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Influence of seed treatments and storage containers on Angoumois grain moth (*Sitotroga cerealella*) infestation in rice seed storability

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Abstract
Angoumois grain moth, *Sitotroga cerealella* (*Olivier*) is a major pest that causes severe damage to rice seeds during storage. A study was conducted to evaluate the effect of seed treatments *viz.*, *Acorus calamus* rhizome powder @ 3 g/kg, Diatomaceous earth @ 5 g/kg and Thiamethoxam 30 FS @ 5 ml/kg and storage containers *viz.*, gunny bag and non-woven bags against Angoumois grain moth, *Sitotroga cerealella* (*Olivier*) infestation during storage. Among different seed treatment methods**,** Thiamethoxam 30 FS @ 5 ml/kg exhibited significantly very less insect damage (1.5%) followed by Diatomaceous Earth @ 5 g/kg (4.4%). Among the containers, insect damage was lower in non-woven bag (2.0%) compared to gunny bag (5.7%). The Thiamethoxam treated seeds stored in non-woven bags maintained 90% germination, even after nine months of storage when compared to control (71%).

Keywords: Angoumois grain moth, seed treatment, non woven bags, insect damage, germination

Introduction
India is the second largest producer and consumer of rice in the world. In India rice is grown in 43.5 million ha with the productivity of about 2400 kg/ha (Anon, 2018) [3]. In the last 50 years of post green revolution, rice area, production and yield have increased by 1.24, 3.08 and 2.8 times, respectively (Anon, 2016) [4]. This is mainly due to the enhancement of Seed Replacement Rate (SRR) and Varietal Replacement Rates in addition to proper management practices. Because, quality seed plays an important and critical role in bridging the yield gaps through improved productivity and it alone contributes about 15-20% to the crop yield.

A strong and vibrant seed system is essential for increasing the SRR and accelerating growth in agriculture. Presently, Indian seed sector comprises public sector institutions as well as private seed companies. Around 8765 quintals of breeder seed and 66.84 lakh quintals of certified seeds of paddy were produced and supplied to farmers during 2014-15. But storage insects are the major threat to seed sectors in most countries. Post harvest losses are huge at the farm and trade level, where nearly 70 per cent of the farm produce is stored either for food, feed or seed. On an average, losses due to insects at storage are reported to be in the range of 10-20 per cent but at times may be as high as 30 per cent (Rajsri and Kavitha, 2015) [13] In an empirical study to assess the type of storage problems faced by seed producers of Andra Pradesh in storing their paddy seeds, 55% of the respondents revealed pests as the major problem (Raju and Reddy, 2015) [15]. Hence, seed storage is an essential segment of seed industry.

Angoumois grain moth, *Sitotroga cerealella* (*Olivier*) is the foremost pest of seed storage godowns. It is regarded as one of the most destructive internal feeder in stored grains of rice (Togola *et al*., 2013) [17]. Early infestation is difficult to detect because the hole made by young larva is so small that it cannot be seen. The appearance of moths in the stores and round holes on the grain or sometimes heating of the grain in the bin provides the first indication of infestation. Each adult lays about 120-350 eggs which multiply soon and damages the seed lot at faster rate. Under conditions of heavy infestation, the stored products can suffer even 100% loss.

S. cerealella caused reduction in weight, germination of seed and the loss of nutritional value and market value of rice.

At Agricultural Research Station, Bhavanisagar, yearly 100 tonnes of foundation and certified seeds of rice are produced and supplied to the farmers and seed producers. As per Indian Minimum Seed Certification Standards (IMSCS), the certified seed bags once tagged should not be opened until it completes the validity period of nine months. So the possibility of drying, reprocessing and treating the seed lots in the mid of validity period is impossible. Hence, protecting the seeds without insect damage and maintaining the minimum seed germination percentage as per IMSCS prescribed by the Central Seed Certification Board, 1988 is still challenging. The process involved in the production of genetically pure seeds needs more attention unlike grains and also the high cost of seeds increases the inevitability of protecting the seeds from the vulnerability of storage pests.

With this background a study was conducted at Agricultural Research Station, Bhavanisagar to find an integrated management approach to control Angoumois grain moth (*S. cerealella*) infestation to improve rice seed storability.

Materials and Methods

The experiment was conducted under ambient storage conditions at Agricultural Research Station, Bhavanisagar. The experiment was laid out in Completely Randomized Design with three replications. The seeds of paddy cv. ADT (R) 45 harvested during October 2017 were used for this experiment after drying to a safe moisture level (11- 12%) by sun drying method. Then the seeds were treated with *Acorus calamus* rhizome powder @ 3 g/kg (T_2), Diatomaceous earth @ 5 g/kg (T_3), Thiamethoxam 30 FS @ 5 ml/kg (T_4). The treated seeds were packed in gunny bag (C_1) and non-woven bag (C_2) and stored for a period of 12 months (P_0 to P_{12}) along with the Control (T_1).

The seeds were evaluated at three month intervals for Moisture Content using INDOSAW moisture meter, Seed germination (%) (ISTA, 1999), Seedling Vigour (Abdul Baki and Anderson, 1973), Insect Damage (%) and Electrical conductivity (Presley, 1958). Data was subjected to statistical analysis using analysis of variance (ANOVA) after transforming the percentage data to arcsine value to homogenize the variance (Panse and Sukhatme, 1985). The critical differences (CD) were calculated at 5 per cent probability level. The data were tested for statistical significance (*). If F test is non-significant, it was indicated as NS.

Results and discussion

Moisture content

Proper storage of the seeds plays a major role in preserving the viability and vigour of the seeds. The major factor which determines the stored seed viability is the moisture content which accelerates seed deterioration and invites storage pest and fungi. Proper drying of seed to low moisture content has a negative effect on biological activities of many insects. Due to the hygroscopic nature of seed, variation in atmospheric moisture content and relative humidity alters its moisture content. Hence, moisture vapour proof containers like polythene bag, aluminum foil pouch or tin are used to store the seeds for longer period.

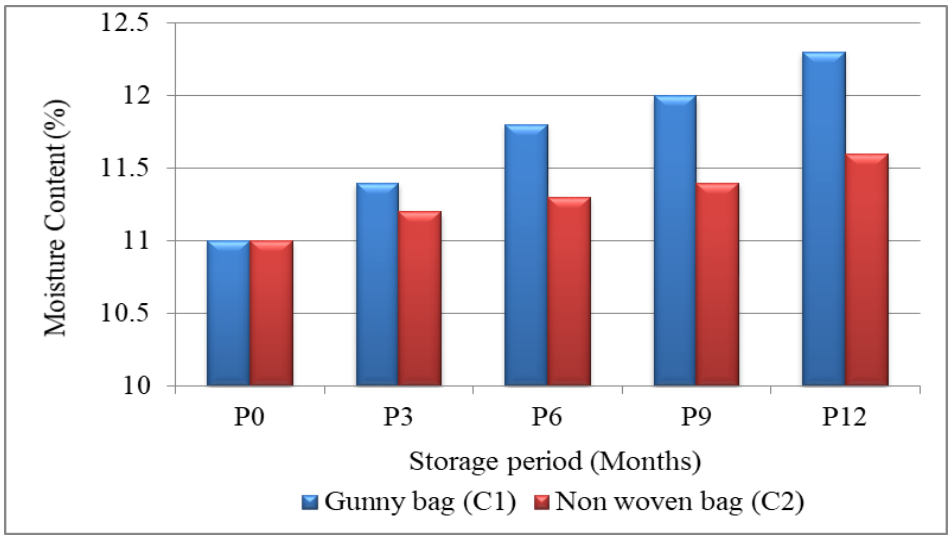

Fig 1: Influence of seed treatment and storage containers on Moisture content (%) of paddy seeds during storage

In this study, non woven bags (A web or sheet of polypropylene fibers bonded together by entangling the fiber or filaments mechanically, thermally or chemically which are recyclable) are used as one of the storage containers. These non woven bags are moisture proof and non porous unlike jute gunny bags which is the standard bag used for rice seed packing. Hence, the increase in moisture content of non woven bags was less compared to gunny bags even after 12 months of storage (Fig 1.). The increase in moisture content was up to 1.3% in case of gunny bag (12.3%) and 0.6% in case of non oven bags (11.6%) irrespective of treatments.

Seed germination

The quality of the seed lot is decided by the germination potential and vigour of the seed lot. The results of germination tests showed considerable decrease in germination percentage (96 to 80%) with increase in storage period. This might be due to the deterioration process that occurs in seeds due to ageing by depletion of food reserves and decline in synthetic activity (Heydecker, 1972). In case of containers, germinability of the seeds stored in gunny bags started declining and reached 73% after twelve months of storage which is less than the minimum seed certification standard compared to non woven bags (86%), irrespective of treatments. This clearly indicated that the containers play a considerable roll in extending the storage period of seeds by reducing the seed deterioration and Angoumois grain moth infestation.

Table 1: Influence of seed treatment and storage containers on germination (%) of paddy seeds during storage

Treatment	Gunny bag (C_1)						Non woven bag (C_2)						T Mean
	P_0	P_3	P_6	P_9	P_{12}	Mean	P_0	P_3	P_6	P_9	P_{12}	Mean	
T_1	96	88	80	71	65	80	96	92	88	84	80	88	84
T_2	97	91	85	79	75	85	97	95	93	90	86	92	89
T_3	96	91	85	80	75	86	96	95	93	90	88	92	89
T_4	97	93	89	83	77	88	97	96	93	90	88	93	90
Mean	97	91	85	78	73	85	97	95	92	89	86	91	
	T	C	P	TC	CP	TP	TCP	P Mean	P_0	P_3	P_6	P_9	P_{12}
SEd	0.52	0.37	0.59	0.74	0.84	1.18	1.67		97	93	88	83	79
CD (P=0.05)	1.04	0.74	1.17	1.48	1.66	2.34	3.31						

The germination per cent was recorded significantly higher in all treatments over control even after 12 months of storage irrespective of the containers. Among the treatments, the seeds treated with Thiamethoxam 30 FS @ 5 ml/kg recorded the highest germination percentage (90%). The efficacy of the chemical in controlling the Angoumois grain moth infestation is clearly seen in case of gunny bag where the infestation is more. The Thiamethoxam treated seeds stored in gunny bags and non-woven bags could able to maintain 83% and 90% germination respectively which is above IMSCS level, even after nine months of storage when compared to control (71%).

Vigour Index

The vigour index values varied significantly in storage due to seed treatments, containers, periods of storage and their interactions. The vigour index value decreased from 2466 to 1949 with the increase in storage period irrespective of treatments and containers. Among the seed treatments, vigour index value was significantly higher in seeds treated with Thiamethoxam 30 FS @ 5 ml/kg (2349) followed by *Acorus calamus* rhizome powder @ 3 g/kg (2243) while Control (2074) recorded lower vigour index value irrespective of containers and periods of storage. Among the containers, non-woven bag recorded higher value (2309) and gunny bag recorded lower value (2135). This might be due to the sizeable infestation and depletion of feed reserves by Angoumois grain moth. The development and survival of an individual larva of Angoumois grain moth strongly directly depending on the available food resources, which are determined and limited by a single inhabited kernel itself (Ignjatovic Cupina *et al*., 2018) [7].

Table 2: Influence of seed treatment and storage containers on Vigour Index of paddy seeds during storage

Treatment	Gunny bag (C_1)						Non woven bag (C_2)						T Mean
	P_0	P_3	P_6	P_9	P_{12}	Mean	P_0	P_3	P_6	P_9	P_{12}	Mean	
T_1	2381	2033	1976	1740	1417	1909	2362	2346	2121	2058	1808	2139	2023
T_2	2477	2202	2108	1976	1688	2089	2458	2385	2390	2232	2112	2305	2197
T_3	2396	2284	2117	1880	1770	2090	2503	2423	2297	2169	2133	2315	2202
T_4	2493	2520	2198	1967	1910	2218	2600	2381	2381	2187	2270	2364	2290
Mean	2475	2331	2140	1948	1782	2077	2487	2418	2325	2204	2116	2281	
	T	C	P	TC	TP	CP	TCP	P Mean	P_0	P_3	P_6	P_9	P_{12}
SEd	8.00	5.65	8.93	11.30	17.90	12.63	25.25		2458	2321	2198	2026	1888
CD (P=0.05)	16	11	18	22	35	25	50						

Insect Damage

Among the containers, insect damage was lower in non-woven bag (2.0%) compared to gunny bag (5.7%). Fletcher and Ghosh (1919) observed that a female laid 120-350 eggs on paddy grains and other cereals and also on depressions, cracks, crevices and holes of storage structures and godowns. And also the female moth prefers a rough surface than a smooth one for egg lying (Prakash et *al*., 1981) [11]. Thus the rough surface and holes in the gunny bags made it a preferable site for egg laying compared to non woven bags. Mainly the non porous nature of non oven bags prevented the entry of larvae into the grains. In addition, the increased moisture content in the seeds of gunny bags increased the insect infestation. However, the seeds treated with Thiamethoxam 30 FS @ 5 ml/kg exhibited significantly very less insect damage (1.5%) followed by Diatomaceous Earth @ 5 g/kg (4.4%) irrespective of containers. Shah and Khan (2014) [16] reported Diatomaceous Earth as the most efficacious natural dust used as an insecticide. Yue *et al*., 2003 [20] suggested that the stored corn or sorghum grain treated with thiamethoxam or imidacloprid at rates commonly used to control field crop pests should be well protected from the possibility of infestations by these two lepidopteran species *Ostrinia nubilalis* and Indian meal moth, *Plodia interpunctella* larvae in stored grain. Wakil *et al*. (2012) [19] reported that Diatomaceous Earth in combination with *Beauveria bassiana* or a neonicotinoid insecticide thiamethoxam may provide safety for an extended period against *R. dominica*. Rajsri and Meenakumari, 2014 recommended diatomaceous earth as an alternative to conventional insecticides like deltamethrin for long term safe storage of rice seed.

Table 3: Influence of seed treatment and storage containers on insect damage (%) of paddy seeds during storage

Treatment	Gunny bag (C_1)						Non woven bag (C_2)						T
	P_0	P_3	P_6	P_9	P_{12}	Mean	P_0	P_3	P_6	P_9	P_{12}	Mean	Mean
T_1	0.0	5.3	11.0	16.0	25.3	11.5	0.0	2.0	1.0	5.0	10.8	3.8	7.6
T_2	0.0	3.0	10.0	13.0	16.0	8.4	0.0	0.0	0.0	4.0	9.0	2.6	5.5
T_3	0.0	2.0	7.0	11.0	13.0	6.6	0.0	0.0	0.0	4.3	7.0	2.3	4.4
T_4	0.0	0.0	0.0	2.5	8.3	2.2	0.0	0.0	0.0	1.0	3.0	0.8	1.5
Mean	0.0	2.6	7.0	10.6	15.6	7.2	0.0	0.5	0.3	3.6	7.4	2.4	
	T	C	P	TC	TP	CP	TCP	P Mean	P_0	P_3	P_6	P_9	P_{12}
SEd	0.29	0.20	0.32	0.41	0.64	0.45	0.91		0.0	1.5	3.6	7.1	11.5
CD (P=0.05)	0.6	0.4	0.6	0.8	1.3	0.9	1.8						

Electrical Conductivity

Moisture content is the single most important factor controlling rate of deterioration. Electrical conductivity test aims to indirectly evaluate the extent of damage caused to cell membranes resulting from seed deterioration (Abreu *et al*., 2011) [2]. As the storage period prolonged the electrical conductivity also increased from 27.52 µScm^{-1} (P_0) to 84.60 µScm^{-1} (P_{12}) irrespective of treatments and containers. The seeds stored in non-woven bag (C_2) registered lower electrical conductivity (50.98 µScm^{-1}) than gunny bag (C_1) (52.13 µScm^{-1}). The higher electrical conductivity in gunny bag might be due to higher moisture content and insect damage. The attack of insects on grains also leads to an increase in electrical conductivity by rupturing the outer wall and perforating the grain tegument (Vieira *et al*. 2001) [18]. Among the treatments, Thiamethoxam 30 FS @ 5 ml/kg treated seeds recorded lower electrical conductivity (51.38 µScm^{-1}) which is on par with *Acorus calamus* rhizome powder @ 3 g /kg treated seeds irrespective of containers and periods of storage. Lower electrical conductivity in treated seed might be due to less insect damage in treated seeds. And also the *Acorus calamus* rhizome powder is found to have free radical scavenging property (Manju e*t al*., 2013) [9].

Table 4: Influence of seed treatment, surface treatment and storage containers on Electrical conductivity (µScm^{-1}) of paddy seeds during storage

Treatment	Gunny bag (C_1)						Non woven bag (C_2)						T
	P_0	P_3	P_6	P_9	P_{12}	Mean	P_0	P_3	P_6	P_9	P_{12}	Mean	Mean
T_1	28.12	36.84	48.63	64.87	86.21	52.94	28.51	34.52	46.12	64.55	84.23	51.57	52.25
T_2	27.18	36.25	47.85	65.12	85.46	52.37	27.69	33.74	46.38	64.59	84.36	51.35	51.86
T_3	29.54	37.21	47.52	65.69	86.11	53.21	27.38	33.28	46.12	65.12	84.75	51.33	52.27
T_4	28.12	35.78	47.11	64.86	85.00	52.17	27.19	34.21	45.97	65.43	83.64	51.26	51.72
Mean	28.24	36.52	47.78	65.14	85.70	52.67	27.64	33.94	46.15	64.92	84.25	51.38	
	T	C	P	TC	CP	TP	TCP	P Mean	P_0	P_3	P_6	P_9	P_{12}
SEd	0.31	0.22	0.34	0.43	0.49	0.69	0.98		27.94	35.23	46.96	65.02	84.97
CD(P=0.05)	0.61	0.43	0.68	0.86	0.97	1.37	1.93						

Conclusion

Seed treatment with *Thiamethoxam* 30 FS @ 5 ml/kg is very effective in controlling the Angoumois grain moth infestation during paddy seed storage. Non-woven bags can be used as alternate seed packing material without compromising seed quality with less cost compared to gunny bags. Among the organic treatments Diatomaceous earth @ 5 g/kg seed is efficient in controlling the insects whereas *Acorus calamus* rhizome powder @ 3 g/kg seed treatment is found to be effective in reducing the seed deterioration.

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