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RESEARCH PAPER

Influence of packaging materials and storage duration on seed quality parameters on sweet corn hybrid *var*. madhuram

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Abstract: An experiment was conducted during 2022 and 2023 to study the role of packaging materials and duration on seed storability of sweet corn. The experiment was carried out in four packaging materials *viz.,* non-woven laminated polypropylene bag (P_1), aluminium foil bag (P_2), high density polyethylene bag (P_3) and air tight plastic container (P_4). It was stored for three different storage duration *viz.,* 6 months (D_1), 9 months (D_2) and 12 months (D_3) under two different environmental condition *viz.,* Ambient condition (E_1) and Cold storage (E_2) with silica gel (S_1) and without silica gel (S_2). Seed stored in air tight plastic container and high density polythelene bag maintained higher seed germination percentage as compared to other bags whereas, seedling vigour index I was at par with aluminium foil bag. The Highest seed germination percentage, seed moisture content and vigour index II was recorded 98.67, 5.62 per cent and 2541 respectively. Seed stored for 6 months maintained higher germination and other quality parameters. Results from the present study. It seems that the hybrid *var*. madhuram kept better during cold storage (6°C) compared to ambient conditions. Seed stored with silica gel (S_1) maintained higher germination of seed as compared to seed storage without silica gel (S_2). Prior to this storage condition, seed of sweet corn was stored in non- woven laminated polypropylene bag after harvesting for six months under ambient condition. Over all, sweet corn seed could be store in aluminium foil bag and air tight plastic container under cold storage condition (6°C) for long duration of storage without silica gel.

Keywords: Sweet corn hybrid *var.* Madhuram · Aluminium foil · Air tight plastic container · Cold condition · Silicagel · Seedling vigour index I

Introduction

Sweet corn (*Zea mays* L. *schharata*) also called American corn or pole corn. It is an attractive crop for many farmers because these plants can grow very quickly and harvest can be mechanized (Johnson, 1991). The total production of sweet corn in India during 2022-23 was around 34.61 million metric tons (Anonymous, 2023). In Gujarat, it is cultivated in district like Mehsana, Kheda, Anand, Vadodara and Patan. It is a source of antioxidants and other phytochemicals such as melatonin and tryptophan (Revilla *et al*., 2021). In moderate amounts, they also supply essential minerals, antioxidants, lutein, magnesium; potassium. Yellow sweet corn is more preferred by the consumer because of high amount of vitamin A and C (Gangaiah, 2008).

Seeds are required to be kept in safe storage since they are harvested in the preceding season and usually used for sowing in the subsequent season. Seed storage is an essential segment of seed industry. In storage, viability and vigour of the seeds is regulated by many physiochemical factors like moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials *etc.* (Doijode, 1996). As the sweet corn seed is hygroscopic in nature, seed quality is affected by moisture content variation, relative humidity and temperature. Moisture absorption by seed at high

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temperature during storage was reported as the prime cause of seed deterioration in most of the studies (Meena *et al*., 2017).

The biological activity of the stored seed ecosystem consumes O_2 and releases CO_2, leading to a self-modification of the interstitial atmosphere. Under well sealed conditions, the resulting modified atmosphere has important benefits for seed conservation, including reducing or controlling insect and fungal activity and minimizing seed viability deterioration. Cans, hermetic containers, and laminated aluminium foil containers are all acceptable for both short and long term storage (Anonymous, 2015). So, it is crucial to choose appropriate packaging materials that provide protection against moisture, light, pests, and other factors that can affect seed viability. Freezing maintains more of the seed quality than any of the other feasible approaches. Lower temperature results in a slower rate for most deteriorative reactions such as, senescence, enzymatic decay, chemical decay and microbial growth. To maintain best quality, sweet corn should be stored at 0°C (Xie *et al*., 2017). To maintain high quality seeds during storage, it should been protected from weather (including relative humidity (30% or low and temperature below 59°F (15°C) (Oyekale *et al*., 2012).

The storage period of seeds can be extended through proper seed handling and storage techniques. Seeds are often stored in air tight containers, such as glass jars or sealed bags, to protect them from moisture and pests. Refrigeration or freezing may be used for long-term storage of certain seeds, as low temperatures help slow down the aging process and maintain viability.

Using dry, fresh and in appropriate amount of silica gel based on the size of the storage container and the moisture levels in the surrounding environment enhance the longevity and quality of stored seeds, promoting successful germination when the time comes for planting. Its high specific surface area allows it to by absorb moisture from the air, making it useful as a desiccant (drying agent). By placing silica gel packets or containers in seed storage containers, the gel absorbs any excess moisture present, creating a dry environment. So, it can play a significant role in controlling humidity during seed storage. This prevents the seeds from becoming too damp, which can lead to mold, rot, or germination issues and preserve their viability for longer periods.

To avoid sweet corn seed deterioration in tropical and sub-tropical regions, sweet corn should be dried to a moisture percentage of around 12-13 per cent to prevent deterioration of seeds due to high humidity and temperature. This moisture percentage is considered optimal for storage of sweet corn seeds. Farmers and seed producers in tropical and sub-tropical regions should prioritize proper drying and storage techniques to maintain the quality of sweet corn seeds. This can include using clean and dry storage containers, ensuring good airflow to prevent moisture retention and avoiding exposure to high humidity and temperature. By following these practices, farmers can help to ensure that their sweet corn seeds remain viable and healthy for future planting. These practices could help the farmers in assuring the viability and quality of sweet corn seeds for future planting.

Materials and methods

An experiment was conducted in sweet corn hybrid *var*. Madhuram seeds during 2022 and 2023 at Department of Seed Science and Technology, Anand, Gujarat with the objective to find out the effect of different packing material and storage periods on seed quality parameters. The seeds were obtained from Main Maize Research Station, AAU, Godhra. The seeds were already stored for six months under ambient condition in non-woven laminated polypropylene bag before conducting this research. The germination percentage of sweet corn seeds were 92 per cent observed at the beginning of the experiment.

The seeds of sweet corn hybrid *var.* Madhuram were packed in four packaging containers, *viz.,* Non-woven laminated polypropylene bag (P_1), aluminium foil bag (P_2), high density polyethylene bag (P_3), and air tight plastic container (P_4). The packed seeds were stored at 6°C temperature (cold store) (E_2) and ambient storage (21-33°C) (room temperature) condition (E_1), for three different durations *viz.,* 6 months (D_1), 9 months (D_2) and 12 months (D_3) with silica gel (S_1) and without silica gel (S_2). Completely Randomized Design (Factorial) was used for statistical analysis. The seeds were analyzed for quality parameters as given below.

Germination (%)

Germination percentage was determined by following the between paper towel method as prescribed under ISTA (Indian Minimum Seed Certification Standard) rules

(Anonymous, 1996). Four replications of 100 seeds under each experiment were kept for germination in rolled towels in a germinator maintained at 25°C and 95 per cent relative humidity. Final count of germinated seeds was taken on 7th day. The germination was calculated based on normal seedlings counted on the final day and expressed in percent.

Seed moisture (%)

To determine moisture content of seed, the high constant temperature oven dry method used as per the ISTA procedure. The seed material in three replication was weighted accurately on precision electronic balance and put into aluminium cups. The seed material in sample cup was dried in the hot air oven maintained at 103°C for 24 hours. Then dry weight of material along with cups noted. The moisture content was determined on wet weight basis using the following formula.

Moisture Percentage (M %) = M_2-M_3/M_2-M_1×100

M_1 : weight in gm of the container and its cover

M_2 : weight in gm of the container, its cover and its contents before drying

M_3 : weight in gm of the container, its cover and its contents after drying

Seedling vigour index-I

The seedling vigour index-I was calculated using the procedure suggested by Abdul-Baki and Anderson (1973) and expressed in the whole number.

Seedling Vigour Index-I = Germination (%) × Seedling length (cm)

The root length measured from tip of primary root to base of the hypocotyl and the mean root length was expressed in centimeters. The shoot length measured from the base of primary leaf to the base of hypocotyl and the mean shoot length expressed in centimeters. Seedling length calculated by adding root and shoot length. It is expressed in centimeters.

Results and discussion

Packaging materials showed significant influence on seed germination per cent and the germination data showed significant difference during different storage durations. The seeds stored in aluminium foil bag (P_2) recorded significantly higher germination (92.08) due to its moisture and vapour impervious nature. The seeds stored in the non-woven laminated polypropylene bag (P_1) noted the lowest germination per cent (47.42) and the fast reduction due to its moisture pervious nature (Table 1). This higher moisture in the seed may be the main reason of quick quality deterioration in the seeds of non-woven laminated polypropylene bag.

According to Table 1 the germination potential decreased as per progressive storage duration. Significantly the highest germination per cent (80.87) was observed at 6 months (D_1) storage duration and reduced to (79.60) at 9 months (D_2) of storage. The seed germination of stored seed of sweet corn maintained its germination per cent as per Indian minimum seed certification standard (IMSCS) at very initial 6 months (D_1) of storage duration irrespective of packaging materials. At the end of 12 months (D_3) of storage significantly the lowest germination per cent (78.99) recorded.

The observation on germination indicated that the germination percentage was significantly influenced by different environmental condition. Analysed data showed significantly higher germination percentage (95.02) in (E_2) cold storage (6) condition compare to (E_1) ambient condition (64.03) (Table 1).

Silica gel significant influence on seed germination per cent. The seeds stored with silica gel (S_1) in various packaging materials recorded significantly higher germination (80.68) due to its moisture and vapour absorbing nature from the surrounding atmosphere. The seeds stored without silica gel (S_2) observed the lowest germination per cent (78.67) (Table 1).

As par data pertaining to of Table 1 germination percentage showed a significantly influenced of combine effect of packaging materials, environmental condition and silica gel (P×E×S) on germination percentage and the differences were also found significant. Significantly higher germination (98.22) was observed by the seeds stored under cold storage in high density polyethylene bags without silica gel. At the end of storage period seed stored in ambient condition with ($P_1E_1S_1$) and without silica gel ($P_1E_1S_2$) in non-woven laminated polypropylene bag recorded zero germination percentage means there was no germination of seeds at the end of twelve months.

Table 1. Effect of packaging materials, storage duration, environmental condition and silica gel germination percentage (%)

Silica gel	Environmental condition	Duration	Packaging materials				Mean of S
			P_1	P_2	P_3	P_4	
S_1	E_1	D_1	00.00	91.33	90.67	85.00	S_1 = 80.68
		D_2	00.00	88.00	90.00	85.00	S_2 = 78.67
		D_3	00.00	87.33	89.33	84.00	
	E_2	D_1	94.67	95.33	98.67	96.67	Mean of E
		D_2	93.67	94.00	98.00	95.33	E_1 = 64.03
		D_3	93.33	92.67	98.00	95.33	E_2 = 95.02
S_2	E_1	D_1	00.00	90.00	79.00	84.67	
		D_2	00.00	89.67	74.00	83.33	Mean of D
		D_3	00.00	89.33	74.00	82.00	D_1= 80.67
	E_2	D_1	97.33	96.00	96.00	98.67	D_2= 79.60
		D_2	95.33	95.33	94.00	98.00	D_3= 78.99
		D_3	94.67	96.00	90.67	97.33	
Mean of P			47.42	92.08	89.36	90.44	
Overall mean			78.83				
Comparing the mean			S.Em (±)		CD @ 5%		
Packaging material (P)			0.57		1.61		
Duration (D)			0.50		1.40		
Environmental condition (E)			0.41		1.14		
Silica gel (S)0.41			1.14				
Interaction of P×D×E×S			1.99		NS		
C.V. (%)			4.32				

Seeds packed stored under cold storage (6°C) environment conditions with and without silica gel maintained better seed quality parameters irrespective of packaging materials, but the seeds were already stored in non-woven laminated polypropylene bag after harvesting for 12 months under ambient condition. Overall seeds remain vigorous up to 18 months excluding the non-woven laminated polypropylene bag.

The decrease the germination percentage over the storage duration might be attributed to deterioration due to fluctuating temperature, moisture content and porous nature and interaction with change in atmospheric condition. Aluminum foil bags, air tight plastic container and high density polyethylene bags maintained seed viability for longer storage duration because of their impervious nature so protected the seeds from surrounding environmental fluctuations. These findings are consistent with the earlier finding of Patil and Gouda (2007) in rice hybrid seeds and Owolade *et al*. (2011) in sorghum seeds.

At the initial stage of storage germination percentage of seeds was higher because of initial vigorous nature of seeds and it decrease further with an increase in storage period. As reported by Walter *et al*. (2005) the length of storage time is strongly influenced by environmental and genetic factors such as storage temperature and seed moisture content. When seeds deteriorate during storage, they lose vigour, become more sensitive to stress during germination and ultimately become unable to germinate. These finding are in agreement with the findings of Borza *et al*. (2017) in maize.

Storage of seeds under low temperatures or cold storage (6°C) can extend the lifetime use of sweet corn seeds. Under ambient condition high temperatures accelerated respiration quickly so that faster the changes in food reserves in the seeds that have an impact on the decrease in germination percentage and vigour of the seeds. The rate of seed deterioration enhances with increased moisture levels. Seed moisture content fluctuates with long-term changes in atmospheric humidity. Low temperature and air humidity limit the increase of seed moisture content and the rate of respiration of the seeds during the storage period. These results conform with the findings Timoteo and Marcos-Filho (2013) in corn genotype and Wang *et al*. (2018) in rice seeds.

Seed storage with silica gel drying agent can control the relative humidity of surrounding environment and maintain the low moisture content of seeds. Silica gel is helpful to maintain low relative humidity in cold storage condition and reduces the risk of frost damage during storage. The related result reported by Rao *et al*. (2003) in marigold and Daniel *et al*. (2009) in hybrid maize seeds.

Seed quality is affected by prior storage condition and the resulting enzymatic activity of seed during storage. After harvesting, this sweet corn seeds stored in ambient condition for 6 months in non-woven laminated polypropylene bag. The initial germination percentage was per cent. The germination percentage under cold storage (98.67%) was higher than ambient condition (91.33%) and also than initial germination percentage (92.00) as showed in Table 1. The Probable reason behind these results was a marked decrease or even absence of activity of catalase (CAT) and α-amylase (α-AM) enzyme, higher activity of the alcohol dehydrogenase (ADH) enzyme in corn seed during ambient environmental storage condition. As par the result observed in corn seeds by Timoteo and Marcos-Filho (2013) and Koskosidis *et al*. (2022) in soybean. Because catalase is one of the "scavenger" enzymes, that is, it removes free radicals, the loss of activity of this enzyme. A higher activity of the alcohol dehydrogenase (ADH) enzyme may have promoted the increased breathing that occurs in seeds that are in a more advanced process of deterioration. With the subsequent production of ethanol, toxic to the seeds. The deteriorative changes may occur in the aleurone layer during aging. These changes may determine the decrease in amylase production which in turn affects the germination and the seed performance was reduced during storage due to the lower α-amylase (α-AM) enzyme.

As mentioned in Table 2 the seed moisture content of seeds was significantly affected due to packaging materials. The significantly highest moisture content (4.68%) was noticed in the aluminium foil bag (P_2). Whereas, seeds stored in the non-woven laminated polypropylene bag (P_1) recorded the lowest seed moisture content (3.15%).

Generally seeds stored in moisture impervious containers like aluminum foil pouch, polythene bag (700 gauge), vacuum sealed containers *etc*., have storability for

Table 2. Effect of packaging materials, storage duration, environmental condition and silica gel on seed moisture content (%)

Silica gel	Environmental condition	Duration	Packaging materials				Mean of S
			P_1	P_2	P_3	P_4	
S_1	E_1	D_1	4.31	4.39	4.07	4.90	S_1 = 3.80
		D_2	4.60	4.64	4.33	5.27	S_2 = 3.92
		D_3	5.01	4.92	4.60	5.62	
	E_2	D_1	1.28	4.32	2.31	2.75	Mean of E
		D_2	1.36	4.67	2.45	3.08	E_1 = 4.78
		D_3	1.40	5.00	2.60	3.40	E_2 = 2.93
S_2	E_1	D_1	4.69	4.33	4.27	4.84	
		D_2	4.97	4.63	4.65	5.07	Mean of D
		D_3	5.28	4.89	5.09	5.48	D_1= 3.59
	E_2	D_1	1.39	4.49	1.99	3.09	D_2= 3.85
		D_2	1.63	4.79	2.11	3.39	D_3= 4.14
		D_3	1.86	5.13	2.27	3.66	
Mean of P			3.15	4.68	3.39	4.21	
Overall mean			3.86				
Comparing the mean			S.Em (±)		CD @ 5%		
Packaging material (P)			0.03		0.08		
Duration (D)			0.02		0.07		
Environmental condition (E)			0.02		0.05		
silica gel (S) 0.02			0.05				
Interaction of P×D×E×S			0.09		NS		
C.V. (%)			4.28				

longer period compared to those stored in moisture pervious containers like cloth bag, paper bag, jute bag etc. The concept of storing seeds in moisture impervious sealed containers is to prevent the migration of moisture content from the surrounding environment into the seeds. In sealed storage conditions, the seeds retain viability and vigour for longer period owing to lesser fluctuation of moisture content and temperature, decreased oxygen and enrichment of carbon dioxide in the containers.

Irrespective of the packaging materials and environmental condition and the silica gel, the seed moisture content increase with the advancement of the storage duration and found significant difference in seed moisture content. A significantly lower seed moisture content (3.59%) was recorded after six months of storage (D_1) and increased (3.85%) at nine months of storage (Table 2). A significantly higher seed moisture content (4.14%) was observed at the end of twelve months of storage.

The results about the seed moisture content of seeds indicated that different environmental condition significantly influenced and recorded significant differences. Seeds stored under cold storage (E_2) recorded significantly lower moisture content (2.93%). Significantly the higher seed moisture content (4.78%) was noted under ambient storage condition (E_1). The results are in accordance with Rao *et al*. (2003) in ridge guard seeds.

The data indicated in Table 2 that silica gel was a significant impact. Silica gel (S_1) was used to preserve seeds, which resulted in much lower seed moisture content (3.80%). The seeds stored without silica gel (S_2) had much higher seed moisture content (3.92%) than those stored with it silica gel. While the initial seed moisture content is 7.7 per cent.

The seedling vigour index-I was significantly influenced by different packaging materials and also found significant variation in seedling of sweet corn seeds. Among the different packing materials, seeds packed in aluminium foil bag (P_2) was retained the maximum seedling vigour index-I (2022). While, the lowest seedling vigour index-I (989) was found by seeds stored in the non-woven laminated polypropylene bag (P_1) (Table 3).

According to Table 3 seeding vigour index-I was decreased as per progressive storage duration.

Table 3. Effect of packaging materials, storage duration, environmental condition and silica gel on vigour index I

Silica gel	Environmental condition	Duration	Packaging materials				Mean of S
			P_1	P_2	P_3	P_4	
	E_1	D_1	0.000	2051	2155	1955	S_1 = 1723
		D_2	0.000	1743	1888	1713	S_2 = 1706
		D_3	0.000	1462	1612	1426	
	E_2	D_1	2272	2513	2453	2353	Mean of E
		D_2	2028	2155	2183	2078	E_1 = 1313
		D_3	1744	1879	1891	1802	E_2 = 2116
S_2	E_1	D_1	0.000	2199	1817	2024	
		D_2	0.000	1903	1484	1709	Mean of D
		D_3	0.000	1659	1280	1434	D_1= 1969
	E_2	D_1	2289	2505	2376	2541	D_2= 1710
		D_2	1953	2222	2060	2251	D_3= 1465
		D_3	1579	1977	1704	1989	
Mean of P			989	2022	1908	1940	
Overall mean			1715				
Comparing the mean			S.Em(±)		CD @ 5%		
Packaging material (P)			0.55		1.55		
Duration (D)			0.48		1.34		
Environmental condition (E)			0.39		1.09		
silica gel (S) 0.39			NS				
Interaction of P×D×E×S			1.91		NS		
C.V. (%)			5.78				

Significantly the highest vigour index-I (1969) was recorded at 6 months (D_1) storage duration which was reduced to (1710) at 9 months (D_2) of storage. At the end of 12 months (D_3) of storage significantly lower vigour index-I (1465) was recorded.

The observation on vigour index-I indicated that sweet corn seeds were significantly influenced by different environmental condition. Higher vigour index-I (2116) was observed in cold storage condition (E_2) whereas, under ambient environmental condition (E_1) recorded the lower vigour index-I (1313) (Table 3).

Data pertaining to seedling vigour index-I showed significant influence of combined effect of packaging materials, storage duration and environmental condition on seedling vigour index-I. Significantly maximum seedling vigour index-I (2509) was observed by seeds stored under cold storage in aluminium foil bag for six months ($P_2D_1E_2$). At the end of six, nine and twelve months, seeds stored under ambient condition in cloth bag ($P_1D_1E_1$, $P_1D_2E_1$, $P_1D_3E_1$) recorded zero vigour index-I because there was no germination of seeds (Table 3).

Non-woven laminated polypropylene bag being a pervious container, moisture exchange took place frequently until it reached the equilibrium status with environment, thereby this recorded higher moisture at the end of storage period. Aluminum foil bag which may be attributed to the impervious nature to moisture vapour and thus it has caused less fluctuation in seed moisture content and enhance the seed longevity. These findings were in conformity with the findings of Rai and Mishra (2017) in lentil who reported the less fluctuation in seed moisture in the impervious packaging materials.

Seed deterioration leads to the reduction in the quality, viability and vigour either due to aging or the effect of adverse environmental factors like temperature and relative humidity of surrounding environmental condition. A decrease in seed vigour may be due to decrease in germination indexes and also can increase the susceptibility of seeds to environmental stress. Similar results were also observed by Chattha *et al*. (2012) in wheat and Bhadauria *et al*. (2019) in maize.

Conclusion

Sweet corn hybrid *var*. Madhuram seeds germination per cent, viability, vigour and other seed quality parameters like seed moisture content, seedling vigour index II decreased significantly with storage duration but the rate of seed deterioration was higher in ambient condition compared to cold storage. Seed packaging materials also significantly affected the seed ageing. Among four types of packaging materials, aluminium foil bag (P_2) was found superior for maintaining viability and vigour. Seeds quality parameters significantly reduced with natural ageing but the rate of seed deterioration was very higher in seed stored in non-woven laminated polypropylene bag (P_1). It is not safe for storing the sweet corn seeds for longer time. Similarly, in storage duration seeds preserved at six months recorded significantly higher seed quality parameters. Seed stored without silica gel (S_2) showed higher seed quality in many interactions, but the effect of silica gel with the interactions of packaging material, environmental condition and storage duration showed non-significant difference which might be due to the effect on seed moisture content. Sweet corn seed quality characteristics were sustained better during cold storage (6^{o}C) compared to ambient conditions. Seed stored with silica gel (S_1) maintained higher germination percentage. Overall, sweet corn seed could be stored for a longer time (18 months) in an airtight plastic container and an aluminium foil bag under cold storage conditions (6^{o}C). Seed quality parameters values observed non-significant difference between with silica gel (S_1) and without silica gel condition (S_2) in many characters. Therefore, without silica gel storage condition is suitable for storage.

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