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Effect of packaging materials and desiccant on insect population in wheat (*Triticum aestivum* L.)

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Abstract
Stored seeds are a favorable food source for insects, providing the essential elements required for continued growth and development. Most stored seeds are subject to attack and penetration by insects. Stored seeds are a favorable food source for insects, providing the essential elements required for continued growth and development. In addition reducing food quality, insects annihilate quantity, too. Since, different ways are designed for controlling stored-product pests without application of chemical methods. So, the present study included laboratory methods to evaluate the effectiveness between two dates of sowing condition and four packaging materials, namely packaging materials 5 layered polythene bag, 700 gauge polythene bag with zeolite beads, 700 gauge polythene bags without zeolite beads and cloth bag to prevent or minimize the insect infestation and grain wastage resulting in the attack of wheat grain and their products by two notorious insect species. The results revealed that 5 layered polythene bag, 700 gauge polythene bag were found to be the best over the cloth bag, as the insect population (*Sitophilus oryzae*) and grain damage during entire storage period was less. Cloth bag is pervious to moisture which leads in increment in moisture level of seeds and heat due to seed respiration that enhances seed deterioration. Whereas, seeds packed in 700 gauge polythene bags with zeolite beads maintained low moisture content, insect population throughout storage period. Considering the overall aspects of the study, it may be concluded that 700 gauge polythene bags with zeolite beads was observed to be best packaging material amongst all treatments.

Keywords: Wheat grain, *Sitophilus oryzae*, packaging materials, desiccant, zeolite beads, quality

Introduction
Wheat (*Triticum aestivum* L.) is a most important cereal crop of the world and one third of the world's population depends upon wheat as cereal food which belongs to family *Poaceae* (Kerasa *et al.*, 2000) [9]. Cereals are the major component of the human diet throughout the world. Among the cereals, the production of wheat is third in the world. Seed production is seasonal, yet its consumption is continuous. Therefore, almost all seed must be stored in safe storage. The cereal seeds may be stored for a long period of time under optimal storage conditions, since they are generally harvested at relatively low moisture content. However, they can deteriorate if storage conditions are not suitable (Hoseney, 1994) [8]. During storage, cereal grain losses can reach 50 percent of total harvest in some countries (Fornal *et al*., 2007) [6]. The major portion of this loss is caused by insects. Stored seeds are a favorable food source for insects, providing the essential elements required for continued growth and development (Fornal *et al*., 2007; Mebarkia *et al.*, 2010) [6, 10]. Grain storage occupies a vital place in the economies of developed and developing countries (Ellis *et al.*, 1992) [5].

Seed being hygroscopic in nature, is bound to deteriorate fast in storage due to fluctuations in ambient storage conditions. This deterioration can be detained effectively by storing seeds in suitable storage containers, the seeds stored in moisture proof containers like polythene bag, aluminium foils etc. are found to maintain viability and vigour for longer period compared to those stored in cloth bag and gunny bag. Packing is an essential part of a long term incremental development process to reduce losses. In recent years, packaging seeds in moisture barrier packaging materials to prevent loss of viability and resistant or hermitically sealed packaging materials for storage and marketing has explored. The purpose of such packaging material is to maintain seeds at safe storage moisture levels (Copeland and Mc Donald, 1995) [4]. In seed industry cold storage is very expensive therefore; there is a need for low cost drying methods to be used as alternatives to such expensive seed drying equipment.

Seed drying with desiccants is a novel technology; Seed drying beads (zeolite beads) are modified ceramic materials (aluminium silicates) that exclusively absorb water molecules and hold them very firmly in their microscopic pores. These beads eliminate water from the air, creating very low humidity within closed containers. Storing seeds inside of containers with the drying beads will eliminate water from the seeds and dry them without heating.

For packing purposes, polypropylene, polyethylene, polyvinyl chloride, and cellophane-based plastics are typically utilized (Odian, 2004) [11]. When used as packaging, plastic materials offer the benefit of protection against pest contamination (Paine and Paine, 1992) [13]. Ramadan (2016) [14] found that both conventional storage (wheat seeds were kept in cloth bags) and sealing storage (wheat was kept in plastic jars and metal containers) had a substantial impact on final germination percentages, storage efficacy and insect infestation. Therefore, it will be more advantageous to utilize polythene bags of various thicknesses together with desiccants for storage to retain seed viability for an extended period of time. In order to determine the impact of various packaging materials and desiccant on seed health, this study was conducted.

Materials and Methods

The seed material produced separately for two dates of sowing for the storage studies in 2021 was collected and stored in different packaging materials. Experiment consists of two factors. Factor-I seeds harvested from two different dates of sowing condition (D_1 November 25 and D_2 December 20). Factor II packaging materials (P_1-5 layered polythene bag, P_2-700 gauge polythene bag with zeolite beads, P_3-700 gauge polythene bags without zeolite beads and P_4- cloth bag). The required quantity of desiccants was calculated based on their adsorption capacity to reduce to safe level of seed moisture content. Quantity of desiccants stored per kilograms of seed in wheat is 0.37 kilograms for zeolite beads. The seeds were then mixed with the desiccants and kept in hermetic container for 12 months from May 2021 to May 2022 under ambient conditions.

Parameters like seed moisture and insect population (Number of live and dead adult insects emerged) was recorded bimonthly for 12 months of storage by standard methods. The environmental parameters such as temperature and relative humidity were recorded during storage. Moisture contents of the samples were determined by using hot air oven method as suggested by Sadasivam and Manickam (1996) [15]. Number of live and dead insect counts was recorded in 100g of seeds which was randomly extracted bimonthly from the different packaging material stored for 12 months storage to calculate insect population like rice weevil.

Table 1: Effect of packaging materials and zeolite beads on seed moisture content of wheat (cv. UAS 304) seeds during storage

Treatments	Storage months					
	Seed moisture content (%)					
	2^{nd} month	4^{th} month	6^{th} month	8^{th} month	10^{th} month	12^{th} month
Dates of sowing (D)						
D_1	11.74	11.54	11.78	11.83	11.78	11.73
D_2	12.02	11.86	12.12	12.20	12.14	12.07
S. Em. ±	0.21	0.12	0.08	0.06	0.05	0.05
C. D. (p=0.01)	0.84	0.49	0.32	0.23	0.20	0.20
Packaging containers (P)						
P_1	12.72	13.32	13.67	13.72	13.65	13.59
P_2	8.98	6.16	5.95	5.81	5.76	5.68
P_3	12.37	12.77	12.99	13.07	13.05	12.99
P_4	13.44	14.55	15.20	15.45	15.38	15.34
S. Em. ±	0.30	0.17	0.12	0.08	0.07	0.07
C. D. (p=0.01)	1.19	0.69	0.46	0.32	0.28	0.29
Interactions (D × P)						
D_1P_1	12.49	13.04	13.40	13.44	13.38	13.32
D_1P_2	8.89	6.07	5.88	5.76	5.72	5.65
D_1P_3	12.25	12.61	12.81	12.89	12.88	12.85
D_1P_4	13.32	14.45	15.02	15.22	15.15	15.11
D_2P_1	12.94	13.61	13.94	14.00	13.93	13.86
D_2P_2	9.07	6.25	6.01	5.86	5.80	5.71
D_2P_3	12.50	12.93	13.16	13.26	13.21	13.14
D_2P_4	13.57	14.65	15.39	15.69	15.62	15.57
S. Em. ±	0.11	0.06	0.04	0.03	0.03	0.03
C. D. (p=0.01)	NS	NS	0.16	0.11	0.10	0.10

D_1 - Normal sowing
D_2 - Late sowing
P_1 - 5 layered polythene bag
P_2 - 700 gauge polythene bag with desiccant
P_3 - 700 gauge polythene bag without desiccant
P_4 - Cloth bag

Statistical analysis was carried out by Factorial Completely Randomized Design with four replications. All the treatments were compared at 1 percent level of significance using the critical difference test.

Results

Environmental parameters

Maximum temperature (34.81 °C) was recorded in the month of May while minimum temperature (13.2 °C) was observed in the month of January. Maximum RH was recorded in the month of July (90.61%) while minimum RH was found in the month of February (32.93%).

Studied characters during storage

The data on seed moisture (%), number of adult insects emerged and number of dead insect counts as influenced by date of sowing, packaging materials and their interaction effects during storage are presented in Table 1, 2 and 3.

Date of sowing (D)

The sowing date and storage period had significant effect on seed moisture. At the end of 12 months storage, lower seed moisture (11.73%) was recorded in D_1 (November 25th) and higher seed moisture (12.07%) was recorded in D_2 (December 20th). This trend follows throughout the storage period. The sowing date and storage period showed non-significant difference on number of live adult insects at fourth, sixth and eighth month of storage. However, significant difference was observed for number of live adult insects at the end of storage period of twelve months. Number of live adult insects (*Sitophilus oryzae* L.) was increased progressively with the advancement of storage period irrespective of date of sowing. At the initial month of storage, there was no insect movement in both the seeds obtained from D_1 (Normal sowing) and also the seeds obtained from D_2 (Late sowing). At the end of twelve months storage, higher number of live adult insects (16.88) was recorded in D_2 (Late sowing) and lower number of live adult insects (15.19) was recorded in D_1 (Normal sowing). Similar trend was observed throughout the storage period. The sowing date and storage period showed non-significant difference on number of dead adult insects throughout storage period of twelve months. However numerically higher number of dead adult insects was increased progressively with the advancement of storage period irrespective of date of sowing. At the initial month of storage, there was no insect movement and mortality in both the seeds obtained from D_1 (Normal sowing) and also the seeds obtained from D_2 (Late sowing). At the end of twelve months storage, higher number of dead adult insects (6.25) was recorded in D_2 (Late sowing) and lower number of dead adult insects (6.06) was recorded in D_1 (Normal sowing). Similar trend was observed throughout the storage period.

Table 2: Effect of packaging materials and zeolite beads on number of live adult insect counts found in wheat (cv. UAS 304) seeds during storage

Treatments	Storage months				
	No of live adult insects (counts)				
	4th month	6th month	8th month	10th month	12th month
Dates of sowing (D)					
D_1	1.19	3.06	6.13	9.69	15.19
D_2	1.25	3.31	6.19	10.81	16.88
S. Em. ±	0.44	0.87	1.09	1.09	1.14
C. D. (p=0.01)	NS	NS	NS	4.31	4.51
Packaging containers (P)					
P_1	0.00	3.13	4.75	8.00	12.00
P_2	0.00	0.00	1.25	3.13	4.75
P_3	0.00	1.63	3.63	7.75	12.13
P_4	4.88	8.00	15.00	22.13	35.25
S. Em. ±	0.63	1.22	1.55	1.54	1.61
C. D. (p=0.01)	2.49	4.84	6.12	6.10	6.38
Interactions (D × P)					
D_1P_1	0.00	2.75	4.75	8.00	11.25
D_1P_2	0.00	0.00	1.00	2.75	4.50
D_1P_3	0.00	1.25	4.00	7.50	11.50
D_1P_4	4.75	8.25	14.75	20.50	33.50
D_2P_1	0.00	3.50	4.75	8.00	12.75
D_2P_2	0.00	0.00	1.50	3.50	5.00
D_2P_3	0.00	2.00	3.25	8.00	12.75
D_2P_4	5.00	7.75	15.25	23.75	37.00
S. Em. ±	0.22	0.43	0.55	0.54	0.57
C. D. (p=0.01)	NS	NS	NS	NS	NS

Counts taken in 100gm of seed sample which was extracted from the stored bags
D_1 - Normal sowing
D_2 - Late sowing
P_1 - 5 layered polythene bag
P_2 - 700 gauge polythene bag with desiccant
P_3 - 700 gauge polythene bag without desiccant
P_4 - Cloth bag

Packaging containers (P)

Seed moisture content varied significantly from second month onwards due to different packaging materials. Seed moisture content increased from 12.23 percent to 13.59 percent, 12.99 percent and 15.34 percent in P_1 (5 layered polythene bag), P_3 (700 gauge polythene bag without desiccant) and P_4 (Cloth bag) respectively. However, seed moisture content reduced from 12.23 to 5.68 percent in P_2 (700 gauge polythene bag with desiccant zeolite beads) at the end of twelve months of storage period. Number of live adult insects (*Sitophilus oryzae* L.) differed significantly throughout storage period due to different packaging materials. Number of live adult insects was increased progressively with the advancement of storage period. Significantly higher number of live adult insects (35.25) was recorded in P_4 (Cloth bag) and lower number of live adult insects (4.75) was recorded in P_2 (700 gauge polythene bag with desiccant zeolite beads) at the end of twelve months of storage period. Number of dead adult insects differed significantly throughout storage period due to different packaging materials. Number of dead adult insects was increased progressively with the advancement of storage period. Significantly higher number of dead adult insects (14.25) was recorded in P_4 (Cloth bag) and lower number of dead adult insects (1.88) was recorded in P_2 (700 gauge polythene bag with desiccant zeolite beads) at the end of twelve months of storage period.

Table 3: Effect of packaging materials and zeolite beads on number of dead adult insect counts found in wheat (cv. UAS 304) seeds during storage

Treatments	Storage months		
	No of dead adult insects (counts)		
	8^{th} month	10^{th} month	12^{th} month
Dates of sowing (D)			
D_1	2.50	4.13	6.06
D_2	2.25	3.69	6.25
S. Em. ±	0.80	0.78	0.91
C. D. (p=0.01)	NS	NS	NS
Packaging containers (P)			
P_1	2.13	2.38	3.75
P_2	0.00	0.50	1.88
P_3	1.75	3.25	4.75
P_4	5.63	9.50	14.25
S. Em. ±	1.14	1.11	1.28
C. D. (p=0.01)	4.50	4.39	5.07
Interactions (D × P)			
D_1P_1	2.25	2.50	4.00
D_1P_2	0.00	0.75	1.75
D_1P_3	2.00	3.75	5.00
D_1P_4	5.75	9.50	13.50
D_2P_1	2.00	2.25	3.50
D_2P_2	0.00	0.25	2.00
D_2P_3	1.50	2.75	4.50
D_2P_4	5.50	9.50	15.00
S. Em. ±	0.40	0.39	0.45
C. D. (p=0.01)	NS	NS	NS

Counts taken in 100gm of seed sample which was extracted from the stored bags
D_1 - Normal sowing
D_2 - Late sowing
P_1 - 5 layered polythene bag
P_2 - 700 gauge polythene bag with desiccant
P_3 - 700 gauge polythene bag without desiccant
P_4 - Cloth bag

Interactions between date of sowing and packaging materials (D×P)

Seed moisture content recorded non-significant difference due to the interactions between date of sowing and packaging materials after two and four months of storage period. Whereas, significant difference was observed due to the interactions between date of sowing and packaging materials at the end of twelve months of storage period. Lower seed moisture (5.62%) was recorded in D_1P_2 (seeds obtained from normal sowing and packed in 700 gauge polythene bag with zeolite beads) whereas, significantly highest seed moisture (15.57%) was recorded in D_2P_1 (seeds obtained from late sowing and packed in cloth bag). This trend follows throughout the storage period. Non-significant difference was observed due to the interactions between date of sowing and packaging materials throughout storage period for the number of live adult insects (*Sitophilus oryzae* L.), although, higher number of live adult insects (37) at the end of storage period was recorded in D_2P_4 and lower number of live adult insects (4.5) was recorded in D_1P_2. Similar trend was observed throughout the storage period. Non-significant difference was observed due to the interactions between date of sowing and packaging materials throughout storage period for the number of dead adult insects, although, higher number of dead adult insects (15) at the end of storage period was recorded in D_2P_4 and lower number of live adult insects (1.75) was recorded in D_1P_2. Similar trend was observed throughout the storage period.

Discussion

Moisture content is the key factor for successful seed storage. In the current study, moisture content lowered with zeolite beads at ultra drying level *i.e.,* below 5.5 percent for twelve months. Storage of seeds of different species under slowly reduced moisture has been found to maintain viability for a longer period (Agrawal, 1982) [1]. Similarly, in *Ammopiptanthus mangolica* seed could be stored at ambient temperature (25 °C) with relatively low moisture content and their longevity decreased as seed moisture content increased (Yi *et al*., 2010). Zeolite beads reduced the moisture content in seeds harvested from normal sown condition from (12.13 to 5.64%) in LS (12.33 to 5.71%) respectively. This may be due to highly polar surface within the pores which is main driving force for moisture adsorption from the seeds. Similar results on silica gel was reported by Vodouhe (2008) who had dried three species of egusi seeds with silica gel and gave the lowest moisture content of (3.6 to 4.6%) in *Citrullus lunatus*, (3.3 to 4.3%) in *Cucumeropsis edulis* and (4.6 to 7%) in *Lagenaria siceraria*.

Insect was not observed up to two months of storage period in the wheat grain. It is apparent from the (Table 2 and 3) that the insect population of rice weevil (*Sitophilus oryzae* L.) was only found in cloth bag. However, it started in cloth bag on four months of storage whereas in 700 gauge polythene bags with zeolite beads insect population started after 8 months and the insect population increased cumulative as storage progressed. *i.e.*, 35.25 numbers/100 g of sample at the end of twelve months of storage period. However, the insect population was recorded very less in seeds stored in 700 gauge polythene bags with zeolite beads. Number of dead insects count was observed after eight months of storage in case of seeds stored in cloth bags this might be due to completion of life span of rice weevil *i.e.*, 7-8 months when subjected in congenial ambient environmental conditions, whereas the death counts was observed after ten months of storage in seeds stored in 700 gauge polythene bags with zeolite beads. The results of present study indicated that insect infestation of wheat grain stored in different types of packaging materials increased with the progress of storage period. Where, the highest number of adults emerged were up to 12 months, followed by 8 months and lastly 2 months during storage period. These results may be due to instability of the temperature, humidity and seed moisture fluctuation during storage periods (Attia *et al*., 2014 and 2015) [2, 3].

Conclusion

From the results, it may be concluded that 5 layered polythene bag and 700 gauge polythene bag were found to be the best over the cloth bag, as the insect population and grain damage during entire storage period was less. This was mainly due to the fluctuation in surrounding environmental factors like temperature and relative humidity. Cloth bag is pervious to moisture which leads in increment in moisture level of seeds and heat due to seed respiration that enhances seed deterioration. Maximum moisture content and insect population was recorded in seeds stored in cloth bag. Whereas, seeds packed in 700 gauge polythene bags with zeolite beads maintained low moisture content, insect population throughout storage period. Considering the overall aspects of the study, it may be concluded that 700 gauge polythene bags with zeolite beads was observed to be best packaging material amongst all treatments.

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