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EFFECT OF STORAGE TREATMENTS AND GODOWN TYPES ON WHEAT STORAGE FOR SEED PURPOSE

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ABSTRACT

The present research was carried out investigate the effect of packing methods and storage condition for storage of wheat seed (variety: GW 451) up to eighteen months of storage at Department of Seed Technology, S.D. Agricultural University, Sardarkrushinagar during the year 2021-22 to 2022-23. The experiment were evaluated in two different sets of godown one set in ventilated godown another set in Non-ventilated godown with eleven different treatment of packaging methods (T_1 : Jute bag, T_2 : Cotton bag, T_3 : HDPE bag, T_4 : Jute bag + polythene bag (50 micron), T_5 : Cotton bag + polythene bag (50 micron), T_6 : HDPE Bag + polythene bag (50 micron), T_7: Jute bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g), T_8: Cotton bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g), T_9: HDPE bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g), T_{10}: Polythene laminated HDPE bag, T_{11}: polythene laminated HDPE bag + aluminum phosphide 56% powder (10 gm). The experiment was carried out in a Factorial Experiment in Randomized Complete Block Design (RCBD) with three replications. The pooled analysis results for the year 2021-22 to 2022-23 showed that T_9: HDPE bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g) found best among all the treatment of wheat seed packaging. Wheat grain stored for seed purpose up to eighteen month using HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder either in ventilated or non-ventilated godown for keeping seed upto the standard germination percentage, avoiding stored grain insect damage, obtaining higher seed vigour index and better germination index as well as maintaining optimum seed moisture content of seed.

Keywords **:** Wheat, storage periods, packaging material, Aluminium phosphide.

Introduction

Wheat (*Triticum aestivum* L.) is one of the principal cereal crops grown worldwide and one of the important staples of nearly 2.5 billion of world population. The crop being cultivated as winter and spring in the world, winter wheat is grown in cold countries like Europe, the USA, Australia, Russian Federation, etc., while spring wheat is grown in Asia and in some parts of the USA. India is being blessed and enriched with a diverse agro- ecological condition, ensuring food and nutrition security to a majority of the Indian population (Ramadas *et al.,* 2019).

Seed physiological quality pertains to the capacity of seeds to execute essential functions such as germination, viability, vigor, and longevity, which influence their performance in field conditions. The loss of grains during storage due to both biotic and abiotic factors is estimated to be 10% annually, with insects responsible for approximately 2.5 to 5.0 percent of this loss. Furthermore, the damage inflicted by insects on stored grains and their derivatives varies, ranging from 5-10% in temperate regions to 20-30% in tropical areas. Stored wheat is particularly susceptible to insect infestations, which can lead to a decline in both quality and quantity, resulting in a notable reduction in volume, significant weight loss, and considerable germination

impairment (Phillips and Throne, 2010). Insect infestations also lead to a marked increase in humidity and temperature, which subsequently fosters the growth of fungi and partial germination of grains (Padin *et al*., 2013).

Aluminum phosphide (AlP) is a solid fumigant that has been widely utilized since the 1940s. It is readily accessible and can be acquired in certain countries, including India, under various trade names such as Celphos, Quickphos, Synfume, and Phosfume (Chopra *et al*., 1986). Aluminum phosphide is a solid pesticide that quickly emerged as one of the most frequently utilized grain fumigants due to its properties deemed nearly ideal; it is harmful to all developmental stages of insects, extremely effective, does not compromise seed viability, is devoid of toxic residues, and leaves minimal residue on food grains (Wahab *et al*., 2009). Aluminum phosphide 56 % powder (10 gm) available in plastic pouch in form.

The main objective of seed storage is to prevent or reduce the rate of deterioration. Nevertheless, various storage factors, especially temperature, relative humidity, containers, air circulation, and packaging materials, significantly affect seed storability. An appropriate combination of these storage factors through technology-driven seed storage is essential for preserving the physiological quality of seeds. Although numerous modern storage techniques are currently employed worldwide, these technologies are often unaffordable for resource-poor or marginal farmers in our country and others. It is crucial to explore alternative storage solutions that are cost-effective, hermetic, and simple yet efficient to enhance seed storability, particularly in regions characterized by high temperatures and humidity.

In seed production programme of wheat after maturity of the crop harvesting, threshing, cleaning, grading and packaging were carried out. After packaging seeds are stored until for sowing purpose up to next growing season. Care must be required to maintain viability and vigour of stored seed. In most of the agricultural crop's ageing starts at physiological maturity, which is irreversible. Hence seeds become practically worthless if they fail to give adequate plant stands in addition to healthy and vigorous plants. With this view research was framed to identify effective method of storage for wheat grain for seed purpose.

Materials and Methods

An experiment was carried out under the two storage conditions (Ventilated and Non-Ventilated godown) for the period of eighteen month at Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar during the year 2021-22 to 2022-23. The experiment includes eleven different treatment of packaging methods *viz*., T_1 : Jute bag, T_2 : Cotton bag, T_3 : HDPE bag, T_4 : Jute bag + polythene bag (50 micron), T_5 : Cotton bag + polythene bag (50 micron), T_6 : HDPE Bag + polythene bag (50 micron), T_7: Jute bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g), T_8: Cotton bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g), T_9: HDPE bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g), T_{10}: Polythene laminated HDPE bag, T_{11}: polythene laminated HDPE bag + aluminum phosphide 56% powder (10 gm). All the treatment contain 40 kg seeds in bag. The aim of the experiment was to identify the effective packaging methods for storage of wheat seed. The experiment was arranged in a Factorial Experiment in Randomized Complete Block Design (RCBD) with four replications.

The Aluminium phosphide 56% powder utilized in this study was manufactured by Sumitomo Chemical India Ltd. Phosphine is extremely hazardous to all types of animal life; therefore, human exposure to even minimal quantities must be avoided.

Observations to be recorded

1. Germination (%)

Germination test was conducted by "Between paper method" as per ISTA guidelines of Initial seed lot germination % (at the time of storage) and final germination % from each treatment (at the end of storage i.e. 18 month). Hundred seeds were counted in three replications and kept over moist towel tissue paper in liner fashion. They were wrapped over by wax paper and kept into the germination chamber at 20 ± 10 C temperature and 90 ± 2 per cent relative humidity. At the end of 8th day of germination test, the number of normal, abnormal and dead seedlings in each replication was counted and only normal seedlings were considered as germination and expressed in percentage (ISTA 1996).

2. Damaged seed percentage

At the end of storage period (after 18 months of storage) 1000 grains from each treatment were manually picked from each package randomly for inspection. Grains which having holes or infestation were collected, also the grains which showed signs of insect damage were considered as infested. The infestation level was expressed as number then, percentage damage grains was estimated according to the formula described by, Jood *et al.* (1996).

$$\text{Damaged seed (\%)} = \frac{\text{Number of insect damaged seed}}{\text{Number of total grains inspected}} \times 100$$

3. Seed Vigor Index

Seedling vigor indices were calculated by using the formula suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

Seed vigour index-I = Standard germination (%)

× seedling length (cm)

Seed vigour index-II = Standard germination (%)

× seedling dry weight (mg)

4. Germination index

Germination index was calculated according to ISTA. 2009, International Rules for Seed Testing.

$$GI = \frac{\text{No. of germinated seed at first count}}{\text{Days of first count}} + \ldots \frac{\text{No. of germinated seed at final count}}{\text{Days of final count}}$$

5. Moisture content (%)

Moisture content percent of seed lot was measured with digital moisture metre before and end of seed storage.

Statistical Analysis

Data were subjected to the statistical analysis according to the technique of analysis of variance (ANOVA) for Factorial Experiment in Randomized Complete Block Design (RCBD) as published by Gomez and Gomez (1984).

Results and Discussion

(i) Germination (%)

Year: 2021-22:

The data presented in table1 indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) gave significantly higher germination percentage of wheat seeds than rest of the treatments. Between storage conditions, non-ventilated godown was found significantly superior than ventilated one. Interaction was not significant.

Year: 2022-23:

For germination percentage, the same trend as per year 2021-22 was found. But between storage conditions, ventilated godown was found significantly superior than non-ventilated. Interaction, T_9 G_2 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder non-ventilated godown) gave significantly higher germination percentage of wheat seeds than rest of the treatment combinations.

Pooled:

In pooled data, the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_8, T_6, T_7, T_4, T_{11}, T_5, T_{10} and T_3 gave significantly higher germination percentage of wheat seeds over T_1 and T_2. Looking to the minimum standard germination percentage of wheat seed (85 per cent) only T_9 found valid. Differences for storage godown as well as T × G interaction were not significant. Interactions Y×T, Y×G and Y×T×G were found significant.

(ii) Damaged seed percentage

Year: 2021-22:

The data presented in table 2 indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) gave significantly lower damaged seed percentage of wheat seeds than rest of the treatments. Between storage conditions, non-ventilated godown was found significantly superior than ventilated one. Interaction T_9 G_1 and T_9 G_2 being at par with each other gave significantly lower damaged seed percentage of wheat seeds than rest of the treatments.

Year: 2022-23:

For damaged seed percentage, the same trend for packaging material and interaction as per year 2021-22 was observed. But between storage conditions, non-ventilated godown was found significantly superior than ventilated.

Pooled:

In pooled data, the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_6, T_8, T_7, T_{11} and T_4 gave significantly lower damaged seed percentage of wheat seeds over T_1 and T_2. Differences for storage godown as well as T × G interaction were not significant. Interactions Y×T, Y×G and Y×T×G were found significant.

(iii) Seed vigor index I

Year: 2021-22:

The data presented in table 3 indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) gave significantly higher seed vigor index I of wheat seeds than rest of the treatments. Between storage conditions, non-ventilated godown was found significantly superior than ventilated one. Interaction was not significant.

Year: 2022-23:

The data indicated that the treatment T_8 (Cotton bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) gave significantly higher seed vigor index I of wheat seeds than rest of the treatments.

Between storage conditions, non-ventilated godown was found significantly superior than ventilated. Interaction, T_8 G_2 (Cotton bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder under non-ventilated godown) gave significantly higher seed vigor index I of wheat seeds than rest of the treatment combinations.

Pooled:

In pooled data, the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_8, T_7, T_6, T_4, T_{11}, T_5, T_{10} and T_3 gave significantly higher seed vigor index I of wheat seeds over T_1 and T_2. Between storage conditions, non-ventilated godown was found significantly superior than ventilated one. Interactions Y×T and Y×T×G were found significant.

(iv) Seed vigor index II

Year: 2021-22:

It is observed from the table 4 that for seed vigor index II, the same trend for packaging material storage condition and interaction as per seed vigor index I for year 2021-22 was observed.

Year: 2022-23:

The data indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_8 gave significantly higher seed vigor index II of wheat seeds than rest of the treatments. Between storage conditions, non-ventilated godown was found significantly superior than ventilated. Interaction, T_9 G_1 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder under ventilated godown) being at par with T_9 G_2, T_4 G_2, T_6 G_2 and T_8 G_2 gave significantly higher seed vigor index II of wheat seeds than rest of the treatment combinations.

Pooled:

For seed vigor index II, the differences due to packaging material, storage godown as well as T×G interaction were not significant. Interactions Y×T, Y×G and Y×T×G were found significant.

(v) Germination index

Year: 2021-22:

It is observed from the table 5 that for germination index, the same trend as per seed vigor index II for year 2021-22 for packaging material, storage condition and interaction was observed.

Year: 2022-23:

The data indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_8 gave significantly higher germination index of wheat seeds than rest of the treatments. Between storage conditions, non-ventilated godown was found significantly superior than ventilated. Interaction T_9G_1 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder under ventilated godown) being at par with T_9G_2, T_4G_2, T_6G_2 and T_8G_2 gave significantly higher germination index of wheat seeds than rest of the treatment combinations.

Pooled:

In pooled data, the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_6, T_7, T_8, T_{11}, T_4, T_3, and T_5 gave significantly higher germination index of wheat seeds over T_2 and T_1. Differences for storage godown as well as T × G interaction were not significant. Interactions Y×T, Y×G and Y×T×G were found significant.

(vi) Seed moisture content (%)

Year: 2021-22:

It is observed from the table 6 that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) being at par with T_3, T_6, T_5 and T_4 gave significantly lower seed moisture content of wheat seeds than rest of the treatments. Differences for storage godown as well as T × G interaction were not significant.

Year: 2022-23:

The data indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) gave significantly lower seed moisture content of wheat seeds than rest of the treatments. Between storage conditions, ventilated godown was found significantly superior than non-ventilated one. Differences for T × G interaction were not significant.

Pooled:

The data indicated that the treatment T_9 (HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder) gave significantly lower seed moisture content of wheat seeds than rest of the treatments. Differences for storage godown as well as T × G interaction were not significant. Interaction Y× G was found significant.

Conclusion

The pooled analysis results for the year 2021-22 to 2022-23 showed that packaging of 40 kg wheat seed (variety: GW 451) with HDPE bag + polythene bag (50 micron) + aluminum phosphide 56% powder (10 g) found best among all the treatment of wheat seed

packaging. This study recommend that wheat seed stored for seed purpose up to eighteen month using HDPE bag + polythene bag of 50 micron + 10 g aluminum phosphide 56% powder either in ventilated or non-ventilated godown for keeping seed upto the standard germination percentage, avoiding stored grain insect damage, obtaining higher seed vigour index and better germination index as well as maintaining optimum seed moisture content of seed.

Table 1: Effect of packaging materials and storage condition on germination (%)

Treatment	2021-22			2022-23			Pooled		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	30.64* (25.66)	35.24 (33.00)	32.94 (29.33)	5.74 (00.00)	5.74 (00.00)	5.74 (00.00)	18.19 (12.77)	20.49 (16.42)	19.34 (14.59)
T_2	29.69 (24.33)	34.59 (31.66)	32.14 (28.00)	5.74 (00.00)	5.74 (00.00)	5.74 (00.00)	17.72 (12.08)	20.17 (15.88)	18.95 (13.97)
T_3	54.38 (65.66)	55.14 (67.00)	54.76 (66.33)	34.74 (32.00)	41.63 (43.67)	38.18 (37.84)	44.56 (48.80)	48.39 (55.25)	46.48 (52.03)
T_4	42.13 (44.66)	45.17 (50.00)	43.65 (47.33)	74.59 (92.33)	73.41 (91.33)	74.00 (91.83)	58.36 (68.43)	59.29 (70.58)	58.83 (69.51)
T_5	43.00 (46.00)	46.47 (52.00)	44.73 (49.00)	70.78 (88.67)	53.62 (64.33)	62.20 (76.50)	56.89 (67.35)	50.05 (58.22)	53.47 (62.78)
T_6	59.26 (73.33)	66.03 (83.00)	62.64 (78.16)	76.15 (93.67)	61.45 (76.67)	68.80 (85.17)	67.71 (83.51)	63.74 (79.83)	65.73 (81.68)
T_7	55.82 (68.00)	58.67 (72.66)	57.24 (70.33)	63.79 (80.00)	58.78 (72.67)	61.29 (76.34)	59.81 (73.98)	58.73 (72.58)	59.27 (73.28)
T_8	54.53 (66.00)	57.04 (70.00)	55.79 (68.00)	79.10 (95.67)	76.20 (93.67)	77.65 (94.67)	66.82 (80.77)	66.62 (81.80)	66.72 (81.28)
T_9	72.91 (90.66)	74.56 (92.33)	73.73 (91.50)	77.86 (95.00)	83.54 (97.67)	80.70 (96.34)	75.39 (92.93)	79.05 (95.05)	77.22 (93.99)
T_{10}	38.13 (38.00)	41.11 (42.66)	39.62 (40.33)	67.32 (84.67)	55.64 (67.67)	61.48 (76.17)	52.73 (61.17)	48.38 (55.22)	50.56 (58.19)
T_{11}	46.25 (51.66)	51.01 (60.00)	48.63 (55.83)	67.10 (84.33)	52.43 (62.33)	59.76 (73.33)	56.68 (68.02)	51.72 (61.13)	54.20 (64.58)
Mean	47.88 (54.00)	51.37 (59.48)		56.63 (67.85)	51.65 (60.91)		52.26 (60.81)	51.51 (60.18)	
S.Em.± (T)			0.69			0.92			9.87
C.D. at 5 % (T)			1.97			2.62			31.10
S.Em.± (G)			0.29			0.39			2.99
C.D. at 5 % (G)			0.84			1.12			NS
CV%			3.41			4.15			3.83
Sig. interaction			-			T × G			Y × T,Y × G, Y × T × G

*Arc sin transformed values. Figures in parenthesis are original values. G_1: Ventilated godown, G_2: Non-ventilated godown

Table 1.1: Y × T interaction

Y/T	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
2021-22	32.94 (29.18)*	32.14 27.93)	54.76 66.22)	43.65 (47.18)	44.73 (49.07)	62.64 (78.18)	57.24 (70.23)	55.79 (67.90)	73.74 (91.65)	39.62 (40.22)	48.63 (55.82)
2022-23	5.74 (0.00)	5.74 (0.00)	38.18 (37.83)	74.00 (91.83)	62.20 (76.50)	68.80 (85.17)	61.29 (76.33)	77.65 (94.67)	80.70 (96.33)	61.48 (76.17)	59.76 (73.33)
S.Em.±	0.812										
C.D. at 5 %	2.28										
CV%	3.83										

*Arc sin transformed values. Figures in parenthesis are original values.

Table 1.2: Y × G interaction

Y	G_1	G_2
2021-22	47.88*(53.93)	51.37(59.45)
2022-23	56.63(67.85)	51.65(60.)
S.Em.±	0.346	
C.D. at 5 %	0.973	
CV%	3.83	

Table 1.3: Y × T × G interaction

YT	G_1	G_2
Y_1T_1	30.64*(25.53)	35.24(32.83)
Y_1T_2	29.69(24.10)	34.59(31.77)
Y_1T_3	54.38(65.60)	55.14(66.83)
Y_1T_4	42.13(44.53)	45.17(49.83)
Y_1T_5	43.00(46.03)	46.47(52.10)
Y_1T_6	59.26(73.37)	66.03(83.00)
Y_1T_7	55.82(67.97)	58.67(72.50)
Y_1T_8	54.53(65.87)	57.04(69.93)

Y_1T_9	72.91(90.87)	74.56(92.43)
Y_1T_{10}	38.13(37.67)	41.11(42.77)
Y_1T_{11}	46.25(51.70)	51.01(59.93)
Y_2T_1	5.74(0.00)	51.37(0.00)
Y_2T_2	5.74(0.00)	5.74(0.00)
Y_2T_3	34.74(32.00)	41.63(43.67)
Y_2T_4	74.59(92.33)	73.41(91.33)
Y_2T_5	70.78(88.67)	53.62(64.33)
Y_2T_6	76.15(93.67)	61.45(76.67)
Y_2T_7	63.79(80.00)	58.7872.67()
Y_2T_8	79.10(95.67)	76.20(93.67)
Y_2T_9	77.86(95.00)	83.54(97.67)
Y_2T_{10}	67.32(84.67)	55.64(67.67)
Y_2T_{11}	67.10(84.33)	52.43(62.33)
S.Em.±	1.149	
C.D. at 5 %	3.22	
CV%	3.83	

*Arc sin transformed values. Figures in parenthesis are original values.

Table 2: Effect of packaging materials and storage condition on damaged seed (%)

Trea-tment	2021-22			2022-23			Pooled		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	60.61* (75.40)	55.74 (67.83)	58.18 (29.33)	69.60 (87.33)	66.54 (83.67)	68.07 (85.50)	65.11 (81.37)	61.14 (75.75)	63.13 (78.56)
T_2	56.47 (69.00)	56.02 (68.25)	56.24 (28.00)	74.85 (92.67)	73.81 (91.67)	74.33 (92.17)	65.66 (80.83)	64.92 (79.97)	65.29 (80.40)
T_3	35.31 (32.96)	35.44 (33.16)	35.37 (66.33)	42.21 (44.67)	36.75 (35.33)	39.48 (40.00)	38.76 (30.81)	36.10 (34.25)	37.43 (36.53)
T_4	45.02 (49.56)	45.36 (50.16)	45.19 (47.33)	19.21 (10.33)	13.92 (05.33)	16.56 (07.83)	32.12 (29.95)	29.64 (27.75)	30.88 (28.85)
T_5	44.18 (48.10)	44.08 (47.91)	44.13 (49.00)	16.57 (07.67)	25.95 (18.67)	21.26 (13.17)	30.38 (27.88)	35.02 (33.30)	32.70 (30.59)
T_6	21.05 (12.50)	17.97 (09.03)	19.51 (78.16)	11.27 (03.33)	21.54 (13.00)	16.40 (08.17)	16.16 (07.92)	19.76 (11.02)	17.96 (09.47)
T_7	31.70 (27.13)	31.93 (27.50)	31.82 (70.33)	23.17 (15.00)	19.80 (11.00)	21.49 (13.00)	27.44 (21.67)	25.87 (19.25)	26.66 (20.16)
T_8	33.34 (29.73)	33.57 (30.08)	33.46 (68.00)	12.19 (04.00)	14.33 (05.67)	13.26 (04.84)	22.77 (16.87)	23.95 (17.88)	23.36 (17.38)
T_9	5.74 (00.00)	5.74 (00.00)	5.74 (91.50)	7.03 (01.00)	7.03 (01.00)	7.03 (01.00)	6.39 (00.50)	6.39 (00.50)	6.39 (00.50)
T_{10}	56.00 (68.26)	49.45 (57.25)	52.73 (40.33)	20.09 (11.33)	26.45 (19.67)	23.37 (15.50)	38.05 (39.80)	37.95 (38.47)	38.00 (39.13)
T_{11}	41.28 (43.06)	39.56 (40.08)	40.42 (55.83)	15.87 (7.00)	26.67 (19.67)	21.27 (13.34)	28.58 (25.03)	33.12 (29.88)	30.85 (27.46)
Mean	39.16 (41.43)	37.72 (39.20)		28.37 (25.85)	30.27 (27.70)		33.77 (33.64)	34.00 (33.46)	
S.Em.± (T)			0.645			2.51			8.10
C.D. at 5 % (T)			1.84			7.17			25.53
S.Em.± (G)			0.28			1.07			1.18
C.D. at 5 % (G)			0.79			3.05			NS
CV%			4.12			4.03			4.12
Sig. interaction			T × G			T × G			Y × T, Y × G, Y × T × G

*Arc sin transformed values. Figures in parenthesis are original values. G_1: Ventilated godown, G_2: Non-ventilated godown

Table 2.1: Y × T interaction

Y/T	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
2021-22	58.18* (71.62)	56.24 (68.63)	35.37 (33.07)	45.19 (49.87)	44.13 (48.02)	19.51 (10.77)	31.82 (27.32)	33.46 (29.92)	5.74 (0.00)	52.73 (92.77)	40.42 (41.58)
2022-23	68.07 (85.50)	74.33 (92.17)	39.48 (40.00)	16.56 (7.83)	21.26 (13.17)	16.40 (8.17)	21.49 (13.00)	13.26 (4.83)	7.03 (1.00)	23.37 (15.50)	21.27 (13.33)
S.Em.±	0.570										
C.D. at 5 %	1.60										
CV%	4.12										

*Arc sin transformed values. Figures in parenthesis are original values

Table 2.2: Y × G interaction

Y/G	G_1	G_2
2021-22	39.16*(41.43)	37.71(39.22)
2022-23	28.37(25.85)	30.27(27.70)
S.Em.±	0.243	
C.D. at 5 %	0.684	
CV%	4.12	

Table 2.3: Y × T × G interaction

YT/G	G_1	G_2
Y_1T_1	60.61*(75.40)	55.74(67.83)
Y_1T_2	56.47(69.00)	56.02(68.27)
Y_1T_3	35.31(32.97)	35.44(33.17)
Y_1T_4	45.02 (49.57)	45.36(50.17)
Y_1T_5	44.18(48.10)	44.08(47.93)
Y_1T_6	21.05(12.50)	17.97(9.03)
Y_1T_7	31.70(27.13)	31.93(27.50)
Y_1T_8	33.34 (29.73)	33.57(30.10)
Y_1T_9	5.74(0.00)	5.74(0.00)
Y_1T_{10}	56.00(68.27)	49.45(57.27)
Y_1T_{11}	41.28(43.07)	39.56(40.10)
Y_2T_1	69.60(87.33)	66.54(33.67)
Y_2T_2	74.85(92.67)	73.81(91.67)
Y_2T_3	42.21(44.67)	36.75(35.33)
Y_2T_4	19.21(10.33)	13.92(5.33)
Y_2T_5	16.57(7.67)	25.95(18.67)
Y_2T_6	11.27(3.33)	21.54(13.00)
Y_2T_7	23.17(15.00)	19.80(11.00)
Y_2T_8	12.19(4.00)	14.33(5.67)
Y_2T_9	7.03(1.00)	7.03(1.00)
Y_2T_{10}	20.09(11.33)	26.45(19.67)
Y_2T_{11}	15.87(7.00)	26.67(19.67)
S.Em.±	0.807	
C.D. at 5 %	2.27	
CV%	4.12	

*Arc sin transformed values. Figures in parenthesis are original values.

Table 3: Effect of packaging materials and storage condition on seed vigor index-I

T	2021-22			2022-23			Pooled		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	21.02* (0443.16)	24.16 (0585.40)	22.59 (0514.28)	00.71 (00.00)	00.71 (00.00)	00.71 (00.00)	10.87 (221.58)	12.44 (292.70)	11.66 (257.14)
T_2	20.85 (0435.72)	23.86 (0571.83)	22.36 (0503.77)	00.71 (00.00)	00.71 (00.00)	00.71 (00.00)	10.78 (217.86)	12.29 (285.92)	11.54 (251.89)
T_3	32.69 (1068.96)	31.94 (1021.88)	32.31 (1045.42)	15.81 (0249.41)	12.67 (0160.13)	14.24 (0204.77)	24.25 (659.19)	22.31 (591.00)	23.28 (625.10)
T_4	29.25 (0856.92)	29.95 (0898.13)	29.60 (0877.52)	32.86 (1080.17)	34.42 (1184.69)	33.64 (1132.43)	31.06 (968.55)	32.19 (1041.41)	31.63 (1004.98)
T_5	28.44 (0809.13)	30.68 (0941.39)	29.56 (0875.26)	24.07 (0579.17)	34.32 (1178.42)	29.20 (0878.80)	26.26 (694.15)	32.50 (1059.91)	29.38 (877.03)
T_6	37.13 (1379.14)	39.75 (1579.69)	38.44 (1479.42)	27.33 (0747.20)	32.83 (1077.27)	30.08 (0912.24)	32.23 (1063.17)	36.29 (1328.48)	34.26 (1195.83)
T_7	34.66 (1201.14)	35.91 (1289.56)	35.28 (1245.35)	27.42 (0752.42)	30.62 (0937.00)	29.02 (0844.71)	31.04 (976.78)	33.27 (1113.28)	32.16 (1045.03)
T_8	36.08 (1301.76)	37.45 (1402.12)	36.76 (1351.94)	37.74 (1426.88)	33.92 (1151.30)	35.83 (1289.09)	36.91 (1364.32)	35.69 (1276.71)	36.30 (1320.52)
T_9	41.35 (1709.59)	41.48 (1720.37)	41.42 (1714.98)	32.89 (1081.93)	33.03 (1091.94)	32.96 (1086.94)	37.12 (1395.76)	37.26 (1406.16)	37.19 (1400.96)
T_{10}	24.90 (0619.76)	26.38 (0695.51)	25.64 (0657.63)	21.60 (0465.90)	27.12 (0735.63)	24.36 (0600.77)	23.25 (542.83)	26.75 (715.57)	25.00 (629.20)

T_{11}	30.61 (0936.99)	32.81 (1079.14)	31.70 (1008.07)	24.37 (0597.08)	30.44 (0927.88)	27.40 (0762.48)	27.49 (767.04)	31.63 (1003.51)	29.56 (885.28)
Mean	30.63 (978.39)	32.21 (1071.36)		27.71 0767.66)	25.19 (0634.56)		26.48 (806.47)	28.42 (919.51)	
S.Em.± **(T)**			0.541			0.433			4.462
C.D. at 5 % (T)			1.542			1.235			14.058
S.Em.± **(G)**			0.231			0.185			0.148
C.D. at 5 % (G)			0.658			0.527			0.415
CV%			4.22			4.52			4.38
Sig. interaction			-			T × G			Y × T, Y × G × T

*SQRT values. Figures in parenthesis are original values. G_1: Ventilated godown, G_2: Non-ventilated godown

Table 3.1: Y × T interaction

Y/T	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
2021-22	22.59* (514.28)	22.36 (503.78)	32.31 (1045.42)	29.60 (877.53)	29.56 (875.26)	38.44 (1479.42)	35.28 (1245.35)	36.76 (1351.95)	41.42 (1714.98)	25.64 (657.64)	31.70 (1008.07)
2022-23	0.71 (0.00)	0.71 (0.00)	14.24 (204.77)	33.64 (1132.43)	29.20 (878.80)	30.08 (912.23)	29.02 (844.71)	35.83 (1289.09)	32.96 (1086.93)	24.36 (600.76)	27.40 (762.48)
S.Em.±	0.490										
C.D. at 5 %	1.378										
CV%	4.38										

*SQRT values. Figures in parenthesis are original values.

Table 3.2 : Y × T × G interaction

YT	G_1	G_2
Y_IT_1	21.02*(443.16)	24.16(585.40)
Y_IT_2	20.85(435.72)	23.86(571.83)
Y_IT_3	32.69(1068.96)	31.94(1021.88)
Y_IT_4	29.25 (856.92)	29.95(898.13)
Y_IT_5	28.44(809.13)	30.68(941.39)
Y_IT_6	37.13(1379.15)	39.75(1579.70)
Y_IT_7	34.66(1201.14)	35.91(1279.57)
Y_IT_8	36.08(1301.77)	37.45(1402.12)
Y_IT_9	41.35(1709.59)	41.48(1720.37)
Y_IT_{10}	24.90(619.76)	26.38(695.51)
Y_IT_{11}	30.61(937.00)	32.81(1079.15)
Y_2T_1	0.71(0.00)	0.71(0.00)
Y_2T_2	0.71(0.00)	0.71(0.00)
Y_2T_3	15.81(249.41)	12.67(160.13)
Y_2T_4	32.86(1080.17)	34.42(1184.69)
Y_2T_5	24.07(579.17)	34.32(1178.42)
Y_2T_6	27.33(747.20)	32.83(1077.27)
Y_2T_7	27.42(752.42)	30.62(937.00)
Y_2T_8	37.74(1426.88)	33.92(1151.30)
Y_2T_9	32.89(1081.93)	33.03(1091.94)
Y_2T_{10}	21.60(465.90)	27.12(735.63)
Y_2T_{11}	24.37(597.08)	30.44(927.88)
S.Em.±	0.693	
C.D. at 5 %	1.95	
CV%	4.38	

*SQRT values. Figures in parenthesis are original values.

Table 4: Effect of packaging materials and storage condition on seed vigor index-II

Treat-ment	2021-22			2022-23			Pooled		
	G_1	**G_2**	**Mean**	**G_1**	**G_2**	**Mean**	**G_1**	**G_2**	**Mean**
T_1	2.99* (08.44)	3.47 (11.57)	3.23 (10.00)	0.71 (00.00)	0.71 (00.00)	0.71 (00.00)	1.85 (4.22)	2.09 (5.79)	1.975.00 ()
T_2	2.85 (07.65)	3.21 (09.85)	3.03 (08.75)	0.71 (00.00)	0.71 (00.00)	0.71 (00.00)	1.78 (3.83)	1.96 (4.93)	1.87 (4.38)
T_3	4.61 (20.74)	4.75 (22.09)	4.68 (21.41)	5.32 (27.92)	4.92 (23.72)	5.12 (25.82)	4.97 (24.33)	4.84 (22.91)	4.91 (23.62)
T_4	3.87 (14.51)	4.07 (16.08)	3.97 (15.30)	10.20 (103.57)	12.97 (167.92)	11.58 (135.75)	7.04 (59.05)	8.52 (92.00)	7.78 (75.52)
T_5	3.59 (12.42)	3.81 (14.05)	3.70 (13.26)	10.01 (99.90)	11.66 (135.93)	10.84 (117.91)	6.80 (56.16)	7.74 (74.99)	7.27 (65.58)
T_6	4.79 (22.54)	4.98 (24.35)	4.89 (23.44)	8.29 (68.72)	12.40 (153.19)	10.34 (110.95)	6.5445.63 ()	8.69 (88.77)	7.62 (67.20)
T_7	4.59 (20.60)	4.72 (21.75)	4.65 (21.17)	11.08 (122.33)	12.05 (144.68)	11.56 (133.51)	7.84 (71.47)	8.39 (83.22)	8.12 (77.34)
T_8	4.71 (21.74)	4.83 (22.84)	4.77 (22.29)	12.08 (145.37)	12.25 (149.62)	12.16 (147.49)	8.40 (83.55)	8.54 (86.23)	8.47 (84.89)
T_9	5.84 (33.61)	5.78 (32.96)	5.81 (33.29)	12.85 (164.54)	12.55 (157.17)	12.70 (160.86)	9.35 (99.08)	9.17 (95.07)	9.26 (97.07)
T_{10}	3.61 (12.66)	3.81 (14.06)	3.71 (13.36)	6.56 (42.62)	8.41 (71.52)	7.49 (57.07)	5.09 (27.64)	6.11 (42.79)	5.60 (35.22)
T_{11}	4.32 (18.16)	4.57 (20.37)	4.44 (19.26)	7.59 (57.15)	9.74 (94.46)	8.67 (75.80)	5.96 (37.65)	7.16 (57.42)	6.56 (47.53)
Mean	4.16 (17.55)	4.36 (19.08)		7.76 (75.65)	8.94 (99.84)		5.96 (46.60)	6.65 (59.46)	
S.Em.± (T)			0.071			0.794			1.927
C.D. at 5 % (T)			0.201			0.553			NS
S.Em.± (G)			0.030			0.083			0.345
C.D. at 5 % (G)			0.086			0.236			NS
CV%			4.06			5.69			5.67
Sig. interaction			-			T × G			Y × T, Y × G, Y × T × G

*SQRT values. Figures in parenthesis are original values. G_1: Ventilated godown, G_2: Non-ventilated godown

Table 4.1: Y × T interaction

Y/T	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
2021-22	3.23* (10.00)	3.03 (8.75)	4.68 (21.42)	3.97 (15.30)	3.70 (13.24)	4.89 (23.45)	4.65 (21.18)	4.77 (22.29)	5.81 (33.29)	3.71 (13.36)	4.44 (19.27)
2022-23	0.71 (0.00)	0.71 (0.00)	5.12 (25.82)	11.58 (135.75)	10.84 (117.91)	10.34 (110.95)	11.56 (133.51)	12.16 (147.49)	12.70 (160.86)	7.49 (57.07)	8.67 (75.80)
S.Em.±	0.146										
C.D. at 5 %	0.410										
CV%	5.67										

*SQRT values. Figures in parenthesis are original values.

Table 4.2: Y × G interaction

Y	G_1	G_2
2021-22	4.16*(17.55)	4.36(19.09)
2022-23	7.76(75.65)	8.94(99.84)
S.Em.±	0.062	
C.D. at 5 %	0.175	
CV%	5.67	

Table 4.3: Y × T × G interaction

YT	G_1	G_2
Y_IT_1	2.99*(8.44)	3.47(11.57)
Y_IT_2	2.85(7.65)	3.21(9.85)
Y_IT_3	4.61(20.74)	4.75(22.09)
Y_IT_4	3.87(14.52)	4.07(16.09)
Y_IT_5	3.59(12.42)	3.81(14.05)
Y_IT_6	4.79(22.54)	4.98(24.35)
Y_IT_7	4.59(20.60)	4.72(21.75)
Y_IT_8	4.71(21.74)	4.83(22.84)

Y_1T_9	5.84(33.62)	5.78(32.96)
Y_1T_{10}	3.61(12.66)	3.81(14.06)
Y_1T_{11}	4.32(18.16)	4.57(20.37)
Y_2T_1	0.71(0.00)	0.71 (0.00)
Y_2T_2	0.71(0.00)	0.71 (0.00)
Y_2T_3	5.32(27.92)	4.92(23.72)
Y_2T_4	10.20(103.57)	12.97(167.92)
Y_2T_5	10.01(99.90)	11.66(135.93)
Y_2T_6	8.29(68.72)	12.40(153.19)
Y_2T_7	11.08(122.33)	12.05(144.68)
Y_2T_8	12.08(145.37)	12.25(149.62)
Y_2T_9	12.85(164.54)	12.55(157.17)
Y_2T_{10}	6.56(42.62)	8.41(71.52)
Y_2T_{11}	7.59(57.15)	9.74(94.46)
S.Em.±	0.206	
C.D. at 5 %	0.579	
CV%	5.67	

*SQRT values. Figures in parenthesis are original values.

Table 5: Effect of packaging materials and storage condition on speed of germination

Treat-ment	2021-22			2022-23			Pooled		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	4.72* (21.84)	5.35 (28.12)	5.03 (24.98)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	2.72 (10.92)	3.03 (14.07)	2.88 (12.49)
T_2	4.59 (20.63)	5.26 (27.20)	4.93 (23.91)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	2.65 (10.33)	2.99 (13.62)	2.82 (11.98)
T_3	7.53 (56.18)	7.60 (57.26)	7.56 (56.72)	2.72 (6.97)	2.75 (7.12)	2.74 (7.05)	5.13 (31.58)	5.18 (32.18)	5.16 (31.88)
T_4	6.21 (38.12)	6.57 (42.69)	6.39 (40.67)	4.23 (17.39)	3.81 (14.03)	4.02 (15.71)	5.22 (27.77)	5.19 (28.35)	5.21 (28.06)
T_5	6.32 (39.40)	6.71 (44.61)	6.52 (42.01)	3.89 (14.67)	3.53 (11.95)	3.71 (13.31)	5.11 (27.05)	5.12 (28.30)	5.12 (27.68)
T_6	7.96 (62.82)	8.46 (71.10)	8.21 (66.96)	4.08 (16.13)	3.57 (12.25)	3.82 (14.19)	6.02 (39.48)	6.02 (41.65)	6.02 (40.57)
T_7	7.66 (58.18)	7.91 (62.11)	7.79 (60.15)	4.10 (16.38)	3.91 (q14.78)	4.00 (15.58)	5.88 (37.28)	5.91 (38.43)	5.90 (37.86)
T_8	7.54 (56.40)	7.77 (59.89)	7.66 (58.15)	3.68 (13.05)	4.11 (16.38)	3.89 (14.72)	5.61 (34.72)	5.94 (38.15)	5.78 (36.43)
T_9	8.84 (77.81)	8.93 (79.17)	8.89 (78.49)	4.05 (15.94)	3.84 (14.26)	3.95 (15.10)	6.45 (46.87)	6.39 (46.72)	6.42 (46.79)
T_{10}	5.72 (32.26)	6.10 (36.62)	5.91 (34.44)	3.80 (13.96)	3.62 (12.58)	3.71 (13.27)	4.76 (23.13)	4.86 (24.62)	4.81 (23.88)
T_{11}	6.69 (44.26)	7.20 (51.33)	6.94 (47.79)	3.71 (13.28)	3.78 (13.78)	3.75 (13.53)	5.20 (28.77)	5.49 (32.57)	5.35 (30.67)
Mean	6.71 (46.17)	7.08 (50.92)		3.24 (11.62)	3.12 (10.65)		4.98 (28.90)	5.10 (30.79)	
S.Em.± (T)			0.078			0.053			0.475
C.D. at 5 % (T)			0.224			0.151			1.497
S.Em.± (G)			0.033			0.023			0.174
C.D. at 5 % (G)			0.095			0.064			NS
CV%			2.79			4.07			3.25
Sig. interaction			-			T × G			Y × T, Y × G, Y × T × G

*SQRT values. Figures in parenthesis are original values. G_1: Ventilated godown, G_2: Non-ventilated godown

Table 5.1: Y × T interaction

Y/T	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
2021-22	5.03* (24.98)	4.93 (23.95)	7.56 (56.73)	6.39 (40.42)	6.52 (42.03)	8.21 (66.95)	7.79(60.13)	7.66 (58.15)	8.89 (78.48)	5.91 (34.47)	6.94 (47.80)
2022-23	0.71	0.71	2.74	4.02	3.71	3.82	4.01	3.89	3.95	3.71	3.75

	(0.00)	(0.00)	(7.03)	(15.70)	(13.32)	(14.18)	(15.58)	(14.72)	(15.10)	(13.28)	(13.53)
S.Em.±	0.067										
C.D. at 5 %	0.188										
CV%	3.25										

*SQRT values. Figures in parenthesis are original values

Table 5.2: Y × G interaction

Y	G_1	G_2
2021-22	6.71*(46.18)	7.08(50.92)
2022-23	3.24(11.62)	3.12(10.65)
S.Em.±	0.029	
C.D. at 5 %	0.080	
CV%	3.25	

Table 5.3: Y × T × G interaction

Y	G_1	G_2
Y_1T_1	4.72*(21.83)	5.35(28.13)
Y_1T_2	4.59(20.67)	5.26(27.23)
Y_1T_3	7.53(56.20)	7.60(57.27)
Y_1T_4	6.21(38.13)	6.57 (42.70)
Y_1T_5	6.32(39.43)	6.71(44.63)
Y_1T_6	7.96(62.83)	8.46(71.06)
Y_1T_7	7.66(58.17)	7.91(62.10)
Y_1T_8	7.54(56.40)	7.77(59.90)
Y_1T_9	8.85(77.80)	8.93(79.17)
Y_1T_{10}	5.72(32.30)	6.10(36.63)
Y_1T_{11}	6.69(44.27)	7.20(51.33)
Y_2T_1	0.71(0.00)	0.71(0.00)
Y_2T_2	0.71(0.00)	0.71(0.00)
Y_2T_3	2.71(6.97)	2.75(7.10)
Y_2T_4	4.23(17.40)	3.81(14.00)
Y_2T_5	3.89(14.67)	3.53(11.97)
Y_2T_6	4.08(16.13)	3.57(12.23)
Y_2T_7	4.10(16.40)	3.91(14.77)
Y_2T_8	3.68(13.03)	4.11(16.40)
Y_2T_9	4.05(15.93)	3.84(14.27)
Y_2T_{10}	3.80(13.97)	3.62(12.60)
Y_2T_{11}	3.71(13.27)	3.78(13.80)
S.Em.±	0.095	
C.D. at 5 %	0.267	
CV%	3.25	

*SQRT values. Figures in parenthesis are original values.

Table 6 : Effect of packaging materials and storage condition on seed moisture (%)

Treatment	**2021-22**			**2022-23**			**Pooled**		
	G_1	**G_2**	**Mean**	**G_1**	**G_2**	**Mean**	**G_1**	**G_2**	**Mean**
T_1	10.26	10.26	10.26	10.17	10.33	10.25	10.22	10.30	10.26
T_2	10.13	10.06	10.10	9.90	10.10	10.00	10.02	10.08	10.05
T_3	9.80	9.70	9.75	9.63	9.87	9.75	9.72	9.79	9.75
T_4	9.83	9.80	9.81	9.70	9.83	9.77	9.77	9.82	9.79
T_5	9.80	9.77	9.78	9.70	9.77	9.74	9.75	9.77	9.76
T_6	9.70	9.80	9.75	9.73	9.70	9.72	9.72	9.75	9.74
T_7	10.03	10.06	10.05	10.03	10.03	10.03	10.03	10.05	10.04
T_8	10.03	10.00	10.01	10.07	10.20	10.14	10.05	10.10	10.08
T_9	9.77	9.70	9.73	9.40	9.60	9.50	9.59	9.65	9.62
T_{10}	10.10	10.13	10.11	9.90	10.07	9.99	10.00	10.10	10.05
T_{11}	10.06	9.96	10.01	10.03	10.17	10.10	10.05	10.07	10.06
Mean	9.96	9.93		9.84	9.97		9.90	9.95	
S.Em.± (T)			0.035			0.066			0.038
C.D. at 5 % (T)			0.100			0.189			0.106
S.Em.± (G)			0.015			0.028			0.054
C.D. at 5 % (G)			NS			0.081			NS
CV%			0.87			1.64			1.31
Sig. interaction			-			-			Y × G

$G_{1:}$ Ventilated godown, $G_{2:,}$ Non-ventilated godown

Table 6.1: Y × G interaction

Y	G_1	G_2
2021-22	9.96	9.93
2022-23	9.84	9.97
S.Em.±	0.023	
C.D. at 5 %	0.064	
CV%	1.31	

Y:Year G_1: Ventilated godown, G_2: Non-ventilated godown

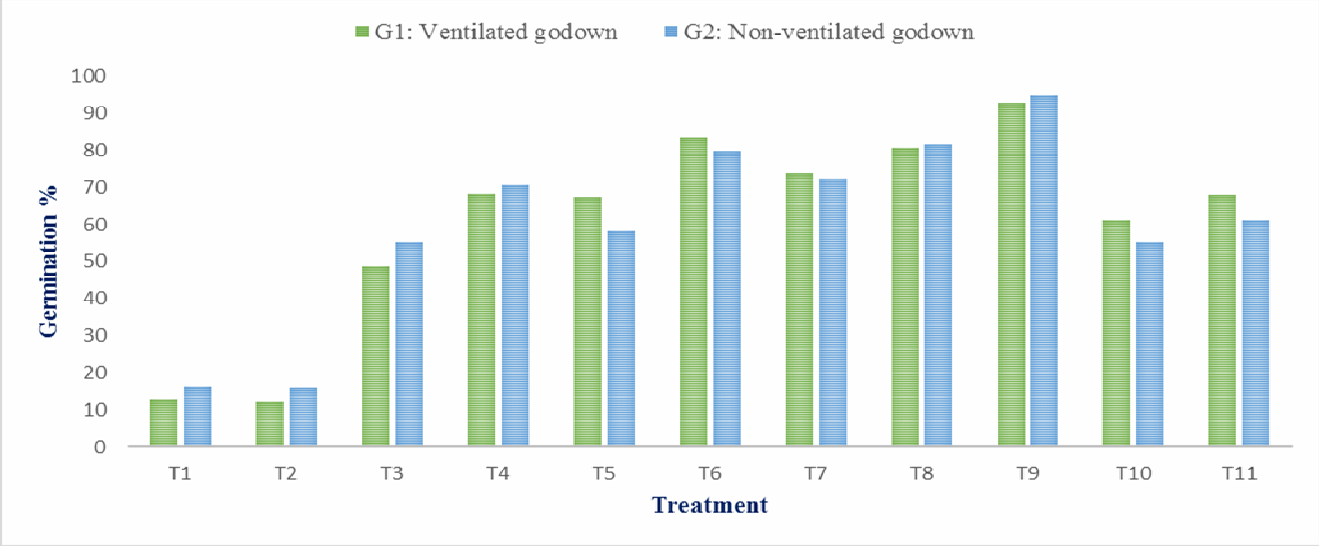

Fig. 1 : Germination % based on pooled mean of year 2021-22 to 2022-23

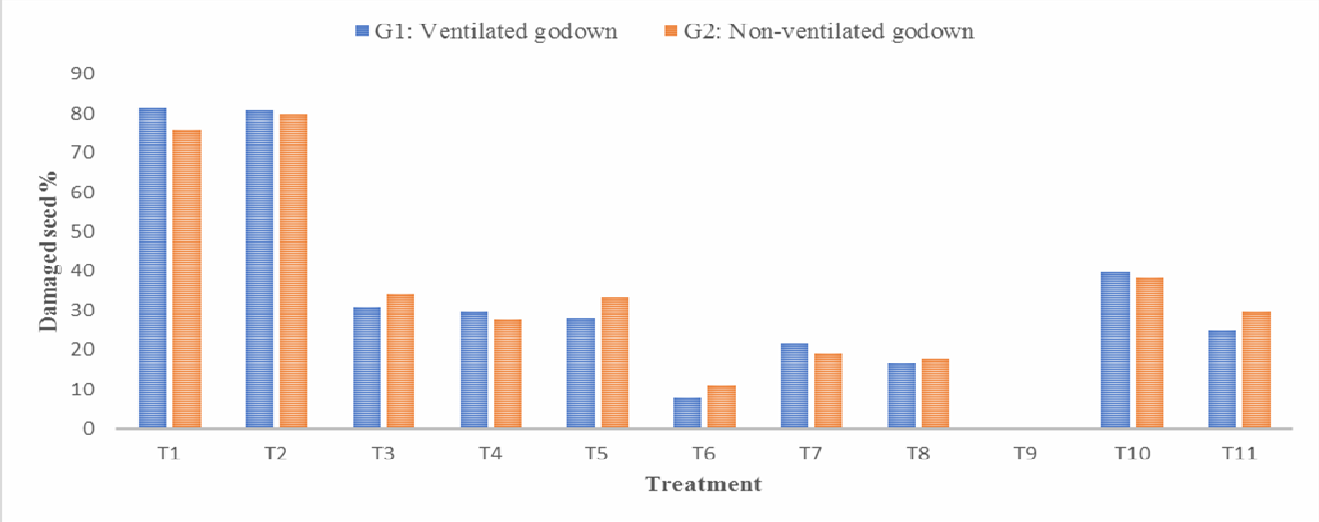

Fig. 2 : Damaged seed % based on pooled mean of year 2021-22 to 2022-23

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