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Relationship between seed physical traits and maize weevil (*Sitophilus zeamais*) damage parameters in selected Quality Protein Maize (QPM) varieties

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The vulnerability of Quality Protein Maize (QPM) varieties to *Sitophilus zeamais* Motschulsky attack causes substantial postharvest loss to farmers. A study was conducted in the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria, to evaluate the response of the newly released QPM and High Protein Maize (HPM) varieties of the Institute to *Sitophilus zeamais* infestation. Five varieties comprising two QPM (ART/98/SW6-OB and ILE 1-OB); one HPM (ART/98/SW1) and two conventional maize varieties (KU1414SR/SR and TZPB) were used for the experiment. Two hundred seeds of each variety were artificially infested with eggs of *Sitophilus zeamais* and arranged in a completely randomized design with three replicates under two storage conditions (dark room and opened well-ventilated room) for three months. Data were collected on seed traits and weevil damage parameters. Results showed that there were significant differences among the varieties and between the storage conditions for most of the traits. Both QPM varieties significantly harbored *Sitophilus zeamais* as the number of emerged adult insects at 3 weeks after infestation (WAI), damage rating, total number of insects at termination and grain weight loss were highest in both, though higher in ILE 1-OB. The conventional inbred line (KU1414SR/SR) experienced less damage. Grain weight loss was positively correlated with insect damage rating, while seed coat thickness was negatively correlated with grain weight loss and other damage parameters. The released QPM varieties of the Institute are highly susceptible to *Sitophilius zeamais* infestation and therefore require genetic improvement. Seed coat thickness and damage ratings are important traits to be considered in improvement programmes for resistance to *Sitophilus zeamais* in QPM varieties.

1. Introduction

Maize has been reported to be the most widely cultivated staple food crop in Sub-Saharan Africa, providing up to 70% of the daily calorie intake (FAO, 2007). Normal maize has a major nutritional constraint as human food because the protein content (about 10%) is deficient in two essential amino acids, lysine and tryptophan. Quality Protein Maize (QPM) has been developed to contain twice the amount of lysine and tryptophan of normal maize and is now being used to correct this deficiency in protein quality. However, in spite of the nutritional superiority of the quality protein maize (QPM), an important concern is the vulnerability of QPM varieties to *Sitophilus zeamais* infestation.

The maize weevil (*Sitophilus zeamais* Motschulsky) is a serious pest of stored maize grain in the tropical and subtropical regions causing grain yield losses of 15–90% (Bergvinson, 2001; Derera et al., 2001; Tefera et al., 2011). Chemical control has been the popular control measure against the weevils, but lately emergence of insecticide-resistant *S. zeamais* populations has been reported (Guedes et al., 1995; Ribeiro et al., 2003; Kljajic and Peric, 2006; Asawalam et al., 2006; Oliveira et al., 2007). This factor, as well as the high cost and residual effect of synthetic pesticides, implies that host plant resistance approach which is cheaper and environmentally safe should be considered.

Different information exists on resistance of QPM to *S. zeamais*. Ortega et al. (1974) reported that QPM varieties were very vulnerable to stored grain pests. Golob (2000) studied some QPM inbred

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lines along with non-QPM inbred lines and their hybrids, and reported that most of the elite QPM inbred lines were highly susceptible to *S. zeamais* infestation. However, other studies have reported a great variability among QPM varieties ranging from moderately resistant to very susceptible to *S. zeamais* (Arnason et al., 1993; Firoz et al., 2007; Temesgen and Waktole, 2013).

Opinions about the most important trait contributing to *S. zeamais* resistance in maize differ. Some of the traits that have been reported include kernel hardiness (Dobie, 1974; Ortega et al., 1974; Siwale et al., 2009), larger seed (Vowotor et al., 1995), thick testa, large and hard kernels (Lale and Kartay, 2006), and high moisture content (Lale et al., 2013), while a number of others reported chemical factors. There is a need to critically assess the level of resistance of the new QPM varieties to *S. zeamais* infestation to safeguard farmers from post-harvest loss. There is also a need to assess the interrelationship between weevil damage parameters and seed physical traits so as to determine trait(s) that should be selected in improvement programme for resistance to *S. zeamais*. This study was therefore carried out to (i) assess the response of the released QPM and HPM varieties of IAR&T to *S. zeamais* infestation (ii) determine the interrelationship among weevil damage parameters and seed physical traits.

2. Materials and methods

2.1. Experimental protocol

The experiment was set up in the Entomology laboratory of the Institute of Agricultural Research and Training, Ibadan Nigeria under two storage conditions (open laboratory and dark room). The open laboratory (Relative Humidity (RH) 74.7%, Temp.81.8F) was well-ventilated, while the dark room (RH 75.5%, Temp.82.9F) was a closed environment. Five maize varieties which included two newly released Quality Protein Maize (QPM) of the Institute- (ART/98/SW6-OB, ILE1-OB), one High Protein Maize (HPM) of the Institute (ART/98/SW1), one conventional maize variety (TZPB) and one inbred line (KU1414SR/SR) were used for the experiment (Table 1). TZPB and KU1414SR/SR were selected based on their inherent resistance to storage pests.

Two hundred seeds of each variety were weighed into a jar. Twenty unsexed adult of *S. zeamais* previously reared in the insect laboratory of IAR&T were introduced into each jar with an assumption ratio of one male to one female. Each jar was covered with a lid containing 40 μm mesh screen to provide ventilation and prevent insects from escaping. After two weeks, all the adult *S. zeamaiss* were removed. The experiment was laid out in a completely randomized design with three replicates. The experiment ran for three months before termination. Germination percentage of the seeds of each maize variety was tested before and after the experiment according to ISTA rules (ISTA, 1996). At the end of the storage period, all *S. zeamais* in each jar were removed, counted and sorted into male and female according James and Adebayo (2012). The seeds in each jar were sieved and weighed again to determine final grain weight.

Table 1
List of maize varieties used for the study.

S/n	Variety	Nature	Kernel color	Source
1	ART/98/SW6-OB	QPM	White	IAR&T
2	ART/98/SW1	HPM	Yellow	IAR&T
3	ILE 1-OB	QPM	White	IAR&T
4	TZPB	Conventional variety	White	IITA
5	KU1414SR/SR	Conventional inbred line	Yellow	IITA

2.2. Data collection

Data were collected on percentage grain weight loss, which was estimated by deducting the final grain weight of the seeds from the initial weight before infestation and the difference expressed as percentage of initial seed weight. Viability loss was estimated as the difference between initial and final germination percentage. Seed hardness was measured using a Grain hardness tester (Fujihara Seisakusho Ltd, Tokyo, Japan). Ten seeds in three replicates were used for each sample. The handle of the equipment was initially turned anti-clockwise to give room to place a seed on the sample table. The handle was then turned clockwise until a cracking sound was heard. At this time, the black pointer returns to the zero point while the red pointer remained. The reading of the red pointer (kg) indicated the hardness of the seed. Seed coat weight was obtained by soaking a known quantity of seed of each variety in water for about 20 min. The seeds were then removed and the seed coat was peeled off using razor blade. The seed coats were then air-dried for about 24 h and weighed. The weight was then expressed as percentage of the weight of the seeds before removing the coat. Seed damage rating was done to determine the level of damage on monthly basis for 3 months as damage rating 1,2 and 3. The scale used was 1–5. 1 represented very clean seeds without holes or powdery particles; 2 represented very little damage on the seeds (about 20% damage); 3 represented 50% damage on the seeds with some powdery particles at the base of the jar; 4 represented considerable damage on the seeds where about 70% of the seeds were damaged with penetrating holes and powdery particles at the base of the jar, while 5 represented above 70% damage where almost all the seeds have holes with a lot of powder and kernel fragments at the base of the jar. The number of emerged adult insects was counted at 3 weeks after removal of the adult insects as number of emerged adult insects 3 weeks after infestation (3WAI). The total number of insects at termination was assessed by sieving the content of each bottle to remove all the insects and their number counted. Sex ratio was estimated by sorting all the insects into males and females according to the method of James and Adebayo (2012)and the ratio of male to female insects was estimated. Seed coat of a known quantity of seed was removed for each of the maize varieties and the thickness measured using a digital vernier caliper. The average thickness was found for each variety and recorded as Seed coat thickness.

2.3. Data analyses

All the data recorded in percentage were transformed using arcsine transformation, while count data were log-transformed before analysis. Analysis of variance (ANOVA) was carried out using PROC GLM of SAS (Version 9.2). Combined analysis of variance was carried out for both storage conditions. Means were separated using Least Significant Difference (LSD). Correlation analysis was also conducted.

3. Results

3.1. Analysis of variance for the traits studied

The result of combined analysis of variance for the two storage conditions (open laboratory and dark room) is as shown in Table 2. Mean squares for varieties were significantly different for all the traits except viability loss and insect sex ratio. Also, there were significant difference between the storage conditions for grain weight loss, number of adult at 3WAI, damage rating, viability loss and total number of insect at termination.