REVIEW OF LITERATURE

REVIEW OF LITERATURE

About the Crop

Origin

The cultivation of pea is a very ancient. De Candolle opined that it existed in Northern India before advent of the Aryans. Vavilov (1949) recognized the probable centre of origin of pea is to be Ethiopia, the Mediterranean and central Asia with a secondary centre of diversity in North-Eastern centre where others related types, such as elatius, humile and fulvum were also found. In Europe, pea has been grown since Bronze Age (about 3000- 1100 B.C.). It is probably the indigenous of the region consisting of Italy and South Western Asia east wards of Himalayas including North India.

Taxonomic Classification

Pea is a dicotyledonous crop in the Class Magnoliopsida Subclass Rosidae, Order Fabales family Fabaceae, Genus pisum. It contains chromosomes 2n=14. Govorov (1928) suggested the inclusion of all cultivated forms of pea in one Species, *P. sativum* L. and sub-divided into sub-species *P. sativum* ssp. Sativum L. and *P. sativum* ssp. Arvense L. A third subspecies asiaticum has also been suggested. Trebuchet et al (1953) identified three different species like *P. formosum* – perennial, *P. fulvum* –annual: and *P. sativum* – annual . They also differentiated the subspecies of *P. sativum* as hortense , syrianicum , abyssinicum, jomardi, elatius, arvense. Singh and Joshi (1970) recognized two main forms of pea viz. garden pea, *P. sativum* var hortense and field pea, *P. sativum* var arvense.

About the plant

Pea (*Pisum sativum* L.) is a cool season crop. Pea plays a major role in human nutrition for its good protein quality with a high nutritional value. It can germinate over a wide range of soil temperature. For germination, about 22^0 c temperature is considered favourable . High temperatures are more injurious to pea crop than frost. The optimum mean temperature for pea growth are between 13^0 c and 18^0 c. Growth stops above 29^0 c .

It is grown on a variety of soil ranging from sandy loam to clay loam. However, a well drained loam soil is considered best for the cultivation of pea. They tolerate a moderate soil PH range (6-7.5). The optimum PH is 6.5.

Nutritive value

A 100 gm of dried edible portion contains the following constituents :-

Moisture –	11 gm	Calcium –	64 mg
Protein –	22.5 gm	Iron-	4.8 mg
Fat –	1.8 gm	Riboflavin –	0.15 mg
Carbohydrate –	62.1 gm	Thiamin –	0.72 mg
Niacin –	2.4 mg		

Seed Quality

Quality seed is a prime parameter behind a good harvest. Seed quality affects not only its germination capacity but also other associated qualities like emergence potential, field stand and uniformity and seedling growth and finally crop productivity. Seed vigour is defined as "the Sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence".

The rate and degree of vigour declining depends upon the environmental factors prevailing following the physiological maturity, harvesting, processing and storage conditions.

Abdul Baki (1980) suggested that the each Seed in any lot might fall into 3 categories with respect to their vigour potential are as follows (i) Seed that never reached high vigour , in this case the Seed was harvested at an immature stage and never attained optimum physiological maturity (ii) Seed that attained and maintained high vigour , seed was developed from a healthy plant under optimum environmental conditions of seed development and maturity , was properly harvested at physiological maturity, carefully

conditioned and stored under optimum conditions. (iii) Seed that attained vigor and then lost it partially or totally, the seed reached maximum vigour as in case ii , but lost its vigour through damage from delayed harvest , method of harvest , conditioning and storage under unsuitable conditions. He also suggested that the more vigorous the seed lot , the fewer seeds it contains of categories i and iii .

Brocklehurst (1985) listed the principal factors influencing the quality of seed throughout its life span , from the time of fertilization on the mother plant until the moment of seedlings , as : Seed genotype , environmental conditions during seed development , environmental conditions during seed development , seed position on the mother plant , harvesting timing and techniques and storage conditions and pre sowing treatments.

Basu (1995) reported the factors influencing seed quality, as pre harvest conditions include quality of initial seed, soil fertility, temperature and photoperiod, moisture status of soil and pesticide or including: seed moisture and drying, storage temperature and oxygen pressure.

Quality of initial seed

Uneven emergence or lack of uniformity in the rate of emergence greatly affect the overall yield and scope of harvest at one time.

Perry (1969) observed that pea seed lots of low vigour level , germinated slowly in the laboratory, emerged poorly in the field and produced relatively small seedlings.

Harman et al.(1978,1980) found that the volatile substance (aldehydes)released from aged pea seed during germination stimulated spore germination of several common soil fungi.

Larson et al. (1998) demonstrated that seedling produced from the older pea seed lots emerged more slowly than seedling from the younger seed lots.

Taweekul et al. (1998) recorded that high pea seed lots emerged well under wet and cold soil conditions (more than 90 %) . In contrast , low vigour seed lots , depending on

cultivar and vigour status ,was emerged poorly (43-62 %) and slowly resulting in lower plant establishment , low leaf area index and leaf area duration.

Nitrogen

Padrit et al. (1996) reported that application of nitrogen significantly improved pea seed vigour as conductivity value and hollow heart percentage were reduced and post accelereated ageing germination was increased.

Harrington (1960) reported that severe nitrogen deficiency in pepper resulted in very low seed yield and a major proportion of the seed was abnormal.

Phosphorus

Phosphorus reserves (phytic acid) in the seed have very significant roles in the metabolism of germinating seeds. In addition to its nutritional role, it might act as natural antioxidant.

Austin (1966) found that the pea seeds harvested from plants grown under sever phosphorus deficiency, was deficient, produced small plants and yielded lower yields than seeds produced from corresponding non-deficient phosphorus pea parent plants.

Padrit et al.(1996) revealed that phosphorus application improved pea seed vigour through reducing hallow heart and increasing post accelerated germination.

Potassium

Extreme potassium deficiency in pepper resulted in a higher percentage of abnormal seed and lower pre and post storage germinability than seeds from corresponding non-defecient potassium mother plants (Basu 1995).

Temperature

Extreme temperatures are not preferable to growth and development of the seeds. Hallingam (1986) observed that at high temperature and seed moisture 70-80 %, the

incidence of hollow heart was the highest and it increased with the length of exposure to high temperature.

Dornbos,1995 reported that damage from excessive heat during seed fill can dramatically decrease seed quality .

Pre harvest soil condition

Adequate soil moisture and regular water supply is essential depending upon the requirement of crop, provides seeds of good quality growth.

Extreme drought stimulates premature dessication and reduces the seed quality in terms of pre and post storage germinability (Basu,1995) .

Pre harvest rains can cause serious injury to seed quality in terms of stimulation of pathogen infection, possibility of sprouting or partial germination of non dormant seeds and seeds badly affected by pre-harvest rains should not be stored for seeding purpose.

Harvesting period

Physical or mechanical damages to the seed can be occurred during harvest, and post harvest conditioning (threshing, cleaning and packaging) and movement of seed from bin to bin , improper storage and careless handling of seed bags . Damages may be obvious, in case of cracked and split or covert, as physiological bruises to the embryo or seed testa fractures.

Biddle (1980) found a high number of cracked seeds when harvested at both high and low moisture content 70 % or 18-19 % , compared with seed harvested at 30-40% . He also indicated that the number of seeds with cracked seed coat increased during threshing as seed moisture content increased or decreased as harvest operating. This might be due to that at high or low moisture content , the testa are very soft or very brittle respectively and in both the cases , the seeds are easily damaged.

Mattews ey al. (1980) reported that the high incidence of testa cracks caused by mechanical harvesting and harvesting operations of the seeds at too low seed moisture content , is the most likely cause of low vigour in pea seed .

Delouche (1988) reported that, yield losses due to pod drop and shattering up to 15 percent can be expected in late harvested crops. It is well recognized that excessive delay in harvest, increase yield losses due to pod dehiscence and shattering in desi chick pea.

Suryavanshi and patil (1995) revealed that the stage of physiological maturity varies with crop and also with variety. In case of mung bean cultivars by considering dry weight , germination percentage and vigour index reported that the seeds attain physiological maturity at 20-30 days after anthesis .

Post harvest condition

Post harvest conditions include threshing , drying and cleaning , packaging pre storage seed treatments and storage . Care must be taken to avoid any damage to the seed during seed handling operations as feasible.

The longevity of dry-stored orthodox seeds depends on seed moisture contents, storage temperature and relative humidity, oxygen pressure and to some extent on the integrity of the seed coat at the time of harvest and subsequent operations.

At high moisture , the respiration rate of the seeds and the associated organisms increases and then the temperature around the seeds increases too.

Excessive seed drying is undesirable because it causes physiological deterioration . Schultz et al., (1962) found that at 5 % seed moisture content , the monomolecular water layer surrounding the macromolecular in seed ceases to be continuous and that may enhance lipid peroxidation activity .

On the other hand Shen et al . (1998) reported that drying to a low moisture levels (5-1%) before storage had no imbibitional damage to pepper seeds . Zeng et al. (1998) stated that drying seeds to water content as low as 2.4 % could slow the ageing damage in cucumber seeds.

Mc. Neal (1966) reported that soybean seeds at 14.6 percent moisture content could be stored for one year at 60^0F without suffering excessive loss in germination percentage or rise in free fatty acid content.

Christensen (1969) revealed that seeds of sunflower stored at moisture content of 10,12 and 14 percent and temperature of 3-5,8-10 and 27-28^0c , invasion by fungi and decrease in germinability were proportional to increasing moisture content , temperature and storage time.

Ghosh and Basak (1958) reported that the Jute seeds stored for more than 19 months impairing its germination , provided the moisture content of seed brought down to minimum 7.2 percent through during in sun and then storing then in air tight containers.

Mechanism of Seed deterioration

The irreversible changes takes place within the seed, leads to its ageing and loss of viability, are collectively known as deterioration.

Abdul-Baki and Anderson, 1972, propose seed deteriorate on as an irreversible change in the quality of a Seed after it reaches its maximum quality level.

Copeland and Mc Donald, 1985 , express seed deterioration is an irreversible catabolic process which once occurred cannot be reversed.

Deterioration on the parent plant

Process of seed ageing begins from the moment the seed attains physiological maturity . At this point the vitality of the seeds are at peak and from that point deterioration in the quality of the seed begins which is rapid in some species and in others relatively slow.

Arulnandhyd and Senanayak (1990) notice that seeds harvested at physiological maturity followed by drying in open shed were significantly better in viability and vigour than the seeds harvested at harvest maturity in three soybean cultivars grown in the wet season. Delayed harvest by two weeks beyond harvest maturity significantly reduces the seed quality.

Shivankar et al. (2001) revealed that soybean seeds collected at physiological maturity (90 DAS) were found to be higher in germination than those collected from prior and after physiological maturity. Delayed harvesting badly affected the seed quality due to field weathering under high atmospheric humidity and pod shattering in the field and seed moisture content reduced down to 13 percent in soybean .

Murthy and Dushyenth kumar (2004) reported that field bean cv. Hebbal avare attained physiological maturity 90 DAS .The seeds harvested at their physiological maturity around 35 days from anthesis or 94 days from sowing showed highest dry seed weight , germination percentage and vigour index .

Maximum seed quality is attained from the time the developing seed reaches its maximum dry weight, normally referred to as physiological maturity (Harrington , 1972 ; Justice and Brass , 1978). However Kermod et al., 1986 reported that many seeds continue to accumulate specific reserve after physiological maturity (Aldana, Fites and Pattee, 1972)

Tekrony et al. 1980 cited weathering as a problem for maintaining the seed quality in many crops which may often occur in the period between attainment of maximum dry weight and harvest ripeness.

Delouche, 1980 mentioned high temperature and high humidity are the major environmental factors favouring weathering damage of seed.

Wood Stock et al. 1985 experienced up to 50 % reduction in field emergence of cotton when kept in the field for five weeks after harvest. Weathering caused disruption to membrane resulting in leakage of cations and change in both lipid and protein bodies as well as loss of ribosomes and impaired respiratory capacity.

Sprouting damage

Vivipary is one of the problem which can seriously affect the food value of many economical grains and can be of major economic concern particularly when there is a

high probability of wet weather during seed ripening and at harvest time. Humphrey – Taylor and Larsen (1990) during their survey for 16 years period from 1971 to 1986 in Newzealand observed that 12.5% of wheat seed in that country suffered from sprouting damage due to increase in α amylase activity .

Gordon et al. 1990 came to a conclusion that there are at least three independently inheritable physiological traits which can make the wheat crop susceptible to sprouting damage .

Symptom of Seed deterioration in storage

The most common symptom of seed deterioration is change in colour of seed and increase in free fatty acid levels with levels within seeds (Harrington , 1973) . Darkening of seed coats with age is very likely due to the oxidation of phenolics or similar compound within the seed coat. Fatty acid production is usually the result of lipase action on seed reserves with the increase in seed moisture content is inevitable. When these organisms take hold , symptoms of rapid decay become evident and include musty odors , raised temperatures and increased moisture contents with in the areas of the stored seed.

In large seeded legumes, when deterioration occurs causes an increase in the conductivity of leachates as they are placed in contact with water (Powell and Mathews , 1977 ; Mc. Donald and Wilson, 1980).

Mechanism of seed deterioration

Membrane damage

Disruption of membrane integrity is a major physiological symptom of seed deterioration . Powell and Matthews (1977) demonstrated that there was increased in leakage from pea seed which ultimately cause cell death determined by tetrazolium chloride staining.

Similar results were obtained by Ferguson et al. 1990a, indicated that increase in conductivity of leachate from isolated areas were primarily symptom of seed deterioration.

Delouche (1973) and Copeland (1988) have highlighted that membrane degradation , accumulation of toxic metabolites , decreased enzymatic activity , lipid auto-oxidation , failure of repair mechanisms, genetic degradation, reduced yield, finally loss of germination or death are the major consequence of deteriorative changes in seed .

Degradation of cellular membrane increase the permeability of those membrane resulting in greater leakage of sugars, amino acids and inorganic solutes from the seed which leads to senescence (Abdul-Baki and Anderson,1970).

It is widely accepted that loss in cellular membrane integrity is one of the chief cause for loss of viability, presumably, a loss in membrane integrity under un favourable conditions for storage lead to increased leaching of seed constituents and thus loss in viability (Ching and Schoolcraft,1968 and Sen,1977).

Krishnaveni and Ramasamy (1985) reported that the electrical conductivity and the leaching of free amino acids and sugars significantly increased with the increase in storage periods of maize seeds. Similarly Dey and Mukherjee (1988), Deshpandey (1988) and Dighe et al. (1995) in sunflower reported that electrolyte leakage increase with storage period.

Ultrastructural Changes

As the seed ageing progress plasmalemma might get withdraw from cell walls which in turn leads to leakage of cytoplasmic contents through the membrane (Hallom 1973 ; villers 1980; Sakunnarak , 1992 in rye, lettuce and soybean respectively).

Several other changes like fusion of lipid bodies (Harman and Granett,1972), changes in the appearance of mitochondria , plastids and golgi stacks (Berjak and villers, 1972 a) including damage to the nuclear envelop (Vishnyakova et al.,1976 ; villers , 1980) occurs during the process of seed deterioration .

On the contrary , Berjak and Villers (1972 a) observed to cell that changes organelles were observable in tissue from seeds which has not yet deteriorated sufficiently to show much decrease in germination and were reversible on imbibition.

Loss of Membrane Phospholipid

At very early stage of seed deterioration when storage conditions are not suitable there is an increase in conductivity in association with change in membrane composition.

Powell and Mathews (1981) revealed that during the ageing process of pea seeds the very early events is the loss in phospholipid particularly phosphatidyl choline.

Pearce and Abdel Samad (1980) and Francis and Coolbear (1987) also found similar pattern of decline in phospholipid composition in slowly aged peanut and tomato respectively.

Petruzzelli and Taranto (1984) stated that dry stored seed had a significant loss of phospholipid from embryos in comparison to the seeds stored at higher moisture content.

Changes in fatty acid composition and lipid peroxidation

Seed deterioration is a natural phenomenon which occurs in all the seeds leading to gradual decline of seed vigour during storage. Oilseeds deteriorate faster than others seeds containing less oil, as the poly unsaturated fatty acid present in these seeds are more susceptible to peroxidation (Priestley and Leopold 1983) .

Pukacka and Kuiper (1988) revealed that phospholipid degradation and peroxidation of unsaturated fatty acids, followed by membrane destruction, play an important role in maple seed ageing. They found that the level of linoleic (18:2) and linolenic (18:3) acids in the phospholipid fraction decreased considerably in the course of the accelerated ageing.

Lima et al. (2010) observed that seed quality of the genotypes with low linolenic acid content (with or without lipoxygenase) was better and was less susceptible to deterioration when stored under unfavourable conditions.

Oxidative damage to membrane system in seeds can occur via free radical driven lipid peroxidation (Wilson and Mc. Donald, 1986 b; Benson 1990). Free radicals like Hydroxyl and Superoxide radical produced in the presence of oxygen initiate highly

lethal oxidative chain reaction especially with polyunsaturated fatty acids such as linoleic acid to form lipid hydroperoxides which ultimately form mobile secondary product like malondialdehyde (a result of the lipid peroxidation of 18:3 linolenic acid) can cause significant damage to membrane proteins by inducing cross-linking reactions. Seed possess inbuilt detoxification system in the form of enzymes such as superoxide dismutase or glutathione peroxidase/reductase which can neutralize lipid hydroperoxides (Benson, 1990).

Stewart and Bewley (1980) demonstrated that viable soybean seeds upon imbibition produce superoxide dismutase enzyme but nonviable seeds did not have the capacity to produce the same. There is a wide range of non-enzymatic compounds like tocophenols , ascorbate and glutathione have antioxidant properties and is active against free radical (Benson,1990).

Several research workers have demonstrated the efficiency of certain antioxidant treatments in protecting seeds from deterioration during storage (wood stock et al., 1983; Gorecki and Harman, 1987).

Puntalaro and Boveris (1990) reported that there is a sharp increase in free radical production on as the seed begin to imbibe water during initial phase of germination.

Harman and Mattick (1976) during their study disclose that during ageing of pea seed under high humidity condition, there is a loss of germinability which is associated with loss of linoleic (18:2) and linolenic acid (18:3) with no alternation in the other fatty acid component.

Genetic Damage

Roos, 1982 reported unpaired breaks in genome due to several factors like free radical damage, hydrolytic enzyme activity or mutagenic compounds which may accumulate in deteriorating seeds.

Study on lettuce conducted by Rao (1990) inferred that at high temperature and seed moisture content genetic damage viz. chromosomal aberrations and chromatid aberration occur while at 18 percent seed moisture , chromosomal aberrations were almost absent.

Osborne (1980) and her coworkers reported that damage to DNA does occur in dry seed.

Villers, 1980, observed substantial ultra structural evidence of damage to nuclei as the seed age and the typical feature being that nuclei lose their even granular appearance as clumps of electron-dense chromatin develop.

Cheah and Osborne (1978) recommended that damage to DNA was due to slow hydrolic activity.

Deterioration of seed during storage may be due to free radical actitvity, either direct intereactions, especially with the hydroxyl free radical on thymine or intereactions with secondary products of lipid peroxidation such as Malondialdehyde (Benson, 1990).

Villers ,1974; Osborne ,1982 ; Guy,Smith and Black ,1991 concluded that partially deteriorated seeds have the ability to repair damaged strands of DNA by replacing segments using complementary strands as a template.

Change in respiratory activity

Seed deterioration involves damage to their respiratory capacity for early germination as a consequence of damage to mitochondrial membranes. Deteriorated seeds mostly show reduced oxygen uptake and elevated respiratory quotient on early imbibitions.

Wood Stock, Furman and Solomos (1984) observed decrease in respiratory activity to be associated with reduced vigour in soybean.

Low vigour of seed associated with increased level of toxic by-products such as ethanol and aldehydes , indicating the inability of damaged mitochondria to keep up with glycolytic activity , resulting in anaerobic catabolism (Wood stock and Taylorson,1981).

In many species it was observed that oxygen uptake by deteriorating seeds did not in fact decrease much compare to high vigour seed but the respiratory efficiency of those aged seed decrease substantially thus producing less ATP (Abu-Shakra and Ching,1976).

Ferguson,Tekrony and Egli (1990a , 1990b) confirmed that mitochondrial membrane damage is a very early event in soybean deterioration resulting in less oxygen uptake and ATP production by isolated mitochondria after very short period of ageing . Reduction of mitochondrial activity was found to be associated with deletion of polyunsaturated acids from mitochondrial membrane indicating peroxidation damage to these organelles.

Takayanagi (1977) observed that the proportion of glucose catabolized by the pentose phosphate pathway rather than normal glycolysis route was considerably elevated in aged seeds.

Change in Carbohydrates

Seed deterioration also found to be associated with the change in the soluble carbohydrate content resulting in reduced viability and vigour of seed. As the ageing of the seed proceed the soluble carbohydrate in the seed generally decline (Madhava Rao and Kalpana 1994) and this decline might results in limited availability of respiratory substrates for germination.

Sugars also assumed to play an important role in maintaining the structural integrity of bio membranes and proteins under dry conditions (Crowe et al. 1984a and 1984b ,Carpenter et al.1987) Reduction of disaccharides decrease the ability of the seeds to maintain the vitrified or 'glassy' state , a non crystalline liquid state of high viscosity (Williams and Leopold 1991) . According to Rao and Kalpana (1994) starch and soluble sugars decrease while reducing sugars increased in pigeonpea seeds exposed to accelerated ageing . Rashed et al. (2010) observed decrease in total carbohydrate content in aged seeds of watermelon. Horbowicz (1997) described various change in mono and oligosaccharides content in vegetable seeds during ageing. Ravikumar et al. 2002. reported that during accelerated ageing of Dendrocalamus seeds there is a decrease in total soluble sugars and starch content.

Change in enzyme activity

Ageing inhibits the activities of peroxide scavenging enzymes like peroxidase , catalase, superoxide dismutase (Jeng and Sung 1994 , Chiu et al. 1995 , Bailly et al. 1996 , Demirkaya 2013). Thus, reduction in the activity of these enzymes results in greater damage caused by free radical mediated reactions leading to deterioration of seeds.

Plants have evolved defense antioxidant mechanisms to combat the danger posed by the presence of ROS. Antioxidant systems in plants include enzymes capable of scavenging the free radicals and peroxides , such as superoxide dismutase (SOD) , Catalase (CAT) and enzymes of ascorbate glutathione cycle viz. Peroxidase (POX) (Bowler et al . 1992, Foyer et al. 1994 a , Song et al. 2004) . An initial oxyradical product, the superoxide radical , upon further reaction within the cell can form ROS such as hydroxyl radicals and singlet oxygen (Halliwell and Gutteridge 1989) . Superoxide dismutase catalyeses the conversion of superoxide radical to H_2o_2 (Grene 2002). Hydrogen peroxide can be dispose off by catalase and ascorbate peroxidase. Catalase converts H_2o_2 to water and oxygen, ascorbate peroxidase forms water and dehydroascorbate from ascorbic acid and H_2o_2 (Williekens et al. 1995, Bolkliva et al.2003).

Gholami and Golpayegani (2011) observed that free fatty acid content increase linearly in accordance with the seed ageing period. The results suggest that the process of accelerated ageing correlated to increased accumulation of total peroxide content and decreased activities of peroxidase, antioxidant activity.

Seeds of sweet sorghum (*Sorghum bicolor* cv. Yidali)subjected to accelerated ageing under 100% relative humidity and 43^0c for 0-16 days experienced increase activity of superoxide dismutase ,ascorbate peroxidase, catalase glutathione reductase and dehydroascorbate during initial phase and then decreased (liu et al.2008).

Tatic et al.2012 observed decrease in seed vigour and fatty acid content especially linoleic acid during natural ageing process for six and twelve month under conventional storage as well as under accelerated ageing test for 3 to 5 days.

Chauhan et al. 2011 demonstrated that all the antioxidant enzyme viz. catalase ,peroxidase, dehydrogenase and amylase decreased after natural and artificial ageing treatment in six varieties of wheat (*Triticum aestivum* viz. C.306,PBW 502,WH 283 and RAJ 3765) resulting in deterioration of seed quality.

Ageing is the main problem of seed storage. Changes of biochemical reduction of seedling growth are consequence of seed deterioration. Seed placed for accelerated ageing at 41^0c and 100% R.H. for 0,2,4, 6,8 days showed that increase in ageing period resulted in higher reduction in germination characteristics, catalase and ascorbate peroxidase. (Nooshabadi and Mashayekhi ,2013).

Agrawal 1990 stated that there is a decrease in the activity of PEP carboxylase and RUBP carboxylase and an increase in protease activity during seed storage. With the progress of seed deterioration there is increase in water soluble sugar and Leucin-14.

Some of the seed evolved volatiles, which were mainly composed of methanol, acetaldehyde, ethanol and acetone are the main cause of loss of germinability during storage. Acetaldehyde had the greatest deleterious effect regardless of relative humidity and temperature, while ethanol caused seed deterioration only at high relative humidity (Zhang et al. 1994). Luria and Gelmond (1978) pointed out that protease enzyme activity increase during seed ageing which has a potential to destroy other enzyme in seed.

Sung and Chiu 1995 revealed that natural ageing of soybean seed in alluminium foil bags coated with polythene 5 or 25^0c for 3,6,9 and 12 months inhibits seed germination and enhanced lipid peroxidation but more rapid seed deterioration at latter temperature due to inhibition of activities of peroxidase , catalase, ascorbate peroxidase , Superoxide dismutase and lipoxygenase.

Bailly et al. 1996 concluded that sunflower seed deterioration during accelerated ageing is closely related to decrease in the activities of detoxifying enzymes like SOD, CAT, glutathione reductase and to an increase in lipid peroxidation . The reversibility of these biochemical events during osmopriming with polyehelene glycol-6000 solution suggest

that the cell detoxifying system ,by preventing accumulation of toxic form of oxygen ,might play an important role in seed resistance to deterioration.

Yang-ya ping et al. 2008 , observed that artificially ageing treatment of rice (cultivar – 99-Zao-677 and Xiangzaoxian 24)reduce the germination percentage due to injury in cell membrane resulting in higher relative electro-conductivity and free amino acid content and decrease in total protein in seed . They also reported reduction in catalase activity during ageing.

Change in Protein

The hydrolysis of polymeric storage compound such as proteins take place under unfavourable storage conditions of high moisture and temperature. Reduction in protein content and increase in amino acid content was attributed to loss of vigour and viability in crimson clover (Ching and Schoolcraft , 1968). Positive relationship of protein with seed vigour in terms of subsequent crop growth and yield was reported by Ries(1971).

Kalpana and Madhava Rao (1994) reported that decrease in protein content in pigeon pea is accompanied by an increase in amino acid level during ageing might be due to their greater degradation of protein by proteinases as continuous increase in proteinases activity was associated with rapid ageing of pigeon pea seeds. Abdul Baki (1969), also observed a rise in proteinase activity during accelerated ageing of seeds in barley and wheat.

Rashed et.al.2010, reported significant decline in the total protein content in the aged seed of water melon. In pea and soybean seeds, a decrease in the rate of in vivo protein synthesis was observed during accelerated ageing conditions (Gridol et al.1998).

Reduction in seed protein content as well as change in protein banding patterns in sunflower seed were observed during ageing (Dadlani et al. 1995). In maize and soybean change in the intensity of certain bands was observed during accelerated ageing (Vijay 2000).

Protein synthesis reduced during early period of seed deterioration due to seed deterioration due to damage of protein synthetic mechinary which could takes place at both translational and transcriptional level (Abdul-baki, 1969, Stormonth and Bray,1980).

Denaturation of nucleic acid

One of the probable cause of seed deterioration is the denaturation of nucleic acid during ageing. Roberts et al. (1967) showed that with the progress of seed senescence, the number of breaks in the DNA increase. Free radicals are suspected of assault on chromosomal DNA. Potential targets for oxidative damage in the DNA chain include the purine and pyrimidine bases as well as the deoxyribose sugar moieties (Larson, 1997). Grzesiuk and kulka (1971) noticed that with the increase in the duration of ageing there is a decrease in quantity of nucleic acid due to increase activity of nuclease.

Denaturation of lipoprotein membrane

Lipoprotein membrane contains high proportion of polyunsaturated lipids; in presence of oxygen, the unsaturated lipid will form free radical intermediates and unstable peroxides, thus changing the semi permeable nature of membrane (Roubal and Tappel, 1996).

Production of Toxic Metabolites

Numerous studies have pointed out a relationship between volatile aldehyde production during early cha germination and stable changes in seed vigour during natural and accelerated ageing (Harman et al., 1982; Wilson and McDonald, 1986a).

Esashi, Kamataki and Zhang (1997) experimented with seeds of five different crops and detected production of 11 volatile aldehyde compounds with seed ageing.

The amount of evolved volatiles increases with increasing period or temperature of seed storage suggests that these volatiles are produced metabolically even in dry seed (Zhang, Lin, Torii, Sasaki and Esashi, 1993).

Zang et al. (1995) identified fifty nine types of volatile compounds evolved from dry seeds after different storage conditions, of which the major components were methanol,

ethanol, acetone, isopropanol, 2-butanone and various aldehydes like acetaldehyde, 2-methylpropanol, 2 and 3 methyl butanal , pentanal and hexanal .

Wood stock and Taylorson (1981) found an inverse relation between the amount of ethanol and acetaldehyde accumulation with subsequent seedling growth of deteriorating soybean seeds in both natural and accelerated ageing conditions.

Simailar observation was noted by wilson and Mc.Donald (1986a), confirmed that evolution of aldehyde during the first 48 hour of germination of soybean was inversely correlated with field performance and other parameter determining the seed vigour.

Low vigour seed produce high quality of hexaldehyde (Hexanal) as compare to high vigour seed (Castro and Sediyama, 1990).

Dey and Sircar (1968) implicated that accumulation of number of phenolics, supraoptimal concentration of indoleacetic acid and abscissic acid to the loss of rice seed viability. Mukhopadayay et al. (1983) recorded a large accumulation of the polyamine in non-viable rice embryos.

Change in the endogenous plant growth regulator

Application of plant growth regulator such as gibberellins, cytokynins and ethylene proved to be very effective in maintaining the vigour of aged seed (Harrington 1973). Likewise treatment of dry grains with acetone solution of gibberellic acid or ethephon prior to storage found maintain the viability of durum wheat (*Triticum durum*) in store at 14.5 % seed moisture content and 30^0c temperature (Petruzelli and Taranto,1985).

Bhattacharjee (1986) revealed that jute seed when pretreated with aqueous solutions of growth retardants including CCC, an inhibitor of GA biosynthesis prolonged the storability of jute seed.

Aspinall and Paleg (1971) observed that rate of radical emergence in wheat decreased when stored for long duration as the ability of endosperm section to produce α amylase in response to GA fell sharply.

Free radicals in seed deterioration

A free radical is an atom with an unpaired electron, which posses the ability of donating or receiving an atom. The hydroxyl (-OH) and super oxide (O_2^-) are the two most important radicals believed to cause most damaging biological action.

Free radical is one of the most important participants in causing oxidative damage of polyunsaturated lipids in cell and cell components in the biological system (Tappel, 1973; Demopoulos, 1973a, 1973b; Milvy ,1973) . Various forms of free radicals have been observed or detected in living tissue, each with a differing capability for cell damage (Gille and Joenje, 1991; Larson, 1997).

Harman and Mattick (1976) and Berjak (1978) implicated free radical and lipid peroxidation reactions in the deterioration of pea and maize seeds respectively.

Justice and Brass, 1978, observed that under very dry conditions lipids are subjected to direct autocatalytic attack by enzymically and non-enzymically leading to the production of hydroperoxides, other oxygenated fatty acids and free radicals.

Stored seed subjected to lipid peroxidation showed consistent attack by oxygen, forming hydro peroxides,other oxygenated fatty acids and free radicals, which are unstable and may react with and damage nearby molecules. The total amount of oxygenated fatty acid generated would be proportional to the age of the seed (Wilson and Mc Donald, 1986).

Cytological Changes

Cytological changes including chromosomal abnormalities, mutation and other disorders in cytoplasmic components as influenced by ageing have been studied over a long period. Navashin(1933a,1933b) observed that high frequencies of chromosome aberrations occurred in roots produced from old seeds. A number of other workers have subsequently reported increases in number of chromosome aberrations and cytological changes with increase in age of seed of a wide range of species; in durum wheat, barley, rye and peas (Gunthardt et al.,1953), in lettuce (Harrison ,1966), in onion (Sax and Sax,1964) in peas (D'Amato,1951), in spring onion (Kato,1951) and in maize (Berjak,

1968b). Osborne (1990) observed fragmentation of nuclear DNA occurs in dry seeds with the increase in age. Elder and Osborne (1993) reported that DNA degradation occurred with seed deterioration.

Failure of protein synthesis, especially during first hour of imbibitions in aged seeds, damage to ribosomes , loss of enzyme activity, loss of DNA and or mRNA can occur at the ageing lesions(Osborne et al.1980).

Aberration of chromosomes is one of the changes associated with seed ageing, which are also referred as mutagenic effects. Some of the chromosome aberrations in the aged seeds include fragmentation, bridges, fusion ring formation of chromosomes and variation in nuclear size. Roberts et al.(1967) revealed that chromosomal damages in seeds is accelerated by temperature, moisture content and duration of storage and chromosome breakage is probably also induced by increased concentration of oxygen.

The deteriorated seeds contained more chromosomal aberrations and the incidence of chromosome breakages during anaphase is highly correlated with loss of viability in barley and pea seeds (Dourado and Roberts, 1984).

Khan et al (2003) through an accelerated ageing experiment suggested that the storage conditions viz. moisture and temperature are the one of the determining factor for chromosomal aberrations during storage which increases with the increase in ageing time.

Kumar and Rai (2009) observed that Gamma rays and ageing treatments induced a number of chromosomal anomalies independently, but a combination of the two treatments effectively suppressed the frequency of chromosomal anomalies considerably in somatic as well as gametic cells of maize.

Effect of microflora in seed deterioration

The microflora, bacteria and fungi are closely associated with seeds during storage, resulting in the deterioration of seed. Saprophytic fungi are most important micro organisms responsible for initiating or accelerating the seed deterioration process. Field fungi such as Fusarium, Cladosporium,Curvularia and Alternaria species are active

during harvesting period of seed as they require at least 22 % of moisture content in starchy seed to initiate the attack . During storage period fungi especially *Aspergillus* and *Penicillium* species predominantly attack the seed causing damage.

Fields and king (1962) and Harman and Granett (1972) observed that out of various species of Aspergillus , especially *A.candidus* nd *A.flavus* cause rapid deterioration in healthy seed. Though other species like *A. restrictus* and *A. glaucus* are most important for their 'lead in' effect and can grow actively at low moisture content.

Almost all the storage and field fungi produce toxic compound, collectively termed as mycotoxins (Christensen and Kaufmann, 1974) mostly affect animals and humans who might eat the affected grain. Many of these mycotoxins have adverse effects on seed quality also (Hallion, 1986).

Mycotoxins constitute a wide range of different compounds ranging from simple substituted organic β-nitropropionic acids to extremely complex multicyclic system (cole and cox, 1981). Many of these compounds are known inhibit nucleic acid and protein synthesis, but some may also have anti respiratory or mutagenic properties (Moule, 1984).

Betina,1984;Hallion,1986, observed Several adverse effects of mycotoxin on plants which include inhibition of germination , impaired photosynthetic activity , inhibition of cell extension and membrane damage etc.

Biologically, storage fungi increase as seeds deteriorated and reduce seed germination separately from the physiological causes of seed deterioration (Ghosh and Nandi,1986 ; Mycock and Berjak, 1995) . The major effects of storage fungi upon seeds are decrease in germinability , discolouration , production of mycotoxins, heating and total decay. Storage of seeds under high humidity and high temperature conditions increase the rapidity of invasion of microflora on seed, resulting eventually in excess heating and mould growth.

Harman and Granette (1972) observed that the invasion of *Aspergillus rubber* caused an increased in the leakage of solute from pea seeds. Dewivedi (1990) reported that changes

in the concentration of total phenolic compounds in gram seed influenced by fungal invasion during storage.

Christensen and Kauffman (1969) reported that even under limited moisture conditions were fungi and other microorganisms cannot grow, storage fungi adversely affect the seed by bringing down the seed viability, seedling vigour and also affect the chemical composition of seed.

Mandal (2001) collected 42 samples jute (*Corchorous* sp.) from different parts of the country and he observed many seed borne pathogens namely *Macrophophomina phasiolina, Colletotrichum gleosporiodes, C.corchori, Botryodiplodia theobromae, Sclerotium rolfisii, Alternaria tenuis, Aspergillus , Penicillium, and Fusarium* spp. , among them *Macrophomona phasiolina* had the highest infection rate ranging from 0.25 to 21.5 %.

Basavaraju et al. (2004) revealed that *plasmophora haestedii* is the seed borne pathogen and the seeds infected severely by this pathogen (75-100%) resulted in lower germination (47%) with less vigour index (470) in sunflower.

Effect of mechanical injury

Mechanical injury to the seeds during the entire process of processing (harsvesting , threshing and handling) is also considered to one of the reason of seed deterioration . During storage, the injured areas serve as centers of infection which aggravate the accelerated ageing, leading to shorten the life span of seeds.

Karma (1967) used X-ray method to analyze the internal injuries causing immediate or premature loss of viability. Intensity of mechanical injury varies depending upon the embryo structure of different crops. Flat seeds like sesamum (*Sesamum indicum*) have a very thin , flexible seed coats are more prone to critical mechanical injuries as compare to Flax seeds(*Linum usitatissimum*) with a firm brittle seed coat. On the other hand spherical shaped seeds are better protected than elongated or irregular shaped seeds. Interestingly, Atkin (1958) observed that white seeds are more susceptible to injury than

coloured seeds. Moore (1972) reported possibilities of seed damage due to rapid water uptake by different seeds.

Storage environment

During the storage period, seed moisture content, relative humidity, temperature, pest and temperature, pest and disease affect the storage potential of seeds.

Ghosh et al., (1951) observed best performance in terms of vigour and viability of jute seed up to 14 months when stored at a moisture content of 7.5 percent through sun drying.

Ghosh and Basak (1958) noticed that jute seed could be stored for more than 18 month without deteriorating its germination percentage when stored in air tight conditions after lowering down the moisture content to 7.2 percent through drying in sun.

Halder and Gupta (1980) observed that sunflower seeds deteriorated completely within 90 days when kept at 95 percent relative humidity and 28 $\pm 1^0$c but remained fully viable for 120 days at 80 percent relative humidity.

Narayanaswamy (2003) reported that ground nut seeds at 8 to 9.53 percent moisture content moisture content could be stored for 8 months without losing its germination under ambient conditions at Bangalore.

Gupta Anuja and Aneja (2004) observed that soybean seed stored in cloth bag showed decline in germination per cent after seven months of storage due to increase in temperature about 30^0c and relative humidity about 75 percent.

Control of seed deterioration and seed invigoration treatments

A. Temperature and humidity control for extending storage life

Storage temperature and relative air humidity are two major external factors affecting storage duration and degree of seed deterioration. Low moisture content and low temperature are the ideal for prolonging storability of orthodox seeds. According to

Harrington (1973) , it is possible to keep seeds of most of the species for hundred years , if the storage conditions are provided with relative humidity of 15 % , low oxygen and high carbon dioxide conditions . Seed moisture content is also one of the most important determinants of longevity in storage. The important thing from the perspective of chemical reactions in seed is water activity, which means the chemical potential of water in the system (Basra, 1984). Bass (1973) reported that properly dried seeds stored in moisture proof containers can be stored safely for 2-3 years at ordinary room temperature (21-30^{0}c) which could be extended for much longer time at low temperature (5-29^{0}c). Bass (1975) reported that papaya seeds stored at 10^{0}c and 50% relative humidity in cloth bags and 5^{0}c in sealed moisture barrier packages retained their viability reasonably well during six years storage. Roberts (1961b) conducted an experiment in rice, sealed in ampoules in oxygen, air and nitrogen at various moisture content from 12-14.5% and temperature from 30-45^{0}c and found there was a tendency of greater viability at decreased partial pressure of oxygen, particularly under low temperature and humidity conditions. Dasgupta (1978) reported that sealed glass bottle is the best for the preservation of wheat seed under warm humid conditions. Mohammadi et al., 2011 reported that lower temperature and humidity result in delayed seed deteriorative process and which in turn leads to prolonged viability period. Rahman and Rahman (1997) observed that highest germination and lowest prevalence of fungi was recorded in the jute seeds stored in tin container followed by polythene bag and gunny bag with polythene lining compared to gunny bag alone and also a positive correlation between increase in population of storage fungi and loss in germination was obtained. Harrington (1973) reported that packing of seeds in moisture proof or moisture resistant containers was most important in prolonging the germination and vigour. Anjali Devi (1998) reported that RCH-2 hybrid cotton seeds packed in poly lined cloth bag for 10 months maintained high germination (88%), seedling vigour, dry matter production and vigour index. Nataraj *et al.*,(2011) revealed that sunflower hybrid seeds stored in polythene bag (700 gauge) recorded higher germination (80%), vigour index (1869), total dehydrogenase activity (1.258) and lower electric conductivity of leachet (194.53d Sm-1) in KBSH-53 treated with neem seed powder @ 5g kg-1of seeds compared to cloth bag and poly lined cloth bag. Ransing, et al. (2011) revealed that ground nut stored in the form of pods could

maintain germination above minimum seed certification standards up to 240 days than kernels up to 180 days, where the poly lined cloth bags were best container for storage of ground nut pods compare to cloth bags.

B.Control of pathological deterioration by storage microflora

It is well known that most of the seed borne pathogens are likely to be detrimental to seed quality, especially with respect to germination potential. Certain pathogens-fungi, bacteria and viruses are borne on the seed surface and or within the seed tissues and they penetrate the seed while it is on the plant. Some pathogens invade the seed after harvest, mainly in storage period and can be prevented with suitable fungicides during storage of seeds. Usually at a moisture content of 70-90 percent, the storage fungi grow well on seeds or other plant materials. The activity of microflora increased with the increases of relative humidity rather than moisture contents of seeds because different seeds have different relationship between these two factors. Semeniuk (1954) suggested that usually storage fungi are inactive below 62 percent relative humidity. Milner and Geddes (1954) also observed very little fugal activity below 75 percent relative humidity. Semeniuk (1954) reported that storage bacteria require 90 percent relative humidity for growth and certain microorganisms would grow at a temperature as low as -8^0c , others at a temperature as high as 80^0c. Dry dressing of seed with systemic fungicide like carboxin could effectively control loose smut fungus during storage (Schmeding and Kulka,1966).

Hampton(1979a) treated wheat and barley seeds with a number of fungicides found that the seeds could be safely stored up to 12 months but the germination of the barley seeds treated with carboxin and carboxin plus thiram was significantly reduced after 18 months of storage. Seed treated with fungicides such as thiram (Shekaramurthy,Patkar,Shetty,Prakash and Shetty,1994) ,vitavax (Gupta, Schmitthenner and McDonald,1993) controlled storage fungi development under accelerated ageing conditions leading to increased germination.

Kumar and Agarwal (1999) reported that seed treatment with fungicides like thiram, rovral (iprodione), dithane M-45(mancozeb), dithane Z-78(Zineb), ridomil

MZ(mancozeb+metalaxyl) and bavistin (Carbendazim)+Thiram (1:1) considerably reduce seed borne pathogens of maize seed.

Ji and Singh (1977) reported that jute (JRC 321) seed treatment with NI ceresin and Agrosan GN gave satisfactory control of *Macrophomina phaseolina* than Captan, DithaneM-45 or Hexasan in 2 year of field trials.

Merwade (2000) reported significant increase in germination percentage (64.15%), vigour index (1443)and seedling dry weight (1.73g) in captan treated chickpea seeds as compared to untreated control (59.06%,1312 and 1.54g) respectively.

Patil(2010) revealed that sorghum seeds treated with captan @ 2gm per kg of seeds recorded significantly higher germination (74%) up to 8 months compared to untreated control, with higher root length, shoot length, vigour index, seedling dry weight and lower EC values.

Ravindranath et al.(1990) reported that cowpea seeds treated with malathion(5%) dust and thiram maintained higher germination compared to control upto six months of storage . Whereas, sudden decrease in germination and seedling dry weight was seen in untreated seeds after three months of storage due to infestation of pulse beetle.

Patil(2000) observed that malathion treated chickpea seeds recorded higher germination(67.89%), seedling length (19.69 cm) , dry weight (1.60 gm) and vigour index (1340) at the end of 10 months of storage period by controlling pulse beetle infestation compared to other chemicals.

Biradar (2001) observed that green gram seeds treated with malathion @ 10 g per kg of seeds recorded higher germination (80.76%), germinate rate index(17.09), root length (9.75cm),shoot length (7.0cm) and vigour index (1332) as against control at the end of 10 months storage.

C.Physico-chemical treatments for controlling seed deterioration

1) Hydration-dehydration treatments

The hydration-dehydration treatments for the maintenance of vigour and viability of seeds has been put forward by Basu and coworker (Basu et al., 1974; 1978; Basu and Dasgupta, 1974; Basu 1976). The effects were spectracular and highly reproducible not only in maintaining vigour and viability but also for productivity of the crop raised from treated seeds (Basu et al .,1974; Dasgupta et al.,1976; Basu and Pal,1978;Mitra and Basu,1979; Kundu and Basu,1981; Punjabi et al., 1982). Short term treatments (dipping) with water or chemicals followed by drying back also proved very effective (Mandal and Basu, 1982). Pre storage chemical fortification of red gram (*Cajanas cajan*), black gram (*Vigna radiata*) seed employing dilute solution of ascorbic acid, manganese sulphate, zinc sulphate, potassium chloride and indole 3-butyric acid, followed by drying back significantly improve storability (vanangamudi and Karivaratharaju,1986). Andrea et al. (1993) reported that the Hydration -dehydration treatment is a viable alternative to improve performance in medium physiological quality seed lots but not in high vigour lots.

Dasgupta et al.(1977),Basu and Dasgupta(1978) and Dey and Basu (1985) reported that seed invigoration treatments could effectively reduce γ –irradiation damage in wheat and jute seeds. Pre and post irradiation soaking –drying treatment effectively counter-acted the damaging effect of γ-irradiation on growth of the seedlings, activity of amylase and dehydrogenase enzymes, membrane integrity and chromosomal aberrations.

When seeds or their embryonic axes are in direct contact with pure water, imbibation is rapid which may cause injury to the seed (Abedona and Odu, 1972; Roos and Pollock, 1971; Saha and Basu, 1984; Powell, Oliveira and Matthews, 1986).

The causes of the injury have not been fully elucidated. Kidd and West (1919) put forward several views as possible explanation of this injury :(i) disorganized metabolism resulting from deficient oxygen supply and/or accumulation of carbon-dioxide,(ii) leaching out of essential soluble seed reserves and (iii) a combination of (i) and (ii).

Eyster(1940) reported that raising the moisture content of seeds could protect them from the damage associated with rapid water imbibition. In 1938, he reported a method whereby bean seeds could be conditioned to tolerate submergence in water at 10^0c. He placed bean seeds on moist cloth or paper towels in moist chamber at a moderate temperature. These seeds absorbed water and swelled and when placed for more than two weeks in water at 10^0c showed very little loss of cell content.

Orphanos and Heydecker et al. (1968) reported that brief initial aerobic inhibition would sometimes prevent the permanent soaking damage to French bean (*Phaseolus vulgaris* L.) seeds.

Heydecker et al (1975) reported that seeds of several vegetable or ornamental plants soaked in aerated, aqueous solutions of polyethylene glycol (PEG) partially imbibed water did not germinate. Moreover, when these seeds were dried subsequently germination proceeded more rapidly, uniformly, and over a wider range of environmental conditions than that of non-aerated seeds.

Saha and Basu (1981) have reported a modified hydration-dehydration method for the maintenance of vigour and viability of stored soybean seeds. The technique involves preconditioning of medium vigour seeds by moisture equilibration with a water-saturated atmosphere for 24 hour followed by soaking in water for 2 hour and then drying back the seeds to original weight. The effect of moisture equilibration could be successfully simulated by keeping seeds within folds of a moist cloth.

Penaloza and Eira (1993) studied the effects of hydration-dehydration seed treatment on vigour and viability of medium vigour (5 months old) tomato seed. They found an improvement in the performance of medium vigour seed lots but not that of high vigour seed.

Aged seed lots of cauliflower with varied vigour levels when invigourated with hydration-dehydration ,PEG 6000-1.0Mpa and NaH_2po_4 reported significant improvement in field performance and advancement in curd maturity in the high vigour seed over others including control (Pallavi et al.,2005/2006).

Nirmala and Umarani (2008) tried a range of priming method viz. hydro priming, Sand matric priming, Halo priming and Osmo priming for a range of duration with okra seed and beet root. They found sand matric priming, halo priming and osmo priming for a range of duration with okra seed and beet root. They found sand matric priming (3 hour in 60 % WHC of sand) to be the best for okra seed and hydro priming (12 hour in water at double volume of seed) for beet root in improving germination percentage , speed of germination and days of 50% germination.

Daniel et al., 2012 observed that hydropriming, a wet seed invigoration treatment, for 24 hours optimized seed germination and vigour of kneaf seed.

Inayat et al., 2013, found that during storage there is a reduction in unsaturated fatty acids and protein content and increase in hexal content in okra seed. However priming with PEG at 1.2 Mpa water potential for 18 hour duration followed by priming with Mannitol at the same water potential and duration significantly control in reduction of unsaturated fatty acid and protein content compared to water treatments and dry seeds.

Pijlen et al., 1996 deduced that pre storage humidification and hydropriming of tomato seeds resulted in a significant increase in resistance to deterioration due to metabolic activities induced by partial hydration. But osmoprimed seeds were more sensitive to deterioration resulting decrease in DNA repair activity due to progression in the cell cycle.

Tilebeni and Sadeghi (2011) demonstrated that hydropriming for 2 hours and ascorbic acid priming for 12 hours partially maintained germination of chamomile (*Matricaria recutita, Chamemelum nobile*) . They also found decrease in accumulation of peroxide and MDA content under artificial ageing condition.

Kibinza et al., 2011, investigate the role of catalase in oxidation protection during accelerated ageing and extend of repair during subsequent priming treatment of Sunflower (*Helianthus annus* L.) seeds. Seeds after accelerated ageing for various periods were subjected to priming treatment reversed partially the ageing effect. The

result clearly indicated that priming induced catalase synthesis by activating expression and translation of the enzyme.

Sadhu et al.,2011, observed that short term soaking for 1 or 2 hours in dilute solutions of ascorbic acid (10^{-3}M) followed by drying was found very effective in retaining viability and vigour of bringal seeds in cloth bag as well as tin container than long term storage for 4 hours. Seeds receiving soaking drying treatments recorded more intense amylase activity than control.

Siadat et al. ,2012 found increase in anti oxidant enzyme activity (Catalase and peroxidase) after seed priming treatment with $KN0_3$ in maize seeds with an overall improvement in seed performance of aged and non-aged seeds especially for high aged seed.

(ii) Dry permeation of chemicals

Organic solvent such as ethyl alcohol or acetone have been used for improvement of germination in hard coated seeds as these solvents made the seed coats permeable (Cox et al., 1945; Crocker and Barton, 1953). Incorporation of bioactive chemicals into seeds via organic solvents was first suggested by Milborrow (1963). Tao et al. (1974) successfully prevented seed deterioration by using anti ageing compounds like actinomycin-D, antibiotics, Chloramphenicol in a medium of different organic solvents. Dey and Mukherjee (1988) successfully invigorated the seeds of maize and mustard by using chemicals like para amino benzoic acid, para hydroxybenzoic acid, α-tocopherol and caffeine through acetone. The organic solvents themselves had no adverse effect on seed germinability up to a 6 hour of soaking. Several chemicals such as potassium iodide, p-hydroxybezoic acid, tannic acid etc introduced into the mustard seed via acetone significantly minimize the loss of viability (Basu et al., 1980). Pea seeds treated with α-tocopherol and butylated hydroxyl anisole dissolved in acetone and then aged at 92% RH and 30^0c for up to 12 weeks retained the highest seed viability and vigour compared to non aerated seeds (Gorecki and Harman,1987).

Vanangamudi and Karivaratharaju (1986) treated pulse seeds with indole-3-butyric acid prior to storage to retard deterioration and maintain vigour and germination with minimum loss in seed quality for 48 months. Sing and Amritphale (1993) used solvents as dry permeation of GA_3 and benzyladenine into soybean seeds causing increased vigour of artificially and naturally aged seed.

(iii) Dry dressing treatment

Dry dressing of seed with halogenated compounds such as bleaching powder (major ingredient , calcium hypochlorite) or iodinated calcium carbonate or in the vapour forms of iodine , chlorine and bromine has been useful in a number of harvest fresh non-leguminous and leguminous seeds (Basu and Rudrapaul,1980; Mandal and Basu ,1986;Pal and Basu ,1988). Mandal and Basu (1986) reported that dry dressing of wheat seed with calcium hypochlorite (@2g/kg of seed) significantly reduce physiological as well as pathological deterioration during storage under accelerated and natural ageing conditions. Basu and coworkers tested a number of crude plants preparations which are generally used traditionally as spices and household preservatives. They found that treatment of high vigour (harvest-fresh) wheat seed with 500 mg of red chilli powder per kg of seed , 1 g of turmeric rhizome and nisinda leaf powder ,per kg of seed, bael , mango and vinca leaf powder and 1 g of trigonella seed powder per kg of seed significantly slowed down deterioration of seeds in storage (pal and Basu ,1993; 1994; Mandal et al. 1999 ; 2000) . They have also reported that acetyl salicylic acid (aspirin) , a plant derivative and widely used pharmaceutical formulations (Aspro), proved very effective even at a much lower concentration (50-100 mg per kg of seed).

Soybean seeds treated with potassium chloride and calcium chloride reduced accumulation of sodium chloride accumulation coupled with an adaptive control of hydrolytic activity (Guerrier –G, 1991).

Significant difference in terms of germinability and vigour were observed when different cultivars of wheat seed were treated with insecticides like aldrin, endosulfan, formothion and chloropyriophos (Kashyap,-R.K.; chowdhury,O.P.; Sheoran , I.S.,1994).

Duan-Qiang et al., 2012, reported that maize seed when dry dressed with imidachloprid proved to have higher seedling height, germination potential and vigour index over untreated control.

Increased germination percentage was reported by Gupta et al., 1993, when soybean seeds were treated with fungicides like benomyl , thiram and captan.

Shekaramurth et al., 1994, viewed that thiram treatment on sorghum seed delay the seed deterioration as the treated seed showed higher formazan content and lipoxygenase activity after six days of accelerated ageing.

Effect on dry treatment further envisaged by Rathinavel et al., 1999 during their experiment on effect of iodine treatment on the control of seed deterioration where they found increase germination rate, seedling growth, vigour and field emergence of cotton seed.

Mandal et al. in the year 2008 suggested that pre storage dry physiological treatment with red chilli powder and aspirin improve the germinability and field performance of sunflower.

Reshma et al., 2009 observed maximum germination of 74% after 12 months of storage when treated the hedge lucern seed with diflubenzuron followed by halogen 70% and bavistin 70%.

Mukhopadhayay, pal and Basu (1997) treated the soybean seeds with turmeric, nishinda leaf powder, Aspirin, celin and P-amino benzoic acid reported to have improved seed storability over untreated control.

Layek et al., 2006 suggested pre storage dry seed invigoration treatment of freshly harvested chick pea with bleaching powder @ 2 g/kg , aspirin @ 50 mg/kg and red chilli powder @ 1 g/kg of seed for improving storability and field performance.

Ramamoorthy et.al, 2009 revealed that permeation of halogen i.e. chlorine and iodine through calcium carbonate as carrier lower down the electrical conductivity and lipid peroxidation in black gram seed.

Loss of vigour and viability of high medium-vigour (harvest-fresh) sesamum seeds could be effectively controlled by pre storage dry treatment with aspirin @ 50 mg/kg of seed, bleaching powder @ 2 gm/kg of seed including soaking-drying treatment (Biswas et.al, 2012).

Pre storage dry seed treatments with red chilli powder (@1 g/kg of seed) and bleaching powder (@2g/kg of seed) as well as mid storage soaking-drying treatment effectively maintain germinability during storage period and also field performance of okra seed (Guha et. al,2012).

Pati et. al,2011 demonstrated that pre treatment of the pea seeds with leaf extract of bel (*Aegisel marmelos*) and Kalmegh (*Andrographis paniculata*) 50 mg in 250 ml of distilled water for six hours before accelerated ageing (100% R.H. and 30 ± 2^0c temperature) for 45 days have much better field performance than untreated control.

Aman et.al, 2005 pointed out that iodination of wheat seed retard the loss in membrane integrity possibly by stabilizing the unsaturated fatty acids of the membrane lipoproteins and hence minimizing the changes in membrane functions and development of rancidity in lipid component of cell organelles.

De et al., 2004 reported that dry physiological treatment with bleaching powder, red chilli powder resulted in improvement of germination percentage and field emergence of stored soybean seed with reduced lipid peroxidation and dehydrogenase enzyme activity.

Others treatments

Seed treatments has also been attempted with various forms of energy i.e. heat, light, magnetic fields, electrical treatments, ultrasound, noise, ionizing radiation and shock.

The germination of oil palm seeds has been improved by storing them for 90 days at 39.5^0c (wonky-Appiah, 1974) and that of okra seeds by exposure to 45^0c for 10 h (Onwueme, 1975). Babuchkin et al. (1974) reported that the irradiation of seeds with concentration of sunlight improved yield and quality of the resulting crop.

Pittman and his colleagues have reported the beneficial effects of magnetic pre sowing treatments using fields of 1500-1800 oersteds and exposure times of up to 240 h in several species of winter wheat (Pittman, 1967; pittman and Ormord , 1970).

Generally X-ray and γ-rays were disadvantageous, whilst electro-magnetic fields alone, of up to 300-oersteds, produced growth advantages in the plants, and there was evidence that electromagnetic treatments alleviated the effects of ionizing radiations on buck wheat (Zolyneck and Bicu, 1972; Zolyneck and penor, 1972). Mukhamedkhanov and Shermukhamedov (1971) reported that seed treatment with ultra-sound for 5-10 minutes improved the subsequent seedling growth of cotton.

Holm and Miller (1972) found that hot water soaks infrared radiation and ultra-sound could equally well improve seed germination of many week species. Singh et al. (1974) found that X-rays and thermal shocks (as well as thio-urea and ascorbic acid) could improve germination.