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Chemical bases for maize grain resistance to infestation and damage by the maize weevil, *Sitophilus zeamais* Motschulsky

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ABSTRACT

It was suggested that the factors that confer resistance on a maize variety against *Sitophilus zeamais* Motschulsky are chemically based. To test this hypothesis, resistance indices of the weevil were assessed using a new scale developed by Nwosu et al. (2015a) after performing detailed chemical analysis of the whole-maize grain using twenty elite maize varieties under ambient temperature and relative humidity of 30.7 °C and 74.5% respectively. Increases in maize varietal crude fibre, phenolic acid and trypsin inhibitor increased significantly mortality of *S. zeamais* adults and reduced significantly survival rate of *S. zeamais* adults, percent of grain damage, percent of weight loss, weight of grain flour and oviposition by the adult females. The level of cystein proteinase inhibitor (a natural protectant of plants against insect attack) in the grains was not on its own responsible for increased mortality, reduced grain damage and reduced oviposition. The study identified crude fibre, phenolic acid and trypsin inhibitor of whole-maize grain as the bases for resistance. Their significant increase in grains resulted in low infestation. Whereas, increased protein, zinc, magnesium, calcium, sodium, phosphorus, manganese, iron, cobalt and starch rendered the elite maize grains susceptible to *S. zeamais* attack. Therefore, significant incorporation of the bases for resistance and significant reduction of the bases for susceptibility in maize grains during breeding programmes is advocated; provided this does not adversely affect palatability and nutritional needs of man. Eighty-five percent of the elite maize varieties were at least resistant to *S. zeamais* infestation and damage. The resistant varieties, particularly 2000SYNEE-WSTR and TZBRELD3C5 maize with high resistance should be promoted for growing. Antibiosis, antixenosis and preference were the mechanisms of maize grain resistance to *S. zeamais* attack.

1. Introduction

Maize is an important staple food crop in parts of the world where it is grown (Nwosu et al., 2015a). Apart from the role maize plays as food, it serves as cash crop and used as an industrial raw material (Nwosu et al., 2015b, 2016). McCann (2006) observed decreasing maize production due to some environmental constraints. The reproductive and feeding activities of the maize weevil, *Sitophilus zeamais* adults have worsened decreasing maize production through grain loss in storage and loss can be up to 90% in unprotected maize grains (Nwosu et al., 2015b, 2015c).

Several strategies have been used to control weevil infestation in stored maize. The use of conventional synthetic insecticide is effective, but its environmental implication and other demerits such as health hazards and high market price have discouraged its application (Munyiri et al., 2013). Host plant resistance is particularly important and can be a very useful technique in grain protection against stored product insects, because it is packaged in the grain, causes no hazard to the environment and is compatible with other control methods (Gemechu et al., 2011; Munyiri et al., 2013). In developing nations, maize weevil management options must necessarily include use of resistant variety as it is sustainable on account of entailing low cost and requiring little or no skill. Resistant varieties are known to provide substantial direct control of the weevil in stored maize (Ashamo, 2001; Abebe et al., 2009; Adedire et al., 2011; Mwololo et al., 2012; Nwosu et al., 2015c). However, overreliance on it can seriously undermine its effectiveness through 'breakdown of resistance'. Widespread breakdown of resistance by *S. zeamais* in maize varieties can be prevented or managed by routine screening to identify new sources of resistance for inclusion during maize programmes' breeding. This further justifies the need for the present study. In other words, much as this effective control measure remains operational, efforts should be

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continued towards augmenting/improving on its efficacy through further scientific studies.

Debate on the bases for maize grain resistance to *S. zeamais* infestation and damage is still on (Dobie, 1974; Shafique and Chaudry, 2007; Munyiri et al., 2013; Nwosu et al., 2015a). Grain hardness among other grain physical properties such as length, width, thickness and weight has been shown to be a basis for resistance to the attack of *S. zeamais* and some other insect pests of stored maize (Dobie, 1974; Osipitan and Odebiyi, 2007). However, Olusanya (1981) and Garcia-Lara et al. (2004) informed that there is a dearth of information on the relationship of chemical constituents of maize grain with resistance to *S. zeamais* infestation and therefore directed that this should be given serious attention. Indeed, extensive studies on the chemical bases for maize grain response to *S. zeamais* infestation among the varieties in Africa are grossly absent (Nwosu et al., 2015a); a feature which the present study seriously hopes to tackle. The hint that much hope lies in maize grain chemical characters as critical agents that can be considered during maize programmes' breeding for resistance to *S. zeamais* (Nwosu et al., 2015a) formed part of the motivation for the present study. Therefore, the advice of earlier workers has compelled reorientation of research focus to the contribution of chemical attributes of maize grain to varietal resistance to *S. zeamais* infestation and damage. It is against this background that the present study carried out a detailed investigation on the chemical profile of twenty elite maize varieties with a view to identify the characteristics that confer resistance to *S. zeamais* infestation on a maize variety.

2. Materials and methods

2.1. Test maize varieties

The twenty elite maize varieties (with their identities and some agronomic information) used in the study are presented in Table 1. The first ten varieties were provided by International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria and the remaining ones were obtained from Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria. The Maize Breeders at the research institutes certified that the maize samples are open-pollinated elite varieties (with differences) which have not been subjected to hybridization to harness the desirable resistance characters. A weevil resistant variety, 2000SYNEE-WSTR and weevil susceptible variety, PVASYN3F2 (Nwosu et al., 2015a) were designated as controls to help to identify the resistance chemical characters in the present entomological studies.

2.2. Standardization of maize varieties

The grain samples were examined and cleaned before chemical characterization was done. The cleaned grains for oviposition and resistance bioassays were frozen at -20 ± 2 °C for 1 week to disinfest them and then stored at 4 °C to prevent re-infestation (Sulehrie et al., 2003). Maize grains were kept for 2 weeks in muslin-covered plastic containers under experimental conditions for acclimatization and stabilization of moisture content at 12–13% (Abebe et al., 2009; Nwosu et al., 2015a) prior to oviposition and resistance bioassays.

2.3. Chemical characterization of the elite maize varieties

One-hundred and fifty grammes of each of the twenty test maize varieties were milled and sieved through 0.4 mm sieve. The milled samples were subjected to chemical analysis at the central laboratory of IAR&T to determine the proximate, mineral and phytochemical contents the maize grains. Proximate compositions (protein, ash, moisture, fat, crude fibre and carbohydrate) of whole-grain of each maize variety were determined using the standard method of AOAC (1990). Carbohydrate content was determined by difference.

The minerals determined in whole-maize grains were cobalt, calcium, magnesium, potassium, sodium, phosphorus, manganese, iron, zinc and copper. Potassium and sodium present in each of the twenty varieties were determined by flame photometry (Onwuka, 2005). Phosphorus was determined spectrophotometrically by Molybdate method using hydroquinone as a reducing agent after obtaining the mineral digest (Fiske and Subbarrow, 1925). The mineral digest was obtained by adding 20 ml of acid mixture

Table 1
Identities of the twenty sampled elite maize varieties and some agronomic information collected on them.

Maize varieties	Colour	Shape	Face-type	Place of release	Target area of cultivation	Survives early season planting	Seed production
DTSYN -11-W	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good
TZBRCOMP.2C1F1	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good
IWDC3SYN-W	White	Oblong	Dent	Nigeria	Country wide	Yes	Certified good
TZBRELD3C5	White	Hexagonal	Dent	Nigeria	Country wide	Yes	Certified good
PVASYN-6F2	Red	Oval	Dent	Nigeria	Country wide	Yes	Certified good
2000SYNEE-WSTR*	White	Oblong	Dent	Nigeria	Country wide	Yes	Certified good
2008DTMA-YSTR	Yellow	Oval	Dent	Nigeria	Country wide	Yes	Certified good
PVASYN-3F2**	Red	Oval	Dent	Nigeria	Country wide	Yes	Certified good
WHITE DTSTRSYN	White	Hexagonal	Dent	Nigeria	Country wide	Yes	Certified good
BR9943DMRSR	White	Rectangular	Dent	Nigeria	Country wide	Yes	Certified good
ILE-1-OB	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good
IFE MAIZE HYBRID-1	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good
IFE MAIZE HYBRID-2	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good
IFE MAIZE HYBRID-5	Red	Oval	Dent	Nigeria	Country wide	Yes	Certified good
IFE MAIZE HYBRID-6	Red-Yellow	Oval	Dent	Nigeria	Country wide	Yes	Certified good
ART COMPOSITA-Y	Red-Yellow	Oblong	Dent	Nigeria	Country wide	Yes	Certified good
ART COMPOSITE B-Y	Red-Yellow	Round	Dent	Nigeria	Country wide	Yes	Certified good
ART/98/SW1-OB	Yellow	Round	Dent	Nigeria	Country wide	Yes	Certified good
ART/98/SW4-OB	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good
ART/98/SW5-OB	White	Oval	Dent	Nigeria	Country wide	Yes	Certified good

Maize varieties 1 to 10: IITA, Ibadan, Nigeria.
Maize varieties 11 to 20: IAR&T, Ibadan, Nigeria.
* Highly resistant control maize variety.
** Susceptible control maize variety.