Effect of accelerated ageing on viability and longevity of wheat (*Triticum aestivum*) seed

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ABSTRACT

The accelerated ageing test (AAT) has been successfully used to rank and determine germinability of seed lots in various kind and varieties. An experiment was conducted to determine the influence of artificial ageing on seed viability and longevity of wheat seed of 2 varieties, viz. GW 496 and Lok 1. Progressive ageing period resulted in lowered seed quality in both wheat varieties. Combined effect of varieties and ageing duration showed the significant effect on all the observed seed quality parameters and recorded significant variation in these characters during (2015-16 and 2016-17) and in pooled analysis. The fresh seeds (without ageing) of wheat variety Lok 1 recorded highest average pooled germination (97.50%), seedling vigour index I (2166), seedling vigour index II (20.32) as well as observed biochemical parameters at the end of 5 days of accelerated ageing. Progressive ageing duration showed negative effect on biochemical parameters of the 5 days aged seeds of wheat variety GW 496 recorded lowest average pooled protein content (9.78%), carbohydrate content (60.36%), α amylase assay (6.19 micromoles/mg/min) and higher electrical conductivity (28.60 μS/cm/g) due to fast deterioration at the end of artificial ageing. 

Key words: Accelerated ageing, α Amylase assay, Carbohydrate, Protein, Seed quality

Wheat (*Triticum aestivum* L.) is the most important stable food crop for more than one third of the world population and contributes more calories and proteins to the world diet than any other cereal crops. It is considered a good source of protein, minerals, B-group vitamins and dietary fibre although the environmental conditions can affect nutritional composition of wheat grains with its essential coating of bran, vitamins and minerals; it is an excellent health-building food.

The deterioration of the stored seed is a natural phenomenon and the seeds tend to lose viability even under ideal storage conditions. Degradation and inactivation of enzymes due to changes in their macromolecular structures is one of the most important hypotheses proposed regarding causes of ageing in seeds. Lipid auto-oxidation and increase in free fatty acid content during storage are the most often mentioned reason for accelerated damage of seed. Controlled atmosphere storage offers a pesticide residue free alternative to conventional storage and protection techniques. Seed in commercial sealed storage is not readily accessible for routine quality evaluation and thus methods of predicting the safe storage period from the outset of storage are desirable. A model for accelerated ageing at 30-60°C, moderate relative humidity levels was developed which indicated that the condition of the seeds was crucial in determining seed life-period and the accelerated ageing model can be used to accurate prediction of seed life.

Artificial ageing treatments take advantage of the fact that seed ageing process is determined by the seed moisture level and temperature. Manipulation of these factors, therefore, hastens movement of seed through the pattern of deterioration. The controlled deterioration and accelerated ageing (AA) tests have been successfully used to rank and predict relative field emergence potential of seed lots in various crops. The objective of artificial ageing is to study the sequence and relationship of process of deterioration over short period and its effect on seed viability, seedling vigour and biochemical process. Biochemical and physiological deterioration during seed ageing had been studied mostly under accelerated ageing conditions using high temperature and high seed water content (Jatoi *et al.* 2001, Hsu *et al.* 2003). For increasing awareness among farmers about the use of quality seeds, there is also a need to have some reliable parameters that evaluate the seed quality before it is sown in the field. Accelerated ageing has been recognized as a good predictor of the storability of seed lots by investigating the seed quality status of the naturally aged seed vis-a-vis the freshly harvested seeds. The study on post-harvest losses in food grains at different stages of their handling would help to assess the extent and magnitude of losses and identify...
the factors responsible for such losses which are important for scientists, technologists, policymakers, administrators and industrialists. Keeping these above problems in view the present investigation was conducted for evaluation of detrimental effect of artificial ageing on seed viability and longevity.

MATERIALS AND METHODS
The laboratory experiment was conducted at Anand Agricultural University, Gujarat with factorial CRD design with 3 repetitions. Seeds of 2 varieties, viz. $V_1$: GW 496 and $V_2$: Lok 1 were subjected to accelerated ageing for $D_1$: 0 day (fresh seed), $D_2$: 1 day, $D_3$: 2 day, $D_4$: 3 day, $D_5$: 4 day and $D_6$: 5 day. The seed quality parameters, viz. germination (%), seedling shoot length (cm), seedling root length (cm), seedling fresh weight (g), seedling dry weight (g), seedling vigour index I, seedling vigour index II and electrical conductivity (µS/cm/g) as well as biochemical changes, viz. protein (%), carbohydrate (%) and α-amylase assay (micromoles/mg/min) were recorded.
Accelerated ageing: The fresh seeds of wheat varieties, viz. GW 496 and Lok 1 were tied in a fine muslin cloth bag for evaluation of seed viability during the year 2015-16 and 2016-17.

Fig 2 Effect of varieties and ageing period on seedling root length (cm) and shoot length (cm) of wheat seed. $V_1$, GW 496; $V_2$, Lok 1; $D_1$, 0 day; $D_2$, 1 day; $D_3$, 2 day; $D_4$, 3 day; $D_5$, 4 day; $D_6$, 5 day.
in 3 repetitions. The tied seeds were placed in desiccators on a wire mesh. The lower part of the desiccators was filled with water. Common salt was added in the water for maintaining high humidity. The desiccators were covered with the lid and sealed with paraffin wax to make it air tight and then placed in hot air oven at 45°C for 0 (control), 1, 2, 3, 4 and 5 days. The desiccators were removed after specified period and the seeds were placed for cooling at room temperature. The aged seeds were then tested for normal germination test and other seed quality parameters.

**Electrical conductivity (μS/cm/g):** Electrical conductivity was measured following the standard procedure given by Agrawal and Dadlani (1992). Five gram of seeds in 3 replications were imbibed in 25 ml of deionised water at 20 ± 1°C for 24 h, the electrical conductance of the leachate was measured at room temperature and expressed as µS/cm/g.

**Estimation of biochemical parameters (%):** The protein and carbohydrate content was determined by Micro-Kjeldhal method (AOAC 1990) and phenol-sulphuric acid method (Dubois et al. 1956) respectively and α-amylase activity was assayed as per the procedure given by Bernfeld (1955).

**Statistical analysis method:** The results were illustrated as the means and standard deviation of 3 repetitions with pooled analysis. Statistical analyses were performed by two factor analysis (ANOVA), with Factorial CRD design as the means and standard deviation of 3 repetitions with pooled analysis respectively (11%), significantly higher protein content (11%), and biochemical parameters due to artificial ageing among experimental duration higher values of electrical conductivity during the same and biochemical parameters and faster deterioration with experimental duration in the seeds at different temperatures, depicting specific genotypic potentials. These differences revealed that the rate of deterioration varied with the varieties (Kapoor et al. 2010). The distinguishing behaviour of these varieties could be attributed to genotypic differences to sustain the ageing treatments. The differences in the seed growth potential have also been observed by Kalpana and Madhav Rao (1995) in pigeon pea. Merritt et al. (2003) reported that, the rate of seed deterioration can vary among various plant species. The negative relationship between seed size and germination index, root and shoot length was also observed by Kaya et al. (2008). Likewise, differential response of genotypes to withstand the ageing has been reported for naturally aged seeds of cotton by Goel et al. (2002). The experimental findings are in accordance with Anderson and Gupta (1986), Gidrol et al. (1998), Filho et al. (2001) in soybean and Kapoor et al. (2011) in rice.

**Effect of ageing duration on seed quality and biochemical parameters:** The seed quality of both varieties was significantly affected due to ageing duration and significant variation found during both the experimental years. Significantly, higher germination (96%), (97.67%) and (96.83%), seedling vigour index I (1910), (2125) and (2017), seedling vigour index II (18.73), (20.03) and (19.38), higher protein content (12.52%), (12.57%) and (12.55%), carbohydrate content (70.28%), (72.28%) and (71.28%), higher α-amylase assay (10.41 micromoles/mg/ min), (11.07 micromoles/mg/min) and (10.74 micromoles/ mg/min) and lowest electrical conductivity (20.22 µS/cm/g), (16.19 µS/cm/g) and (18.46 µS/cm/g) was recorded by the seeds without ageing treatment for the year 2015-16, 2016-17 and in pooled analysis respectively. At par values were recorded by 1 day aged seeds in most of the observed characters during both the years and pooled analysis. Increasing duration of ageing drastically decreased the seed quality. Lowest seed quality parameters were recorded by 5 days aged seeds.

**Combined effect of variety and ageing duration on seed quality and biochemical parameters:** Without aged seeds of Lok 1 variety recorded significantly higher germination (97.00%), (98.00%) and (97.50%), seedling vigour index I (2055) and (2276), seedling vigour index II (19.72), (20.91) and (20.32), higher protein content (12.53%), (12.64%) and (12.59%), carbohydrate content (70.85%) and (72.76%) and lowest electrical conductivity (19.68 µS/cm/g) and (15.75 µS/cm) for the year 2015-16, 2016-17 and in pooled analysis respectively. Whereas, the 5 days aged seeds of wheat variety GW 496 recorded significantly lower seed quality and biochemical parameters indicating the rapid deterioration of seeds due to artificial ageing. The α-amylase
Table 1  Effect of accelerated ageing on seed quality parameter

| Treatment | Germination (%) | Seedling vigour index I | Seedling vigour index II |
|-----------|-----------------|-------------------------|-------------------------|
|           | 2015-16        | 2016-17  | Pooled | 2015-16        | 2016-17 | Pooled | 2015-16        | 2016-17 | Pooled |
| Variety   | Variety        | Variety | Variety | Variety        | Variety | Variety | Variety        | Variety | Variety |
| V<sub>1</sub> | 95.00 | 97.00 | 96.00 | 97.33 | 98.00 | 97.67 | 96.17 | 97.50 | 96.83 |
| V<sub>2</sub> | 1764 | 2055 | 1910 | 1973 | 2276 | 2125 | 1869 | 2166 | 2017 |
| Mean      | 17.4 | 19.72 | 18.73 | 19.15 | 20.91 | 20.03 | 18.44 | 20.32 | 19.38 |
| V<sub>3</sub> | 91.33 | 93.33 | 92.33 | 96.33 | 96.67 | 96.50 | 93.83 | 95.00 | 94.42 |
| V<sub>4</sub> | 1511 | 1858 | 1684 | 1823 | 2044 | 1933 | 1667 | 1951 | 1809 |
| Mean      | 16.13 | 17.72 | 16.92 | 17.98 | 19.01 | 18.49 | 17.05 | 18.36 | 17.71 |
| V<sub>5</sub> | 90.67 | 92.67 | 91.67 | 93.33 | 95.33 | 94.33 | 92.00 | 94.00 | 93.00 |
| V<sub>6</sub> | 1407 | 1532 | 1469 | 1695 | 1925 | 1810 | 1551 | 1728 | 1640 |
| Mean      | 13.59 | 16.66 | 15.13 | 14.31 | 17.79 | 16.05 | 13.95 | 17.23 | 15.59 |
| D<sub>1</sub> | 88.00 | 90.00 | 89.00 | 90.00 | 92.00 | 91.00 | 89.00 | 91.00 | 90.00 |
| D<sub>2</sub> | 1092 | 1379 | 1235 | 1413 | 1685 | 1549 | 1253 | 1532 | 1392 |
| Mean      | 12.91 | 14.71 | 13.81 | 12.91 | 15.03 | 13.97 | 12.91 | 14.87 | 13.89 |
| D<sub>3</sub> | 72.67 | 73.00 | 72.83 | 82.00 | 83.33 | 82.67 | 77.33 | 78.17 | 77.75 |
| D<sub>4</sub> | 788 | 946 | 867 | 1044 | 1081 | 1062 | 916 | 1013 | 965 |
| Mean      | 6.79 | 10.46 | 8.63 | 7.92 | 11.93 | 9.92 | 7.36 | 11.19 | 9.27 |
| D<sub>5</sub> | 24.00 | 33.67 | 28.83 | 27.67 | 38.67 | 33.17 | 25.83 | 36.17 | 31.00 |
| D<sub>6</sub> | 229 | 387 | 308 | 313 | 491 | 402 | 271 | 439 | 355 |
| Mean      | 2.07 | 3.93 | 3.00 | 2.59 | 4.13 | 3.36 | 2.33 | 4.03 | 3.18 |

For comparing the means of S.E.M ± 5%  C.D.@ 5%  S.E.M ± 5%  C.D.@ 5%  S.E.M ± 5%  C.D.@ 5%  S.E.M ± 5%  C.D.@ 5%  S.E.M ± 5%  C.D.@ 5%  S.E.M ± 5%  C.D.@ 5%

V  0.57  1.67  0.53  1.56  0.39  1.11  11.21  32.73  10.27  29.98  7.60  21.61  0.15  0.43  0.14  0.42  0.10  0.29
D  0.99  2.90  0.93  2.70  1.51  5.47  19.42  56.69  17.79  51.92  44.42  161.52  0.25  0.74  0.25  0.72  0.28  1.03
V × D  1.40  4.10  1.31  3.82  0.96  2.73  27.46  80.17  25.16  73.43  31.48  NS  0.36  1.05  0.35  1.02  0.25  1.71
CV (%)  3.10  2.75  2.92  3.82  2.94  3.35  4.89  4.42  4.65

V<sub>1</sub>-GW 496; V<sub>2</sub>-Lok 1; D<sub>1</sub>, 0 day; D<sub>2</sub>, 1 day; D<sub>3</sub>, 2 day; D<sub>4</sub>, 3 day; D<sub>5</sub>, 4 day; D<sub>6</sub>, 5 day.
Table 2  Effect of accelerated ageing on protein content (%) and carbohydrate (%)

| Treatment | Protein content (%) | Carbohydrate (%) |
|-----------|---------------------|------------------|
|           | Variety 2015-16     | Variety 2016-17  | Pooled | Variety 2015-16 | Variety 2016-17 | Pooled |
|           | V₁ V₂ Mean         | V₁ V₂ Mean      |         | V₁ V₂ Mean      | V₁ V₂ Mean      |         |
| D₁        | 12.51 12.53 12.52  | 12.51 12.64 12.57|        | 69.72 70.85 70.28| 71.81 72.76 72.28|         |
| D₂        | 11.98 12.51 12.24  | 11.84 12.24 12.04|        | 67.45 69.89 68.67| 70.50 71.46 70.98|         |
| D₃        | 11.44 12.38 11.91  | 11.31 12.24 11.78|        | 65.80 68.06 66.93| 69.46 70.59 70.02|         |
| D₄        | 11.44 11.71 11.58  | 11.44 11.31 11.38|        | 65.36 67.19 66.28| 68.67 69.98 69.32|         |
| D₅        | 10.91 10.91 10.91  | 10.51 11.04 10.78|        | 63.80 62.84 63.32| 67.28 68.58 67.93|         |
| D₆        | 9.85 10.78 10.31   | 9.71 9.85 9.78   |        | 59.27 60.93 60.10| 61.45 66.06 63.75|         |
| Mean      | 11.36 11.80 11.58  | 11.22 11.55 11.39|        | 65.23 66.63 65.93| 68.19 69.90 69.05|         |

For comparing the means of:

| SEM ± | C.D. @ 5% | SEM ± | C.D. @ 5% | SEM ± | C.D. @ 5% | SEM ± | C.D. @ 5% | SEM ± | C.D. @ 5% |
|-------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|-----------|
| V     | 0.07      | 0.21  | 0.07      | 0.19  | 0.05      | 0.14  | 0.21      | 0.62  | 0.20      | 0.58  | 0.15      | 0.41  |
| D     | 0.12      | 0.36  | 0.12      | 0.34  | 0.09      | 0.24  | 0.37      | 1.07  | 0.34      | 1.00  | 0.47      | 1.71  |
| V × D | 0.18      | 0.51  | 0.16      | 0.48  | 0.12      | 0.34  | 0.52      | 1.52  | 0.49      | 1.41  | 0.65      | NS    |
| CV (%)| 2.63      | 2.48  | 2.55      | 1.37  | 1.22      | 1.29  |

V₁: GW 496; V₂: Lok 1; D₁: 0 day; D₂: 1 day; D₃: 2 day; D₄: 3 day; D₅: 4 day; D₆: 5 day.
| Treatment | α amylase (micromoles/mg/min) | Electrical conductivity (µS/cm/g) |
|-----------|-----------------------------|---------------------------------|
|           | 2015-16                      | 2016-17                         | Pooled | 2015-16 | 2016-17 | Pooled |
|           | Variety | Variety | Variety | Variety | Variety | Variety | Variety | Variety | Variety | Variety | Variety | Variety |
| V         | V₁      | V₂      | Mean    | V₁      | V₂      | Mean    | V₁      | V₂      | Mean    | V₁      | V₂      | Mean    | V₁      | V₂      | Mean    |
| D₁        | 10.28   | 10.53   | 10.41   | 11.02   | 11.11   | 11.07   | 10.65   | 10.82   | 10.74   | 20.76   | 19.68   | 20.22   | 17.61   | 15.78   | 16.69   |
| D₂        | 9.74    | 10.02   | 9.88    | 9.91    | 10.17   | 10.04   | 9.83    | 10.10   | 9.96    | 22.71   | 21.94   | 22.33   | 18.66   | 18.11   | 18.38   |
| D₃        | 8.91    | 9.23    | 9.07    | 9.12    | 9.28    | 9.20    | 9.02    | 9.26    | 9.14    | 24.31   | 23.10   | 23.71   | 20.85   | 18.67   | 19.76   |
| D₄        | 7.31    | 7.82    | 7.57    | 7.88    | 8.24    | 8.06    | 7.60    | 8.03    | 7.81    | 25.78   | 23.87   | 24.83   | 22.10   | 21.03   | 21.57   |
| D₅        | 6.84    | 7.39    | 7.12    | 7.18    | 7.61    | 7.39    | 7.01    | 7.50    | 7.25    | 27.21   | 25.62   | 26.41   | 24.47   | 21.67   | 23.07   |
| D₆        | 6.01    | 6.61    | 6.31    | 6.38    | 6.68    | 6.53    | 6.19    | 6.65    | 6.42    | 28.60   | 26.40   | 27.50   | 26.26   | 24.11   | 25.19   |
| Mean      | 8.18    | 8.60    | 8.39    | 8.58    | 8.85    | 8.71    | 8.38    | 8.73    | 8.55    | 24.90   | 23.43   | 24.16   | 21.66   | 19.89   | 20.78   |

For comparing the means of

- SEM ± C.D.@ 5%
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- SEM ± C.D.@ 5%
- SEM ± C.D.@ 5%

| V         | 0.09   | 0.25   | 0.08   | 0.24   | 0.06   | 0.17   | 0.08   | 0.24   | 0.10   | 0.28   | 0.06   | 0.18   |
| D         | 0.15   | 0.44   | 0.14   | 0.41   | 0.10   | 0.29   | 0.14   | 0.41   | 0.17   | 0.48   | 0.30   | 1.10   |
| V × D     | 0.21   | NS     | 0.20   | NS     | 0.16   | NS     | 0.20   | 0.58   | 0.23   | 0.68   | 0.28   | NS     |
| CV (%)    | 4.35   | 3.98   | 4.16   | 2.43   | 2.95   | 2.68   |

V₁: GW 496; V₂: Lok 1; D₁: 0 day; D₂: 1 day; D₃: 2 day; D₄: 3 day; D₅: 4 day; D₆: 5 day.
assay (micromoles/mg/min) was not found significantly different during both the years and in pooled analysis.

Accelerated ageing resulted in progressive loss of seed viability and vigour. Wheat seeds exhibited an initial germination around 98% which declined progressively with increasing period of artificial ageing. The possible reason of this reduction might be the lowered biochemical activities in seed. Iqbal et al. (2002) reported damaging effect of ageing on enzymes that are necessary to convert reserve food in the embryo to usable form and ultimately production of normal seedlings. Reduced seed quality mainly attributed to degradation of mitochondrial membrane leading to reduction in energy supply necessary for germination. The ageing treatment caused inability of seeds to maintain the integrity of membranes and this accounts for the reduced germinability of seeds. Important processes during seed germination, such as the establishment of respiration, ATP production and protein synthesis are often perturbed by seed ageing. The chromosomal aberrations and DNA degradation with ageing leads to impaired transcription causing incomplete or faulty enzyme synthesis which is essential for earlier stages of germination.

Increase in stress level, reduced metabolic activities and increased division activity may be the possible reasons for the reduction in the rootlets and shoot growth. The reduction in seed viability is mainly a function of interaction between temperature and seed moisture content. Mohammadi et al. (2011) recorded seedling growth reduction due to ageing might be the result of decline in weight of mobilized seed reserve and reduction in growth parameters of artificially aged wheat seeds. Reduced protein content with progressed ageing duration might be attributed to denaturation of protein, elevated superoxide dismutase activity and lack of ATP. Channabasana gowda et al. (2008) stated that, the free fatty acid content and free radicals are the main causes of seed ageing and deterioration. Lower carbohydrate content (%) might be associated with denaturation of bio molecules, accumulation of toxic substances and loss of membrane integrity. The increase in thermo-chemiluminescence (TCL) due to higher temperature resulted in activation of carbohydrate hydrolysis in aged seeds. The decrease in carbohydrate content and the increase in moisture content activate the amino carbonyl reaction. Similar findings were also reported by Ravikumar et al. (2002) in Dendrocalamus strictus, Veselovsky and Veselova (2012) in buck wheat and Lakshmi et al. (2014) in edible bamboo seeds. Advanced deterioration due to ageing resulted in accumulation of aldehyde compounds especially methyl jasmonate (MeJA) which is a potential inhibitor of α-amylase. Higher concentration of MeJA reduced the concentration of the enzyme protein and also resulted in inhibition of gibberellin biosynthesis (Norathchana et al. 2007). A gradual decline in amylase activity with progressive ageing duration was also reported by Agarwal and Kharlukhik (1987) in chickpea and Petruzelli and Taranto (1990) in wheat.

Progressive ageing duration showed negative effect on seed quality attributes and biochemical parameters. Significantly lower seed germination (%), seedling length (cm), vigour indices and biochemical parameters, viz. protein content (%), carbohydrate content (%), α-amylase assay (micromoles/mg/min) and higher electrical conductivity (µS/cm/g) was observed at the end of 5 days of accelerated aging.

REFERENCE

Agrawal P K and Dadlani M. 1992. Techniques in Seed Science and Technology, pp 114–20. SouthAsian Publishers, New Delhi.
Agrawal P K and Kharlukhik L. 1987. Enzyme activities in seed during storage. Indian Journal of Experimental Biology 25: 719–22.
Ananthi M, Selvaraju P and Srimathi P. 2015. Effect of seed treatment on seed and seedling quality characters in red gram. International Journal of Science and Nature 6(2): 205–08.
Anderson J D and Gupta K. 1986. Nucleotide alterations during seed deterioration. pp 47–63. Physiology of Seed Deterioration no. 11. (Eds) McDonald Jr. M B and Nelson C J. CSSA Special Publication, USA.
AOAC 1990. Association of Official Analytical Chemist. Official Method of Analysis, 15th (Edn). Washington DC.
Bernfeld P. 1955. Methods of assay α and β-amylase enzymes and starch degradation synthesis. Enzymology 1: 149–58.
Channabasana gowda, Biradar Patil N K, Ninganu B T, Patil B N, Hanje R and Awaknavar J S. 2008. Effect of botanical seed treatment on storability of wheat. Karnatakà Journal of Agricultural Science 21(3): 361–5.
Dubois M K, Gills J, Hamilton, Rebers P and Smith F. 1956. Colorimetric method for determination of sugars and related substances. Analytical Chemistry 28(3): 350–6.
Filho J, Novembre A D C and Chamma H M C P. 2001. Accelerated ageing and controlled deterioration seed vigour tests for soybean. Scientia Agricola 58: 421–6.
Gidrol X, Noubhani A, Mocquot B, Fournier A and Pradal A. 1998. Effect of accelerated ageing on protein synthesis in two legume seeds. Journal of Plant Biochemistry and Physiology 26: 281–8.
Goel A, Goel A K, Sheoran I S. 2002. Changes in oxidative stress enzymes during artificial aging in cotton (Gossypium hirsutum L.) seeds. Journal of Plant Physiology 160: 1093–1100.
Hsu C C, Chen C L, Chen J J and Sung J M. 2003. Accelerated ageing-enhanced lipid peroxidation in bitter gourd seeds and effects of pruning and hot water soakings. Scientia Horticulture 98: 201–12.
Iqbal N, Shahzad A, Basra M and Khalil U R. 2002. Evaluation of vigor and oil quality in cotton seed during accelerated aging. International Journal of Agriculture and Biology 4(3): 318–22.
Jatoi S A, Afzal M, Nasim S and Anwar R. 2001. Seed deterioration study in pea using accelerated ageing techniques. Pakistan Journal of Biological Sciences 4(12): 1490–4.
Kalpana R and Madhav Rao K V. 1995. On the ageing mechanism in pigeon pea [Cajanus cajan (L.) Mill sp. ] seeds. Seed Science and Technology 23: 1–9.
Kapoor N, Arya A, Siddiqui M A, Kumar H and Amir A. 2011. Physiological and biochemical changes during seed deterioration in aged seeds of rice. American Journal of Plant Physiology 6(1): 28–35.
Kapoor N, Arya A, Siddiqui M A, Amir A and Kumar H. 2010. Seed deterioration in chickpea under accelerated ageing. Asian Journal of Plant Sciences 9(3): 158–62.
Kaya M, Kaya G, Kaya M D, Atak M, Saglam S, Khawar K M and Ciftci C Y. 2008. Interaction between seed size and NaCl on germination and early seedling growth of some Turkish
cultivars of chickpea (*Cicer arietinum* L.). *Journal of Zhejiang University Science* 9: 371–7.

Lakshmi C J, Seethalakshmi K K, Chandrasekhara P K and Raveendran V P. 2014. Effect of accelerated ageing on seed viability and biochemical components of the edible Bamboo (*Dendrocalamus brandisii* (Munro) Kurz)). *Research Journal of Recent Sciences* 3: 15--18.

Lucia C, Antonella C, Luciano G, Silvia G, Franco S and Maurizio Z. 2004. Antioxidants, free radicals, storage proteins, puroindolines, and proteolytic activities in Bread Wheat (*Triticum aestivum*) seeds during accelerated ageing. *Journal of Agricultural and Food Chemistry* 52(13): 4274–81.

Merritt D J, Senaratna T, Touchell D H, Dixon K W and Sivasithamparam K. 2003. Seed ageing of four Western Australian species in relation to storage environment and seed antioxidant activity. *Seed Science Research* 13: 155–65.

Mohammadi H A, Soltani H, Sadeghipour R and Zeinali E. 2011. Effect of seed ageing on subsequent seed reserve utilization and seedling growth in soybean. *International Journal of Plant Production* 5(1): 1735–43.

Norastehnia R H, Sajedi M and Nojavan-Asghari. 2007. Inhibitory effects of methyl jasmonate on seed germination in maize (*Zea mays* L.). Effect on α-amylase activity and ethylene production. *General and Applied Plant Physiology* 33(1-2): 13–23.

Petruzzelli L and Taranto G. 1990. Amylase activity and loss of viability in wheat. *Annals of botany* 66(4): 375–80.

Ravikumar R, Ananthakrishnan G, Girija S and Ganapathi A. 2002. Seed viability and biochemical changes associated with accelerated ageing in *Dendrocalamus strictus* seeds. *Biologia Plantarum* 45(1): 152–6.

Veselovsky V A and Veselova T V. 2012. Lipid peroxidation, carbohydrate hydrolysis, and amadori-maillard reaction at early stages of dry seed aging. *Russian Journal of Plant Physiology* 59(6): 763–70.