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Effects of Harvest Time and Storage Form on Insect Population and Damage of Maize

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Abstract. The aim of this study *was* to determine the effects of harvest time and storage form on population levels of insect pests and their damage on stored maize. Maize was cultivated on a total land area of 19 x 23m^2 during the major season (April to August 2020) and minor season (September to December 2020). Maize was harvested at three stages; early harvest, mid harvest and late harvest. Harvested maize was stored in three ways; husked, de-husked and shelled. Analysis of variance (ANOVA) was applied to the data through Sisvar version 5.6. Insect pests that were sampled during the study were *Sitophilus zeamais*, *Cathartus quadricollis*, *Carpophilus dimidiatus* and *Tribolium castaneum*. *Carpophilus dimidiatus* were sampled from treatments during the major season whereas *Tribolium castaneum* was sampled during the minor season. *Sitophilus zeamais* and *Cathartus quadricollis* were sampled in both seasons. In the major season, late harvest shelled maize (LHS) recorded 689% more *S. zeamais* numbers as compared to early harvest husked maize (EHH). Mid-harvest husked maize (MHH) had 307% less number of *S. zeamais* compared to LHS in the minor season. Late-harvest shelled maize (LHS) had the highest percentage insect damaged kernels (86.94%) in the major season.

Keywords: harvest time, insect damage, insect population, maize, storage form

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1. Introduction

Maize is cultivated in every part of the world. The top three maize–growing countries in the world are the United States of America, China and Brazil [1]. In the trading year 2021/2022, they produced 772 of the 1,914 million metric tons of maize [2]. Maize is the most preferred cereal in Eastern and Southern Africa, Mexico and Central America.

Several vitamins, minerals, oil and fiber can be found in maize. Maize is a multi-purpose crop which contains about 4% fat, 10% protein and 72% starch [1]. Although it is a significant food crop, especially in sub–Saharan Africa and Latin America, the crop can also be used in industries

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and in the formulation of animal diets [3]. In Africa, maize production increased from 84 million metric tons in 2017/2018 to 89.3 million metric tons in 2020/2021. Production of maize is expected to increase to over 90 million metric tons in 2021/2022 [4].

Maize has become the main staple crop in several parts of sub-Saharan Africa. From 2007 to 2017, the area in which maize is cultivated increased by 60% [5]. In Ghana, maize is the most cultivated and consumed cereal [6]-[7]. The major and minor cropping seasons in the Middle Belt occur during the periods April-August and September-December, respectively [8]-[9]. Postharvest Loss (PHL) of approximately 50% has been reported in Ghana along the value chain. Reducing PHL is an important objective of the Ministry of Food and Agriculture (MoFA) since losses divert the essential income of farmers and reduce food availability [9].

Time of harvest, handling and weevil infestation are among the major causes of loss in maize [10]. According to [9], timely harvest, proper handling and storage help reduce PHL in the maize value chain. However, most small-scale farmers delay harvest due to weather conditions, the size of the crop and how quickly the farmer wants to utilize the crop [11]. [12] argues that, early harvest lowers grain yield through short filling duration. Early harvested maize has a higher moisture content which increases storage risk and cost [13]. On the other hand, delayed harvest and post-harvest handling methods expose maize grains to insect infestation, fungi infection and increased levels of aflatoxin contamination, which could have significant economic implications for the farmers/traders and health implications for the final consumer [14]. Inappropriate handling, bacteria and fungal contaminations, harvesting methods, post-harvest handling procedures and attack of crops by insects, birds, rodents, etc. are some other factors that cause postharvest losses [15]. For the past years, pest incidence on crops has led to the introduction of several botanicals and synthetic pesticides in advanced agriculture. However, these affect pollinators and other beneficial insect populations negatively. For instance, synthetic pesticides can kill non–targeted species when applied. Certain plant–derived pesticides are also non–specific and toxic [16].

Some pesticides are environmentally stable and have the tendency to bioaccumulate and persist in the environment for years. Environmental contaminations caused by the use of pesticides can expose the general population to pesticide residues [17]. Soil, surface and groundwater, air and non-targeted vegetation in the environment are all prone to contamination by pesticides [18]. Hence, although pesticides may be effective in extenuating harmful insects, the risks associated with them transcends their beneficial effects. These pesticides are also very expensive to use. Biological and cultural methods of mitigating insect pests are less costly, safer and eco-friendly. Biological control methods use living natural enemies of insect pests to inhibit the actions of the latter. Examples of these natural enemies include parasitoids, predators, pathogens and parasites [19]. In a developing country like Ghana, efficient methods that are cheaper, less hazardous and environment-friendly will be beneficial in decreasing populations of *S. zeamais* on maize during storage [20]. Cultural practices are very helpful alternative methods of pest control that are not only cheaper but also safer for humans and the environment. They include crop rotation, alteration of harvesting and planting dates, sanitation, growing trap crops and diversification of crops [19]. However, limited studies have been carried out on cultural practice methods of pest control, especially harvest time and its impacts on insect pest population levels and their damage on stored maize in Ghana.

Therefore, this study examined the effects of harvest time and storage form on insect pest population levels and their damage to stored maize.

2. Materials and Methods

2.1. Production of Samples

2.1.1. Maize cultivar used, planting and harvesting

Obaatanpa maize variety was planted on a total land area of 19 x 23 m^2, which was subdivided into 36 plots. A randomized complete block design was used for the field experiment. There were nine treatments with four replications. The treatments were; cobs harvested early, dried, de-husked (EHD), cobs harvested early, dried, stored with husk (EHH), cobs harvested early, dried, shelled before storage (EHS), cobs harvested at physiological maturity period, dried, de-husked (MHD), cobs harvested at physiological maturity period, stored with husk (MHH), cobs harvested at physiological maturity period, shelled before storage (MHS), cobs harvested late, dried, de-husked (LHD), cobs harvested late, dried, stored with husk (LHH) and cobs harvested late, dried, shelled before storage (LHS). Planting was done from April to August (major season) and September to December (minor season). Harvesting was done in August/September (major season) and December/January (minor season). Maize cobs from each treatment were harvested at three different times (15, 17 and 19 weeks) after germination. Cobs were harvested by handpicking from plants located on the inner rows of each plot to eliminate border errors.

2.1.2. Drying and storage

Cobs were dried with their husks for two weeks for each time of harvest to achieve optimum MC before cobs were transferred to the laboratory for storage. After the drying process, 10 cobs were randomly selected for each treatment. Husk was removed for treatments Dehusked (D) and Shelled (S) while husk was maintained for Husked (H). Maize was then shelled by hand for treatment "S". Maize was stored in 10-liter plastic buckets covered with polyester cloth and fastened with jute string to aid aeration but to prevent insects from escaping. The storage period lasted for 90 days for each season, September-November, 2020 (major) and February-April, 2021 (minor). Data was taken on population levels of stored insect pests, insect damage and weight loss.

2.2. Determination of Insect Pest Population and Weight of Dust Produced

The number of insects was estimated and identified weekly. Treatments "D" and "H" cobs were tapped gently against the inner sides of the bucket to displace insects for counting. Treatment "S" was sieved using U.S. Standard #10 (2-mm openings) and #25 sieves (0.71-mm openings) (Dual Manufacturing Co., Franklin Park, IL, USA) to recover insects and dust produced. Dust produced was weighed using an electronic balance (Mettler, Toledo, OH, USA).

2.3. Assessment of Insect Damage

Grains were separated based on feeding holes created by insect feeding. The number of damaged and undamaged grains was counted from a 100 g sample for each treatment per replicate. Counted grains were subsequently weighed using an electronic balance. Percentage of IDK (Insect Damage Kernel) was calculated by number (% IDKnb) and by weight (% IDKwb) using the formulas [21] below:

$$\%IDK\ (by\ number) = \frac{Number\ of\ IDK}{Total\ number\ of\ kernels}\ x\ 100 \quad (1)$$

$$\%IDK\ (by\ weight) = \frac{weight\ of\ IDK}{100}\ x\ 100 \quad (2)$$

Weight loss due to insect damage was calculated using the count and weigh method [22] and the equation:

$$\%\ Wt\ Loss = \frac{[(Wu\ x\ Nd)-(Wd\ x\ Nu)]}{Wu\ x\ (Nd+Nu)}\ x\ 100 \quad (3)$$

where Wu is the weight of undamaged grain (kernels), Nu is the number of undamaged grain, Wd is the weight of damaged grain, and Nd is the number of damaged grain.

2.4. Data Analysis

Data was entered in Microsoft Excel (2016). The data was checked for normality using Shapiro-Wilk's test. Analysis of variance (ANOVA) was applied to the data through Sisvar version 5.6 [23]. The Scott-Knot test at 5% probability was used to compare treatment means.

3. Results and Discussion

3.1. Interactive Effect of Season, Harvest Time, and Storage Form on Insect Population

The interactive effect of treatment and season on S*itophilus zeamais* was statistically significant ($P<0.05$) (Table 1). Significant differences existed between late-harvest shelled maize (LHS) and EHS for *S. zeamais* in the major season ($P<0.05$) (Table 1).

In the minor season, LHS recorded the largest number of *S. zeamais.* However, the difference was not significant from the other treatments ($P > 0.05$). Significant differences existed between early harvest de-husked maize (EHD) and early harvest shelled maize (EHS) with regard to *Cathartus* *quadricollis* (P<0.05) (Table 1). There were no significant differences between late harvest husked maize (LHH) and EHS (P>0.05) (Table 1).

Table 1 Effect of Season, Harvest Time and Pre-storage Handling Practices on *S. zeamais* and *C. quadricollis* Population (means ± SE)

Treatments (T)	Season (S)	*Sitophilus zeamais*	*Cathartus quadricollis*
EHD	Major	106.73±48.4^{cA}	59.71±25.6^{aA}
EHH	Major	73.19±32.7^{cA}	46.31±30.5^{aA}
EHS	Major	33.23±21.0^{cA}	6.17±4.31^{bA}
LHD	Major	542.13±144.6^{aA}	77.90±48.1^{aA}
LHH	Major	229.02±61.4^{bA}	48.10±51.4^{aA}
LHS	Major	577.67±84.5^{aA}	16.85±2.68^{bA}
MHD	Major	239.15±31.4^{bA}	82.04±50.1^{aA}
MHH	Major	100.13±92.1^{cA}	47.63±46.8^{aA}
MHS	Major	181.60±123.2^{bA}	13.77±7.41^{bA}
EHD	Minor	23.38±6.92^{aA}	4.48±3.87^{aB}
EHH	Minor	26.23±6.52^{aA}	14.02±8.57^{aA}
EHS	Minor	21.54±12.35^{aA}	3.40±2.22^{aA}
LHD	Minor	44.17±19.39^{aB}	17.21±13.43^{aB}
LHH	Minor	24.69±20.0^{aB}	20.31±26.2^{aA}
LHS	Minor	73.17±34.6^{aB}	14.21±4.30^{aA}
MHD	Minor	49.21±27.5^{aB}	16.54±12.82^{aB}
MHH	Minor	17.96±7.47^{aB}	5.40±1.52^{aB}
MHS	Minor	33.00±20.5^{aB}	4.88±3.82^{aA}
P-values			
T		*0.00001*	*0.0129*
S		*0.00001*	*0.00001*
*T * S*		*0.00001*	*0.1152*

3.2. Effect of Harvest Time and Storage Form on Insect Population

Although late-harvest shelled maize (LHS) recorded the largest number of *S. zeamais*, it was not significantly different (P>0.05) from late-harvest de-husked maize (LHD). The least number was recorded on EHS, which was not significantly different from EHD, EHH, LHH, MHD and MHS (Figure 1). From the study, *S. zeamais*, *C. quadricollis*, *C. dimidiatus* and *Tribolium* spp. were the insect pests recovered from maize samples during the storage period, with *S. zeamais* being the most abundant. [21] found *T. castaneum*, *Sitophilus* spp., *R. dominica*, and *C. ferrugineus* as the dominant insect pest species infesting stored maize in the northern belt of Ghana. However, [8] recorded *Sitophilus* spp., *C. quadricollis*, *C. dimidiatus*, *S. cerealella*, *T. castaneum*, and *C. ferrugineus* from maize samples from markets in the Middle Belt of Ghana. In Africa, *S. zeamais* has been reported as the most abundant insect pest of maize in various studies [8], [21], [24]. The results showed that the number of *S. zeamais* recovered from stored maize harvested early was generally lower compared to late and mid-harvested maize. [25] detected *Prostephanus truncatus* infestation at the beginning of storage on late harvested maize. They also found significantly lower populations in early harvested treatments compared to late harvested maize after their trial. [26] also reported smaller number of emerged adults and lower rate of population increase from early harvested cowpea. The number of *C. quadricollis* recovered from shelled maize from the different harvest times were smaller than that of the husked and de-husked treatments in the major season. This could be due to the fact that shelled maize exposed *C. quadricollis* to natural enemies, unlike the husked and de-husked maize. Large numbers of insects were observed in maize during the major season, corroborating with [25], who found increased insect populations in July-December, which was mostly humid. This was probably because higher relative humidity is conducive to insect population growth [27]. Insect counts on pre-stored and harvested maize were found to be 10 times or more in the major season which is cooler (high %r. h., low-temperature ºC) than in the minor season [8], [28]. The number of emerged F_1 adults, susceptibility index (SI) and eggs laid were found to be highest on shelled stored maize followed by dehusked cobs while husked maize recorded the least [29]. According to [30], favourable conditions exist in maize stored shelled as it promotes high oviposition, egg and larval development and reduces mortality. Husked cobs on the other hand provide a protective layer against insect attack. However, mixed results were obtained from this study as shelled grains from the early harvested crop recorded the least insect population while husked cobs recorded the least number of insects in mid and late harvested maize. This was probably because the shelled grains had no husks to serve as a protective layer against insect attacks [25].

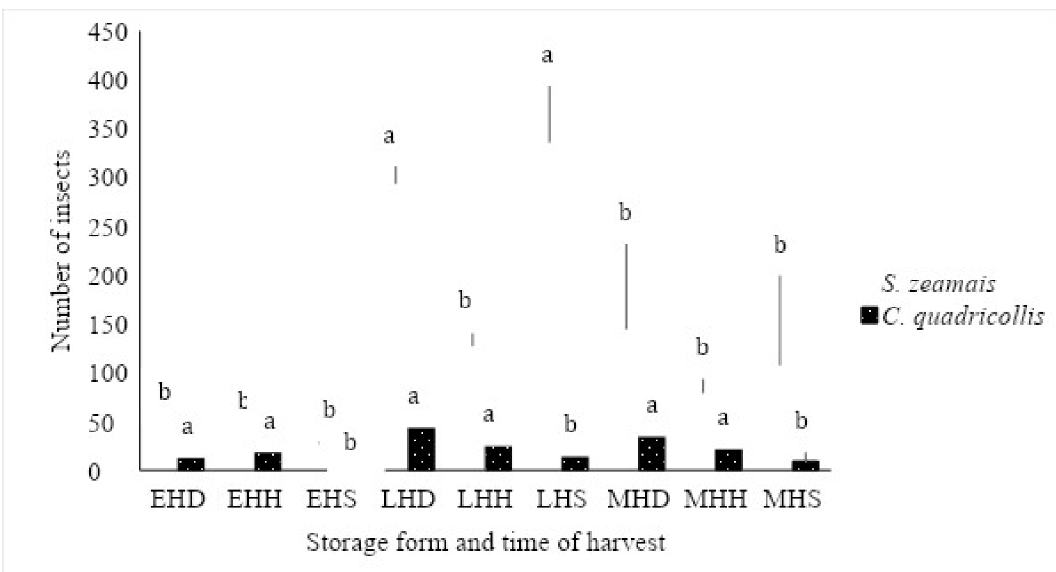

Figure 1. Effect of Harvest Time and Storage Form on *Sitophilus zeamais* and *Cathartus quadricollis* Population on Stored Maize

For *Carpophilus dimidiatus*, late-harvest husked maize (LHH) was significantly different from LHS. No significant difference existed between LHH and mid-harvest husked (MHH). (Figure 2)

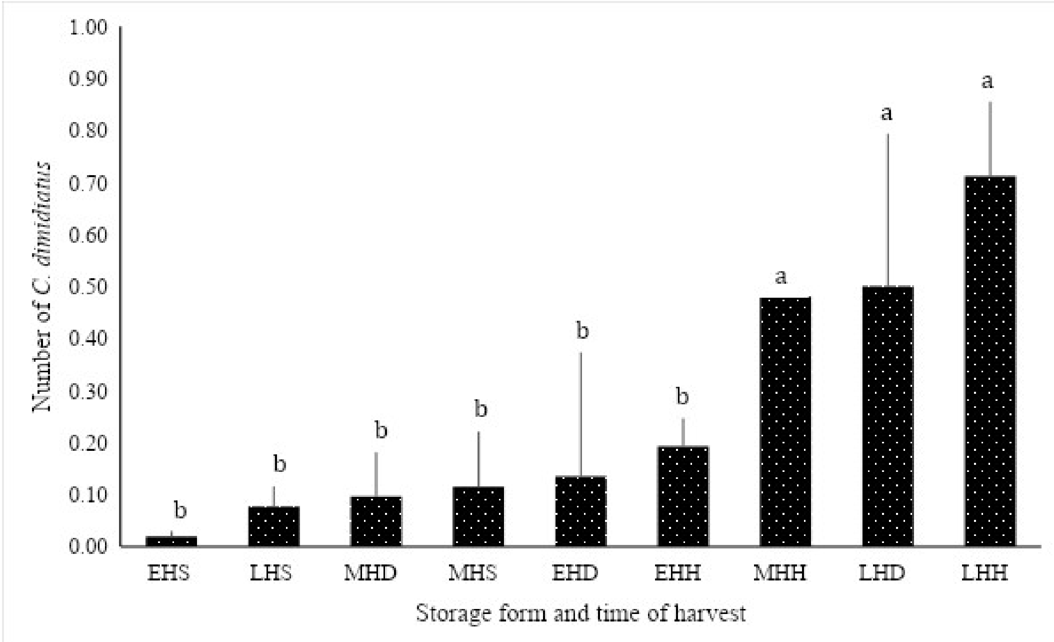

Figure 2. Effect of Harvest Time and Storage Form on *C. dimidiatus* Population on Stored Maize

There were no significant differences between treatments for *Tribolium castaneum* (P>0.05) (Fig. 3).

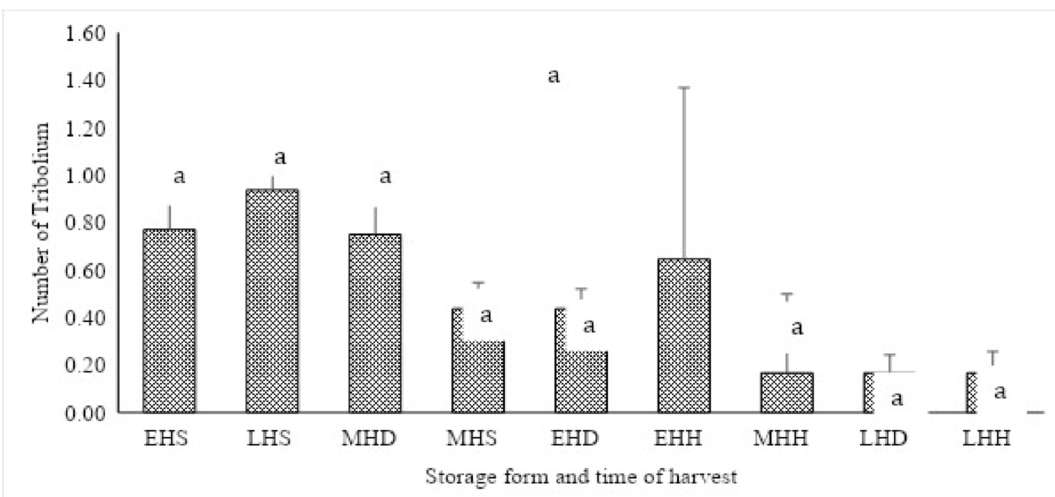

Figure 3. Effect of Harvest Time and Storage Form on population of *T. castaneum* on Stored Maize

3.3. Grain Damage and Weight Loss

Insect-damaged kernels (IDK) showed significant differences among the treatments in the major season while the minor season recorded no significant differences. In the minor season, the number of IDK from LHD decreased by 122% compared to the same treatment in the major season (Table 2).

With respect to IDK (%), the interactive effect of season and treatment was not significant and there were no significant differences between LHD and LHS in the major season. In the minor season, LHD was not statistically different from LHH and LHS (Table 2).

Physical descriptions such as feeding value, maximum limits of damaged kernels, discolouration, foreign materials, heat-damaged kernels, percentage IDK and test-weight/weight loss are used to group maize into different classes and grades, for trading purposes [31]. Results showed no differences in IDK per the seasons, although differences existed between treatments. Cobs harvested late, dried, and de-husked (LHD) and LHS showed the highest IDK. Initial insect infestation levels are greatly related to levels of IDK [32].

The positive correlation between the percentage insect damage kernel (%IDK), percentage weight loss (%WL) and insect numbers confirm how grain quality can reduce due to pest populations [32]. Late harvest husked maize (LHH) however did not show any difference to early and mid-harvested maize treatments. According to [30], *S. zeamais* does not readily attack cobs with intact husks. The initial population distribution of *S. zeamais* in the field has an effect on densities during storage [25]. Percentage of IDK ranged from 11-27% for early harvest, 30-52% for mid-harvest and 32-87% for late harvest.

3.3.1. Dust produced from insect feeding

In the major season, significant differences existed between late-harvest de-husked maize (LHD) and the other treatments with regard to the quantity of dust produced. However, there were no significant differences between treatments in the minor season. (Table 2).

3.3.2. Percent weight loss

Interaction between treatment and season showed significant differences (P<0.05). In the major season, late harvest shelled maize (LHS) and LHD did not have any significant differences between them (Table 2). There were no significant differences between treatments (P>0.05) in the minor season.

Table 2. Insect Damage Kernels (IDK), Percentage IDK, Dust (g) and Weight Loss (%) of Maize Treatments after the Storage Period Mean Number (±SE)

Treatments (T)	Season (S)	IDK /100g	IDK (%)/100g	Dust (g)	%weight loss/100g
EHD	Major	115.75±21.5^{cA}	19.93±4.35^{bA}	0.77±0.39^{cA}	0.23±0.05^{bA}
EHH	Major	151.25±30.7^{cA}	26.89±9.69^{bA}	0.75±0.31^{cA}	2.00±0.04^{bA}
EHS	Major	60.00±52.7^{cA}	11.29±10.15^{bA}	0.16±0.09^{cA}	1.00±0.06^{bA}
LHD	Major	536.00±153.5^{aA}	78.86±12.15^{aA}	3.15±0.62^{aA}	32.75±0.27^{aA}
LHH	Major	139.50±19.42^{cA}	32.20±7.24^{bA}	1.84±0.56^{bA}	7.50±0.82^{bA}
LHS	Major	388.50±48.7^{bA}	86.94±8.83^{aA}	1.80±0.27^{bA}	18.25±2.05^{aA}
MHD	Major	225.25±105.4^{cA}	42.92±16.22^{bA}	1.30±1.09^{cA}	4.25±0.21^{bA}
MHH	Major	149.75±109.0^{cA}	29.95±21.40^{bA}	1.59±1.97^{bA}	2.50±0.24^{bA}

Table 2. Continued

Treatments (T)	Season (S)	IDK /100g	IDK (%)/100g	Dust (g)	%weight loss/100g
MHS	Major	293.75 ± 228.0^{bA}	52.00 ± 32.60^{bA}	0.63 ± 0.43^{cA}	11.25 ± 0.57^{bA}
EHD	Minor	176.75 ± 109.0^{aA}	28.29 ± 13.86^{bA}	0.28 ± 0.19^{aA}	0.23 ± 0.05^{aA}
EHH	Minor	96.25 ± 22.0^{aA}	18.88 ± 6.71^{bA}	0.21 ± 0.05^{aA}	1.75 ± 0.07^{aA}
EHS	Minor	166.00 ± 137.6^{aA}	27.29 ± 23.80^{bA}	0.31 ± 0.29^{aA}	4.00 ± 0.32^{aA}
LHD	Minor	241.50 ± 77.9^{aA}	58.45 ± 17.19^{aA}	0.59 ± 0.29^{aB}	1.00 ± 0.26^{aB}
LHH	Minor	292.50 ± 233.0^{aA}	55.63 ± 40.20^{aA}	0.25 ± 0.23^{aB}	0.80 ± 0.16^{aB}
LHS	Minor	202.75 ± 108.2^{aA}	47.36 ± 18.49^{aA}	0.96 ± 0.67^{aA}	2.75 ± 2.64^{aB}
MHD	Minor	178.50 ± 73.5^{aA}	35.27 ± 13.78^{bA}	0.76 ± 0.59^{aA}	1.50 ± 0.26^{aA}
MHH	Minor	146.00 ± 183.9^{aA}	30.32 ± 37.50^{bA}	0.16 ± 0.09^{aB}	4.25 ± 0.13^{aA}
MHS	Minor	163.25 ± 169.9^{aA}	29.36 ± 32.20^{bA}	0.48 ± 0.41^{aA}	0.15 ± 0.08^{aB}
P-values					
T		*0.0003*	*0.00001*	*0.00001*	*0.0126*
S		*0.1229*	*0.2597*	*0.00001*	*0.0021*
*T * S*		*0.0096*	*0.0828*	*0.0027*	*0.0126*

4. Conclusion and Recommendation

This study focused on the effect of harvest time and storage form on population levels of insect pests and insect damage on maize. The study provides the following insights: Firstly, it shows that insect pest population levels were significantly affected by a delay in harvest. Secondly, a delay in harvest also influenced the damage levels of maize.

The majority of smallholder maize farmers in Ghana continually fail to harvest their produce at the optimum time, which causes major pre-harvest and post-harvest losses. Most farmers delay harvest because of fear of post-harvest losses due to inefficient drying. Inefficient drying of grains leads to higher moisture content, which exposes grains to insect attacks and damage. Maize drying interventions can play a vital role in minimizing postharvest losses, which can also lead to an increase in farmers' income. For instance, in developing countries, the government or other stakeholders may set up more commercial maize dryers in various maize-growing communities. This will enable maize farmers to safely dry their maize to the optimum moisture content levels before storage.

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