

ROLE OF MECHANICAL DAMAGE IN DETERIORATION OF SOYBEAN SEED QUALITY DURING STORAGE- A REVIEW

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ABSTRACT

Soybean seed quality is affected during pre and post harvest periods. The soybean seed is highly susceptible to mechanical injury and damage occurring during post harvest handling. The soybean seeds have only moderately thick seed coat. The orientation of the embryo within the seed and the nature of protection covering are important attributes of any seed that is subjected to the numerous mechanical and handling processes from harvest to planting. Seeds may receive internal fractures from impaction. These injuries were produced due to mechanical shock to the seeds and were greater with reduced seed moisture. The type and amount of mechanical damage caused during handling affect the viability and vigour of soybean seed during storage. The seed quality and viability during storage depend upon the initial quality of seed and the manner in which it is stored. The work on these aspects of soybean seed quality deterioration and factors responsible during post harvest handling has been reviewed in this article.

Soybean [*Glycine max* (L.) Merrill] is an important legume crop. Soybean has become a miracle crop of the twentieth century and is often designated as a 'Golden bean'. The soybean is a number one in world oil production and is a cheap source of protein for food and feed. The share of India in world soybean production in 1987 was conspicuously insignificant. It was producing only 1 per cent of the world's soybean. The important soybean producing countries in those years were the USA (52 %) followed by Brazil (17 %). Nowadays the importance of soybean in India has been recognized as indicated by the increased area under soybean to the tune of 62.50 lakh hectares which comes to 12 % of world's soybean (Anonymous, 2001). However, the average productivity of soybean in India is 13.92 q/ha. The average productivity of soybean in USA and Brazil is 26.2 and 22.9 q/ha, respectively (Anonymous, 1997). Thus there is a great potential to this crop in India.

The constraints in soybean production are becoming increasingly evident especially those associated with seed quality problems, which is dependent on the manner in which seeds are handled during harvesting, processing and storage. Loss of seed viability during

storage and resultant poor stand are the major constraints in soybean production in tropical and subtropical countries mainly owing to prevailing high temperature and high relative humidity (Wien and Kueneman, 1981). High quality seed that provides adequate plant stand is the basis for profitable production and expansion of this crop. In order to increase the production of soybean, a source of high quality, disease free seed must be established and maintained. Soybean seed deteriorates faster than those of most other crops (Priestley *et al.*, 1985) especially under tropical conditions (Delouche *et al.*, 1973). Two main factors appear to contribute to the low storability of soybean seed. Besides inherent poor storability, mechanical damage is one more factor strongly responsible for seed quality deterioration especially by small farmers in developing countries which has been overshadowed by more important problems such as storage deterioration, insect infestation and diseases (Wilson and McDonald Jr., 1992). Three factors affect the severity of threshing injury; one is threshing system, the environmental and the cultivar threshed. Seeds which are free from pathogens and mechanical damage can be expected to survive for longer period.

Deterioration due to mechanical damage

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Mechanical damage is major cause of soybean seed deterioration during storage. Soybean seed quality is greatly affected by method of harvesting and handling. In these operations, beans are subjected repeatedly to many impacts on metal surface and against other beans. In nearly all handling operations beans are accelerated to some velocity and then discharged on to stationary objects or other grains (Paulsen *et al.* 1981b).

Storability of soybean seed is greatly influenced by the degree to which they have deteriorated prior to storage. Soybean seeds are subjected to weathering before harvest, mechanical damage during harvesting, threshing, processing do not store well even though they have fairly good initial germination (Gupta, 1976). Physical seed damage can take many forms. In its severest form, physical seed damage is exhibited by splitting of the cotyledon and broken seeds. A more common form of readily visible physical seed damage is seed coat fractures which is difficult to remove through conditioning. During storage, injured or deeply bruised areas may serve as centers for infection and results in deterioration. Injuries close to vital parts of the embryonic axis or near the point of attachment of cotyledons to the axis usually bring about the most rapid losses of viability (Bewley and Black, 1984). Fabrizio *et al.* (1997) reported that high initial levels of mechanical injury or seed infection had little effect on rate of deterioration and storability as compared with sound seed lots. Reduction in germinability immediately after intensive mechanical injury has been reported by Moore (1972). A small injury has not been observed to cause an immediate loss in germination but with ageing during storage the injured portion will bring infection in adjoining healthy tissue which may produce abnormal seedlings ultimately reducing the germination

percentage. Mechanically damaged or broken seed coats permit early entry and easy access for microflora to enter the seed. Both the fungi and chemical damage reduce the keeping quality of stored seeds. Fiscus *et al.* (1971) studied the various handling techniques which causes physical damage of grains and concluded that corn incurred more breakage than soybean and soybean had more breakage than wheat. Stanway (1978) reported that germination of soybeans can be greatly affected by condition of the seed coat and cotyledons.

Paulsen and Nave (1979) developed an improved indoxyl acetate test for detecting seed coat cracks in soybean. The test was effective in finding higher levels of cracks and detected minute seed coat imperfections is as much as 16 % of the seeds that would have otherwise gone undetected by visual observation alone. McDonald Jr. (1985) stated that soybean seeds are particularly susceptible to physical seed damage. He reviewed the causes of physical seed damage and the mechanism to assess physical seed damage. Franca-Neto *et al.* (1988) evaluated soybean seed for multiple quality and reported that mechanical damage during harvesting was the most detrimental factor affecting the seed quality. Okabe (1996) observed that seed coat cracking of soybeans leads to the deterioration of seed quality. It also affects the storage ability of seed and decreases germination rates. Yadav and Sharma (1998) observed that the cracked seed coats reflect poor quality of seeds as they may be prone to imbibitional and pathogenic injury. Takahashi and Abe (1999) reported that the exposure of soybean to chilling temperature (15°C) at flowering induces browning around the hilum region and cracking of the seed coat. Both pigmentation and cracking degrade the commercial value of soybean. Rollan *et al.* (2001) stated that the poor quality in soybean can be due to physiological, pathological or mechanical causes. Seed morphological and anatomical features also

make soybean more susceptible to damage factors than other plant species. The damage factor had different influence on seed quality. Rotten seed and damaged cotyledons caused by moisture had a striking influence on seed quality and preservation during storage. Shelar, (2002) reported that the soybean seed threshed and processed by machine had lost viability rapidly as compared to the seed threshed by stick beating and processed by manual processing. The viability above MSCS was maintained for 300 days in JS-335 and for 240 days in MACS-124.

Role of Moisture Content in Mechanical Damage

Initial seed moisture content is another major factor, which affects storage life of seed through its effects on mediating damage by threshing and processing machinery and handling. Very dry seeds are susceptible to mechanical damage and related injuries. Such damage may result in physical damage or fracturing of essential seed parts, make the seed vulnerable to fungal attack and reduce storage potential (Justice and Bass, 1979).

Wilson and McDonald Jr. (1992) reported that higher quality seeds were produced by open flail threshing or hand shelling and observed average 65 % emergence in field plantings. Mechanical threshing reduced mean final stand to an average of 58 % but damage was much worse for large dry seed with field emergence dropping as low as an average of 39 % for seed threshed at seed moisture content of 8-10 %. Zang *et al.* (1995) stated that the activity of mitochondria increased only in seeds stored at 75 % RH, it reaches a maximum after the third month of storage and then rapidly declined. The major cause of the rapid deterioration of seed at 75 % RH at room temperature seems to be rapid development of mitochondrial respiration which accompanied by the consumption of CoA and its acetyl derivatives. Sonowski and

Kuzniar (1999) observed that the cultivar differed greatly in their susceptibility to mechanical damage at low moisture content range of 7-14 %. The optimum moisture content at which the damage was below 5 % was 13.1 %. Nave and Paulsen (1979) observed that percentage split increased as soybean moisture level decreased from 15 to 7 %. Large seeded varieties were more susceptible to mechanical damage than small seeds. Paulsen *et al.* (1981) stored soybean seed damaged by combine harvesting at 10.6 % moisture and reported that the percentage of split soybean was more than double as harvest moisture decreased from 16 to 12 %. Paulsen *et al.* (1981b) used a centrifugal impact or to impact soybean varieties at controlled velocities and stated that the percentage of split beans and fine material increased as the impact velocity was increased and as the seed mc decreased from 17 to 8 %. Burchett *et al.* (1985) reported that the seed lots of etched seed generally were found to have 18 % lower germination and were more susceptible to damage than non-etched seed lots. Bartsch *et al.* (1986) impacted soybean seeds at 8, 13 and 18 % mc at controlled orientation with velocity of 5, 10 and 15 m/s and the resulting damage was measured with TZ test. Impact damage increased significantly as mc dropped from 13 to 8 %. Direct impact to the radical produced the largest reduction in seed germination.

Parde *et.at.* (2002) studied the effect of seed cleaning and handling on soybean seed germination and physical integrity with changing seed moisture content. They also studied the damage resulting from free fall of soybean seed from different height. The vertical bucket elevator significantly decreased germination and increased splits and seed coat damage. The seed lots at 12 % m..c. (dry basis), suffered less loss in seed quality than the lots at 10% or 11% m.c. A free fall of soybean seed from different heights on to the cement floor

resulted in greater loss in quality than when dropped on to galvanized iron floor.

Effect of threshing methods

Soybean seed being inherently a weak structure is more prone to mechanical thrust which increases its deterioration (Tekrony *et al.*, 1987). However, seeds threshed by stick beating are least mechanically injured therefore, prolong the viability of seeds in storage period (Jha *et al.*, 1995). The low germination per cent was mainly due to the occurrence of high percentage of abnormal seedlings. The abnormality was due to the presence of scars on more than half of the cotyledon thus making it non-photosynthetic area and split hypocotyls. The presence of scar and split hypocotyls suggested that the seed either had received natural crushing or mechanical injury or both.

Shelar, (2002) reported that, the vigour index of soybean seed threshed by stick beating and processed manually was significantly higher than that of seeds threshed and processed by machine irrespective of varieties. The different threshing methods produces breaks, cracks, bruises and abrasions in seeds which in turn results in abnormal seedlings of questionable planting value. It is obvious from the available information that mechanical injury to seed not only reduces production of normal seedlings but also decreases the storage potential of damaged seed that apparently would have produced normal seedlings prior to storage. The obvious manifestation of physical seed damage include fractures of the radical or bruising of the cotyledons which are difficult to detect under the seed coat. In extreme instances damage to the radical can result in abnormal seedlings which fail to germinate. Any damage to the cotyledons is also concerns because it retards translocation of essential nutrients to growing embryonic axis which culminates in delayed seedling growth. Hahalis and Smith (1997) reported that root growth was more sensitive

to ageing than shoot growth in soybean. These findings suggest that seed deterioration is generally initiated in meristematic areas of the seed and that the radical tip may be most prone to deterioration. The plumule or embryonic stem is fairly well developed in the resting seed and lies between two cotyledons or seed leaves. Also the radical or embryonic root has practically no protection except that provided by the seed coat and thus it is unusually vulnerable to breakage especially when dry and roughly treated. The radical and plumule or cotyledon can be damaged. Moreover, the resistance is a genetic characteristic that varies among soybean cultivars (Carbonell and Krzyzonowski, 1995). Green *et al.* (1966) observed that hand harvested seed lots had higher viability and lower incidence of split and cracked seed coats than machine harvested seed lots. Within the machine harvested seed lots, harvesting at lower cylinder speed produced seed with higher percentage of normal seedlings, a lower percentage of split and cracked seed coats and larger average seed size.

Prakobban (1982) reported that seed threshed by hand have a higher germination percentage and lower percentage of abnormal seedlings than beaten and machine threshed seeds. At high initial moisture content (20 %), the threshing method did not affect seedlings abnormality when compared with threshing at low and medium moisture content (8-12 %). Saini *et al.* (1982) reported that soybean threshed by hand shelling maintained the maximum viability and vigour during storage. Threshing at 500 rpm caused the highest mechanical damage resulting in lower percentage of healthy seeds. Seeds obtained after threshing at 400 rpm and 500 rpm showed relatively greater loss in viability and vigour in storage. Loss in viability of seeds obtained by stick beating and threshing at 300 rpm were similar but gave significantly lower values than

hand shelled seeds. Kamble (1986) found that all the variables significantly influenced the germination capacity of seed. Sangakkara (1988) stated that seeds threshed mechanically and dried at higher temperature showed a higher percentage of infection by pathogen. This was more prominent when the seeds were stored at high RH and was reflected by the rapid development of fungal infection leading to rapid loss of germinability. In contrast, hand threshed seeds were relatively free of fungal infection. Kausal *et al.* (1991) threshed soybean cv. MACS-13, MACS-58, PK-472 and Moneta by stick beating, tractor treading or using thresher at 820, 600 or 400 rpm gave 2.4, 2.7, 8.2, 5.4 and 2.4 per cent mechanical damage, 85.8, 84.7, 71.6, 77.4 and 88.6 % germination and test weight of 10.07, 9.97, 9.67, 10.06 and 10.09 g, respectively. Murata *et al.* (1991) observed seed coat cracking in soybean increased with increasing machine speed. Giordano *et al.* (1992) observed that the toothed drum combine reduce grain threshing and separating losses by 55 % at 5.3 km/h and by 44 % at 7 km/h. Kausal *et al.* (1992) reported that mechanical damage to seed ranged from 7.5 % with bullock treading to 12.9 % with multi crop thresher and not significantly differed between the cultivars. Percentage germination and seed vigour index were highest with bullock treading and lowest with multi crop thresher.

Mesquita and Hanna (1993) reported that the energy required to thresh the soybean from one pod was 0.012 Joule, whereas the energy used by conventional combines to thresh soybean is four times the energy required by the rubbing belt device. Reddy *et al.* (1993) reported that beating of the sun dried soybean plants and pods with wooden stick by placing them on gunny bags on cement floor gave seed with fairly good quality and associated with higher recovery. Zdradzisc and Urbaniak (1993) combine harvested soybean using peripheral drum speed of 400, 500 or 600 rpm

and slit aperture of 9, 12 or 15 mm. and stated that the amount of seed damage was decreased with increasing drum speed and decreased with increasing slit aperture. Jha *et al.* (1996) reported that percentage of mechanical damage were not significant for varieties. Ujjinaiah and Shreedhara (1998) recorded significantly higher mechanical damage of 6.55 % in multi crop thresher as compared to beating with stick (2.33 %). The longevity was prolonged up to 15 months, whereas multi crop thresher used seeds could retained only for eight months. Non-significant differences were observed for different moisture levels tried for threshing.

Roberts (1972) stated that the small and spherical seeds generally escape injury caused due to mechanical damage during harvesting, handling and processing and tends to suffer less damage, whereas larger or irregularly shaped and elongated seeds are more likely to be extensively damaged. The large cotyledons and the location of the embryo axis represent a structure that will tolerate only low level of impact. Paulsen *et al.* (1981a) found that percentage split and seed coat damage were greater for varieties having bold seed size. Lignin content of the soybean seed coat plays an important role in resistance to mechanical damage (Alvarez *et al.*, 1997). They reported that higher the percentage of lignin content in the seed coat, higher is the resistance to mechanical damage. Patil and Suryawanshi (2001) observed higher resistance to mechanical damage in variety JS-335 due to high lignin content in seed coat as compared to MACS-124. However, they found negative correlation of seed coat thickness and resistance to mechanical damage and stated that in spite of thin seed coat but higher lignin content in variety JS-335 it was more resistant to mechanical damage as compared to variety MACS-124. Sharma *et al.* (2001) studied the difference between mechanical and manual post harvest handling of soybean seed. They observed 14-36% mechanical damage due to mechanical

handling as against insignificant due to manual handling. They reported less damage associated with higher moisture content at the time of processing. The genotypic susceptibility to mechanical damage as influenced by seed size and moisture was also discussed by them.

Effect of Processing methods

During processing, seed is frequently moved through suction type conveyors at great speed and force, impacting with metal at curves and bends and fell great distance as well as horizontal seed movements. This might have resulted in considerable breakage and damage in machine processing as compared to manual processing. Many studies indicated that even minimal drop of 5 ft. can create a reduction in seed quality of soybean. Delouche (1972) demonstrated that soybean seed dropped from 0 to 20 ft exhibited increased damage as measured by per cent seed germination. Misra *et al.* (1985) observed that air screen cleaner and the gravity separator improved the quality of soybean seed lots. Seed lots below 10 % moisture declined in germination as a result of conditioning. Temperature influenced the amount of split produced during conditioning. Vieira *et al.* (1994) reported that seed quality was reduced as storage period increased. Seed processing can increase seed quality depending on cultivar and the initial seed quality.

Storage containers

The rate of loss of germination varied with the container. Maurya (1971) reported that the seed viability could be extended if stored in polycoated Hessian bags as compared to seeds stored in Hessian bags. Further, he stated that the difference was not carried out too far if moisture content of seed in polycoated Hessian bags is high. Srivastava (1976), Justice and Bass (1979) and Vanangud and Ramaswamy (1984) also demonstrated the superiority of moisture vapour impervious containers over the ordinary moisture pervious containers for successful carryover of seed. The soybean seed

stored in polylined gunny bags had higher germination percentage than the germination percentage of soybean seed stored in gunny bags during storage irrespective of varieties, threshing and processing methods (Shelar, 2002). The seeds stored in polylined gunny bags had got very less fluctuations in their moisture content which is very important factor in maintaining the viability of the seed during storage and seeds are kept away from the contact of oxygen, which is deleterious to seed storage. Reducing the quantity of oxygen around the seed might also decrease the initiation of free radicals (McDonald, 1999). This may be one of the reasons for the success of storing seed for longer periods in hermetically sealed containers.

The RS length of seedlings of seed stored in polylined gunny bags was significantly higher during storage as compared to gunny bag. The RS length of variety JS-335 was higher than the variety MACS-124 (Shelar, 2002). These findings are in contrast with those reported by (Arulnandhy and Senanayake, 1988) stated that large seeds had longer RS length than the small seeds. However, the dry matter content of variety MACS-124 was higher, may be due to higher seed weight, and its cotyledonary and primary leaf area (Shibles *et al.*, 1975). Higher viability and vigour of seed were associated with polythene bags which minimized the moisture fluctuation of seed in storage. The moisture content of the soybean seeds stored in polylined gunny bags is significantly lower with less fluctuations than the seeds stored in gunny bags irrespective of varieties, threshing and processing methods (Shelar 2002). This could be due to less permeability of medium and high density polythene films to moisture vapour. Justice and Bass (1978) reported that high and medium density polythene tested at 37.8° C and 100 % RH will permit 0.3 – 0.7 g moisture vapour through 100 sq. inches of film during 24 hours. Similarly, Barton (1949) and (1953) stated that

the thin gauge of polythene and similar material do not provide very much moisture protection. The water vapour transmission rate of polythene material is inversely proportional to their protective value for seed storage under tropical, temperate and warehouse conditions (Ching and Abu Shakra, 1965).

Byrd and Delouche (1971), Rodda and Ravalo (1978), Ravalo *et al.* (1980), Arulnandhy *et al.* (1984) also reported that one of the most important factor affecting viability of seed in storage is the seed moisture content. Srivastava (1976) stated that the loss in viability of soybean is minimised if stored with 10.5 ± 0.5 % moisture and in polythene bags of 300 gauge. Bags should be tightly sealed and kept at $12 \pm 1^{\circ}\text{C}$.

Ravalo *et al.* (1980) stated that the successful storage require protection against moisture absorption from the atmosphere. The loss of seed viability was associated with a marked gain in seed moisture during storage. El-Bagoury *et al.* (1986) observed that 100 seed weight varied between cultivars but was not affected by storage containers. Underground storage had decreased germination percentage as compared with other storage conditions. Vanangmudi (1988) reported that seeds stored in paper alluminium foil, polyethylene laminated pouches showed higher viability and vigour than those stored in cloth bags. Arulnandhy and

Senanayake (1988) reported that seeds in polyethylene bags maintained significantly higher viability and vigour for 9 months as compared to 3 months by seeds in other containers. Sealed polyethylene bags which minimizes fluctuation in stored seeds may be the appropriate container for storing soybean seeds in the humid tropics, however, seed must be dried to around 9 % moisture content before storage. Singh and Singh (1992) observed that at 10 % moisture, seed could be stored in sealed containers for only 6 months before losing viability while at 4.3 % mc 90 % germination was retained after 28 months storage at room temperature. At 10 % moisture content seed could be stored for 12 months in gunny bags. Phor *et al.* (1994) stored two cultivars of soybean viz., PK-327 and kalitur in various containers and reported that both the cultivars satisfactorily maintained the germination potential up to next planting season.

Thus the seed quality of soybean during storage is greatly influenced by mechanical damage, if proper management of threshing and processing methods, moisture content of seed during storage, storage conditions, storage containers is not done we may deprive of good quality seed.

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