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# PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN PEARL MILLET SEEDS UNDER DIFFERENT STORAGE CONDITIONS AND CONTAINERS

**ANKUSH GUPTA*, R. C. PUNIA AND O. S. DHAIYA**
Department of Seed Science and Technology,
C.C.S., Haryana Agricultural University, Hisar -125 004, Haryana, INDIA
e-mail: ankushgupta1010@gmail.com

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***Corresponding author**

**ABSTRACT**
The studies were carried out to evaluate the physiological and biochemical changesin the pearlmillet genotypes at different storage conditions and containers during 24 months of storage. Result from the study indicated thatseed stored in cold storage conditions and packed in poly set bin container maintained higher seedquality parameters*viz.*,highest germination (41.29% and 38.57%), catalase (0.167$\mu$moles/ml/min and 0.165$\mu$moles/ml/min) and peroxidase (0.084ÄA $min^{-1}$ $g^{-1}$and 0.083ÄA $min^{-1}$ $g^{-1}$) activity with lowest free fatty acid (FFA) (33.73% and 34.07%), after24 months of storage period as compared to ambient condition and cloth bag.Germination percentage, catalase and peroxidase activity decreased while FFA increased with the advancement of storage period. It is concluded thatcold storage conditions and poly set bin container can be used for storage of pearlmillet seeds in order to maintaining seed viability for longer period.

## INTRODUCTION

Pearl millet (*Pennisetum typhoides*), is one of the major coarse grain food crops of developing countries of dry areas with low rainfall. In general, bajra grains contain a higher amount of fat (7.0-7.9 %) than other cereals, and it has poor storability, especially under conditions of moderately high moisture and oxygen exposure (Yadav *et al.,* 2012). One of the major constraints in bajra cultivation is the limited availability of vigorous seeds at the time of sowing due to poor storability under fluctuating ambient temperature and relative humidity. However, lowering either of these factors during storage significantly increases storage life of seeds(Roberts, 1972 and Sharon *et al,* 2015).

Several attempts have been made on many crops to develop methods for maintaining the seed viability and vigor of seeds for longer period during storage (Rao *et al.,* 2006; Badiger *et al.,* 2015 andKumar*et al.,* 2014). Use of moisture impervious containers and low temperature improves the storability as several physiological and biochemical process and products are being regulated during dry storage (Dhatt and Kumar, 2009 and Pathak *et al.*,2015). Alhamdan *et al.* (2011) reported thatlow storage temperatures favor the maintenance of biochemical processes in the embryo, subsequently allowing normal seedling development and uniform germination.Tiwari *et al.* (2014) suggested that usingof appropriate storage containers with proper environmental exposure that can sustain the viability of seeds following better germination even after long time.

Peroxidation of unsaturated fatty acid is considered to be one of the main reasons for loss of storability, which occur due to decreased level of antioxidant, reduced activity of free radical and increased free fatty acid (Bailly *et al.,* 1996; Begum *et al.,* 2014 and Lins *et al.,* 2014). Standardization of appropriate seed conditioning, packaging and storage conditions could ensure satisfactory planting quality of pearl millet seeds at the time of sowing.Therefore, thisstudy was planned to find out thepossible way to improve storability of bajra seed with respect to packaging and storage conditions.Germination performance, isoenzymatic activity(catalase and peroxidase) and FFA were analyzed in rapidly aged bajra seed.

## MATERIALS AND METHODS

Seeds of one pearl millet hybrid(HHB 197(G1)) along with their parental lines (A, B and R lines *viz.* A- ICMA97111(G2), B- ICMB97111(G3) and R- HBL-11(G4)) were obtained from the Bajra section department of Genetic and Plant Breeding CCS Haryana Agricultural University Hisar.All the four genotypes were dried up to 8% moisture content and packed in three containers (poly set bin(P1), poly thin bag(P2) and cloth bag (P3)) under two storage conditions (ambient(C1) and cold storage at 20ºC (C2))for a period of 24 months. Seed samples were drawn subsequently at intervals of 3 months and tested for the following physiological and biochemical parameters of seed quality (Dhatt and Kumar, 2009).

Germination per cent was determined as per ISTA rules for seed testing. The seeds were placed in rolled paper towels. Hundred seeds of three replications were tested at a constant temperature of 25ºC. The number of normal seedlings was

evaluated on 7th day and per cent germination was expressed on normal seedling basis (ISTA, 2006).

For the extraction of free radical scavenging enzymes activities was performed in potassium phosphate buffered saline (pH 7.2). Seed samples weighing (0.1 g) each of three replicates was extracted in buffer with the help of pestle and mortar; phenyl methyl sulfonyl fluoride (PMSF) (10 mM) was used as proteases inhibitor. Finally, centrifuged at 10,000 × g at 4°C and supernatant was used for enzyme assay (Razzaq *et al*., 2013). Activities of catalase (CAT) and peroxidase (POD) were measured following the methods of Shannon *et al*. (1966)and Aebi (1983) respectively. The CAT reaction solution (3mL)contained 0.3 M phosphate buffer (pH 7.0), 0.3M H2O2, and 0.5 mLenzyme extract. The reaction was initiated by adding the plant seed extract. Changes in absorbance of the reaction solution at 570 nm were taken after every 20 sec. One unit of CAT activity was defined as an absorbance change of 0.01 units per min. The POD reaction solution (3 mL) contained 0.1M phosphate buffer (pH 4.5),0.2M H2O2, 10mg O-dianisidine and 0.1 mL plant seed extract. Changes in absorbance of the reaction solution at 470 nm were determined every 20 seconds. One unit of POD activity was defined as an absorbance change of 0.01 units per minute.

The free fatty acid content of seed samples was determined using acid-base titration technique according to the method ofAOAC (1990). The free fatty acids were calculated as oleic acid using the equation 1ml N/10 NaOH-0.028 g oleic acid.

The data obtained during the investigation was analyzed by using standard statistical procedure for a three factorial completely randomized block design. Standard error of mean (SEm ±) were computed in each case and the critical difference (CD) at 5 percentage level of probability was calculated only for significant effects (Panse and Sukhatme (1995).

## RESULTS

### Germination percent

Germination percent was significantly influenced by storage conditions, packaging materials and genotypes throughout the storage period (Table1). It was found that hybrid HHB-197 (G1) recorded significantly higher germination percent (89.30%) as compared to B line (G3) (88.33%) followed by R line (G4) (81.33%) during initial storage period. Similarly G1 recorded significantly higher germination and slow rate of declining trend of germination in all the 24 months of storage followed by G4. In cold storage condition (C2) germination percent (77.25%) was maintained up to 15 month of storage while in ambient storage condition (C1) it's maintained only up to 9 month. Seeds stored in C2 retained higher germination percent (41.29%) at the end of 24 months of storage period as compared to the C1 (27.90%). It was also observed that seeds stored in poly set bin recorded significantly higher germination percent*i.e*.83.33% to 38.57% during all the 24 months of storage as compare to cloth bag (81.02% to 30.21%).

### Free radical scavenging enzymes

Activity of both the enzymes *viz*. catalase (CAT) and peroxidase (POD)was decreased with prolonged storage period, but minimum decrement had occurred in cold storage conditions under poly set bin as compared to ambient conditions and cloth bag. Highest POD and CAT activity was showed by hybrid HHB-197 (G1) as compared to B- line (G3) during all the 24 months of storage.At the initial storage period POD activity was 0.361; it had reduced to 0.077 under ambient condition (C1), while under cold storage condition (C2) ithad reduced to 0.084 respectively.Seed stored in poly set bin (P1) retained higher POD activity (0.083) as compared to cloth bag (P3)(0.080)(Table 2). It was observed that at the initial storage period seeds had low CATactivity as compared to POD(0.272) but deterioration rate was lower as compared to POD. At the end of 24 month of storage seed stored in C2 retained higher CAT activity (0.163) as compare to C1 (0.155). Seed stored in P1 recorded significantly higher CAT activity during all the 24 months as compared to P3 followed by P2. (Table 3)

### Free fatty acid

It was revealed that FFA was increased with increment of storage periods. The G1 recorded significantly lower FFA of 4.71% as compare to G3 (5.44%) after initial period of storage However, the same genotype G1 retained significantly lower FFA values as compared to G3 during the complete storage

**Table 1: Effect of storage conditions, packaging materials and genotypes on standard germination (%) of pearl millet seed during storage**

| Treatments | Storage period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 |
| C1 | 85.40 | 80.78 | 77.19 | 75.00 | 68.97 | 51.87 | 38.79 | 32.63 | 27.90 |
| C2 | 85.40 | 83.62 | 81.21 | 80.14 | 78.73 | 75.57 | 71.46 | 50.70 | 41.29 |
| S.Em ± | 0.07 | 0.05 | 0.05 | 0.05 | 0.06 | 0.07 | 0.07 | 0.13 | 0.108 |
| C.D.at 5% | N.S. | 0.13 | 0.13 | 0.14 | 0.15 | 0.21 | 0.2 | 0.38 | 0.303 |
| P1 | 85.40 | 83.33 | 80.55 | 78.88 | 75.71 | 66.17 | 57.95 | 45.52 | 38.57 |
| P2 | 85.40 | 82.24 | 79.21 | 77.55 | 75 | 64.02 | 55.24 | 41.74 | 35.00 |
| P3 | 85.40 | 81.02 | 77.83 | 76.24 | 71.86 | 60.98 | 52.19 | 37.74 | 30.21 |
| S.Em ± | 0.09 | 0.06 | 0.06 | 0.06 | 0.07 | 0.09 | 0.09 | 0.17 | 0.187 |
| C.D.at 5% | N.S. | 0.16 | 0.16 | 0.18 | 0.19 | 0.25 | 0.24 | 0.46 | 0.372 |
| G1 | 89.33 | 86.67 | 83.94 | 82.39 | 78.39 | 70.44 | 63.61 | 52.22 | 44.11 |
| G2 | 84.33 | 80.39 | 78.39 | 75.50 | 72.00 | 61.61 | 54.33 | 38.56 | 31.78 |
| G3 | 81.33 | 77.28 | 74.11 | 73.89 | 69.28 | 55.28 | 41.06 | 26.56 | 21.17 |
| G4 | 88.33 | 85.22 | 81.83 | 80.33 | 77.00 | 67.72 | 60.94 | 48.78 | 41.83 |
| S.Em ± | 0.14 | 0.09 | 0.09 | 0.10 | 0.10 | 0.14 | 0.13 | 0.25 | 0.202 |
| C.D.at 5% | 0.39 | 0.25 | 0.25 | 0.27 | 0.29 | 0.38 | 0.37 | 0.71 | 0.568 |

C1: at ambient condition , C2: at 20°C; P1: Poly set bin, P2: Polythene bag, P3: Cloth bag ; G1: HHB 197, G2: A-LINE( ICMA97111), G3: B-LINE(ICMB 97111), G4: R-LINE( HBL-11)

**Table 2: Effect of storage conditions, packaging materials and genotypes on peroxidase activity of pearl millet seed during storage**

| Treatments | Storage period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 |
| C1 | 0.361 | 0.328 | 0.311 | 0.300 | 0.255 | 0.185 | 0.177 | 0.107 | 0.077 |
| C2 | 0.361 | 0.334 | 0.317 | 0.306 | 0.261 | 0.191 | 0.184 | 0.114 | 0.084 |
| S.Em± | 0.001 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| C.D.at 5% | N.S. | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| P1 | 0.361 | 0.334 | 0.319 | 0.306 | 0.260 | 0.190 | 0.183 | 0.113 | 0.083 |
| P2 | 0.361 | 0.332 | 0.314 | 0.303 | 0.258 | 0.188 | 0.180 | 0.110 | 0.080 |
| P3 | 0.361 | 0.329 | 0.312 | 0.300 | 0.255 | 0.185 | 0.177 | 0.107 | 0.077 |
| S.Em± | 0.001 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| C.D.at 5% | N.S. | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| G1 | 0.373 | 0.344 | 0.325 | 0.315 | 0.272 | 0.202 | 0.198 | 0.128 | 0.098 |
| G2 | 0.352 | 0.329 | 0.311 | 0.301 | 0.255 | 0.185 | 0.178 | 0.108 | 0.078 |
| G3 | 0.344 | 0.318 | 0.301 | 0.285 | 0.246 | 0.176 | 0.162 | 0.092 | 0.062 |
| G4 | 0.379 | 0.339 | 0.322 | 0.312 | 0.264 | 0.194 | 0.190 | 0.120 | 0.090 |
| S.Em± | 0.002 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| C.D.at 5% | 0.005 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |

*values less than 0.001

**Table 3: Effect of storage conditions, packaging materials and genotypes on catalase activity of pearl millet seed during storage**

| Treatments | Storage period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 |
| C1 | 0.272 | 0.259 | 0.248 | 0.235 | 0.224 | 0.212 | 0.195 | 0.179 | 0.155 |
| C2 | 0.271 | 0.266 | 0.256 | 0.242 | 0.230 | 0.218 | 0.201 | 0.187 | 0.163 |
| S.Em± | 0.001 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| C.D.at 5% | N.S. | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| P1 | 0.272 | 0.265 | 0.259 | 0.244 | 0.231 | 0.220 | 0.203 | 0.189 | 0.165 |
| P2 | 0.272 | 0.262 | 0.252 | 0.238 | 0.227 | 0.215 | 0.198 | 0.183 | 0.159 |
| P3 | 0.272 | 0.259 | 0.249 | 0.233 | 0.223 | 0.211 | 0.193 | 0.178 | 0.154 |
| S.Em± | 0.001 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| C.D.at 5% | N.S. | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| G1 | 0.290 | 0.280 | 0.274 | 0.265 | 0.254 | 0.245 | 0.230 | 0.213 | 0.158 |
| G2 | 0.267 | 0.258 | 0.246 | 0.228 | 0.218 | 0.207 | 0.183 | 0.179 | 0.132 |
| G3 | 0.256 | 0.245 | 0.236 | 0.226 | 0.205 | 0.195 | 0.171 | 0.152 | 0.130 |
| G4 | 0.283 | 0.274 | 0.263 | 0.249 | 0.243 | 0.238 | 0.216 | 0.203 | 0.142 |
| S.Em± | 0.001 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |
| C.D.at 5% | 0.001 | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |

*values less than 0.001

period. The seeds stored in cold storage conditions (C2) recorded significantly less FFA value (12.96%) compared to ambient condition (C1) (13.93%) at the end of 3 month of storage period. The same treatment (C2) recorded significantly lower FFA compared to C1 during the entire storage period.The FFA values were significantly lower in vapour proof packaging materials (P1 and P2) compared to vapour pervious containers P3. However, at the end of 24 months of storage P3 recorded highest FFA as compared to P1.(Table 4)

## DISCUSSION

Seed storage and retention of seed viability is always an important consideration in agricultural practice. The rate of seed deterioration is inûuenced by confounding environmental and biological factors. High temperature during storage enhances seed deterioration as does high moisture content (Mc Donald, 1999). Relative effects of seed moisture contentand temperature on longevity differwith species, and thestructural and biochemical composition of seeds. A completepattern of loss in viability couldbe understood on the basisof seed moisture and storage temperature (Ellis *et al*., 1982). Drastic fluctuations as well as prevailing high temperature and humidity under subtropical Indian conditions aggravate the loss of germination in stored pearl millet seeds.

Pearl millet hybrid (HHB-197) has retained higher germination above minimum seed certification standards up to 12 months as compared to B-line (ICMB 94555) that could not able to retain germination even up to 3 months. However, overall loss of germination was slower in cold storage conditions and within poly set bin containeras compared to ambient conditions and cloth bag. The difference in temperature and relative humidity in these two environments likely played a key role in the rate of seed deterioration and in the loss of seed viability (Barton, 1943 and Harrington, 1973).Seeds preserved at cold storage maintained higher seed quality because of lower respiration rate, lower metabolic activity and inactivation of enzymes required for retention of germination for longer period (Dhatt *et al.,* 2009). Alhamdan *et al.,* (2011) reported that storage temperature of 5ºC was low enough to slow down

**Table 4: Effect of storage conditions, packaging material and genotypes on free fatty acid (%) of pearl millet seed during storage**

| Treatments | Storage period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 |
| C1 | 5.11 | 13.93 | 17.61 | 21.56 | 24.69 | 28.28 | 30.31 | 33.45 | 35.21 |
| C2 | 5.11 | 12.96 | 15.66 | 19.45 | 22.90 | 26.30 | 28.43 | 31.46 | 33.73 |
| S.Em± | 0.003 | 0.016 | 0.013 | 0.011 | 0.011 | 0.011 | 0.012 | 0.012 | 0.022 |
| C.D.at 5% | N.S. | 0.045 | 0.036 | 0.030 | 0.030 | 0.032 | 0.035 | 0.033 | 0.063 |
| P1 | 5.11 | 12.94 | 15.61 | 19.92 | 23.27 | 26.76 | 28.84 | 31.93 | 34.07 |
| P2 | 5.11 | 13.40 | 16.41 | 20.31 | 23.63 | 27.04 | 29.15 | 32.28 | 34.51 |
| P3 | 5.11 | 14.00 | 17.49 | 21.28 | 24.49 | 28.06 | 30.13 | 33.15 | 34.84 |
| S.Em± | 0.003 | 0.020 | 0.016 | 0.013 | 0.013 | 0.014 | 0.015 | 0.014 | 0.027 |
| C.D.at 5% | N.S. | 0.055 | 0.044 | 0.037 | 0.037 | 0.039 | 0.043 | 0.040 | 0.077 |
| G1 | 4.72 | 10.31 | 14.00 | 18.32 | 21.84 | 25.37 | 27.56 | 31.04 | 33.26 |
| G2 | 5.34 | 14.71 | 17.88 | 20.69 | 23.96 | 27.44 | 29.50 | 33.08 | 35.08 |
| G3 | 5.44 | 15.71 | 18.51 | 22.14 | 25.26 | 28.16 | 30.18 | 33.28 | 35.92 |
| G4 | 4.82 | 11.57 | 15.11 | 19.78 | 23.15 | 27.43 | 29.51 | 31.25 | 33.21 |
| S.Em± | 0.004 | 0.030 | 0.024 | 0.020 | 0.020 | 0.021 | 0.023 | 0.022 | 0.042 |
| C.D.at 5% | 0.012 | 0.084 | 0.067 | 0.056 | 0.056 | 0.059 | 0.065 | 0.061 | 0.117 |

the biochemical and physiological processes which lead to seed deterioration. These results are in conformity with Mbofung *et al*. (2013) in soybean and Gao *et al*. (2015) in *jatropha curcas l*. seeds.

The quality parameters declined at a faster rate in cloth bag as compared to poly set bin container and polythene bag. This could be attributed to slower rate of deterioration in poly set bin container and polythene bag due to their impervious nature with maintenance of low moisture content. Whereas, in cloth bag seed moisture fluctuated with the change in ambient relative humidity (Kumar *et al.,* 2014). Increase in moisture content leads to a greater decrease in metabolic activity, increased respiration rate which in turn leads to more utilization of food reserves (Tiwari *et al.,* 2014). Such rapid loss of viability in cloth bag due to decrease in metabolic processes and the products of metabolism were sources for developing microflora was reported by Likhatchev *et al*. (1984).This is agreement with Rao *et al*. (2006) who concluded that drying of onion seed at low moisture contentfollowed by packaging in impervious containerand low temperature (25$^0$C) resulting in enhance the storability of onion seeds.Reducing quantity of oxygen around the seed might also decrease the initiation of free radicals (McDonald 1999) that can partially prohibited by the effect of containers. Agarwal *et al*. (1990) observed that germination loss during storage was due to oxidation of Glucose by EMP pathway as well as pentose phosphate pathway where container played a crucial role.The storage effects on seed relating to containers depend on internal microenvironment like temperature, seed moisture *etc.* that can induce the biochemical activity (Vasudevan *et al*., 2012; Tatipata, 2010). These results are in agreement with the findings of Mostarin *et al*. (2012) in bush bean, Azadi *and* Younesi (2013) in sorghum and Badiger *et al*. (2015) in cotton seed.

The reduction in percentage of germination was associated with increase in free fatty acid contents and greaterdecrease in peroxidase and catalase activity in seeds. In the present study, the level of various enzymes has been studied so as to find the cause of seed deterioration of pearl millet seed during storage and it was revealed that seeds stored under cold storage and packed within poly set bin container recorded significantly higher and slow declining trend of enzymatic activity with increment of storage period as compared to ambient condition and cloth bag. The decreased activity of peroxidase and catalase was dueto accumulation of H2O2 (Begum *et al.,* 2014). According Kibinza *et al*. (2006) the activities of detoxifying enzymes decreased rapidly, thus leading to ROS accumulation in sunflower seed. In addition, Bailly *et al*. (1996) observed reduced enzyme activities associated with loss of sunflower seed viability. Lins (2014) found greater catalase and peroxidase activity in sunflower seed that were stored in vacuum-sealed in a cold chamber after 8 to 12 months of storage.Similarly, Srivastava *et al*. (2015) reported highest level of catalase activity at the 3ºC and 19ºC temperature than normal room temperature it was due to lowest level of H2O2 at cold storage. Hydrogen peroxide is highly deleterious to the cell and its accumulation causes oxidation of cellular targets such as DNA, proteins, and lipids leading to mutagenesis and cell death. Removal of the $H_2O_2$ from the cell by catalase and peroxidase provides protection against oxidative damage to the cell (Deisseroth, and Dounce, 1970).

In this study, the determination of the free fatty acid (FFA) was very important to determine the degree of deterioration, as it evaluates the extent of hydrolysis. The free fatty acid content of the seed increased linearly over the storage period (Rani *et al.,* 2013; Sravanthi *et al.,* 2013). Fatty acids are formed by the hydrolytic reaction caused by the enzymatic secretions of micro-organisms on stored grain. At higher moisture level and temperature grain undergoes drastic changes due to the proliferation of moulds resulting in production of more free fatty acids (Berchmans and Hirata 2008 and Nithya *et al.,* 2011). The increase in FFA is the action of the enzymes lipases, peroxidases and phospholipases present in the grains or produced by the associated microflora that contributes to the breakdown of triglyceride ester bonds (Zadernowski *et al.,* 1999). According to Olanrewaju and Ogunbusola (2013) during storage partial hydrolysistakes place thus increasing free fatty acid content, the extent of this hydrolysis depends on the packaging material and storage condition. Sharon *et al*. (2015) reported that FFA accumulation is lower at 20ºC temperature in black gram as compared to 40ºC. Similar finding

of low accumulation of FFA at cold storage within moisture impervious containers was reported by Fotouo-M *et al*. (2016) in moringa seed andIskander *et al*. (2011) insunflower seed oil.

The present study revealed that, with the advance in the storage period, irrespective ofcontainers and conditions all the seed quality parameters were gradually decreased. This might be due to ageing phenomenon and due to the depletion of food reserves, increase in fat acidity, ultra structural changes,and reduced activity of enzymes and weakening of membrane integrity (Dhatt and Kumar, 2009).

In general, storage temperature and container influenced the physiological and biochemical quality of pearl millet seeds. Although inevitable and irreversible, the process of seed deterioration can be reduced by storage at appropriate temperatures and containers. At low temperatures under moisture impervious containers, the biochemical and physiological changes that cause seed deterioration are reduced, resulting in the maintenance of seed quality and therefore, the quality of seedlings.

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