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Influence of Agro-ecologies, Traditional Storage Containers and Major Insect Pests on Stored Maize (*Zea mays* L.) in Selected Woredas of Jimma Zone

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Abstract: Maize is a versatile cosmopolitan crop cultivated in diverse climate and used as sources of energy for humans and animals, raw materials for diverse industries, construction materials and fuel in rural areas. Worldwide demand for maize crop, its production and land coverage are increasing despite many biological, physical and environmental constraints. Impact of two agro-ecologies, two traditional storage structures, storage periods and major insect pests on maize variety BH-660 were studied in two selected Zones of Jimma, South Western Ethiopia in 2010. Three factors, the first two each at two levels and the other at four levels were arranged in Completely Randomized Design replicated twice. Number of insects, insect damaged kernels and percentage germination showed significant differences ($p<0.05$) in Gombisa and Sacks over the storage periods under both agro-ecologies. Under intermediate agro-ecology number of insects in 1 kg of grain increased from 1.83 to 101 and 79.10; insect damage increased from 2.42 to 20.75% and 2.33 to 20.08%; germination percentage decreased from 98.00 and 97.5% to 68.5 and 80.5% for grains stored in Gombisa and Sacks respectively over six months of storage periods. Similar trend was observed under lowland agro-ecology. Maize weevil (*Sitophilus zeamais* M.) and Angoumois grain moth (*Sitotroga cerealella* (O.)) were the two major insect pests identified from maize samples. Storage of maize grain for more than one moth demands eco-friendly maize weevil and grain moth management in both agro-ecologies and storage containers.

Key words: Maize, storage container, Gombisa, Sack, insect pests, intermediate and lowland agro-ecologies

INTRODUCTION

Maize is a dominant food crop in Ethiopia and majority of the population depends on it as sources of energy (Demissie *et al*., 2008). It ranks first in total production and yield per hectare (CSA, 2007). In Ethiopia, maize is identified as strategic commodity crop that contributes towards the country's food self sufficiency strategy (Demissie *et al*., 2008). Never the less, maize grains suffer from quantitative and qualitative losses during storage. The losses occur due to several reasons. Yet, the main causes of losses are improper storage structures (Niaz and Dawar, 2009) and insect pest damage (Tadesse, 1997; Emana and Tsedeke, 1999). According to Shurtleff (1980), over all pests of maize do cause an estimated annual loss of about 9.4% on maize grain worldwide.

Both in the field and storage, insects are the principal cause of maize grain losses (Adams and Schulten, 1978; Tadesse, 1991, 1996, 1997; Khosravi *et al*., 2007). Survey conducted in three major grain producing areas of Ethiopia indicated that majority of farmers (93.3%) uses traditional storage containers that expose their stored grains to attack by storage insect pests and/or other loss factors. The average actual loss per household was about 12% of the average total grain produce (Gabriel and Hundie, 2006). Deterioration of stored grains results from the interactions of several factors such as physical, chemical and biological variables existing in the overall chains from production to consumption and understanding of these factors and their overall interaction and relationships are very crucial in designing effective, economically feasible and environmentally benign management practices of storage pests (Adejumo and Raji, 2007). Grain storage containers being used by majority of farmers in Jimma zone (more than 97%) are traditional ones that couldn't protect the stored grain from deterioration (Kemeru, 2004). There is no information on the exact cause of deterioration of grains stored in these traditional storages in the zone that could

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serve as basis to take corrective measures. Availability of such information will help to take corrective measures in improving post harvest grain management and hence support the efforts being made to become a food secured country for Ethiopia. The patterns of storage temperature, relative humidity and maize grain's associated major insect pests in the traditional storage containers over storage periods in the area are not clearly known and documented. Thus, the objectives of this study were to determine the influence of agro-ecologies, storage containers and associated key insect pests on stored maize over six months of storage period.

MATERIALS AND METHODS

Study area: The study was carried out in Jimma zone, Ethiopia for six months from December 2009 to June 2010 on a newly harvested maize variety BH-660. Jimma Zone is found at about 345 km from Addis Ababa in South west and lies between 36°10'E longitude and 7°40'N latitude. The zone has an elevation ranging from 880-3360 m.a.s.l. The area experiences annual average rainfall of 1000 mm for eight to 10 months. The main rainy season extends from May to September and the small rainy season takes place in February, March and April. The temperature of Jimma zone varies from 8-28°C. The annual average temperature is 20°C (Haile and Tolemariam, 2008).

The agro-ecologies of the study area have an altitude range of 1000-1500 (lowlands), 1500-2500 (intermediate) and 2500-3360 m.a.s.l. (highlands) (FAO, 2009). Only two agro-ecologies (intermediate and lowlands) growing BH-660 maize variety were selected for the study since BH-660 maize variety is not produced in the highland agro-ecology of the study area currently. Districts Omo Nada and Kersa were selected from intermediate agro-ecology and Tiro Afeta and Sekoru were selected from the lowland agro-ecology. The selection of these districts from both agro-ecologies was done randomly based on wide production of BH-660 maize variety.

Experimental materials and study periods: The experimental materials used for the study were BH-660 variety of maize grain harvested in December 2009 and two types of traditional maize storage containers (Gombisa and Sacks) under two agro-ecologies for six months (December 2009 to June 2010). Gombisa is an above ground traditional storage bin used to store maize cob in the study area. It is cylindrical in shape and its wall is un-plastered, open woven from tree stems usually Eucalyptus to allow free movement of air through openings, providing cooling and ventilating effect to the stored grain. The container has conical grass-thatched roofing. It rests on a low level (10-60 cm) wooden platform mounted on four, six or eight stone piles or on a short yoked wooden post (10-60 cm) firmly fixed in to the ground (penetrating the ground). The floor is made of mats of woven bamboo splits and stalks of sorghum under which a wooden beam of Eucalyptus lied. The top of the container is normally covered usually by an overhanging thatched roof (about 70 cm). The height of Gombisa ranges from 124-155 cm while its diameter ranges from 148-304 cm. Its capacity varies from 10-25 Quintals (1 Quintal = 100 kg) of maize cobs.

Maize cob inlet and outlet mechanism is done by removing the thatched roofing. The container is cleaned before the new harvest is taken in to the container using a broom or any plant leaves found in the vicinity of the container. It is generally neither air tight, nor moisture or insect proof. The cracks and crevices found over the wall would provide a breeding ground for insect pests and inflict infestation of the stored maize.

A polypropylene Sack is another type of storage container used in the study area. It is made from a woven synthetic fiber similar to plastic. It is a low cost indoor storage container that can handle up to 100 kg of shelled maize. Sacks are stacked horizontally one on top of the other close to the wall inside the living room spreading lumber or plastic sheets under it.

Experimental design: Factorial arrangement using Completely Randomized Design (CRD) was employed for the experiment in two replications. There were three factors (traditional maize storage containers at two levels (Gombisa and Sack), agro-ecologies at two levels (lowland and intermediate) and storage periods at four levels (initial, 60, 120 and 180 days after harvest)) making up 16 treatment combinations. The study was conducted for six months in 2009/2010 harvesting season by taking samples at two months interval. Baseline data was collected at the start of the study period for comparison (initial loading day).

Sampling of the grain for evaluation: Initial sample of six cobs were randomly taken before the bulk was loaded in to Gombisa, shelled manually to make 1 kg and was kept in an air-tight plastic bag. The initial maize samples were taken as a control for comparison at the beginning of the storage period immediately after harvest. Subsequent sampling from Gombisa (unshelled maize on cobs are stored in this traditional storage container) and Sacks (shelled maize grains is stored in this traditional storage container) was carried out at an interval of two months for the storage period of six months. Three cobs were drawn from each cage via the tube using strings, shelled manually and thoroughly mixed. For sampling shelled grain from the Sacks, procedure described in AOAC (1995) was followed.

Physical variables

Grain moisture content: The grain moisture content was measured using calibrated moisture tester (Dickey-john Corp. Auburn, IL 62615 USA) immediately before storage and during the subsequent grain sampling periods from each storage container under both agro-ecologies.

Storage temperature and relative humidity: The storage temperature and relative humidity were measured at an interval of 15 days (Arain *et al*., 2006) during the storage periods using portable digital Thermo-Hygrometer (Hanna, HI8564, Italy). Measurements were taken from the center, sides and top portion of the storage structures as per the method described by Lemessa *et al*. (2000).

Seed germination test: Seed germination test was conducted using standard procedures of ISTA (1996). Four hundred maize kernels per sample were used. The seeds were kept in petri-dishes lined with filter paper moistened with about 4 mL distilled water in four replicates (100 seeds per petri-dish) and incubated at room temperature (av. 25°C) for 5 to 7 days. The germinated seeds were counted visually up on appearance of radicle and/or plumule and percentage germination was calculated as follows:

$$\text{Germination (\%)} = \frac{\text{No. of germinated seed}}{\text{No. of seed planted}} \times 100$$

Major insect pests identification: Each sample collected from both agro-ecologies stored in both storage structures for the study period was sieved over 2 mm mesh sieve as described by Tadesse (1996). Both live and dead insects were removed, counted and identified using insect identification procedure outlined in study of insect by Borror *et al.* (2005). The samples were re-bagged and held at room temperature (av. 25°C) to determine internal infestation or parasitism. After about a month, any emerged insects were counted and recorded as previous (Tadesse, 1996). The numbers of insects (live and dead) per a kg of a sample was recorded for each insect identified (EI-Kashlan *et al*., 1995).

Insect damage assessment and grain weight loss: Insect damage was assessed by count method (Lemessa *et al.* 2000; Wambugu *et al*., 2009). Two hundred seeds were randomly taken from a kilogram of each sealed maize sample and the number of insect damaged and un-damaged seeds was observed with hand lens for the presence of hole or burrow. The percentage of insect damaged seed was then calculated as follows:

$$\text{Insect damaged grains} = \frac{\text{No. of insect damaged grain}}{\text{Total No. of grains}} \times 100$$

The grain weight losses was determined using the thousand grain mass (TGM). From a kilogram of sampled grain at each sampling day, 1000 grain kernels were randomly taken and weighed using digital balance and recorded as Thousand Grain Mass (Proctor and Rowley, 1983; Mashilla, 2004). Then the percentage weight loss was computed using the formula indicated below:

$$\text{Weight loss(\%)} = \frac{M_1 - Mx}{M_1} \times 100$$

where, M_1 is Thousand Grain Mass (TGM) at the beginning of the study and M_x is the TGM of grain on occasion "x".

Data analysis: Statistical analysis was performed on insect abundance, germination percentage and insect damage over the storage periods for the two agro-ecologies using SPSS (Statistical Package for the Social Sciences) Version 16.0. Means were compared for the significant factors using Least Significant Difference (LSD) test and significance was accepted at 5%. Descriptive statistics was also used for organizing and presenting some of the data.

RESULTS AND DISCUSSION

Physical characteristics

Moisture content: At the beginning of the storage period, under the intermediate agro-ecology, the average moisture content of maize grain was 13.23 and 13.50% for the cobs in Gombisa and shelled maize grains in Sacks, respectively. On the other hand, in the lowland agro-ecology, the average moisture content of the grain on the cob (Gombisa) and shelled grain (Sacks) was 14.58 and 13.58%, respectively at initial loading day (Table 1). The average moisture content of maize just after harvest before storage was 13.37±0.41 and 14.08±0.33 in intermediate and lowland agro-ecologies, respectively. Differences in the initial grain moisture content of grains could be due to initial exposure of sampled grains to different ambient temperature and relative humidity. Grains stored in both storage containers lost moisture as storage time increased to 60 days reaching 10.07% and 10.57% in Gombisa and Sack, respectively under intermediate agro-ecology. In the following storage days, grain with the cob stored in Gombisa continued to lose moisture attaining the lowest value of about 9.17% after

Table 1: Moisture content of maize grain sampled from Gombisa and Sacks under intermediate and lowland agro-ecologies over six months storage periods

	Moisture content (%)					
	Intermediate agro-ecology			Lowland agro-ecology		
Storage period (days)	Gombisa	Sack	Mean±SE	Gombisa	Sack	Mean±SE
Initial loading day	13.23	13.50	13.37±0.41	14.58	13.58	14.08±0.33
60	10.07	10.57	10.32±0.11	10.47	9.93	10.20±0.22
120	10.10	11.08	10.59±0.35	10.18	10.80	10.49±0.19
180	9.17	11.70	11.18±0.27	9.20	12.30	11.38±0.32

Values are mean of six observations

Table 2: Storage temperature and relative humidity (RH) profiles of Gombisa under intermediate agro-ecology with storage periods

Storage period (days)	Temp. (°C)	RH (%)
ID	24.55±1.72	36.17±2.63
15	25.27±2.14	34.00±1.59
30	27.97±1.27	36.67±2.92
45	26.13±2.94	30.83±1.35
60	24.20±1.11	38.50±2.64
75	29.98±1.09	34.33±1.23
90	29.25±0.65	42.00±1.61
105	30.00±1.74	41.83±2.77
120	30.18±0.34	47.67±2.50
135	27.00±1.64	51.00±2.05
150	20.00±1.42	49.00±2.16
165	20.57±2.86	52.00±2.71
180	18.50±0.79	54.67±5.12
Overall mean	25.66±3.83	42.21±7.57

Values are Mean±SE of twelve observations, ID: Initial loading day

Table 3: Storage temperature and relative humidity (RH) profiles of Sacks under intermediate agro-ecology with storage periods

Storage period (days)	Temp. (°C)	RH (%)
ID	19.87±0.39	29.33±0.62
15	19.93±1.89	30.83±1.08
30	20.48±0.43	30.00±0.45
45	24.03±1.81	33.33±1.33
60	25.75±0.35	32.00±0.45
75	23.00±1.30	30.50±1.34
90	26.97±0.12	40.00±0.89
105	24.05±1.82	40.00±1.75
120	28.82±0.53	48.83±1.49
135	21.03±1.08	65.17±2.68
150	19.08±1.29	53.00±1.59
165	15.00±1.30	60.00±1.73
180	17.00±0.82	41.00±0.82
Overall mean	21.92±3.81	41.08±11.65

Values are Mean±SE of twelve observations, ID: Initial loading day

180 days. The situation with shelled grains stored in the Sacks was different in that the moisture content exhibited increment to 11.08% at 120 days and 11.70% at 180 days of storage time. This is probably due to poor level of natural aeration in the grain stored in Sacks as compared to Gombisa along with cumulative effect of respiration from grain itself, insects and fungi. Maize grain stored in polypropylene Sacks exhibited an increment in moisture content from 11.21% at initial storage period to 11.53% after 90 days of storage (Chulze, 2010; Hell *et al*., 2010). The changes in grain moisture content can be attributed to variations in ambient temperature and relative humidity during storage. Polypropylene sack is moderately permeable to moisture, gases and odors (Fellows and Hampton, 1992). The decrease in the moisture content from grains in both Gombisa and Sacks could be due to release of moisture in to the surrounding dry air. The decrease in the moisture content in Gombisa was higher than that in Sacks. This might be due to more ventilating capacity of perforated wall of Gombisa than that of the Sack. Similar trend was observed in terms of moisture content in both storage structures under lowland agro-ecology. Moisture content of stored maize grain depends on the surrounding environment because maize grain absorbs and releases moisture from and to the surrounding environment depending on the moisture content of the environment. Where the air temperature and relative humidity are variable, the grain moisture content will also vary (Ogendo *et al*., 2004). Mirna *et al*. (2007) and Agboka (2009) observed similar moisture content variation (decrease and abrupt increment) in polypropylene Sack stored grain at a temperature of 20°C and varying relative humidity. It has been reported that high moisture content of the grain significantly affects grain quality in storage causing rapid decline in quality characteristics of maize grain (Ken, 2005; Mathew, 2010) apart from toxin production making the grain unfit for human consumption (Adesida, 1988). Moisture content of grains is inversely correlated with storage time (Harold and Morey, 1991). Management of moisture content of maize grain is important to maintain grain quality from deterioration (David and David, 1998). The maximum safe moisture content of shelled maize grain was reported to be 13.5% at a temperature below 27°C (Hayma, 2003).

Storage temperature and relative humidity: The average temperature had ranged from 18.50 to 30.18°C with an overall average of 25.66±3.83°C in Gombisa stored maize cobs in intermediate agro-ecology (Table 2). Under the same ecology, the average temperature recorded from shelled maize stored in Sacks ranged from 15.00 to 28.82°C with an overall average of 21.92±3.81°C (Table 3). Similarly, under lowland agro-ecology, the average temperature had ranged from 21.30 to 35.00°C with an overall average of 28.12±3.91°C in Gombisa stored maize cobs (Table 4) whereas the average temperature recorded

Table 4: Storage temperature and relative humidity (RH) profiles of Gombisa under lowland agro-ecology with storage periods

Storage period (days)	Temp. (°C)	RH (%)
ID	27.50±0.74	40.00±1.21
15	25.10±2.63	43.00±4.68
30	27.13±1.92	41.17±0.95
45	33.05±2.95	39.17±2.85
60	28.08±0.53	42.33±1.20
75	30.20±1.99	39.33±1.41
90	30.70±0.28	43.00±0.68
105	35.00±1.82	43.00±1.92
120	29.32±0.30	45.00±1.29
135	31.40±1.89	41.00±2.21
150	24.62±1.22	47.00±1.46
165	22.20±0.97	49.83±2.15
180	21.30±1.24	51.00±1.65
Over all mean	28.12±3.91	43.45±3.65

Values are Mean±SE of twelve observations, ID: Initial loading day

Table 5: Storage temperature and relative humidity (RH) profiles of Sacks under lowland agro-ecology with storage periods

Storage period (days)	Tem. (°C)	RH (%)
ID	21.58±0.69	32.33±0.96
15	20.22±1.97	35.00±0.86
30	21.80±0.39	32.67±1.05
45	26.20±2.26	29.83±1.92
60	22.53±0.45	35.00±1.03
75	27.40±2.32	32.00±1.37
90	27.75±0.23	45.33±0.84
105	26.60±2.24	45.00±1.32
120	28.95±0.20	56.83±1.35
135	23.65±1.10	62.17±4.17
150	22.03±1.36	58.17±1.33
165	16.55±1.19	62.33±1.71
180	20.00±1.43	53.00±1.92
Over all mean	23.48±3.52	44.59±12.03

Values are Mean±SE of twelve observations, ID: Initial loading day

Table 6: Number of insect pests (live and dead) sampled from Gombisa and sack under intermediate and lowland agro-ecologies

	No. of insects (kg^{-1} grain)			
	Intermediate agro-ecology		Lowland agro-ecology	
Storage period (days)	Gombisa	Sack	Gombisa	Sack
Initial loading day	1.83±0.17^{d}	1.83±0.17^{d}	1.83±0.17^{d}	1.83±0.17^{d}
60	50.50±0.99^{c}	35.50±2.29^{c}	53.17±1.25^{c}	45.17±3.36^{c}
120	86.51±2.39^{b}	64.00±3.37^{b}	90.50±2.25^{b}	69.83±4.97^{b}
180	101.00±2.45^{a}	79.10±3.68^{a}	101.84±2.51^{a}	82.34±3.67^{a}
LSD (0.05)	14.50	15.00	11.33	12.50
r (p<0.01)	0.97	0.98	0.96	0.96

Values are Mean±SE of twelve observations, Values with different letters in a column are significantly different at p<0.05 according to LSD test

from shelled maize stored in Sacks ranged from 16.55 to 28.95°C with an overall average of 23.48°C±3.52°C (Table 5). Average relative humidity ranges of 30.83 to 54.67% and 29.33 to 65.17% were recorded for Gombisa and Sack respectively. These temperature and relative humidity recorded were optimal for maize storage and stored maize insect pests to flourish and inflict maximum damage. This finding agrees with the report of Fields and Muir (1996) who stated the optimum temperature for the growth and development of stored product insects ranges between 25-33°C. The surrounding temperature and relative humidity influences the storage temperature and relative humidity affecting maize quality (Fleurat, 2004; Alabadan and Oyewo, 2005). Proper aeration of storage structures is therefore important in enabling longer storage of maize grain in humid and damp environment (David and David, 1998). When storage temperature is minimum, maize grains can be stored for longer period of time at constant moisture content (Harold and Morey, 1991). However, higher maize grain temperatures of 60-65°C for a few seconds or minutes are necessary and lethal to kill all stored grain insects (Banks and Fields, 1995; Arain *et al*., 2006).

Identification of major insects pests: Insect pests belonging to orders Coleoptera and Lepidoptera were identified from maize samples stored in the two traditional storage containers (Gombisa and Sack) in both agro-ecologies. Two major insect pests, angoumois grain moth *(Sitotroga cerealella* (Olivier)) and maize weevil *(Sitophilus zeamais* (Motschlsky*)* were identified under both agro-ecologies in the two storage structures. The first insect pest belongs to Order Lepidoptera family Gelechiidae and the second to Order Coleoptera family Curculionidae. Both insect pests are known to be the primary pest of stored grains (Dobie *et al*., 1984; Emana, 1993; Tadesse, 1997; Emana and Tsedeke, 1999) in tropical storage and are the most important causes of maize damage and losses (Adams and Schulter, 1978; Tadesse, 1991, 1996, 1997; Khosravi *et al*., 2007).

Abundance of major insect pests over storage periods: Initially the average number of insects (live and dead) per kg of grain sampled from Gombisa and Sacks was 1.83 in both storage types and agro-ecologies (Table 6). This could be from insect infestation on standing plant in the field or later in stacks during sun drying. A statistically significant (p<0.05) increment in the number of insects counted was observed in both storage containers and agro-ecologies for every two months increment in the storage period. As storage period extends from harvesting to 180 days of storage, the insect number increased from 1.83 to 101.0 kg^{-1} of seed grain in Gombisa under intermediate agro-ecology. The trend was similar for maize grain stored in sacks and lowland agro-ecology. There was a highly significant (p<0.01) and positive correlation between insect abundance and storage period in both storage structures under both agro-ecologies (Table 6). Similar finding was reported by other researchers (EI-Kashlan *et al*., 1995; Agboka, 2009).

Effect of storage periods and containers on maize insect damage (intermediate agro-ecology): The damage level caused to maize kernels by insect pests at the beginning of the storage period under intermediate agro-ecology

Table 7: Average percentage insect-damaged kernels and germination of maize grain sampled from Gombisa and Sacks under intermediate agro-ecology

Storage period (days)	Damaged kernels (%)		Germination (%)*	
	Gombisa	Sacks	Gombisa	Sacks
Initial loading day	2.42±0.20[c]	2.33±0.17[c]	98.00±0.52[a]	97.50±0.62[a]
60	11.50±0.84[b]	10.75±0.54[b]	87.50±1.23[b]	92.00±1.77[a]
120	20.83±0.79[a]	19.75±1.05[a]	81.33±4.73[b]	80.17±2.75[b]
180	20.75±0.96[a]	20.08±0.82[a]	68.50±2.90[c]	80.50±2.01[b]
LSD (0.05)	9.08	8.42	10.50	11.50
r (p<0.01)	0.94	0.95	-0.99	-0.94

Values are Mean±SE of twelve observations, Values error with different letters in a column are significantly different at p<0.05 according to LSD test

Table 8: Average percentage of insect damaged kernels and germination of maize grain sampled from Gombisa and Sacks under lowland agro-ecologies

Storage period (days)	Damaged kernels (%)		Germination (%)*	
	Gombisa	Sacks	Gombisa	Sacks
Initial loading day	2.50±0.45[c]	2.58±0.15[c]	97.50±0.76[a]	96.50±0.76[a]
60	11.83±0.67[b]	10.58±0.60[b]	79.50±7.29[b]	86.00±5.82[b]
120	19.42±0.55[a]	19.92±1.45[a]	79.17±4.24[b]	83.67±1.54[b]
180	20.92±0.54[a]	18.08±0.75[a]	70.17±4.29[b]	83.83±1.85[b]
LSD (0.05)	7.58	7.50	18.00	10.50
r (p<0.01)	0.96	0.91	-0.93	-0.85

Values are Mean±SE of twelve observations, Values with different letters in a column are significantly different at p<0.05 according to LSD test

was only 2.42 and 2.33% for Gombisa and Sacks respectively (Table 7). This could be the attack while the crop was in the field before harvest and later while in stack for drying. The data for both storage containers indicated a swift significant (p<0.05) increase, 11.50 and 10.75%, in the percentage kernel damage for Gombisa and Sack respectively after 60 days of storage. The data showed continued damage in the following two months with statistically significant increase (p<0.05) to 20.83 and 19.75% for Gombisa and Sack, respectively. The damage level remained non significant between 120 and 180 days in both storage structures. However, the damage levels in both storage types are quite enormous as one fifth of the grain was subjected to damage during six months of the storage period. The correlation coefficient between storage periods and percentage insect damaged kernel was highly significant (p<0.05) and positive (r = 0.94 (Gombisa) and r = 0.95 (sacks)) (Table 7). As the storage period proceeds from initial loading day to 120 days, the percentage damaged kernels increased from 2.42 to 20.83% in four months and 2.33 to 20.08% in six months in Gombisa and sacks, respectively. The decrease in damaged kernels percentage towards the end of the storage period may be due to lack of sufficient grains that supports reproduced insects leading to their death. Maize grain loss of 80% (Nukenine *et al*., 2002), 10-12% (Hell *et al*., 2010) and 12% (Gabriel and Hundie, 2006) was reported in different countries.

Effect of storage periods and containers on maize insect damage (lowland agro-ecology): The general trend of percentage insect damaged kernels under lowland agro-ecology was similar with intermediate agro-ecology. The damage level was initially 2.50 and 2.58% for maize sampled from Gombisa and Sacks, respectively (Table 8). This damage could be due to the attack while the crop was in the field before harvest and later while in stack for drying. The data for both storage containers indicated a rapid and significant (p<0.05) increase in percentage kernel damage, 11.83 and 10.58%, in Gombisa and Sacks after two months of the storage periods respectively. The data showed continual damage in the following two months with statistically significant increase (p<0.05) to 19.42 and 19.92% in Gombisa and Sacks, respectively. The damage level remained statistically non-significant in the final two record periods (between 120 and 180 days after storage). However, the damage levels recorded in both storage containers are quite enormous as one fifth of the grain was subjected to damage by insects. The correlation coefficient between storage periods and percentage insect damaged kernel was highly significant (p<0.05) and positive (r = 0.96 (Gombisa) and r = 0.91 (Sacks)) (Table 8). As the storage period proceeds from initial storage time, the percentage of damaged kernels increased from 2.50 to 20.92% in six months and 2.58 to 19.92 % in four months in Gombisa and sacks, respectively.

The extent of maize grain loss estimated due to problems associated with storage by farmers in the study area ranges from 10-70% of their total maize yield. In the study area, 10-12% of stored maize was estimated to be lost due to insects in traditional storage containers such as Gombisa. Loss of about 18% was also reported for maize grain stored in polypropylene Sacks for the storage periods of six months in other African countries (Hell *et al*., 2010). Survey conducted in three major grain producing areas of Ethiopia indicated that majority of the farmers (93.3%) using traditional storage containers lose their stored grains. Household average actual loss reported was about 12% of the average total grain produce (Gabriel and Hundie, 2006). Mashilla (2004) reported biotic factor as the main sources of challenges in stored maize grains. The need for postharvest management of stored grain was mentioned by several previous workers (Kemeru, 2004; Gabriel and Hundie, 2006; Niaz and Dawar, 2009). Shurtleff (1980) reported that pests do cause about 9.4% loss of maize grain worldwide annually. Biotic factors including insect pests are the major causes of maize grain damage (Desjardins *et al*., 2000; Mohammed *et al*., 2001; Hayma, 2003; Askun, 2006; Mathew, 2010).

Effect of storage periods and containers on germination percentage of maize seeds: Initial test of germination under intermediate agro-ecology indicated 98.00 and 97.75% germination in Gombisa and Sacks, respectively (Table 7). However, the values exhibited statistically significant ($p<0.05$) reduction as storage period proceeds. After two months, it was significantly different from initial germination percentage and dropped to 87.5% for kernels collected from Gombisa while it remained non-significant in Sacks, though it decreased to 92.00%. A statistically significant ($p<0.05$) reduction to 80.17% was obtained for grains collected from Sacks. The germination capacity of kernels obtained from Gombisa further reduced to 68.50% in six months, while that of the kernels stored in the Sack remain non-significantly different.

The trend in germination percentage under lowland agro-ecologies was similar to intermediate agro-ecology indicating 97.50 and 96.50% initial germination percentage in Gombisa and Sacks, respectively (Table 8). However, the reduction in germination percentage was statistically significant ($p<0.05$) as storage period increased to two months at which it dropped to 79.50 and 86.00% for kernels collected from Gombisa and Sacks, respectively. These values remained non-significantly different for the last four and six months in both storage containers with final values of 70.17 and 83.83% in Gombisa and Sacks respectively. Germination loss of grain stored in Gombisa and Sacks as the period of storage increased might be due to destruction of seed embryo by weevils (*Sitophilus* species) and angoumois grain moth (*S. cerealella*) under both agro-ecologies. Maize kernel damage and germination loss due to weevils attack (Lemessa *et al*., 2000; Wambugu *et al*., 2009) and fungi infection was reported.

CONCLUSION

The current study revealed that *S. zeamais* and *S. cerealella* are the major insect pests of maize stored in traditional storage structures (Gombisa and Sacks) under intermediate and low land agro-ecologies of Jimma zone, Western Ethiopia. As the storage period proceeds from initial loading day to 180 days of storage; the number of insect pests increased, their damage to stored maize increased in both storage structures and ecologies affecting viability (germination capacity) of the seeds for the next planting season and the usability of the seeds as food and feed. These calls for future research to identify alternative eco-friendly and cost effective weevils and grain moth management methods. Furthermore, there is a strong need to train maize producers, traders and consumers who are involved in production and marketing chains of maize crop in the area of storage pests and their effective management; techniques of maize monitoring, inspection and timely corrective measures; appropriate grain harvesting, drying, cleaning and storage methods. Improved storage structures need to be investigated for maize grain storage in the study area too.

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REFERENCES

AOAC, 1995. Official Methods of Analysis, of the Association of Official Analytical Chemists. 16th Edn., Vol. 1, AOAC International, Arlington, VA, USA.

Adams, J.M. and G.G.M. Schulten, 1978. Losses Caused by Insects, Mites and Microorganisms. In: Postharvest Grain Loss Assessment Methods, Harris, K.L. and C.J. Lindblad (Eds.). American Association of Cereal Chemists, St. Paul MN., pp: 83-95.

Adejumo, B.A. and A.O. Raji, 2007. Technical appraisal of grain storage systems in the Nigerian Sudan savannah. Agric. Eng. Int. CIGR J., 9: 1-12.

Adesida, A., 1988. On-farm storage structure in Nigeria. Proceedings of the Processing and Storage Unit Seminar, April 12-18, 1988, Nigeria.

Agboka, K., 2009. Developing and testing plant health management options against the maize cob borer, *Mussidia nigrivenella* Ragonot (Lepidoptera: Pyralidae) in West Africa. Ph.D. Thesis, Georg-August-University Gottingen, Germany.

Alabadan, B.A. and O.A. Oyewo, 2005. Temperature variations within wooden and metal grain silos in the tropics during storage of maize (*Zea mays*). Leonardo J. Sci., 6: 59-67.

Arain, M.A., A. Ahmad, T. Ahmad and M. Afzal, 2006. Use of solar radiation at village level for thermal disinfestation of wheat stored in galvanized steel bins. Pak. Entomol., 28: 57-63.

Askun, T., 2006. Investigation of fungal species diversity of maize kernels. J. Biol. Sci., 6: 275-281.

Banks, H.J. and J.B. Fields, 1995. Physical Methods for Insect Control in Stored-grain Ecosystem. In: Stored Gain Ecosystem, Jayas, D.S., N.D.G. White and W.E. Muir (Eds.). Marcel Dekker, New York, pp: 353-409.

Borror, D.J., D.M. de Long, C.A. Triplehorn and F.J. Norman, 2005. Introduction to the Study of Insects. Peter Marshal Publisher, USA., pp: 377-610.

CSA, 2007. Agricultural sample survey report on area and production of crops (Private Peasant Holding, Meher Season). Statistical Bulletin, No. 388, Addis Ababa, Ethiopia.

Chulze, S.N., 2010. Strategies to reduce mycotoxin levels in maize during storage: A review. Food Addit. Contam. A, 27: 651-657.

David, P.S. and D.J. David, 1998. Management-the key to maintaining stored grain quality. http://lancaster.unl.edu/ag/crops/inservice/manage-i98.html.

Demissie, G., T. Tefera and A. Tadesse, 2008. Importance of husk covering on field infestation of maize by Sitophilus zeamais Motsch (Coleoptera: Curculionidea) at Bako, Western Ethiopia. Afr. J. Biotechnol., 7: 3777-3782.

Desjardins, A.E., G. Manandhar, R.D. Plattner, C.M. Maragos, K. Shrestha and S.P. McCormick, 2000. Occurrence of *Fusarium* species and mycotoxins in Nepalese maize and wheat and the effect of traditional processing methods on mycotoxin levels. J. Agric. Food Chem., 48: 1377-1388.

Dobie, P., C.P. Haines, R.J. Hodges and P.F. Prevett, 1984. Insects and Arachnids of Tropical Stored Products: Their Biology and Identification. Tropical Development and Research Institute, Slough, England, Pages: 273.

El-Kashlan, L.U., E. Defat, M. Abd El-Uamid and M.A. Abdellatif, 1995. Insect pests associated with stored grains in Alexandria Governorate, A.R.E. J. King Saud Univ. Agric. Sci., 7: 123-127.

Emana, G. and A. Tsedeke, 1999. Management of maize stem borer using sowing date at Arsi-Negele. Pest Manage. J. Ethiopia, 3: 47-51.

Emana, G., 1993. Studies on the distribution and control of Angoumois grain moth, *Sitotroga cerealella* (Oliver) (Lepidoptera:Gelchidae) in Sidama Administrative Region. M.Sc. Thesis, Alemaya University of Agriculture, Alemaya, Ethiopia.

FAO, 2009. Ethiopia: Agriculture and environment. Food and Agriculture Organization of the United Nations, Rome.

Fellows, P. and A. Hampton, 1992. Small-Scale Food Processing: A Guide to Appropriate Equipment. Intermediate Technology Publications, London, ISBN: 9781853391088 Pages: 158.

Fields, P.G. and W.E. Muir, 1996. Physical Control. In: Integrated Management of Insects in Stored Products, Subramanyam, B. and D.W. Hagstrum (Eds.). Marcel Dekker Inc., New York, pp: 195-221.

Fleurat, L.F., 2004. Stored Grain Pest Management. In: Encyclopedia of Grain Science, Wrigley, C., H. Corke and C.E. Walker (Eds.). Elsevier, UK., pp: 254-263.

Gabriel, A.H. and B. Hundie, 2006. Farmers post-harvest grain management choices under liquidity constraints and impending risks: Implications for achieving food security objectives in Ethiopia. Proceedings of the International Association of Agricultural Economists Conference, August 12-18, 2006, Gold Coast, Australia..

Haile, A. and T. Tolemariam, 2008. The feed values of indigenous multipurpose trees for sheep in Ethiopia: The case of *Vernonia amygdalina*, *Buddleja polystachya* and *Maesa lanceolata*. Livest. Res. Rural Dev., Vol. 20.

Harold, A. and R.V. Morey, 1991. Management of stored grain with aeration. College of Food, Agricultural and Natural Resources Science, University of Minnesota. http://www.extension.umn.edu/distribution/cropsystems/dc1327.html

Hayma, J., 2003. The Storage of Tropical Agricultural Products. 4th Edn., Agromisa Foundation, The Netherlands, ISBN: 9789077073605, pp: 6-25.

Hell, K., K.E, Ognakossan, A.K, Tonou, Y, Lamboni, K.E, Adabe and O, Coulibaly, 2010. Maize stored pests control by PICS-bags: Technological and economic evaluation. Proceedings of the 5th World Cowpea Conference in Saly, September 27-October 1, 2010, Senegal.

ISTA, 1996. International Rules for Seed Testing. Vol. 24, International Seed Testing Association, Zurich, Switzerland.

Kemeru, D., 2004. Farm level survey on farm tools and implements in Jimma and Iluababor Zones. A research Report, Oromiya Agricultural Research Institute, Jimma Rural Technology Research Center, Oromiya, Ethiopia.

Ken, B., 2005. Grain storage basic design principles. Agriculture Fisheries and Forestry. http://www2.dpi.qld.gov.au/fieldcrops/15052.html

Khosravi, A.R., M. Mansouri, A.R. Bahonar and H. Shokri, 2007. Mycoflora of maize harvested from Iran and imported maize. Pak. J. Biol. Sci., 10: 4432-4437.

Lemessa, F., G. Bultosa and W. Wakgari, 2000. Quality of grain sorghum (*Sorghum bicolor* (L.) Moench) stored in traditional underground pits: Case studies in two agro-climatic zones in Hararghe, Ethiopia. J. Food Sci. Technol., 37: 238-244.

Mashilla, D., 2004. Grain storage methods and their effects on sorghum grain quality in Hararghe, Ethiopia. Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala.

Mathew, S., 2010. A review on the wheat grain quality under post harvest storage. Int. J. Pharm. Applied Sci., 1: 38-42.

Mirna, V., V. Rozman, I. Kalinovic, A. Liska, D. Kis and B. Simic, 2007. Influence of relative humidity and temperature on the changes in grain moisture in stored soybean and maize. Agric. Conspectus Sci., 72: 215-219.

Mohammed, S.S., A.Y. Abdul-Malik, M.A. Abdul-Sattar and A.A. Al-Abssy, 2001. Mycobiota and mycotoxin of stored imported wheat grains in Egypt. Botany Department, Faculty of Science, Assiut University, Assiut, Egypt.

Niaz, I. and S. Dawar, 2009. Detection of seed borne my coflora in maize (*Zea mays* L.). Pak. J. Bot., 41: 443-451.

Nukenine, E.N., B. Monglo, I. Awasom, F.F.N. Tchuenguen and M.B. Ngassoum, 2002. Farmer's Perception on some aspects of maize production and Infestation level of stored maize by *Sitophilus zeamais* in the Ngaoundere region of Cameroon. Cam. J. Biol. Biochem. Sci., 12: 18-30.

Ogendo, J.O., A.L. Deng, S.R. Belmain, D.J. Walker and A.A.O. Musandu, 2004. Effect of insecticidal plant materials *Lantana camara* and *Tephrosia vogelii* Hook, on the quality parameters of stored maize grains. J. Food Technol. Afr., 9: 29-36.

Proctor, D.L. and J.Q. Rowley, 1983. The thousand grains mass (TGM): A basis for better assessment of weight losses in stored grain. Trop. Stored Prod. Inform., 45: 19-23.

Shurtleff, M.C., 1980. Compendium of Corn Diseases.12 American Phytopathological Society, St. Paul, MN., USA., ISBN: 9780890540299, Pages: 105.

Tadesse, A., 1991. The biology, significance and control of the maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera:Curculionidae) on stored maize. M.Sc. Thesis, AUA, Alemaya University of Agriculture, Alemaya, Ethiopia.

Tadesse, A., 1996. Insects and other arthropods recorded from stored maize in Western Ethiopia. Afr. Crop Sci. J., 4: 339-343.

Tadesse, A., 1997. Arthropoda associated with stored maize and farmers management practices in the Bako area, Western Ethiopia. Pest Manage. J. Ethiopia, 1: 19-27.

Wambugu, P.W., P.W. Mathenge, E.O. Auma and H.A. van Rheenen, 2009. Efficacy of traditional maize (*Zea mays* L.) seed storage methods in western Kenya. Afr. J. Food, Agric. Nutr. Dev., 9: 1110-1128.