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Effect of different storage containers on incidence of maize weevil *Sitophilus zeamais* on stored maize

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Abstract
A laboratory experiment was conducted to know the effect of different storage containers on the incidence of maize weevil *Sitophilus zeamais* on stored maize during 2017-18. Results revealed that among the storage containers, seeds stored in polythene bags were recorded with the less per cent (16.58 %) seed damage, lowest per cent weight loss (5.41 %), less moisture content (10.98 %) and the less pest population (40.00 adults) of *S. zeamais* followed by plastic containers (17.17 %, 6.83 %, 11.06 % and 42.33 adults, respectively). Whereas, highest per cent seed damage (50. 25 %), weight loss (15.88 %), more moisture content (12.34 %) and the highest pest population (80.33 adults) was recorded in earthen pots followed by gunny bags (48.00 %, 15.13 %, 12.25 % and 78.67 adults) recorded by *S. zeamais* at 120 days after storage period.

Keywords: Maize weevil, Storage containers, per cent seed damage, per cent weight loss

1. Introduction
Maize is the most widely distributed crop of the world. It is cultivated in tropics, subtropics, temperate and semiarid condition. The world area under maize is 183 m ha with a production of 1065 m t. In India it is being grown on an area of 9.6 m ha with a production of 26 m t with an average productivity of 2710 kg/ha. Karnataka accounts for 1.26 m ha area with a production of 3.31mt and productivity of 2612 kg/ha (Anon., 2016) [3]. During postharvest storage, maize grains are vulnerable to many insects. Among those, Angoumois grain moth *Sitotroga cerealella* (Olivier), lesser grain borer *Rhyzopertha dominica*, weevils complex *Sitophlilus* spp., Khapra beetle, *Trogoderma granarium* Everts and red flour beetle, *Tribolium castaneum* (Herbst) are important (Ebeling, 2002) [7]. It is estimated that 5 to 10 per cent of world's grain production is lost due to the ravages of insect pests. These losses reach to 50 per cent in tropical countries where temperature and humidity run high during the summer season (Ahmad and Ahmad, 2002) [1]. Weevils from the genus *Sitophilus* are major pests of stored maize all over the world (Grenier *et al.*, 1994) [8]. Maize weevil, *Sitophilus zeamais* (Mostch.) (Coleoptera: Curculionidae) is an important insect-pest of maize in the tropics, causing serious losses to many poor farmers who store grains on farm for use as food and seed (Thanda and Kevin, 2003) [11]. Worldwide, seed losses from *S. zeamais* are 20 to 90 per cent from untreated maize (Derera *et al.*, 1999) [6]. An annual average of 20 to 30 per cent of maize grain is then lost through damage by this pest (Demissie *et al.*, 2008) [5]. *S. zeamais* causes enormous losses up to 100 per cent in stored maize in India and other countries (Irabagon, 1959) [9]. This evidently indicates the importance of *S. zeamais* in storage of maize. Prevention of losses in stored products due to insects is of paramount importance. The present study was undertaken to investigate quality change of maize seeds in different storage containers subject to infestation by *S. zeamais* on stored maize.

2. Materials and Methods
The eight different containers were selected to conduct the experiment with three replications.
1. Polythene bags of 700 guage
2. Cloth bags
3. Porous HDPE bags
4. Gunny bags
5. 5. Earthen pots

6. Bags metal bins
7. Plastic containers
8. Glass bottles

250 g of maize seeds were taken in each container of one kg capacity. Freshly emerged twenty adults of *S. zeamais* were released in each container separately and maintained up to four months. The culture was maintained in plastic containers of one kg capacity containing maize seeds in order to maintain a stock culture for a continuous fresh supply of large number of insects required for the experimentation. Observation on percentage of insects damaged seeds was recorded and per cent weight loss and per cent moisture content was estimated on 15, 30, 60, 90 and 120 days after release and also recorded observations on pest multiplication on 60 and 120 days after release.

Per cent seeds damage was calculated for all the samples collected in the study area by using the formula given by Wambugu *et al.,* (2009).

$$\text{Insect damaged seeds (\%)} = \frac{\text{Number of insect damaged seeds}}{\text{Total number of seeds}} \times 100$$

Per cent seeds weight loss was calculated according to the formula given by Adams and Schulter (1978).

$$\text{Seeds weight loss (\%)} = \frac{(\text{UNd} - \text{Dnu})}{(\text{Nd} + \text{Nu})} \times 100$$

Where
U: Weight of undamaged seeds
ND: Number of damaged seeds
D: Weight of damaged seeds and
NU: Number of undamaged seeds

Moisture content of seed was estimated by oven dry method. Five grams of maize seeds were taken from each replication of each treatment and by taking the initial weight, the seeds were ground and kept in an oven for 4 h at 130 °C and the final weight was recorded. The moisture content of the seed was calculated by using following formula.

$$\text{Moisture content (\%)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

Where
W_1= Weight of empty cup with lid (g)
W_2= weight of cup with seed sample before drying (g)
W_3= weight of cup with seed sample after drying (g)

Statistical analysis: The data were analysed statistically following CRD design with 95 per cent confidence level.

3. Results and discussion

3.1 Effect of different storage containers on per cent seed damage by *S. zeamais* adults and its multiplication

Fifteen days after treatment polythene bags of 700 gauge recorded least per cent (2.42 %) seed damage and was on par with plastic containers (3 %) found superior to all other treatments followed by glass bottles (3.75 %), bags metal bins (5.08 %), porous HDPE bags (6.25 %), cloth bags (8.5 %) and gunny bags (10 %). Earthen pots recorded the highest per cent seed damage (10.92 %) (Table 1).

The treatment polythene bags of 700 gauge continued to record the lowest per cent seed damage after 30 days and continued to record up to 120 days *i.e.,* 3.17 to 16.58 per cent and it was superior over all other treatments, followed by plastic containers (4.92-17.17 %), glass bottles (5.83-20.08 %), bags metal bins (7.83-27.08 %), porous HDPE bags (9.83-29.17 %) and cloth bags (12.33-38.67 %). Whereas the treatment earthen pots continued to recorded the highest per cent seed damage up to 120 days *i.e.,* 16.25 to 50.25 per cent (table 1).

With respect to the pest population also the treatment polythene bags of 700 gauge was significantly superior which recorded less number of *S. zeamais* adults *i.e.,* 25.67 adults at 60 DAT and this treatment was on par with plastic containers (27.33 adults) and glass bottles (30.00 adults). The next better treatment was bags metal bins which recorded 36 adults and it was on par with porous HDPE bags (38.67 adults). The treatment cloth bags found inferior with recorded 53 adults. However, gunny bags and earthen pots recorded the highest number *i.e.,* 64.33 to 66 adults. Similar trend was observed at 120 DAT *i.e.,* 40 to 43 adults were recorded in the treatment polythene bags of 700 gauge, Plastic containers and glass bottles. While, porous HDPE bags, cloth bags, gunny bags and earthen pots treatments recorded the highest pest population (49.33-80.33 adults) (table 1).

3.2 Effect of different storage containers on maize seed weight loss due to *S. zeamais* adults

Polythene bags of 700 gauge treatment recorded the least per cent weight loss *i.e.,* 1.3 per cent at 15 days after treatment and superior to all other treatments and it was on par with plastic containers (1.51 %) and glass bottles (1.80 %). The next best treatment was bags metal bins (2.11 %), followed by porous HDPE bags, cloth bags which recorded 2.71 to 3.31 per cent weight loss. While the highest weight loss was recorded in gunny bags and earthen pots were recorded 4.30 to 4.61 per cent (table 2).

Similar trend was observed at 30 days after treatment and up to 120 days *i.e.,* polythene bags of 700 gauge treatment recorded the lower weight loss of 2.05 to 5.41 per cent and it was superior to all other treatments, followed by plastic containers (2.19-6.83 %), glass bottles (2.78-7.81 %), bags metal bins (3.59-9.09 %), porous HDPE bags (4.13 – 9.68 %), cloth bags (4.50-11.62 %). Whereas, the highest weight loss was recorded in the treatment gunny bags (5.16-15.13 %) and earthen pots (5.53-15.88 %) (Table 2).

3.3 Effect of different storage containers on moisture content of maize seeds due to *S. zeamais* adults

Effect of different storage containers on moisture content revealed that the treatment polythene bags of 700 gauge recorded the lowest moisture content of 10.12 per cent and it was superior to all other treatments, followed by plastic containers, glass bottles, bags metal bins, porous HDPE bags, cloth bags, gunny bags and earthen pots which recorded 10.30 to 11.32 per cent moisture content (table 3).

After 30 days, the polythene bags of 700 gauges recorded the lowest per cent moisture content *i.e.,* 10.22 per cent and superior to all other treatments. The next better treatment was plastic containers which recorded 10.38 per cent, followed by glass bottles, bags metal bins, porous HDPE bags, cloth bags and gunny bags which recorded 10.55 to 11.37 per cent. The highest moisture per cent was recorded in earthen pots *i.e.,* 11.65 per cent.

Sixty days after treatment, similarly the treatment polythene bags of 700 gauges recorded the lower moisture content of 10.36 per cent and superior to all other treatments, but on par with plastic containers (10.54 %). The next best treatment was glass bottles which recorded 10. 74 per cent, followed by bags metal bins, porous HDPE bags, cloth bags, gunny bags, earthen pots were recorded the highest per cent moisture (10.74 % to 11.82 %) (Table 3).

At 90 and 120 days after treatment, the treatment polythene bags of 700 gauge recorded 10.83 to 10.98 per cent moisture content was significantly superior, but on par with plastic containers 10.86 to 11.06 per cent. The highest moisture content was recorded in the treatment gunny bags, which recorded 11.84 to 12.25 per cent moisture content (table 3).

Among the storage containers, the polythene bags recorded the less per cent (16.58 %) seed damage, lowest per cent weight loss (5.41 %), less moisture content (10.98 %) and the less pest population (40.00) of *S. zeamais* followed by plastic containers (17.17 %, 6.83 %, 11.06 % and 42.33 adults, respectively). Whereas, highest per cent seed damage (50. 25 %), weight loss (15.88 %), more moisture content (12.34 %) and the highest pest population (80.33 adults) were recorded in earthen pots followed by gunny bags (48.00 %, 15.13 %, 12.25 % and 78.67 adults) during 120 days of storage period. These findings are in accordance with the Vardhani (1999) [12] found that the sorghum seeds stored in polythene bag and plastic containers recorded 4.0 per cent less seed damage by *R. dominia* compared to 8.0 per cent in other containers. The dry matter loss expressed in per cent loss of weight has shown polythene bags (2.9 %) and plastic containers (3.2 %) were more efficient for safe storage as compared to others containers like gunny bag, cloth bag (4.0 %). The pest multiplication was also minimum in polythene bags and plastic containers (3.0 adults per container) as compared to other containers (4-5 adults per container) [12]. Tammanagouda (2002) revealed that significantly lower moisture content (9.21 %) and seed infestation (34.10 %) in green gram seeds stored in polythene bag as compared to those in cloth bag at the end of 10 months storage period [10]. Ali *et al.* (2009) reported that among the different containers, the lowest population of grain moth (1.40 - 7.93), red flour beetle (6.40 - 35.33) and rice weevil (0.20 - 9.13) was recorded from the plastic containers [2]. Channakeshava *et al*. (2001) reported that African tall fodder maize seeds stored in moisture impervious containers maintained the initial moisture content (8 ± 1%) and registered higher germination (74-91.5%) as compared to seeds stored in moisture pervious containers (cloth and gunny bags) [4].

Table 1: Effect of different storage containers on per cent seed damage by *S. zeamais* adults and its multiplication

Treatments		Seed damage (%)*					Pest population	
		15 DAT	30 DAT	60 DAT	90 DAT	120 DAT	60 DAT	120 DAT
T_1	Polythene bags of 700 gauge	2.42 (8.92)^{a}	3.17 (10.24)^{a}	6.58 (14.86)^{a}	10.50 (18.9)^{a}	16.58 (24.02)^{a}	25.67^{a}	40.00^{a}
T_2	Cloth bags	8.50 (16.95)^{e}	12.33 (20.56)^{f}	21.00 (27.27)^{e}	33.50 (35.36)^{f}	38.67 (38.45)^{e}	53.00^{c}	69.00^{d}
T_3	Porous HDPE bags	6.25 (14.48)^{d}	9.83 (18.27)^{e}	17.67 (24.85)^{d}	28.42 (32.21)^{e}	29.17 (32.69)^{d}	38.67^{b}	49.33^{c}
T_4	Gunny bags	10.00 (18.43)^{f}	15.42 (23.12)^{g}	29.33 (32.79)^{f}	39.33 (38.84)^{g}	48.00 (43.85)^{f}	64.33^{d}	78.67^{e}
T_5	Earthen pots	10.92 (19.29)^{g}	16.25 (23.77)^{h}	30.25 (33.37)^{g}	41.17 (39.91)^{g}	50.25 (45.14)^{g}	66.00^{d}	80.33^{e}
T_6	Bags metal bins	5.08 (13.02)^{c}	7.83 (16.25)^{d}	13.50 (21.56)^{c}	19.92 (26.5)^{d}	27.08 (31.36)^{c}	36.00^{b}	48.00^{bc}
T_7	Plastic containers	3.00 (9.97)^{ab}	4.92 (12.8)^{b}	7.92 (16.34)^{b}	11.75 (20.04)^{b}	17.17 (24.48)^{a}	27.33^{a}	42.33^{a}
T_8	Glass bottles	3.75 (11.16)^{b}	5.83(13.97)^{c}	8.17 (16.6)^{b}	14.75 (22.58)^{c}	20.08 (26.62)^{b}	30.00^{a}	43.00^{ab}
S.Em±		0.25	0.24	0.15	0.35	0.23	1.80	1.75
CD (P = 0.05)		0.73	0.72	0.45	1.03	0.69	5.38	5.24
CV (%)		3.00	2.41	1.11	2.02	1.20	7.30	5.38

* Figures in the parenthesis are Arc sin transformed values; DAT: Days after treatment.
*250 g /container

Table 2: Effect of different storage containers on per cent weight loss due to *S. zeamais* adults

Treatments		15 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T_1	Polythene bags of 700 Guage	1.30 (6.55)^{a}	2.05 (8.24)^{a}	3.19 (10.29)^{a}	5.20 (13.19)^{ab}	5.41 (13.44)^{a}
T_2	Cloth bags	3.31 (10.48)^{e}	4.50 (12.25)^{d}	7.35 (15.73)^{e}	10.78 (19.17)^{e}	11.62 (19.93)^{f}
T_3	Porous HDPE bags	2.71 (9.46)^{de}	4.13 (11.72)^{cd}	6.27 (14.49)^{c}	9.44 (17.9)^{d}	9.68 (18.12)^{e}
T_4	Gunny bags	4.30 (11.97)^{f}	5.16 (13.12)^{e}	9.53 (17.98)^{d}	11.71 (20.01)^{f}	15.13 (22.89)^{g}
T_5	Earthen pots	4.61 (12.39)^{f}	5.53 (13.6)^{f}	10.08 (18.51)^{f}	13.04 (21.17)^{g}	15.88 (23.48)^{h}
T_6	Bags metal bins	2.11 (8.35)^{bcd}	3.59 (10.92)^{c}	4.97 (12.88)^{f}	7.44 (15.83)^{c}	9.09 (17.55)^{d}
T_7	Plastic containers	1.51 (7.03)^{ab}	2.19 (8.52)^{ab}	3.65 (11.01)^{c}	4.95 (12.85)^{a}	6.83 (15.15)^{b}
T_8	Glass bottles	1.80 (7.72)^{abc}	2.78 (9.59)^{b}	4.06 (11.61)^{ab}	5.37 (13.39)^{b}	7.81 (16.23)^{c}
S.Em±		0.20	0.19	0.20	0.09	0.18
CD (P = 0.05)		0.60	0.59	0.63	0.30	0.55
CV (%)		3.80	3.07	2.58	1.03	1.73

Figures in parentheses are arcsine transformed values
Means in the columns followed by the same alphabet do not differ significantly
*250 g /Contained

Table 3: Effect of different storage containers on moisture content due to *S. zeamais* adults damage

Treatments		15 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T_1	Polythene bags of 700 Guage	10.12^{a}	10.22^{a}	10.36^{a}	10.83^{a}	10.98^{a}
T_2	Cloth bags	10.97^{f}	10.99^{f}	11.29^{d}	11.72^{f}	11.84^{d}
T_3	Porous HDPE bags	10.93^{e}	10.74^{d}	10.92^{c}	11.51^{e}	11.76^{d}
T_4	Gunny bags	11.21^{g}	11.37^{g}	11.65^{e}	11.84^{f}	12.25^{e}
T_5	Earthen pots	11.32^{h}	11.65^{h}	11.82^{e}	10.98^{bc}	12.34^{e}
T_6	Bags metal bins	10.79^{d}	10.97^{e}	11.21^{d}	11.32^{d}	11.44^{c}

T_7	Plastic containers	10.30[b]	10.38[b]	10.54[ab]	10.86[ab]	11.06[ab]
T_8	Glass bottles	10.54[c]	10.55[c]	10.74[b]	11.05[c]	11.17[b]
S.Em±		0.03	0.03	0.10	0.04	0.04
CD (P = 0.05)		0.10	0.11	0.32	0.12	0.12
CV (%)		0.58	0.60	1.65	0.64	0.63

Means followed by same alphabet in a column do not differ significantly; DAT: Days after treatment.
*250 g /container

4. Conclusion
Among the storage containers, seeds stored in polythene bags of 700 gauge, was recorded the less per cent seed damage, lowest per cent weight loss, less moisture content and the less pest population followed by plastic containers. Whereas, significantly highest per cent seed damage, weight loss, more moisture content and the highest pest population was recorded in earthen pots followed by gunny bag during 120 days after storage for *S. zeamais.*

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