International Journal of Chemical Studies

**P-ISSN: 2349–8528**
**E-ISSN: 2321–4902**
IJCS 2017; 5(4): 1141-1146

Received: 25-05-2017
Accepted: 26-06-2017

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# Deterioration in sesame (*Sesamum indicum* L.) seeds under natural and accelerated ageing

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**Abstract**
Laboratory studies were conducted at the Department of Seed Science and Technology, TNAU, Coimbatore to evaluate the deterioration in sesame seed under natural and accelerated ageing. Freshly harvested seeds of sesame (VRI 2) were obtained from Soil and Water Management Research Institute (Kattuthotam) were kept under accelerated ageing condition by exposing the seeds to $40^{0}$C temperature and 100 per cent relative humidity. Simultaneously, the seeds were packed in cloth bag and kept under ambient condition for natural ageing for 10 months in order to assess the physical, physiological and biochemical changes taking place during storage. However, reduction of Germination percent was coincided with the reduction Of seed quality parameters. As a conclusion, three days of accelerated ageing was equivalent to ten Months of natural storage at the time maintained the Germination above Indian Minimum Seed Certification Standards.

**Keywords**: sesame seeds, seed storage, natural and accelerated ageing

## Introduction

Sesame (*Sesamum indicum L.*) is an important oil seed crop and good source of edible oil which is often considered as the "queen" of vegetable oils. The seed contains 50 - 60 per cent oil with high variability between varieties. In India, it is cultivated over an area of 1.78 million hectares, with a production of 0.72 million tonnes and the productivity is 426 kg / ha. In Tamil Nadu, it is cultivated over an area of 0.57 lakh hectares with a production of 0.34 lakh tones and the productivity is 596 kg / ha (Source: www.indiastat.com, 2012-2013 and 2013- 2014).

Quality seed is the key input for realizing potential productivity by increasing the yield upto 15-20 per cent. Seeds of oil seed crops are vulnerable to deterioration and considered as poor storer compared to pulses and cereals under ambient storage. Harrington (1972) [14] suggested that within the normal range of moisture and temperature for stored seeds, each one per cent reduction in seed moisture or each $10^{0}$F reduction in temperature doubles the storage life of the seeds. Using such "rules of thumb" and assuming that the effects are additive, it can be assumed that seed vigour would deteriorate 500 times more rapidly at $40^{0}$C and 18 per cent moisture content than it would have been at $20^{0}$C and 8 per cent moisture. Thus, accelerated ageing has been developed as a self-ageing technique. The accelerated ageing test has been used to estimate seed vigour and deterioration during storage (Delouche and Baskin, 1973) [8]. During seed ageing, physiological changes *viz*., delayed germination, reduced seedling growth, dry weight, vigour and biochemical changes *viz*., reduced activity of enzymes like catalase, peroxidase, superoxide dismutase and α-amylase were the notable events which reduce the quality of seeds (Raja, 2003 and Ramanadane, 2003) [24, 25]. Several researchers have studied the pattern of seed deterioration in relation to various physiological, biochemical and anatomical changes under ageing. The study on physical, physiological, biochemical and histological changes will be helpful for better understanding the process of deterioration under both accelerated and natural ageing conditions.

## Materials and methods

Genetically pure and freshly harvested seeds sesame (VRI 2) were obtained from Soil and Water Management Research Institute (Kattuthotam) were kept under accelerated ageing condition by exposing the seeds to $40^{0}$C temperature and 100 per cent relative humidity. Simultaneously, the seeds were packed in cloth bag and kept under ambient condition for natural ageing for 10 months. The experiment was designed in Completely Randomized

Design (CRD) with four replications. For accelerated ageing, the samples were drawn at daily interval and for natural ageing, samples were drawn at monthly intervals and analyzed for physical, physiological, biochemical and histological observations were recorded *viz.*, seed moisture content, germination per cent, root length, shoot length, dry matter production, vigour index, electrical conductivity, α-amylase, catalase, peroxidase activity, oil content and free amino acid were made. The storability period was calculated based on the time taken to reach the germination as per the IMSCS. In order to assess the pattern of deterioration, the accelerated ageing was continued when seed reaches the germination of about 50 per cent. The data collected from the various experiments were analysed statistically adopting the procedure described by Rangaswamy (2002) [26], wherever necessary, the per cent values were transformed to angular (arcsine) values before analysis. The critical differences (CD) were calculated at 5 per cent probability level. The data were tested for statistical significance. If the F test expressed is non-significant of variant it was indicated by the letter NS.

**Results and Discussion**

From the present investigation, control seeds recorded 5.0 per cent moisture content and it was found to be increased and reached 11.8 per cent on 9$^{th}$ day of accelerated ageing. In case of natural ageing, the moisture content increased and attained 9.2 per cent in 10 months stored seeds. The increase in moisture content due to the increase in relative humidity of the storage environment. This result was in agreement with Bharathi (1991) [5] in maize and Sawant *et al*. (2012) [29] in wheat which showed increasing trend of moisture content with respect to the storage period.

Deterioration in seed quality was associated with decrease in seedling quality parameters become evident with advancement of time in storage under both accelerated and natural ageing. With respect to sesame, the initial germination was recorded as 91 per cent and reached 81 per cent on 3$^{rd}$ day of accelerated ageing. After 9 days of accelerated ageing it was declined and showed as 44 per cent. The germination of 81 per cent was recorded which is above IMSCS (80 per cent) upto 10 months of storage. Ghassemi *et al.* (2010) [11] reported that decrease in germination per cent and other indices can be related to physiological and biochemical changes during seed ageing. Decrease in plasma membrane sustainability, changes in molecular structure of nucleic acids, decrease in enzyme activities and increase in time for germination were happened while ageing (Justice and Bass, 1979). The decline in germination over the period of storage might be due to depletion of food reserves coupled with decline in synthetic activity as reported by Pal and Basu (1988) [18] and Ravichandran (1994) [27] in paddy.

**Control (fresh seeds)** **9 days accelerated ageing** **10 months natural ageing**

**Plate 1:** Physiological quality of control (fresh seeds), accelerated aged and natural aged seeds of sesame

The accelerated and natural ageing resulted significant reduction of seedling length. The root and shoot length were reduced from 0 to 9 days [(15.1cm to 5.6 cm) and (6.6 cm to 3.5 cm)]. At the same time, a decline was also observed in root length (15.1 cm to 9.6 cm) and shoot length (6.6 cm to 4.1cm) from 0 to 10 months of storage under natural ageing. Similar results of decrease in seedling length was also reported by Roy *et al.* (1994) [28] in chickpea, Kalpana and Madhav Rao (1995) [15] in pigeon pea, Preze and Arguello (1995) [22] in peanuts and Basra *et al*. (2003) [3] in cotton.

**Table 1:** Physical and physiological changes due to accelerated ageing of sesame seeds

| Accelerated ageing (days) | Moisture content (%) | Germination (%) | Root length (cm) | Shoot length (cm) | Dry matter production (g 10 seedlings$^{-1}$) | Vigour index |
|---|---|---|---|---|---|---|
| 0 (control) | 5.0 | 91 (72.54) | 15.1 | 6.6 | 0.025 | 1975 |
| 1 | 5.5 | 88 (69.73) | 14.9 | 6.3 | 0.024 | 1866 |
| 2 | 5.7 | 85 (67.21) | 13.7 | 5.4 | 0.023 | 1624 |
| 3 | 6.0 | 81 (64.15) | 11.9 | 4.6 | 0.022 | 1336 |
| 4 | 6.1 | 75 (60.00) | 10.6 | 4.5 | 0.021 | 1132 |
| 5 | 8.2 | 68 (55.55) | 9.8 | 4.4 | 0.019 | 966 |
| 6 | 8.7 | 67 (54.94) | 8.9 | 4.2 | 0.018 | 878 |
| 7 | 10.0 | 64 (53.13) | 7.8 | 4.1 | 0.016 | 762 |
| 8 | 10.7 | 59 (50.18) | 6.9 | 3.9 | 0.014 | 637 |
| 9 | 11.8 | 44 (41.55) | 5.6 | 3.5 | 0.012 | 400 |
| Mean | 7.8 | 72 (58.05) | 10.5 | 4.8 | 0.019 | 1158 |
| SEd | 0.15 | 1.07 | 0.20 | 0.10 | 0.0002 | 17.19 |
| CD (P=0.05) | 0.31 | 2.18 | 0.41 | 0.21 | 0.0005 | 35.12 |

(Figures in parenthesis indicate arcsine values)

When subjecting the sesame seeds to accelerated ageing, dry matter production and vigour index were drastically reduced from 0 to 9 days from 0.025 g 10 seedlings$^{-1}$ to 0.012 g 10 seedlings$^{-1}$ and 1975 to 400, respectively. A gradual decline from 0 to 10 months was observed with dry matter production (0.014 g 10 seedlings$^{-1}$) and vigour index (1109). Deshpande and Mahadevappa (1994) [10] observed decrease in germinability and seedling vigour as the accelerated and natural ageing prolonged in rice. Verma *et al.* (1999) [34] also found that seedling vigour decreased with increase in age of seeds in rapeseed and mustard. Atici *et al.* (2007) [1] reported that aged seeds showed decreased vigour and produced weak seedlings that are unable to survive once reintroduced into a habitat.

**Table 2:** Physical and physiological changes due to natural ageing of sesame seeds

| Natural ageing (months) | Moisture content (%) | Germination (%) | Root length (cm) | Shoot length (cm) | Dry matter production (g 10 seedlings$^{-1}$) | Vigour index |
|---|---|---|---|---|---|---|
| 0 (Control) | 5.0 | 91 (72.54) | 15.1 | 6.6 | 0.025 | 1975 |
| 1 | 5.3 | 90 (71.56) | 14.7 | 6.5 | 0.024 | 1908 |
| 2 | 5.7 | 90 (71.56) | 13.9 | 5.8 | 0.023 | 1773 |
| 3 | 6.1 | 90 (71.56) | 13.4 | 5.6 | 0.022 | 1710 |
| 4 | 6.8 | 89 (70.63) | 13.1 | 5.3 | 0.022 | 1638 |
| 5 | 7.1 | 88 (69.73) | 12.7 | 4.9 | 0.021 | 1549 |
| 6 | 7.2 | 86 (68.02) | 11.7 | 4.7 | 0.019 | 1410 |
| 7 | 7.7 | 84 (66.42) | 11.1 | 4.5 | 0.019 | 1310 |
| 8 | 8.2 | 83 (65.65) | 10.5 | 4.4 | 0.017 | 1237 |
| 9 | 8.7 | 82 (64.89) | 10.2 | 4.2 | 0.016 | 1181 |
| 10 | 9.2 | 81 (64.15) | 9.6 | 4.1 | 0.014 | 1109 |
| Mean | 7.0 | 87 (68.86) | 12.4 | 5.1 | 0.020 | 1527 |
| SEd | 0.12 | 1.29 | 0.18 | 0.10 | 0.0003 | 20.38 |
| CD (P=0.05) | 0.25 | 2.62 | 0.38 | 0.21 | 0.0007 | 41.48 |

(Figures in parenthesis indicate arcsine values)

The electrical conductivity of seed leachate increased with increase in period of accelerated and natural ageing. The electrical conductivity was increased from 20.8 µS cm$^{-1}$ to 30.1 µS cm$^{-1}$ and eventually it reached 61.7 µS cm$^{-1}$ on 10$^{th}$ day of accelerated ageing. Simultaneously, in natural ageing the electrical conductivity on 10$^{th}$ month was 35.4 µS cm$^{-1}$. Gupta *et al.* (2005) [13] reported that electrical conductivity increased after the seeds were subjected to accelerated ageing because of membrane deterioration and metabolic changes in the seed. Loss of seed vigour and viability is associated with deterioration of membrane properties (Priestley, 1986) [23].

**Table 3:** Biochemical changes due to accelerated ageing of sesame seeds

| Accelerated ageing (days) | Electrical conductivity (µS cm$^{-1}$) | α-amylase (mg maltose min$^{-1}$) | Catalase (m mol $H_2O_2$ reduced min$^{-1}$ g$^{-1}$ seed) | Peroxidase (m mol tetra guaiacol formed min$^{-1}$ g$^{-1}$ seed) | Oil content (%) | Free fatty acid (%) |
|---|---|---|---|---|---|---|
| 0 (control) | 20.8 | 19.34 | 0.549 | 0.497 | 47.3 | 0.33 |
| 1 | 22.3 | 19.29 | 0.469 | 0.475 | 45.3 | 0.35 |
| 2 | 24.9 | 18.94 | 0.350 | 0.427 | 44.2 | 0.38 |
| 3 | 30.1 | 16.21 | 0.340 | 0.401 | 40.5 | 0.42 |
| 4 | 35.6 | 15.66 | 0.325 | 0.391 | 38.6 | 0.44 |
| 5 | 40.4 | 14.02 | 0.289 | 0.378 | 36.3 | 0.49 |
| 6 | 43.7 | 11.83 | 0.274 | 0.371 | 32.2 | 0.52 |
| 7 | 48.8 | 10.44 | 0.263 | 0.259 | 29.4 | 0.56 |
| 8 | 55.5 | 9.89 | 0.253 | 0.239 | 24.8 | 0.61 |
| 9 | 61.7 | 8.56 | 0.242 | 0.219 | 21.7 | 0.64 |
| Mean | 38.4 | 14.42 | 0.335 | 0.366 | 36.0 | 0.47 |
| SEd | 0.51 | 0.13 | 0.004 | 0.001 | 0.40 | 0.006 |
| CD (P=0.05) | 1.04 | 0.27 | 0.009 | 0.003 | 0.81 | 0.013 |

The α-amylase activity was decreased with increasing period of storage both under accelerated and natural ageing. It was reduced to 8.56 mg maltose min$^{-1}$ from 19.34 mg maltose min$^{-1}$ over the period of 9 days whereas in natural ageing it was 16.29 mg maltose min$^{-1}$ by 10$^{th}$ month of storage. It might be due to the accumulation of aldehyde compounds especially methyl jasmonte which act as potential inhibitor of α-amylase by arresting the biosynthesis of gibbrellic acid which stimulates α-amylase synthesis and its secretion from aleurone layers in cereals (Norastehnia *et al*. 2007).

The catalase activity of sesame seeds was initially measured as 0.549 m mol $H_2O_2$ reduced min$^{-1}$ g$^{-1}$ seed and reduced to 0.340 m mol $H_2O_2$ reduced min$^{-1}$ g$^{-1}$ seed on 3$^{rd}$ day of accelerated ageing and finally it was reached 0.242 m mol $H_2O_2$ reduced min$^{-1}$ g$^{-1}$ seed on 9$^{th}$ day of accelerated ageing. In case of natural ageing, declining trend was observed and the value was 0.397 m mol $H_2O_2$ reduced min$^{-1}$ g$^{-1}$ seed during 10$^{th}$ month of natural ageing. The peroxidase activity followed the similar trend of results as that of catalase activity under both accelerated and natural ageing. Gidrol *et al.* (1989) reported that the decreased activity of catalase and peroxidase was due to accumulation of $H_2O_2$ and this accumulation of hydrogen peroxide itself was detrimental to seeds. Cakmak *et al.* (2009) observed a decrease in the activities of catalase and peroxidase enzymes, but an increase in activity of superoxide dismutase in the old dry seeds of legumes during storage for

40 years. Similar results were reported by Bhanuprakash *et al.* (2010) in bell pepper, Demirkaya *et al.* (2010) in onion seeds, Scialabba *et al.* (2002) in radish and Pallavi *et al.* (2003) sunflower.

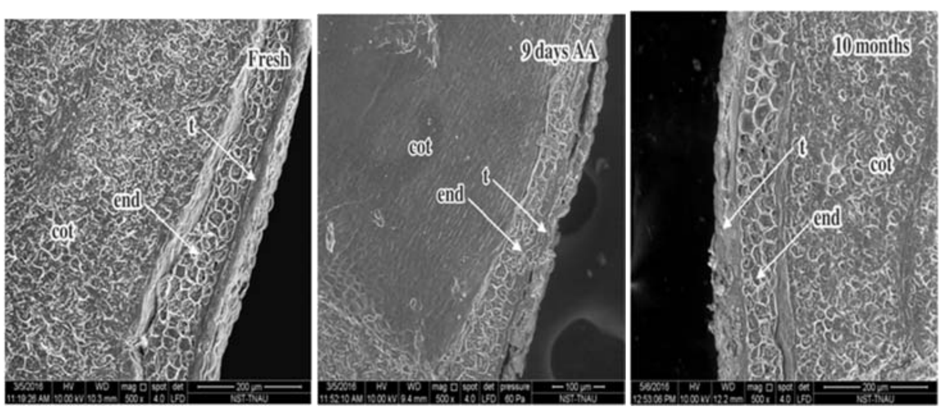
**Table 4:** Biochemical changes due to natural ageing of sesame seeds

| Natural ageing (months) | Electrical conductivity (µS cm$^{-1}$) | α-amylase (mg maltose min$^{-1}$) | Catalase (m mol $H_2O_2$ reduced min$^{-1}$ g$^{-1}$ seed) | Peroxidase (m mol tetraguaiacol formed min$^{-1}$ g$^{-1}$ seed) | Oil content (%) | Free fatty acid (%) |
|---|---|---|---|---|---|---|
| 0 (control) | 20.8 | 19.34 | 0.549 | 0.497 | 47.3 | 0.33 |
| 2 | 23.4 | 19.06 | 0.526 | 0.478 | 45.1 | 0.34 |
| 4 | 24.8 | 18.99 | 0.498 | 0.466 | 44.4 | 0.36 |
| 6 | 31.3 | 17.46 | 0.438 | 0.459 | 42.4 | 0.38 |
| 8 | 33.5 | 16.54 | 0.411 | 0.421 | 41.2 | 0.40 |
| 10 | 35.4 | 16.29 | 0.397 | 0.411 | 40.7 | 0.42 |
| Mean | 28.0 | 17.94 | 0.470 | 0.455 | 43.5 | 0.37 |
| SEd | 0.47 | 0.29 | 0.007 | 0.004 | 0.38 | 0.007 |
| CD (P=0.05) | 0.96 | 0.62 | 0.016 | 0.008 | 0.81 | 0.016 |

At initially, the oil content was estimated as 47.3 per cent. Thereafter, it was started to reduce and reached to 40.5 per cent on 3rd day of accelerated ageing correspondingly the value during 10th month of storage under natural ageing was 40.7 per cent. Further, it was reduced to 21.7 per cent on 9th day of accelerated ageing. An increasing trend was observed in case of free fatty acid. The free fatty acid content was same (0.42 per cent) in 3 days accelerated of aged seeds and 10 months stored seeds under natural ageing. It was increased from 3rd day onwards and observed as 0.64 per cent on 9th day of accelerated ageing. The results agreed with the findings of Narayanaswamy (2003) in groundnut, Simic *et al*. (2007) in sunflower, soybean and maize and Paramasivam and Balamurugan (2007) in groundnut. The decrease in oil content with increased free fatty acid content may be due to the hydrolysis of storage lipids, coalescence of lipid bodies, subsequent formation of free radical that lead to lipid peroxidation (Balamurugan, 1993 and Paramasivam, 2005). The results of Sharma (1977) clearly pointed out the declining trends in total oil content and seed germination during storage of oilseed species.

The histological changes have been studied using Scanning Electron Microscope (SEM) for control, accelerated aged and naturally aged seeds. In sesame, the cell arrangement

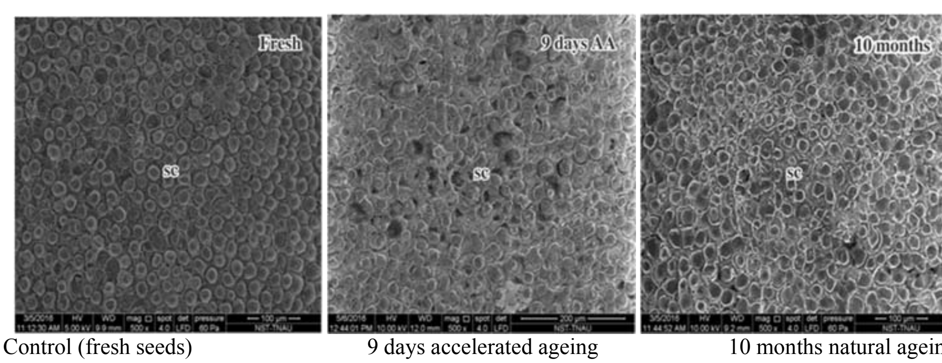
Pattern of seed coat surface, endosperm and cotyledon were found to be clear and intact in fresh seeds. Disintegration of these parts were observed in accelerated and naturally aged and disintegration was very deeper when period of storage was prolonged (9 days of accelerated ageing).




Control (fresh seeds) 9 days accelerated ageing 10 months natural ageing

t - testa, end - endosperm, cot - cotyledon

**Plate 3:** Longitudinal section of sesame seed viewed under Scanning Electron Microscope (SEM) - testa, endosperm and cotyledon




Control (fresh seeds) 9 days accelerated ageing 10 months natural ageing

sc – seed coat texture

**Plate 4:** Sesame seed viewed under Scanning Electron Microscope (SEM) - seed coat surface texture

The present results thus support the 'classical' conception of Briggs (1978) and Varner and Ho (1976) concerning the role of the aleurone layer in the production of α-amylase in barley. This result was also in hormony with the findings of Ramanadane and Ponnuswamy (2004) in rice.

## Conclusion

It is summarized that, three days of accelerated ageing was equivalent to ten Months of natural storage at the time maintained the Germination above Indian Minimum Seed Certification Standards.

## References


1. Atici O, Agar G, Battal P. Influence of long term storage on plant growth substance levels, germination and seedling growth in legume seeds stored for 37 years. Indian J. Plant Physiol. 2007; 12:1-5.
2. Balamurugan P. Seed production techniques in BSH 1 and quality assessment in parental lines and hybrid of sunflower (*Helianthus annuus* L.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 1993.
3. Basra SMA, Ahmad N, Khan MM, Iqbal N and Cheema MA. Assessment of cotton seed deterioration during accelerated ageing. Seed Sci. & Technol. 2003; 31:531-540.
4. Bhanuprakash K, Yogeesha HS and Arun MN. Physiological and biochemical changes in relation to seed quality in ageing bell pepper seed. Indian J. Agri. Sci. 2010; 80(9):777-780.
5. Bharathi A. Irrigation management and nitrogen fertilization on yield, quality and storability of Maize (*Zea mays*). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 1991.
6. Briggs DE. Barley. Chmann & Hall, London, 1978.
7. Cakmak T, Atici O and Agar G. The natural ageing-related biochemical changes in the seeds of two legume varieties stored for 40 years. Plant Soil Sci., 2009; 60 (4): 353-360.
8. Delouche JC, Baskin CC. Accelerated ageing techniques for predicting the relative storability seed lots. Seed Sci. & Technol. 1973; 1(2):427-252.
9. Demirkaya M, Dietz KJ, Sivritepe HO. Changes in Antioxidant Enzymes during Ageing of Onion Seeds. Not. Bot. Hort. Agrobot. Cluj. 2010; 38(1):49-52.
10. Deshpande VK, Mahadevappa M. Effect of provenance and seed treatments on seed quality and storability of rice genotypes. Seed Tech. News. 1994; 24(4):36.
11. Ghassemi GK, Khomari S, Dalili B, Hosseinzadeh-Mahootchy B, Chadordooz-Jedi A. Effect of seed ageing on field performance of winter oil seed rape. J. Food Agric. Envir. 2010; 8(1):175-178.
12. Gidrol X, Serghini H, Noubhani A, Mocoquot B, Mazliak P. Biochemical changes induced by accelerated ageing in sunflower seeds. I. Lipid peroxidation and membrane damage. Physiol. Plant. 1989; 76:591- 597.
13. Gupta V, Arya L, Pandy C and Kak A. Effect of accelerated ageing on seed vigour in pearl millet (*Pennisetum glaucum*) hybrids and their parents. Indian J. Agric. Sci. 2005; 75:346-347.
14. Harrington JF, Seed storage, longevity. In: Seed Biology, TT. Kozlowski (Ed.), Academic Press, New York and London. 1972, 145-245.
15. Kalpana R, Madhav Rao KV. On the ageing mechanism in pigeonpea (*Cajanus cajan* L. Mill sp.) seeds. Seeds Sci. & Technol. 1995; 23:1-9.
16. Narayanaswamy S. Effect of packaging and location of storage on groundnut seed. In: Proc. National Workshop on Groundnut Seed Technology, University of Agricultural Sciences Campus, Raichur, India. 2003, 164-167.
17. Norastehnia RH, Sajedi M, Nojavan-Asghari d. Inhibitory effects of methyl jasmonate on seed germination in maize (*Zea mays* L.): Effect on alpha-amylase activity and ethylene production. Gen. Appl. Plant Physiol. 2007; 33(1-2):13-23.
18. Pal P, Basu RN. Treatment of rice seed with iodine and chloride for the maintenance of vigour, viability and productivity. Indian agriculturist. 1988; 32(1):71-76.
19. Pallavi M, Kumar SS, Dangi KS, Reddy AV. Effect of seed ageing on physiological, biochemical and yield attributes in sunflower cv. Morden. Seed Res. 2003; 31(2):161-168.
20. Paramasivam V, Balamurugan P. Biochemical and Physiological changes in rainfed and irrigated groundnut seeds during storage. Seed Res. 2007; 34:73-79.
21. Paramasivam V. Seed and nutrient management in groundnut (*Arachis hypogea* L.) M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 2005.
22. Preze MA, Arguello JA. Deterioration in peanuts (*Arachis hypogeal* L. cv Florman) seeds under natural and accelerated ageing. Seed Sci. & Technol. 1995; 23:39-445.
23. Priestley DA. Loss of seed viability in storage. In: Seed Ageing, Cornell University press, Bhaca, London. 1986, 39-75.
24. Raja K. Investigation on nursery management techniques for quality seed production of rice hybrid CORH 2. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 2003.
25. Ramanadane T. Studies on ecological influence and post-harvest seed management techniques on seed quality in hybrid rice (*Oryza sativa* L.). Ph.D. Thesis, 2003; Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.
26. Rangaswamy R. A text book of agricultural statistics. New Age International Pvt., Ltd. New Delhi, 2002.
27. Ravichandran R. Studies on certain aspects of post-harvest factors affecting quality of paddy (1) Compaction effect of stacking, 2) Impact of transportation and handling and 3) Provenance influence on storability. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 1994.
28. Roy A, Paul SR, Sarma RN. Effect of seed size on germination and seed vigour in chickpea (*Cicer arietinum* L.). Ann. Agric. Res. 1994; 15:383-384.
29. Sawant AA, Patil SC, Kalse SB, Thakor NJ. Effect of temperature, relative humidity and moisture content on germination percentage of wheat stored in different storage structures. Agricultural Engineering International: CIGR Journal. 2012; 4(2):110-118.
30. Scialabba A, Bellani LM, Dell'aquila A. Effects of ageing on peroxidase activity and localization in radish (*Raphanus sativus* L.) seeds. European J. Histochemistry. 2002; 46(4):351-358.
31. Sharma KD. Biochemical changes in stored oil seeds. Indian J. Agri. Res. 1977; 11(3):137- 141.

32. Simic B, Ruza Popovic, Aleksandra Sudaric, Vlatka Rozman, Irma Kalinovic, Jasenka Cosic. Influence of storage condition on seed oil content of maize, soybean and sunflower. Agriculture Conspectus Scientifics. 2007; 72(3):211-213.
33. Varner JE, Ho THD. Hormones. In. J. Bonner, J.E. Varner, eds, Plant Biochemistry. Academic Press, New York. 1976, 714-765.
34. Verma SS, Tomar RPS, Verma U. Study on seed quality parameters in rape seed and mustard under ambient condition. Indian J. Agric. Sci. 1999; 39:840-842.