Discussion
V. DISCUSSION

Sunflower emerged as one of the most important source of edible oils since last four decades and widely accepted due to its high polyunsaturated fatty acids (PUFA) content with higher proportion of linoleic acid (40-70%). Seed is a basic and crucial input in crop production. Hence, use of quality seeds is an effective means of improving the crop yield. Seed quality depends on complex conditions evoking the most favourable interactions between genetic makeup of seed and environment. The production of good quality seeds is highly skilled and exacting task involves high investments and evoking the most favourable interactions between the genetic makeup of the seed and the environment under which it is produced, harvested, processed and stored. Hence, the suitable choice of location and optimum date of planting are the major requirements for the success of any seed production programme. Although seed multiplication ratio in sunflower is in the order of 1:100, rapid loss of seed viability in storage leads to poor crop stand and low production. Hence, storage of seed after harvest till next cropping season is another important pre requisite for successful crop production. During storage, the viability of seed is affected by various factors. Among them seed moisture content, temperature, relative humidity and packaging materials are considered to be the most important.

Keeping these factors in view, the present investigation entitled “Studies on flowering behaviour of parental lines, seed setting, seed yield, quality and storage behaviour of hybrids in sunflower (Helianthus annuus L.)” was carried out at the Department of Seed Science and Technology, University of Agricultural Sciences, GKVK, Bengaluru. The results obtained from the study are discussed in this chapter under the following sub headings.

5.1 Influence of seasons on flowering behaviour, seed yield and quality of parental lines of sunflower hybrids

Hybrid seed production is dependent on several factors such as planting ratio, nicking of flowering, pollen production ability of restorer line, viability of pollens and duration of stigma receptivity. Information on flowering behaviour of parental lines of
sunflower hybrids is a pre-requisite to ensure timely and continuous supply of sufficient pollens to receptive stigma of female parent which finally decides better seed setting, seed yield and quality. Flowering behaviour of parental lines varies from season to season and location to location (Patil et al., 1993). Besides, due to impulsive altering of climate, it is a felt that there is need to examine flowering behaviour of parental lines of promising public hybrids especially with different seasons in order to achieve better synchronization of flowering and also for identifying the best sowing period for hybrid seed production.

5.1.1 Effect of seasons on flowering behaviour

The information on flowering behaviour like days to opening of first ray floret, days to 50 per cent flowering and days to completion of flowering were studied and found to differ significantly due to seasons in different parental lines of sunflower F₁ hybrids. The number of days taken for opening of first ray floret differed significantly among the different parental lines in both the seasons during 2010 and 2011. In general, crop sown during kharif took less number of days for first ray floret opening in both female and male parents of different hybrids but it was higher in rabi season, irrespective of years.

Female parents took less number of days when compared to male parents, irrespective of seasons and years. During 2010, maximum number of days taken for opening of first ray floret in female parent CMS 335A (62.33, 72.67) and it was less in CMS 234A (50.33, 58.33) in kharif and rabi, respectively. However in male parents, RHA 95C-1 and RHA 6D-1 took higher number of days (60.67 and 66.33, respectively) as against minimum in RHA 95C-1 (59.33, 65.00) in kharif and rabi, respectively. In 2011 also, the number of days taken for opening of first ray floret in both the seasons was more in CMS 335A and least number of days recorded in CMS 234A. Among the male parents, RHA 6D-1 took higher number of days (58.33) compared to RHA 95C-1 (55.67) during kharif, however in rabi, RHA-95C-1 took more days than RHA 6D-1. Irrespective of seasons and years, the female parents took higher number of days for opening of first ray floret in rabi 2010 (62.47) compared to kharif 2011 (53.53). However the male parents, took more number of days (66.27) in rabi 2011 compared to kharif 2011 (56.33).
Significant differences were observed for days to 50 per cent flowering among different parental lines in both the seasons during 2010 (Fig 5.1). Higher number of days taken for 50 per cent flowering in female parent CMS 335A (69.67, 80.67) and less number of days recorded in CMS 234A (55.33, 64.67) in both kharif and rabi, respectively. Among the pollen parents, maximum days for 50 per cent flowering was noticed in RHA 95C-1 (65.33), however it was lowest in RHA 6D-1 (63.67) during kharif. But in rabi, maximum days took in RHA 6D-1 (73.33) and it was minimum in RHA 95C-1 (71.67). During 2011 also, the number of days took for 50 per cent flowering in female parent was maximum in CMS 335A in both kharif and rabi, but it was less in CMS 234A. Among the male parents, RHA 6D-1 recorded highest number of days (63.00) to 50 per cent flowering and less in RHA 95C-1 (59.33) during kharif. While in rabi, RHA 95C-1 took higher number of days (74.33) and least number of days was registered in RHA 6D-1 (72.33).

Between the seasons and years, female parents took highest mean number of days taken to 50 per cent flowering in rabi 2010 (69.33) and it was less during kharif 2011 (58.80). But in male parents, rabi 2011 recorded more number of days (73.20) compared to kharif 2011 (60.60), irrespective of parental lines.

The delayed flowering in rabi season might be due to varied range of temperature and photoperiod prevailing during the crop growth. Though the sunflower is said to be photo and thermo insensitive, it behaved differently with respect to flowering, when grown in different seasons. Similar results were reported by Yadava et al. (1976), Kara (1988), Ujjinaiah et al. (1991) and Vyakaranahal (1998). Sowing in rabi season coincides with low temperature during crop growth which delayed the field emergence, increased the growing period, delayed the heading and flowering. These results are in conformity with the findings of Shekhargouda (1993) and Vasudevan et al. (1997). Further the higher minimum temperature prevailed in kharif season might have induced early flowering in the parents. These results are in accordance with the findings of Pandusastry (1981) and Biradarpatl and Kulkarni (1990) in sorghum. Besides, genotypic variation in flowering duration due to different dates of sowing was also observed by Jagadish et al. (1996) in sunflower seed production.
Fig 5.1. Influence of seasons on days to 50 per cent flowering in parental lines of sunflower hybrids
Days to completion of flowering differed significantly among the parental lines in both seasons during 2010. More number of days taken to completion of flowering in female parent CMS 335A (74.67, 84.33) and it was less in CMS 234A (59.00, 69.33) in kharif and rabi, respectively. Among the restorer lines, RHA 95C-1 (68.33) took more number of days for completion of flowering during kharif. However in rabi, more number of days was registered in RHA 6D-1 (78.00), while it was less in RHA 95C-1 (76.00). During 2011 also, the number of days taken to completion of flowering was maximum in female parent CMS 335A compared to CMS 234A, irrespective of seasons. Among the male parents, RHA 6D-1 registered more number of days (67.00) for completion of flowering but it was significantly lower in RHA 95C-1 (63.00) during kharif. However in rabi, RHA 95C-1 took higher number of days (79.00) and it was minimum in RHA 6D-1 (75.67).

Among the seasons and years, the number of days taken for completion of flowering was maximum in female parents during rabi 2010 (73.87) compared to kharif 2011 (62.13). However in pollen parents, rabi 2011 recorded more number of days (77.47) but it was less in kharif 2011 (63.87), irrespective of parental lines. The variation in flowering days in parental lines may be attributed to the genetic characteristics of the parents. Similar variation in flowering behaviour of female and male parent has been reported by Vranceanu (1980), Kempegowda (1992), Anagod (1994) and Somasekhara (1997) in sunflower hybrid seed production. The genotypic differences in the flowering may further be revealed to the differences in flower bud initiation, which in turn affected by environmental factors like temperature, photoperiod and their interactions.

5.1.2 Influence of seasons on growth parameters

In general, growth attributes were influenced by several biotic, abiotic, agronomic and management practices besides genetic makeup of varieties. In the present study also growth attributes like plant stand at maturity and plant height at harvest were significantly influenced by the seasons in different parental lines of sunflower F₁ hybrids.

Plant stand at maturity differed significantly among the parental lines in both the seasons during 2010 and 2011. In general higher number of plant populations was
obtained in rabi than kharif, irrespective of years. However in kharif 2010, among the different parental lines the plant stand at maturity was maximum in CMS 335A (55.67) but it was significantly lowest in RHA 95C-1 (21.67). While in rabi, higher plant stand at maturity was obtained in CMS 335A (58.33) but it was lowest in RHA 6D-1 (25.33). During kharif 2011, maximum plant stand at maturity was recorded in CMS 234A (52.67) of KBSH-41 F<sub>1</sub> hybrid and lowest was registered in RHA 6D-1 (22.75). But in rabi season, the plant stand at maturity was maximum in CMS 335A (57.67), however it was lowest in RHA 6D-1 (24.67). Among the seasons and years, highest mean plant stand at maturity was recorded in rabi 2010 (48.07) compared to lowest recorded in kharif 2011 (42.89), irrespective of parental lines.

The plant height at harvest differed significantly among the parental lines in both the seasons during 2010 and 2011. The plant height was more in kharif than rabi because of variation in the environmental conditions. During kharif, highest plant height was recorded in CMS 335A (162.83 cm, 151.20 cm), however it was lowest in CMS 851A (117.70 cm, 118.60 cm) in 2010 and 2011 respectively. While in rabi, highest plant height was noticed in CMS 234A (143.33 cm, 138.67 cm) of KBSH-41 F<sub>1</sub> hybrid and significantly lower plant height was noticed in RHA 95C-1 (113.87 cm) and CMS 851A (101.88 cm) in 2010 and 2011, respectively. Between the seasons and years, highest mean plant height at harvest was recorded in kharif 2010 (148.27 cm) and it was lowest in rabi 2011 (126.95 cm), irrespective of parental lines. This difference in the plant height among the seasons may be due to favourable temperature and sunshine reaching the crop during its growth period. Besides it may be attributed to efficient accumulation of photosynthates in the vegetative plant parts. Further, the plant height is a genetic character due to which varietal differences in plant height was evident. Similar findings were also observed by Ujjinaiah et al. (1987) and Kara (1988) in sunflower.

5.1.3 Influence of seasons on yield parameters

The seed yield in crop plants is the ultimate result of genotype and environmental interaction. It is therefore, imperative that a group of hybrids or genotypes (restorer lines) need to be tested in a set of environmental conditions to identify the best hybrid or
genotype that can yield better for a particular season or environment. In the present investigation, the yield determining components such as capitulum diameter, capitulum weight, total number of seeds, filled seeds, unfilled seeds per capitulum, test weight, seed filling percentage, seed recovery percentage, seed yield per plant, seed yield per hectare, and processed seed yield were recorded and found to differ significantly due to seasons in different parental lines of sunflower F₁ hybrids. Similar results were also reported by Ghosh and Chatterjee (1975), Shanthamallaiah et al. (1976), Bhattacharya et al. (1983), Meharwade et al. (1993) and Vyakaranahal et al. (2001) in sunflower hybrid seed production.

It could be seen from the data that capitulum diameter and capitulum weight differed significantly among the parental lines in both the seasons during 2010 and 2011. CMS 851A recorded maximum capitulum diameter (16.85 cm) and it was minimum in RHA 95C-1 (9.12 cm) during kharif, 2010. However in rabi, the capitulum diameter was maximum in CMS 335A (14.90 cm) and it was lowest in RHA 6D-1 (9.07 cm). During 2011, CMS 17A recorded maximum capitulum diameter (17.97 cm) and it was lowest in RHA 6D-1 (10.17 cm) during kharif. But in rabi, the capitulum diameter was highest in CMS 335A (15.12 cm), however it was lowest in RHA 6D-1 (9.37 cm). Among the seasons and years, highest mean capitulum diameter was noticed in kharif 2011 (14.12 cm) as well as 2010 (13.91 cm) and it was lowest in rabi 2010 (12.62 cm), irrespective of parental lines (Fig 5.2). In general, the capitulum size was higher in kharif as compared to rabi which helped in accommodation of more number of filled seeds per capitulum and higher seed setting. This increased sink strength might have allowed more translocations of photosynthates. These results are in agreement with the findings of Habeebullah et al. (1983) and Bange et al. (1998) in sunflower.

The number of filled seeds per capitulum differed significantly between the parental lines in both the seasons during 2010 and 2011 (Fig 5.3). Highest number of filled seeds per capitulum was recorded in CMS 335A (763.13 and 1083.87) and it was lowest in RHA 95C-1 (152.60 and 261.33) in kharif and rabi, 2010, respectively. However in 2011 also, number of filled seeds per capitulum was significantly higher in CMS 335A (892.67 and 958.33), while it was lower in RHA 95C-1 (256.73) and RHA
Fig 5.2. Influence of seasons on capitulum diameter in parental lines of sunflower hybrids
Fig 5.3. Influence of seasons on number of filled seeds per capitulum in parental lines of sunflower hybrids
6D-1 (260.50) during kharif and rabi, respectively. Among the seasons and years, highest mean number of filled seeds per capitulum was more in kharif 2011 (673.97) followed by rabi 2010 (653.00), while it was lowest in kharif 2010 (472.59), irrespective of parental lines.

The seed filling and seed recovery percentage differed significantly among the parental lines in both the seasons during 2010 and 2011 (Fig 5.4 and 5.5). During kharif 2010, highest seed filling was noticed in CMS 851A (97.95 %) and it was lowest in CMS 234A (66.77 %) of KBSH-1 F1 hybrid. But in rabi, CMS 335A registered highest seed filling (95.47 %), however it was lowest in RHA 6D-1 (81.48 %). In 2011, highest seed filling was obtained in CMS 17A (94.56 %) and lowest values was registered in CMS 851A (88.09 %) during kharif. However in rabi it was highest in CMS 851A (94.21 %) as against lowest recorded in RHA 6D-1 (80.01 %). Among the seasons and years, highest mean seed filling was recorded in rabi 2010 (90.90 %) and it was lowest in kharif 2010 (85.51 %), irrespective of parental lines.

Seed yield per plant also differed significantly among the parental lines in both the seasons during 2010 and 2011. Highest seed yield per plant was recorded in CMS 17A (37.20 g) and CMS 335A (46.44 g), while it was lowest in RHA 95C-1 (5.53 g and 14.67 g) during kharif and rabi, 2010, respectively. However in kharif 2011, highest seed yield per plant was obtained in CMS 17A (50.17 g) and it was lowest in RHA 95C-1 (13.14 g). But in rabi, highest seed yield per plant was recorded in CMS 335A (43.64 g), while it was lowest in RHA 6D-1 (14.16 g). Between the seasons and years, highest mean seed yield per plant was recorded in kharif 2011 (34.71 g) followed by rabi 2010 (33.59 g), however it was lowest in kharif 2010 (24.18 g), irrespective of parental lines. The differences in yield and yield attributing characters among the parental lines may be attributed to genetic potential and also differences in plant height, flowering and plant population at maturity, besides their high yielding ability. Similar varietal differences with respect to yield and yield attributing characters over seasons were also reported by Vyakaranahal (1998) and Balakrishna (2010) in sunflower.

Significant differences were observed for the bulk seed yield among the parental lines in both the seasons during 2010 and 2011. During kharif, among the female parents,
Fig 5.4. Influence of seasons on seed filling (%) in parental lines of sunflower hybrids
Fig 5.5. Influence of seasons on seed recovery (%) in F$_1$ hybrids and restorer lines of sunflower
highest bulk seed yield was obtained in CMS 17A (18.61 q/ha and 22.91 q/ha) and it was lowest in CMS 234A (12.25 q/ha) and CMS 851A (15.60 q/ha) in 2010 and 2011, respectively. However in male parents, RHA 95C-1 recorded highest bulk seed yield (7.12 q/ha) than RHA 6D-1 (6.91 q/ha) in 2010, while in 2011, RHA 95C-1 recorded highest bulk seed yield (5.90 q/ha) than RHA 6D-1 (5.81 q/ha). During *rabi*, among the female parents, CMS 335A recorded highest bulk seed yield (25.09 q/ha and 23.33 q/ha) and it was lowest in CMS 234A (19.26 q/ha) and CMS 851A (17.53 q/ha) in 2010 and 2011, respectively. However in the male parents, RHA 95C-1 recorded highest bulk seed yield (7.12 q/ha and 6.80 q/ha) than RHA 6D-1 (6.91 q/ha and 6.51 q/ha) in 2010 and 2011, respectively. Among the seasons and years, the mean bulk seed yield was significantly higher in *rabi* 2010 (21.82 q/ha) and it was lowest in *kharif* 2010 (15.25 q/ha) in the female parents. However in the male parents, *rabi* 2010 obtained highest bulk seed yield (7.02 q/ha) and it was lowest in *kharif* 2010 (2.52 q/ha). The higher seed yield in *rabi* was due to higher number of filled seeds per capitulum, higher percentage of seed set, higher seed weight per capitulum and test weight in all hybrids compared to *kharif* season. These results are in accordance with the findings of Bhattacharya et al. (1983), Kara (1988), Vasudevan (1992) and Vyakaranahal (1998). Dry weather, low relative humidity and moderate temperature prevailing during rabi at flowering stage of the crop might have helped for higher fertilization and higher seed setting (Kushwaha and Sharma, 1973, Ujjinaiah et al., 1987 and Umesh, 2005). The environmental factors like rainfall, number of rainy days, temperature, relative humidity and sunshine hours play an important role in seed yield (Bhattacharya et al., 1983). The rapid pollen tube development due to warm and bright days prevailed during *rabi* has also helped in increasing the seed yield in sunflower (Chaudhary and Anand, 1989 and Vyakaranahal, 1998). Temperature prevailed during *rabi* season helped in getting healthy crop growth which in turn contributed for increased seed yield. Further, fewer incidences of diseases like *Alternaria* leaf spot and necrosis in rabi compared to *kharif* resulted in good crop growth and better yields (Raut et al., 1985).

Significant differences were observed for the processed seed yield among the parental lines in both the seasons during 2010 and 2011 (Fig 5.6). During *kharif*, highest processed seed yield was obtained in CMS 17A (16.07 q/ha and 20.58 q/ha) and it was
Fig 5.6. Influence of seasons on processed seed yield (q/ha) in parental lines of sunflower hybrids
lowest in CMS 234A (9.83 q/ha) and CMS 851A (13.97 q/ha) during 2010 and 2011, respectively. However the male parents, RHA 6D-1 recorded highest processed seed yield (2.59 q/ha and 5.39 q/ha) than RHA 95C-1 (1.83 q/ha and 5.36 q/ha) during 2010 and 2011, respectively. During *rabi*, CMS 335A recorded highest processed seed yield (23.66 q/ha and 21.67 q/ha) but it was lowest in CMS 234A (18.19 q/ha) and CMS 851A (16.14 q/ha) in 2010 and 2011, respectively. However the male parents, RHA 95C-1 recorded highest processed seed yield (6.63 q/ha and 6.43 q/ha) than RHA 6D-1 (6.44 q/ha and 5.84 q/ha) during 2010 and 2011, respectively. Among the seasons and years, the mean processed seed yield was significantly superior in *rabi* 2010 (20.47 q/ha) as well as *rabi* 2011 (18.45 q/ha) and it was lowest in *kharif* 2010 (13.27 q/ha). However the male parents, *rabi* 2010 obtained highest processed seed yield (6.53 q/ha) than lowest recorded in *kharif* 2010 (2.21 q/ha). Increase in processed yield can be attributed to the increased head diameter, number of filled seeds, test weight, seed filling percentage and seed recovery percentage. These results are in accordance with the reports of Sankappanavar (1984), Narwal and Malik (1985), Shekhargouda (1993) and Umesh (2005). A positive correlation between seed yield and yield components was observed in sunflower genotypes by Girija *et al.* (1979) and Sidhu and Bains (1980). Doddamani *et al.* (1997) also reported positive association between seed yield per plant, head diameter and 100 seed weight in sunflower genotypes. Furthermore, large differences among dates of planting resulted primarily from the effect of precipitation amount and distribution during the growing season (Flagella *et al.*, 2002; Narwal and Malik, 1985).

### 5.1.4 Influence of seasons on seed quality parameters

Assessment of seed quality attributes of resultant seed crop is rather essential segment to determine the planting value and the performance of seeds due to different parental lines over seasons. Seed quality attributes like 100 seed weight, seed density and germination percentage significantly influence the seed yield over seasons in parental lines and F1 hybrids of sunflower.

A significant variation in 100 seed weight was observed among the parental lines in both the seasons during 2010 and 2011 (Fig 5.7). 100 seed weight was highest in CMS
Fig 5.8. Influence of seasons on germination (%) in parental lines of sunflower hybrids
234A (5.98 g) and CMS 17A (6.24 q) during kharif 2010 and 2011, respectively and it was lowest in CMS 335A (3.66 g) and CMS 851A (3.53 g) in kharif 2010 and 2011, respectively. However the male parents, RHA 6D-1 registered highest 100 seed weight (3.18 g) than RHA 95C-1 (3.04 g) during 2010 and in 2011, RHA 95C-1 recorded highest 100 seed weight (3.67 g) than RHA 6D-1 (3.59 g). During rabi, among the female parents, it was highest in CMS 17A (5.42 g and 5.38 g) and lowest recorded in CMS 851A (3.41 g and 3.45 g) during 2010 and 2011, respectively. However in male parents, RHA 95C-1 recorded highest 100 seed weight (3.97 g and 3.92 g) than RHA 6D-1 (3.33 g and 3.40 g) during 2010 and 2011, respectively. Among the seasons and years, the mean 100 seed weight was significantly superior in kharif 2010 (5.02 g) as well as 2011 (4.48 g) and it was lowest in rabi 2011 (4.39 g) in the female parents. However in male parents, rabi 2011 obtained highest 100 seed weight (3.66 g) than lowest recorded in kharif 2010 (3.11 g). This could be attributed to the efficient metabolism and translocation of photosynthates to the seeds. The results are in accordance with the findings of Kovacik and Skaloud (1972). Furthermore, the differences in 100 seed weight observed among parents may be attributed to character of the genotypes, differences in seed development and food reserves (Bhattacharya et al., 1983 and Vyakaranahal, 1998) in sunflower.

Seed moisture content differed significantly among the parental lines in both the seasons. During 2010, highest seed moisture content was recorded in CMS 17A (10.55 % and 5.92 %) and it was lowest in CMS 851A (8.94 % and 4.70 %) in kharif and rabi, respectively. In 2011 also highest moisture was noticed in CMS 17A (6.89 % and 6.05 %), however, lowest value was obtained in CMS 234A (4.03 %) of KBSH-41 F₁ hybrid and CMS 851A (5.09 %) in kharif and rabi, respectively. Among the seasons and years, highest mean seed moisture content was noticed in kharif 2010 (9.67 %) and it was lowest in rabi 2010 (5.35 %), irrespective of parental lines. This may be attributed to cloudy weather, more rainy days and less sunshine hours during kharif than rabi season.

Germination percentage differed significantly among the parental lines in both the seasons during 2010 and 2011 (Fig 5.8). In both kharif and rabi, dormancy existed immediately after harvesting, however the germination percentage was relatively higher in rabi when compared to kharif season. During kharif, highest seed germination was
Fig 5.7. Influence of seasons on 100 seed weight (g) in parental lines of sunflower hybrids
recorded in CMS 234A (20.67% and 20.00 %) of KBSH-41 F₁ hybrid and it was lowest in CMS 851A (6.00% and 5.00%) during 2010 and 2011, respectively, however the other parental lines did not germinate. In *rabi* also, CMS 234A of KBSH-41 F₁ hybrid registered highest germination (41.33% and 30.00%), however it was lowest in CMS 17A (1.00%) in 2010 and 2011, respectively. Among the seasons and years, highest mean germination was recorded in *rabi* 2010 (19.86%) and it was lowest in *kharif* 2011 (4.50%), irrespective of parental lines. This variation in germination between season could be attributed to the better development of seeds during *rabi* season which reflected in higher test weight in *rabi* than *kharif* season. Jagadish and Shambulingappa (1983) observed positive correlation between seed weight or size with germination. Sivasubramanian and Ramakrishnan (1977), Ujjinaiah et al. (1991) and Umesh (2005) also reported that larger seeds of sunflower exhibited a slightly higher germination potential and greater hypocotyls length.

Electrical conductivity (EC) of seed leachate differed significantly among the parental lines in both the seasons during 2010 and 2011. In general parental lines exhibited variations in EC values over seasons. During 2010, highest electrical conductivity was recorded in RHA 6D-1 (3.68 mS/ppt), however it was lowest in CMS 234A (2.34 mS/ppt) during *kharif*. In *rabi*, CMS 234A recorded highest EC (2.55 mS/ppt) and lowest EC was recorded in CMS 17A (1.16 mS/ppt). In 2011 *kharif*, highest EC was obtained in CMS 335A (3.99 mS/ppt) and it was lowest in RHA 95C-1 (2.23 mS/ppt), but in *rabi*, highest EC was recorded in CMS 234A (2.85 mS/ppt), while it was lowest in CMS 17A (1.40 mS/ppt). Among the seasons and years, highest mean EC was recorded in *kharif* 2011 (3.04 mS/ppt), however it was lowest in *rabi* 2010 (1.57 mS/ppt), irrespective of parental lines. The differences observed in EC of seed leachates among the parental lines may be related to internal higher concentration of food reserves and their passive diffusion process and not due to change in membrane permeability (Abdul-Baki and Anderson, 1970). These results are in conformity with the findings of Ujjinaiah et al. (1991) and Pawar (2006) in sunflower.

Oil content of seed differed significantly among the parental lines in both the seasons during 2010 and 2011 (Fig 5.9). Highest oil content was recorded in CMS 851A
Fig 5.9. Influence of seasons on seed oil content (%) in parental lines of sunflower hybrids
Fig 5.10. Influence of seasons on seed protein content (%) in F₁ hybrids (AxR) and restorer lines of sunflower
(39.04 %) and CMS 335A (39.94 %), however it was lowest in CMS 17A (33.65 % and 35.13 %) during *kharif* and *rabi* 2010, respectively. During 2011, CMS 234A recorded highest oil content (41.31 %) and it was lowest in CMS 17A (34.39 %) during *kharif*. But in *rabi*, highest oil content was obtained in RHA 6D-1 (39.69 %) and lowest in CMS 17A (33.78 %). Among the seasons and years, highest mean oil content was noticed in *kharif* 2011 (39.24 %) and *rabi* 2011 recorded lower oil content (36.82 %), irrespective of parental lines. Protein content of seed also differed significantly among the parental lines in both the seasons during 2010 and 2011 (Fig 5.10). Highest protein content was recorded in CMS 335A (15.73 %) and lowest in RHA 6D-1 (13.11 %) during *kharif*. However in *rabi*, CMS 234A of KBSH-41 F₁ hybrid recorded highest protein content (17.58 %) and it was lowest in RHA 6D-1 (14.67 %) during 2010. But in 2011, highest protein content was noticed in CMS 234A (15.13 % and 16.25 %) of KBSH-41 F₁ hybrid, lowest in RHA 6D-1 (12.79 % and 14.14 %) during *kharif* and *rabi*, respectively. Among the seasons and years, highest protein content was recorded in *rabi* 2010 (16.14 %) and lowest protein content was obtained in *kharif* 2011 (14.11 %), irrespective of parental lines. Similar results of variation of oil and protein content in sunflower genotypes between the seasons reported by Meharwade *et al.* (1993), Somasekhara (1997) and Vasudevan *et al.* (2002) in sunflower.

5.2 Influence of maturity stages on seed quality attributes of sunflower F₁ hybrids and its parental lines produced over seasons and years

Beneficial influence of harvesting of seed crop at physiological maturity for obtaining increased seed yield and quality parameters in terms of viability and vigour have been revealed by several seed technologists. Harvesting at early stage may result in more number of under developed and immature seeds with high seed moisture content and delayed harvesting results in lower seed yield and poor quality due to field weathering. Hence, harvesting at appropriate stage of physiological maturity is important for getting higher seed yield and quality. Certain physiological maturity indices such as visual observations (yellowing of back side of capitulum), physical and physiological indices (dry matter production, dry weight of seed, seed moisture content, germination percentage, electrical conductivity of seed leachate *etc.*) have been adopted for fixing physiological maturity in several crops.
5.2.1 KBSH-1

The seed quality attributes viz., capitulum weight, seed moisture content, fresh and dry weight of seed, germination percentage, electrical conductivity of seed leachate and total dehydrogenase activity harvested at different stages of maturity are influenced by the seasons in sunflower hybrid KBSH-1. The results of the study revealed that both capitulum weight and seed moisture content decreased with the advances in maturity in both the seasons, irrespective of years. The decrease in capitulum weight was concomitant with decrease in moisture content of seed owing to prevailing higher temperature and lower relative humidity at harvesting time. However, the head weights as decreased gradually with days to maturity from 10 DAP to 40 DAP in both the seasons, irrespective of years. Among the seasons and years, highest mean capitulum weight was recorded in rabi 2011 (141.69 g) and it was lowest in kharif 2010 (114.29 g), irrespective of maturity stages. Significant differences were also observed for moisture content of seeds among different stages of maturity in both the seasons during 2010 and 2011. Initially it was high and thereafter declined with the stage of maturity. Higher moisture content was recorded in 10 DAP (76.46% and 70.72%, respectively) in both kharif and rabi and later on decreased to 16.70 and 11.61 per cent when the seeds were harvested at 40 DAP and 35 DAP in kharif and rabi, respectively, during 2010 (Fig 5.11). Similar trend has been observed during 2011. Among the seasons and years, highest mean seed moisture content was noticed in kharif 2010 (48.05 %), however it was lowest in rabi 2010 (33.56 %), irrespective of maturity stages. Similarly, the fresh and dry weight of seeds also differed significantly with the maturity stages in both the seasons, irrespective of years. In general maximum dry weight of seed was obtained at physiological maturity (30 DAP to 40 DAP). However during 2010, maximum dry weight of seed was obtained at 35 DAP (34.59 g and 44.46 g) and minimum dry seed weight was recorded at 10 DAP (11.76 g and 13.89 g) in kharif and rabi, respectively (Fig 5.11). In 2011 also, maximum and minimum dry weights of seeds were noticed at 35 DAP and 10 DAP, respectively in both kharif and rabi. Among the seasons and years, highest mean dry weight of seeds was recorded in rabi 2010 (30.50 g) and it was lowest in kharif 2010 (23.47 g), irrespective of maturity stages. The increased seed weight might be due to the accumulation of food reserves in the cotyledons towards maturity. Sunflower being an oil
Fig 5.11. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower F₁ hybrid KBSH-1 during rabi, 2010
seed crop, the accumulation of oil in the seed increased only after 10 DAP correspondingly resulted in increased seed weight. The accumulation of food reserves have direct relationship with the germination per cent. These results are in conformity with the findings of Bhaskar Rao et al. (1993), Mahesha et al. (2001) and Pallavi et al. (2010) in sunflower.

Germination percentage differed significantly among the different stages of maturity in both the seasons during 2010. The germination of sunflower seeds harvested at 10 DAP was zero in both kharif and rabi, however it was progressively increased towards the maturity. The germination was maximum at 35 DAP and 40 DAP (6.50 % and 34.00 %) in kharif and rabi, respectively (Fig 5.11). In 2011 also, there was no germination at the beginning and it was maximum at 35 DAP and 40 DAP during kharif and rabi, respectively. Among the seasons and years, highest mean germination was recorded in rabi 2010 (13.40 %), however it was lowest in kharif 2010 (2.90 %), irrespective of maturity stages. In general, the electrical conductivity (EC) of seed leachates was higher in all the stages of maturity in both the seasons, irrespective of years. However, the EC slightly decreased as days to maturity advanced from 10 DAP to 40 DAP and it was lowest at 35 DAP. Among the seasons and years, the mean EC was highest in kharif 2010 (4.628 mS/ppt) and it was lowest in rabi 2010 (2.505 mS/ppt), irrespective of maturity stages. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons, irrespective of years. During kharif The TDH was fluctuating between the maturity stages, however highest TDH was recorded at 30 DAP. In rabi, there was a progressive increasing trend in enzymatic activity has been observed towards the seed development and highest TDH was recorded at 35 DAP. Between the seasons and years, highest mean TDH was recorded in rabi 2011 (3.242), however it was lowest in kharif 2011 (1.738), irrespective of maturity stages. Similar results were also observed by Kole and Gupta (1982), Adetunji (1991) and Deshpande et al. (1997) in sunflower.

5.2.2 KBSH-41

Significant differences were observed for seed quality attributes due to stage of maturity in both kharif and rabi, irrespective of years in sunflower hybrid KBSH-41.
(Plate 5.1). The results of the study revealed both capitulum weight and seed moisture content decreased with the advance in maturity in both the seasons, irrespective of years. The decrease in capitulum weight might be due to decrease in moisture content of seed owing to prevailing higher temperature and lower relative humidity at harvesting time. However, the head weights decreased gradually towards the maturity from 10 DAP to 40 DAP in both the seasons. Among the seasons and years, highest mean capitulum weight was recorded in *rabi* 2010 (133.89 g), while it was lowest in *kharif* 2011 (122.70 g), irrespective of maturity stages. Significant differences were also observed for seed moisture content among different stages of maturity in both the seasons during 2010 and 2011. Initially it was high and thereafter declined with the stage of maturity. Higher moisture content of seed was recorded at 10 DAP (76.52% and 63.66%) during *kharif* and *rabi* and later on decreased to 20.22 and 11.10 per cent when the seeds were harvested at 35 DAP in *kharif* and *rabi*, respectively, in 2010 (Fig 5.12). However during 2011 also, moisture content of seed decreased gradually as maturity period advanced from 10 DAP to 40 DAP in both the seasons. Among the seasons and years, highest mean seed moisture content was recorded in *kharif* 2010 (40.98 %) and it was lowest in *rabi* 2010 (29.60 %), irrespective of maturity stages. Similarly fresh and dry weight of seeds also differed significantly due to maturity stages in both the seasons. Maximum dry weight of seed was obtained at physiological maturity (35 DAP) and it was minimum at 10 DAP. However during 2010 (Fig 5.12), maximum dry weight of seed was higher at 35 DAP (36.84 g and 37.04 g) and it was minimum at 10 DAP (28.22 g and 16.57 g) in *kharif* and *rabi*, respectively. In 2011 also, maximum and minimum dry weight of seed was noticed at 35 DAP and 10 DAP, respectively in both *kharif* and *rabi*. Among the seasons and years, highest mean dry weight of seeds was recorded in *rabi* 2011 (35.35 g), while it was lowest in *kharif* 2011 (29.56 g), irrespective of maturity stages. The seed weight increased gradually as the days to maturity advances due to the accumulation of food reserves in cotyledons. Similar results were also observed by Shaik Mohammed *et al.* (1984), Singh *et al.* (1990) and Seiler (1993) in sunflower.

Significant differences were observed for seed germination due to maturity stages in both the seasons during 2010 and 2011. The germination of sunflower seeds harvested
Fig 5.12. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower F$_1$ hybrid KBSH-41 during rabi, 2010.
Plate 5.1. Symptoms of seed maturation stages of sunflower hybrid (KBSH-41) during rabi, 2010
at 10 DAP was very low in both the seasons, however it was progressively increased towards the maturity. During 2010, the germination was maximum at 35 DAP (11.00 % and 35.33 %) in kharif and rabi, respectively (Fig 5.12). In 2011 also, the germination was less at the beginning and reached maximum at 35 DAP in both the seasons. Among the seasons and years, highest mean germination was recorded in rabi 2010 (18.90 %), however it was lowest in kharif 2010 (5.67 %), irrespective of maturity stages. Whereas, the electrical conductivity (EC) of seed leachate decreased gradually as days to maturity advanced from 10 DAP to 40 DAP and it was lowest at 35 DAP. Among the seasons and years, highest mean EC was recorded in rabi 2010 (2.699 mS/ppt) followed by kharif 2010 (2.637 mS/ppt), however it was lowest in rabi 2011 (2.518 mS/ppt), irrespective of maturity stages. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons, irrespective of years. The TDH was highest at 35 DAP in both the seasons. Between the seasons and years, highest mean TDH was recorded in rabi 2011 (2.888) and it was lowest in kharif 2011 (1.362), irrespective of maturity stages. These results are in conformity with the findings of Gerald (1998) and Mahesha et al. (2001) in sunflower.

5.2.3 KBSH-42

Significant differences were observed for seed quality attributes due to different stages of maturity in both the seasons, irrespective of years in sunflower hybrid KBSH-42. The results of the study indicated that both capitulum weight and seed moisture content decreased with the advance in maturity in both the seasons irrespective of years. The decrease in capitulum weight was concomitant with decrease in moisture content of seed owing to prevailing higher temperature and lower relative humidity at harvesting time. The head weights decreased gradually as days to maturity progressed from 10 DAP to 40 DAP in both the seasons. The seed moisture content differed with stages of maturity in both the seasons of 2010 and 2011. Highest seed moisture content was recorded at 10 DAP (71.60% and 63.37%) in kharif and rabi and later on it decreased to 17.83 and 6.23 per cent with the seeds of 35 DAP in kharif and rabi, respectively, during 2010 (Fig 5.13). However in 2011 also, moisture content of seed decreased gradually with the maturity stages in both the seasons. Among the seasons and years, highest mean seed
Fig 5.13. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower F$_1$ hybrid KBSH-42 during rabi, 2010
moisture content was noticed in *kharif* 2010 (37.20 %), however it was lowest in *rabi* 2011 (27.19 %), irrespective of maturity stages. Similarly the fresh and dry weight of seeds also differed significantly with the maturity stages in both the seasons. The maximum dry weight of seed was obtained at physiological maturity (35 DAP) and minimum dry weight of seed was recorded at 10 DAP in both the seasons. During 2010, maximum dry weight of seed was obtained at 35 DAP (46.80 g and 39.42 g) and minimum dry seed weight was recorded at 10 DAP (10.17 g and 10.99 g) in *kharif* and *rabi*, respectively (Fig 5.13). In 2011 also maximum and minimum dry weights of seeds were noticed at 35 DAP and 10 DAP, respectively in both *kharif* and *rabi*. Among the seasons and years, highest mean dry weight of seed was recorded in *rabi* 2011 (29.47 g) and it was lowest in *kharif* 2011 (23.89 g), irrespective of maturity stages. Germination percentage also differed significantly among the different stages of maturity in both the seasons. There was no germination till the seeds reach maximum dry weight in both the seasons (Fig 5.13). The EC was slightly decreased as days to maturity advanced from 10 DAP to 40 DAP in both the seasons. Among the seasons and years, on an average highest EC was recorded in *kharif* 2010 (3.288 mS/ppt) and it was lowest in *kharif* 2011 (2.522 mS/ppt), irrespective of maturity stages. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons. Highest mean TDH was recorded in *rabi* 2010 (2.950) and it was lowest in *kharif* 2011 (1.517), irrespective of maturity stages. Similar results were also observed by Kole and Gupta (1982), Adetunji (1991), Bhaskar Rao *et al.* (1993) and Mahesha *et al.* (2001) in sunflower.

### 5.2.4 KBSH-44

Seed quality attributes differed significantly due to stage of maturity in both *kharif* and *rabi*, in KBSH-44 (Plate 5.2). Capitulum weight and seed moisture content decreased with the advance in maturity in both the seasons, irrespective of years. Significant differences were observed for seed moisture content among different stages of maturity in both the seasons during 2010 and 2011. Initially it was high and thereafter declined with the stage of maturity. Higher moisture content of seed was recorded at 10 DAP (80.33% and 64.10%) during *kharif* and *rabi* and later on decreased to 31.52 and
Fig 5.14. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower F₁ hybrid KBSH-44 during *rabi*, 2010
Plate 5.2. Symptoms of seed maturation stages of sunflower hybrid (KBSH-44) during kharif, 2011
20.99 per cent at 40 DAP in kharif and rabi, respectively, during 2010 (Fig 5.14). Similar trend has also been observed during 2011. Among the seasons and years, highest mean seed moisture content was recorded in kharif 2011 (53.24 %) and it was lowest in rabi 2010 (37.84 %), irrespective of maturity stages. Similarly fresh and dry weight of seeds also differed significantly due to maturity stages in both the seasons. Maximum dry weight of seed was obtained at 40 DAP and it was minimum at 10 DAP. During 2010, dry weight was maximum at 40 DAP (53.71 g and 31.41 g) and minimum at 10 DAP (15.77 g and 15.89 g) in kharif and rabi, respectively (Fig 5.14). In 2011 also, maximum and minimum dry weight of seed was noticed at 40 DAP and 10 DAP, respectively in both kharif and rabi. Among the seasons and years, highest mean dry weight of seeds was recorded in kharif 2010 (36.94 g), while it was lowest in rabi 2010 (24.71 g), irrespective of maturity stages. Germination percentage varied due to maturity stages in both the seasons during 2010 and 2011 (Fig 5.14). There was no germination till the seeds reach maximum weight (30 DAP). The electrical conductivity (EC) of seed leachate decreased significantly as days to maturity advanced from 10 DAP to 40 DAP and it was lowest at 35 DAP. Among the seasons and years, highest mean EC was recorded in kharif 2011 (4.464 mS/ppt), however it was lowest in rabi 2010 (2.214 mS/ppt), irrespective of maturity stages. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons, irrespective of years. TDH was highest at 35 DAP in both the seasons. Between the seasons and years, highest mean TDH was recorded in rabi 2011 (3.278) and it was lowest in kharif 2011 (1.391), irrespective of maturity stages. These results are in conformity with the findings of Pallavi et al. (2010) in sunflower.

### 5.2.5 KBSH-53

Both capitulum weight and seed moisture content decreased with the advance in maturity in both the seasons, irrespective of years. The seed moisture content declined steadily in both the seasons during 2010 and 2011. Initially it was high and thereafter declined with the stage of maturity. Higher moisture content of seed was recorded at 10 DAP (81.44% and 63.28%) during kharif and rabi and later on decreased to 28.97 and 7.22 per cent when the seeds were harvested at 40 DAP in kharif and rabi, respectively,
Fig 5.15. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower F$_1$ hybrid KBSH-53 during rabi, 2010.
in 2010 (Fig 5.15). During 2011 also, moisture content of seed decreased gradually as maturity period advanced from 10 DAP to 40 DAP in both the seasons. Among the seasons and years, highest mean seed moisture content was recorded in kharif 2011 (55.33 %) and it was lowest in rabi 2010 (23.07 %), irrespective of maturity stages. Similarly fresh and dry weight of seeds also differed significantly due to maturity stages in both the seasons. Maximum dry weight of seed was obtained at physiological maturity (30 DAP to 40 DAP) (Fig 5.15). Among the seasons and years, highest mean dry weight of seeds was recorded in rabi 2011 (29.21 g), while it was lowest in kharif 2010 (23.46 g), irrespective of maturity stages. The accumulation of food reserves have direct relationship with the germination per cent. Germination percentage differed significantly due to maturity stages in both the seasons during 2010 and 2011. There was no germination when the sunflower seeds harvested at 10 DAP in both the seasons, however it was progressively increased towards the maturity. During 2010, the germination was maximum at 35 DAP (2.00 % and 52.84 %) in kharif and rabi, respectively (Fig 5.15). In 2011 also, there was no germination at the beginning and maximum at 35 - 40 DAP in both the seasons. Among the seasons and years, highest mean germination was recorded in rabi 2010 (28.10 %) and it was lowest in kharif 2010 (0.80 %), irrespective of maturity stages. This is probably due to dormancy of fresh seeds and the occurrence of dormancy is more in kharif compared to rabi. The electrical conductivity (EC) of seed leachate decreased significantly as days to maturity advanced and it was lowest at 35 to 40 DAP. Among the seasons and years, highest mean EC was more in kharif 2010 (4.533 mS/ppt) but it was lowest in rabi 2010 (2.634 mS/ppt), irrespective of maturity stages. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons. Mean TDH was significantly higher in rabi 2011 (3.373) compared to kharif 2011 (1.501), irrespective of maturity stages.

5.2.6 RHA 6D-1

Significant differences were observed for seed moisture content among different stages of maturity in both the seasons during 2010 and 2011. Initially it was high and thereafter declined with the stage of maturity. Higher moisture content of seed was recorded at 10 DAP (80.31% and 70.39%) during kharif and rabi and later on decreased
Fig 5.16. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower male parent RHA 6D-1 during rabi, 2010
to 35.55 and 6.88 per cent when the seeds were harvested at 40 DAP in kharif and rabi, respectively, in 2010 (Fig 5.16). During 2011 also, similar trend has been noticed in both the seasons. Among the seasons and years, highest mean seed moisture was recorded in kharif 2010 (54.72 %) and it was lowest in rabi 2010 (31.34 %), irrespective of maturity stages. Similarly fresh and dry weight of seeds also differed significantly due to maturity stages in both the seasons. Maximum dry weight of seed was obtained at physiological maturity (35-40 DAP). However during 2010, maximum dry weight of seed was obtained at 35 DAP and 40 DAP (9.77 g and 10.46 g) and minimum dry seed weight was recorded at 10 DAP (3.08 g and 6.78 g) in kharif and rabi, respectively (Fig 5.16). In 2011 also maximum and minimum dry weight of seed was noticed at 40 DAP and 10 DAP, respectively in both kharif and rabi. Among the seasons and years, highest mean dry weight of seeds was recorded in rabi 2011 (11.98 g), while it was lowest in kharif 2010 (5.10 g), irrespective of maturity stages. Germination percentage varied due to maturity stages in both the seasons during 2010 and 2011 (Fig 5.16). There was no germination till the seeds reach maximum weight. The electrical conductivity (EC) of seed leachate decreased significantly as days to maturity advanced from 10 DAP to 35 DAP and it was lowest at 30-35 DAP. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons. TDH was highest in rabi 2011 (3.183) and it was lowest in kharif 2011 (1.268). These results are in conformity with the findings of Gerald (1998) and Pallavi et al. (2010) in sunflower.

5.2.7 RHA 95C-1

Significant differences were observed for seed moisture content among different stages of maturity in both the seasons during 2010 and 2011. Initially it was high and thereafter declined with the stage of maturity. Higher moisture content of seed was recorded at 10 DAP (67.41% and 56.73%) during kharif and rabi and later on decreased to 32.30 and 16.97 per cent at 40 DAP and 35 DAP in kharif and rabi, respectively in 2010 (Fig 5.17). Similar trend has also been observed during 2011. Similarly dry weight of seeds also differed significantly due to maturity stages in both the seasons and it was maximum at 35 DAP (Fig 5.17). In 2011 also maximum dry weight of seed was noticed at 35 DAP. Among the seasons and years, highest mean dry weight of seeds was recorded
Fig 5.17. Influence of maturity stages on seed moisture content (%), dry weight of seeds (g) and germination (%) of sunflower male parent RHA 95C-1 during *rabi*, 2010.
in *rabi* 2010 (16.79 g), while it was lowest in *kharif* 2011 (7.58 g), irrespective of maturity stages. There was no germination at 10 DAP in both the seasons, however it was progressively increased towards the maturity. During 2010, the germination was maximum at 35 DAP (1.50 % and 39.00 %) in *kharif* and *rabi*, respectively (Fig 5.17). Similar trend has also been observed during 2011. Mean germination was highest in *rabi* 2010 (17.27 %) and it was lowest in *kharif* 2010 (0.70 %), irrespective of maturity stages. The electrical conductivity (EC) of seed leachate decreased significantly as days to maturity advanced from 10 DAP to 40 DAP and it was lowest at 35 DAP. Among the seasons and years, highest mean EC was recorded in *kharif* 2011 (2.868 mS/ppt) but it was lowest in *rabi* 2010 (1.665 mS/ppt), irrespective of maturity stages. Similarly, the total dehydrogenase activity (TDH) also differed significantly among the different stages of maturity in both the seasons. The TDH was highest at 35 DAP in both the seasons. Between the seasons and years, highest mean TDH was recorded in *rabi* 2011 (3.394) and it was lowest in *kharif* 2011 (1.194), irrespective of maturity stages. Similar results were also observed by Adetunji (1991) and Bhaskar Rao *et al.* (1993).

5.3 Natural dissipation of dormancy and germination criteria of sunflower F1 hybrids and its parental lines produced over seasons and years

Dormancy is an important component of physiological quality of seeds. Domesticated species have lost longer dormancy than the wild species due to selection for early germination. Presence of dormancy causes germination problems in sunflower seeds. Dormancy delays the embryo growth and development and is controlled by endogenous action of seeds (Amen, 1968). Sunflower require 40-45 days to attain germination capacity, thereby delays the immediate sowing of the seeds for commercial crop production. Dormancy increases when germination takes place under stress.

Freshly harvested matured seeds of sunflower F1 hybrids and their parental lines obtained from Experiment-I were dried to safe moisture level and tested for its germination and other seed quality attributes at ten days interval to know the natural dissipation of seed dormancy and other seed quality attributes like mean seedling length, mean seedling dry weight and seedling vigour index based on seedling length (SVI-I) and seedling dry weight (SVI-II).
5.3.1 KBSH-1

During *kharif* 2010, the occurrence of seed dormancy significantly varied from 79.33 to 4.67 per cent from 10 DAH to 70 DAH, respectively. However during *rabi*, the occurrence of seed dormancy was ranging from 59.67 to 0.33 per cent from 10 DAH to 50 DAH, respectively (Fig 5.18). In 2011 also, similar trend has been observed. Among the seasons and years, highest mean seed dormancy was recorded in *kharif* 2011 (39.00 %), however it was lowest in *rabi* 2010 (21.57 %), irrespective of days after harvest. It means the presence of dormancy was high in *kharif* season than *rabi* season. Srivastava and Dey (1982) reported that the dormancy period varies with the season. In summer, the mean duration of dormancy in few cultivars of sunflower was about 33 days as against 48 days in winter. Further, Krishnamurthy (1990) opined that seeds of sunflower exhibit a dormancy period of about 35 to 45 days and the extent of dormancy depends on genotype and environmental conditions.

Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons of 2010 and 2011. During *kharif*, the seeds that showed only 20.67 and 12.33 per cent germination at 10 DAH increased gradually attained maximum (95.33 % and 99.50 %) at 70 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower hybrid KBSH-1. However, the seeds attained 75.50 and 81.83 per cent of germination at 50 DAH which is more than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 50 days after harvest. But complete elimination of dormancy was observed only after 70 DAH. But in *rabi*, seeds obtained MSCS of germination at 30 DAH (88.50 % and 84.50 %) and maximum germination was recorded at 50 DAH (99.67 % and 99.33 %) in 2010 and 2011, respectively (Fig 5.18). Among the seasons and years, highest mean germination was recorded in *rabi* 2010 (78.43 %) and it was lowest in *kharif* 2011 (60.98 %), irrespective of days after harvest. Therefore the presence of dormancy was high in *kharif* than *rabi*. Deshpande *et al.* (1997) found that there was an increase in germination per cent from 7.0 in freshly harvested sunflower seeds to 50 per cent in 36 days after harvest (DAH). A rapid increase in germinability was noticed from 40 DAH to 100 per cent at 52 DAH in
Fig 5.18. Natural dissipation of dormancy (%) and germination (%) of sunflower F₁ hybrid KBSH-1 produced during kharif and rabi, 2010 and 2011
summer and at 56 DAH in kharif. The dormancy in sunflower is mainly due to underdeveloped embryo and disappears during dry storage in sunflower (Oracz et al., 2008). Dormancy of sunflower seeds can be released by after-ripening and involves hormonal changes like decrease in ABA biosynthesis and sensitivity (Corbineau et al., 1990; Le Page-Degivry and Garello, 1992; Le Page-Degivry et al., 1996). Dry storage of mature or immature seeds strongly improves germination by breaking embryo dormancy and seed coat inhibition (Corbineau et al., 1989). Similar results were also observed by Singh et al. (1994), Rama et al. (2002) and Pallavi et al. (2010) in sunflower.

Significant differences were also observed for mean seedling length and mean seedling dry weight among different days after harvest (DAH) in both the seasons during 2010 and 2011. Mean seedling length was less at the initial and thereafter gradual increase in seedling length with higher germination over days after harvest. During kharif, highest mean seedling length was recorded at 70 DAH (35.83 cm and 30.50 cm) and it was lowest at 10 DAH (30.78 cm and 23.56 cm) in 2010 and 2011, respectively. In rabi, highest mean seedling length was obtained at 50 DAH (30.76 cm and 28.88 cm), while it was lowest at 10 DAH (26.53 cm and 24.46 cm). Among the seasons and years, highest mean seedling length was obtained in kharif 2010 (33.48 cm), however it was lowest in rabi 2011 (27.05 cm), irrespective of days after harvest. Similarly, seedling dry weight was also differed significantly due to different days after harvest in both the seasons. Both seedling vigour index I and II varied similar to germination and seedling growth parameters since it was the product of these two traits. These results are in conformity with the findings of Singh et al. (1990) and Subramanyam et al. (2002) in sunflower.

5.3.2 KBSH-41

The occurrence of dormancy was high at the initial and thereafter the level of dormancy reduced over days after harvest. The dormancy period varied from season to season and it was slightly higher in kharif when compared to rabi season, irrespective of years. However the dormancy was completely disappeared at 50 DAH in both the seasons (Table 4.27, 4.28 and Fig 5.19). Among the seasons and years, highest mean seed
Fig 5.19. Natural dissipation of dormancy (%) and germination (%) of sunflower F₁ hybrid KBSH-41 produced during kharif and rabi, 2010 and 2011.
dormancy was recorded in *kharif* 2010 (31.40 %) followed by *kharif* 2011 (30.63 %), however it was lowest in *rabi* 2010 (18.37 %), irrespective of days after harvest. Singh *et al.* (1994) found genotypic variation for dormancy period, in RHA 274 (15-30 days), RHA-83 R6; RHA 297 and 234B (31-45 days); 207B (46-60 days), RHA 6D-1 and RHA856 (61-75 days) and RHA 272 and 86b3 (76-90 days). Further, Rama *et al.* (2002) found genotypic differences for dormancy in sunflower. Among the 84 genotypes tested, majority of the genotypes recorded less than 30 days dormancy. Genotypes 89-B, IB-24 and 852-B recorded more than 50 days of dormancy and Maiti *et al.* (2006) indicated that sunflower genotypes showed a large variability in dormancy. In general, sunflower hybrids showed greater levels of seed dormancy than the cultivated genotypes. Some genotypes are highly dormant, and some are nearly non-dormant. Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons during 2010 and 2011. During *kharif*, the seeds that showed 27.50 and 24.33 per cent germination at 10 DAH increased gradually and attained maximum (99.50 %) at 50 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower. However, the seeds attained 78.00 and 74.33 per cent of germination at 30 DAH which is more than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 30 days after harvest. However complete elimination of dormancy was observed only after 50 DAH. But in *rabi*, seeds obtained MSCS of germination at 20 DAH (73.33 % and 71.67 %), however maximum germination was recorded at 50 DAH (99.67 %) in 2010 and 2011, respectively (Fig 5.19). The embryos gained germination capacity at 40 DAA (Ramazunova, 1994). At the time of maturity, the balance in promoter- inhibitor is more towards inhibitors, imposing dormancy. Mature seeds of sunflower exhibiting dormancy will be eliminated during storage in dry conditions (Corbineau and Come, 1987).

Significant differences were also observed for mean seedling length and dry weight due to different days after harvest (DAH) in both the seasons during 2010 and 2011. It was less at the initial and thereafter gradual increase in seedling length and dry weight with higher germination over days after harvest. In both *kharif* and *rabi*, highest seedling length and dry weight was obtained at 50 DAH, at this level the germination was
maximum. However, lowest seedling length and dry weight was obtained at the freshly harvested seeds *ie*, 10 DAH, because of higher dormancy and less germination at this stage. Between the seasons, *kharif* season was recorded highest seedling length and dry weight when compared to *rabi*. Similarly seedling vigour index (SVI-I and SVI-II) also differed significantly due to different days after harvest (DAH) in both the seasons and years. Bianco *et al.* (1994) and Subramanyam *et al.* (2002) also reported similar results in sunflower.

5.3.3 KBSH-42

Occurrence of seed dormancy differed significantly due to different days after harvest (DAH) in both the seasons during 2010 and 2011. It was highest in freshly harvested seeds and thereafter the level of dormancy reduced over days after harvest. The dormancy period varied from season to season and it was slightly higher in *kharif* season when compared to *rabi* season, irrespective of years. However the dormancy was completely disappeared at 70 DAH and 50 DAH in *kharif* and *rabi*, respectively (Table 4.29, 4.30 and Fig 5.20). Among the seasons and years, highest mean seed dormancy was recorded in *kharif* 2010 (37.64 %), while it was lowest in *rabi* 2010 (20.90 %), irrespective of days after harvest. Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons during 2010 and 2011. During *kharif*, the seeds that showed 13.17 and 15.00 per cent germination at 10 DAH increased gradually and attained maximum (99.50 % and 98.50 %) at 70 DAH and 50 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower. However, the seeds attained 72.33 and 75.83 per cent of germination at 30 DAH- 40DAH which is more than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 40 days after harvest. However complete elimination of dormancy was observed only after 60-70 DAH. But in *rabi*, seeds obtained MSCS of germination at 20 DAH (70.33 % and 71.67 %), however maximum germination was recorded at 50 DAH (99.33 % and 99.00 %) in 2010 and 2011, respectively (Fig 5.20). The presence of dormancy was high in *kharif* than *rabi*. Significant differences were also observed for mean seedling length and dry weight due to different days after harvest (DAH) in both
Fig 5.20. Natural dissipation of dormancy (%) and germination (%) of sunflower F$_1$ hybrid KBSH-42 produced during *kharif* and *rabi*, 2010 and 2011
the seasons. It was less at the initial and thereafter gradual increase in seedling length and dry weight with higher germination over days after harvest. Highest seedling length and dry weight was obtained at 70 DAH and 50 DAH in kharif and rabi, respectively, due to increase in germination percentage was maximum. However, lowest seedling length and dry weight was obtained at the freshly harvested seeds i.e., 10 DAH, because of higher dormancy and less germination at this stage. Between the seasons, kharif season was recorded highest seedling length and dry weight when compared to rabi during 2010. However in 2011, rabi season obtained highest seedling length and dry weight. Similarly seedling vigour index (SVI-I and SVI-II) also differed significantly due to different days after harvest (DAH) in both the seasons and years. Similarly, Srivastava and Dey (1982) and Krishnamurthy (1990) also noticed such results in sunflower.

5.3.4 KBSH-44

The dormancy was completely disappeared at 70 DAH in both the seasons (Table 4.31, 4.32 and Fig 5.21). Among the seasons and years, highest mean seed dormancy was recorded in kharif 2010 (48.83 %), however it was lowest in rabi 2010 (27.07 %), irrespective of days after harvest. Rama et al. (2002) found genotypic differences for dormancy in sunflower. Among the 84 genotypes tested, majority of the genotypes recorded less than 30 days dormancy. Genotypes 89-B, IB-24 and 852-B recorded more than 50 days of dormancy and Maiti et al. (2006) indicated that sunflower genotypes showed a large variability in dormancy. Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons during 2010 and 2011. During kharif, the seeds that showed only 10.00 and 12.50 per cent germination at 10 DAH increased gradually and attained maximum (92.67 % and 96.50 %) at 70 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower. However, the seeds attained 71.00 and 75.17 per cent of germination at 50 DAH which is more than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 50 days after harvest. However complete elimination of dormancy was observed only after 70 DAH. But in rabi, seeds obtained MSCS of germination at 40 DAH (79.67 % and 80.33 %), however maximum germination was recorded at 70 DAH (99.50 % and 99.00 %).
Fig 5.21. Natural dissipation of dormancy (%) and germination (%) of sunflower F$_1$ hybrid KBSH-44 produced during kharif and rabi, 2010 and 2011.
%) in 2010 and 2011, respectively (Fig 5.21). Significant differences were also observed for mean seedling length and dry weight due to different days after harvest (DAH) in both the seasons during 2010 and 2011. It was less at the initial and thereafter gradual increase in seedling length and dry weight with higher germination per cent over days after harvest. In both kharif and rabi, highest seedling length and dry weight was obtained at 70 DAH, at this level the germination was maximum. However, lowest seedling length and dry weight was obtained at 10 DAH, because of higher dormancy and less germination at this stage. Between the seasons, rabi was recorded highest seedling length and dry weight when compared to kharif. Similarly seedling vigour indices (SVI-I and SVI-II) also differed significantly due to stage of harvest (DAH) in both the seasons and years. Similar results were also observed by Seiler (1993), Bianco et al. (1994), Subramanyam et al. (2002) and Pallavi et al. (2010) in sunflower.

5.3.5 KBSH-53

The dormancy period varied from season to season and it was slightly higher in kharif season when compared to rabi season, irrespective of years. However the dormancy was completely disappeared at 70 DAH to 90 DAH and 50 DAH in kharif and rabi, respectively (Table 4.33, 4.34 Fig 5.22). Among the seasons and years, highest mean seed dormancy was recorded in kharif 2010 (37.07 %) and it was lowest in rabi 2010 (23.47 %), irrespective of days after harvest. Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons during 2010 and 2011. During kharif, the seeds that showed 12.50 and 13.67 per cent germination at 10 DAH increased gradually and attained maximum (98.67 % and 96.50 %) at 90 DAH and 70 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower. However, the seeds attained 71.67 and 71.33 per cent of germination at 40 DAH- 50 DAH which is more than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 40-50 days after harvest. However complete elimination of dormancy was observed only after 70-90 DAH. But in rabi, seeds obtained MSCS of germination at 30 DAH (83.50 % and 79.17 %), however maximum germination was recorded at 50 DAH (99.83 % and 98.67 %) in 2010 and 2011, respectively (Fig 5.22). Significant differences
Fig 5.22. Natural dissipation of dormancy (%) and germination (%) of sunflower $F_1$ hybrid KBSH-53 produced during kharif and rabi, 2010 and 2011.
were also observed for mean seedling length, seedling dry weight and seedling vigour index I and II due to different days after harvest (DAH) in both the seasons. Srivastava and Dey (1982), Krishnamurthy (1990) and Subramanyam et al. (2002) also noticed such results in sunflower.

5.3.6 RHA 6D-1

The dormancy was completely disappeared at 90 DAH and 70 DAH in kharif and rabi, respectively (Table 4.35, 4.36 and Fig 5.23). Among the seasons and years, highest mean seed dormancy was recorded in kharif 2010 (54.50 %), however it was lowest in rabi 2010 (34.86 %), irrespective of days after harvest. The occurrence of dormancy was higher when compared to other hybrids and its parental lines. Rama et al. (2002) found genotypic differences for dormancy in sunflower. Among the 84 genotypes tested, majority of the genotypes recorded less than 30 days dormancy. Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons during 2010 and 2011. During kharif, the seeds that showed only 5.00 and 7.33 per cent germination at 10 DAH increased gradually and attained maximum (87.67 % and 90.50 %) at 90 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower. However, the seeds attained 78.00 and 70.33 per cent of germination at 70 and 80 DAH, respectively which was higher than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 70 days after harvest. However, almost complete elimination of dormancy was observed only after 90 DAH. But in rabi, seeds obtained MSCS of germination at 40 DAH (74 % and 72.67 %), however maximum germination was recorded at 70 DAH (94.50 % and 94.75 %) in 2010 and 2011, respectively (Fig 5.23). Significant differences were also observed for mean seedling length, dry weight and seedling vigour index I and II due to different days after harvest (DAH) in both the seasons during 2010 and 2011. These results are in conformity with the findings of Seiler (1993), Bianco et al. (1994), Deshpande et al. (1997) and Pallavi et al. (2010) in sunflower.
Fig 5.23. Natural dissipation of dormancy (%) and germination (%) of sunflower male parent RHA 6D-1 produced during kharif and rabi, 2010 and 2011.
5.3.7 RHA 95C-1

The dormancy was completely disappeared at 90 DAH and 50 DAH in *kharif* and *rabi*, respectively (Table 4.37, 4.38 and Fig 5.24). Among the seasons and years, highest mean seed dormancy was recorded in *kharif* 2010 (36.98 %), however it was lowest in *rabi* 2010 (29.30 %), irrespective of days after harvest. Significant differences were observed for seed germination due to different days after harvest (DAH) in both the seasons during 2010 and 2011. During *kharif*, the seeds that showed only 10.00 and 11.83 per cent germination at 10 DAH increased gradually and attained maximum (95.50 % and 96.67 %) at 90 DAH in 2010 and 2011, respectively. This confirmed the presence of dormancy in freshly harvested seeds of sunflower. However, the seeds attained 77.00 and 80.50 per cent of germination at 60 DAH which is more than the minimum seed certification standards (MSCS). Thus the seeds of sunflower could be safely used for sowing after 60 days after harvest. However complete elimination of dormancy was observed only after 90 DAH. But in *rabi*, seeds obtained MSCS of germination at 30 DAH (77.50 % and 73.00 %), however maximum germination was recorded at 50 DAH (96.67 % and 95.00 %) in 2010 and 2011, respectively (Fig 5.24). Significant differences were also observed for mean seedling length, dry weight and seedling vigour index due to different days after harvest (DAH) in both the seasons during 2010 and 2011. Similar results were also observed by Dighe and Patil (1980), Singh *et al.* (1990), Deshpande *et al.* (1997) and Subramanyam *et al.* (2002) in sunflower.

5.4 Influence of seed dormancy breaking treatments on seed quality attributes of sunflower F₁ hybrids and its parental lines produced over seasons and years

Dormancy is an important component of physiological quality of seeds. Domesticated species have lost longer dormancy than the wild species due to selection for early germination. Presence of dormancy causes germination problems in sunflower seeds. Dormancy delays the embryo growth and development and is controlled by endogenous action of seeds (Amen, 1968). Sunflower require 40-45 days to attain germination capacity, thereby delays the immediate sowing of the seeds for commercial crop production. Dormancy increases when germination takes place under stress (poor field conditions) probably due to induction of secondary dormancy. Dormancy in
Fig 5.24. Natural dissipation of dormancy (%) and germination (%) of sunflower male parent RHA 95C-1 produced during *kharif* and *rabi*, 2010 and 2011
sunflower is reported to be innate and is the resultant of interaction between maternal and embryonic genotypes (Zimmerman and Zimmer, 1978). Bianco et al. (1994) studied the occurrence of dormancy and found that period of dormancy varied between cultivars ranging from 12 to 40 days after maturity. After knowing the occurrence of seed dormancy in sunflower F₁ hybrids and its parental lines, the freshly harvested seeds of sunflower F₁ hybrids and its parental lines were treated with different physical and chemical treatments for its safe removal of dormancy and tested for its germination and other seed quality attributes like mean seedling length, mean seedling dry weight and seedling vigour index based on seedling length (SVI-I) and seedling dry weight (SVI-II). The results of the study of each hybrid and its parental lines are presented below separately.

5.4.1 KBSH-1

Seeds of kharif 2010 treated with Ethrel @ 25 ppm recorded maximum germination (89.00 %) followed by GA₃ @ 100 ppm (86.33 %), pre-chilling @ 4°C for 72 hours (84.67 %) and KNO₃ @ 0.2% (83.00 %) as against untreated control (24.00 %). Similar trend has also been observed in rabi and so also in 2011. Among the seasons and years, highest mean germination was recorded in rabi 2010 (85.70 %), however it was lowest in kharif 2011 (74.85 %), irrespective of dormancy breaking treatments. Similar results have been reported by Singh et al. (1994), Gerald (1998) and Pallavi et al. (2010). Fabian Borghetti et al. (2002) opined that the protease activity might be involved in breaking dormancy by ethylene and thereby improvement noticed in germination of sunflower embryo. Other seed quality attributes like seedling growth attributes and seedling vigour index were slightly enhanced by GA₃ treatment compared to Ethrel (Fig 5.25). These results are in accordance with the findings of Ankaiah et al. (1993) and Deshpande et al. (1997) in sunflower.

5.4.2 KBSH-41

Seeds of kharif 2010 treated with Ethrel @ 25 ppm recorded maximum germination (95.00 %) followed by KNO₃ @ 0.2% (94.00 %) and GA₃ @ 100 ppm (92.67 %) as against untreated control (29.00 %). In rabi also, seeds treated with Ethrel
**Fig 5.25.** Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower F$_1$ hybrid KBSH-1 produced during rabi, 2010

**Treatments details**

- **T$_1$:** Control (untreated)
- **T$_2$:** Water soaking for 18 hours
- **T$_3$:** Pre-drying @ 45°C for 8 hours
- **T$_4$:** Pre-chilling @ 4°C for 72 hours
- **T$_5$:** $GA_3$ (100 ppm) for 18 hours
- **T$_6$:** Ethrel (25 ppm) for 18 hours
- **T$_7$:** KNO$_3$ (0.2 %) for 18 hours
- **T$_8$:** Thiourea (0.1 %) for 18 hours
- **T$_9$:** Vermiwash (1:1) for 18 hours
Fig 5.26. Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower F₁ hybrid KBSH-41 produced during *rabi*, 2010

**Treatments details**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>T₁</td>
<td>Control (untreated)</td>
</tr>
<tr>
<td>T₂</td>
<td>Water soaking for 18 hours</td>
</tr>
<tr>
<td>T₃</td>
<td>Pre-drying @ 45°C for 8 hours</td>
</tr>
<tr>
<td>T₄</td>
<td>Pre-chilling @ 4°C for 72 hours</td>
</tr>
<tr>
<td>T₅</td>
<td>KNO₃ (0.2 %) for 18 hours</td>
</tr>
<tr>
<td>T₆</td>
<td>Ethrel (25 ppm) for 18 hours</td>
</tr>
<tr>
<td>T₇</td>
<td>Thiourea (0.1 %) for 18 hours</td>
</tr>
<tr>
<td>T₈</td>
<td>Vermiwash (1:1) for 18 hours</td>
</tr>
</tbody>
</table>
Plate 5.3. Influence of dormancy breaking treatments on germination in sunflower hybrid KBSH-41 produced during rabi, 2010
@ 25 ppm recorded higher germination (100 %) followed by pre-chilling @ 4°C for 72 hours (99.00 %) and GA₃ @ 100 ppm (98.00 %), while it was lowest in untreated control (50.33 %) (Fig 5.26). Similar trend has also been observed in 2011. Singh and Rao (1994), Akinola et al. (2000) and Oracz et al. (2008) reported that dormancy is mainly due to embryo factor and disappears during dry storage in sunflower. Further, seedling length, seedling dry weight and seedling vigour index also differed significantly due to various dormancy breaking treatments in both the seasons. All the treatments studied have significantly higher in seedling length and dry weight when compared to Ethrel and next to untreated control (Plate 5.3). Maiti et al. (2006) and Brunick and Robert (2008) also noticed such enhanced germination and seedling growth attributes due to dormancy breaking treatments.

5.4.3 KBSH-42

Ethrel @ 25 ppm treated seeds of kharif recorded higher germination (93.00 %) followed by pre-chilling @ 4°C for 72 hours (91.67 %) and GA₃ @ 100 ppm (90.00 %), however lowest germination was noticed in untreated control (16.00 %). While in rabi, seeds treated with KNO₃ @ 0.2% recorded higher germination (97.67 %) followed by Ethrel @ 25 ppm (97.00 %) and it was lowest control (45.33 %) during 2010 (Fig 5.27). But in 2011, seeds treated with Ethrel @ 25 ppm recorded higher germination (94.67 % and 96.33) followed by GA₃ @ 100 ppm (93.33 % and 95 %) and KNO₃ @ 0.2% (92.00 % and 94.67 %) as against untreated control (18.33 % and 43 %) in kharif and rabi, respectively. Further seedling length, dry weight and seedling vigour index also differed significantly due to various dormancy breaking treatments in both the seasons. Kumari and Singh (2000) and Subramanyam et al. (2002) also noticed such variations with treatments in sunflower.

5.4.4 KBSH-44

Seeds of kharif 2010 treated with Ethrel @ 25 ppm recorded maximum germination (88.67 %) followed by pre-chilling @ 4°C for 72 hours (86.33 %) and GA₃ @ 100 ppm (85.67 %) as against untreated control (14 %). In rabi also, seeds treated with Ethrel @ 25 ppm recorded higher germination (94.33 %) followed by Thiourea @ 0.1 %
Fig 5.27. Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower F\textsubscript{1} hybrid KBSH-42 produced during rabi, 2010

**Treatments details**

<table>
<thead>
<tr>
<th>Treatment (code)</th>
<th>Description</th>
</tr>
</thead>
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<tr>
<td>T\textsubscript{1}</td>
<td>Control (untreated)</td>
</tr>
<tr>
<td>T\textsubscript{2}</td>
<td>Water soaking for 18 hours</td>
</tr>
<tr>
<td>T\textsubscript{3}</td>
<td>Pre-drying @ 45\textdegree C for 8 hours</td>
</tr>
<tr>
<td>T\textsubscript{4}</td>
<td>Pre-chilling @ 4\textdegree C for 72 hours</td>
</tr>
<tr>
<td>T\textsubscript{5}</td>
<td>GA\textsubscript{3} (100 ppm) for 18 hours</td>
</tr>
<tr>
<td>T\textsubscript{6}</td>
<td>Ethrel (25 ppm) for 18 hours</td>
</tr>
<tr>
<td>T\textsubscript{7}</td>
<td>KNO\textsubscript{3} (0.2 %) for 18 hours</td>
</tr>
<tr>
<td>T\textsubscript{8}</td>
<td>Thiourea (0.1 %) for 18 hours</td>
</tr>
<tr>
<td>T\textsubscript{9}</td>
<td>Vermiwash (1:1) for 18 hours</td>
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</tbody>
</table>
and GA$_3$ @ 100 ppm (91.33 %), while it was lowest in untreated control (32.33 %). During 2011, seeds were treated with Ethrel @ 25 ppm recorded higher germination (89 % and 93.67 %) followed by GA$_3$ @ 100 ppm (87.33 % and 92.00 %) as against the control where it was only 15.33 % and 30 per cent in *kharif* and *rabi*, respectively (Fig 5.28). Among the seasons and years, highest mean germination percentage was recorded in *rabi* 2010 (82.67 %) and it was lowest in *kharif* 2010 (75.33 %), irrespective of dormancy breaking treatments. Similar results have been reported by Singh and Rao (1994) and Akinola *et al.* (2000). Seedling length, dry weight and seedling vigour index also differed significantly due to various dormancy breaking treatments in both the seasons. All the treatments studied have significantly improved seedling length and dry weight when compared to untreated control. These results are in conformity with the findings of Singh *et al.* (1994), Gerald (1998) and Pallavi *et al.* (2010) in sunflower. The higher seed quality parameters in seeds treated with 100 ppm GA$_3$ was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growing points and higher activity of enzymes. The growth regulator treatments through enzymatic and hormonal mechanism stimulate metabolic process such as sugar mobilization, protein hydrolysis, oxidation etc. (Earlpuls and Lambeth, 1974).

### 5.4.5 KBSH-53

The results of the study revealed significant differences were observed for germination due to various dormancy breaking treatments in both the seasons during 2010 and 2011 (Plate 5.4 and Fig 5.29). All the treatments studied have registered higher germination when compared to control in both the seasons; however differences in seed germination could be existed due to treatments between the seasons. *Rabi* season was obtained maximum germination than *kharif*. During *kharif*, seeds were treated with Ethrel @ 25 ppm recorded maximum germination (96.33 % and 97.00 %) followed by GA$_3$ @ 100 ppm (94.67 % and 95.67 %) as against untreated control (13.33 % and 17.00 %) in the year 2010 and 2011, respectively. However in *rabi* also, seeds treated with Ethrel @ 25 ppm recorded maximum germination (99.67 % and 99.00 %) followed by GA$_3$ @ 100 ppm (99.33 % and 97.65 %) and Thiourea @ 0.1 % (98.33 % and 97.00 %) and it was
Fig 5.28. Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower F₁ hybrid KBSH-44 produced during *rabi*, 2010

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
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<tbody>
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<td>T₁</td>
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<td>T₂</td>
<td>Water soaking for 18 hours</td>
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<td>T₃</td>
<td>Pre-drying @ 45°C for 8 hours</td>
</tr>
<tr>
<td>T₄</td>
<td>Pre-chilling @ 4°C for 72 hours</td>
</tr>
<tr>
<td>T₅</td>
<td>KNO₃ (0.2 %) for 18 hours</td>
</tr>
<tr>
<td>T₆</td>
<td>Ethrel (25 ppm) for 18 hours</td>
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<tr>
<td>T₇</td>
<td>Thiourea (0.1 %) for 18 hours</td>
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<tr>
<td>T₈</td>
<td>Vermiwash (1:1) for 18 hours</td>
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Fig 5.29. Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower F<sub>1</sub> hybrid KBSH-53 produced during rabi, 2010

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Plate 5.4. Influence of dormancy breaking treatments on germination in sunflower hybrid KBSH-53 produced during kharif, 2011
lowest in control (43 % and 40.33 %) in the year 2010 and 2011, respectively. Seedling length, seedling dry weight and seedling vigour index also differed significantly due to various dormancy breaking treatments in both the seasons. All the treatments studied have significantly improved seedling length and dry weight and so also seedling vigour index (Plate 5.4). Similar results were also reported by Ankaiah et al. (1993), Deshpande et al. (1997) and Akinola et al. (2000) in sunflower where in seed hydration treatment mobilizes seed resources that are utilized for rapid germination and other quality traits (Khan, 1992).

5.4.6 RHA 6D-1

Seeds of kharif treated with Ethrel @ 25 ppm recorded maximum germination (79.67 % and 81.33 %) followed by KNO₃ @ 0.2 % (76.33 % and 78.67 %) and GA₃ @ 100 ppm (73.00 % and 76.67 %) as against untreated control (6.67 % and 9.33 %) in both year 2010 and 2011, respectively. However in rabi 2010 (Fig 5.30), seeds treated with Ethrel @ 25 ppm recorded maximum germination (83.00 %) followed by KNO₃ @ 0.2 % (80 %) and it was lowest in control (22 %), but rabi 2011, obtained maximum germination when the seeds were treated with Ethrel @ 25 ppm (84.33 %) followed by soaking in water (83 %), however the germination was lowest in control (20.67 %). The mean seedling length, seedling dry weight and seedling vigour index were also differed significantly due to various dormancy breaking treatments in both the seasons. The seeds treated with GA₃ enhanced the seedling growth and other attributes compared to other dormancy breaking treatments. These results are in conformity with the findings of Singh and Rao (1994), Kumari and Singh (2000) and Pallavi et al. (2010) in sunflower.

5.4.7 RHA 95C-1

Seeds treated with Ethrel @ 25 ppm recorded maximum germination (92.67 % and 94.00 %) followed by GA₃ @ 100 ppm (91.33 % and 92.67 %) and KNO₃ @ 0.2 % (90.00 % and 91.33 %) when compared to untreated control (11.67 % and 13.33 %) in both 2010 and 2011, respectively. However in rabi, seeds treated with Ethrel @ 25 ppm recorded maximum germination (96.33 % and 97.00) followed by GA₃ @ 100 ppm (95.00 % and 96.33 %) and KNO₃ @ 0.2 % (94.00 % and 95.67 %) and it was lowest in
Fig 5.30. Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower male parent RHA 6D-1 produced during *rabi*, 2010

<table>
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<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt;: Thio urea (0.1 %) for 18 hours</td>
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<td>T&lt;sub&gt;9&lt;/sub&gt;: Vermi wash (1:1) for 18 hours</td>
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control (36.00 % and 39.33) in 2010 and 2011, respectively (Fig 5.31). The seedling growth parameters also followed similar trend.

5.5 Influence of seed treatment chemicals and packing materials on storability of sunflower hybrids

Seed deterioration is an irreversible, inexorable and inevitable process that could not be stopped during storage but could be slowed down to some extent by seed management practices This rapid deterioration of stored seeds is a serious problem, particularly in India where high temperature and high relative humidity prevail and associated with accelerated ageing. The mechanism (s) causing deterioration is yet to be elucidated. Changes that occur during storage and are associated with deterioration such as delayed germination, reduced seedling growth rates, decreased tolerance to adverse germination conditions and loss of germinability (Abdul-Baki and Anderson, 1972) are some of the ‘physiological manifestations’ of seed deterioration.

The quality of the seed is at its highest when it completes structural and functional development on plant itself; thereafter it deteriorates irrevocably at varying rates (Delouche et al., 1973). Seed quality maintenance especially during storage has paramount importance in the present context. Since agriculture is season bound, the storage of seeds has become inevitable for farmers, seed producers, breeders and seed businessmen. It is quite natural phenomenon that seed loses its viability and vigour during storage like any other biological material. The loss of seed viability due to seed deterioration is clearly evident, but the rate of deterioration could be slowed down to a greater extent during storage by manipulating storage conditions or by imposing certain seed treatments before storage.

Various factors such as sensitivity of seed to environment, multiplicity of varieties, seasonal demand, specificity of planting time, disposal of end use areas, necessity of carryover seeds, seed treatments, packing materials and need for buffer stocks make seed storage an imperative and inescapable proposition. Physiological quality of seed is highest when it completes ‘structural’ and ‘functional’ development on the plant itself, i.e., at physiological maturity. Thereafter, it deteriorates much faster at
Fig 5.31. Influence of seed dormancy breaking treatments on germination (%) and seedling vigour index based on mean seedling length (SVI-I) and mean seedling dry weight (SVI-II) of sunflower male parent RHA 95C-1 produced during *rabi*, 2010

<table>
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<th>Treatments</th>
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<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Control (untreated)</td>
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<td>T&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Water soaking for 18 hours</td>
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<td>T&lt;sub&gt;3&lt;/sub&gt;</td>
<td>Pre-drying @ 45°C for 8 hours</td>
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<td>T&lt;sub&gt;4&lt;/sub&gt;</td>
<td>Pre-chilling @ 4°C for 72 hours</td>
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<td>T&lt;sub&gt;5&lt;/sub&gt;</td>
<td>GA&lt;sub&gt;3&lt;/sub&gt; (100 ppm) for 18 hours</td>
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<td>T&lt;sub&gt;6&lt;/sub&gt;</td>
<td>Ethrel (25 ppm) for 18 hours</td>
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<td>T&lt;sub&gt;7&lt;/sub&gt;</td>
<td>KNO&lt;sub&gt;3&lt;/sub&gt; (0.2 %) for 18 hours</td>
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<td>T&lt;sub&gt;8&lt;/sub&gt;</td>
<td>Thiourea (0.1 %) for 18 hours</td>
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<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt;</td>
<td>Vermiwash (1:1) for 18 hours</td>
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varying rates depending on how the seeds are held subsequently. This rapid deterioration of stored seeds is a serious problem where, high temperature and relative humidity prevailed and very much associated with accelerates ageing phenomena. The control of temperature and humidity during storage has a profound influence on the ‘viability’ and ‘vigour’ potential of seeds. It is also known that such facilities are always not available to all the seed producers and small producers.

Therefore, an understanding of seed deterioration may help to find out how best the seed could be stored for longer period under ambient conditions at relatively low cost with minimum deterioration would be of immense use to seed industry and farming community. The present study is an attempt to gather more information on the nature of seed viability, effect of packing materials and seed treatment chemicals on the retention of seed viability of sunflower hybrids during storage under ambient conditions. The results obtained are discussed below.

5.5.1 Physical seed quality attributes

The hundred seed weight which would indicate the amount of chemical constituents probably determines the storage potential of seeds besides its vigour. In the present study, it is observed that hundred seed weight differed significantly between the hybrids, both at the beginning and subsequent months of storage. Varietal differences were also existed for hundred seed weight. It was significantly higher in H₂ (6.29 g) followed by H₁ (5.69 g) and lesser in H₃ (3.52 g) initially. Similarly at the end of storage period, higher hundred seed weight was recorded in H₂ (6.06 g) and H₃ (3.28 g) recorded lower values. Highest 100 seed weight was noticed Imidacloprid, liquid form (EC) @ 5ml/kg (5.04 g) followed by Imidacloprid, powder form (WP) @ 5g/kg (4.96 g) and it was lowest in control (4.82 g) at the end of storage period. (Fig 5.32), probably in treated seeds loss in weight was minimized. Among packing materials, highest 100 seed weight (4.99 g) was in polypouches followed by super grain bag (4.94 g) and lowest was in cloth bag (4.86 g) at the end of storage period. The reduction in 100 seed weight over storage is presumably due to chemical effects, higher activities of fungi, insect damage, more respiration in seeds stored in cloth bags which might have ultimately responsible for loss
Fig 5.32. 100 seed weight (g) as influenced by hybrids, packing material and treatments during storage of sunflower.
in weight. The rate of decline in test weight differed between the hybrids indicating that the reduction is influenced by the hybrids. Similar reduction in seed weight was also noticed upon storage by Nataraj (2008) and Balakrishna (2010) in sunflower.

The seed moisture is an important factor, which decides the quality of stored seeds (Copeland and McDonald, 1995). Low seed moisture maintains the viability and vigour of seed in storage; whereas, high seed moisture increases the metabolic rate and invasion of seeds by storage fungi (Justice and Bass, 1978). In general as the storage period increases, the seed moisture content progressively increases depending upon the weather conditions. In the present study also, moisture content (%) differed significantly between the hybrids throughout the storage period. Initially, it was low in all hybrids with lowest recorded in H₃ (7.0%) but it was slightly higher in H₂ (7.09%). Thereafter, there was an increasing trend in moisture content till the end of storage. After twelve months of storage, H₂ recorded the highest moisture content (9.37%) and lowest was recorded in H₃ (8.82%). However, all hybrids treated with Imidacloprid, liquid form (EC) @ 5ml/kg and untreated control recorded slightly higher moisture (9.44 and 9.40%, respectively). Among the packing materials, cloth bag recorded high moisture content (9.19%) than polypouches (9.05%) (Fig 5.33). This may be due to fluctuation in relative humidity existed during storage period (59.0 % to 76.50 %). These results are in agreement with the findings of Bhattacharyya et al. (1983); Balamurugan et al. (1989); Shekhargouda et al. (1994); Patra et al. (2000); Lakshmi (2004) and Nataraj (2008) while on they also reported such variations in sunflower.

5.5.2 Physiological seed quality attributes

Decline in germination with advance in storage period may be attributed to aging effect, leading to depletion of food reserves and decline in synthetic activity of embryo that leads to loss of viability and vigour. In the present study, a decline in per cent germination was observed in all the hybrids with the advancement of storage period. However, the extent of reduction over initial was highest in KBSH-53 (79.67%) and it was lowest in KBSH-44 (34.21%). At the end of 12th month of storage, germination was highest in H₂ (60.67%) followed by H₁ (34.81%) but H₃ recorded significantly lower
Fig 5.33. Seed moisture (%) as influenced by hybrids, packing material and treatments during storage period of sunflower.

Sunflower hybrid KBSH-44 maintained minimum seed certification standards of germination (75.58%) up to ten months whereas KBSH-1 (80.00%) up to eight months but germination per cent decreased drastically in KBSH-53 sunflower hybrid (63.83%) due to insect damage and fungal infection from 8th months onwards and at the end of 12 months of storage it was hardly 18.83 per cent, irrespective of treatments.

Among the seed treatment chemicals, Imidacloprid powder form and Thiram treated seeds maintained prescribed standards of germination (70.00%) up to nine months. Imidacloprid, powder form (WP) @ 5g/kg seed dressing helped in extending the viability and found effective in maintaining germination (46.11%) followed by Thiram @ 2.5 g/kg (42.30%) and but Imidacloprid, liquid form (EC) @ 5ml/kg recorded lower germination (25.22 %) at the end of storage period. Effect of containers on viability and vigour during storage period clearly suggested that the packing materials are more important for preserving the seed quality for longer period. Seeds packed in polypouches maintained prescribed minimum certification standards of germination up to nine months. Germination was highest in polypouches (46.42%) followed by super grain bag (35.89%) as against lowest recorded in cloth bag (32.00%) at the end of 12th month storage (Fig 5.34). Naphade and Sagare (1983), Elementry (1993), Ramaiah (1994), Suneeta et al. (2002), Shakuntala (2009) have also reported faster decline in germination.

Significant differences were observed among hybrids pertaining to mean seedling length during storage. Mean seedling length followed a decreasing trend with the increase in storage period, initially higher seedling length was observed in H1 (31.30 cm) and lower was noticed in H3 (29.07 cm) but at the end of storage, higher MSL was obtained in H2 (24.29 cm) and lower was recorded in H3 (15.47 cm). Imidacloprid, powder form
Fig 5.34. Germination (%) as influenced by hybrids, packing material and treatments during storage of sunflower.
(WP) @ 5g/kg recorded higher mean seedling length (23.95 cm) followed by Thiram @ 2.5 g/kg (22.77 cm) and lowest was recorded in Imidacloprid, liquid form (EC) @ 5ml/kg (14.75 cm) at the end of storage period.

Among the packing materials, polypouches recorded higher mean seedling length (21.64 cm) followed by super grain bag (20.93 cm) and cloth bag recorded the lowest seedling length (18.19 cm) at the end of storage period (Fig 5.35).

Seedling dry weight showed a diminishing trend with the increase in storage period. Significant differences were found between the hybrids for mean seedling dry weight during storage. Initially, higher value was recorded in H₁ (31.40 mg) and it was lesser in H₃ (29.52 mg) and even at the end of storage higher seedling dry weight was recorded in H₁ (21.47 mg) while it was lower in H₃ (15.71 mg). Among the seed treating chemicals, Imidacloprid, powder form (WP) @ 5g/kg recorded the highest seedling dry weight (23.40 mg) followed by Thiram @ 2.5 g/kg (21.24 mg). But it was lowest in control (19.05 mg). Polypouches recorded highest value (20.66 mg) followed by super grain bag (19.78 mg) and cloth bag (18.13 mg) (Fig. 5.36).

The differences in seedling growth attributes due to packing materials and seed treatments may be attributed to the inherent genotypic differences and the amount of reserve food material mobilized during seedling growth which ultimately contributed to seedling growth and dry weight. The reduction in dry weight of seedling during storage may be due to decreased synthetic activity and lower mobilization that might have resulted in lesser shoot and root lengths. These findings of the study are in accordance with (Sung, 1996). The decline in seedling length in storage may also be due to depletion of food reserves resulted in loss of seed viability and capacity to germinate (Barton, 1961). Harrington (1967) also suggested that depletion of available oxidizable material in meristematic cells (embryonic axis) might cause deterioration, even when adjacent tissues such as cotyledons and endosperms still contained abundant food material. In such case, the lack of mobilization of food in dry seeds would lead to starvation of these meristematic cells. Thus, it was speculated that perhaps the meristematic cells exhausted their energy supply with no way to convert ADP to ATP.
Fig 5.35. Mean seedling length (cm) as influenced by hybrids, packing material and treatments during storage of sunflower.
Fig 5.36. Mean seedling dry weight (mg) as influenced by hybrids, packing material and treatments during storage of sunflower.
Seedling vigour index (SVI) is another aspect related to quality of seeds. It decreased in all the treatment combinations with increase in the storage duration. But extent of decrease varied with hybrids, containers and seed treatment chemicals. Seedling length, dry matter production and vigour index are considered to be the best indicator of seedling vigour. Higher vigour index based on seedling length observed in H₂ (1478) followed by H₁ (770) and less in H₃ (369) but on the contrary, seedling vigour index based on mean seedling dry weight was higher in H₂ (1306) and lower in H₃ (378) at the end of 12th month of storage which is mainly due to higher amount of food reserves. Among seed treatment chemicals, in Imidacloprid, powder form (WP) @ 5g/kg recorded higher vigour index-I (1140) followed by Thiram @ 2.5 g/kg (1005) and it was lower in Imidacloprid, liquid form (EC) @ 5ml/kg (546) at the end of storage period. Vigour index-II also greatly influenced by treatments which showed higher value with Imidacloprid, powder form (WP) @ 5g/kg (1095) followed by Thiram @ 2.5 g/kg (922) and it was lowest in Imidacloprid, liquid form (EC) @ 5ml/kg (510). Vigour index based on mean seedling length was highest in polypouches (1126) as against lowest recorded in cloth bag (678). The seed vigour index based on seedling dry weight was also maximum in polypouches (1055) followed by super grain bag (753) and cloth bag (651) at the end of 12th months of storage (Fig 5.37 and 5.38). The decrease in the vigour index can be ascribed to decreased shoot length, root length and decreased dry weight. Similar findings were also reported by Rame Gowda (1981), Bhaskar (1988), Ramaiah (1994), Lakshmi, (2004), Nataraja (2008) and Balakrishna (2010) in sunflower.

5.5.3 Biochemical seed quality attributes

Another aspect which related to the vigour and viability of seed is electrical conductivity (EC) of seed leachate. This is an attribute which is related to loss of membrane integrity and the extent of leakage, which is directly proportional to the conductivity of steeped water. The loss of membrane integrity is one of earliest biochemical symptoms of seed deterioration. Many workers recorded significant but negative correlation between germination and EC values (Sen and Pal, 1979; Halder and Gupta, 1980; Rame Gowda, 1981; Balamurugan and Vadivelu, 1994 and Pallavi et al., 2003). A number of water soluble compounds such as electrolytes, sugars, amino acids and organic acids release in to water upon imbibition contribute for increased EC values.
Fig 5.37. Seedling vigour index-I based on mean seedling length as influenced by hybrids, packing material and treatments during storage of sunflower.
Fig 5.38. Seedling vigour index-II based on mean seedling dry weight as influenced by hybrids, packing material and treatments during storage of sunflower.
The loss of membrane integrity with ageing might be thought to explain the fact that aged seeds show a greater tendency to break metabolites into the germination medium than fresh seeds do. This solute leakage has been closely associated with the loss of viability and vigour. The electrical conductivity of seed leachate indicates the membrane integrity and it is negatively correlated with seed quality. Significant differences were obtained among the hybrids for electrical conductivity throughout the storage period. Initially, it was less in H3 (0.226 mS/ppt) and more in H1 (0.324 mS/ppt). At the end of storage, H1 recorded significantly lower EC value (4.821 mS/ppt) compared to highest recorded in H3 (5.300 mS/ppt). Probably because of this factor, H3 lost germination earlier to H1 and H2. Imidacloprid, powder form (WP) @ 5g/kg recorded lower EC (4.754 mS/ppt) followed by Thiram @ 2.5 g/kg (4.911 mS/ppt) and it was highest in Imidacloprid, liquid form (EC) @ 5ml/kg (5.280 mS/ppt). Seeds stored in polypouches recorded slightly lower EC (4.804 mS/ppt) over super grain bag (4.953 mS/ppt) and cloth bag showed maximum EC (5.319 mS/ppt) (Fig. 5.39). This variation in electrical conductivity of seed leachate indicate increased membrane permeability and decrease in integrity of seed coat and cellular membrane deterioration. Such findings were also reported by Agrawal (1980), Rame Gowda (1981), Dighe et al. (1995) and Balakrishna (2010) in sunflower and Vasundhara and Bomme Gowda (1999) in groundnut. In the present investigation also, it is clearly evident that a progressive but tremendous increase in EC of seed leachate was recorded during storage among the hybrids. Further, it is apparent that loss of vigour and reduced germination of stored seeds might be due to lesser dehydrogenase activity. Loss of membrane integrity during storage would be the main reason for increased electrical conductivity and also evidenced by structural change and changes in membrane composition (Delouche and Baskin, 1973).

Measurement of enzymatic activities could also be taken as biochemical indices to assess seed deterioration. Enzymes such as dehydrogenases, peroxidases, catalases and GADA activity declined with loss of viability, while the hydrolytic enzymes viz., phytases, proteases and phosphatases increased over storage. Decline in dehydrogenase activity over storage period reported in sunflower (Rame Gowda, 1981; Balamurugan and Vadivelu, 1994; Kannababu and Karivaratharaju, 2001 and Pallavi et al., 2003).
Fig 5.39. Electrical conductivity of seed leachate (mS/ppt) as influenced by hybrids, packing material and treatments during storage of sunflower.
Total dehydrogenase enzyme (TDH) is one of the important enzymes essential for protein synthesis and energy production during germination. In the present study, the hybrids having lower germination and vigour had lower TDH values. Initially, maximum activity was noticed in H$_2$ (3.892) and minimum in H$_3$ (3.720). Further, TDH activity showed decreasing trend with advance in storage period and at the end of storage, higher dehydrogenase activity was registered in H$_2$ (2.337) and it was less in H$_3$ (2.090). Imidacloprid, powder form (WP) @ 5g/kg treated seeds recorded higher TDH (2.411) followed by Thiram (2.252) and it was less in Imidacloprid, liquid form (EC) @ 5ml/kg (1.866). Further, it was also higher in polypouches (2.344) followed by super grain bag (2.187) and seeds of cloth bag showed very low TDH activity (2.031) (Fig 5.40). These findings are in concurrence with the results of Rame Gowda (1981), Balamurugan and Vadivelu (1994), Bailly et al., (1997), Pallavi et al., (2003) and Nataraj (2008) in sunflower.

Generally, storage fungi increased with the increase in storage period and field fungi reduced. Similar trend of reduction in field fungi has been observed by Prasanna (1994). However, the percentage infection differed with cultivars, containers, treatment, storage period and several other factors. Storage fungi have been reported to invade and destroy seeds of many kinds (Rame Gowda, 1981; Charjan and Tarar, 1992; Murthy and Raveesha, 1996; Vamadevappa, 1998; Krishnappa, 1997; Narayanaswamy, 2002; Lakshmi 2004). Under favorable conditions, they invade any kind of seeds leading to loss of viability, development of musty odor and discoloration of seeds.

In the present study, the fungi associated with sunflower seeds during storage were Aspergillus, Rhizopus, Penicillium Alternaria and Fusarium and infection due to these fungi varied significantly among the treatments during storage (Plate 5.5). It showed an increasing trend with the advancement of storage. After 12$^{th}$ months of storage, H$_2$ recorded minimum infection (18.36%) and it was significantly higher in H$_3$ (43.39%). However seeds treated with Thiram showed significantly lower infection (23.59%) followed by Imidacloprid, powder form (WP) @ 5g/kg (25.57%) while higher infection was registered in Imidacloprid, liquid form (EC) @ 5ml/kg (40.98%) at the end of storage. Further, the infection was significantly lower in polypouches (30.11%)
Fig 5.40. Total dehydrogenase activity (A_{480}) as influenced by hybrids, packing material and treatments during storage of sunflower.
compared to cloth bag (33.71%) (Fig 5.41). The differences in infection levels may be attributed to the fluctuations in seed moisture especially in cloth bag. Similar increase in fungal infection during storage with the fluctuations in seed moisture has also been reported by several workers. These results are in lineage with the findings of Rame Gowda (1981), Ramaiah (1994), Thippeswamy and Lokesh (1997), Savitri et al. (1998) and Nataraj (2008).

Another important factor contributes for lower seed quality in oil seeds is fat content and its degradation. The seed oil (%) differed significantly between the hybrids throughout the testing period. Initially, H₃ recorded higher oil content (40.43%) and it was lower in H₂ (34.96%). Concomitantly thereafter, there was a slight reduction in oil (%) till the end of storage. H₃ recorded higher amount of oil (39.81%) and H₂ showed lower seed oil (34.53%) at the end of storage. Seed treatment also differed slightly for oil per cent. It was slightly higher in seeds treated with Imidacloprid, liquid form (37.85%) followed by Imidacloprid, powder form (37.69%) and Thiram (37.66%) and less oil content was recorded in control (37.51) at the end of storage period. Among the packing materials, polypouches recorded high oil content (37.76%) followed by super grain bag (37.73%) and the cloth bag (37.54%). This is probably due to more fungal infection that occurred in cloth bag and untreated seeds. The effect of packing materials and seed damage is pronounced in decreased oil percentage (Fig 5.42). Besides, storing of seeds with moisture impervious containers would protect the seeds against auto-oxidation since the variations in relative humidity did not influence seed moisture level significantly during storage. These results are in conformity with the findings of Rame Gowda (1981) in sunflower, Saxena et al. (1998) in safflower and Simic et al. (2006) and Ghasemnezhada and Honermeierb (2009) in sunflower.
Fig 5.41. Seed infection (%) as influenced by hybrids, packing material and treatments during storage of sunflower.
Fig 5.42. Seed oil (%) as influenced by hybrids, packing material and treatments during storage of sunflower.
Plate 5.5. Sunflower seeds infected with *Fungal* sp. during germination of stored seeds
**Future line of work**

The flowering behaviour of parental lines may vary in different agro-climate conditions. Hence the experiments with different planting ratios and staggered planting of male and female parents need to studied for optimizing the same for better seed setting and yield due to climate change that would help to take large scale hybrid seed production in identified provenance.

Little more cheaper and effective dormancy breaking treatments need to be identified that can be adoptable in organic seed production. So, in this regard the influence of bio-digester or any plant based products need to be identified and revalidated for dormancy breaking in sunflower.

The efficacy of new pesticide products *viz.* Agribrom, Orthene, Assail, Mitac, Quadris, Ficam, Crown, Tattoo, Helix etc., and packing materials like high density paper pouches lined with ultra thin plastic, polythene-aluminum laminated pouches, interwoven HDPE bags, high density cartoon box with thermo-cool lining, high density plastic bins etc., that are being used for packing of other agri-products and pharmaceuticals could also be tested for enhancing the storability of oilseeds especially the sunflower. Further, other than biochemical changes associated with ageing in storage, the QTLs in relation to seed ageing mechanism need to be identified for better understanding of seed deterioration process at the molecular level for crop improvement.