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Effect of Gombisa, Sack and Hermetic Bag Storage Structures on Insect Infestation to the Stored Maize Grain (*Zea mays* L.): The Case of West Shawa Zone, Bako, Ethiopia

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Abstract

Maize grain storage practices involve traditional storage structures, which was largely ineffective in the protecting of the stored products from deterioration. *Maize grain storage losses due to insect pests have been a serious problem the livelihood of small-scale farmers. The experiment was conducted between December 2017 and May 2018 at the Bako, Ethiopia to study the effectiveness of traditional (Gombisa, Sack) and Hermetic bag storage structures. The infestation of insectsto storedmaize grain was determined forT0, T1, T2, T3, T4, T5 and T6 months of storage periods. The experimental design was arranged in 3x4factorial fashions. The treatments were three storage types (Gombisa, sack and Hermetic bag), one variety of maize (Bako hybrid-661) and storage periods (T0, T1, T2, T3, T4, T5 and T6) months. The collected data were analyzed statistically using Generalized Linear Model (GLM) procedure of SAS and means that were significantly different were separated using Least Significant Difference (LSD). The number of insects, dead or alive, was not recorded in the first two storage and increased significantly (P<0.05) with storage periods. Maximum number 85/kg of alive Sitophilus zeamais was recorded at the end of six months. Maximum numbers17.7/kg of deadSitophiluszeamais was recorded at the last six months of storage. Sitophilus zeamais was the most dominant insect pest and records 84.3/kg in gombisa in the six months of storage. In this finding Sitophilus zeamais was the major storage insect pests followed by Sitophilus granurius. Therefore, gombisa and sack storages were inadequate for protecting stored maize from insect pests and fungal attacks. Overall, the hermetic bag storage can protect insect infestation and fungal development and consequently maintains seed viability and nutritional content during storage without use of insecticides.*

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Keywords

Insect mortality, Storage insect, Maize grain, Traditional storage, Damaged grain.

Introduction

Maize (*Zea mays* L.) is the third most important crop after rice and wheat cultivated in the world and occupying more than 120 million hectares of cropland annually (Marta and Ruswandi, 2017). It is a basic staple food grain for large parts of world including Africa, Latin America, and Asia (Yaouba *et al.,* 2012). In Ethiopia, maize is the second most widely cultivated crop and grown under diverse agro-ecologies and socioeconomic conditions typically under rain-fed (Tsedeke *et al.,* 2015). It stands first in total production and productivity, and second in area coverage next to tef [*Eragrostistef* (Zucc) Trotter] of all cereal crops cultivated in Ethiopia (Mosisa *et al.*, 2012; FAOSTAT, 2015). However, in many developing countries, including in Ethiopia, maize grain storage practices involves traditional storage structures, which are largely ineffective in the prevention of insect infestation to stored products (Abraham, 1995). Among all the biotic factors, post-harvest insect pests are considered as the most important and cause huge of losses in the grains (30%–40%) (Boxall, 2002).

Befikadu *et al.*, (2015) reported that from the harvest to the consumer market, maize grain postharvest losses in Africa are estimated to range 14 to 36% (Tadele *et al.*, 2011; Tadele, 2012). The loss of insect pests to stored grains and grain products may accounts for 5–10% in the temperate zone and 20–30% in the tropical zone (Nakakita, 1998). He also reported that losses due to insects in stored maize have been reported from 12 to 44% in the western highlands of Cameroon. In Ghana, about 15 % of maize grains harvested are lost annually due to attacks by maize weevils (*Sitophilus zeamais* (Baidoo *et al.*, 2010).Thus, this study was conducted to assess the major insect pests associated with stored maize grains the damage and loss caused by the insect pests efficacy of traditional and hermetic bag storage structures.

Materials and Methods

Description of the study area

This study was conducted at the Bako Agricultural Research Center located in the East Wollega Zone of the Oromia Regional State, western Ethiopia at an altitude of 1650 meters above sea level (m.a.s.l). Bako lies at 9° 6" north latitude and 37°9" east longitude in the sub-humid ecology of the country 260 km west of Addis Ababa and 8 km away to the South from the main road to Nekemte. Average annual rainfall at this location is 1237 mm.

The rainy season extends from May to October and maximum rain is received in the months of July and August. Agro-ecologically, it has a warm humid climate with mean minimum, maximum and average air temperatures of 15, 30 and 23°C respectively. The RH minimum, maximum and average of the area is (49, 74.7 and 61.85%), respectively (Source, Bako National maize Research Center Metrological data of 2016). The major annual and perennial crops of the area include maize, sorghum, teff, noug, hot pepper, haricot bean, sweet potato, mango, banana, and sugar cane in order of importance. The study was conducted for six (6) moths starting from harvesting time in December, 2017 to May, 2018 at Bako National Maize Research Center.

Experimental plan and design

The experiment was arranged in a factorial combination with two factors, storage types and storage period in complete randomized design with three (3) replications.

Storage types have three levels i.e. Gombisa, Sack and Hermetic bag while storage period have four levels i.e. (T0, T1, T2, T3, T4, T5 and T6) months of storage periods. Data were collected at every one month interval, including at the start of the study making up four levels for the factor storage period.

Experimental materials

The study materials were BH-661 maize of variety harvested in December, 2017 and three types of traditional (Gombisa and Sack) and Hermetic bag storage structures.

Sampling of the stored maize grain

A total of 90 samples of the BH-661 maize variety were collected from each of the three storage structures periodically starting from the beginning of the storage (T0, T1, T2, T3, T4, T5 and T6) months of storage periods. The samples were taken from the top, side, middle and bottom of the storage.

The initial stored maize grain samples taken were service as a control at the beginning of the storage. Each sample was taken by inserting the spear into the grain mass straight to the maximum depth from the top, side, middle and the bottom the storage.

Physical parameters

Temperature and relative humidity

The temperature and relative humidity of the internal and external environment of the storage was measured at an interval of every week by using portable digital thermo-hygrometer (Hanna, HI8564) and measurement was done in the afternoon 3.00 p.m. in the day (to reduce variations) and at the time three data was taken and its average was recorded.

Measurements were taken from the top, side, middle and bottom portion of the storage.

Moisture content

Grain moisture content was determined by using the (AACC, 2005) standard procedure of oven dry methods. The grain was dried at a temperature of 105°C for three hours and after removed from the oven wait to cool in a dissector and then weighed. Then, the moisture content was calculated as follows: -

$$MC\ (\%) = \frac{Wi - Wf}{Wf} \times 100$$

Where, Wi = weight initial
W_f = weight final

Identification of major insect pest

About 500g of sample was taken from each of the storage for identification of insects in the laboratory. The grain samples were sieved through 2 mm mesh sieve (to remove dead and alive insects from the sample taken and to left the grain on the sieve. The insects that passed through the sieve were collected and identified using of specimen collected preserved in the entomology section of Bako Agricultural Research Center. Also, both live and dead insect were isolated by using hand lens, counted and removed using procedure outlined by entomology department, Bako National Maize Research Center.

Percentage of damage grain

Insect damage was recorded by the count and weighing method. Each five hundred (500g) grains were taken from initial to last storage periods and from each of the storage types and the number of insect damaged and un-damaged grain were obtained using a hand lens by searching for the presence of hole on the seeds. The percentage of insect damaged grains was calculated according to the methods used by (Wambugu *et al.*, 2009) as follows:

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

Statistical analysis

All the data collected were subjected to analysis of variance (ANOVA) by using the PROC GLM procedure (SAS institute, 2004 version 9.0) and difference among means were compared by the Least Significant Difference at 5% level of significance (Steel and Torrie, 1980).

Results and Discussions

Relative humidity of the stored maize grain

Mean relative humidity of stored maize grains over the storage periods was presented in (Table 1). The initial loading data of relative humidity for all storages just before closed was 23.60% which was the same as that of the ambient relative humidity. In the subsequent months the relative humidity kept on increasing in the storage as well as on the ambient environment and reached 41.80, 37.15, 36.45 and 35.00%, respectively. Similarly, Befikadu *et al.*, (2012) reported average relative humidity was ranged from 30.83to 54.67% and 29.33 to 65.17% be recorded inside Gombisa and Sack.

Temperature of the grain

Table 2 presents monthly average temperature data of the three storage types and that of the ambient atmosphere. The initial temperature during loading the storages was 22.25°C. The temperature readings continued to increase continuously and reached 35.65, 34.15, 33.05 and 31.05°C for Gombisa, Sack, Hermetic bag and the ambient, in the six months. Befikadu *et al.*, (2014) reported the average temperature had ranged from 21.30 to 35°C for *Gombisa* and 16.55 to 28.95 °C for Sack while Marek *et al.*, (2018) reported average values of temperature inside of the floored warehouse is 21.9°C within the timeframe, with the maximum value of 32.6°C and minimal value of 12.6°C.

Effect of storage type with storage period on grain moisture content

The values of grain moisture content was not significantly ($p<0.05$) changed after one month storage periods of Table 3. As time passed by the moisture contents in all three storage types decreased. For, instance the moisture content of samples in Gombisa dropped to 7.40% after two months, and that of Sack reduced to 8.40% and of the Hermetic bag to 7.80%. The reduction in moisture content of grains could be loss of moisture to the air in the storage through transpiration (Evaporation).

The moisture content of the stored grains after the fourth months showed continued increment reach 13.9, 11.7 and 10.70% at the end of six months storage periods for samples in Gombisa, Sack and Hermetic bag, respectively.

Effect of storage type with storage period on insect grain damage

The percentage of damaged grains was given in Table 4. Initially the percentage of damaged grains was zero and increased significantly to 12.3% in Gombisa, 9.3% in Sack and 5.7% in hermetic bag, respectively in the six months. Befikadu *et al.*, (2012) reported that 11.50 and 10.75% percentage of kernel damage for Gombisa and Sack, respectively after 60 days of storage. The weight loss also showed similar trends of increasing with the storage time.

Effect of storage period on insect population growth in stored maize grains

The numbers of insects, dead or alive, started to increase after one month of storage Table 5. The number of alive *Sitophilus zeamais* insects increased from 0.0 to 85.3 per kilogram of grains and the dead *Sitophilus zeamais* from 0.0 to 17.7 per kilogram of grains by the end of sixth months of storage. All the numbers of alive and dead insects were significantly different (P<0.05) from each other. Similarly, the number of alive *Sitophilus granurius* increased from 0.0 to 65.8 per kilogram of grains and the dead *Sitophilus granurius* from 0.0 to 14.7 per kilogram of grains by the end of sixth months of storage. The number of alive *Sitotrogacereallela* alive increased from 0.0 to 48.0 per kilogram of grains and the dead *Sitotrogacereallela* alive from 0.0 to 9.9 per kilogram of grains by the end of sixth months of storage. The same trends prevailed in all storage insects during the six months.

Effect of storage type on insect population growth in stored maize grains

The infestation of all insect pests were significantly different (p<0.05) with storage periods Table 6. The highest numbers 43.6 of alive *Sitophilus zeamais* was recorded in Gombisa. Maximum numbers *Sitophilus granurius* dead 18.5/kg of grains was obtained from hermetic bag. The numbers of alive and dead insects were increased significantly (p<0.05) as storage periods increased to six months. However, Waktole and Amsalu (2012) higher mean number of maize weevils, *S. zeamais* was 69.98, *While* grain moth, *S. cerealella and* Rice weevil, S. *oryzae* occurred with a mean number of11.26 and 9.09, respectively.

Interaction effect of storage type with storage periods on insect population growth and mortality

Insect pest data in each storage types for each storage period are given in Table 7. Highest numbers 84.3 of alive *Sitophilus zeamais* was recorded in gombisa at the end of six months of storage periods. However, the mortality of this insect also increased 9.3 in the six months. Maximum numbers 51.33 of alive *Sitotroga of cereallela* alive was recorded in gombisa at the end of six months of storage periods. The highest numbers 9.0 of mortality of this insect was recorded in Hermetic bag in the six months. The numbers of all alive and dead insects was significantly (p<0.05) increased among storage types in the end of six months. Likewise, Abass *et al.*, (2014) reported *T. castaneum* was occurred with the higher mean death number in gombisa and hermetic 4.4 and 3.5 $kg^{-1}$of seed grain as compared to sack storage that number of insect mean death was recorded with 2.4.

Table.1 Meanrelative humidity of stored maize grains over the storage periods, 2017/18

Storage period (Months)	Mean of RH(%)			Mean of ambient RH(%)
	Gombisa	Sack	Hermetic	
ILD	23.60g	23.60g	23.60g	23.60f
1	27.75f	27.05f	26.35f	25.0e
2	30. 50e	30.35e	28.50e	27.0d
3	32.50d	33.50d	30.70d	29.5c
4	34. 35c	34.50c	32.90c	32.0b
5	36.55b	35.10b	34.10b	32.5b
6	41.80a	37.15a	36.45a	35.0a
LSD (5%)	1.3	1.0	0.85	0.65
CV (%)	3.5	4.8	2.7	4.8

Note: Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, ILD: initial loading date, RH: relative humidity.

Table.1 Mean of grain temperature of stored maize grains over the storage periods, 2017/18

Storage period (months)	Mean of temperature (°C)			Mean of ambient temperature (°C)
	Gombisa	Sack	Hermetic bag	
ILD	22.25^{f}	22.25^{f}	22.25^{b}	22.25e
1	23.15^{f}	23.10^{f}	22.40^{b}	25.0d
2	24.95^{e}	25.00^{e}	24.15^{b}	27.0c
3	27.30^{d}	26.85^{d}	26.20^{b}	28.0b
4	28.95^{c}	28.00^{c}	27.85^{b}	29.5b
5	32.80^{b}	30.85^{b}	29.55^{b}	31.0a
6	35.65^{a}	34.15^{a}	33.05^{a}	31.05a
LSD (5%)	0.9	1.0	0.6	0.8
CV (%)	3.5	4.8	2.7	4.8

Note: Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, ILD: initial loading date.

Table.2 Effect of storage type with storage period on moisture content, 2017/18

Storage Period (Months)	Mean of grain moisture content (%db)		
	Gombisa	Sack	Hermetic
ILD	10.00 ± 0.7^{c}	10.00 ± 0.52^{c}	10.0 ± 0.32^{c}
1	9.93 ± 0.71^{c}	10.00 ± 0.52^{c}	9.30 ± 0.13^{c}
2	7.40 ± 0.14^{d}	8.40 ± 0.21^{d}	7.80 ± 0.12^{d}
3	8.36 ± 0.23^{d}	8.00 ± 0.21^{d}	7.50 ± 0.11^{d}
4	10.50 ± 0.29^{c}	10.20 ± 0.26^{c}	9.86 ± 0.18^{c}
5	11.23 ± 0.29^{b}	10.46 ± 0.26^{c}	10.03 ± 0.22^{c}
6	13.9 ± 0.29^{a}	11.70 ± 0.20^{b}	10.70 ± 0.24^{c}
LSD (5%)	0.53	0.48	0.72
CV (%)	3.4	2.30	2.81

Note: Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, ILD: initial loading date.

Table.4 Effect of storage types with storage period on grain damage over the storage periods, 2017/18

Storage Period (Months)	Damaged Grain (%)		
	Gombisa	Sack	Hermetic
ILD	-	-	-
1	-	-	-
2	-	-	-
3	1.10 ± 0.00^{g}	1.00 ± 0.00^{g}	0.6 ± 0.00^{h}
4	2.9 ± 0.58^{f}	2.7 ± 0.62^{f}	2.6 ± 0.00^{f}
5	5.3 ± 0.58^{c}	4.1 ± 0.47^{d}	3.7 ± 0.44^{e}
6	12.3 ± 0.58^{a}	9.3 ± 0.47^{b}	5.7 ± 0.44^{c}
LSD (5%)	0.67	0.53	0.39
CV (%)	4.50	3.67	8.60

Note: Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, ILD: initial loading date

Table.5 Effect of storage period on alive and dead insect in stored maize grains, 2017/18

Storage Periods	Number of *Sitophilus zeamais dead/kg*$^{-1}$	Number of *Sitophilus zeamais* alive/*kg*$^{-1}$	Number of *Sitophilus granaries dead/kg-1*	Number of *Sitophilus granarius* alive/*kg*$^{-1}$	Number of *Sitotroga cereallela dead/kg*$^{-1}$	Number of *Sitotroga cereallela* alive/*kg*$^{-1}$	Number of *Tribolium castaneum dead/ kg*$^{-1}$	Number of *Tribolium castaneum* alive/*kg*$^{-1}$
ILD	0.0 ±0.00^{f}	0.00 ±0.00^{f}	0.00 ±0.00^{f}	0.00±0.00^{f}	0.00±0.00^{d}	0.00 ±0.00^{f}	0.00 ±0.00^{d}	0.00 ±0.00^{e}
1	0.71 ±0.00^{f}	0.00 ±0.00^{f}	0.00 ±0.00^{f}	0.71 ±0.00^{f}	0.71±0.00^{d}	0.71±0.00^{f}	0.10 ±0.00^{d}	0.71 ±0.00^{f}
2	2.0 ±0.15^{e}	11.6 ±1.49^{e}	0.4 ±0.00^{e}	8.0 ±2.94^{e}	0.84 ±0.00^{d}	4.0 ±0.77^{e}	0.70 ±0.00^{d}	6.4 ±1.16^{e}
3	5.2 ±0.85^{d}	23.7 ±1.86^{d}	2.1 ±0.17^{d}	17.4 ±1.90^{d}	1.5 ±0.00^{d}	10.2 ±1.42^{d}	1.2 ±0.15^{d}	17.0 ±1.21^{d}
4	9.2 ±1.15^{c}	33.1 ±1.90^{c}	5.2 ±0.22^{c}	25.7 ±2.86^{c}	3.4 ±0.51^{c}	17.4 ±1.54^{c}	3.3 ±0.36^{c}	29.4 ±1.24^{c}
5	12.4 ±2.08^{b}	49.0 ±2.30^{b}	6.7 ±0.49^{b}	41.1 ±2.32^{b}	6.7 ±0.64^{b}	29.7±2.77^{b}	5.7 ±0.66^{b}	43.4 ±2.87^{b}
6	17.7 ±2.18^{a}	85.3 ±3.29^{a}	14.7±1.30^{a}	65.8±2.53^{a}	9.9 ±1.21^{a}	48.0 ±3.11^{a}	10.1±1.73^{a}	58.3 ±3.09^{a}
LSD(5%)	2.7	3.4	1.4	1.6	1.4	2.5	2.2	1.2

Table.6 Effect of storage types on alive and dead insect in stored maize grains, 2017/18

Storage type	Number of *Sitophilus zeamais* dead/kg^{-1}	Number of *Sitophilus zeamais* alive/*kg*$^{-1}$	Number of *Sitophilus granaries* dead/kg^{-1}	Number of *Sitophilus granaries* alive/*kg*$^{-1}$	Number of *Sitotroga cereallela* dead/kg^{-1}	Number of *Sitotroga cereallela* alive/*kg*$^{-1}$	Number of *Tribolium castaneum* dead/kg^{-1}	Number of *Tribolium castaneum* alive/*kg*$^{-1}$
Gombisa	8.6 ±1.36 ^{a}	43.6 ±1.08^{a}	3.0 ±1.15 ^{c}	33.8 ±1.21^{a}	2.4 ±0.79 ^{c}	23.7 ±1.32^{b}	2.4±0.59 ^{a}	33.6±1.79^{a}
Sack	7.6 ±1.13 ^{a}	39.1 ±1.72^{b}	4.5 ±1.15 ^{b}	25.4±1.16^{b}	6.1 ±2.32 ^{b}	16.2±0.56^{c}	3.5±0.61 ^{a}	29.5 ±1.54^{b}
Hermetic	7.2 ±1.08 ^{a}	18.6±1.44^{c}	6.3 ±1.72 ^{a}	18.5 ±1.54^{c}	8.8 ±1.21 ^{a}	29.8 ±1.41^{a}	4.4 ±0.61 ^{a}	14.2 ±1.21^{c}
LSD (5%)	2.7	2.4	1.4	2.6	1.6	2.5	2.2	2.3
CV (%)	1.2	4.7	3.3	7.7	4.1	4.7	2.1	3

Note: Mean values ± standard deviation of three replicates within each column sharing similar letters is not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, ILD: initial loading date.

Table.7 Interaction effect of storage type with storage period on insect population growths in stored maize grains, 2017/18

Storage period (months)	Number of *Sitophilus zeamais alive*			Number Sitotroga of cereallela alive			Number of *Tribolium castaneum* alive		
	Gombisa	Sack	Hermetic	Gombisa	Sack	Hermetic	Gombisa	Sack	Hermetic
2	16.6±1.52^{ij}	15.3±1.79^{ij}	14.0±0.58^{ij}	11.33±1.2^{g}	8.33±1.34^{h}	7.67±1.17^{h}	6.0 ±0.51^{h}	4.6±0.30^{h}	3.67 ±0.21^{h}
3	21.0±1.52^{h}	18.7±2.29^{i}	14.0±0.58^{ij}	11.33±1.2^{g}	8.33 ±1.34^{h}	17.67±1.23^{f}	24.0 ±1.08^{f}	22.0 ±1.21^{f}	13.3 ±1.06^{g}
4	32.0±1.73^{f}	26.3±2.61^{g}	22.3±0.58^{h}	19.00±2.2^{e}	16.33±1.67^{f}	19.67±1.35^{e}	38.3 ±2.66^{e}	38.3±2.26^{e}	21.3±1. 15^{f}
5	61.0±3.3^{b}	40.3±3.61^{e}	32.3±2.32^{f}	44.00±3.3^{c}	26.60±2.22^{d}	27.00±2.33^{d}	57.67±2.75^{c}	48.7 ±2.36^{d}	36.6 ±1.23^{e}
6	84.3±3.77^{a}	47.7±3.83^{c}	44.0 ±3.79^{d}	51.33±3.7^{a}	49.00±3.55^{b}	44.00±3.55^{c}	60.0 ±3.51^{a}	56±2.40^{b}	47 ±1.31^{d}
LSD(5%)	2.7			1.4				2.4	
CV (%)	1.2			3.3				4.7	
	Number of *Sitophilus zeamais* dead			Number of *Sitotroga cereallela* dead			Number of *Tribolium castaneum* dead		
	Gombisa	Sack	Hermetic	Gombisa	Sack	Hermetic	Gombisa	Sack	Hermetic
2	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-
4	9.3±1.73^{a}	7.7±1.73^{a}	5.0±1.08^{a}	1.00±0.00^{d}	1.33±0.15^{d}	2.67±0.58^{c}	2.67 ±0.58^{b}	1.67 ±1.53^{b}	1.00 ±0.00^{b}
5	8.0 ±1.24^{a}	7.0±1.08^{a}	3.0±0.52^{a}	1.67±0.15^{d}	1.33±0.15^{d}	2.67±0.58^{c}	2.67 ±0.58^{b}	2.67 ±0.58^{b}	1.00 ±0.00^{b}
6	5.3±0.22^{b}	4.0±0.18^{b}	2.7±0.58^{a}	2.67 ±0.58^{c}	5.67±1.62^{b}	9.00 ±1.31^{a}	2.33 ±0.53^{b}	2.67 ±0.58^{b}	4.00 ±1.00^{a}
LSD(5%)	2.6			0.6			1.5		
CV (%)	7.7			4.1			4.7		
	Number of *Sitophilus granaries* alive			Number of *Sitophilus granaries* dead					
	Gombisa	Sack	Hermetic	Gombisa	Sack	Hermetic			
2	11.3±1.65^{h}	8.3±0.65^{i}	4.7±0.15^{j}	-	-	-			
3	17.6±1.75^{g}	11.3±165^{h}	8.3±0.85^{i}	-	-	-			
4	19.7±1.95^{f}	19.0±1.74^{f}	16.3±1.15^{g}	0.3±0.00^{c}	0.7 ±0.00^{c}	0.3 ±0.00c			
5	55.0±2.61^{b}	27.0±1.86^{e}	26.6±2.06^{e}	3.3 ±1.15^{b}	2.7 ±0.58^{b}	2.3±0.15^{b}			
6	70.3±3.61^{a}	49.0±2.55^{c}	44.0±2.28^{d}	4.0±1.15^{b}	5.3±1.65^{a}	5.3±1.25^{a}			
LSD(5%)	2.2			1.3					
CV (%)	2.1			3.0					

Note: Mean values ± standard deviation of three replicates within each column sharing similar letters is not significantly different by LSD test at P≤0.05, LSD: least significant different, CV: coefficient of variation, ILD: initial loading date.

Conclusions

Four insect pests were identified from the stored maize grains in the area. These were *Sitophilus zeamais, Sitophilus granaries, Sitotrogacerellela and Tribolium castanum*. The lowest grain temperature value and moisture content value were recorded in Hermetic bag, whereas the highest in Gombisa and Sack, respectively. *Sitophilus zeamais* alive occurred with the highest number in gombisa and followed by *Sitophilus granurius*. The percentage of damaged grains was zero at initial and increased significantly to 12.3% in Gombisa, 9.3% in Sack and 5.7% in hermetic bag, respectively in the six months. The infestation of all insect pests were significantly different ($p<0.05$) with storage periods. The highest numbers 84.3 of alive *Sitophilus zeamais* was recorded in gombisa at the end of six months of stor age periods than the two storage types. From the three storage types evaluated hermetic bag storage can be more efficient than Gombisa and Sack in protecting the maize from insect infestation, fungal attack and storage losses while maintaining the germination power and nutritional quality of stored maize grains. Hereafter, the acceptance of this technology must be encouraged to reduce the number of insect growth and increase mortality rate of the insects.

Conflict of Interest

Conflict of Interest nobody affirmed.

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