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SUSCEPTIBILITY OF PRO-VITAMIN A BIOFORTIFIED MAIZE GENOTYPES TO *SITOPHILUS ZEAMAIS* (Mots) IN GHANA

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ABSTRACT

Pro-Vitamin A Biofortified maize is one of the crops with the cheapest and most sustainable option for preventing Vitamin A deficiency in humans in Ghana. It is also a key energy component of feed for layer chicken, forming about 60-70% of the total feed. *Sitophilus zeamais* is one of the most serious primary internal feeding pests of maize and other grains in sub-Saharan Africa. It causes both quantitative and qualitative grain losses. Two no - choice laboratory experiments in 112 days cumulative feeding of *S. zeamais* and 60 days susceptibility of six pro-Vitamin A Biofortified Maize (PVABM) genotypes to the insect were conducted. The experimental designs were Completely Randomized Design in four replications. Percentage grain damage and weight loss were significantly lower ($P<0.05$) in Aburokokoo than the other genotypes. Significantly more *S. zeamais* emerged from Accession GH2354 which also had significant ($P<0.05$) higher percentage grain damage than other genotypes. In the 60-day susceptibility experiment, grain hardness had significant ($P<0.05$) negative correlation with F_1 progeny, index of susceptibility and protein content but positive significant correlation with median development period. Large number of *S. zeamais* F_1 progeny, high susceptibility index, high protein, low total carbohydrate content, short median development time with low grain hardness value were observed on accession GH2354. Aburokokoo had significantly ($P<0.05$) small number of F_1 progeny, low index of susceptibility, low protein and high total carbohydrate, long development period and intermediate value of grain hardness. The ascending order of grain hardness among the maize genotypes was GH2354<Obatanpa <Aburokokoo<Abontem<Honampa<Ahoodzin. There was no relationship between grain length, width and thickness and grain susceptibility. A cluster dendrogram obtained from the maize genotypes with regard to resistance parameters to *S. zeamais* showed that accession GH2354 and Obatanpa-QPM were susceptible, Ahoodzin, Honampa and Abontem were moderately resistant, with Aburokokoo resistant to the maize weevil infestation.

Key words: Biofortified maize, stored produce, insect pest, Vitamin A deficiency, grain damage

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INTRODUCTION

Maize (*Zea mays* L.) is Ghana's most important cereal crop and is cultivated in all parts of the country. It is the second most important staple food in Ghana, next to cassava [1]. In most industrialized nations maize is largely used as livestock and poultry feed and also as raw material for industrial products, while in the low-income countries, it is largely used as a staple [2]. Cultivation and consumption of white maize predominate in Ghana. However, demand for yellow maize is for poultry and animal feed is on the increase. Poultry farmers prefer pro-Vitamin A biofortified maize or yellow maize for layer and egg production, of which most is imported. When yellow maize is fed poultry, it gives a deep yellow colouration to egg yolk, poultry skin, and animal fats as reported by Anthony; Iken and Amusa [3, 4] which consumers attribute to healthiness and freshness. Field survey results on utilization of yellow maize as poultry feed in layers and egg production in Bono and Ashanti regions by Baomah [5] revealed benefits such as egg yolk and skin colour, brown shanks/legs colour, shiny and bright feathers, and low feed conversion ratio. Coupled with its utilization as the main source of energy in the feed for layers in egg production, pro-Vitamin A biofortified maize, is cheaper, sustainable, convenient, and an easy source of Vitamin A. Human beings as well as animals are unable to synthesize their own Vitamin A and rely on dietary pro-Vitamin A carotenoid pigments [6]. Most of the maize that is produced and consumed in sub-Saharan Africa is white and devoid of pro-Vitamin A carotenoids [7]. Vitamin A deficiency is prevalent in sub-Saharan Africa and a major public health problem. According to FAO [8], there are only two countries in the world, Sao Tome et Principé (95.6%) and Kenya (84.4%) with more severe Vitamin A deficiencies prevalence than Ghana (75.8%).

In sub-Saharan Africa, large quantities of maize produce by small-scale farmers are lost between harvest and consumption [9]. Greater losses of maize caused by insect pests occur in storage, especially where it is kept for a relatively long time for future utilization [10]. The most serious insect pest that causes severe damage to maize in storage is the maize weevil. *Sitophilus zeamais* Mots (Coleoptera: Curculionidae) infestation often begins in the field, but severe damage is done in storage. Heavy weevil infestation may cause weight losses of as much as 30-40% [11, 12]. It has also been reported by Nwosu [13] that the maize weevil causes severe quantitative and qualitative losses in stored maize grain in Africa.

The use of conventional broad spectrum synthetic insecticides is the main method of controlling weevil infestation in stored maize [13]. The use of these chemical insecticides to control weevil is bedeviled with challenges including environmental

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pollution, building of resistance to the chemical, presence of chemical residues in foods, health risk to maize consumers and applicators. The cost of the pesticide is exorbitant, and its application is either not permitted or restricted. Its action is broad-spectrum, and further impacts non-target organism [14, 15]. Biological control methods, which are environmentally friendly are perceived as not feasible under most storage conditions due to customers' low acceptance of any insect inside processed foods. Additionally, some insects can migrate to areas with no or fewer biological agents [16]. Increase in public education on environmental safety has led to reorientation of research to focus on development of alternative management strategies. Cost-effective and environmentally friendly methods of reducing maize weevil damage is needed in sub-Saharan Africa [17]. However, much hope lies in varietal resistance, plant-products, and biopesticides use against storage pests [18]. Economically and socially, the use of host plant resistance, and plant and animal-derived insecticides as strategies in post-harvest control of weevil infesting maize grain is acceptable. Again, it is well known from various stored product entomologists that no variety of stored maize is immune or resistant to maize weevil infestation, as each has an element of susceptibility depending on the exposure period and other interacting environmental factors.

The use of plant-host/varietal resistance should be combined with plant and animal-derived insecticides, biopesticides in an Integrated Pest Management against stored grain pests.

The main objective of the study was to evaluate the susceptibility of pro-Vitamin A Bio fortified maize genotypes to *S. zeamais*.

MATERIALS AND METHODS

Maintenance of insect culture

The parent stock of adult *S. zeamais* was obtained from the insectary of Entomology Section of the Department of Crop and Soil Sciences of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. An improved white maize variety Omankwa was obtained from CSIR-Crops Research Institute for the culturing. The maize grains were cleaned and sterilized by storing at -20°C for one week. Two hundred unsexed adults of *S. zeamais* were introduced into 600 g whole maize grain in 1.5 L Kilner jar. The opening of the Kilner jar lids was covered with metal gauze and a muslin cloth to firmly secure them to prevent possible escape or re-infestation. The insects were allowed to oviposit for 14 days after which they were sieved out. The F_1 adult of the insect that emerged were introduced into another 600 g sterilized whole grain

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maize in 1.5 L Kilner jars containing the Omankwa variety and the resulting F_2 adults were used for the experiments. This was to ensure insects of the same age were always available for the experiment [19]. The cultures were maintained under a relative humidity of 70 ± 5% and temperature of 28 ± 2°C and 12L:12D photo regimes [20].

Grain for the laboratory experiments

A clean harvest of sun-dried, pro-Vitamin A Biofortified Maize genotypes namely Abontem, Honampa, Ahoodzin obtained from (CSIR-CRI), GH2354 (maize accession from CSIR-PGRRI), Aburokokoo (Poultry farmers´ stored maize in Dormaa East District) and Obatanpa (QPM: CSIR-CRI)) were used for the laboratory experiments. The moisture content of the grain was determined using John Deere Grain Moisture tester (Moisture Chek Plus ™ SW08120, U.S.A)

Sexing of *S. zeamais* for the laboratory experiments

F_1 adult maize weevils were sexed using the method described by Ojo and Omoloye; Rees [12, 21].

Cumulative feeding effect and emergence of *S. zeamais*

Five pro-Vitamin A Biofortified Maize (PVABM) were evaluated in two no-choice laboratory experiments in 112 days cumulative feeding and 60 days susceptibility tests against *S. zeamais*. The five PVABM genotypes used were GH2354, Aburokokoo, Abontem, Honampa, and Ahoodzin. Obatanpa (white maize) was used as a check. There were six treatments arranged in a Completely Randomized Design in four replications. Each experimental unit consisted of 400 g of sterilized maize genotype in a 1-liter glass container. Twenty newly emerged F_2 adults of *S. zeamais* 10 males and 10 females were sexed and put on each experimental unit for 8 days and subsequently sieved out. Data was collected at 4, 8, 12, and 16 weeks after the experiment was set-up. For each sampling date, the content of each experimental unit was sieved using a set of standard U S A sieve series (2.00 mm and 0.710 mm). After sieving, 100 grains were randomly sampled from each sample for the assessment and data collection. After data collection live adult insects were counted and placed back on the maize variety in their respective jars, and dead adult insects were discarded after taking data. Immobile insects that were unresponsive to three probes with a blunt dissecting probe after 5 minutes recovery period was considered dead [22].

Effect of maize susceptibility on the emergence of *S. zeamais*

Fourteen days before the experiment, all the adult insects in the culture were sieved out. The fresh or live adult insects, which emerged between 0-8 days were

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sieved sexed and used to infest the experimental maize stock at 70 ± 5 % relative humidity and a temperature of 28 ± 2°C. An average of 50 g maize grain in four replications was taken from each variety and placed in a 1000 ml glass container covered with muslin cloth and fastened with a metal lid. Each container with a maize variety was infested with 10 males and 10 females of 0- 8-day old adults. The insects were placed on the infested free maize genotypes for 8 days and removed. The daily count of the insect for data collection began 25 days after the onset of the experiment. The progeny of adult insects that emerged were counted and removed until the emergence of the new last weevil.

The susceptibility index (SI) was determined using the formula

$$SI = \frac{\mathrm{LogeX}}{\mathrm{MDP}} X\ 100$$

Where LogeX is the natural logarithm of the total number of F_1 progeny that emerged and MDP is the median development period.

The median development period was calculated as the time (in days) from the middle of the oviposition period to the 50% emergence of F_1 adults [23].
The following data, percentage of grains infested (attacked) by insects, grain weight loss, number of live adults, number of dead adults, weight of insect-damaged kernels and weight of undamaged kernels were collected on the storage insects.

Percentage Damage
100 maize grains from each treatment were randomly sampled from the sub-samples by the cone and quarter method. Bored maize grains were separated from whole grains and their numbers recorded. Percentage of damaged maize grains was calculated using the formula described by Adams and Schulten [24].

$$\%\ \text{Damaged grains} = \frac{\text{Number of bored grains}}{\text{Total number ofgrains in sample}} \times 100$$

Weight loss (Count and weigh method)
100 maize grains from the already infested grain samples were counted at random from the sieved-out samples of all the treatments, from which damaged and undamaged grains were sorted. The number of damaged or undamaged grains was recorded and weighed. Weight loss was calculated using the formula by Gwinner *et al.* [25].

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$$\% \text{ Weight loss} = \frac{(QNs)-(SNq)}{(Ns+Nq)} \times 100$$

Where:
Q = weight of undamaged grains
S = weight of damaged grains
Nq= number of undamaged grains
Ns = number of damaged grains

Data analysis
Statistix 9 was used for the data analysis. Count data were square root transformed and percentage data also arcsine or angular transformed to stabilize variances. Tukey's Honestly Significant Difference (HSD) was used to separate the means. Untransformed means and standard errors are reported. Pearson's correlation test was used to determine if F_1 progeny, Susceptibility index, median development period, insect damage variables had relationship with protein, total carbohydrate, grain hardness, and Beta-carotene content of the maize varieties used. Cluster analysis was also performed using resistant parameters.

RESULTS AND DISCUSSION

Effect of Cumulative feeding on emergence of *S. zeamais*
Significant differences (P<0.05) were observed in the number of *S. zeamais* that emerged from the maize genotypes after 112 days of the cumulative feeding (Figure 1). The smallest number of F_1 was recorded in Aburokokoo after 112 days which differed significantly from all the remaining genotypes except Honampa. The number of dead weevils on Aburokokoo did not differ significantly from the other maize genotypes except for accession GH2354 (F = 4:27; P<0.01) (Figure 1). Differences in the percentage grain damage and weight loss among the maize genotypes due to *S. zeamais* feeding, and development after 112 days of were significant (F = 5:65; P<0.01) and (F = 15:6; P<0.01), respectively. Aburokokoo had the least mean percentage grain damage (28.1± 0.5) and weight loss (13.68 ± 0.7). Accession GH2354 suffered the highest percentage grain damage and percentage weight loss (P<0.05). However, Abontem, Honampa, Ahoodzin, and Obatanpa did not differ significantly in respect of percentage grain damage (Figure 1). Ahoodzin and Abontem did not also differ significantly from Aburokokoo on weight loss, likewise, Obatanpa, Ahoodzin, Honampa, and Abontem which did not differ significantly at 5% from each other in terms of percentage weight loss (Figure 1). The feeding, development, and emergence of *S. zeamais* varied on the various maize genotypes tested for four months. A comparable number of weevils

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emerged on accession GH2354 and the released PVABM varieties–Abontem, Honampa, and Ahoodzin and the check Obatanpa at the end of the four months period. Percentage grain damage and percentage weight loss were high in these varieties due to low insect mortality and high survival rate. Generally, maize grain/seed resistance is associated with low percentage of grain damage and weight loss and a reduced number of progenies. According to Nwololo *et al.* [26], the most important variable to determine the level of grain varietal resistance against *S. zeamais* is grain weight loss. From the current study, Aburokokoo recorded high weevil mortality and a small number of live weevils leading to both low percentages of grain damage and weight loss. Aburokokoo, therefore, showed some level of resistance against *S. zeamais*. The results of this current study are consistent with the findings of Chitio *et al.* [27] whose work indicated resistance of Surenō grain to maize weevil. Similarly, Mikami *et al.* [28], reported that BR 106 is a resistant genotype to maize weevil since it had the lowest grain weight loss after 6 months of storage. The large weevil numbers, high percentage grain damage and weight loss observed in the other varieties suggest they are susceptible to the maize weevil. For example, accession GH2354 favoured the survival and emergence of a large number of the insect throughout the experiment. The defense mechanism of plants against pests is also influenced by factors such as physical or chemical plant phenolic compounds [29]. Small number of insects and low grain weight loss can be used as an indicator of resilience of grains against stored insect pests like *S. zeamais* [18, 30].

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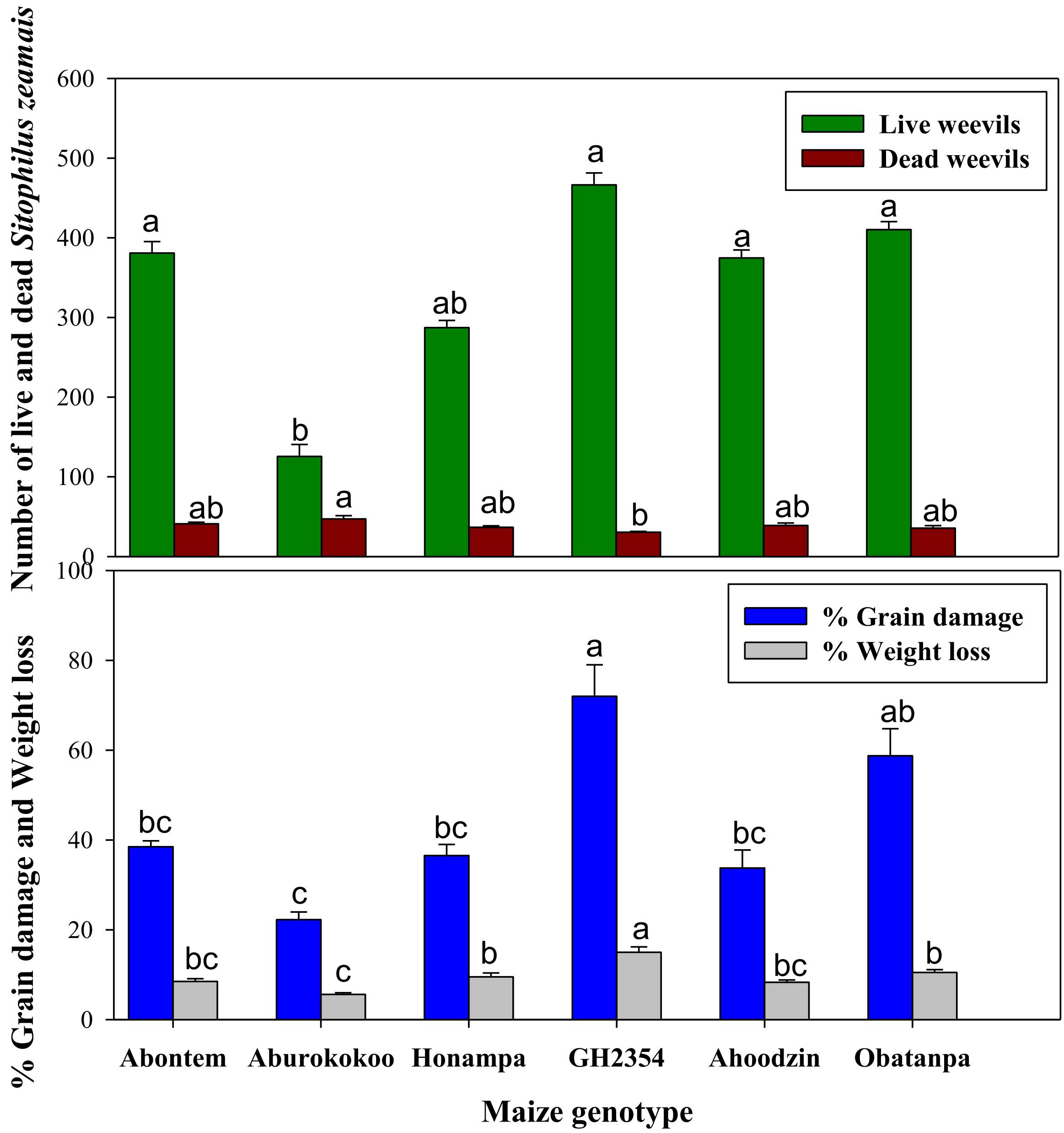

Figure 1: Mean number of live and dead *Sitophilus zeamais* adults recorded and percentage grain damage and weight loss observed after 112 days of cumulative feeding

Effect of maize grain physicochemical parameters and susceptibility on the emergence of *Sitophilus zeamais*

Grain resistance parameters including weight loss, grain damage, susceptibility index, number of F_1 progeny, and median development time were significant ($P<0.05$) in a no-choice experiment. Mean number of F_1 progeny was smaller in Aburokokoo but differed significantly ($F = 44{:}9$; $P<0.01$) among the genotypes except Ahoodzin. Number of F_1 in GH2354 was significantly greater than all the

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other genotupes. The median development period was also significant (F = 12:6; P<0.01) between the genotypes. The longest period of weevil development was recorded in Aburokokoo but was not statistically different from Abontem, Honampa, and Ahoodzin. The shortest development time was recorded on Accession GH2354 and it was statistically different from Obatanpa. Significant differences (F = 64:9; P<.0.01) were detected in the susceptibility indexes (SI) of the genotypes (Table 1). Aburokokoo had the lowest SI value and differed significantly from other genotypes. Honampa, Abontem, and Ahoodzin did not show any difference statistically from each. GH2354 Obatanpa had the highest SI values and were statistically significantly different from the other four genotypes. The differences among maize genotypes on per cent grain attacked and grain weight loss by *S. zeamais* were significant (F = 8:33; P< 0.01) and (F = 12:54; P<0.01) correspondingly (Table 1). Aburokokoo had the least values of both and differed significantly from the other five genotypes, apart from Ahoodzin for the grain damage. Higher values of percentage grain damage and percentage weight loss were detected in GH2354 but it did not differ significantly different from Obatanpa, Ahoodzin, Honampa, and Abontem in grain damage. For percentage weight loss GH2354 differed from the remaining genotypes (Table 1).

Aburokokoo had the highest value of total carbohydrate (73.30) and was not significantly different from Abontem, Honampa, Ahoodzin, and Obatanpa (Table 2). The grain protein value in GH2354 was also observed to be significantly different from the rest. Aburokokoo had the lowest value of protein. The maize grain Beta-carotene content was significantly different among the genotypes. Aburokokoo had the highest value and different significantly from the rest with Obatanpa having the lowest value. Obatanpa and Aburokokoo had significant lower ash content than the other four genotypes, which did not differ significantly from each other. The crude fiber and moisture contents of the maize grains were not significantly different (Table 2). Grain hardness was significantly different among genotypes. Ahoodzin had the highest compressive strength value against pressure (Force/unit area) to break or crack (22.50 N/mm^2), with Accession GH2354 having the lowest (7.20 N/mm^2). Obatanpa variety had the highest grain density value and was significantly different from the other five maize genotypes. GH2354 and Abontem had the lowest density value (Table 3).

Pearson correlation matrix between maize susceptibility parameters and grain intrinsic characteristics against *S. zeamais*

Grain percentage damage and weight loss were positively correlated with the susceptibility index (SI) of the maize genotypes, while grain hardness and Beta-carotene content were negatively correlated with susceptibility index (r = -0.64) and

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(r = -0.56) respectively. The amount of protein in the grain was positively correlated with SI (r = 0.67), while total grain carbohydrate was negatively related (r = -0.66). The number of weevils that emerged was positively correlated to susceptibility index (r = 0.97) while the median development period was negatively associated (r = -0.94) with the susceptibility index. The number of emerged adults associated negatively with to grain hardness (r = -0.61), Beta-carotene content (r = -0.54), total carbohydrate (r = -0.61) but positively correlated with protein content (r = 0.68), percentage grain damage (r = 0.85), and weight loss (r = 0.97). Grain protein content was negatively correlated to hardness (r = -0.85), but positively related to grain damage (r = 0.69) and weight loss (r = 0.77) (Table 4).

The current study showed that maize genotypes with high protein content are susceptible to attack and weight loss and support large number F_1 progeny. Grain susceptibility is dependent on the nutritional content of the maize varieties. For instance, Fourar-Belaifa R and F Fleurat-Lessard [31] reported that protein content increased with maize susceptibility to *S. zeamais*. There has also been a report that phenolic acid biochemical components in maize correlated with maize weevil resistance [32]. Grain nutritional quality traits such as sugar, protein, fat, and amino acids have negative or positive relationship with the maize weevil in terms of susceptibility or resistance of the maize grain [33]. In this study, accession GH2354 had high protein content and was susceptible to the maize weevil, while Aburokokoo with high total carbohydrate was resistant to the weevils. Results from other studies have indicated that certain chemical composition and physical properties of grain could make it favourable, or less favourable for the survival and reproduction of maize weevil [34].

Interestingly, the results of some studies have attributed grain resistance to *S. zeamais* to protein and lipid contents, phenolic compounds and amylase inhibitors [35]. The high larval mortality, longer developmental periods (antibiosis), and reduced oviposition (non-preference) found in *Sitophilus oryzae* were an indication of resistant factors to sorghum grain [36]. The findings of Guzzo *et al.* [37] showed the existence of larval antibiosis leading to a lower number of F_1 progeny. The longest median development period of the weevil was observed on Aburokokoo and the commercially released varieties including Abontem, Honampa, and Ahoodzin. The low number of F_1 progeny of the weevil emerged suggests the existence of larval antibiosis, antixenosis or non-preference for oviposition in these varieties.

Grain intrinsic characteristics such as hardness and pericarp surface texture can also impart resistance or susceptibility to maize weevil [38]. In this study, grain

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hardness had a negative relationship with F_1 progeny, susceptibility index, and protein content of maize varieties, but positive relationship with median development period. Accession GH2354 had a larger number of F_1 progeny, high index susceptibility level, high protein content, and short median development time with very low grain hardness value. Aburokokoo, which had small number of F_1 progeny, low susceptibility index, low protein content, and long median development period, however, did not have the highest value for grain hardness. Therefore, besides grain hardness, other factors may be equally important in conferring resistance in the Aburokokoo. Grain hardness as a basis of conferring resistance to the *S. zeamais* is limited by its moisture content according to Lale [39]. It was further stated that at the grain moisture content of 16%, maize becomes susceptible to storage insects such as the maize weevil. Maize grain resistance to the weevil attributed to its hardness has been challenged due to limitation by grain moisture content above 14%. [40].

Cluster analysis of the maize genotype

The cluster analysis dendrogram for susceptibility parameters of maize genotypes to *S. zeamais* in Figure 2. show two main groups out of the six genotypes assessed. Aburokokoo (2) is distinct while the remaining five genotypes (Abontem, Honampa, GH2354, Ahoodzin and Obatanpa) belongs to another group [41] Susceptibility description used for cluster dendrogram obtained from the maize varieties with regard to resistance parameters to *S. zeamais* showed that GH2354 and Obatanpa are susceptible, Ahoodzin, Honampa and Abontem are moderately resistant and Aburokokoo resistant to the maize weevil infestation (Figure 2).

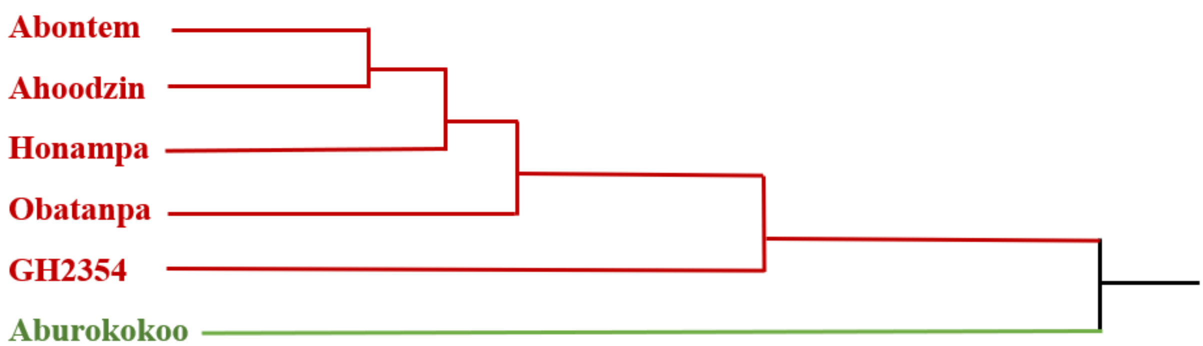

Figure 2: The cluster dendrogram of susceptibility of maize genotypes to *S. zeamais*

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CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Based on the performance of Aburokokoo using the susceptibility parameters tested against the weevil, it can be classified as resistant to developmental *S. zeamais.* Therefore, it can be stored for some months and can also be used as source of resistance in future breeding program against the pest. Abontem, Honampa, and Ahoodzin with higher grain hardness values than the other varieties have moderate resistance to the pest as against Obatanpa (QPM) and accession GH2354 which was highly susceptible.

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Table 1: Mean susceptibility parameters of six maize genotypes against *Sitophilus zeamais* after 60 days

Treatment	F_1 progeny	MDP	IS	% GD	% Wt loss
Abontem	45.3 ± 2.9c	41.0 ±0.6a	4.02 ±0.1b	24.3 ±2.7a	2.7 ±0.4c
Aburokokoo	29.3 ±2.6d	42.0 ±0.6a	3.42 ±0.03c	11.0 ±0.6b	1.3 ±0.1d
Honampa	48.0 ±1.4c	41.0 ±0.7a	4.1 ±0.01b	26.0 ±4.0a	3.1 ±0.1c
GH2354	87.0 ±4.3a	35.0 ±1.2c	5.5 ±0.1a	33.0 ±3.1a	6.0 ±0.1a
Ahoodzin	38.5 ±3.2cd	39.7 ±0.3ab	4.0 ±0.1b	21.0 ±0.6ab	2.6 ±0.2c
Obatanpa	66.7 ±4.4b	36.0 ±0.7bc	5.1 ±0.1a	30.0 ±2.9a	4.2 ±0.3b

Means followed by the same letters in the columns are not significantly different (P<0.05), according to Tukey
MDP = Median Development Period, SI = Susceptibility index, %GD = Percent grain damage, % Wt. loss = Percent weight loss

Table 2: Mean intrinsic characteristics of the different maize genotypes

Treatments	%Protein	%CHO	%Ash	%Fat	%CF	%Moisture	B. carotene
Abontem	10.3 ±0.3c	71.7 ±0.3ab	2.5 ±0.3ab	3.3±0.7bc	3.3 ±0.7a	8.6 ±0.1a	26.7 ±0.3e
Aburokokoo	8.7 ±0.1e	73.2 ±0.8a	1.2 ±0.4c	4.3±0.5ab	4.2 ±0.1a	8.8 ±0.1a	43.6 ±0.3a
Honampa	10.8 ±0.4b	72.7 ±0.6ab	2.9 ±0.3ab	2.3 ±0.7c	2.4 ±0.1a	8.8 ±0.3a	36.9 ±0.2b
GH2354	12.0 ±0.0a	67.8 ±0.2b	3.2 ±0.5a	3.8±0.5ab	3.5 ±0.4a	8.9 ±0.4a	28.6 ±0.4d
Ahoodzin	10.8 ±0.2b	69.6 ±0.7ab	2.8 ±0.5ab	4.8 ±0.0a	2.5 ±0.1a	9.0 ±0.2a	35.8 ±0.3c
Obatanpa	9.9 ±0.1d	70.5 ±0.4ab	1.8 ±0.7bc	4.27 ±ab	3.4 ±0.2a	9.6 ±0.2a	2.0 ±0.1f

Means followed by the same letters in the columns are not significantly different (P<0.05), according to Tukey. % CHO = Percent total carbohydrate, %CF = percent crude

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Table 3: Mean Physical characteristics of the different maize genotypes

Treatment	Length (mm)	Width (mm)	Thickness (mm)	Hardness (N/mm²)	Density (g/cc)
Abontem	9.10 ± 0.2b	8.1 ±0.5b	4.2 ±0.1	13.1 ±0.1c	1.2 ±0.04e
Aburokokoo	12.1 ±0.4a	9.1 ±0.3ab	4.1 ±0.1	12.5 ±0.6c	1.3 ±0.03c
Honampa	9.6 ±0.4b	8.8 ±0.04ab	4.5 ±0.3	19.1 ±0.3b	1.28 ±0.01d
GH2354	9.9 ±0.3b	8.9 ±0.2ab	3.9 ±0.4	7.20 ±0.7d	1.2 ±0.01e
Ahoodzin	12.5 ±0.2a	9.5 ±0.2a	4.6 ±0.02	22.5 ±0.7a	1.37 ±0.01b
Obatanpa	12.9 ±0.2a	9.6 ±0.1a	4.5 ±0.4	11.5 ±0.2c	1.43 ±0.01a

Means followed by the same letters in the columns are not significantly different ($P<0.05$), according to Tukey

Table 4: Pearson correlation matrix between grain intrinsic properties and varietal susceptibility

	F_1 progeny	MDP	SI	% GD	% Wt.loss	% Protein	% CHO	B. carotene	Hardness
F_1 progeny	1								
MDP	-0.86**	1							
SI	0.97**	-0.94**	1						
% GD	0.85**	-0.74**	0.84**	1					
% Wt.loss	0.97**	-0.84**	0.95**	0.82**	1				
% Protein	0.68**	-0.54*	0.67**	0.69**	0.77**	1			
% CHO	-0.61*	0.64**	-0.66**	-0.52*	-0.70*	-0.64**	1		
B. carotene	-0.54**	0.63**	-0.64**	-0.57**	-0.09	-0.09	0.27	1	
Hardness	-0.61**	0.50*	-0.56*	-0.54	-0.53	-0.85**	0.53	0.38	1

*Significant at ($P<0.05$), ** significant ($P<0.01$) level
MDP = Median Development Period, SI = Susceptibility index, %GD = Percent grain damage, % Wt. loss = Percent weight loss, % CHO = Percent total carbohydrate, Beta-carotene = Beta-carotene

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