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Effect of storage temperature and packaging material on seed germination and seed viability of gaillardia

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ABSTRACT

The seeds of *Gaillardia aristata* were packed in five different packaging material (cloth bag in desiccator, poly set bin, polyethylene bag - 600 gauze, cloth bag and aluminium foil) for a period of 18 months. The germination was recorded maximum (39.51%) in cold storage followed by ambient conditions (31.62%) and incubator (22.98%). Among the packaging material, the cloth bag maintained the maximum germination (34.29%) and poly set bin the minimum (25.77%) at the end of storage period. After one year of seed storage, highest germination (45.67%) was obtained in desiccator kept in cold store. The seed viability was significantly better in cold store (46.05%) than ambient (35.88%) and incubator (34.57%). The cloth and aluminium foil maintained 41.48 and 39.93% seed viability that is considerably higher than all other packaging. The maximum viability after one year was also recorded in aluminium foil (51.33%) followed by cloth bag under cold storage.

Key words: Gaillardia, seed storage, seed germination, seed viability.

INTRODUCTION

Gaillardia aristata is one of the important species of annual flowers which had gained wide adaptability and popularity among the flower growers. It belongs to family compositae and is a native of America especially in the west. It is commercially grown for loose flower production in in Gujarat, Madhya Pradesh, Maharashtra and Rajasthan. Like many of the perennial crops of temperate region, *Gaillardia aristata* and *G. pulchella* are being grown for seed production in winter season under north western Indian plains. Punjab exports nearly 90 tones of seed per year from 400 ha of land with an estimated annual return of Rs. 7.00 crores. This seed is exported to Holland, France, England, Germany, USA and Japan (Nancy, 11). Seeds possess remarkably complex and effective mechanism to ensure their long survival or to remain viable in dormant or active state until next growing season. As seeds deteriorate, they loose vigor capacity for normal germination and finally viability. The storage conditions that minimize seed deterioration are those that slow respiration and other metabolic processes without injuring the embryo. The climatic conditions and cultural practices in terms of nutrition, planting time and spacing affected plant growth and flower production of gaillardia as reported by Patil *et al*. (9), and Mishra (10). So far limited information is available on the storage of flower seeds. Banovetz and Scheiner (1) reported that the imbibed seeds of *Coreopsis lanceolata* entered in secondary dormancy, when subjected to 5°C and the germination was greater at 15°C and 25°C at 12-h light/dark cycle. Therefore keeping this in view, these studies were undertaken to determine the response of gaillardia seed to different packaging and storage conditions to maintain higher seed germination and viability for a longer period.

MATERIALS AND METHODS

The present experiment was conducted in the Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana during 2003-2004. The seeds of *Gaillardia aristata* were air-dried and packed in five different packaging (poly set bin, polyethylene bag (600 gauze), cloth bag, aluminium foil pack and dessicator). For keeping in desiccator, the seeds were packed in cloth bags which were then kept in desiccator containing calcium chloride at the base. All the five packaging were kept at three storage conditions *viz.,* cold storage (0-4°C and 90 ± 2.7% RH), incubator (20-22 °C and 75 ± 1.5% RH and ambient storage for a period of 18 months from June 2003 to November 2004. The experiment was conducted in split plot design with storage conditions as main treatments, packaging as sub treatments and storage period as sub-sub-treatment. Seed germination was recorded from every packaging and storage conditions in three replications of 100 seed each at monthly interval from July 2003 to December 2004. The seed germination

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and seed viability in percentage were recorded as described by Singh *et al.* (8). The seed germination was determined by using towel paper method.

To determine seed viability, 100 seed from each treatment were soaked in water for 24 h and split into two halves, which were subsequently treated with 2,3,5-Triphenyl-tetrazolium chloride for 4 h. The seeds stained red on rinsing with water were considered viable and seed viability was calculated.

RESULTS AND DISCUSSION

The observations on percentage seed germination revealed that seeds of gaillardia maintained higher germination under cold storage than ambient and incubator storage (Table 1). The maximum germination (39.51%) was recorded in cold storage followed by ambient storage (31.62%) and incubator storage conditions (22.98%). It was also evident from the results that germination declined significantly with course of time. The maximum germination was recorded after one month of storage in July (66.89%), which declined to 48.47% after six months in December. As per the results of interaction, maximum germination (70.33%) was recorded in ambient storage in July, which was significantly higher than all other storage treatments. After 6 months in December, cold storage conditions resulted in higher germination (56.60%) than ambient conditions (50.00%) and incubator (38.80%). Similarly after 12 months of storage, cold storage showed 36.00% germination, which was significantly higher than ambient (20.80%) and incubator (6.20%) storage. Under cold storage, the loss of germination at slow rate could be due to reduced rate of metabolic activities and inactivation of enzymes required for retention of germination for longer period. Whereas with course of time decline in germination could be due to depletion of food reserve, increase in fat acidity, ultra structural changes, reduced activity of enzymes and weakening of membrane integrity. The temperature and moisture are the two major environmental factors that influence the seed longevity during storage. As per the Harrington (192) the seed looses half of their storage life with every 5°C increase in storage temperature between 0°C and 50°C and halved with every 1 percent increase in seed moisture between 5 and 14 percent. Below 5% the speed of aging may increase because of autoxidation of lipids and above 14%, storage fungi destroy the capacity of seed for germination. The poor germination under ambient and incubator storage has been reported in *Kochia prostata* (Bao *et al*., 2), and cosmos (Dubey *et al*., 4).

It is evident from the Table 2 that the seed packed in cloth bag and desiccator shows higher germination (34.29 and 33.62%, respectively) as compared to the poly set bin (25.77%) at the end of storage period. However, the seed germination recorded in polyethylene bag (31.57%) and in aluminium foil (31.61%) was statistically at par, but was significantly higher than poly set bin (25.77%). The maximum germination (66.89%) was recorded after one month of storage in July, which declined to 48.47% after six months of seed storage. The results of interaction between packaging and storage period significantly influenced the seed germination.

The interaction between storage conditions and packaging showed significant variation in seed germination. The seed stored in aluminium foil under cold storage maintained the maximum germination (41.70%) which was statistically at par with storage in cloth bag (40.93%) and desiccator (40.30%) under similar conditions (Table 3). Under ambient conditions, desiccator was recorded to be the adequate storage pack with 37.17% germination.

The interaction effect of storage conditions, packaging and storage period reveals that maximum germination (78.67%) was observed when seeds were stored in desiccator at ambient temperature after one month of storage (Table 4). After six months, desiccator showed 59.00 % germination in cold store and 60.0% at ambient conditions. However, after one year, maximum germination was recorded in desiccator (45.67%) followed by polyethylene bag (41.00%) and aluminium foil (38.67%) under cold storage. The seed packed in aluminium foil kept under cold store gave 21.67% count in next planting season, i.e. in September but at the same time failed to germinate when kept in incubator and ambient conditions irrespective of packaging. Here the decline in germination with course of time may be due to depletion of food reserve, increase in acids, ultra structural changes, reduced activity of enzymes and weakening of membrane integrity. Carpenter and Ostmark (3) also recorded 75% germination of coreopsis seed stored at 5°C temperatures and 10-20% relative humidity and 80% germination at 15°C temperature and 20-35% relative humidity after six months of storage. The seed stored in aluminium foil under incubator and in poly set bin under ambient conditions failed to germinate after one year of storage. The poor germination under ambient and incubator storage was in conformity with the results of Gujar *et al.* (5) in China aster.

Table 1. Effect of storage conditions on seed germination (%) in *Gaillardia.*

Storage period	Storage condition			
	Cold storage	Incubator	Ambient	Mean
July, 2003	68.73 (56.70)*	61.60 (50.5)	70.33 (57.08)	66.89
Aug, 2003	67.33 (55.21)	59.33 (48.65)	68.20 (55.92)	64.96
Sept, 2003	64.60 (52.79)	55.47 (45.48)	65.40 (54.88)	61.82
Oct, 2003	63.40 (51.66)	54.53 (44.71)	64.07 (52.53)	60.67
Nov, 2003	62.60 (50.84)	52.33 (42.91)	62.13 (50.94)	59.02
Dec, 2003	56.60 (46.41)	38.80 (31.98)	50.00 (38.88)	48.47
Jan, 2004	50.80 (41.73)	26.47 (21.70)	34.80 (28.53)	37.36
Feb, 2004	47.40 (39.36)	18.87 (15.47)	32.60 (26.73)	32.96
March, 2004	42.53 (34.85)	14.27 (11.70)	27.47 (22.52)	28.09
April, 2004	39.33 (32.25)	9.07 (7.43)	26.40 (21.16)	24.93
May, 2004	37.07 (30.39)	6.67 (5.46)	23.20 (19.02)	22.31
June, 2004	36.00 (29.52)	6.20 (5.08)	20.80 (17.05)	21.00
July, 2004	32.67 (26.54)	4.40 (3.60)	12.93 (10.60)	16.67
Aug, 2004	24.27 (19.90)	5.67 (4.64)	10.87 (8.91)	13.60
Sept, 2004	17.93 (14.70)	0.0 (0.0)	0.0 (0.0)	5.98
Oct, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Nov, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Dec, 2004	0.0 (0.0)	0.0 (0.0)	0.00 (0.0)	0.0
Mean	39.51	22.98	31.62	

CD (P = 0.05) Storage period = 1.45; Storage condition = 0.56; Storage period × Storage conditions = 2.38; *Figures in parenthesis indicate arc sine √% values.

The data presented in Table 5 shows that storage conditions exhibited significant difference in the seed viability. The maximum seed viability (46.05%) was recorded in cold storage, followed by ambient storage (35.88%) and incubator (34.57%) after 18 months. It was also evident from the table that viability declined with the passage of time. The maximum viability (76.96%) was recorded after one month in July, which declined to 57.58% after 6 months in December and 29.47% after 12 months in June. The results of interaction between storage conditions and storage period were also recorded to be significant. After one

Table 2. Effect of storage period and packaging on seed germination (%) in *Gaillardia*.

Storage period	Packaging					
	Desiccator	Poly set bin	Poly bag	Cloth bag	Al. foil	Mean
July, 2003	69.56 (59.30)*	63.11 (52.71)	65.00 (57.49)	66.00 (56.10)	70.78 (61.12)	66.89
Aug, 2003	67.00 (57.11)	59.89 (50.76)	62.56 (55.05)	65.22 (55.43)	70.11 (60.87)	64.96
Sept, 2003	65.11 (55.34)	57.44 (48.16)	55.89 (49.18)	64.33 (54.68)	66.33 (57.12)	61.82
Oct, 2003	63.33 (53.83)	57.67 (48.45)	54.33 (48.06)	64.33 (54.68)	63.67 (54.87)	60.67
Nov, 2003	62.00 (52.7)	56.67 (47.03)	53.11 (46.73)	63.78 (54.21)	59.56 (51.42)	59.02
Dec, 2003	49.67 (42.21)	46.11 (39.19)	50.56 (44.49)	45.56 (38.72)	50.45 (43.50)	48.47
Jan, 2004	40.44 (34.37)	25.45 (21.12)	43.00 (37.84)	45.11 (38.34)	32.78 (28.70)	37.36
Feb, 2004	37.00 (31.45)	24.67 (20.47)	33.45 (29.43)	42.44 (36.07)	28.22 (24.55)	32.96
March, 2004	29.67 (25.21)	14.89 (12.35)	29.89 (26.30)	37.45 (31.83)	28.56 (24.84)	28.09
April, 2004	30.11 (25.59)	12.22 (10.14)	29.67 (26.22)	29.00 (24.65)	23.67 (20.59)	24.93
May, 2004	28.67 (24.36)	10.22 (8.48)	27.11 (23.85)	25.89 (22.00)	19.67 (17.11)	22.31
June, 2004	24.22 (20.58)	10.22 (8.48)	26.11 (22.97)	23.22 (19.73)	17.89 (15.56)	21.00
July, 2004	18.33 (15.58)	10.33 (8.57)	18.33 (16.13)	21.78 (18.51)	14.56 (12.66)	16.67
Aug, 2004	14.44 (12.27)	9.67 (8.02)	13.56 (11.93)	17.11 (14.54)	13.22 (11.50)	13.60
Sept, 2004	5.67 (4.81)	5.33 (4.42)	5.67 (4.98)	6.00 (5.1)	7.22 (6.28)	5.98
Oct, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Nov, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Dec, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Mean	33.62	25.77	31.57	34.29	31.61	

CD (P = 0.05) Storage period = 1.45; Packaging = 0.68; Storage period × Packaging = 2.90; *Figures in parenthesis indicate arc sine √% values

Table 3. Effect of storage conditions and packaging on seed germination (%) in *Gaillardia.*

Packaging	Storage condition			
	Cold storage	Incubator	Ambient	Mean
Desiccator	40.30 (29.17)*	23.41 (16.58)	37.17 (26.76)	33.62
Poly set bin	36.83 (26.51)	20.31 (14.62)	20.17 (14.52)	25.77
Poly bag	37.82 (27.23)	23.39 (17.05)	33.50 (24.12)	31.57
Cloth bag	40.93 (29.46)	27.17 (20.55)	34.78 (25.04)	34.29
Al. foil	41.70 (30.13)	20.63 (14.85)	32.50 (23.40)	31.61
Mean	39.51	22.98	31.62	

CD (P = 0.05) Packaging = 0.68; Storage conditions = 0.56; Packing × Storage conditions = 1.25; *Figures in parenthesis indicate arc sine √% values.

month, incubator storage showed 78.40% viability, whereas, it was highest under cold storage after six months (61.93%) and twelve months (43.86%).

The effect of various packaging and storage period on the seed viability presented in Table 6 indicates that cloth bag and aluminium foil showed 41.48 and 39.93% viability, respectively. The viability recorded after one month (76.96%) was considerably higher than 57.58% after 6 months in December and 29.47% after 12 months in June. The results of interaction between packaging and storage period were also significant. Aluminium foil showed maximum viability (81.56%) after one month of storage whereas after six months aluminium foil and polyethylene bag showed comparable results with 59.56% and 59.33% viability respectively. Desiccator and aluminium foil showed non-significant differences with 33.89 and 32.55% viability, respectively after one year of storage. The higher germination and viability in desiccator might be due to strongly hygroscopic nature of calcium chloride, which absorb the excessive moisture inside the container and maintain the seed quality. Whereas, in aluminium foil and polyethylene bag it can be attributed to non-permeability to moisture. These results are in conformity with the result of higher germination in poppy as reported by Verma *et al.* (13).

It is evident from the results of Table 7 that after storage period of 18 months, the maximum viability was recorded in cloth bag (41.48%) followed by aluminium foil (39.93%). It was observed to be minimum in poly set bin (35.37%). Among the storage chambers higher viability (46.05%) was maintained in cold storage conditions as compared with incubator (34.57%) and ambient storage (35.88%). The results of interaction between storage conditions and packaging also differed significantly. The seed packed in cloth bag and aluminium foil kept under cold storage showed 48.93 and 48.80% viability, respectively, which was significantly better than other packaging and storage conditions. Selvaraju and Selvaraj (12) reported that cloth bag and polyethylene bag were the adequate packaging for maintaining the maximum seed viability of marigold for six and eight months, respectively.

The results of interaction between storage conditions, packaging and storage period presented in Table 8 show that aluminium foil packing in incubator showed the maximum viability of 87.00 after one year of storage. Whereas, after six months, seed stored in polyethylene bags, aluminium foil and cloth bag under cold storage exhibited non-significant difference for seed viability. After 12 months, aluminium foil retained highest seed viability (51.33%) under cold storage and this trend was consistent in the succeeding months also. Banovetz and Scheiner (1) reported that seed germination and viability of coreopsis was greatly influenced by adequate moisture content at a particular temperature during packaging. These results are in line with the findings of Yogeesha *et al.* (14) in aster where laminated aluminium foil packing resulted in higher germination. These results also justify the findings of Kumar *et al.* (7) that vegetable seeds stored with high seed moisture content significantly affected the storability and thus resulted in poor and scattered seedling emergence.

Table 4. Interaction effect of storage conditions, packaging and storage period on seed germination (%) in *Gaillardia*.

Storage period	Cold storage					Incubator					Ambient				
	Desiccator	Poly bin	Poly bag	Cloth Bag	A.foil	Desiccator	Poly bin	Poly bag	Cloth bag	A.foil	Desiccator	Poly bin	Poly bag	Cloth bag	A.foil
July, 2003	66.00 (54.3)*	73.67 (59.1)	60.00 (51.7)	72.00 (58.3)	72.00 (58.1)	64.00 (53.1)	52.33 (46.3)	65.67 (54.1)	60.00 (51.0)	66.00 (54.5)	78.67 (62.5)	63.33 (52.7)	69.33 (56.3)	66.00 (54.3)	74.33 (59.5)
Aug, 2003	65.33 (53.7)	69.33 (56.3)	58.00 (50.3)	71.67 (58.2)	72.33 (58.4)	60.67 (51.1)	49.33 (44.6)	62.67 (52.3)	59.00 (50.5)	65.00 (53.9)	75.00 (59.9)	61.00 (51.3)	67.00 (54.9)	65.00 (53.7)	73.00 (58.7)
Sept, 2003	65.00 (53.1)	67.00 (54.6)	57.00 (50.0)	70.00 (57.9)	64.00 (51.5)	58.33 (49.8)	46.33 (42.9)	52.67 (46.5)	57.00 (48.7)	63.00 (52.5)	72.00 (56.5)	59.00 (49.1)	58.00 (47.1)	66.00 (54.3)	72.00 (57.5)
Oct, 2003	65.00 (53.1)	66.00 (54.2)	56.00 (48.8)	70.00 (57.1)	60.00 (48.0)	54.00 (44.2)	47.00 (43.0)	51.00 (45.2)	56.00 (47.1)	64.67 (53.5)	71.00 (55.4)	60.00 (50.7)	56.00 (45.7)	67.00 (55.2)	66.33 (54.5)
Nov, 2003	64.00 (52.9)	66.00 (54.2)	55.00 (47.9)	69.00 (56.0)	59.00 (47.2)	53.00 (43.9)	47.00 (43.0)	49.00 (44.4)	54.00 (45.9)	58.67 (51.3)	69.00 (53.8)	57.00 (48.2)	55.33 (44.5)	68.33 (56.0)	61.00 (48.8)
Dec, 2003	59.00 (50.2)	58.00 (49.8)	54.00 (44.8)	55.00 (47.7)	57.00 (45.6)	30.00 (24.6)	24.67 (19.0)	49.67 (43.8)	44.00 (37.4)	45.67 (37.4)	60.00 (48.4)	55.67 (46.3)	48.00 (38.9)	37.67 (30.9)	48.67 (38.4)
Jan, 2004	47.00 (30.9)	48.00 (41.3)	52.00 (43.8)	54.00 (46.1)	53.00 (42.4)	26.33 (21.6)	23.67 (18.5)	31.00 (25.7)	43.00 (36.5)	8.33 (6.91)	48.00 (37.9)	4.67 (3.7)	46.00 (37.3)	38.33 (31.4)	37.00 (29.6)
Feb, 2004	47.00 (24.3)	48.00 (41.8)	42.00 (30.6)	48.00 (39.1)	52.00 (41.6)	17.00 (13.9)	23.67 (18.5)	12.67 (10.5)	41.00 (34.8)	0.0 (0.0)	47.00 (37.1)	2.33 (1.93)	45.67 (36.9)	38.33 (31.4)	29.67 (23.7)
Mar, 2004	40.00 (22.2)	33.67 (29.3)	42.00 (30.5)	45.00 (35.4)	52.00 (41.6)	14.33 (11.5)	11.00 (9.5)	12.33 (10.2)	33.67 (30.3)	0.0 (0.0)	34.67 (26.0)	0.0 (0.0)	35.33 (28.6)	33.67 (27.6)	33.67 (26.9)
April, 2004	46.00 (21.4)	26.67 (26.4)	42.00 (30.6)	43.33 (33.7)	38.67 (31.0)	13.33 (10.9)	10.00 (9.0)	12.00 (9.8)	10.00 (8.5)	0.0 (0.)	31.00 (24.1)	0.0 (0.0)	35.00 (28.3)	33.67 (27.6)	32.33 (25.8)
May, 2004	47.00 (30.9)	22.33 (17.8)	41.00 (30.7)	34.33 (27.3)	40.67 (31.9)	7.67 (6.3)	8.33 (7.6)	7.33 (6.08)	10.00 (8.5)	0.0 (0.0)	31.33 (24.7)	0.0 (0.0)	33.00 (26.7)	33.33 (27.3)	18.33 (14.6)
June, 2004	45.67 (29.9)	23.33 (18.4)	41.00 (30.4)	31.33 (24.7)	38.67 (31.0)	8.00 (6.6)	7.33 (6.5)	10.00 (8.3)	5.67 (4.8)	0.0 (0.0)	19.00 (15.0)	0.0 (0.0)	27.33 (22.1)	32.67 (26.8)	25.00 (20.0)
July, 2004	32.00 (26.2)	23.67 (18.7)	40.00 (30.5)	28.00 (22.4)	39.67 (32.0)	6.33 (5.2)	7.33 (6.5)	0.0 (0.0)	8.33 (7.0)	0.0 (0.0)	16.67 (13.2)	0.0 (0.0)	15.00 (12.1)	29.00 (23.8)	4.00 (3.2)
Aug, 2004	19.33 (15.8)	21.33 (12.1)	23.67 (12.9)	27.00 (21.6)	30.00 (24.0)	8.33 (6.8)	7.67 (6.0)	0.0 (0.)	7.33 (6.2)	0.0 (0.0)	15.67 (12.3)	0.0 (0.0)	12.00 (12.1)	17.00 (13.9)	9.67 (7.7)
Sept, 2004	17.00 (14.1)	16.00 (11.1)	17.00 (11.2)	18.00 (14.4)	21.67 (16.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Nov, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

CD (P = 0.05) Storage conditions × Packaging × Storage period = 2.04; *Figures in parenthesis indicate arc sine √% values.

Table 5. Effect of storage conditions and period on seed viability (%) in *Gaillardia.*

Storage period	Storage conditions			
	Cold storage	Incubator	Ambient	Mean
July, 2003	76.80 (61.25)*	78.40 (62.46)	75.67 (60.53)	76.96
Aug, 2003	75.80 (60.53)	75.87 (60.74)	74.27 (59.58)	75.31
Sept, 2003	72.07 (58.16)	69.80 (56.74)	69.00 (56.23)	70.29
Oct, 2003	70.40 (57.12)	68.80 (56.14)	66.20 (54.51)	68.47
Nov, 2003	69.20 (56.33)	67.07 (55.04)	65.13 (53.85)	67.13
Dec, 2003	61.93 (51.90)	54.80 (47.74)	56.00 (48.43)	57.58
Jan, 2004	54.80 (47.74)	48.40 (44.06)	49.60 (44.75)	50.93
Feb, 2004	51.40 (45.78)	34.87 (36.15)	36.87 (37.36)	41.04
March, 2004	48.93 (44.37)	27.47 (31.58)	34.93 (36.19)	37.11
April, 2004	46.86 (43.16)	27.00 (31.19)	32.27 (34.52)	35.38
May, 2004	45.33 (42.27)	25.00 (29.92)	25.87 (27.70)	32.07
June, 2004	43.86 (41.42)	21.00 (27.16)	23.53 (26.25)	29.47
July, 2004	37.73 (37.84)	14.60 (19.99)	18.67 (23.02)	23.67
Aug, 2004	31.13 (33.85)	9.27 (15.86)	14.20 (19.85)	18.20
Sept, 2004	25.00 (29.95)	0.0 (0.0)	3.67 (5.07)	9.56
Oct, 2004	13.60 (21.53)	0.0 (0.0)	0.0 (0.0)	4.53
Nov, 2004	4.13 (7.48)	0.0 (0.0)	0.0 (0.0)	1.38
Dec, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Mean	46.05	34.57	35.88	

CD (P = 0.05) Storage period = 0.84; Storage conditions = 0.28; Storage period × Storage conditions = 1.21; *Figures in parenthesis indicate arc sine √% values.

Table 6. Effect of packaging and storage period on seed viability (%) in *Gaillardia.*

Storage Period	Packaging					
	Desiccator	Poly set bin	Poly bag	Cloth bag	Al. foil	Mean
July, 2003	76.44 (61.00)*	73.78 (59.24)	74.33 (59.58)	78.67 (62.52)	81.56 (64.73)	76.96
Aug, 2003	73.89 (59.34)	71.89 (58.00)	75.00 (60.03)	77.89 (61.94)	77.89 (62.12)	75.31
Sept, 2003	66.78 (54.83)	66.66 (54.73)	71.33 (57.72)	77.00 (61.34)	69.67 (56.61)	70.29
Oct, 2003	65.45 (54.02)	68.22 (55.72)	68.89 (56.22)	71.11 (57.70)	68.66 (55.98)	68.47
Nov, 2003	63.56 (52.86)	65.33 (53.92)	66.44 (54.72)	74.11 (59.40)	66.22 (54.47)	67.13
Dec, 2003	56.22 (48.86)	54.89 (47.80)	59.33 (50.37)	57.89 (49.55)	59.56 (50.50)	57.58
Jan, 2004	48.67 (44.22)	46.00 (42.68)	53.11 (46.77)	52.22 (46.26)	54.67 (47.66)	50.93
Feb, 2004	40.67 (39.57)	39.33 (38.76)	40.44 (39.38)	42.78 (40.78)	42.00 (40.33)	41.04
March, 2004	37.78 (37.80)	34.67 (35.95)	34.33 (35.74)	40.00 (39.09)	38.78 (38.31)	37.11
April, 2004	36.22 (36.86)	29.89 (32.96)	32.56 (34.71)	41.22 (39.86)	37.00 (37.06)	35.38
May, 2004	36.44 (37.00)	20.78 (22.55)	32.11 (34.42)	37.33 (37.50)	33.67 (35.02)	32.07
June, 2004	33.89 (35.38)	18.33 (21.01)	30.11 (32.92)	32.44 (34.43)	32.55 (34.31)	29.47
July, 2004	25.00 (29.76)	19.78 (21.98)	23.55 (28.65)	28.00 (31.28)	22.00 (23.08)	23.67
Aug, 2004	18.67 (25.42)	14.78 (18.38)	19.11 (25.41)	22.56 (27.65)	15. 89 (19.08)	18.20
Sept, 2004	13.67 (17.92)	9.22 (10.56)	7.44 (9.39)	8.33 (9.99)	9.11 (10.50)	9.56
Oct, 2004	4.33 (7.04)	3.11 (5.91)	4.56 (7.23)	5.00 (7.59)	5.67 (8.11)	4.53
Nov, 2004	3.11 (5.91)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	3.78 (6.56)	1.38
Dec, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0
Mean	38.93	35.37	38.48	41.48	39.93	

CD (P = 0.05) Storage period = 0.84; Packaging = 0.34; Storage period × Packaging =1.46; *Figures in parenthesis indicate arc sine √% values

Table 7. Effect of storage conditions and packaging on seed viability in Gaillardia.

Packaging	Storage conditions			
	Cold storage	Incubator	Ambient	Mean
Desiccator	44.93 (40.81)*	33.31 (31.52)	38.56 (35.59)	38.93
Poly set bin	42.43 (38.66)	33.74 (31.80)	29.94 (26.24)	35.37
Poly bag	45.20 (40.42)	34.19 (31.89)	36.06 (32.23)	38.48
Cloth bag	48.93 (42.63)	36.98 (33.63)	38.52 (34.89)	41.48
Al. foil	48.80 (43.22)	34.65 (30.83)	36.33 (33.36)	39.93
Mean	46.05	34.57	35.88	

CD (P = 0.05) Packaging = 0.34; Sorage conditions = 0.28; Packaging × Storage conditions = 0.64; *Figures in parenthesis indicate arc sine √% values

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Table 8. Interaction effect of storage conditions, packaging and storage period on seed viability (%) in *Gaillardia.*

Storage period	Cold storage					Incubator					Ambient				
	Desiccator	Polybin	Poly bag	Cloth bag	A.foil	Desiccator	Poly bin	Poly bag	Cloth bag	A.foil	Desiccator	Poly bin	Poly bag	Cloth bag	A.foil
July, 2003	75.00 (59.9)*	78.33 (62.2)	72.00 (58.0)	78.00 (62.0)	80.67 (63.9)	73.33 (58.9)	74.67 (59.8)	78.33 (62.2)	78.67 (62.5)	87.00 (68.9)	81.00 (64.1)	68.33 55.7	72.67 (58.5)	79.33 (63.0)	77.00 (61.3)
Aug, 2003	74.00 |(59.3)	75.00 (60.0)	79.00 (62.7)	77.33 (61.5)	73.67 (59.1)	69.67 (56.7)	73.00 (58.7)	75.00 (59.9)	76.33 (60.9)	85.33 (67.5)	78.00 (62.0)	67.67 (55.3)	71.00 (57.4)	80.00 (63.4)	74.67 (59.8)
Sept, 2003	69.00 (56.1)	68.33 (55.7)	78.00 (62.0)	77.33 (61.6)	67.67 (55.3)	60.33 (50.9)	67.33 (55.1)	71.00 (57.4)	76.00 (60.6)	74.33 (59.6)	71.00 (57.0)	64.33 (53.3)	65.00 (53.7)	77.67 (61.8)	67.00 (54.9)
Oct, 2003	67.67 (55.3)	66.00 (54.3)	77.00 (61.3)	77.00 (61.3)	64.33 (53.3)	59.00 (50.2)	64.33 (53.3)	69.67 (56.6)	77.67 (61.8)	73.33 (58.9)	69.67 (56.6)	74.33 (59.5)	60.00 (50.8)	58.67 (49.9)	68.33 (55.7)
Nov, 2003	65.00 (53.7)	66.33 (54.5)	75.33 (60.2)	74.00 (59.3)	65.33 (53.9)	59.67 (50.5)	62.33 (52.1)	67.67 (55.3)	75.00 (60.0)	70.67 (57.2)	66.00 (54.3)	67.33 (55.1)	56.33 (48.6)	73.33 (58.9)	62.67 (52.3)
Dec, 2003	59.67 (50.5)	58.00 (49.6)	64.33 (53.3)	63.67 (52.9)	64.00 (53.1)	53.33 (46.9)	48.67 (44.2)	56.67 (48.8)	58.33 (49.8)	57.00 (49.0)	55.67 (48.2)	58.00 (49.6)	57.00 (49.0)	51.67 (45.9)	57.67 (49.4)
Jan, 2004	51.67 (45.9)	50.00 (44.9)	57.67 (49.4)	57.33 (49.2)	57.33 (49.2)	44.67 (41.9)	40.33 (39.4)	49.33 (44.6)	52.00 (46.1)	55.67 (48.2)	49.67 (44.8)	47.67 (43.6)	52.33 (46.3)	47.33 (43.4)	51.00 (45.5)
Feb, 2004	48.67 (44.2)	47.67 (43.6)	53.33 (46.9)	54.00 (47.3)	53.33 (46.9)	37.00 (37.4)	32.00 (34.4)	30.00 (33.2)	37.33 (37.6)	38.00 (38.0)	36.33 (37.0)	38.33 (38.2)	38.00 (38.0)	37.00 (37.4)	34.67 (36.0)
Mar, 2004	48.33 (44.0)	45.00 (42.1)	41.00 (39.8)	55.00 (47.8)	55.33 (48.0)	28.00 (31.9)	29.00 (32.6)	25.00 (29.9)	29.33 (32.8)	26.00 (30.6)	37.00 (37.4)	30.00 (33.2)	37.00 (37.4)	35.67 (36.6)	35.00 (36.2)
April, 2004	48.33 (44.0)	40.33 (39.4)	35.00 (36.2)	54.33 (47.5)	56.33 (48.6)	27.33 (31.5)	26.33 (30.9)	26.00 (30.6)	35.67 (36.7)	19.67 (26.1)	33.00 (35.0)	23.00 (28.6)	36.67 (37.2)	33.67 (35.4)	35.00 (36.2)
May, 2004	48.33 (44.0)	36.67 (37.2)	37.33 (37.6)	51.33 (45.7)	53.00 (46.7)	28.00 (31.9)	25.67 (30.4)	24.67 (29.8)	28.00 (31.9)	18.67 (25.6)	33.00 (35.0)	0.0 (0.0)	34.33 (35.8)	32.67 (34.8)	29.33 (32.8)
June, 2004	48.33 (44.0)	32.33 (34.6)	43.00 (40.9)	44.33 (41.7)	51.33 (45.7)	27.00 (31.3)	22.67 (28.4)	17.67 (24.8)	19.67 (26.3)	18.00 (25.0)	26.33 (30.8)	0.0 (0.0)	29.67 (33.0)	33.33 (35.2)	28.33 (32.1)
July, 2004	35.67 (36.6)	31.33 (34.0)	34.33 (35.8)	41.33 (40.0)	46.00 (42.7)	19.00 (25.8)	28.00 (31.9)	14.00 (21.9)	12.00 (20.2)	0.0 (0.0)	20.33 (26.8)	0.0 (0.0)	22.33 (28.1)	30.67 (33.6)	20.00 (26.5)
Aug, 2004	24.00 (29.3)	31.33 (34.0)	30.33 (33.4)	35.67 (36.6)	34.33 (35.8)	13.33 (21.4)	13.00 (21.1)	10.33 (18.7)	9.67 (18.1)	0.0 (0.0)	18.67 (25.6)	0.0 (0.0)	16.67 (24.1)	22.33 (28.2)	13.33 (21.4)
Sept, 2004	22.67 (28.4)	27.67 (31.7)	22.33 (28.2)	25.00 (29.9)	27.33 (31.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	18.33 (25.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Oct, 2004	13.00 (21.1)	9.33 (17.7)	13.67 (21.7)	15.00 (22.8)	17.00 (24.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Nov, 2004	9.33 (17.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	11.33 (19.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Dec, 2004	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

CD (P = 0.05) Storage conditions × Packaging × Storage period = 2.72; *Figures in parenthesis indicate arc sine √% values.