Chapter – V

Discussion
Soybean has become a miracle crop of the twentieth century and is often designated as a “Golden bean”. 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 the storage. The environmental and physiological factors are also involved in loss of seed viability during storage and resultant is poor plant stand are the major constraints in soybean seed production in the tropical countries. High quality seed that provides adequate plant stand is the basis for profitable production and expansion of this crop. Loss of seed viability and vigour under high temperature and RH conditions is a common phenomenon in many crop seeds but it is well marked in soybean. Soybean seed deteriorates faster than those of most other crops. Several factors appears to contribute to the low storability and quality of soybean seed.

An investigation was carried out to study the “Seed Quality of Soybean (Glycine max (L.) Merrill) as Influenced by Environment.” Availability of quality seed in general is a prerequisite to boost up productivity of any crop. Soybean is a
triple beneficiary crop as it supplies a unique food, valuable feed and an industrial raw material with considerable potential. The soybean ranks first position in oil production in the world and is a cheap source of protein. The soybean seed has greater industrial value both in India and abroad with greater export potential. The area under soybean cultivation is increasing in India and concentrated in Maharashtra, specially in Marathwada region.

The maintenance of seed quality (viability) is a main problem in soybean as a seed from harvest to next sowing. The literature is available on effect of different factors on seed viability describing their impact individually, but a combined impact of season’s, varieties and storage containers during storage is not traceable in the available literature. Therefore, present investigation, aim to study combining impact of various treatments on seed quality parameters. The results obtained during these investigation are discussed in this chapter.

5.1 Effect of Seasons on Seed Production Feasibility

5.1.1 Influence of season on different parameters of soybean varieties

In the present investigation, soybean varieties exhibited significant differences amongst seed yield in all the three seasons. (Table 4.4) In general the yield qt/ha in soybean varieties was significantly higher in kharif followed by summer as compared to rabi season. Taware et al. (1994) also found considerable seasonal variations in grain yield of soybean. Kharif season was indicated as the most favourable season for soybean
seed production. Similarly, Sen and Mukharjee (1986) studied the potentialities of soybeans and found that *kharif* and late *kharif* are the more favourable season for soybean cultivation. Shelar (2002) also studied the performance of soybean seed production in different seasons i.e. *kharif*, *rabi* and summer and found that the *kharif* as the best season for seed production of soybean followed by summer irrespective of varieties. Borade (1998) studied the seasonal performance of eight soybean genotype in respect of yield in *kharif*, *rabi* and summer season and found that in general in *kharif*, grain yield are more as compared to *rabi* and summer.

The variety MAUS-71 followed by MAUS-81, JS-335 and MAUS-61 recorded significantly highest seed yield over MAUS-47 in all the seasons. Anonymous (2004) strongly supported that the variety MAUS-71 followed by MAUS-81, JS-335 and MAUS-61 recorded highest seed yield during Breeder seed production programme-2003-04.

The differences in number of pods/Plant, number of seed/Plant, seed weight/Plant and 100 seed weight(g) were found significant among the varieties in *kharif*, *rabi* and summer season. The highest number of pods/plant, number of seed/plant, seed weight/plant and 100 seed weight (g) were found in *kharif* followed by summer season, whereas, it was lowest in *rabi* season. The variety MAUS-71 followed by MAUS-81 was recorded significantly highest number of pods/plant, number of seed/plant and seed weight/plant, than other varieties.
Whereas, the 100 seed weight (g) was significantly highest in variety MAUS-61 than all other varieties. In soybean, varietial and seasonal differences in respect of different characters were also reported by Hudge *et al.* (1982), Raut *et al.* (1992), Shahidullah *et al.* (1997), Shelar (2002), Taware *et al.* (1994), Borade (1998) and Anderson and Vasillas (1985).

The plant density at harvest was significantly differentiates among the varieties in *kharif, rabi* and summer season. The highest plant density at harvest was recorded in *kharif* as compared to *rabi* and summer season. The highest plant density at harvest was recorded in MAUS-71 followed by MAUS-81 than all other varieties. Similar results were also reported by Hudge *et al.*(1982), Paschal and Ellis(1978) and Neumaier *et al.*(1979).

The differences in days to 50% flowering and maturity were significant among the varieties in all the three season. The minimum days to 50% flowering and maturity were required in *kharif* followed by summer than *rabi* season. Whereas, the maximum days to 50% flowering and maturity were required in *rabi* season. The variety MAUS-47 taken significantly minimum days to 50% flowering and maturity in all the three seasons than other varieties. The maximum days to 50% flowering was taken by variety MAUS-61. Whereas, the maximum days to maturity was taken by variety JS-335 in *kharif* and MAUS-61 in *rabi* and summer season. Similar results were reported by Taware *et al.* (1994), Sarmah *et al.* (1984) and Shelar (2002).
There were significant differences in plant height and number of nodes/plant of soybean varieties in all the seasons *viz.* *kharif*, *rabi* and summer. The plant height and number of nodes/plant were found to be highest in *kharif* followed by summer than *rabi* season. The variety MAUS-61 was found to be highest in plant height and number of nodes/plant than other varieties. Whereas, the plant height and number of nodes/plant were found to be lowest in variety MAUS-47. In soybean, the differences in plant height and number of nodes/plant were also reported by Hudge *et al.* (1982), Raut *et al.* (1992), Shelar (2002) and Borade (1998).

### 5.1.2 Influence of Season on Maturity and Seed Yield in Soybean

Seed yield is an expression of the integrated effect of genetic makeup of the cultivar and the climatic factors against which the growth and development occurs. In broad sense, the maturity period can be considered as a sum of time period required for the vegetative growth to the reproductive stage. Mehetre and Jamdagni (1997) reported that the average pre-flowering period is 39 days, whereas, the post-flowering period is 55 days in soybean. They also reported that the soybean is characterised by concurrent occurrence of vegetative and reproductive phase.

In present investigation, the average pre-flowering period of the five genotypes over three seasons was found to be 41.60 days, whereas, the post-flowering and pod development period was 57.08 days making 98.68 days as an average duration of
soybean crop when taken over three seasons. The average number of pods/plant of the five genotypes over the three seasons were 46.84, whereas, the average seed yield was 16.31 qt/ha. (Table 4.2 and Fig. 5.1)

The critical persuasal of coefficient of variation revealed that there was a maximum fluctuation for seed yield (CV=13.36%) followed by pods/plant (CV=5.20%). Among the two components of maturity period the pod development period had least magnitude of coefficient of variation (CV=4.70%), whereas, pre-flowering period had high coefficient of variation (CV=6.43%). The variation for maturity period was very less (CV=2.82%). This clearly indicated that the average maturity and pod development period were less affected either by genetic makeup or by climatic factors. The pre-flowering period is greatly influenced by the genetic constitution as well as season of cultivation. The fluctuation in length of pre-flowering period could be considered as the basis for instability in expression of number of pods per plant and seed yield of the genotypes over season. Further, it could also be concluded that the effect of fluctuation in pre-flowering is amplified while expressing the performance in terms of number of pods and seed yield.

Identification of individual genotypes, which can perform consistently under all kinds of season, yield is a important character, which is principally determined by number of pods per plant. In present investigation, the highest mean seed yield was obtained from MAUS-71 (17.82 qt/ha) over three seasons
Figure 5.1
Influence of Season on Maturity and Yield in Soybean

![Bar chart showing the influence of season on maturity and yield in soybean. The seasons compared are Kharif, Rabi, and Summer. Each season has different varieties, JS-335, MAUS-81, MAUS-71, MAUS-47, and MAUS-61. The graph displays the days to maturity and seed yield (qt/ha).]
followed by MAUS-81 (17.52 Q/ha), JS-335 (16.63 qt/ha) and MAUS-61 (16.09 qt/ha) over three seasons. The MAUS-47 had significantly low average yield (13.48 Q/ha). The critical perusal of magnitude of co-efficient of variation for seed yield indicated that highest yield of genotype MAUS-71 had very low magnitude of co-efficient of variation (CV=12.07%) suggesting stable behaviour over three seasons followed by MAUS-81, JS-335 & MAUS-61 with 12.43%, 12.94% and 13.37% respectively suggesting stable behaviour over three seasons. The genotype MAUS-47 was characterised by maximum magnitude of co-efficient of variation (CV=15.99) with lowest average seed yield indicating the most unstable nature for yield performance. High yield performance with stable consistency is the prime object for practical purpose. The MAUS-71 could be regarded as the most ideal type as it had first ranking in yield performance (17.82 Q/ha) and low magnitude of co-efficient of variation (12.07%) over seasons. Secondly MAUS-81 was also found the most ideal type as it ranks second ranking in yield performance (17.52 Q/ha) and low magnitude of co-efficient of variation (12.43%) over seasons. From the forgoing discussion, it can be concluded that the maturity period is the sum of length of pre-flowering period and pod development among these the pre-flowering period is greatly influenced by seasonal variation, whereas, pod development and maturity are relatively stable. The fluctuation in yield and number of pods plant is the amplified effect of variation in pre-flowering period occurring
under the influence of seasonal changes. The genotypes MAUS-71 and MAUS-81 were found most ideal for year round cultivation as it has high yield potential, least co-efficient of variation and highest number of pods/plant. These results are in agreement with Sahoo et al. (1991), Nian et al. (1996), Mehetre and Jamdagni (1997) and Shelar (2002).

5.2 Effect of environments, varieties and storage containers on different seed quality parameters of soybean seed during storage

Physico-physiological Components

5.2.1 Germination (%)

The germination of soybean seed from various treatments during storage period has been shown in Table 4.13 and Fig. 5.2.

In present investigation seed quality of soybean was influenced by environments, varieties and storage containers during storage. It was revealed that the germination of different seasons seed was found decreased during storage irrespective of varieties and storage containers. The decrease in seed germination was more pronounced in rabi season than kharif and summer. Thus stated that the soybean seed crop grown during kharif followed by summer were known to produce better quality seed than crop grown in rabi season. A comparison of kharif, rabi and summer seasons were attributed to early morning fog or dew, fluctuation in temperature and high or low humidity before and during the harvest are the some of important factors that determine seed quality. The work on influence of climatic factors on soybean seed quality is
Figure 5.2
Effect of Main Factors on Germination of Soybean Seed during Storage
limited for production of quality seed parameter. Hunter Andrew (1982) reported that in rabi season, the early morning fog or dew and low humidity before and during the harvest are some of factors, which determines the seed quality of soybean. Reddy et al. (1995) also reported that the soybean seed grown in kharif was found superior in seed quality and storability as compared to rabi season. Neumajer et al. (1979) reported that the lowest seed germination percentage was found in early cultures of soybean sown in October.

The crop seeds attained physiological maturity and if it rained at this time, seeds of poor quality were produced and it deteriorate the seed quality. Seed harvested after completion of monsoon were of better quality and had a lower incidence of seed-borne fungi than seeds harvested during the monsoon. Alternate wetting and drying, which can occur at the end of the monsoon season is detrimental to soybean seed (Nicholus and Sinclair, 1973). Taware et al. (1994) revealed that the kharif season was the most favourable season for soybean seed production and seed quality than summer season. Shelar (2002) also reported that the kharif season followed by summer season was the most favourable season for soybean seed production and seed quality than rabi season. Adam et al. (1989) reported that standard germination, seedling growth rate and vigour test indicated that late planting and late harvesting enhanced seed quality. Seed quality in terms of germination percentage was generally higher with the latest sowing dates (Bhering et al.,
1991). Some of the genotypes of soybean were highly prone to seed deterioration due to field weathering and delayed harvesting coupled with rains or high humidity further aggravates the problems (Bhatia et al., 1996). In summer season, the standard germination 90% at RH-7 but declined to near 50% by RH-8 (Horlings et al., 1991).

The viability of seed tested by germination test indicated that the viability of seed was significantly higher in seed of kharif season followed by summer season than rabi season during storage. All the seasons were showed germination percentage above seed certification standard (70%) up to 330 days of storage period. As storage increases germination was found to decreases in all seasons. Soybean seed of kharif, rabi and summer seasons were maintained germination above certification standard for 360, 330 and 360 days respectively, whereas, the viability of seed tested by TZ test also indicated that kharif, rabi and summer seasons were maintained germination above certification standard for 360, 360 and 390 days respectively. The seed viability tested by TZ test was more by 30 days for rabi and summer season than germination test, whereas the viability of seed tested by TZ test and germination test were similar during kharif season.

The germination of soybean varieties was found to have decreased during storage irrespective of varieties, environments and storage containers. The decrease was more pronounced in the variety MAUS-61 than MAUS-71 and MAUS-47. The variation in
speed of deterioration of seed of soybean varieties is a genetic character. Soybean genotypes differ in their ability to maintain seed longevity (Wien and Kueneman, 1981). The decrease in germination could be attributed to the deterioration in soybean seed during storage. The longevity of seed in storage is influenced by four major factors viz. (i) genetics, (ii) quality of the seed at the time of storage, (iii) moisture content of seed or ambient RH and (iv) temperature of storage environment (Gupta, 1976).

In the present investigation, the viability of soybean variety MAUS-71, MAUS-47 and MAUS-61 could be maintained up to certification standard for 420, 360 and 300 days, respectively. The viability was maintained more by 60 and 120 days in MAUS-47 and MAUS-71 respectively. Soybean seed maintained minimum germination standard for 14 months in MAUS-71, 12 months in MAUS-47 and 10 months in MAUS-61 at ambient temperature. These results are in confirmation with the findings of Calton and Hartwing (1971). Differential storability of various species was attributed to genetics, species and varietal characters (Kurdikeri et al., 2000). Kuenman and Wein (1983) also reported that the there are some genotypes which can be stored for longer period under ambient condition due to genetic control of seed longivity in soybean. The bold seeded soybean genotypes showed quick fall in germination percentage, while medium seeded genotypes showed steady fall in germination percentage (Jawle et al., 2001). The small seeded lines had the
best seed quality in terms of germination percentage in the summer season (Anonymous, 1988). Delouches (1974) reported that soybean seed lots cannot be stored for two consecutive planting seasons. The deterioration processes begin since from seed development. During seed development, anabolic process predominate and bring about gradual decrease in dry matter including development of an embryo and food reserve following maturation, biochemical changes continue and eventually catabolic process predominates and deterioration becomes apparent. Catabolic changes occur more slowly under low temperature and low relative humidity than under high temperature and high relative humidity could be the reason for fast deterioration after 210 days of storage (Justice and Bass, 1979). Changes associated with seed deterioration are depletion in food reserve, increased enzyme activity, increased fat acidity and membrane permeability. As the catabolic changes continue with increasing age, the ability of the seed to germinate is reduced. Decline in viability or germination capacity does not begin immediately after maturation. Under favourable storage conditions, the initiation of decline in germination may be from few months to many years depending on storage conditions, kind of seed and conditions during seed development.

The significant differences in viability of seeds obtained from different treatments combinations were observed for all the varieties. Many factors contribute to loss of seed quality. Generally, these can be classified into either physical or
physiological categories. Physical seed quality is associated with visible manifestations of the structure or physical appearance of the seed, such as fracture of the seed coat or a lesion in the embryo. Physiological seed quality is related to changes in cellular metabolism. As seed deteriorates a cascade of disorganisation ensures ultimately leading to complete lack of function and cell death. Studies examining seed deterioration invariably find physical, physiological effects. The current model of seed deterioration accepts lipid peroxidation as a central theme causing cellular degeneration through free radical assault on important cellular molecules and structures. Lipid peroxidation has been suggested as the cause of loss of soybean seed viability (Sung, 1996).

The mechanism of lipid peroxidation is often initiated by oxygen around unsaturated or polyunsaturated fatty acids such as oleic and linoleic acid found commonly in seed membranes. Result is the release of free radicals. Once these free radicals are initiated they create profound damage to membrane and continue to propagate other free radicals, which ultimately combine terminating the destructive reactions. Free radical assault may cause lipid peroxidation that destroys the nuclear membrane and ultimately cause DNA degradation. This could lead to faulty DNA synthesis and poor mRNA transcription culminating in reduced synthesis of enzyme critical for the earliest stage of germination (McDonald, 1999).
Both the losses of membrane integrity and decrease in the proportion of unsaturated fatty acids have been reported as seed deteriorates. It is suggested that seed deterioration is generally initiated in meristematic areas of the seed and the embryonic axes were the most sensitive seed part to deterioration in soybean (Seneratna et al., 1998). Amable and Obendrof (1986) also found a decrease in oxygen consumption with soybean seed aging and proposed that the mitochondria may be the site of most sensitive to deterioration. The general consensus is that DNA is somehow degraded leading to impaired transcription causing incomplete or faulty enzyme synthesis essential for the earliest stage of germination. Without enzyme activity, storage reserves are not hydrolyzed and energy molecules remain unavailable for the synthesis of ATP.

Storability of soybean seed is greatly influenced by the degree of which they have deteriorated prior to storage. Soybean seeds are subjected to weathering before harvest, mechanical damage during harvesting, threshing and 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 seed. A more common form of readily visible physical seed damage is seed coat fractures, which is difficult to remove through conditioning.

In spite of higher initial germination of MAUS-71 (90.50%), MAUS-47 (88%) and MAUS-61 (88.28%), the decrease in seed
viability of variety MAUS-61 was more sharp and rapid at later stages of storage. Mechanical damage inflicted during harvesting can severely reduce the viability of seeds could be the reason for sharp decrease in MAUS-61. During storage, injured or deeply brushed areas may serve as centres 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).

Mechanically damaged or broken seed coats permit early entry and easy access for microflora to enter the seed. Broken or cracked seed coat also enhance embryo damage by chemical treatment including chemicals used for disinfectants (Byrd and Delouche, 1971). Both the fungi and chemical damage reduce the keeping quality of stored seeds.

Soybean seed being inherently a weak structure is more prone to mechanical crusts, which increases its deterioration (Tekrony et al., 1987). 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 seed either had received natural crushing or mechanical injury or both (Shelar, 2002).

The viability of the variety MAUS-71 was found higher from initial stage, whereas, MAUS-61 was at par with MAUS-47 at 60
days. However, after 120 days of storage the varieties MAUS-47 had higher germination. This could be attributed to the smaller seed size of the variety MAUS-71 and MAUS-47 than MAUS-61. Seed viability in storage is a genetic character and is influenced by species and varieties (Delouche et al., 1973). Large seed size has been linked with better germination and seedling vigour, it has not been found to be true with some crops like chickpea and soybean (Bhor et al., 1988). Wien and Kueneman (1981) observed superior storability of soybean seeds of smaller size as compared to larger seeds. Longer seeds deteriorate faster than small seeds. Verma and Gupta (1975) observed that the small seed was found to deteriorate slowly than large seeds. 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 infection in adjoining healthy tissue which may produce abnormal seedlings ultimately reducing the germination percentage. This could be the possible reason due to which the variety MAUS-61 showed less germination during storage period.

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 environments and varieties. 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. The results suggest that soybean seed stored in polylined gunny bags are liable with least amount of viability (MSCS) to a greater extent as compared to seed in gunny bag when stored under ambient conditions, one more proposal, which is consistent with the success of hermatic i.e. polylined gunny bags seed storage pertaining to this research studies might be that the 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. This may be one of the reasons for the success of storing seed for longer periods in hermetically sealed containers. Reducing the exposure of seed to oxygen may retard seed deterioration (McDonald, 1999). The rate of loss of germination various with the container. The germination of seeds stored in polylined gunny bags declined at very slow rate (Shelar, 2002). The seed viability could be extended if stored in polycoated Hessian bags as compared to seeds stored in Hessian bags (Maurya, 1971). Further, he stated that the difference was not carried out too far if moisture content of seed in polycoated Hessian bags was high. These results are in agreement with those reported by Srivastava (1976). Justice and Bass (1979) and Vanangud and Ramaswamy (1984) who demonstrated the superiority of moisture vapour impervious containers over the ordinary moisture pervious containers for successful carryover of seed. Karivaratharaju et al. (1987) and Jawale et al. (2001) also
reported that the seed stored in polylined cloth bags showed more germination percentage than seed stored in cloth bags.

5.2.2 Root-Shoot Length, Vigour Index and Dry Matter Content

The effect of environments, varieties and storage container on RS length, vigour index and dry matter content of seedling of soybean seed during storage have depicted in Fig. 5.3, 5.4, and 5.5 and presented in Table 4.14, 4.15 and 4.16.

In the present investigation, it was observed that the RS length, vigour index and dry matter of the seedlings of soybean seed found to have decreased irrespective of environments, varieties during storage. The decrease in RS length of seedling of soybean seed could be ascribed to the ageing or deterioration of seed, which is progressive process accompanied by accumulation of metabolites, which progressively depress germination and growth of seedling with increased age (Floris, 1970); ultimately reducing the dry matter and vigour of soybean seed during storage. The RS length and dry matter content of seed stored in gunny bags was found to be significantly lower than the seeds stored in polylined gunny bags. This could be ascribed to low percentage of germination of these seeds during subsequent storage periods and the slow senescence or deterioration of soybean seed stored in polylined gunny bags as compared to gunny bag. One of the first indications of deteriorated seed is shown by the reduced rate of germination and production of weak or watery seedlings, seedling with stunted radicals. Seedling growth is considered to be important
tool that can be used for assessing the magnitude of deterioration (Toole et al., 1957). Relative poor growth in terms of radical, hypocotyls and leaf length was observed in highly deteriorated lots (Srivastava and Gill, 1975a) resulting in low vigour as seed deteriorates during storage.

Mitochondria provide ATP necessary for rapid seedling growth during germination. Lipid peroxidation that results in loss of intact membrane in the cristae thereby decreasing the amount of ATP formed during germination and Mitochondrial DNA present in the nucleus is a prime target of free radical assault damage to mitochondrial DNA would manifest itself in poor replication of mitochondria during cell division.
Figure 5.3
Effect of Main Factors on Root-Shoot Length of Soybean Seed during Storage
Figure 5.4
Effect of Main Factors on Seedling Vigour Index of Soybean Seed during Storage
Figure 5.5
Effect of Main Factors on Dry Matter Content of Soybean Seed during Storage
Thus, the seed deterioration may lead to reduced seedling growth as a consequence of both lower respiration and reduced mitochondria in cells (McDonald, 1999).

The RS length, vigour index and dry matter content was significantly higher in seed of *kharif* season followed by summer season than that of in seed of *rabi* season. Arulnandhy and Senanayake (1988) reported that the root shoot length and seedling vigour were decreased more by delay in harvesting in the wet season than dry season. Egli (1975) reported increased seed viability and vigour when seed crop sown in July as compared to May planting. Germination, root-shoot length, seedling dry weight and vigour index were higher in early two dates of sowing. Late sowing reduced seedling vigour components (Prijil *et al.*, 1984). Seed germination and seedling vigour components (RS length, vigour index) are the major aspects of deciding higher productivity because of plant population depends upon healthy and vigorous growth of seedlings which is possible mainly by the use of better quality seeds for the sowing purpose. The RS length, vigour index and dry matter content were found to be gradually decreased with advancement of storage period in all the seasons. The vigour of the seeds at the time of storage is an important factor that affect their storage life. Seeds of most crop species are mature when they attain maximum dry weight. Most seeds are physiologically mature at this point. When physiologically mature, the seed possesses its greatest vigour. From this point, it gradually loses
vigour and eventually dies. The rate in decline is conditioned by several factors, including genetic constitution of the species or cultivar, condition of the seed, storage condition, uniformity of seed lot. Loss of vigour can be thought as an intermediate stage in the life of the seed, occurring between the onset and termination of death.

The less percentage of mechanical damage during harvesting and threshing to the seed may be one of the causes for reduction in RS length of the seedlings of soybean seed. The threshing produces breaks, cracks, bruises and abrasions in seed which in turn results in abnormal seedling of questionable planting value. 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. This could be the reason for significant difference in RS length during storage period.

The physical seed damage include fractures of the radical or bruising of the cotyledons which are difficult to detect under the seed coat and produces seedlings with short stubby root and or weak root system which perform poorly in the field. In extreme instances damage to the radical can result in abnormal seedlings which fail to germinate. Any damage to 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 area of the seed and that the radical tip may be most prone to deterioration.

The RS length of seedling of variety MAUS-71 followed by MAUS-61 was significantly higher than the RS length of seedling of the variety MAUS-47. These findings are in contrast with those reported by (Arulnandhy and Senanayake, 1988) stated that large seeds had longer RS length than the small seed. The vigour index of soybean seed of variety MAUS-71 followed by MAUS-61 was significantly higher than the vigour index of variety MAUS-47 during all the periods of storage. Agrawal and Gupta (1975) were also reported varietal differences in seedling vigour of soybean seed. However, the dry matter content of variety MAUS-61 had significantly higher upto 330 days of storage than variety MAUS-71 and MAUS-47. After 330 days of storage, the dry matter content of MAUS-71 had higher than MAUS-61. This could be attributed to higher seed weight, and its cotyledonary and primary leaf area (Shibles et al., 1975). Also the seedling of variety MAUS-61 was robust but shorter than the variety MAUS-71. This might be mainly due to more initial capital in large seeds as compared to lesser food reserve in small seeds. These results are in confirmation with the finding of Shelar (2002). Burris et al. (1971) also reported that root-shoot length of soybean seedling increased with decreased in seed size.
5.2.3 Moisture Content

The moisture content of soybean seed differed significantly due to various treatments have been shown in Fig. 5.6 and presented in Table 4.17.

The moisture content of soybean seed differed significantly due to environments, varieties and storage containers during storage. From the data it is observed that the seed losses the water and showed decreasing trend in seed moisture content of *kharif* season up to 180 days and upto 120 days of *rabi* season. However, in summer season the minimum moisture content was noticed at initial stage i.e. at 60 days of storage.

During these storage periods and seasons the moisture content of seed could be ascribed to the low relative humidity and low temperature, thereafter low RH and high temperature might have resulted in low moisture content of seed as compared to the initial moisture content. The first rain of the seasons during the conduct of experiment was received on 24th meteorological week, resulting in increase in RH (Annexure - I) which had reflected in increasing moisture content of seed by attaining the equilibrium moisture content (EMC) of the seed with prevailing RH of the atmosphere with subsequent increase in storage period.

High seed moisture content is the most important single factor governing loss of germinability during storage. Seeds are hygroscopic, they absorb or lose moisture until the vapour pressure of seed moisture and atmospheric moisture reach
Figure 5.6
Effect of Main Factors on Moisture Content of Soybean Seed during Storage
equilibrium. The seed moisture content attained under these conditions is referred to as equilibrium moisture content. The EMC in seed at given RH decrease slowly with increasing temperature. Therefore, low seed moisture content was due to the RH which was prevailing during seed storage upto 180 days, 120 days and 60 days in seeds of kharif, rabi and summer seasons, respectively.

The results are analogous with those reported by Gupta (1976) who stated that in winter, seed is protected by low temperature and during early summer, the seed is protected by low humidity. The temperature generally rises from March onwards while RH goes down making storage safe for soybean. From late June or early July the RH rises and the bulk storage become problem.

After 180, 120 and 60 days of storage of kharif, rabi and summer seasons, respectively, the seed moisture content rises with subsequent rise in storage period irrespective of varieties and storage containers. The soybean seed imbibe high amount of water to create equilibrium inside and outside the seed. The hydrophilic nature of high protein content of soybean (Hartwing and Potts, 1987) helps in more absorption of water and high oil content in seed increases deterioration of seed (Potts, 1972) by increased hydrolytic enzyme activity enhanced respiration and increases free fatty acid. High temperature accelerated the rate of biochemical process causing more rapid deterioration that
might have resulted in rapid losses in seed having high moisture content.

It is obvious from the results that when there was slow decrease in moisture content at initial period of storage, the decrease in germination percentage of seed was also slow and increases with increase in moisture content irrespective of environments, varieties and storage containers. Thus it could be stated that the increase in moisture content might be related to the loss of germination percentage of soybean. The moisture content of seed during storage is no doubt the most influential factor affecting the longevity. Barton (1961) reported that moisture content of utmost important in seed deterioration. Seed deterioration increases as moisture content is increased. As seed deterioration is affected by moisture content, it is important to know, what factor affects water absorption and retention as well as their effects. The mechanical damaged seed of soybean had higher moisture content. The cracks and bruises caused due to handling gave exposure of carbohydrate and proteins material of seed to the prevailing environment, which absorbs the moisture from atmosphere. Obviously the thickness, structure and chemical composition of the seed coat affect the rate of water absorption and retention by seeds. In hard seeds the seed coat restricts total water uptake of the various seed constituents, proteins are most hygroscopic (readily taking up and holding moisture) carbohydrates are slightly less hygroscopic so and the lipids are hydrophobic (lacking an affinity of water).
The moisture content in seed of variety MAUS-61 followed by MAUS-47 had significantly higher than MAUS-71. Thus, it could be stated that the increase in moisture content might be related to the loss of germination. Therefore, the variety MAUS-61 loose the germination rapidly than MAUS-47 and MAUS-71. The moisture content of the soybean seed stored in polylined gunny bags was significantly lower with less fluctuation than seed stored in gunny bags irrespective of varieties and treatments during all the periods of storage. This could be attributed to less permeability of medium and high density polythene film 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).

Higher viability and vigour of seed were associated with polythene bags which minimise the moisture fluctuation of seed in storage. Similar findings were also reported by Burd and Delouche (1971); Rodda and Ravalo (1978); Ravalo et al. (1980), Arulnandhy (1987); Umarani and Selvaraj (1996); Jawale et al. (2001) and Shelar (2002).
5.3 Physico-biochemical Components

5.3.1 Electrical Conductivity

The electrical conductivity of soybean seed from various treatment combinations during storage has been presented in Fig. 5.7 and Table 4.19.

The electrical conductivity of the soybean seed differed significantly due to varieties, environments and storage containers during storage. The electrical conductivity was found increased with subsequent increase in storage period irrespective of varieties and treatments. This could be attributed to the deterioration or ageing of soybean seed. The electrical conductivity of seeds of rabri season was significantly higher than kharif and summer seasons and increased with increases deterioration of seed. Increase in conductivity might be caused by increase in permeability of membrane of deteriorated seed. Membrane deterioration is progressive, probably even after death (Kar-Ling, 1978). In dead seeds, therefore, the membranes are deteriorated to the considerable degree causing less control on solute movement.

Loss of membrane integrity of deteriorated seeds leaks more substances into medium upon imbibition than the viable ones. Excess leakage of sugars may represent loss of respirable substrate from seeds. Similar, low vigour seeds of all the varieties from different treatments had higher EC. This could be attributed to the poor membrane structure and leaky cells. This results in greater loss of electrolytes such as sugars, amino and
Figure 5.7
Effect of Main Factors on Electrical Conductivity Content of Soybean Seed during Storage
organic acids from seeds and increases conductivity in the soak water (Abdul Baki and Anderson (1970); Agrawal (1977); Kar-Ling (1978)).

The degradation changes in the cellular membrane causing leakiness or increased permeability (Stewart and Bewley, 1980). The deteriorated seed when imbibed in water, leaches more water soluble compounds than vigorous ones. Membrane permeability is assessed by analysing the seed leachates for various kinds of solutes like electrolytes, water soluble sugar and amino acids. This higher EC of the leachate of seeds irrespective of varieties and treatments at the end of storage period could be ascribed to the loss of viability during storage of seeds have less membrane competence following storage for longer period. This is often expressed at the whole seed level by greater membrane permeability in aged seed and is the foundation for the success of the conductivity test. The cause of membrane degradation is likely due to lipid peroxidation which is detrimental at the intracellular level.

The higher EC in seeds stored in gunny bags as compared to seeds stored in polylined gunny bags could be ascribed to the rapid loss of viability in seed stored in gunny bag due to high moisture content. Membrane and macromolecules become unstabilised during storage under adverse condition may be ascribed to hydrolysis or breakdown of lipoprotein membrane component due to relatively high moisture content in aged seed.
The EC of the seed leachate is a good indicator of such damage (Matthews and Bradnock, 1968).

The higher EC in soybean variety MAUS-61 than MAUS-71 and MAUS-47 could be ascribed to rapid loss in viability, bolder seed size and less lignin content of seed coat. Low quality seeds have poor membrane structure that allows the outward diffusion of ions during imbibition that are detected by monitoring the electrolytes present in the steep water (Simon and Mills, 1983). McDonald (1999) showed that seed size may also influence conductivity results because longer seed leak more electrolytes than that of smaller seeds of equivalent quality. EC varies according to the soybean cultivars as evidenced by other authors (Panobianco and Vieira, 1996 and Vieira et al., 1996). This variation is due to the content of lignin in seed coat, that high lignin content is desirable characteristic for improving soybean seed quality.

5.3.2 Protein and Oil Content

The protein and oil content in soybean seed differed due to various environments, varieties and storage containers have been shown in Fig. 5.8, 5.9 and Table 4.20 and 4.21.

In the present investigation, it was observed that the protein and oil content of the soybean seed found to be decreased irrespective of environments and varieties. The protein and oil content of the soybean seed decreased slowly with the advancement of storage period could be ascribed to the ageing or deterioration of seed. Loss of germination or viability
Figure 5.8
Effect of Main Factors on Protein Content of Soybean Seed during Storage
Figure 5.9
Effect of Main Factors on Oil Content of Soybean Seed during Storage
with increase in moisture content during storage has been found to be closely associated with decrease in protein and oil content of soybean seed by increase in membrane leakage (Abdul-Baki and Anderson, 1972), free fatty acids and lipase activity (St. Angelo and Ory, 1983). Lipid peroxidation and free radical chain reaction go hand in hand for destroying the lipoprotein membrane structure of vital bio-organells.

The increased leaching of substances from the seed was perhaps due to damage to the semi-permeable cell membrane. The soybean seed imbibe high amount of water to create equilibrium inside and outside the seed. The hydrophilic nature of high protein content of soybean (Hartwing and Potts, 1987) helps in more absorption of water and high oil content in seed increases deterioration of seed (Potts, 1972) by increased hydrolytic enzyme activity enhanced respiration and an increase in free fatty acids (Potts, 1972).

High temperature accelerated the rate of these biochemical processes causing more rapid deterioration that might have resulted in rapid losses in seed having high moisture content. Seed priming or restricted hydration is associated with increase in protein synthesis, nucleic acid synthesis and repair and changes in seed stored food, which may get affected and could result in either restoration of viability or loss of viability. The loss of membrane integrity and decrease in the level of unsaturated fatty acid have been reported in deteriorated seeds. eg. free linoleic and linolenic fatty acid increased two fold during
deterioration of the soybean seed. The reducing sugars, protein and free amino acids decreased during storage in bajra (Sinha, 1978). The protein and oil seed content was decreased during storage in oil seed (Singh, 1973). Puspamma and Reddy (1979) found decrease in protein and free amino acid nitrogen during storage in sorghum and rice.

The protein and oil content of soybean seed higher in seeds of *kharif* season followed by *rabi* than summer season. The early sowing gave higher oil and protein content in soybean (Kolak, 1989). Variation in soybean seed protein content were studied for different years and sowing dates, seed protein content was higher in 1983 than in 1982 and decreased with delay of slowing (Nakamura *et al.*, 1989). Seed protein content was highest from the early sowing and delay in sowing reduced seed oil content and seed yield. (Jasani *et al.*, 1994). Borade (1998) reported that significant differences in respect of protein and oil content in soybean was observed in all the season i.e. *kharif*, *rabi* and summer seasons. The variety, year, location and year × location interaction had significant effect on protein, oil and protein + oil content. Variance components due to location were consistently greater than those due to year during study on protein and oil content of soybean seed as influenced by years and locations (Meng *et al.*, 1991). Valivia (1979) studied effects of date of planting on the yield, protein and oil content of soybean. Oil content of Amsoy cultivar decreased gradually with
increase in late sowing. Protein content of cultivar Hark and Amsey decreased slightly between first and second sowing dates.

The protein and oil content of the variety MAUS-71 followed by MAUS-61 was significantly higher than variety MAUS-47 during all the period of storage. Trehan et al. (1972) reported variation in oil and protein content in seed due to genotypes. Considerable difference in protein and oil content amongst different varieties of soybean (Lal et al., 1973). Laxman Rao and Shankar Reddy (1978) investigated that highest protein content of 39.5 per cent on 15th July sowing and lowest protein content 36.84% in 15th May sowing. There was decrease in oil content of seed with delay in sowing time. Canviness (1974) reported that there was significant difference in protein and oil content of varieties. Out of five varieties viz. Lee 68, Bragg, Hill, Devic and Dare; Lee 68 was with highest protein (44%), significant difference were observed due to location for both protein and oil. Jayapragasam (1981) reported that the variety differences in protein, oil and methionine content in soybean seed.

The seed stored in polylined gunny bags had significantly higher protein and oil content of soybean seed than those stored in gunny bags during all the periods of storage irrespective of environments and varieties. These results suggest that the soybean seed in polylined gunny bags are liable to the least amount of viability (MSCS) to a greater extent as compared to seed in gunny bag when stored under ambient conditions. The seed viability and seedling vigour remained higher when seed
stored for 8 months in polyethylene bags compared with cloth bags. There was a decline in protein and oil content over this period, but the decline was less with polyethylene bags than cloth bags during storage (Umarani and Selvaraj, 1996). The loss in viability of soybean is minimised if seed stored with 10.5 ± 0.5% moisture and in polythene bags of 300 gauge with tightly sealed and kept at 12 ± 1°C. In such condition there is reduction in mobilisation efficiency, DNA and RNA level. RNAse activities in the seed are some of the metabolic aspects related with seed deterioration. Higher electrical conductivity of the seed leachase is also associated with high magnitude of seed deterioration (Shrivastava, 1976). Ravalo et al. (1980) stated that the successful seed storage requires protection against moisture absorption from the atmosphere. The loss of seed viability was associated with a marked gain in seed moisture during storage.