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Research Article

Demonstration and Promotion of Hermetic Bag Storage for The Management of Maize Weevil in Mid-Altitude Agroecology's of Ethiopia

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ABSTRACT

The experiment was conducted for two years in 2018 to 2019 cropping seasons to demonstrate and promote hermetic bag storage for the management of maize weevil and to disseminate/scale-out possible knowledge of maize storage. The experiment was replicated 3 × 5 in randomized complete block designs. Three farmers from each selected kebele's are used as replication 3 × 5 from five agroecology's of Bako, Ambo, Hawassa, Jimma and Bure. From each kebele's in each agroecology's nine household farmers were selected where a total of 270 samples were collected. All the data the collected were analyzed using analysis of variance (ANOVA) and difference among means were separated by the least significant difference (LSD). The correlation between parameters were examined using Pearson's correlation coefficient using PROC CORR procedure of the SAS software. The result revealed that hermetic bag storage structures was significant different ($P < 0.05$) form the two storage and caused 100% mortality of the weevils. Significant ($P < 0.05$) high mean values 9.22 and 9.66% of grain damage and weight losses was observed in the untreated sack from this research, it can be concluded that hermetic bag storage showed better result in reducing insect-damage, maintaining weight loss, germination percentage and grain quality than chemically treated sack in each location. This is due to the biochemical analysis between the grains and insect respiration which reduces oxygen in the storage and increases carbon dioxide and cause of lack of oxygen resulted in insect's mortality. Therefore, it is concluded that hermetic bag better than using insecticides in reducing of weevils, grains damage and weight losses and maintaining grain quality as well as germination percentage.

Keywords: Hermetic bag; Grain damage; Insect infestation; Mortality; Agroecology

INTRODUCTION

Maize is one of the most important crops grown in Africa and the primary cereal grain [1], and the most widely grown crop in Ethiopia from lowland to highland agroecology's [2]. In Ethiopia, it is one of the strategic field crops targeted to ensure food security due to its peak productivity potential. It stands first in total production and productivity, and second in area coverage next to tef [*Eragrostis tef* (Zucc) Trotter] of all cereal crops cultivated in Ethiopia [3,4]. Ethiopia currently produces more maize than any other crop [5]. A total of 7.8 million tons of maize (31% of the total cereal) was produced on 2.1 million hectares (21% of the total area planted cereals) of land by nearly 11 million small households (31% of the total cereal) in 2016, [6]. Three forth of the maize produced is consumed at the house hold level by the small-scale producers themselves [2].

Thus, the seasonality of grain production amid constant demand all over the year gives storage a major role to play in ensuring domestic food security and a basis of income until the subsequent harvest. Storage insect pests pose a risk to household food security as they feed on stored grain resulting in quantitative, qualitative and economic losses. Worldwide image of losses of grain and pulse crops after harvest is valued to be 10% typically due to insect pests and this is actually thoughtful in developing countries [7]. The yearly grain losses in Ethiopia range between 2 and 30% [8]. In addition, [9] reported 20 to 30% of Ethiopian maize is missing to *S. zeamais* infestation, while 100% damage has been found in maize stored for 6 to 8 months in the Bako Oromia region, of the country. This loss renders to weight loss, loss of seed viability and reduce a price values which affects the livelihood of farmers. Some farmers avoid suffering storage losses by selling grain soon after the harvest [10,11] irrespective of the low price practiced during the early period of storage season. Prevention of pests is significant as losses during storage reduce food accessibility, quality, and the permanency of farmers' food supply and income [7].

Synthetic pesticide is expensive may not be accessible in the

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market repeatedly and may be illegitimately mixed with other mixtures [12,13]. Even when applied properly, damage can arise and the necessity to frequently apply chemical agents increases the ways of human or environmentally harmfulness [14,15]. The Purdue Improved crop storage (PICS) bag has recognized to be an effective substitute to chemical pesticide for stored grain. Villers P, et al. (2010) [16] reported that Hermetic storage has become a replacement for older storage method, mainly in hot, humid climates because of its "Green" chemical free technology, control of moisture content, avoidance of pesticides and of essential for freezing. The research done in India indicated that (PICS) bag is effective up to 98% in eliminating of all insect pest within just one month of storage reducing damage and weight loss caused by feeding [17]. Paper presented at conferences in Portugal by Villers P, et al. [16] indicated that PICS bag "kills" 100% insect pests and control of moulds and free fatty acid. However, little information is available for the use of triple-layer hermetic storage bag structures for smallholder to reduce postharvest losses of maize farmers in the country which was considered in this study. Therefore, the objective of this researchis:1) to develop and promote technological uses of triple-layer hermetic bag storage structures for the managementof post-harvest losses due to storage insect pests and 2) to demonstrate and disseminate improved storage technologies for maize producing farmers.

MATERIALS AND METHODS

Dissemination

Theoretical and practical workshops, provision of adequate training, demonstrations and audio-visual discussions will be used to scale-out and disseminate potential of technology to the areas.

Experimental materials

Hermetic bag

Triple-layer hermetic bag (0.3 m by 0.6 m) was constructed from 100 kg PICS bag. In the bottom a wood was put and, on the side, protect not to touch the wall in order protects moisture adherence, rodent, hen, and other insect bowdlerized and other contamination. Each of the layers was twisted and tied separately to arrange an air tight seal. 100kg of maize grain was filled in the center of the layer and tied from inner to outer woven and the bag stored at room temperature. Hundred (100) kilograms of maize grains were stored in each storage as well as in each experimental location. 100 to 200 kg will be used to store for a six-month storage period. From each five locations nine farmers selected and on each farmer. Generally, there were nine (9) treatment combinations with forty-five (45) observation. The data was collected at every two months interval, including at the start of the study making up four levels for the factor storage period. The samples were removed at two months interval for insect-damage and undamaged and Weight loss using the count and weigh and germination percentage was estimated.

Experimental design

The experiments were arranged in a factorial fashion with three factors storage types, storage period and agroecology's in complete randomized block design with five (5) replications. The farmers used as a replication and nine farmers were selected purposively from each five locations. Storage types have three levels i.e., PICS bag, sack with chemical and sack without chemical, storage period have four levels that is (Initial, 2, 4 and 6) and agroecology's have four levels (West Shewa, SNNP, Jimma and Amhara) which was considered as replications.

Sampling methods

A total of 270 samples of stored maize grain were collected from the maize farmers periodically from the beginning of the storage to the last six months of storage periods. The initial samples taken from each storage structures were considered as a control. Each sample was taken by inserting the compartmented spear into the grain mass straight to the maximum depth from the top, side, middle and the bottom of the storage (Figures 1, 2, 3).

Germination test

Germination test was carried out according to international seed testing association standard [18]. This was done by using counting of 25 maize seeds from the pure seed by multi auto electric counter. This was done by using counting of 25 maize seed from pure seeds by multi auto electric counter of each sample were placed in petri dishes containing filter paper soaked with distilled water. The 25 pure seeds of each sample were in petri dish containing filter paper soaked with distilled water. Germination count was made every day up to the completion of germination at seven days. A seed was plumule and radicle arose out up to 2mm length. Germination percentage was calculated using the formula described by Tame VT [19].

$$\text{Germination}(\%) = \frac{\text{No. of germinated seeds}}{\text{Total No. of seeds soaked}} \text{X } 100$$

Figure 1: On farm demonstration and promotion of PICS bag structures.

Figure 2: Theoretical and practical training, demonstrations and audio-visual discussions.

Figure 3: Developing of visual score of damage scale in different storage structures data to be collected.

Grain damage

Grain damage was collected and assessed for insect-damage using a conventional 'count and weigh' method. Each five hundred (500 g) 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. [20] as follows:

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

Where, PIDG = Percentage of insect damaged grain

Weight loss

Percentage weight loss was computed by count and weigh method according to the procedure used by Gwinner et al. [21] using the following equation.

$$\text{Weight loss}(\%) = \frac{(UNd)-(DNu)]}{U(Nu + Nd)} \times 100$$

Where, U = weight of undamaged grain, D = weight of damaged grain, Nu = number of undamaged grains, Nd = number of damaged grains.

Statistical analysis

All the data collected in 2017-2019 were subjected to analysis of variance (ANOVA) by using the PROC GLM procedure (SAS Institute, 2004) and difference among means were compared by the Least Significant Difference at 5% level of significance [22]. The correlation parameters were examined using Pearson's correlation coefficient using PROC CORR procedure of the SAS software (SAS Institute, 2004).

RESULTS AND DISCUSSION

Demonstration and promotion of PICS bag storage

The performance testing of hermetic bag (i.e., PICS) was conducted in five locations whereby three treatments were used. The treatments were: 100 kg of PICS bags and 100 kg of farmers used woven polypropylene with chemicals and woven polypropylene without chemicals as control were used. In each location the experiments were laid in 3 × 3 arrangements that is three storage types in individual farmer house. From five experimental locations nine (9) farmers house were selected in each for the demonstration. The bags were filled with fresh undamaged and clean maize seeds/ grains and left for more than 6 months in a farmer's home room at ambient temperature 25–30°C.

After the storage period of six months, many maize weevils were observed in the untreated (control) and treated storage and not live weevils were found in the PICS bags as the farmer's observation during the fields. Forty-five farmers were participated in the technology demonstration and promotion and a total of 386 farmers were trained of which 300 male and 86 female households. The farmers used their own criteria for the selection of the storage structures during the demonstrations like presences of weevils, grains color; damage grains either holes or any visible changes seen on the grains. Therefore, from the three storage structures hermetic bag better for maize grains storage and selected as a number one for the maize farmers to reduces the problems of weevil's infestations with handling the bag from rodents and hens tearing, appropriate place for keeping from moisture observation of the bag from the grounds and other damaging insect.

Effect of storage types and agroecology on population density weevil's

Table 1 presents the mean number of weevils observed in each experimental location. Highly significantly (P ≤ 0.001) shows increasing trends of population density of weevils among storage types and agroecology's. Four weevils' species were identified from the samples collected in all experimental location after four months of storage. *S. oryzae*, and *S. zeamais* the most dominant spp. of weevils recorded in all tested locations (Figure 4). Highly significant different (P ≤ 0.001) among the weevils' species and *S. zeamais* was occurred with high mean number 114, 122, 164, 130 and 120 in Ambo, Bure, Hawassa, Jimma and Bako, respectively after six months of storage.

There were not significant differences (P ≤ 0.05) observed among

Table 1: Effect of storage types and agroecology on population density weevil.

Weevils Species	Experimental locations				
	Ambo	Bure	Hawassa	Jimma	Bako
S. zeamais	114^{a}	122^{a}	164^{a}	130^{a}	120^{a}
S. oryzae	110^{b}	110^{b}	135^{b}	100^{b}	102^{b}
T. castaneum	15^{d}	34^{c}	45^{d}	83^{c}	51^{c}
S. cerealella	52^{c}	112^{b}	82^{c}	57^{c}	69^{c}
CV (%)	4.0	12.0	29.0	30.0	18.0
LSD (%)	2.12	2.42	3.47	2.44	3.52

Note: Note: Means with the same letter were not significantly different by LSD test at P ≤ 0.05, P ≤ 0.001, CV: coefficient of variation, LSD: least significant different.

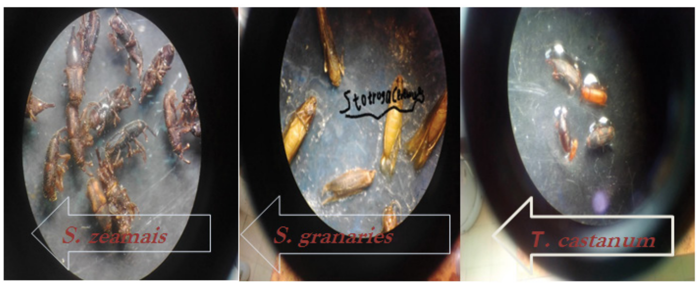

Figure 4: Weevil's species identified in the laboratory from the 500 g samples.

the treated sack and hermetic bag on the weevil's mortality after storage but, significant (P ≤ 0.05) high mean number 50.58/250 gm of live weevils recorded in untreated sack storage (Table 2) [23]. Reported that the mean difference of the number of adult *P. truncatus* differed significantly with treatment ($F7, 24 = 65.26$; $P < 0.0001$; coefficient of variation = 0.95) and storage period ($F2, 48 = 55.78$; $P < 0.0001$; coefficient of variation = 0.70) [23]. Regardless, of the mean number of weevils' mortality there was not significant different ($p \leq 0.05$) in all locations (Table 3). Similarly, Yakubu A, et al. [24] reported that insect mortality in treatments containing only maize and insects was 100% at 9 days, and significant differences in mortality between hermetic and non-hermetic treatments were found ($P \leq 0.01$). The same author reported *S. zeamais* was the most important dominant maize weevils in a number of studies; in steel silos, in sacks and barns throughout Ghana.

Effects of storage periods on weight loss, grains damaged and germination

The initial mean germination value of the maize before storage was 97.40%. Regardless of periods or locations, germination highly significantly ($P \leq 0.001$) decreased from the initial 97.40 value to 84.00% after six months of storage (Table 2). This is due to high weevils' development in the storage at these periods because of the favorable conditions of the storage structures and environmental conditions. Similarly, Befikadu D, et al. [25] reported that germination loss of grain stored in Gombisa and sack increased might be due to destruction of seed by weevil (*Sitophilus species*) and Angoumois gran moth (*S. cerealella*). According to Kaleta A and Górnicki K [26], germination percentage decreased during the storage period, and decreased as the moisture content increased. With 18 % moisture content and above the germination decreased to zero after 35 days of storage. Irrespective of storage periods or locations, weight loss and grain damage were highly significantly ($P \leq 0.001$) increased from the initial value 0.00% to 9.81 and 9.90%, respectively after six months of storage. This is due to increasing numbers of weevils as the storage periods increase which was caused by the larvae in the grains infected from the fields developed and favorable conditions of the storage structures for re-infestation of the grains after storage (Figures 3B & 3C).

Effect of storage structures on grain damaged, weight loss and germination

There were highly significant different ($P \leq 0.05$) among the storage structures on the mean grain damaged, weight loss and germination. Significantly ($P \leq 0.05$) high mean value 9.22% of weight losses was recorded in the untreated sack than the treated sack and hermetic bag storage. There were significant different ($P \leq 0.05$) among the storage structures on grains damage. Maximum mean value 9.66%of grains damage was recorded in the untreated sack whereas, the minimum mean value 0.00% recorded in hermetic bag. This is due to the weevil's mortality in the storage because of the hermetic nature of the storage which kills the weevils due to lack of oxygen. Likewise, Befikadu D, et al. [25] estimated that 11.50 and 10.75% percentage of kernel damage for Gombisa and Sack respectively after 60 days of storage. Also, other author [27] explained that 10-20% of maize grains were lost after three months of storage. He found the problem is due to ineffective storage technologies. According to Waktole S and Amsalu A [19], the mean grain damage and weight losses caused by the pests in traditional storage practices were 64.50 and 58.85%, respectively. The color of the maize grains stored in the untreated sacks was changed to brown after four months of storage. This is due to insect infestation and mould developed in the storage (Figure 3C). There were differences in the percentage grain discoloration with treatments ($F7, 24 = 191.23$; $P < 0.0001$; coefficient of variation = 0.98) and storage period ($F2, 48 = 88.56$; $P < 0.0001$; coefficient of variation = 0.79 (19). The respiration of the grains, insects, and moulds within hermetic stores result in depletion of oxygen and increase of carbon dioxide [26]. Under such conditions, fungal growth may be inhibited [20], and when the oxygen level falls to 10%, insect activity is reduced and insect will die if subjected to less than 2% oxygen for periods in excess of

Table 2: Effect of storage periods on number of dead and alive weevils, weight loss, damaged grains and germination.

Storage Periods	Dead weevils/250 g	Alive weevils/250 g	Weight loss	Damaged grain/250 g	Germination (%)
0	0.53^d	0.00^d	0.00^d	0.00^c	97.40^a
2	12.40^b	20.07^c	2.87^c	1.79^c	94.93^a
4	24.81^a	32.20^b	6.11^b	4.39^b	88.00^b
6	14.56^b	52.13^a	9.81^a	9.90^a	84.60^c
CV (%)	27.55	5.16	16.28	25.83	4.18
LSD (%)	9.58	9.62	1.03	1.89	2.81

Note: Means with the same letter were not significantly different by LSD test at P ≤ 0.05, CV: coefficient of variation, LSD: least significant different.

Table 3: Effect of storage structures on weight loss, damaged grains and germination.

Storage structure	Weight loss/250 g	Damaged grain/250 g	Germination (%)
Sack without chemicals	9.22^a	9.66^a	86.55^a
Sack with chemicals	3.25^b	2.40^b	91.45^c
Hermetic bag	1.63^c	0.00^c	95.70^b
CV (%)	16.28	25.83	4.18
LSD (%)	0.89	1.65	2.43

Note: Means with the same letter were not significantly different by LSD test at P ≤ 0.05, CV: Coefficient of Variation, LSD: Least Significant Different.

Table 4: Effect of agroecology's on weight loss, damaged grains and germination.

Experimental Location	Weight loss	Damaged grain/250 g	Germination (%)
Bako	8.69^b	12.22^b	80.00^d
Bure	7.29^c	8.28^c	84.00^c
Hawassa	10.19^a	16.43^a	76.58^e
Ambo	3.74^e	2.66^e	92.17^a
Jimma	4.98^d	5.51^d	88.33^b
CV (%)	16.28	25.83	4.18
LSD (%)	1.15	2.12	3.14

Note: Means with the same letter were not significantly different by LSD test at P ≤ 0.05, CV: Coefficient of Variation, LSD: Least Significant Different.

14 days. Consequently, hermetic storage can be used to maintain grain quality without the need for pesticide application [28]. The rate at which oxygen is reduced and carbon dioxide generated is a function of both grain moisture content and the ambient temperature; the rate is low at temperatures below 20°C [11].

Effect of agroecology's on weight loss, grains damaged and germination

Significantly different ($p \leq 0.001$) among storage structures over agroecology's on weight loss, grains damage and germination. Significantly ($p \leq 0.001$) high mean 92.17% of germination was recorded in Ambo location whereas, the low mean 76.58%of germination percentage was recorded in Hawassa. In Ambo, location there was no as such climate variation for the proliferation weevil's which was a reverse to the climatic conditions of Hawassa, Bako, Jimma and Bure locations which favors high weevils' proliferation and infestation of the weevils (Table 4). Similarly, the levels of weight loss and grains damaged were significantly different ($p \leq 0.001$) among the storage bags on over agroecology's. High mean value 16.43 and 10.19% of grains damaged and weight loss was recorded in Hawassa agroecological areas whereas, the low mean values 3.74 and 2.66% were recorded in Ambo -Wadessa agroecological areas.

CONCLUSION

Demonstration and promotion of Hermetic bag storage was conducted in five agroecological zones of Ethiopia. Forty-five farmers were participated in the technology demonstration and promotion and a total of 386 farmers were trained of which 300 male and 86 female households. Four weevils' species were identified from the samples collected in all the experimental location after four months of storage. High number of weevils was observed in the untreated sack than the treated and hermetic bag storage. *S. zeamai*s occurred with high number in Ambo, Bure, Hawassa, Jimma and Bako, respectively after six months of storage. Germination percentage shows decreasing after six months of storage whereas, grain damaged and weight loss showed increasing trends in the untreated sack. This is due to the stored grains was infested by weevils. Regarding to the storage type no grain damage was observed in hermetic bag in all the tested locations. It can be concluded that hermetic bag storage showed better result in preventing insect-damage, maintaining weight loss, and germination percentage and grain quality than the treated and untreated sack in the five experimental locations. Therefore, hermetic bag storage unaccompanied can be suggested to the farmers provided appropriate application of technology is ensured if hermetic bag storage kept in comprehensive handling and management by farmers that are proper placement, well sealing and protection of the bag's tears by the rodents and poultries.

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CONFLICT OF INTERESTS

The authors affirmed that here was no conflict of interest.

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