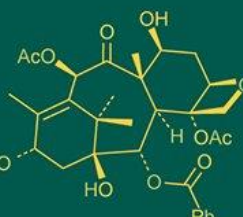
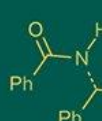


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## Genotypic variation in seed longevity and vigour retention of sorghum (*Sorghum bicolor* L. Moench) under ambient storage conditions

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### Abstract

Seed longevity is an important seed quality attribute that determines the ability of seeds to maintain viability and vigour during storage, thereby influencing seed quality, crop establishment and the efficiency of seed production systems. The present study was undertaken to evaluate genotypic variation in seed longevity and vigour retention among sixteen sorghum (*Sorghum bicolor* L. Moench) genotypes stored under ambient laboratory conditions. Freshly harvested seeds of sixteen genotypes were stored in cloth bags and seed quality parameters, including germination, root length, shoot length, seedling length, seedling dry weight, Seedling Vigour Index-I (SVI-I) and Seedling Vigour Index-II (SVI-II) were assessed initially and after 1, 3, 5, 7 and 9 months of storage following ISTA procedures. Significant genotypic differences were observed for all seed quality traits throughout the storage period. Mean germination declined from 86.42 % after one month to 73.69 % after nine months of storage, accompanied by progressive reductions in root length (22.69 to 14.26 cm), shoot length (13.50 to 10.58 cm), seedling length (36.19 to 24.84 cm), seedling dry weight (10.71 to 9.25 mg), SVI-I (3128 to 1832) and SVI-II (928 to 682). Among the evaluated genotypes, SSV 84 consistently maintained the highest germination, seedling growth and vigour indices throughout storage, followed by DSV 6 indicating superior seed longevity and storability. In contrast, CSV 22, *Phule Suchitra* and *Phule Revati* exhibited rapid deterioration and poor vigour retention. The observed variation among genotypes demonstrates the existence of substantial genetic variability for seed longevity in sorghum. The identification of superior-storing genotypes provides valuable information for seed production, storage management, breeding programmes and germplasm conservation aimed at improving seed quality and storability under ambient storage conditions.

**Keywords:** *Sorghum bicolor*, Seed longevity, Seed ageing, Seed deterioration

### Introduction

Sorghum (*Sorghum bicolor* L. Moench) is the fifth most important cereal crop in the world after maize, rice, wheat and barley, serving as a staple food, livestock feed and industrial raw material for millions of people, particularly in the semi-arid tropics (Memeshoy *et al.*, 2026). Its exceptional tolerance to drought, high temperature and marginal soil conditions makes sorghum one of the most climate-resilient cereal crops and an important component of sustainable agricultural systems under changing climatic conditions. Besides its role in ensuring food and nutritional security, sorghum is increasingly recognized for its potential in the feed, biofuel, brewing and starch industries (Bogapov *et al.*, 2026) [6]. The crop possesses high nutritional value owing to its appreciable contents of carbohydrates, proteins, dietary fibre, minerals and health-promoting phytochemicals, making it an important crop for both subsistence and commercial agriculture. Consequently, maintaining high-quality seed is fundamental for realizing the genetic yield potential of improved sorghum cultivars and ensuring successful crop establishment (Rajendra, 2023) [20].

Seed quality is one of the most important determinants of crop productivity because it directly influences germination, field emergence, seedling establishment and ultimately grain yield (Nikumbe and Shanttaraja, 2024) [18]. Among the various attributes of seed quality, seed longevity represents the inherent ability of seeds to retain viability and vigour during storage. High seed longevity enables seeds to withstand storage for extended periods while maintaining acceptable germination and field performance. This characteristic is particularly important in commercial seed production systems, where seeds are often stored for several

months before distribution to farmers. Similarly, long-term maintenance of seed viability is essential for germplasm conservation, seed banks, breeding programmes and national genetic resource management (Elangovan and Venkatesh, 2024) <sup>[8]</sup>. Seeds possessing greater longevity reduce storage losses, improve seed availability and contribute significantly to the economic efficiency of the seed industry.

Despite considerable advances in seed production technologies, deterioration of seed quality during storage remains one of the major constraints affecting agricultural productivity worldwide. Seed deterioration is a naturally occurring, continuous and irreversible process that begins immediately after physiological maturity and progresses during storage irrespective of storage conditions, although the rate of deterioration varies depending upon genotype, seed moisture content, temperature, storage environment and seed composition (Singh *et al.*, 2022) <sup>[24]</sup>. As deterioration progresses, seeds gradually lose their capacity to germinate rapidly and produce vigorous seedlings, resulting in poor field establishment and reduced crop performance. Therefore, understanding the mechanisms governing seed longevity has become an important area of research in seed science and technology (Waterworth *et al.*, 2024) <sup>[25]</sup>.

Seed ageing is associated with a series of complex physiological, biochemical and molecular changes that collectively impair seed viability and vigour. During storage, excessive accumulation of reactive oxygen species (ROS) induces oxidative damage to cellular membranes, nucleic acids, proteins and lipids, leading to membrane disintegration, lipid peroxidation, enzyme inactivation and mitochondrial dysfunction (Bailly, 2004) <sup>[4]</sup>. These alterations adversely affect respiratory metabolism, reserve mobilization and energy production required during germination. Consequently, aged seeds exhibit reduced germination percentage, slower seedling growth, lower dry matter accumulation and diminished seedling vigour (Bailly, 2023). Recent advances in seed biology have further demonstrated that antioxidant defence systems, DNA repair mechanisms, hormonal regulation and maintenance of membrane integrity play critical roles in determining the longevity of orthodox seeds during storage (Waterworth *et al.*, 2024) <sup>[25]</sup>.

Although seed deterioration is inevitable, considerable variation exists among crop species and even among genotypes within the same species with respect to their ability to withstand storage-induced ageing. Such variability is primarily governed by genetic factors controlling antioxidant capacity, membrane stability, reserve composition, seed coat characteristics and stress-responsive metabolic pathways. Identification of genotypes possessing superior seed longevity is therefore of considerable practical importance for crop improvement programmes (Assfaw *et al.*, 2025) <sup>[3]</sup>. These genotypes can serve as valuable genetic resources for developing cultivars with improved storability, enhanced seed quality and better adaptability to diverse storage environments. Furthermore, knowledge regarding inherent variation in seed longevity assists seed producers in planning storage duration, inventory management and marketing strategies while minimizing quantitative and qualitative seed losses.

Several investigators have reported significant genotypic differences for seed longevity and vigour retention in cereals and other crop species. Previous studies have demonstrated that deterioration during storage is generally accompanied

by progressive reductions in germination, seedling growth, seedling dry weight and vigour indices due to oxidative stress and impaired reserve mobilization (Gerna *et al.*, 2026) <sup>[9]</sup>. Comparatively fewer studies have comprehensively assessed naturally occurring seed deterioration among diverse sorghum genotypes stored under ambient conditions, which more closely resemble practical storage situations encountered in commercial seed production and distribution systems. Consequently, reliable information regarding the inherent variability of sorghum genotypes for maintaining seed viability and vigour during ambient storage remains limited (Nagel and Börner, 2010) <sup>[17]</sup>.

The identification of sorghum genotypes capable of maintaining high seed quality during storage has important implications for seed producers, breeders, germplasm conservation programmes and the seed industry (Kusumawardana *et al.*, 2025) <sup>[13]</sup>. Genotypes exhibiting superior longevity are expected to provide greater planting value after prolonged storage, reduce economic losses associated with seed deterioration and improve the efficiency of seed supply chains. In addition, understanding genotypic differences in seed storability contributes to the selection of suitable parental materials for breeding programmes aimed at improving seed longevity, which is increasingly recognized as an important component of seed quality under changing climatic conditions (Aruna *et al.*, 2021) <sup>[2]</sup>.

In view of the limited information available on the comparative seed longevity of diverse sorghum genotypes under ambient storage conditions, the present investigation was undertaken to evaluate sixteen sorghum genotypes for their ability to maintain seed viability and vigour during storage. The study aimed to quantify changes in germination, root length, shoot length, seedling length, seedling dry weight and seedling vigour indices over different storage periods and to identify genotypes possessing superior storability. The findings of this investigation are expected to provide useful information for seed production, storage management, breeding programmes and conservation of sorghum genetic resources by identifying genotypes with enhanced seed longevity and vigour retention.

## Materials and Methods:

### Plant material and storage conditions

Freshly harvested seeds of sixteen sorghum [*Sorghum bicolor* (L.) Moench] genotypes, namely SPV 462, CSV 15, CSV 20, CSV 23, CSV 27, CSV 17, DSV 6, SPV 2366, SSV 74, SSV 84, CSV 22, CSV 26, CSV 29, Phule Suchitra, Phule Revati and Gundlupet Local, were obtained from the All India Coordinated Research Project (AICRP) on Sorghum, Haradanahalli Farm, Chamarajanagara, Karnataka, India. The seeds were cleaned, dried to a safe moisture level and stored in cloth bags under ambient laboratory conditions at the Department of Seed Science and Technology, University of Agricultural Sciences, GKVK, Bengaluru.

Initial seed quality parameters were recorded immediately after harvest (0 month) were presented in Table 1 and subsequent observations were taken after 1, 3, 5, 7 and 9 months of storage to assess seed longevity and vigour retention.

### Seed germination test:

Seed germination was evaluated according to the procedures prescribed by the International Seed Testing Association

(ISTA, 2015) using the between-paper method. Four replications of 100 seeds each were placed in germination papers and incubated in a germinator maintained at  $25 \pm 2^\circ\text{C}$  with  $95 \pm 3$  per cent relative humidity. Normal seedlings were counted on the tenth day and germination was expressed as percentage.

#### Seedling growth measurements

Ten normal seedlings were randomly selected from each replication at the final count of the germination test for measurement of seedling growth parameters. Root length was measured from the tip of the primary root to the hypocotyl junction and expressed in centimetres (cm). Shoot length was measured from the base of the hypocotyl to the tip of the primary leaf and expressed in centimetres. Seedling length was calculated as the sum of root length and shoot length.

**Seedling dry weight:** The seedlings used for length measurements were dried in a hot-air oven at  $80 \pm 2^\circ\text{C}$  for 24 h. The dried seedlings were cooled in a desiccator and weighed using an electronic balance. The average dry weight of ten seedlings was recorded and expressed in milligrams (mg).

**Seedling vigour indices:** Seedling vigour indices were calculated according to the method proposed by Abdul-Baki and Anderson (1973) <sup>[1]</sup>.

Seedling Vigour Index-I (SVI-I)

$\text{SVI-I} = \text{Germination (\%)} \times \text{Seedling length (cm)}$

Seedling Vigour Index-II (SVI-II)

$\text{SVI-II} = \text{Germination (\%)} \times \text{Seedling dry weight (mg)}$

#### Experimental design and statistical analysis

The experiment was conducted in a Completely Randomized Design (CRD). Data recorded for different seed quality parameters during storage were subjected to analysis of variance (ANOVA). The significance of differences among genotype means was tested using the critical difference (CD) at the 5 per cent probability level. Standard error of mean (SEm) and coefficient of variation (CV) were also computed wherever applicable.

#### Results and Discussion:

The present investigation revealed substantial variation among sorghum genotypes in their ability to maintain viability and vigour during ambient storage. Germination percentage, seedling growth parameters, seedling dry weight and vigour indices declined progressively with storage duration in all genotypes. However, the magnitude of deterioration differed significantly among genotypes, indicating the existence of considerable genetic variability for seed longevity and storability (Kannababu *et al.*, 2016) <sup>[11]</sup>. The decline in seed quality parameters observed during storage may be attributed to the natural ageing process, which is associated with membrane deterioration, lipid peroxidation, oxidative stress and impairment of enzymatic systems involved in reserve mobilization. These physiological and biochemical changes ultimately reduce seed viability and seedling growth potential, resulting in lower germination, shorter seedlings and reduced vigour indices (Pirredda *et al.*, 2024) <sup>[19]</sup>.

#### Seed germination (%) during storage:

The study showed significant differences for seed germination (%) for all the sixteen genotypes with the advancement of storage period. The mean germination percentage decreased from 86.42 per cent after one month of storage to 73.69 per cent after nine months, representing a reduction of 14.73 per cent over the storage period. Among the genotypes, SSV 84 consistently maintained the highest germination percentage during storage, recording 94.33, 90.00, 88.00, 83.67 and 81.67 per cent germination at 1, 3, 5, 7 and 9 months of storage, respectively. DSV 6 also exhibited superior germination retention, maintaining 79.00 per cent germination after nine months of storage. In contrast, CSV 22 recorded the lowest germination percentage throughout the storage period and declined to 65.67 per cent at nine months of storage (Fig 1).

The germination percentage gradually decreased in all the genotypes with the advancement of storage period. The reduction in germination percentage is mainly due to age induced phenomenon in the seed which is inevitable and irreversible (Abdul-Baki and Anderson, 1973) <sup>[1]</sup>. Also, due to increase in moisture content and membrane leakages which releases large number of leachates resulting in loss of membrane integrity, reduced enzymatic activity and accumulation of reactive oxygen species (ROS), which collectively impair seed viability and germination (Bailly, 2004 and Pirredda *et al.*, 2024) <sup>[4, 19]</sup>.

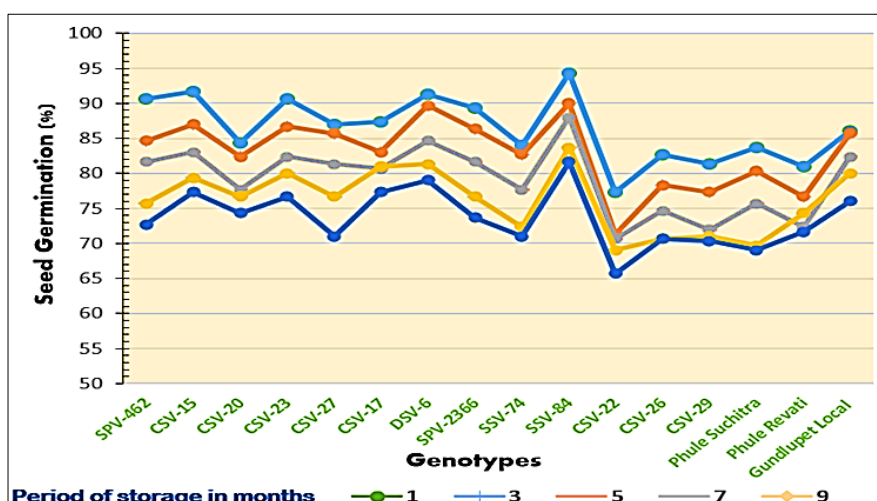


Fig 1: Seed germination (%) of sorghum genotypes during storage

**Table 1:** Initial seed quality parameters of sorghum genotypes

| Genotypes              | Seed moisture (%) | Seed germination (%) | Root length (cm) | Shoot length (cm) | Seedling length (cm) | Seedling dry weight (mg) | Vigour index I | Vigour index II |
|------------------------|-------------------|----------------------|------------------|-------------------|----------------------|--------------------------|----------------|-----------------|
| SPV 462                | 10.09             | 91.00                | 24.24            | 13.88             | 35.40                | 17.10                    | 3221           | 1556            |
| CSV 15                 | 10.00             | 92.00                | 26.13            | 13.81             | 38.30                | 18.00                    | 3523           | 1656            |
| CSV 20                 | 10.08             | 85.00                | 23.01            | 13.55             | 34.80                | 15.70                    | 2958           | 1335            |
| CSV 23                 | 10.05             | 91.00                | 25.45            | 12.80             | 36.70                | 17.80                    | 3340           | 1620            |
| CSV 27                 | 10.45             | 89.00                | 22.85            | 13.60             | 35.90                | 16.20                    | 3195           | 1442            |
| CSV 17                 | 10.10             | 88.00                | 23.45            | 13.40             | 35.90                | 17.00                    | 3159           | 1496            |
| DSV 6                  | 10.05             | 92.00                | 27.55            | 14.45             | 41.10                | 19.00                    | 3781           | 1558            |
| SPV 2366               | 10.20             | 90.00                | 23.00            | 13.60             | 35.80                | 15.80                    | 3222           | 1422            |
| SSV 74                 | 10.00             | 86.00                | 23.14            | 13.20             | 34.80                | 17.20                    | 2993           | 1479            |
| SSV 84                 | 10.05             | 95.00                | 30.00            | 16.40             | 44.90                | 19.70                    | 4266           | 1872            |
| CSV 22                 | 10.44             | 80.00                | 20.20            | 13.70             | 31.60                | 14.80                    | 2528           | 1184            |
| CSV 26                 | 10.58             | 84.00                | 21.20            | 13.80             | 34.80                | 14.70                    | 2923           | 1235            |
| CSV 29                 | 10.40             | 83.00                | 19.14            | 13.50             | 30.40                | 13.70                    | 2523           | 1137            |
| <i>Phule Suchitra</i>  | 10.80             | 84.00                | 19.55            | 12.30             | 31.20                | 14.40                    | 2621           | 1210            |
| <i>Phule Revati</i>    | 10.71             | 83.00                | 19.40            | 12.70             | 301.10               | 14.40                    | 2498           | 1195            |
| <i>Gundlupet Local</i> | 10.51             | 88.00                | 22.80            | 13.70             | 35.60                | 15.60                    | 3132           | 1373            |

**Table 2:** Root and shoot length (cm) of sorghum genotypes during storage

| Genotypes              | Period of storage in months |              |             |              |             |              |             |              |             |              |
|------------------------|-----------------------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|
|                        | 1                           |              | 3           |              | 5           |              | 7           |              | 9           |              |
|                        | Root length                 | Shoot length | Root length | Shoot length | Root length | Shoot length | Root length | Shoot length | Root length | Shoot length |
| SPV-462                | 23.54                       | 13.42        | 22.97       | 12.59        | 21.45       | 12.00        | 18.97       | 10.56        | 15.71       | 10.29        |
| CSV-15                 | 25.53                       | 13.83        | 21.74       | 13.47        | 19.82       | 12.43        | 17.23       | 11.13        | 14.96       | 10.93        |
| CSV-20                 | 22.45                       | 13.32        | 19.34       | 12.33        | 16.63       | 11.17        | 15.10       | 10.63        | 12.04       | 9.73         |
| CSV-23                 | 25.15                       | 12.78        | 22.19       | 11.80        | 18.59       | 11.97        | 16.50       | 12.50        | 14.34       | 11.40        |
| CSV-27                 | 22.75                       | 13.60        | 20.90       | 13.54        | 17.95       | 12.55        | 15.65       | 12.37        | 12.85       | 10.26        |
| CSV-17                 | 23.46                       | 13.39        | 19.60       | 12.46        | 17.97       | 11.97        | 15.43       | 12.40        | 13.33       | 11.00        |
| DSV-6                  | 27.51                       | 14.32        | 22.12       | 13.83        | 20.08       | 12.47        | 17.56       | 11.08        | 16.67       | 10.43        |
| SPV-2366               | 22.29                       | 13.37        | 20.96       | 13.23        | 17.32       | 11.67        | 15.55       | 11.53        | 14.74       | 10.57        |
| SSV-74                 | 22.45                       | 13.16        | 19.82       | 12.37        | 16.97       | 11.77        | 15.44       | 10.84        | 14.26       | 12.07        |
| SSV-84                 | 29.55                       | 16.25        | 24.94       | 14.92        | 21.00       | 14.00        | 19.89       | 13.11        | 17.30       | 11.96        |
| CSV-22                 | 19.28                       | 13.67        | 16.56       | 13.22        | 15.47       | 12.90        | 15.59       | 12.57        | 13.26       | 11.43        |
| CSV-26                 | 20.67                       | 13.43        | 18.38       | 13.23        | 16.38       | 12.83        | 15.07       | 12.77        | 13.59       | 10.57        |
| CSV-29                 | 18.42                       | 13.27        | 18.49       | 12.93        | 18.11       | 13.03        | 15.55       | 11.80        | 14.63       | 10.27        |
| <i>Phule Suchitra</i>  | 19.07                       | 12.14        | 18.02       | 11.47        | 16.93       | 11.17        | 15.33       | 10.06        | 13.00       | 10.09        |
| <i>Phule Revati</i>    | 19.42                       | 12.46        | 19.15       | 11.17        | 16.22       | 11.80        | 14.00       | 10.47        | 12.63       | 9.08         |
| <i>Gundlupet Local</i> | 22.50                       | 13.57        | 17.75       | 13.40        | 15.73       | 12.97        | 14.22       | 12.03        | 12.34       | 11.33        |
| Mean                   | 22.69                       | 13.50        | 20.23       | 12.87        | 17.91       | 12.25        | 16.07       | 11.55        | 14.26       | 10.58        |
| S.Em $\pm$             | 0.56                        | 0.24         | 0.51        | 0.21         | 0.50        | 0.33         | 0.40        | 0.31         | 0.40        | 0.29         |
| CD at 5 %              | 2.16                        | 0.91         | 1.97        | 0.83         | 1.93        | 1.29         | 1.55        | 1.21         | 1.55        | 1.11         |
| CV (%)                 | 4.26                        | 3.03         | 4.35        | 2.87         | 4.81        | 4.73         | 4.31        | 4.68         | 4.86        | 4.71         |

**Table 3:** Seedling length (cm) and Seedling dry weight (mg) of sorghum genotypes during storage

| Genotypes              | Period of storage in months |                     |                 |                     |                 |                     |                 |                     |                 |                     |
|------------------------|-----------------------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|
|                        | 1                           |                     | 3               |                     | 5               |                     | 7               |                     | 9               |                     |
|                        | Seedling length             | Seedling dry weight | Seedling length | Seedling dry weight | Seedling length | Seedling dry weight | Seedling length | Seedling dry weight | Seedling length | Seedling dry weight |
| SPV-462                | 35.24                       | 16.85               | 33.55           | 15.39               | 32.63           | 13.30               | 28.55           | 11.35               | 24.47           | 9.92                |
| CSV-15                 | 38.14                       | 17.95               | 34.86           | 16.36               | 31.89           | 13.86               | 28.01           | 11.51               | 24.30           | 10.09               |
| CSV-20                 | 34.63                       | 15.60               | 30.89           | 14.34               | 27.08           | 12.77               | 24.70           | 10.93               | 20.14           | 9.08                |
| CSV-23                 | 36.57                       | 17.65               | 33.73           | 15.46               | 29.76           | 13.14               | 28.50           | 11.36               | 24.80           | 10.23               |
| CSV-27                 | 35.78                       | 16.01               | 33.65           | 14.97               | 30.16           | 12.87               | 27.61           | 10.90               | 22.77           | 9.61                |
| CSV-17                 | 35.64                       | 16.83               | 31.52           | 14.85               | 29.15           | 13.16               | 26.78           | 11.46               | 23.73           | 9.72                |
| DSV-6                  | 40.74                       | 18.83               | 34.93           | 17.15               | 32.03           | 15.36               | 28.62           | 13.31               | 25.40           | 10.22               |
| SPV-2366               | 35.43                       | 15.65               | 33.60           | 14.03               | 28.25           | 12.61               | 26.09           | 10.63               | 24.50           | 9.28                |
| SSV-74                 | 34.50                       | 17.03               | 31.53           | 15.78               | 28.05           | 13.44               | 25.74           | 11.32               | 22.84           | 9.80                |
| SSV-84                 | 44.63                       | 19.56               | 38.81           | 17.91               | 34.43           | 15.33               | 32.18           | 13.30               | 27.82           | 10.27               |
| CSV-22                 | 31.33                       | 14.71               | 28.76           | 13.36               | 26.80           | 12.27               | 24.59           | 10.18               | 23.37           | 8.94                |
| CSV-26                 | 34.16                       | 14.54               | 30.80           | 13.18               | 28.17           | 12.01               | 26.80           | 10.16               | 23.16           | 8.62                |
| CSV-29                 | 30.28                       | 13.53               | 29.97           | 12.19               | 27.62           | 13.20               | 25.56           | 11.19               | 22.70           | 10.05               |
| <i>Phule Suchitra</i>  | 30.66                       | 14.25               | 29.00           | 12.61               | 26.49           | 11.15               | 24.12           | 10.02               | 21.33           | 8.27                |
| <i>Phule Revati</i>    | 30.47                       | 14.25               | 29.37           | 12.47               | 27.25           | 11.67               | 24.30           | 10.16               | 21.57           | 9.02                |
| <i>Gundlupet Local</i> | 35.50                       | 15.39               | 30.78           | 13.66               | 27.90           | 12.82               | 25.33           | 10.83               | 23.05           | 9.37                |
| Mean                   | 35.23                       | 16.17               | 32.23           | 14.61               | 29.23           | 13.06               | 23.72           | 11.16               | 23.56           | 9.53                |
| S.Em $\pm$             | 0.68                        | 0.38                | 0.61            | 0.35                | 0.48            | 0.29                | 0.33            | 0.26                | 0.22            | 0.24                |
| CD at 5 %              | 2.03                        | 1.20                | 2.10            | 1.07                | 1.74            | 0.94                | 1.13            | 0.90                | 0.72            | 0.81                |
| CV (%)                 | 2.57                        | 2.62                | 2.92            | 3.81                | 2.67            | 3.66                | 1.89            | 3.60                | 1.56            | 4.29                |

**Root length (cm) during storage:**

Root length declined progressively with increasing storage duration in all sorghum genotypes. The mean root length decreased from 22.69 cm at one month of storage to 14.26 cm after nine months of storage, reflecting a substantial reduction in seedling growth potential during storage. Significant genotypic differences were observed throughout the storage period. Among the genotypes, SSV 84 consistently recorded the highest root length, measuring 29.55, 24.94, 21.00, 19.89 and 17.30 cm at 1, 3, 5, 7 and 9 months of storage, respectively. DSV 6 also maintained relatively higher root growth during storage, recording a root length of 16.67 cm after nine months. In contrast, lower root lengths were observed in CSV 20, Gundlupet Local, Phule Suchitra and Phule Revati, with Phule Revati recording only 12.63 cm after nine months of storage (Table 2).

The results indicated that, root length of sorghum seedlings decreased with the advancement of storage period irrespective of sorghum genotypes (Odiemah, 1987). Root growth is a sensitive indicator of seed vigour because it reflects the ability of seedlings to establish rapidly under field conditions. The reduction in root length during storage may be attributed to the progressive deterioration of seed tissues and reduced metabolic efficiency associated with seed ageing. Loss of membrane integrity, impairment of enzyme systems involved in reserve mobilization and reduced cellular division during germination adversely affect seedling growth, resulting in shorter roots. Genotypic differences in root length retention further indicate the existence of substantial variability for seed storability among sorghum genotypes, which can be exploited in breeding and seed production programmes aimed at improving seed longevity.

**Shoot length (cm) during storage:**

Shoot length exhibited a gradual decline with the advancement of storage period in all sorghum genotypes. The mean shoot length decreased from 13.50 cm at one month of storage to 10.58 cm after nine months of storage, demonstrating the adverse effect of prolonged storage on seedling growth. Among the evaluated genotypes, SSV 84 consistently recorded the highest shoot length, measuring 16.25, 14.92, 14.00, 13.11 and 11.96 cm at 1, 3, 5, 7 and 9 months of storage, respectively. DSV 6 and CSV 15 also maintained relatively higher shoot growth during storage significantly. In contrast, Phule Revati and CSV 20 recorded lower shoot lengths after nine months of storage, indicating a greater loss of seedling vigour (Table 2).

The shoot length of sorghum seedlings decreased with the advancement of storage period irrespective of sorghum genotypes (Odiemah, 1987). Seed ageing is known to reduce the efficiency of metabolic processes involved in germination and seedling development, thereby limiting shoot elongation. The decline in shoot length during storage can be attributed to the deterioration of cellular membranes, reduced enzymatic activity and impaired mobilization of stored food reserves required for seedling growth. Genotypes capable of maintaining higher shoot growth during storage are generally considered to possess superior vigour and greater tolerance to storage-induced deterioration (Pirredda *et al.*, 2023 and Xing *et al.*, 2025) <sup>[19, 27]</sup>.

**Seedling length (cm) during storage:**

Seedling length, a composite measure of root and shoot growth, declined significantly with the advancement of storage period in all sorghum genotypes. The mean seedling length decreased from 36.19 cm at one month of storage to 24.84 cm after nine months of storage, indicating a substantial reduction in seedling vigour as a consequence of seed ageing under ambient storage conditions. Among the evaluated genotypes, SSV 84 consistently recorded the highest seedling length, measuring 45.80, 39.86, 35.00, 33.00 and 27.82 cm at 1, 3, 5, 7 and 9 months of storage, respectively. DSV 6 also maintained comparatively higher seedling length during storage, recording 25.40 cm after nine months. Conversely, lower seedling lengths were observed in Phule Revati, CSV 20 and Phule Suchitra, indicating a greater loss of seedling vigour during storage (Table 3).

The vigour of seed is measured by seedling length. Seedling length is widely recognized as a reliable indicator of seed vigour because it integrates both root and shoot growth responses. The reduction in seedling length with increasing storage duration is likely due to seed ageing-induced deterioration, which lowers metabolic activity and impairs mobilization of stored reserves required for seedling growth. Seed ageing-related membrane damage, oxidative stress and reduced enzyme activity further restrict cell division and elongation during germination. The significant genotypic variation observed suggests considerable potential for selecting sorghum genotypes with enhanced storability, while seed ageing adversely affected seedling growth and vigour (Pirredda *et al.*, 2023 and Xing *et al.*, 2023) <sup>[19, 26]</sup>.

**Seedling dry weight (mg) during storage**

Storage duration exerted a significant effect on seedling dry weight, which declined from a mean of 10.71 mg after one month to 9.25 mg after nine months of storage. The reduced biomass accumulation in seedlings from aged seeds suggests a progressive deterioration in seed vigour during storage. Genotypic differences in seedling dry weight were evident throughout the storage period. SSV 84 maintained the highest values, recording 19.17, 17.89, 15.40, 12.95 and 10.36 mg at 1, 3, 5, 7 and 9 months of storage, respectively. DSV 6 also exhibited better retention of seedling dry weight, with a value of 10.35 mg after nine months of storage. Conversely, CSV 22, Phule Suchitra and Phule Revati recorded comparatively lower seedling dry weights, reflecting a greater decline in seed vigour during storage (Table 3).

The gradual decline in seedling dry weight of genotypes may be due to deterioration of seed which causes the loss of food reserve which ultimately affects the germination percentage, seedling length and thus affects the seedling dry weight (Singh *et al.* 2016). As an integrative measure of reserve utilization efficiency, seedling dry weight provides a sensitive assessment of seed vigour. The decline in dry matter accumulation with storage duration reflects the progressive loss of seed physiological quality associated with ageing. Seedling dry weight reflects the efficiency of reserve mobilization and biomass accumulation during seedling establishment. Similar observations have been reported in studies linking seed ageing with impaired reserve utilization and reduced seedling establishment potential (Rehmani *et al.*, 2023 and Corbineau, 2024) <sup>[23, 7]</sup>.

**Seedling Vigour Index-I during storage:**

Seedling Vigour Index-I (SVI-I) decreased significantly with storage duration in all sorghum genotypes, declining from a mean of 3128 after one month to 1832 after nine months of storage, indicating a progressive loss of seed vigour under ambient conditions. Significant genotypic differences were evident throughout the storage period. SSV 84 consistently recorded the highest SVI-I values (4320, 3587, 3080, 2761 and 2382 at 1, 3, 5, 7 and 9 months, respectively), followed by DSV 6, which maintained an SVI-I of 2038 after nine months of storage. Conversely, CSV 22, Phule Suchitra and Phule Revati exhibited comparatively lower SVI-I values, indicating greater vigour loss during storage (Fig 2).

The reduction in germination, root length and shoot length with increasing storage duration resulted in a corresponding

decline in Seedling Vigour Index-I (Abdul-Baki and Anderson, 1973) <sup>[1]</sup>. The reduction in Seedling Vigour Index-I with prolonged storage may be attributed to the progressive disruption of physiological and biochemical processes essential for successful germination and seedling establishment. Seed ageing is associated with oxidative damage to cellular components, reduced mitochondrial efficiency and impaired reserve mobilization, which collectively limit both germination capacity and seedling growth (Sharma *et al.*, 2025). Because SVI-I integrates these two components, it provides a sensitive measure of the cumulative effects of deterioration on seed performance. Consequently, even modest reductions in germination and seedling length are amplified in the vigour index, resulting in a marked decline with advancing storage duration (Reed *et al.*, 2022 and Xing *et al.*, 2023) <sup>[23, 26]</sup>.

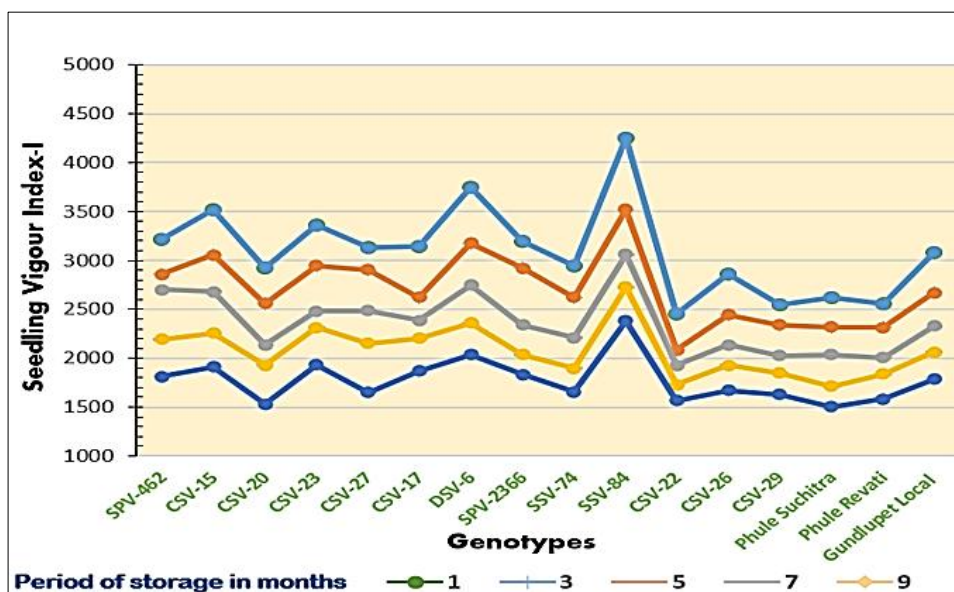


Fig 2: Seedling Vigour Index-I of sorghum genotypes during storage

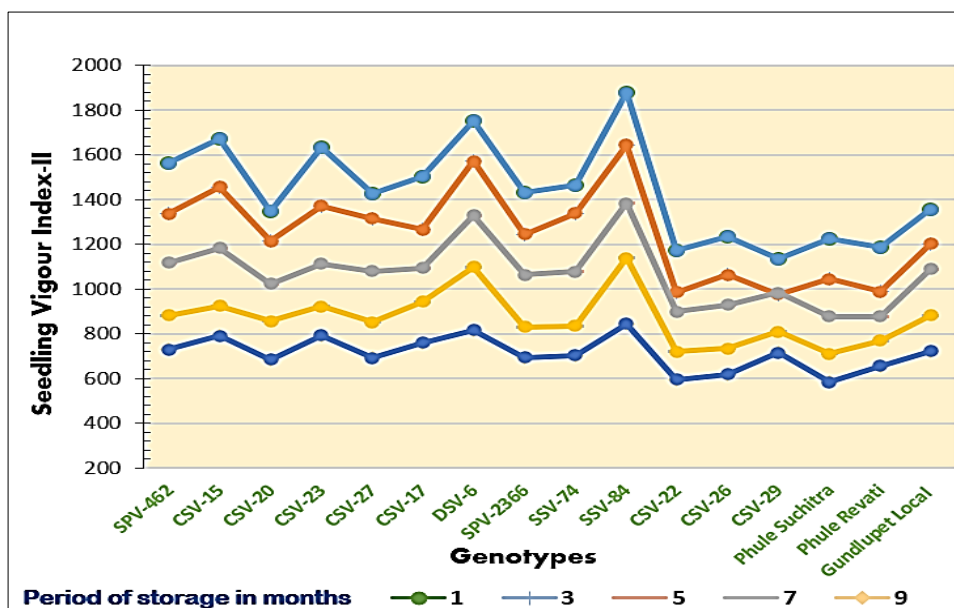


Fig 3: Seedling Vigour Index-II of sorghum genotypes during storage

**Seedling Vigour Index-II during storage:**

Seedling Vigour Index-II (SVI-II) was significantly influenced by storage duration, declining from a mean of 928 at one month to 682 after nine months of storage,

indicating a progressive loss of seed vigour and biomass accumulation potential. Significant genotypic differences were observed throughout the storage period. SSV 84 consistently recorded the highest SVI-II values (1808, 1610,

1355, 1083 and 846 at 1, 3, 5, 7 and 9 months of storage, respectively), followed by DSV 6, which maintained an SVI-II value of 818 after nine months. Conversely, CSV 22, Phule Suchitra and Phule Revati exhibited comparatively lower SVI-II values, indicating greater vigour loss during storage (Fig 3).

The variation in seedling length, seedling dry weight and seedling vigour index among sorghum genotypes may be attributed to inherent genetic differences, differential rates of seed deterioration, initial seed quality, reserve food content and seed coat characteristics (Rajjou and Debeaujon, 2008). The decline in Seedling Vigour Index-II with storage duration reflects the combined reduction in seed viability and seedling biomass accumulation associated with seed ageing. As SVI-II integrates germination and seedling dry weight, its reduction indicates a diminished capacity of aged seeds to mobilize and convert stored reserves into seedling tissues. Impaired reserve utilization and reduced dry matter production during germination have been recognized as important consequences of seed deterioration, resulting in lower vigour and seedling establishment potential (Nadarajan *et al.*, 2023 and Kannababu *et al.*, 2024) <sup>[10]</sup>.

### Integrated discussion:

The progressive decline in germination, seedling growth, seedling dry weight and vigour indices during storage indicates a gradual loss of seed physiological quality as a consequence of seed ageing. This deterioration is primarily associated with oxidative damage, loss of membrane integrity, impaired energy metabolism and reduced reserve mobilization, which collectively limit germination potential and seedling establishment. The greater reduction observed in vigour indices compared with germination alone highlights the sensitivity of post-germination growth traits to storage-induced deterioration. Overall, the results demonstrate that seed longevity is closely linked to the ability of seeds to maintain metabolic functionality and support vigorous seedling development during storage (Xing *et al.*, 2023; Pirredda *et al.*, 2024; Rehmani *et al.*, 2023) <sup>[26, 23, 19]</sup>.

### Conclusion:

The present investigation demonstrated significant genotypic variation in seed longevity and vigour retention among sixteen sorghum genotypes under ambient storage conditions, confirming that seed storability is a genotype-dependent trait. Progressive declines in germination, seedling growth, seedling dry weight and seedling vigour indices were observed with increasing storage duration, however, the extent of deterioration varied markedly among genotypes. SSV 84 and DSV 6 consistently exhibited superior storability by maintaining higher seed viability and vigour throughout the storage period, whereas CSV 22, Phule Suchitra and Phule Revati showed comparatively poor storage performance. The identification of genotypes with enhanced seed longevity provides valuable genetic resources for seed production, breeding and germplasm conservation programmes while also supporting improved storage management and reducing post-harvest seed quality losses. Overall, the findings contribute to a better understanding of genotypic differences in sorghum seed storability and provide a strong foundation for future physiological, biochemical and molecular investigations aimed at elucidating the mechanisms governing seed

longevity and developing cultivars with enhanced storage resilience.

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