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Assessment of seed storability of onion varieties with accelerated ageing test

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ABSTRACT

A study was conducted to assess quality and storage potential of seeds of onion varieties with accelerated ageing test. Fresh seeds of seventeen onion varieties were pre-conditioned and subjected to accelerated ageing (AA) at 42°C and 100% RH for six days. The results showed differential and significant response of AA treatment on onion seed quality traits with respect to germination per cent, germination rate, seed vigour and electrical conductance of seed leachates. The seed germination and seed vigour index-I (SVI-I) ranged from 87.0 to 99.0% and 743.07 to 1204.17 in unaged seeds which declined to 40.0 to 76.0% and 190.62 to 593.64, respectively, after the ageing treatment. The onion varieties could be categorised as good, medium and poor storer based on response to AA treatment using cluster analysis. Among the varieties under study, Bhima Kiran, Bhima Shakti, Bhima Super, Bhima Shweta, Arka Bheem, Pusa Red, Pusa Riddhi, Agrifound Light Red were good storers as they retained high seed quality (seed germination : 70 ± 1.33% and seed vigour index-1: 481.55 ± 24.58) and showed least decline in studied traits after AA test; Pusa Madhavi, Early Grano and Bhima Shubhra as medium storers (seed germination: 62 ± 2.37% and SVI-I: 400.98 ± 34.04) and Arka Pragati, Arka Kalyan, Arka Ujjwal, Arka Niketan, NHRDF Red and Agrifound Dark Red as poor storers (seed germination : 58 ± 2.23% and SVI-I: 368.90 ± 37.72). The study helped in classification of onion varieties into different storage groups based on performance under accelerated ageing test.

Key words: Onion; seed storability; accelerated ageing test; germination; vigour

INTRODUCTION

Onion (*Allium cepa* L.) is an important bulb crop of Indian sub-continent. It is grown in an area of 1.28 mha with a production and productivity of 23.26 MT and 18.10 t/ha respectively (Agricultural statistics at a glance, 2). The non-availability of quality seeds coupled with low seed vigour and longevity are the major constraints of onion production in India (Rao *et al.*, 15). Germination and vigour are highest at physiological maturity but seeds are seldom planted immediately after harvest and are stored for variable duration under different storage conditions. During storage, seed deteriorates gradually in quality (vigour, viability) and performance (Rajjou and Debeaujon, 14). The rate of deterioration depends on temperature, relative humidity, moisture content and initial seed quality. Seed longevity of a crop depends on its chemical composition, seed physical traits, maternal influence, production environment and storage conditions. Onion seeds are categorized as poor storer and undergoes rapid deterioration due to high oil content (22-25%) and fragile seed coat (Hornke *et al.*, 8, Yalamalle *et al.,* 17) and a considerable variability existed among onion varieties for seed storability (Bhanuprakash *et al.*, 4) (Complete the sentence. It is not complete). Onion seed are stored for 6-8 months after harvest until next planting season but frequent fluctuations in temperature and relative humidity predominant in the hot and humid tropical and subtropical regions of India leads to faster decline in seed quality and poor storability (Ellis and Roberts, 6). Hence assessment of seed storability of onion varieties is of immense importance for understanding their storage behaviour and developing suitable storage and packaging protocols.

Seed storability can be assessed by physiological, biochemical tests and storage studies. Artificial ageing treatments (controlled deterioration and accelerated ageing) mimic the natural ageing process (Rajjou and Debeaujon, 14). The accelerated ageing test (AAT) developed by Delouche and Baskin (5) is one of the most frequently used tests for prediction of seed vigour and storability. In AAT, seeds are conditioned under high temperature and humidity for given time simulating conditions of seed exposure during storage under ambient conditions. There exists a direct correlation of seed storability and seed germination i.e., higher the decline in germination percent after AAT, lower the seed storability (Delouche and Baskin, 5). Seed germination is a dynamic process, but there are many quantitative parameters such as time and speed of germination which helps in more realistic prediction of seed germination thus its correlation with storability (Kader, 12). Many researchers have studied onion seed storage under different packaging

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and storage conditions but no published information in available on comparative assessment of seed storability of onion varieties which are in active seed production chain. The present study was undertaken to assess seed quality and storage potential of 17 onion varieties with accelerated ageing test and categorise them into differential storage groups. The information generated on variability of storage potential of onion varieties could be explored for characterization of germplasm lines and varieties for seed longevity and developing breeding lines and mapping population with better storability.

MATERIALS AND METHODS

Freshly harvested seeds (2018-19) of seventeen popular onion varieties produced at ICAR- Indian Agricultural Research Institute, New Delhi (Pusa Riddhi, Pusa Red, Pusa Madhavi, Early Grano), ICAR-Indian Institute of Horticultural Research, Bengaluru (Arka Pragati, Arka Kalyan, Arka Bheem, Arka Ujjwal, Arka Niketan), ICAR-Directorate of Onion and Garlic Research, Pune (Bhima Kiran, Bhima Shakti, Bhima Shweta, Bhima Shubhra, Bhima Super) and National Horticultural Research and Development Foundation, New Delhi (NHRDF Red, Agrifound Dark Red, Agrifound Light Red) were used for the study.

The initial moisture content of fresh onion seeds ranged from 4-7% which were brought to 13-15% by conditioning seeds for three days with saturated solution of sodium chloride (40mg/100ml) in desiccators (76% R.H.). Seed lots were artificially aged by maintaining temperature (42°C) and 100% relative humidity throughout the ageing period in desiccators for six days and an unaged control was used for comparative studies. After ageing treatment, the seeds were dried back to their initial moisture content under 30°C and used for further studies.

Four replicates of one hundred seeds were placed on top of paper germination paper in a Petridish and placed in walk-in germinator chambers maintained at 20°C and 100% relative humidity for twelve days (ISTA, 10). The number of normal seedlings was counted after twelve days and germination percent was calculated as GR= $\sum_{i=1}^{k} Ni.Ki$

Where Ni is the total no. of seeds germinated on i^{th} day and K_i is the number of days at final count of test.

After taking the final count of germination test, ten normal seedlings from each replication were selected, root and shoot length was measured and expressed in centimetres (cm). The seedlings were dried overnight at 80 + 1°C and weighed for dry weight estimation. Seedling dry weight was expressed in mg/ten seedlings. Vigour indices were calculated by the procedure as suggested by the Abdul-Baki and Anderson (1).

Vigour index I = Germination (%) × Seedling length (cm)

Vigour index II = Germination (%) × Seedling dry weight (mg)

Electrical conductivity (EC) was measured by soaking twenty-five seeds in 25 ml of double distilled water at 25°C for 24 h. Electrical conductance of seed leachate was measured by a conductivity meter and expressed in µS/cm/g of seed (micro-Simon /cm /gram of seed). Seed quality evaluation was done under laboratory conditions. MVApp, a multivariate analysis software was used to conduct cluster analysis for classifying seventeen onion varieties into different categories based on relative storability (Julkowska *et al*., 11). The ANOVA test, complemented by a pairwise Tukey's HSD test was used to examine significant differences among the different clusters.

RESULTS AND DISCUSSION

Harrington (7) defined safe storage conditions as those which maintain seed quality without loss of vigour for 3 years. However, such conditions are not always economically achievable/available under sub-tropical conditions of Indian sub-continent. Often due to delay in seed processing, packaging and marketing, the onion seeds remain unsold for about 6-8 months (Hourston *et al*., 9). Under ambient conditions, maintenance of high germination (70% as per Indian minimum seed certification standards) becomes difficult (especially for low vigour onion seeds) due to its faster deterioration behaviour. In addition, to meet upsurge in seed demand during cropping season due to fluctuations in marketable onion bulb prices a buffer stock needs to be maintained. Hence, the storage behaviour of onion seeds need to be studied for developing genotype specific packaging and storage protocols for safe storage. The results of the study showed significant varietal variation in seed quality and storability. The control (unaged) seeds of onion varieties had high initial germination percentage which ranged from 87.0 to 99.0%. Among varieties, 'Arka Kalyan', 'Arka Bheem', 'Agrifound Light Red', 'Pusa Madhavi', 'Bhima Kiran' had 99.0% germination whereas 'Agrifound Dark Red' showed lowest germination of 87.0%. Decline in seed germination was significant after ageing and ranged from 40.0 to 76.0%. Highest germination being in 'Bhima Kiran' (76%) and the lowest in 'Arka Niketan' (40.0%) (Table 1). Among varieties, highest decline in seed germination was observed in 'Arka Niketan' (53%) and least in 'Bhima Kiran' (23%). The variability in ageing induced reduction in seed germination could be attributed to differential initial seed quality, seed composition, varietal differences and fragile seed coat

Table 1. Assessment of seed quality parameters in onion varieties after accelerated ageing test

Variety/Seed quality Parameter	Germination percent		Germination rate		Seed vigour-I		Seed vigour-II		Electrical conductivity (µS/cm/g of seed)	
	Control	Aged	Control	Aged	Control	Aged	Control	Aged	Control	Aged
Arka Pragati	96.0 (78.46)^{c}	61.0 (51.35)^{e}	74.67^{c}	63.00^{cd}	743.07^{i}	400.64^{f}	1.98^{a}	1.49^{b}	2.45^{b}	6.21^{c}
Arka Kalyan	99.0 (83.36)^{a}	72.0 (57.41)^{b}	74.33^{c}	65.33^{c}	924.09^{f}	364.64^{g}	1.73^{c}	1.53^{b}	2.15^{b}	6.54^{b}
Arka Ujjwal	96.0 (78.46)^{c}	59.0 (50.18)^{e}	114.00^{b}	64.33^{c}	830.48^{h}	407.45^{f}	1.29^{g}	0.92^{f}	3.51^{a}	7.63^{a}
Arka Bheem	99.0 (83.32)^{a}	72.0 (58.05)^{b}	129.67^{a}	70.00^{c}	961.80^{e}	421.68^{e}	1.89^{b}	1.73^{a}	1.74^{c}	4.92^{e}
Arka Niketan	93.0 (75.03)^{e}	40.0 (39.23)^{g}	61.33^{d}	21.67^{g}	793.84^{h}	190.62^{i}	1.42^{f}	0.63^{h}	3.16^{a}	6.71^{b}
NHRDF Red	91.0 (72.87)^{f}	63.0 (52.53)^{d}	68.67^{c}	60.00^{d}	1002.36^{d}	392.61^{f}	1.33^{g}	0.89^{g}	0.98^{e}	2.42^{h}
Agrifound Dark Red	87.0 (68.58)^{g}	55.0 (47.86)^{f}	99.00^{b}	65.33^{c}	848.61^{h}	457.45^{d}	1.52^{e}	1.14^{e}	3.33^{a}	5.14^{d}
Agrifound Light Red	99.0 (83.32)^{a}	68.0 (55.55)^{c}	62.33^{c}	71.67^{b}	922.92^{f}	428.67^{e}	2.05^{a}	1.72^{a}	1.21^{e}	3.95^{f}
Pusa Red	95.0 (76.64)^{d}	71.0 (57.41)^{b}	70.33^{c}	53.33^{e}	874.09^{g}	491.03^{c}	2.21^{a}	1.80^{a}	2.09^{b}	5.81^{c}
Pusa Riddhi	97.0 (79.48)^{ab}	69.0 (56.16)^{bc}	71.66^{c}	58.33^{d}	960.91^{e}	392.27^{f}	2.26^{a}	1.72^{a}	0.89^{f}	2.97^{g}
Pusa Madhavi	99.0 (83.32)^{a}	59.0 (50.18)^{e}	77.33^{c}	53.33^{e}	862.00^{g}	406.07^{f}	2.00^{a}	1.33^{c}	2.49^{b}	5.16^{d}
Early Grano	96.0 (78.46)^{c}	57.0(49.02)^{f}	68.00^{c}	49.67^{f}	1038.31^{c}	339.63^{h}	2.02^{a}	1.35^{c}	3.44^{a}	8.53^{a}
Bhima Kiran	99.0 (83.32)^{a}	76.0 (60.66)^{a}	138.00^{a}	82.67^{a}	1204.17^{a}	517.49^{b}	1.71^{bc}	1.50^{b}	0.91^{e}	2.77^{g}
Bhima Super	93.0 (75.03)^{e}	68.0 (55.55)^{c}	126.67^{ab}	65.67^{c}	961.72^{e}	456.03^{d}	2.10^{a}	1.30^{c}	1.29^{d}	3.94^{f}
Bhima Shakti	98.0 (82.58)^{a}	73.0 (58.69)^{a}	135.67^{a}	85.67^{a}	1129.52^{b}	551.61^{a}	2.06^{a}	1.24^{cd}	1.77^{c}	4.36^{e}
Bhima Shubhra	97.0 (80.02)^{b}	69.0 (56.16)^{bc}	127.67^{a}	75.67^{b}	1139.56^{a}	593.64^{a}	1.92^{b}	1.51^{b}	0.97^{e}	3.58^{f}
Bhima Shwetha	97.0 (80.02)^{b}	71.0 (57.41)^{b}	134.67^{a}	82.00^{a}	1178.15^{a}	457.24^{d}	1.61^{d}	1.40^{b}	3.42^{a}	7.41^{b}

Control- unaged seeds; Aged -Aged seeds; Values in parenthesis are Arc Sine transformed values
Means with the same letter are not significantly different at 5% level

and genetic difference. Similar results on decline in seed germination with accelerated ageing test have been reported in onion (Balikai *et al*., 3).

The germination rate of onion varieties expresses the speed of seed germination *i.e*. higher the germination rate greater is the seed vigour or earliness in seed germination. In the present study, a significant difference was observed in the germination rate of both unaged and aged seeds. Unaged seeds of ‘Bhima Kiran’ (138.00), ‘Bhima Shakti’ (135.54), ‘Bhima Shubhra’ (134.67), ‘Bhima Shweta’ (127.45) and ‘Bhima Super’ (126.38) showed higher germination rate whereas ‘Arka Niketan’ (61.33), Agrifound Light Red’ (62.55) and ‘NHRDF Red’ (68.56) showed lower germination rate (Table 1). After accelerated ageing test, varieties showed a significant decline in the germination rate but Bhima Kiran’ (82.46), Bhima Shakti’ (85.34), Bhima Shubhra’ (82) maintained higher values for germination rate exhibiting their better performance in terms of early germination under adverse conditions Rastegar *et al*. (16).

A significant variation was observed for seed vigour index-I (SVI-I) in fresh and aged seeds of selected varieties. Highest and lowest SVI-I was observed in ‘Bhima Kiran’ (1204.17) and ‘Arka Pragati’ (743.07) in fresh seeds, respectively. In aged seeds, the highest SVI-I was recorded in Bhima Shubhra’ (593.64) followed by ‘Bhima Shakti’ (551.61) and ‘Bhima Kiran’ (517.49). The least SVI-I was observed in ‘Arka Niketan’ (190.62) which was 4-fold lower than its performance in unaged fresh seeds (Table 1).

Seed vigour index-II (SVI-II) was comparable among the unaged seeds of varieties except ‘Arka Ujjwal’ (1.29), ‘Arka Niketan’ (1.42), ‘NHRDF Red’ (1.33) and ‘Agrifound Dark Red’ (1.52) which showed lower values of seedling vigour (Fig. 4). The ageing caused substantial decrease in the SVI-II of varieties that ranged from 0.63 (‘Arka Niketan’) to 1.73 (‘Arka Bheem’). Although, ‘Arka Bheem’ (1.73) exhibited higher SVI-II value but ‘Bhima Kiran’ maintained high SVI-II in the aged (1.50) seeds as compared to control (1.71).

The varieties which retained higher germination and seedling growth after ageing treatments showed higher seedling vigour indices depicting their potential for good performance during storage. The poor reserve mobilization and accumulation of metabolites in aged seeds caused lower seedling length and dry weight resulting in lower seedling vigour. The reduced seed germination and vigour indices in artificially aged seeds have also been reported in onion by Balikai *et al*. (3).

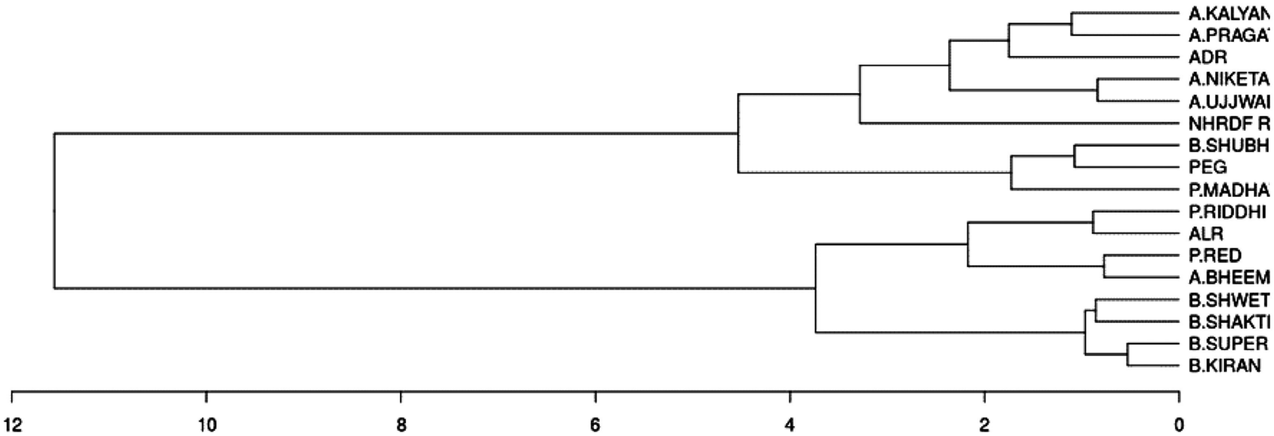

Fig. 1. Clustering of onion varieties based on seed germination and vigour indices of aged seeds

The electrical conductivity indicates the integrity of cell membrane. Reduced membrane integrity due to damaged phospholipids leads to increased membrane permeability and elimination of electrolytes and other substances (Matthews and Powell, 13).

In the present study, significant differences were observed among the varieties for the electrical conductance of seed leachate in both control and aged seeds of varieties. The highest conductance in fresh seeds was observed in 'Arka Ujjwal' (3.51µS/cm/g of seed), 'Early Grano' (3.44µS/cm/g of seed), 'Bhima Shweta' (3.42µS/cm/g of seed), 'ADR' (3.33µS/cm/g of seed) and the lowest in 'Bhima Shubhra' (0.97µS/cm) and 'Bhima Kiran' (0.91µS/cm/g of seed) (Table 1). A significant increase in the electrical conductance was measured in aged seeds, 'Early Grano' (8.53µS/cm/g of seed) and 'NHRDF Red' (2.42 µS/cm/g of seed) recorded highest and lowest electrical conductance of seed leachates respectively among the varieties. The higher solute leakage was found to be the major cause of loss in seed germination. An increase in the EC of aged seeds could be attributed to the fragile seed coat and variability in innate response of seeds to ageing treatment (Matthews and Powell, 13).

The physiological parameters like seed germination, germination rate, electrical conductivity and seed vigour indices-I and II were used to perform cluster analysis of artificially aged seeds of onion varieties and it resulted into three clusters (Fig. 1). Cluster 1 included 'Bhima Kiran', 'Bhima Shakti', 'Bhima Super', 'Bhima Shweta', 'Arka Bheem', 'Pusa Red', 'Pusa Riddhi', 'Agrifound Light Red'. This cluster reported significantly higher germination percent (70±1.35), SVI-I (481.55±24.58), SVI-II (1.56±0.07) and a lower EC (4.03±0.35) (Table 2). Varieties classified in this cluster were good storers. Cluster 2 included 'Pusa Madhavi', 'Early Grano', 'Bhima Shubhra' and this cluster reported significantly higher germination percent (62±2.37), SVI-I (400.98±34.04), SVI-II (1.36±0.02), EC (7.36±0.02) (Table 2). This cluster was classified as medium storer. Cluster 3 included 'NHRDF Red', 'Arka Ujjwal', 'Arka Niketan', 'ADR, 'Arka Pragati and 'Arka Kalyan'. This cluster reported significantly lower germination percent (58±2.23), SVI-I (368.90±37.72), SVI-II (1.1±0.14), EC (5.75±0.74) (Table 2) therefore classified as poor storer.

Based on cluster analysis and seed quality parameters of accelerated aged seeds; onion varieties could be categorised into good, medium and poor storers wherein varieties retained 70%, 62% and 58% seed germination respectively after ageing. Accelerated ageing test simulates natural ageing and shows significantly high correlation with natural ageing in onion. Hence, this classification of onion varieties for seed storage based on accelerated ageing provided a realistic assessment of seed quality and storability of onion varieties. Hourston *et al.*, (9) studied deterioration of onion genotypes and attributed variability in cellular redox environment, storage compounds, seed coat permeability, seed and seedling characters for differences in fast and slow ageing onion seeds.

As per Balikai *et al.*, (3) accelerated ageing was equivalent to 10 months of natural ageing in onion seeds. Based on this information, the varieties classified under good storer category i.e. which retained seed germination above 70% (minimum germination for certified seeds as per seed certification standards) after artificial ageing could safely be stored for 9-10 months. The medium (seed germination : 62%) and poor (seed

Table 2. Seed quality parameters of aged seeds of good, medium and poor storers

Varieties	Germination (%)	Germination rate	SVI-I	SVI-II	EC (µS/cm/g of seed)
Cluster 1: Bhima Kiran, B hima Shakti, B hima Super, BhimaShweta, Arka Bheem, PusaRed, Pusa Riddhi, Agrifound Light Red	70±1.33[a]	71.16±4.17[a]	481.55±24.58[a]	1.56±0.07[a]	4.03±0.35[c]
Cluster 2: Pusa Madhavi, Pusa Early Grano, Bhima Shubhra	62±2.37[b]	59.55±8.12[b]	400.98±34.04[b]	1.36±0.02[b]	5.75±0.74[b]
Cluster 3: NHRDF Red, Arka Ujjwal, Arka Niketan, Agrifound Dark Red, Arka Pragati and Arka Kalyan	58±2.23[c]	56.61±7.03[b]	368.90±37.72[c]	1.10±0.14[c]	7.03±0.99[a]

Cluster validation was performed by Tukey's HSD pairwise test with p-value ≤ 0.05. Means with the same letters are not significantly different at 5% level

germination : 58%) storer varieties which exhibited lower germination percentage and vigour would fail to retain germination above seed certification standards beyond 10 months. Hence, seeds of medium and poor storer varieties should be stored in moisture impervious packaging under controlled storage [(low temperature: 10°C and RH: 60%)] conditions for retaining high planting value.

The study showed differential response of onion varieties for seed physiological parameters and classified them into good, medium and poor storer categories based on performance under accelerated ageing test. The findings of the study would help in developing specific seed packaging and storage protocols based on differential storability of onion varieties. In addition, based on the results of the study, contrasting genotypes (good and poor storer) identified could be used for developing mapping populations for identification of quantitative trait locus for seed storability in onion.

AUTHORS' CONTRIBUTION

Conceptualization of research (SB, AA, SKL and BST); Designing of experiments (SK, SB, AA); Contribution of experimental materials (SB, SKL, BST); Execution of lab experiments and data collection (SK); Analysis and data interpretation (SK, SB, AA), Preparation of manuscript (SK, SB).

DECLARATION

The authors declare no conflict of interest

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