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# Differential Resistance of Maize Varieties to Maize Weevil (*Sitophilus zeamais* Motschulsky) (Coleoptera: Curculionidae) under Laboratory Conditions

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## ABSTRACT

A study was conducted with the objectives to determine the resistance of maize varieties to maize weevil, *Sitophilus zeamais*. It was conducted at Jimma University College of Agriculture and Veterinary Medicine in entomology laboratory at room temperature of 25-27°C and 40-60% RH in 2011/2012. The maize varieties were collected from Bako and Holeta Agricultural Research Centers, Ethiopia and local market, Jimma-Merkato. A total of 13 maize varieties were screened for their relative resistance to *S. zeamais*. Dobie index of susceptibility was used to classify the varieties in to different reaction categories. The varieties were significantly different in terms of susceptibility index. Only one variety, 'BHQP-542', had 3.5 index of susceptibility and was regarded as resistant variety to maize weevil attack. However, most of the varieties, namely BH660, BH670, BH543, BHQPY545, Gibe-1, Gibe-2, Wanchi, Argane, Hora and Local variety-Orome, had index of susceptibility 4.6, 5.3, 4.7, 4.8, 4.9, 4.8, 5.2, 5.7, 5.2, 6.0, respectively and are regarded as moderately resistant to maize weevil attack. Two varieties (BH661 and Kuleni) had index of susceptibility 7.11 and 7.09, respectively and are regarded as moderately susceptible varieties to maize weevil attack. The resistant variety produced low numbers of $F_1$ progenies (51.33), had a high median developmental time (48.33 days), a low percentage of seed damage (15.85%), less production of grain dust (powder (0.03%)), low percentage of seed weight loss (4.11%) and high percent weevils mortality (14.24%) and seed germination (93.66 (undamaged) and 86.60% (damaged)). Weevil progenies emergency is significantly and positively associated with seed damage and weight loss but inversely with median development time. The use of resistant varieties in insect pest management is an eco-friendly and cost effective means that should be promoted for *S. zeamais* management in maize especially for small-scale farmers in the tropics.

**Key words:** Maize varieties, resistance, seed infestation, *Sitophilus zeamais,* susceptibility index

## INTRODUCTION

Maize, *Zea mays* L., is an important crop ranking second in world grain production only preceded by wheat. Maize production and distribution is a cosmopolitan (Makate, 2010) and it is an important component of agriculture and food systems all over the world. The crop is versatile in its uses and environmental adaptation. It is consumed all over the world both by human being and animals. Maize grains find themselves in many industries to be processed in to various food and industrial products of multi-purpose functions. In Ethiopia, maize is predominantly used for human consumption; and the crop is a strategic crop selected as one of the national commodity crops to satisfy the food self-sufficiency program of the country. It is the staple food and one of the main sources of calories in the major producing areas (Abebe *et al.*, 2009).

The production and productivity of maize has increased since the development of high yielding hybrid maize varieties by the Ethiopian Institute of Agricultural Research (Bako Agricultural Research Center) in collaboration with other centers. These hybrid varieties are reported to be highly susceptible to insect pest attacks both in the field and storage (Demissie *et al.,* 2008). Hence, farmers are not as such the beneficiaries of the increased production and productivity potential of the varieties. Traditionally, maize grain is stored by Ethiopian farmers, both in and outdoors for consumption and sell in the later months of the year depending on the quantity produced per household. The stored maize is attacked and damaged by several pests that lead to quality deterioration forcing farmers to sell at throwaway price even below the production cost.

Post-harvest losses of maize due to storage insect pests such as the maize weevil (*Sitophilus zeamais*), rice weevil (*Sitophilus oryzae*), angoumois grain moth (*Sitotroga cerealella*) and larger grain borer (*Prostephanus truncatus*) have been recognized as an increasingly important problem in Africa including Ethiopia (Giga *et al.*, 1991; Bekele *et al.*, 1995; Arnason *et al.*, 1997; Dobie, 1977; Abebe *et al.*, 2009; Tefera *et al.*, 2011). Of course, infestation of maize by maize weevil commences in the field (Demissie *et al.*, 2008) but the lion share of the damage to maize grains by maize weevil is done during storage period. Such damaged grains have reduced nutritional values, low percent germination and reduced weight and market values. Giga *et al.* (1991) reported maize grain loss of 20-90% worldwide due to maize weevil, *S. zeamais*. Often, synthetic chemical insecticides are in use to control *S. zeamais*. However, the widespread use of insecticides causes environmental hazards, resistance development, residues accumulation in food and feed and negative effects on non-target organisms apart from continuous increase of their costs unaffordable by poor farmers (Dhuyo and Ahmed, 2007). Today, there is an increased public awareness and concern for the broader environmental safety which directed several insect pest control researches to the development of alternative management strategies. One of such management option is the use of resistant maize varieties against insect pests of maize including *S. zeamais*. The use of resistant varieties is effective, technically easy, environmentally benign, economically feasible and acceptable by the society. Thus, it was deemed necessary to evaluate commercially available maize varieties in Ethiopia for their resistance to *S. zeamais* on the basis of susceptibility index.

## MATERIALS AND METHODS

**Multiplication of *S. zeamais* for the experiment:** *S. zeamais* was multiplied on susceptible maize variety seed to obtain similar aged weevils for the experiments. Twenty kilo gram seed of BH-660 maize variety was bought from the market in Jimma town and cleaned to remove seeds with visible damage symptoms. The cleaned seeds were disinfested in an oven at 40°C for 4 h and kept in the air cooled condenser before use (Bekele *et al.*, 1995). Seeds were then transferred to plastic bags and kept at room conditions for three weeks. Unsexed *S. zeamais* were collected from infested maize seeds and multiplied on clean and disinfested maize seeds (BH-660) in 6 jars (2.0 L capacities). To each jar containing 600 g of seeds, 75 adult weevils were introduced. Then, the jars were covered with muslin cloth and fixed with rubber band to prevent escape of weevils and allow aeration. Ten days after oviposition, all parent weevils were removed from each jar and the seeds were kept under the same experimental conditions (incubator at temperature of 27°C). The insects were multiplied in jars of maize grain for two to three generation to obtain uniform population for the experiment (Abebe *et al*., 2009).

**Collection of maize varieties (the treatments):** A total of thirteen maize varieties, namely BH-660, BH-670, BH-661, BH-543, BHQP-542, BHQPY-545, Wanchi, Argane, Gibe-1, Gibe-2, Kulani, Hora and a local variety-Orome were collected from different sources and used for the experiment. The varieties were collected from Bako and Holeta Agricultural Research Centers and the local variety-Orome was bought from Jimma-Merkato market. Most of the varieties are hybrids developed by National maize research coordination center-Bako Agricultural Research Center and are currently under production in different maize belts of Ethiopia. Freshly harvested seeds of each variety were procured, cleaned and disinfested by keeping them in a deep freezer at -20°C for one week prior to starting the experiments. The seeds were then kept for one week at the experimental conditions (room temperature) for acclimatization (Abebe *et al*., 2009).

**Procedures and experimental designs:** Three hundred gram of each collected maize variety seeds were placed in a one liter glass jar with brass screw lids at the top allowing ventilation and preventing escape of the weevils. No choice test method in which pre-determined weevils were introduced to each jar was used for the study (Abebe *et al*., 2009). Fifty emerged unsexed adult weevils were introduced to each jar to infest 300 g seeds of each variety and were kept for ten days for oviposition (Siwale *et al*., 2009). A control was maintained for each variety without *S. zeamais* for comparison. The treatments were arranged in a Completely Randomized Design (CRD) with three replications each. The experiment was maintained in a laboratory at room temperature (25-27°C) and 40-60% RH.

**Data collected**

**Protein and moisture contents of maize varieties:** Protein and moisture contents of the thirteen varieties of maize were determined before weevils were introduced into each maize variety. The moisture content of the variety was measured by moisture tester and protein contents were determined by, grounding twenty gram sample of whole maize kernel in laboratory mill for each variety, using the Biuret procedure.

**Adult mortality:** Mortality was assessed ten days after introduction of weevils by counting. All insects were removed; dead and alive insects were counted.

**$F_1$ progeny:** In adult mortality data assessment all the dead and alive adult insects were removed from each jar and the seeds of each test variety were kept under the same experimental conditions to further assess $F_1$ progeny emergency for the subsequent two months period (56 days). Inspection of the progenies was made every day were every emerging progeny were removed and counted per jar on each assessment day. This interval of counts did not pose a risk of the $F_1$ progeny laying eggs in the maize samples to produce the $F_2$ generation (Siwale *et al*., 2009).

**Seed damage and weight loss:** Sixty-six days after introduction of the weevils, 200 seeds were randomly taken from each jar to assess each maize variety seed damage (seeds with hole (s)) and grain weight loss. Seed damage was expressed as a proportion of the total number of seeds sampled (Abebe *et al.*, 2009). The count and weight method of Gwinner *et al.* (1996) was used to determine seed weight loss using the formula:

$$W(\%) = \frac{(Wu \times Nd) - (Wd \times Nu)}{Wu \times (Nd + Nu)} \times 100$$

where, W is the weight loss (%), Wu is the Weight of undamaged seed, Nu is the No. of undamaged seed, Wd is the Weight of damaged seed and Nd is the No. of damaged seed.

**Median development time (in days):** The median development period were calculated as the time (in days) from the middle of the oviposition period to the 50% emergency of F1 adults (Dobie, 1977).

**Index of susceptibility:** The Dobie index of susceptibility was used as the criterion to separate varieties into different resistance groups (Dobie, 1977). The index of susceptibility is given by the formula:

$$IS = \frac{LogeX}{MDP} \times 100$$

where, IS is the Dobie's index of susceptibility, $Log_e^X$ is the natural logarithm of the total number of $F_1$ progeny emerged and MDP is the Median development period.

The Dobie Index was used to classify the maize varieties into susceptibility groups following the scales as follows: scale index of ≤4 was classified as resistant; scale index of 4.1-6.0 as moderately resistant; scale index of 6.1-8.0 as moderately susceptible; scale index of 8.1-10 as susceptible; and scale index of >10 was classified as highly susceptible.

**Germination test:** The viability of the varieties was tested by randomly drawing 100-seeds from each variety before and after the grains was damaged by weevils. The randomly selected seeds were placed in Petri dishes containing moistened filter paper and arranged in a CRD with three replications for each variety. The number of emerged seedlings from each Petri dish were counted and recorded after seven days (standard germination period needed for maize seeds). The percent germination (viability index) was computed according to Ogendo *et al.* (2004) adopted from Zibokere (1994) as follows:

$$VI = \frac{NG}{TG} \times 100$$

where, VI stands for Viability index (germination percentage), NG stands for number of seeds germinated from each Petri-dish and TG is the total number of seeds tested in each Petri-dish.

**Data analysis:** All data collected were subjected to analysis of variance (ANOVA) procedures (SAS, 2008) soft ware package 9.2. Tukey test were used to detect mean differences between treatments. Data with regard to percent adult mortality, seed damage and weight loss were subjected to angular-transformation while numbers of $F_1$ progenies were log transformed in order to ensure assumptions of ANOVA before analysis. Then, the transformed data were analyzed using one-way ANOVA. Tukey standardized "Honestly Significant Difference" (HSD) test were used to differentiate statistically different means at 5% level of significance whenever the means were found significant for pair wise comparison of the treatments.

## RESULTS

**Crude protein and moisture contents of maize varieties:** Crude protein and moisture contents of the thirteen varieties of maize were determined before weevils were introduced into the jars containing maize varieties. The varieties were highly significantly different ($p<0.05$) for crude protein and moisture contents (Table 1). The variety BHQPY-545 contained relatively high and significant crude protein content (8.59%). On the other hand, varieties such as BH-660 (7.10%), Kuleni (7.15%), Orome (7.21%), Hora (7.24%), Argane (7.24%) and BH-670 (7.25%) were found to contain statistically similar and significantly less amount of crude protein content. Varieties such as Kuleni (11.53%) and BH-661 (11.50%) contain relatively higher and significant moisture content were as varieties such as BHQP-542 (9.30%), BH-670 (9.63%), BH-660 (9.70%), BHQPY-545 (9.70%), Hora (9.70%) and Gibe-2 (9.73%) were found to contain significantly lower moisture content as compared to other varieties.

**Adult mortality, $F_1$ progeny emergency and median development time (days):** Percentage adult mortality, $F_1$ progeny emergency and median development period among the varieties was significantly different ($p<0.05$) (Table 2). Maximum and significantly higher weevil's adult mortality was recorded from variety BHQP-542 (14.24%) followed by Gibe-2 (10.41%) and Gibe-1 (10.09%). There was no mortality recorded from BH-660 and BH-661. Among all the maize varieties tested, maximum and significant numbers of $F_1$ progenies were emerged from BH-661(326.00) and Kuleni (322.33) while significantly lower number of $F_1$ progenies was emerged from BHQP-542 (51.33). The median development period ranged from 35.33 days for BH-661 to 48.33 days for BHQP-542 maize variety. Generally, as the median development period increases the $F_1$ progeny emergency decreases were as the percentage adult weevil mortality increases.

Table 1: Crude protein and moisture contents of different maize varieties

| Variety | Crude protein content (%) | Moisture content (%) |
|---|---|---|
| BH-660 | 7.10[e] | 9.70[d] |
| BH-543 | 7.51[d] | 9.86[cd] |
| BH-670 | 7.25[e] | 9.63[d] |
| BH-661 | 7.68[cd] | 11.50[a] |
| BHQP-542 | 8.24[b] | 9.30[d] |
| BHQPY-545 | 8.59[a] | 9.70[d] |
| Gibe-1 | 8.21[b] | 9.80[cd] |
| Gibe-2 | 8.20[b] | 9.73[d] |
| Kuleni | 7.15[e] | 11.53[a] |
| Wanchi | 7.77[c] | 9.83[cd] |
| Argane | 7.24[e] | 10.38[bc] |
| Hora | 7.24[e] | 9.70[d] |
| Orome | 7.21[e] | 10.53[b] |
| P value | <0.0001** | <0.0001** |
| CV | 1.58 | 2.05 |
| LSD | 0.22 | 0.62 |

**Highly significant, CV: Coefficient of variation, LSD: Least significant difference, Values (Means) followed by same letter with in the column are not significantly different at $p<0.05$

Table 2: Adult mortality, $F_1$ progeny and median development period (MDP) of *S. zeamais* on different maize varieties

| Varieties | Adult mortality (%) | No. of $F_1$ progenies emerged | MDP (days) |
|---|---|---|---|
| BH-660 | 1.81$^{h}$ | 106.17$^{g}$ | 44.00$^{b}$ |
| BH-543 | 8.78$^{c}$ | 130.33$^{f}$ | 44.66$^{b}$ |
| BH-670 | 8.19$^{d}$ | 163.00$^{d}$ | 42.00$^{c}$ |
| BH-661 | 1.81$^{h}$ | 326.00$^{a}$ | 35.33$^{f}$ |
| BHQP-542 | 14.24$^{a}$ | 51.33$^{h}$ | 48.33$^{a}$ |
| BHQPY-545 | 8.13$^{d}$ | 155.33$^{de}$ | 41.30$^{cd}$ |
| Gibe-1 | 10.09$^{b}$ | 152.33$^{de}$ | 41.40$^{c}$ |
| Gibe-2 | 10.41$^{b}$ | 143.66$^{ef}$ | 41.60$^{c}$ |
| Kuleni | 2.66$^{g}$ | 322.33$^{a}$ | 35.36$^{f}$ |
| Wanchi | 8.19$^{d}$ | 151.33$^{de}$ | 41.83$^{c}$ |
| Argane | 3.63$^{e}$ | 205.00$^{c}$ | 40.16$^{d}$ |
| Hora | 8.13$^{d}$ | 152.00$^{de}$ | 42.33$^{c}$ |
| Orome | 3.15$^{f}$ | 253.00$^{b}$ | 38.16$^{e}$ |
| P value | <0.0001** | <0.0001** | <0.0001** |
| CV | 1.86 | 3.57 | 0.95 |
| LSD | 0.43 | 18.86 | 1.17 |

**Highly significant, CV: Coefficient of variation, LSD: Least significant difference, Values (Mean) followed by same letter with in the column are not significantly different at p<0.05

Table 3: Extent of infestation of maize varieties due to maize weevil, *S. zeamais*

| | Infestation (%) | | |
|---|---|---|---|
| Varieties | Mean seed damage | Mean weight loss | Mean dust (powder) produced |
| BH-660 | 30.76$^{e}$ | 5.83$^{g}$ | 0.24$^{f}$ |
| BH-543 | 31.46$^{de}$ | 6.55$^{fg}$ | 0.28$^{e}$ |
| BH-670 | 33.95$^{bcd}$ | 7.92$^{de}$ | 0.28$^{e}$ |
| BH-661 | 46.80$^{a}$ | 13.77$^{a}$ | 0.83$^{a}$ |
| BHQP-542 | 15.85$^{g}$ | 4.11$^{i}$ | 0.03$^{g}$ |
| BHQPY-545 | 33.29$^{de}$ | 8.72$^{d}$ | 0.28$^{e}$ |
| Gibe-1 | 33.36$^{cde}$ | 5.76$^{gh}$ | 0.28$^{e}$ |
| Gibe-2 | 26.18$^{f}$ | 4.80$^{hi}$ | 0.28$^{e}$ |
| Kuleni | 45.02$^{a}$ | 12.83$^{a}$ | 0.80$^{b}$ |
| Wanchi | 31.65$^{de}$ | 8.72$^{d}$ | 0.28$^{e}$ |
| Argane | 35.28$^{bc}$ | 10.08$^{c}$ | 0.71$^{d}$ |
| Hora | 33.33$^{de}$ | 6.96$^{ef}$ | 0.28$^{e}$ |
| Orome | 36.21$^{b}$ | 11.24$^{b}$ | 0.74$^{c}$ |
| P value | <0.0001** | <0.0001** | <0.0001** |
| CV | 2.79 | 3.99 | 0.81 |
| LSD | 2.75 | 0.97 | 0.01 |

**Highly significant, CV: Coefficient of variation, LSD: Least significant difference, *Values followed by same letter with in the column are not significantly different at p<0.05

Varieties with high $F_1$ progeny emergency tended to have shorter median development period and very minimum percentage adult mortality.

**Seed infestation (seed damage, weight loss and dust or powder weight):** Significance difference (p<0.05) was recorded among the varieties with respect to maize seed damage, weight loss and percentage dust produced from the different varieties (Table 3). The highest and significantly different percentage seed damage was observed from BH-661(46.80%) and

Table 4: Index of susceptibility (IS) of maize varieties to maize weevil, *S. zeamais*

| Varieties | Dobie's IS | Classification |
|---|---|---|
| BH-660 | 4.60$^{g}$ | Moderately resistance |
| BH-543 | 4.70$^{fg}$ | Moderately resistance |
| BH-670 | 5.30$^{d}$ | Moderately resistance |
| BH-661 | 7.10$^{a}$ | Moderately Susceptible |
| BHQP-542 | 3.50$^{h}$ | Resistance |
| BHQPY-545 | 4.80$^{fe}$ | Moderately resistance |
| Gibe-1 | 4.90$^{e}$ | Moderately resistance |
| Gibe-2 | 4.80$^{fe}$ | Moderately resistance |
| Kulani | 7.09$^{a}$ | Moderately Susceptible |
| Wanchi | 5.20$^{d}$ | Moderately resistance |
| Argane | 5.70$^{c}$ | Moderately resistance |
| Hora | 5.20$^{d}$ | Moderately resistance |
| Orome | 6.00$^{b}$ | Moderately resistance |

CV = 1.19, LSD = 0.18 ,Values (means) followed by same letter with in the column are not significantly different at $p<0.05$

Kulani (45.02%) maize varieties. The trend was similar with respect to weight loss and percent dust produced. On the contrary, significantly lower percentage seed damage (15.85%), weight loss (4.11%) and dust production (0.03%) was observed in BHQP-542 maize variety. Percentage seed damage, weight loss and dust production were high from the varieties with more number of $F_1$ progeny emergency.

**Index of susceptibility (IS):** Significant differences ($p<0.05$) were observed in the index of susceptibility (IS) among the varieties tested (Table 4). The IS ranged from 3.50 for BHQP-542 to 7.10 for BH-661. Out of the thirteen maize varieties tested against *S. zeamais* for resistance, only one variety 'BHQP-542', had 3.5 index of susceptibility and was regarded as resistant to weevil attack. However; most of the varieties, namely BH-660, BH-670, BH-543, BHQPY-545, Gibe-1, Gibe-2, Wanchi, Argane, Hora and Local variety-Orome had index of susceptibility 4.6, 5.3, 4.7, 4.8, 4.9, 4.8, 5.2, 5.7, 5.2 and 6.0, respectively and are regarded as moderately resistance to weevil attack. Two varieties (BH-661 and Kuleni) had index of susceptibility 7.10 and 7.09, respectively and are regarded as moderately susceptible varieties to maize weevil attack.

**Germination test:** Viability index (germination percentage) among the varieties (undamaged and damaged seeds) was significantly different ($p<0.05$) (Table 5). Generally, high percent of germination were recorded on the treatments of undamaged grain when compare to damaged grain for each test variety. Maximum viability (94.83%) was recorded from BHQPY-545 on par with the most resistant variety, BHQP-542 (93.66%) where as minimum was from Wanchi (82.46%) in undamaged seeds. In damaged grain significantly higher percent of germination were recorded from variety BHQP-542 (86.60%) and significantly lower percent germination was recorded from BH-661 (29.50%) and Kulani (31.83%). The resistant variety registered better germination even after weevils attack and the more susceptible variety registered very poor germinability.

**Simple correlation coefficient of the variables:** The simple linear association between variables like weight loss, grain damage, germination percentage, dust or powder produced, moisture content, crude protein content, adult mortality, median development period, $F_1$ progenies emergency and susceptibility index were determined and summarized (Table 6).

Table 5: Mean germination of maize varieties due to maize weevil, *S. zeamais*

| | Germination (%) | |
|---|---|---|
| Varieties | Undamaged grain | Damaged grain |
| BH-660 | $85.16^{edf}$ | $75.06^{b}$ |
| BH-543 | $87.83^{edc}$ | $74.10^{b}$ |
| BH-670 | $89.83^{bdc}$ | $75.10^{b}$ |
| BH-661 | $79.06^{g}$ | $29.50^{f}$ |
| BHQP-542 | $93.66^{ba}$ | $86.60^{a}$ |
| BHQPY-545 | $94.83^{a}$ | $70.70^{cb}$ |
| Gibe-1 | $81.16^{gf}$ | $66.91^{c}$ |
| Gibe-2 | $91.00^{bac}$ | $70.06^{cb}$ |
| Kuleni | $83.33^{egf}$ | $31.83^{fe}$ |
| Wanchi | $82.46^{gf}$ | $60.40^{d}$ |
| Argane | $83.46^{egf}$ | $54.16^{d}$ |
| Hora | $82.76^{gf}$ | $68.66^{cb}$ |
| Orome | $84.90^{ef}$ | $38.06^{e}$ |
| P value | <0.0001** | <0.0001** |
| CV | 1.86 | 3.53 |
| LSD | 4.76 | 6.44 |

**Highly significant, CV: Coefficient of variation, LSD: Least significant difference, *Means followed by same letter with in the column are not significantly different at $p<0.05$

Table 6: Pearson correlation coefficients of *S. zeamais* infestation

| | IS | mor | $F_1P$ | moi | pro | mdp | wl | dam | dust | germ |
|---|---|---|---|---|---|---|---|---|---|---|
| IS | 1 | | | | | | | | | |
| mor | -0.74** | 1 | | | | | | | | |
| $F_1P$ | 0.98** | -0.71** | 1 | | | | | | | |
| moi | 0.89** | -0.69** | 0.93** | 1 | | | | | | |
| pro | -0.44* | 0.59** | -0.35 | -0.29 | 1 | | | | | |
| mdp | -0.98** | 0.75** | -0.95** | -0.87** | 0.52** | 1 | | | | |
| wl | 0.92** | -0.72** | 0.94** | 0.89** | -0.43* | -0.91** | 1 | | | |
| dam | 0.93** | -0.78** | 0.91** | 0.84** | -0.45* | -0.91** | 0.87** | 1 | | |
| dust | 0.92** | -0.71** | 0.95** | 0.89** | -0.44* | -0.91** | 0.91** | 0.83** | 1 | |
| germ | -0.75** | 0.76** | -0.74** | -0.73** | 0.48* | 0.76** | -0.73** | -0.71** | -0.75** | 1 |

*,**Significant at 0.05 and 0.01 probability level, respectively, wl: Seed weight loss, dam: Damaged seeds, germ: Seed germination, dust: Dust or powder produced, moi: Moisture, pro: Protein, mor: Contents, adult mortality, mdp: Median development period, $F_1P$: No. of weevils produced and IS: Index susceptibility

It is evident from Pearson Correlation Coefficients (r) that an inverse relationship existed between the susceptibility index (IS) and percent adult mortality (mor), median developmental period (mdp), percent germination (germ) and crude protein content (pro). However, the numbers of $F_1$ progeny emergency ($F_1P$), percent damaged grain (dam), percent dust produced (dust), moisture content (moi) and seed weight loss (wl) were positively related with the susceptibility index. The median development period appeared to be negatively and significantly associated with $F_1$ progeny emergency (r = -0.95) and positively associated with percentage adult weevil's mortality (r = 0.75). Further, with increasing number of $F_1$ progenies, there was an increasing and highly significant percentage seed damage (r = 0.91), weight loss (r = 0.94) and dust produced (r = 0.95) from the varieties.

## DISCUSSION

In this study, considerable variation was observed among the maize varieties tested with respect to the different variables studied. This indicates that the impact of *S. zeamais* on different maize varieties under production in Ethiopia differs. This difference in the susceptibility of the maize varieties is due to the differences in the ability of a particular variety to resist *S. zeamais* attack. The resistant maize variety produced small quantity of powder/dust; is with minimum weight loss and grain damage, high germination of seeds, less moisture contents, more adult mortality, long median development period and less multiplication of the *S. zeamais*. Resistant variety seeds were less attractive to maize weevil to feed on when compared to the susceptible varieties; this indicates that probably antibiosis cum non-preference are the mechanism of resistance operating within the resistant variety of maize seeds.

More maize weevils were found in maize varieties with higher moisture content, suggesting that moisture plays an important role in maize susceptibility to insects' pests. The seed size of the grains varied considerably among the varieties and there exist a relationship between size and moisture content of the varieties tested. Smaller seeds that were hard and compact had less moisture and were therefore, more resistant to the maize weevil attack. On the other hand bigger grains were loose, soft and contain higher moisture and hence more weevils emerged and are easily attacked by the weevils.

Maize varieties were significantly different with respect to weevils' mortality. However, weevil's adult mortality percentage was generally low with a maximum of 14.24% (from the resistant variety) and minimum of 1.81% (from the moderately resistant and susceptible varieties) and is not a good indicator of susceptibility and or resistance of the varieties. Similarly, Dobie (1974) stated that overall rate of mortality of maize weevils on different maize varieties as low and concluded that there was no evidence for a variation among the varieties in their effects upon the mortality of *S. zeamais*. Also, Abebe *et al.* (2009) found non-significant differences among thirteen maize varieties tested against *S. zeamais*. Adult weevils can survive without food for more than ten days in a laboratory test. These indicate weevil's mortality is not a good indicator of resistance in maize varieties. Never the less, less adult weevils mortality in storage is an indication of more number of egg laying from the survived adult weevils leading to more number of $F_1$ progenies emergency.

Mean number of $F_1$ progenies produced from the different maize varieties were highly variable ranging from 51.33 (in the resistant variety-BHQP-542)-326.00 (in the most susceptible variety-BH-661). More number of progenies productions is strongly associated with more susceptibility of the variety indicating the attractiveness/conduciveness of the varieties for maize weevils to flourish. On such susceptible varieties maize weevils required less developmental time (35.33 days) were as they required longer time on the resistant variety, BHQP-542 (48.33 days) displaying minimum index of susceptibility. Thus, less mortality and more number of progenies production is associated with more infestation to the maize seeds resulting to greater grain loss. Less number of days to complete the life cycle causes more number generations in a year compounding the damage they cause to maize grains. Tefera *et al.* (2011) and Tadesse (1991) indicated that the extent of damage during storage depends on the number of emerging adults during each generation and the duration of each life cycle and varieties permitting more rapid and higher levels of adult emergence are more seriously damaged. Differential reaction of maize varieties to maize weevil have been reported by several authors (Horber, 1988; Giga *et al.*, 1991; Arnason *et al.*, 1993). Similarly, Garcia-Lara *et al.* (2004) indicated that progeny emergency tended to be higher in susceptible genotypes than in resistant ones.

In this experiment, among thirteen maize varieties tested for their resistance to maize weevils, *S. zeamais*, only one variety (BHQP-542), was found resistant to maize weevils based on susceptibility indices. Further, two varieties, BH-661 and Kuleni were moderately susceptible and the remaining ten varieties were moderately resistant. BHQP-542 is a Bako hybrid quality protein maize and resistant to *S. zeamais*. This variety is of compact small sized seeds and contained less moisture which might have contributed for its resistance. Abebe *et al*. (2009) identified the same variety as resistant variety of maize against *S. zeamais*. According to them, the resistance of this variety is attributed due to high tryptophan and lysine content of the variety relative to the other varieties tested. Further, Arnason *et al*. (1993) also indicated protein content was negatively correlated with the susceptibility of maize varieties to *S. zeamais*. On the contrary, this study revealed that there is no consistent relationship between protein content of the maize varieties and resistance to weevil's infestation suggesting the existence of other factors for resistance which need to be further investigated. Arnason *et al*. (1997) reported ferulic acid in the kernels as contributing factor to confer resistance to maize seeds against maize weevil's attack.

The number of insect pest recorded in each maize variety did not vary according to the variation of protein content of the maize varieties. Thus, the authors suggest further study in order to establish the protein content and susceptibility indices of more maize varieties/genotypes/landraces. Moreover, study conducted at CIMMYT (CIMMYT, 2001) revealed the positive association of grain moisture content and maize varieties susceptible to weevil's damage. Grain seeds with higher moisture contents are more susceptible to maize weevil's attack. Similarly, in this study, the moderately susceptible maize varieties (Kuleni and BH-661) are with more moisture contents and bigger seed size. Tongjura *et al*. (2010) indicated the existence of no correlation between nutrient content of maize varieties and their susceptibility to *S. zeamais*. However, they stated variability in the size of the grains among maize varieties does influence the level of damage caused by maize weevils. Smaller seeds that were hard and compact had less moisture and were therefore, more resistant to the maize weevil attack. On the other hand bigger grains were loose, soft and contain higher moisture and hence more easily attacked by the weevils. The harder a seed is, the more resistant it is to storage pests, such as the maize weevils. Kevin (2002) reported seed hardness and thickness, both in the pericarp and the whole kernel confer resistance because such seeds are very hard to penetrate by the weevils. Siwale *et al*. (2009) reported undamaged pericarp serves as barrier against weevils and so reduced the number of insects' progeny emergency. Bergvinson (2004) mentioned maize with tighter husks or a harder kernel are insect resistant variety.

Siwale *et al*. (2009) reported, sugar content as the responsible factor contributing to grain resistance to weevils attack in maize seed. Many workers reported a tendency of increased nutrients in maize varieties association with resistance to weevils attack (Derera *et al*., 2001; Dhliwayo and Pixley, 2003; Garcia-Lara *et al*., 2004).

Percent germination of maize varieties was higher in undamaged grains when compared with damaged kernel. In damaged grain high percent germination was recorded from BHQP-542 (86.60%) when compared to the other varieties. This may be because of less number of $F_1$ progenies emergency from this variety. Viability percentage is low, on the other hand, from BH-661, Kulani, Orome and Argane (29.50, 31.80, 38.06 and 54.16%, respectively), because of higher number of $F_1$ progeny emergency from these varieties. This is in conformity with the work of Martha (2010), who reported that when the number of progeny emerged were high; the endosperms were totally lost therefore, germination was inhibited. Kassa (1993) associated poor viability of haricot bean seeds (reduced germination) with more number of Mexican bean weevil emergence per grain seed.

## CONCLUSION

It can be concluded that there exists differential reaction of different maize varieties currently under production in Ethiopia. From the present study, the most resistant variety among the varieties tested is BHQP-542. This may be due to the differences of this variety from the other varieties in its morphological and biochemical constituents that confer resistance and reduced the successful utilization of itself by maize weevil, *S. zeamais*. BHQP-542 is a variety with less moisture content, $F_1$ progenies emergency, maize seed damage and weight loss, maize dust produced, indices of susceptibility; and more adult mortality, median development time and seed viability. These indicate that the overall loss incurred to this variety during storage will be minimal as compared to other varieties available in the country. This variety can be stored for longer periods of time under traditional storage system of small-scale farmers with reduced cost of weevil's management and no adverse effect on the environment. Thus, the authors suggest the inclusion of this resistant maize variety in the integrated maize production system and the need for further field level studies.

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## REFERENCES

Abebe, F., T. Tefera, S. Mugo, Y. Beyene and S. Vidal, 2009. Resistance of maize varieties to the maize weevil *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). Afr. J. Biotechnol., 8: 5937-5943.

Arnason, J.T., B. Baum, J. Gale, J.D.H. Lambert and D. Bergvinson *et al*., 1993. Variation in resistance of Mexican landraces of maize to maize weevil *Sitophilus zeamais*, in relation to taxanomic and biochemical parameters. Euphytica, 74: 227-236.

Arnason, J.T., B.B. Conilh, B.J.R. Philogene and D.J. Bergvinson *et al*., 1997. Mechanism of Resistance in Maize Grain to the Maize Weevil and the Larger Grain Borer. In: Insect Resistance Maize: Recent Advances and Utilization, Mihm, J.A. (Ed.). CIMMYT, Mexico, pp: 91-95.

Bekele, J.A., D. Obengofori, A. Hassanali and G.H.N. Nyamasyo, 1995. Products derived from the leaves of *Ocimum kilimandscharicum* as post-harvest grain protectants against the infestation of three major stored product insect pests. Bull. Entomol. Res., 85: 361-367.

Bergvinson, D., 2004. Reducing damage to grain stores of the poor. http://www.cimmyt.org/en/newsletter/120-2004/412-reducing-damage-to-grain-stores-of-the-poor

CIMMYT, 2001. Maize Research High Lights 1999-2000. International Maize and Wheat Improvement Center, CIMMYT, Mexico.

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: 3774-3779.

Derera, J., P.D. Giga and K.V. Pixley, 2001. Resistance of maize to the maize weevil: II. Non-preference. Afr. Crop Sci. J., 9: 441-450.

Dhliwayo, T. and K.V. Pixley, 2003. Divergent selection for resistance to maize weevil in six maize populations. Crop Sci., 43: 2043-2049.

Dhuyo, A.R. and S. Ahmed, 2007. Evaluation of fungus *Beauveria bassiana* (Bals.) Infectivity to the larger grain borer *Prostephanus trncatus* (Horn.). Pak. Entomol., 29: 77-82.

Dobie, P., 1974. The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais* Motsch. (Coleoptera, Curculionidae). J. Stored Prod. Res., 10: 183-197.

Dobie, P., 1977. The contributions of tropical stored products centre to the study of insect resistance in stored maize. Trop. Stored Prod. Inform., 3: 7-22.

Garcia-Lara, S., D.J. Bergvinson, A.J. Burt, A.I. Ramputh, D.M.D. Pontones and J.T. Arnason, 2004. The role of pericarp cell wall components in maize weevil resistance. Crop Sci., 44: 1546-1552.

Giga, D.P., S. Mutemerewa, G. Moya and D. Neeley, 1991. Assessment and control of losses caused by insect pests in small farmers stores in Zimbabwe. Crop Prot., 10: 287-292.

Gwinner, J., R. Harnish and O. Muck, 1996. Manual on the Prevention of Post Harvest Grain Loss. GTZ, Eschborn, Germany, pages: 334.

Horber, E., 1988. Methods to detect and evaluate resistance in maize to seed insects in the field and in storage. Proceedings of the International Symposium on Methodologies on Developing Host Plant Resistance to Maize Insects, March 9-14, 1987, CIMMYT, Mexico, pp: 140-150.

Kassa, A., 1993. Damage to weight and germination of haricotbean caused by the Mexican bean weevil, *Zabrot subfasciatus* Boh. (Coleoptera: Burchidea) at bako western Ethiopia. Proceedings of the 1st Annual Conference of the Crop Protection Society of Ethiopia, February 26-27, 1993, IR, Addis Ababa, Ethiopia.

Kevin, J.M., 2002. Maize Kernel Components and their Roles in Maize Weevil Resistance. International Center for the Improvement of Wheat and Maize (CIMMYT). Mexico.

Makate, N., 2010. The susceptibility of different maize varieties to postharvest infestation by *Sitophilus zeamais* (Motsch) (Coleoptera: Cuculionidae). Scientific Res. Essay, 5: 030-034.

Martha, M., 2010. Studies on susceptibility of different pulse grains to *Callosobruchus chinensis* (L.)(Coleoptera: Bruchidae) under laboratory condition. M.Sc. Thesis, AU, Addis Ababa University, Addis Ababa, Ethiopia.

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.

SAS, 2008. SAS/STAT 9.2 Version User's Guide. SAS Institute Inc., Cary, North Carolina, USA.

Siwale, J., K. Mbata, J. Mcrobert and D. Lungu, 2009. Comparative resistance of improved maize genotype and landraces to maize weevil. Afr. Crop Sci. J., 17: 1-16.

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.

Tefera, T., S. Mugo and P. Likhayo, 2011. Effects of insect population density and storage time on grain damage and weight loss in maize due to the maize weevil *Sitophilus zeamais* and the larger grain borer *Prostephanus truncatus*. Afr. J. Agric. Res., 6: 2249-2254.

Tongjura, J.D.C., G.A. Amuga and H.B. Mafuyai, 2010. Laboratory assessment of the susceptibility of some varieties of zeamais infested with *Sitophilus zeamais* Motsch (Coleoptera: Culcleonidea). Sci. World J., 5: 55-57.

Zibokere, D.S., 1994. Insecticidal potency of red pepper (*Capsicum annuum*) on pulse beetle (*Callosobruchus maculatus*) infesting cowpea (*Vigna unguiculata*) seeds during storage. Indian J. Agric. Sci., 64: 727-728.