Short Communication Open Access

Relationship between physical-chemical characteristics of corn kernels and susceptibility to *Sitotroga cerealella*

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Abstract

The Angoumois grain moth, *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae), is a stored-grain pest distributed worldwide. Interaction relationships between physical-chemical characteristics of plants and insects have been found, and this interaction has great potential to be used in integrated pest management strategies. Therefore, our laboratory studies aimed to assess i) the susceptibility of five corn (*Zea mays* L) genotypes (UFVM100, UFVM200, UFVM100X200, AG1051 and DKB747) to *S. cerealella* and, ii) the correlation between physical-chemical characteristics of corn kernels and moth performance. In this study, kernels of five corn genotypes were evaluated for their comparative susceptibility to *S. cerealella*. Developmental period, progeny of emerging adults and kernel weight loss were taken the parameters adopted for this test. *S. cerealella* led to longer development period, shorter survival percentage and lower kernel weight loss percentage on AG1501 genotype. A strong positive correlation between kernel weight loss percentage and protein content was observed. A strong negative correlation was observed between development period and kernel weight, moisture and protein contents. Additionally, a negative correlation was found between survival percentage and kernel hardness. Our study leads to the conclusion that development period, progeny of emerging adults of *S. cerealella* and kernel weight loss were related to some kernel characteristics. Thus, this information may be used as a tool in integrated management programmes and plant breeding programmes for *S. cerealella*.

Keywords: Angoumois grain moth, development, survivorship, stored grain, resistance, grain weight loss

Introduction

The Angoumois grain moth, *Sitotroga cerealella*, Oliver (Lepidoptera: Gelechiidae) is an important pest due to the damage inflicted in stored grains and derived products (Togola et al, 2010; Rizwana et al, 2011). The larvae of *S. cerealella* attack both in the field and/or in the storeroom of a variety of kernels, among which; corn, sorghum, wheat, soybean, rice, paddy, and products prepared from these kernels (Howlader and Matin, 1988; Cônsoli and Filho, 1995; Ashamo, 2010). The larvae of this pest move outside kernels for about 24 hours. Then, they make holes in kernels and stay inside them until the larval-pupa development is completed. This damage makes kernels more susceptible to secondary insect pests (Weston and Rattlingourd, 2000).

Plant resistance to insects is a cultural method that has been neglected as an alternative control for *S. cerealella*. Several studies about resistance of different genotypes of grains to *S. cerealella* were published (Cônsoli and Filho, 1995; Ahmed et al, 2002; Khan et al, 2005; Ashamo and Khanna, 2006b; Shafique and Chaudry, 2007a,b; Ashamo 2010). *S. cerealella* reared on kernels of Shrunken genotype presents a time of development longer than other corn genotypes tested (Cônsoli and Filho, 1995). Some genotypes, such as HO4R 3075-3 were less susceptible which led to longer time of development of larvae, decreased adult emergence and to the lowest susceptibility index (SI) and weight loss when compared with six kernels of corn genotypes (Ashamo and Khanna, 2006b). Seven kernels of corn genotypes were evaluated for their comparative resistance to *S. cerealella*. Adult progeny and weight loss of kernels were significantly low in White Monsanto and Yellow Pioneer, compared to other genotypes (Shafique and Chaudry, 2007a) tested. *S. cerealella* demonstrated feeding preference for genotypes of others cereals, including wheat (Ahmed et al, 2002; Khan et al, 2005), paddy (Ashamo, 2010) and rice (Shafique and Chaudry, 2007b).

Susceptibility to infestation of *S. cerealella* varies among genotypes, according to their physical-chemical characteristics. Seed hardness directly was affected resistance to several stored insect-pests such as: *S. cerealella* in paddy (Aruna et al, 2009), *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) and *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in corn (Gudrups et al, 2001; Meikle et al, 1998). A significant correlation was observed between kernel size of different corn genotypes and number of *S. cerealella* per kernel in a free-choice test (Villacis et al, 1972). The corn kernels with moisture content above 31% were virtually non-infested with *S. cerealella* (Weston et al, 1993). Developmental

 RECEIVED 03/25/2013

time, weight loss and number of progeny produced by *S. cerealella* were correlated with protein, sugar, and fat content of wheat kernels (Khan et al, 2005). The lowest survival from egg to adult was from *S. cerealella* reared on two genotypes, sugary (Su) and sugary-opaco2 (SuO2) (Cônsoli and Filho, 1995) and may be related to the high level of amylose of these genotypes. Therefore, the present research work aimed to: 1) assess the extent to which corn genotypes vary in their resistance to *S. cerealella*, 2) evaluate the physical and chemical characteristics of these corn genotypes related to resistance variability.

Materials and Methods

Insects

The insects of *Sitotroga cerealella* were obtained from stock cultures in the laboratory of Integrated Pest Management (IPM-Grains), Department of Agricultural Engineering (DEA), Federal University of Viçosa (UFV). They were reared on wheat kernels, at 28±1°C, 65±5% relative humidity (rh) and 12:12 photoperiod in glass jars.

Crops

The kernels of five corn genotypes (UFVM100, UFVM200, UFVM100X200, AG1051 and DKB747) were planted and collected in an experimental farm of the UFV without using any insecticides. All kernels were stored in an environmentally controlled chamber under 5°C until the beginning of the experiment.

Development and survivorship experiment

Five samples of 50 g of kernels of each corn genotype were infested with 30 eggs aged for 24 h. The eggs were obtained by transferring *S. cerealella* adults to a plastic container with a piece of gauze for ventilation. A piece of black filter paper was folded according to the Ellington method (Ellington, 1930) to create a narrow oviposition substrate. Corn samples with eggs were placed in plastic containers (350 ml) covered at the top with a piece of gauze for ventilation. They were put in an environmentally controlled chamber at 28±1°C and 65±5% relative humidity. The development period, number of emerging adults and weight loss of kernels were adopted as parameters in this experiment.

Physical-chemical characteristics of tested corn genotypes

Fifteen kernels of each corn genotype were used to determine kernel size by using the caliper rule. Ten replicates of one hundred kernels were randomly collected from each genotype and weighed using an electronic balance to determine the hundred-kernel weight. A set of fifteen kernels was randomly collected from each genotype to evaluate the kernel hardness. Kernel hardness was expressed as the break force (Newtons, N) required breaking the kernels at a maximum deflection of 1 mm. Kernel hardness was measured using a TA.HD texturometer (Stable Micro Systems).

The moisture content of kernels was determined according to the ASAE methods (ASAE 2000). Fat content was determined by the AOCS methods (Am 5-04; AOCS 2009). Ash and protein contents were determined according to the method described by Silva and Queiroz (2002). Carbohydrate content was calculated by the empirical formula: Carbohydrate content = 100 – ∑ (Ash % + Protein % + Fat %). Results from percentages of ash, protein and fat were calculated in the dry material of kernels.

Statistical analysis

The generalized linear modeling (GLM) with appropriated distribution was used. The data from the susceptibility test and physical-chemical characteristics of corn genotypes were subjected to analysis of variance (ANOVA), and correlation analysis was done by correlation test using R program (R Development Core Team, 2010). For all analyses we performed to contrast analyses between categories of the treatments for comparison among the means.

Results

Development and survivorship experiment

The data from the development and survivorship experiment revealed significant differences in the development period, percentage of survival and percentage of kernel weight loss among the genotypes tested (Table 1). The lengthened egg to adult developmental period was found in AG1051 kernels (39.33 days) ($F = 4.20$; $P = 0.012$), and no significant differences were found among other genotypes.

The results for survival % and kernel weight loss % were taken almost the same trend. Lower survival % was observed in UFVM100X200 and AG1051, with 28.67 and 28.00%, respectively ($F = 6.92$; $P = 0.001$), compared to the other genotypes. Similarly, kernel weight loss % was significantly lower in UFVM100X200, AG1051 and DKB747, compared to

Table 1 - Developmental period (days), survival (%) and grain weights loss (%) (Mean ± SE) of Sitotroga cerealella reared on five corn genotypes.

Genotypes	Development period (days)	Survival (%)	Grain weight loss (%)
UFVM 100	34.03±0.26 b	52.00±2.26 a	10.46±1.4 a
UFVM 200	38.16±1.50 b	41.33±4.78 a	7.52±0.98 b
UFVM 100X200	37.83±1.49 b	28.67±3.09 b	4.35±0.47 c
AG1051	39.33±0.82 a	28.00±4.29 b	3.92±0.62 c
DKB747	35.70±0.53 b	55.33±5.37 a	7.18±0.38 c

Means followed by the same letter(s), within the same column, are insignificantly different at 5% level of probability.

Table 2 - Physical and chemical characteristics of kernels of corn genotypes.

Genotypes	Kernel Size (mm)	Hundred-kernel weight (g)	Kernel hardness (N)	Moisture (%) Wet Basis (WB)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)
UFVM 100	247.43±8.81b	29.2±0.28b	347.25±43b	14.5±0.18b	1.9±0.02b	11.5±0.36a	5.0±0.03 c	81.6±0.31c
UFVM 200	219.42±14.04b	25.6±0.64c	379.28±41a	13.9±0.03c	2.1±0.07b	11.2±0.26a	5.7±0.05a	81.0±0.13c
UFVM 100X200	240.26±7.47b	27.8±0.46b	377.56±37b	14.7±0.02b	2.1±0.02 b	10.9±0.22a	5.3±0.04b	81.7±0.28c
AG1051	246.67±11.35b	28.6±0.83b	348.12±42b	13.5±0.03d	1.6±0.02b	9.8±0.04b	4.9±0.03c	83.7±0.01[a]
DKB747	255.99±7.88a	31.2±0.45a	334.70±40b	15.7±0.08a	2.3±0.30a	10.5±0.07b	5.1±0.09c	82.1±0.13b

Means followed by the same letter(s), within the same column, are insignificantly different at 5% level of probability.

the other genotypes (F = 10.77; P < 0.0001).

Physical-chemical characteristics of kernels for development and survivorship experiment

Physical and chemical characteristics of kernels of corn genotypes tested are shown in Table 2. Kernel size (mm), hundred-kernel weight (g), moisture % and ash % parameters were significantly higher in kernels of DKB747 genotype, compared to the genotypes tested. The greater kernel hardness (N) was found in kernels of genotype UFVM200. The moisture % of kernel of AG1051 was significantly lower, compared to the other genotypes (F = 102.28; P < 0.0001), but its percentage of carbohydrate was higher, compared to the other genotypes (F = 23.51; P < 0.0001). Kernels of the genotypes UFVM100, UFVM200 and UFVM100X200 were presented a higher percentage of protein, compared to the other genotypes (F = 8.51; P = 0.003).

Correlation between physical-chemical characteristics of kernels and development and survivorship parameters

The correlation test presented in Table 3 showed that moisture %, protein %, carbohydrates %, kernel hardness (N), and kernel weight were important factors for the determination of susceptibility of corn kernels to infestation with *S. cereallela*. A negative correlation was found between development period and protein %, moisture % and kernel weight; and a positive correlation was observed between it and kernel hardness (N) and carbohydrate %. On the other hand, a positive correlation was found between survival % and protein %, moisture % and ash %; and a negative correlation was observed between it and carbohydrate %. A positively correlation was found between kernel weight loss % and protein %, and a negative correlation, between it and carbohydrate %.

Discussion

Angoumois grain moth did not exhibit the same level of susceptibility to all corn tested genotypes used in this work. However, results of this research indicate that the physical and chemical characteristics of kernels of corn genotypes has a significant impact on *Sitotroga cerealella* development period (days) and survival %. The mean developmental period from egg to adult of *S. cerealella* when reared on the tested corn genotypes was between 34.03 and 39.33 days. This is similar to that reported by Consoli and Filho (1995), who found that the mean developmental period from egg to adult reared on corn was between 5 and 6 weeks. However, the period was shorter on sorghum (Shazali and Smith, 1985; Ashamo and Khanna, 2006a) and rice, *Oryza sativa* L (Cogburn et al, 1989).

The highest survival % was found in genotype DKB747 (55.33 %) (Table 1). Another study found a survival percentage of *S. cerealella* reared on different corn genotypes of between 46.5 and 64.5% (Cônsoli and Filho, 1995). On paddy varieties, it was observed to be between 42.0 to 68.7% (Ashamo, 2010). In our study, survival from egg to adult was lower, compared to the data from Shazali and Smith (1985), they found a survival % of 77.1% for *S. cerealella*, when reared on sorghum. The highest weight kernel loss % was found for UFVM100 kernels (10.46%). Ashamo and Khanna (2006b) found that the highest weight loss of grains was 8.7%, when *S. cerealella* reared on corn varieties.

This study presented a positive and negative correlation between physical-chemical characteristics of kernels and moth performance (Table 3). In wheat, a negative correlation was found between the present weight loss and fat and carbohydrate concentrations; and a positive correlation was found between the present weight loss and protein concentration (Khan et al, 2005). Other reports demonstrated that the development period of *S. cerealella* depended on the maturity of corn kernels (El-Sebai, 2006). Kernel Hardness plays an important role in plant resistance against several stored product insects. In this study, a positive correlation was found between kernel hardness and development period, and a negative correlation was found between it and the percentage of survival and kernel weight loss (Table 3). The resis-

Table 3 - Correlation coefficient (r) between susceptibility preference parameter and physical-chemical characteristics of corn genotypes.

	Development period (days)	Survival (%)	Kernel weight loss (%)
Development period (days)	1.00		
Survival %	-0.85	1.00	
Kernel weight loss %	-0.85	0.84	1.00
Kernel size	-0.43	0.30	-0.01
100 Kernel weight (g)	-0.53	0.49	0.12
Kernel hardness	0.47	-0.55	-0.25
Moisture%	-0.60	0.63	0.25
Ash %	-0.40	0.58	0.27
Protein %	-0.64	0.47	0.78
Fat %	0.22	-0.001	0.13
Carbohydrates %	0.47	-0.48	-0.63

tance of different maize varieties to *P. truncatus* and *S. zeamais* during storage was affected by the trait kernel hardness (Meikle et al, 1998).

The results obtained in this work led to the conclusion that, in development and survivorship experiment, the susceptibility of corn genotypes to *S. cerealella* depended on the physical-chemical characteristics of kernels. Modifications in physical-chemical characteristics of kernels may be an important factor in integrated pest management strategies for *S. cerealella* and in insect resistant genotype programmes.

Acknowledgements

We are grateful to Prof Paulo Cesar Corrêa from Departamento de Engenharia Agrícola, Universidade Federal de Viçosa for his help in the analysis of kernel hardness. We are especially thankful to "National Council for Scientific and Technological Development" (CNPq) and "The Academy of Sciences for the Developing World" (TWAS) for their intellectual contributions and financial support to this research.

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