 days which needs a physiological justification. Keeping the seed in the polybag and putting it into screw cap bottled showed an uncertain picture as 79.50% germination at 15 day period fell down drastically to 4.5, 7.0 and 10.0% at 30, 60 and 120 days of storage, respectively. However, high germination percentage of 81.75% and 90.75% at 90 and 150 days warrants a need for further physiological investigations.

The seeds when stored in an earthen pot and buried in the soil (C_5) gave a very encouraging picture. The seed germination in this practice remained in the range of 62 to 87% throughout the storage period. Thus the germination percentage was quite stable over the entire storage condition. From the above results, it is clear that preserving seeds in a screw cap bottle or an earthen pot buried in soil were reliable techniques for getting successful germination even after five months of storage. Fernandez (1982) also suggested that in jackfruit moist storage in a screw cap bottle is an ideal method that preserves the seed viability for upto 45 days.

Days required for first germination

The period for initiation of first germination has a practical significance in the horticultural programme. Data on days required for first germination are presented in Table 2.

Effect of storage methods on days required for first germination

It is clear from the data presented in Table 2 that during the year 2017, significantly early germination (7.50 days) was noticed in treatment C_5 (Earthen pot buried in soil) followed by treatment C1 (11.42 days). While treatment C_6 recorded significantly maximum days (21.50 days) for germination followed by treatment C_4 (18.83 days). Treatment C_3 and treatment C_7 took 17.00 days for germination. Treatment C_8 and C_2 recorded 14.83 days and 14.13 days for germination respectively. During the year 2018 also significantly early germination (6.83 days) was noticed in treatment C_5 (Earthen pot buried in soil) and 11.80 days in the treatment C_1 whereas, treatment C_2 took significantly more number of days (17.00 days) and was at par with the treatment C_4 (16.33 days) and the treatment C_6 (16.33 days). Other treatments C_8, C_3 and C_7 recorded 15.83, 15.50 and 14.50 days for germination, respectively.

Effect of storage period on days required for first germination

During the year 2017, significantly early germination was noticed in treatment S_6 (6.00 days) and 9.50 days in the treatments S_4 and S_5. Treatments S_3 (10.13 days) were at par with S_4 and S_5 treatment. Significantly a greater number of days for germination was taken by treatment S_2 (19.90 days) and 16.63 days in treatment S_1. During the year 2018, significantly early germination was noticed in treatment S_6 (5.67 days) followed by treatment S_5 (10.00 days). Treatment S_5 (10.00 days) and S_4 (10.40 days) were at par. A significantly more number of days for germination was observed in treatment S_2 (18.46 days), 15.29 days in treatment S_3 and 13.56 days in treatment S_1.

Interaction effect of storage methods and storage period on days required for first germination

During the year 2017 treatment C_5S_6, C_5S_5 and C_5S_4 showed significantly early germination and took only one day for germination. Significantly maximum number of days were taken by treatment C_6S_2 (26.00 days) followed by C_4S_2 (23.50 days) and it was at par with treatments C_8S_2 (23.00 days). During the year 2018 also treatment C_5S_6, C_5S_5 and C_5S_4 showed significantly early germination and took only one day for germination. Significantly more number of days were noticed in treatment C_2S_2 (23.00 days) and 21.00 days in treatment C_2S_3. Treatments C_8S_2 (20.00 days) and C_4S_3 (20.00 days) were at par with treatment C_2S_3.

The storage of seed in an earthen pot buried in soil showed a very promising behaviour. It required 13.75 days, 14.75 days and 11.15 days under 15, 30 and 60 days storage for the first germination of seeds. It is very important to note that the seeds stored under this treatment had already germinated under 90, 120 and 150 days storage *i.e.*, the conditions favoured very much under prolonged storage of five months. The pooled data revealed that under ambient temperature conditions the 15 days storage period exhibited 18.25 days for first germination. A prolonged storage for 30 days resulted in 21.50 days for the first germination of seed after sowing. Interestingly the seeds which was stored for 60 days and sown took a very short duration *i.e.*, 6.25 days for the first germination of seed. This could be due to the initiation of the metabolic processes for germination during the course of storage for 60 days. Under ambient temperature conditions, no germination was noticed in the seeds that were stored for 90, 120 and 150 days. The mud coated seed when stored for 15 days and then sown took 15.75 days for the occurrence of first germination. It must be noted that the storage of 30, 60, 90, 120 and 150 days had an inhibitory effect on the germination of jackfruit seeds.

The seed coated with cow dung showed a relatively consistent period for the first germination to occur.

Table 2. *Effect of storage methods and storage period on days required for first germination of jackfruit seeds*

C x S	2017							2018							Pooled						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)
C_1	11.5	13.5	12.0	13.5	9.5	8.5	11.4	11.0	18.0	12.0	16.0	13.0	6.0	11.8	11.3	15.0	12.0	14.3	11.3	7.3	11.6
C_2	16.0	-	-	14.0	18.0	8.5	14.1	15.0	23.0	21.0	17.0	16.0	10.0	17.0	15.5	23.0	21.0	15.5	17.0	9.3	15.9
C_3	17.0	-	-	-	-	-	17.0	12.5	18.0	16.0	-	-	-	15.5	14.8	18.0	16.0	-	-	-	15.9
C_4	19.0	23.5	14.0	-	-	-	18.8	11.0	18.0	20.0	-	-	-	16.3	15.0	20.8	17.0	-	-	-	17.6
C_5	16.5	13.5	12.0	1.0	1.0	1.0	7.5	11.0	16.0	11.0	1.0	1.0	1.0	6.8	13.8	14.8	11.5	1.0	1.0	1.0	7.2
C_6	17.0	26.0	-	-	-	-	21.5	16.0	16.0	17.0	-	-	-	16.3	16.5	21.0	17.0	-	-	-	18.4
C_7	17.0	-	-	-	-	-	17.0	14.5	-	-	-	-	-	14.5	15.8	-	-	-	-	-	15.8
C_8	19.0	23.0	2.5	-	-	-	14.8	17.5	20.0	10.0	-	-	-	15.8	18.3	21.5	6.3	-	-	-	15.3
Mean (S)	16.6	19.9	10.1	9.5	9.5	6.0		13.6	18.6	15.3	10.4	10.0	5.7		15.1	19.1	13.4	9.9	9.8	5.8	
	Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction		
S. Em ±	0.3		0.4		0.6			0.2		0.2		0.4			0.2		0.2		0.5		
CD at 5 %	0.9		1.2		1.8			0.6		0.7		1.2			0.5		0.7		1.5		

C_1 - Screw cap plastic bottle

C_2 - Polybag - 300 gauge + Screw cap plastic bottle

C_3 - Polybag - 300 gauge

C_4 - Earthen pot

C_5 - Earthen pot buried in soil

C_6 - Coating with fresh cowdung slurry, drying and stored in poly bag

C_7 - Coating with mud slurry, drying and stored in poly bag

C_8 - Storing under open condition at ambient temp. (Control)

S_1 - 15 days

S_2 - 30 days

S_3 - 60 days

S_4 - 90 days

S_5 - 120 days

S_6 - 150 days

Storage in earthen pot exhibited a period of 15 to 20.75 days under 15, 30 and 60 days storage period. In the subsequent storage periods, no germination was noticed. Similar number of days were required for the first germination when seeds were stored in polybags at 15, 30 and 60 days of storage. Storage in screw cap bottles had consistency in days required for the first germination under different storage conditions in the current investigation. The days required for first germination varied between 11.25 to 15 days up to 120 days storage. Interestingly under 150 days of storage, the period of the first germination was lower *i.e*. 7.25 days.

In storage of seeds in polybag kept in screw cap bottle took 15.50 days for first germination at 15 days storage whereas under 30 and 60 days it was prolonged to 23 and 21 days respectively. When the seeds were stored for 150 days, the period for first germination was only 9.25 days. The storage of seed in an earthen pot buried in soil showed a very promising behaviour. It required 13.75, 14.75 and 11.15 days for first germination of seeds under 15, 30 and 60 days storage periods, respectively. It is very important to note that seeds stored under this treatment had already germinated under 90, 120 and 150 days storage *i.e*., the conditions favoured germination very much under prolonged storage of three to five months.

Days required for 50% germination

The information on 50% germination is considered to be a practical aspect in a nursery programme. The data pertaining to the effect of different storage methods, storage period and their interaction on days required for 50% germination are presented in Table 3.

Effect of storage methods on days required for 50% germination

It was revealed that during the first year, C_5 took less number of days (18.42 days) to attain 50% germination and was at par with C_8 (18.50 days), C_1 (19.25 days) and C_2 (20.88 days). The maximum number of days for 50% germination was seen in treatment C_7 (25.00 days) followed by C_6 (23.50 days), C_4 (23.50 days) and C_3 (22.00 days). During the second year, C_5 recorded the minimum number of days (16.08 days) for attaining 50% germination followed by C_6 (20.50 days) which was at par with C_8 (20.67 days), C_1 (20.80 days), C_7 (21.00 days) and C_2 (21.75 days).

Pooled data also indicated that treatment C_5 recorded a significantly minimum number of days (17.25 days) for attaining 50% germination followed by C_8 (19.58 days) which was at par with C_1 (19.95 days). Maximum days for attaining 50% germination were observed in treatment C_4 (23.58 days), C_3 (23.12 days) and C_7 (23.00 days). All were at par with each other. Thus, the study revealed that treatment C_5 (Earthen pot buried in soil) attained 50% germination at the earliest as compared with other treatments. This is in accordance with the findings of Spalding *et al*. (1976) in avocado and Muthanna *et al*. (2016) in karonda. Abbas *et al*. (2003) observed that the ability of seeds to get 50% germination was reduced with a decrease in moisture content of jamun seeds.

Effect of storage period on days required for 50% germination

Data presented in Table 3 revealed that during the first year S_3 recorded the minimum number of days (15.38 days) for attaining 50% germination followed by S_5 (17.33 days) and S_6 (17.50 days) which were at par. The maximum number of days to attain 50% germination was recorded by S_2 (25.00 days) followed by S_1 (21.81 days) and S_4 (21.33 days). During the second year, the minimum number of days for attaining 50% germination was recorded in S_6 (13.33 days) followed by S_5 (19.33 days). The maximum number of days were exhibited by S_2 (22.77 days) followed by S_1 (22.31 days). Treatment S_4 recorded 20.80 days while S_3 recorded 20.07 days for 50% germination and both were at par. Pooled data indicated that the minimum number of days to attain 50% germination were recorded in S_6 (15.42 days) followed by S_5 (18.33 days) and S_3 (18.36 days). The maximum number of days were recorded by S_2 (23.74 days) followed by S_1 (22.06 days) and S_4 (21.09 days). Thus, jackfruit seeds stored for 150 days (S_6) attained 50% germination earlier as compared to other treatments. Nagaveni (2005) reported that seeds stored in moisture impervious sealed containers under ambient conditions stored better as compared to seeds stored in moisture-pervious containers.

Interaction effect of storage methods and storage period on days required for 50% germination

During the first year, the treatment C_8S_3 attained 50% germination significantly earlier (7.00 days) compared to other treatments and was at par with C_5S_5

Table 3. *Effect of storage methods and storage period on days required for 50 % germination of jackfruit seeds*

C x S	2017							2018							Pooled						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)
C_1	19.0	22.0	16.5	22.5	19.5	16.0	19.2	20.5	31.0	19.0	24.0	21.0	16.0	20.8	19.8	25.0	17.8	23.0	20.3	16.0	19.9
C_2	20.0	-	-	25.5	21.5	16.5	20.9	22.5	23.0	22.5	25.5	22.0	15.0	21.8	21.3	23.0	22.5	25.5	21.8	15.8	21.4
C_3	22.0	-	-	-	-	-	22.0	21.5	23.0	26.0	-	-	-	23.5	21.7	23.0	26.0	-	-	-	23.1
C_4	23.5	28.0	19.0	-	-	-	23.5	23.5	24.0	23.5	-	-	-	23.7	23.5	26.0	21.3	-	-	-	23.6
C_5	20.0	24.5	19.0	16.0	11.0	20.0	18.4	18.5	21.0	18.5	14.5	15.0	9.0	16.1	19.2	22.7	18.8	15.2	13.0	14.5	17.3
C_6	21.5	25.5	-	-	-	-	23.5	25.5	17.5	18.5	-	-	-	20.5	23.5	21.5	18.5	-	-	-	21.7
C_7	25.0	-	-	-	-	-	25.0	21.0	-	-	-	-	-	21.0	23.0	-	-	-	-	-	23.0
C_8	23.5	25.0	7.0	-	-	-	18.5	25.5	24.0	12.5	-	-	-	20.7	24.5	24.5	9.8	-	-	-	19.6
Mean (S)	21.8	25.0	15.4	21.3	17.3	17.5		22.3	22.8	20.1	20.8	19.3	13.3		22.1	23.7	18.4	21.1	18.3	15.4	
	Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction		
S. Em ±	0.8		1.1		1.6			0.5		0.6		0.9			0.5		0.6		1.3		
CD at 5 %	2.4		3.2		4.7			1.4		1.6		2.7			1.3		1.6		3.7		

C_1 - Screw cap plastic bottle

C_2 - Polybag - 300 gauge + Screw cap plastic bottle

C_3 - Polybag - 300 gauge

C_4 - Earthen pot

C_5 - Earthen pot buried in soil

C_6 - Coating with fresh cowdung slurry, drying and stored in poly bag

C_7 - Coating with mud slurry, drying and stored in poly bag

C_8 - Storing under open condition at ambient temp. (Control)

S_1 - 15 days

S_2 - 30 days

S_3 - 60 days

S_4 - 90 days

S_5 - 120 days

S_6 - 150 days

(11.00 days). It was followed by C_1S_6 and C_5S_4 (16.00 days). Significantly late 50% germination was noticed in C_4S_2 (28.00 days) followed by C_6S_2 (25.50 days), C_2S_4 (25.50 days), C_8S_2 (25.00 days), C_7S_1 (25.00 days), C_5S_2 (24.50 days), C_4S_1 (23.50 days) and C_8S_1 (23.50 days) which were at par. During the second year, the minimum number of days for 50% germination was recorded in C_5S_6 (9.00 days) followed by C_8S_3 (12.50 days) and C_5S_4 (14.50 days). The late 50% germination was observed in C_1S_2 (31.05 days) which was followed by C_3S_3 (26.00 days). Pooled data indicated that C_8S_3 (9.75 days) recorded a significantly minimum number of days for attaining 50% germination followed by C_5S_5 (13.00 days). Significantly late 50% germination was attained by treatment C_3S_3 and C_4S_2 (26.00 days). Thus, it was found that C_8S_3 (seed storing at ambient temperature for two months) 50% germination was attained at the earliest as compared to other treatments.

The period between initiations of first seed germination till completion of the last seed germination was considered the germination period. The data on the effect of different storage methods, storage period and their interaction on germination period are presented in Table 4.

Effect of storage methods on germination period

During the year 2017, the germination process was completed significantly earliest in treatment C_8 (11.83 days) and 13.50 days in treatment C_4. Treatments C_6 and C_2 recorded 17.25 days and 17.50 days duration respectively to finished germination. Significantly more period was noticed in the treatment C_7 (24.00 days), 21.00 days in the treatment C_3 and 20.67 days in the treatment C_5. During 2018 treatment C_6 finished the germination process within 8.83 days, treatment C_8 took 12.67 days and 13.67 days were taken by treatment C_2. Significantly more period was taken by treatment C_1 (22.40 days) followed by treatment C_7 (21.50 days) and treatment C_5 (20.25 days).

Effect of storage period on germination period

During the first year, treatment S_3 finished germination process at earlier (12.63 days) was at par with the treatment S_2 (13.10 days). Significantly more period was recorded in treatment S_6 (29.67 days), treatment S_1 (19.50 days), S_4 (17.33 days) and S_5 (16.50 days). During second year treatment, S_3 recorded a minimum duration (10.64 days) to complete the germination process followed by treatment S_2 (13.15 days). A significantly maximum period (24.00 days) was noticed in treatment S_6, 22.00 days in treatment S_4, 19.56 days in treatment S_1 and 19.17 days in treatment S_5.

Interaction effect of storage methods and storage period on germination period

During the first year, in treatment C_2S_5, the germination process completed within 6.00 days followed by treatment C_8S_3 (8.50 days) and C_8S_2 (9.50 days) whereas, treatment C_5S_6 recorded maximum period to complete germination (35.50 days) followed by treatment C_2S_6 (28.00 days). During the second year (2018), the germination period was significantly shorter in treatment C_2S_2 (1.00 day) followed by treatments C_2S_3 and C_6S_2 (4.50 days), C_6S_3 (5.50 days), C_8S_3 (6.00 days) and C_4S_3 (6.50 days) whereas, treatment C_1S_6 recorded maximum period to complete germination (27.50 days) followed by treatment C_4S_1 (26.50 days). Other treatments finished the germination process within 12.50 days (C_3S_3) to 26.00 days (C_1S_2). The pooled data in Table 4 revealed that under ambient temperature for seed storage for 15 days had an 18.25 day germination period. This period was shortened remarkably under 30 and 60 days storage period (11.25 and 7.25 days, respectively). In further storage periods, there was no germination of the seeds. Mud coated seeds remained viable only up to 15 days storage period and had 22.75 days germination period. Under cow dung coating, storage in earthen pot and storage in polybag treatment seeds exhibited germination up to 60 days storage period. Beyond these treatments, no germination was observed. The germination period under these three conditions declined with the advancement of the storage period. Coating with cow dung exhibited a quadratic curve of decline in the germination period. Storage in earthen pot and polybag exhibited a linear trend of decline in germination period against the treatment of storage period. The storage in screw cap bottle had a germination period ranging from 15.50 to 26.50 days under different storage periods. The seed stored in polybag which was kept in screw cap bottle showed a varied kind of behaviour of germination period. It was as narrow as 1 day and 4.50 days under 30 and 60 days storage and it was quite long 26.25 days under 150 days storage. This suggested that many a time *i.e.*, 30, 60 and 120 days there was no much wide gap between

Table 4. *Effect of storage methods and storage period on germination period of jackfruit seeds*

C x S	2017							2018							Pooled						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)	S_1	S_2	S_3	S_4	S_5	S_6	Mean (C)
C_1	13.5	20.0	16.0	18.0	20.0	25.5	18.8	17.5	26.0	21.0	18.0	24.0	27.5	22.4	15.5	22.0	18.5	18.0	22.0	26.5	20.5
C_2	18.0	-	-	18.0	6.0	28.0	17.5	16.5	1.0	4.5	23.0	12.5	24.5	13.7	17.3	1.0	4.5	20.5	9.3	26.3	15.2
C_3	21.0	-	-	-	-	-	21.0	19.5	18.0	12.5	-	-	-	16.7	20.3	18.0	12.5	-	-	-	17.8
C_4	19.5	11.0	10.0	-	-	-	13.5	26.5	16.5	6.5	-	-	-	16.5	23.0	13.8	8.3	-	-	-	15.0
C_5	18.0	15.0	16.0	16.0	23.5	35.5	20.7	19.5	19.5	18.5	23.0	21.0	20.0	20.3	18.8	17.3	17.3	19.5	22.3	27.8	20.5
C_6	24.5	10.0	-	-	-	-	17.2	16.5	4.5	5.5	-	-	-	8.8	20.5	7.3	5.5	-	-	-	12.2
C_7	24.0	-	-	-	-	-	24.0	21.5	-	-	-	-	-	21.5	22.8	-	-	-	-	-	22.8
C_8	17.5	9.5	8.5	-	-	-	11.8	19.0	13.0	6.0	-	-	-	12.7	18.3	11.3	7.3	-	-	-	12.3
Mean (S)	19.5	13.1	12.6	17.3	16.5	29.7		19.6	13.1	10.6	22.0	19.2	24.0		19.5	13.1	11.4	19.5	17.8	26.8	
	Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction			Period (S)		Method (C)		Interaction		
S. Em ±	1.1		1.5		2.2			0.5		0.6		1.1			0.6		0.8		1.7		
CD at 5 %	3.3		4.4		6.5			1.5		1.9		3.1			1.7		2.2		4.9		

C_1 - Screw cap plastic bottle

C_2 - Polybag - 300 gauge + Screw cap plastic bottle

C_3 - Polybag - 300 gauge

C_4 - Earthen pot

C_5 - Earthen pot buried in soil

C_6 - Coating with fresh cowdung slurry, drying and stored in poly bag

C_7 - Coating with mud slurry, drying and stored in poly bag

C_8 - Storing under open condition at ambient temp. (Control)

S_1 - 15 days

S_2 - 30 days

S_3 - 60 days

S_4 - 90 days

S_5 - 120 days

S_6 - 150 days

first and last germination. Seed stored in an earthen pot buried in soil exhibited a span of 17.25 to 27.75 days as compared to the other treatments of storage period. Thus germination period varied according to storage condition and storage period.

It can be concluded from the present study that the jackfruit seeds can be effectively stored in a screw cap plastic bottle or polybags of 300 gauge and kept in a screw cap plastic bottle for a period upto 150 days under coastal conditions of Maharashtra. Jackfruit seeds stored in the above storage conditions, exhibited higher germination percentage, early germination and attained 50% germination at the earliest. Seeds stored in an earthen pot buried in soil were already germinated at 90, 120 and 150 days storage period and hence were not effective for maintaining the viability of jackfruit seeds.

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CONFLICTS OF INTEREST

There is no conflict of interest.

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