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Varietal differences in the susceptibility of new rice for Africa (NERICA) to *Sitophilus oryzae* L. (Coleoptera: Curculionidae)

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Eight new rice for Africa (NERICA) varieties obtained from the Savanna Agricultural Research Institute (SARI) in Ghana were investigated for their relative susceptibilities to infestation by *Sitophilus oryzae* L., an important storage pest of milled rice. The completely randomized design was used to obtain data on the infestation and damage indices such as egg oviposition, developmental period, progeny emergence, seed weight loss, and susceptibility index. Overall, the varieties arranged in a descending order of susceptibility were NERICA [N] 8, N3, N5, N2, N1, N4, N9 and N6. NERICAs 9 and 6 consistently, demonstrated high tolerance to *S. oryzae* infestation and damage. These varieties should be incorporated into breeding programmes to help reduce the high grain losses incurred by farmers during storage.

Key words: New rice for Africa (NERICA), *Sitophilus oryzae,* insect infestation, susceptibility.

INTRODUCTION

The new rice for Africa (NERICA) was developed from interspecific crossing between the cultivated Asian rice, *Oryza glaberrima* Steud. and the African rice, *Oryza sativa* L. (Jones et al., 1997). The Asian rice varieties that are generally grown for their high yield potential are known to lack resistance or tolerance to many of the ecological stresses typical of Africa, while the African rice varieties are adaptive to these stresses, but lack specific yield potentials (Chang et al., 1972). In 1999, the African Rice Centre made efforts to combine useful traits of both cultivated species so as to improve the performance of upland rice for use in African farming systems. Seven NERICA varieties (1 to 7) were named and released by the African Rice Centre in 2000. Later, 11 more NERICA varieties were named and characterized based on their excellent performance and popularity among farmers, thus, bringing the total number of upland NERICA to 18 varieties (WARDA, 2002). NERICA rice varieties were introduced into sub-Saharan Africa based on their suitability for the tropical upland ecology. Many of these varieties are known to have yield advantage over their *O. glaberrima* and *O. sativa* parents either through superior weed competitiveness, drought tolerance, or resistance to pests and diseases (Jones et al., 1997). Notwithstanding, insect pest infestation still remains a major biotic constraint to the increased and sustainable production of NERICA rice in many agroecosystems of Africa.

The rice weevil, *Sitophilus oryzae* L. is an economically important pest of stored rice in tropical Africa, causing considerable qualitative, quantitative and viability losses in stored rice every year. Its infestation in milled rice is one of the most serious problems in the rice food chain (Prakash et al., 1987). Shivakoti and Manandhar (2000)

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Table 1. Description of the test NERICA varieties.

Varieties	Source	Grain length (mm)	Grain width (mm)	Grain size	Coat colour	Amylase content (%)	1000 grain weight
NERICA 1	SARI	6.9	2.6	Medium	White	26.6	29.0
NERICA 2	SARI	6.9	2.6	Medium	White	26.4	26.0
NERICA 3	SARI	7.2	2.2	Long	White	23.8	29.0
NERICA 4	SARI	7.2	2.5	Long	White	23.8	29.0
NERICA 5	SARI	5.7	2.5	Short	White	-	-
NERICA 6	SARI	6.2	2.8	Medium	White	24.5	29.0
NERICA 8	SARI	7.2	2.6	Long	White	-	29.0
NERICA 9	SARI	6.2	2.8	Medium	White	-	33.0
Abrekuku	Tamale	5.5	2.4	Short	Reddish-brown	-	-

SARI: Savanna Agricultural Research Institute; Source: African Rice Centre, 2008.

reported that adult *S*. *oryza* can consume 0.49 mg of grain daily and produce 11 to 12 mg of waste products in a single generation. Annual grain loss in storage approaches 15%. A study conducted by Banerjee and Nazimuddin (1985) showed that, the maximum grain loss in wheat attributed to a single weevil was measured at 19%, and nearly 57% in rice. Additionally, the kernel damage caused by the larva enables other species, the external infesters, which are not capable of infesting sound grains, to increase the damage rapidly. The control of *S*. *oryza* is crucial to safe preservation and sustainable production of NERICA in sub-Saharan Africa. While there are several synthetic insecticides such as chemical grain protectants and fumigants for the control of this pest, their use has not been sustainable owing to their high cost, unavailability in local markets, and associated health and environmental risks (Wolfson et al., 1991). The need to reduce over-reliance on synthetic insecticides for pest control in rice has called for a search for resistant strains against *S. oryzae.* Much emphasis has been laid at field level to access NERICA varieties, for resistance to infestation by several field pests. In Nigeria, NERICA 1 and 5 were rated under field conditions as the two most tolerant to rice stem borers, *Chilo* sp, with infestation levels less than 10%. A test against termites infestation in Nigeria, also showed that, NERICA 5 was less susceptible to termites damage whiles NERICA 2 and 3 recorded a degree of tolerance to termites damage (WARDA, 2002). To this effect, it is necessary to determine the resistance levels of NERICA varieties cultivated in the savanna ecology of Ghana against major pests in storage. The present study evaluated the susceptibility of eight NERICA varieties to infestation and damage by *S. oryzae* under laboratory conditions.

MATERIALS AND METHODS

Source of NERICA varieties

Seed grains of eight NERICA cultivars were used for the experiment at the entomology laboratory of the University for Development Studies (UDS), Nyankpala in the Northern Region of Ghana, in 2012 between the months of April and June; a period in which *S. oryzae* is known to be at its peak of activity (Caswell, 1980). It is therefore thought that any variety that inhibits development and damage by the pest at this period is indeed resistant. One of the commonly cultivated local rice varieties known as Abrekuku, which is considered to be tolerant to *S. oryza*, was used as a check. Detailed description of NERICA varieties is shown in Table 1. The seeds were kept in glass jars and oven sterilized at 70°C for an hour to rid them of any postharvest pest or pathogen. The grains were later adjusted to room temperature before being used for the experiment.

Rearing of experimental insects

The experimental weevils were reared for both choice and no-choice experiments. The rearing procedure was carried out at the Entomology Unit of the UDS in the Northern Region of Ghana. The method used in rearing the insects from the no choice experiment was based on that of Swella and Mushobozy (2007).

Adult *S. oryzae* were collected from naturally infested milled rice from Tamale market in Ghana. They were mass reared and bred under laboratory conditions, on diet of NERICA rice grains (1000 g) inside a growth chamber at 28 ± 2°C and 60 ± 15% RH. Forty pairs of newly emerged (1 to 24 h old) adults were initially placed in jars containing the various seeds. The jars were covered with plastic mesh, fastened with rubber bands to allow ventilation, while preventing escape of the insects.

The stock was allowed for 5 days for mating and oviposition, after which the parental insects were removed and seeds containing the eggs were transferred to fresh seeds in rearing jars also covered with the plastic mesh and rubber bands. The subsequent progenies emerging from the stock were then used as parental generation for the experiment. Adult insects for the choice experiment were reared from the culture of insects from the no-choice experiment shown above. The grains of each rice variety were contained in a 20 ml rearing jar. The aim was to precondition the weevils so as to eliminate any short term changes in behaviour associated with the change of host variety from that used for culturing to that being tested (Dobie, 1974).

Experimental design and procedure

With little modifications, the procedures describe by

Table 2. Number of eggs laid and developmental period of *S. oryzae* on seeds of different NERICA varieties.

NERRICA varieties	Mean number of eggs laid on seeds	Mean developmental period (days)
NERICA 8	17.38[a]	23.6[c]
NERICA 3	16.71[a]	22.8[d]
NERICA 5	16.06[a]	24.3[b]
NERICA 2	15.69[a]	22.1[e]
NERICA 1	13.98[ab]	23.5[cd]
NERICA 4	13.45[b]	22.2[de]
NERICA 9	13.2[b]	22.4[d]
NERICA 6	12.9[bc]	21.0[f]
Abrekuku	8.78[c]	27.4[a]
LSD (5%)	3.50	0.32

Column means followed by different letters are significantly different at P<0.05.

Adam and Baidoo (2008) and Swella and Mushobozy (2009) were followed in conducting this experiment. One hundred and fifty healthy grains from each NERICA variety were placed in a glass jar after determining the moisture content using a moisture meter. Fifteen pairs of the *S. oryzae* (a day old F_1) emerging from the culture were selected and introduced with the aid of a pooter into each jar of seeds. Afterwards, the jars were closed with a plastic mesh as illustrated above. Each variety served as a treatment and was replicated four times in a completely randomised design. The set up was kept for seven days in an incubator undisturbed at conditions described above, to enable mating and oviposition. The insects were removed afterwards and observations were made for a maximum of 28 days during which appropriate data were taken as indicated below. The observations were terminated on the 28th day, from the date of first adult emergence and preceded by a measurement of the final seeds weight.

Data collection and analysis

Data were collected on number of eggs laid, developmental period, adult emergence, seed weight loss and susceptibility index. The number of eggs laid on each treatment set up was counted using the egg plugs on seeds, a week from day of infestation, in accordance with the method described by Lambert et al. (1985). Counts of emerged adults were taken daily with the aid of a tally counter, and the number recorded for each sample. Sampling for insect emergence continued up to the 28th day when most F_1 progenies would have completed development. The mean developmental period was determined as the time interval taken for the weevils to develop from egg to adult stage. Percentage weight loss (PWL) in seeds was estimated following the method given by Jackai and Asante (2003) as:

$$\text{PWL} = \frac{Initial\ \ seed\ \ weight - Final\ \ seed\ \ weight}{Initial\ \ seed\ \ weight} \times 100$$

The index of susceptibility (Si) was calculated from the number of emerged weevils using the formula of Dobie (1977) as follows:

$$\text{SI} = \frac{Log\ F_1}{D} \times 100.$$

Where, F_1 = Total number of emergence adults, and D = Mean developmental period (days), estimated as the time from middle of oviposition to the emergence of 50% of the F_1 generations. Using the one-way analysis of variance (ANOVA), the differences in susceptibility of the various treatments were determined based on the above parameters. All percentages and numerical data were square root and arcsine transformed before the analysis. Where ANOVA test indicated significant difference between the treatments, the least significant difference (LSD) test was used to separate the means.

RESULTS

Egg oviposition

The mean number of eggs laid by adult females of *S. oryzae* on seeds of the different NERICA varieties is presented in Table 2. The mean egg oviposition ranged from 12.94 in NERICA 6 to 17.38 in NERICA 8. Mean egg oviposition was lowest in the control (Abrekuku) treatment (8.78) and was significantly different from the other treatments. Egg oviposition was significantly affected (P<0.05) by the different NERICA varieties. Eggs deposited on NERICA 8 were significantly higher than that of NERICA 4, 6 or 9. Among the NERICA varieties, NERICA 6 recorded the least egg count. Egg-adult development was longest (27 days) in the Abrekuku variety.

Developmental period and progeny emergence

The developmental period of *S. oryzae* on of the various NERICA varieties during the experiment is presented in Table 2. Among the NERICAs, egg-adult developmental period was found to range from 21.0 days on NERICA 6 to 24.3 days on NERICA 5. The analysis of variance (ANOVA) showed a significant difference (P<0.02) between the treatments means. The developmental period of *S. oryzae* was significantly prolonged in NERICAs 5 and 8. However, the developmental period between NERICAs 8 and 1, NERICAs 1 and 4 as well as that of NERICA 2 and 4 did not differ significantly. Also, a significant difference (P<0.001) was observed in the percentage of adults that emerged from the NERICA

Table 3. Mean progeny emergence of *S. oryzae* from seeds of different NERICA varieties.

NERICA varieties	Mean number of adults	Percentage progeny emergence
NERICA 8	29.8[a]	89.4
NERICA 3	29.7[a]	89.1
NERICA 5	29.1[a]	87.4
NERICA 2	29.2[a]	87.6
NERICA 1	27.8[a]	83.3
NERICA 4	27.6[a]	83.1
NERICA 9	26.5[a]	79.5
NERICA 6	26.7[ab]	80.1
Control	23.6[b]	70.8
LSD (5%)	3.5	Ns

Column means followed by different letters are significantly different at P<0.05.

Table 4. Seed weight loss and susceptibility index of *S. oryzae* on different NERICA varieties.

NERICA varieties	Mean weight loss	% weight loss	Susceptibility index
NERICA 8	7.1[ab]	3.76[a]	4.84[a]
NERICA 3	7.3[a]	3.81[a]	4.94[a]
NERICA 5	7.0[bc]	3.74[a]	4.71[a]
NERICA 2	5.9 [d]	3.41[a]	4.94[a]
NERRICA 1	5.6[e]	3.34[ab]	4.71[a]
NERICA 4	5.3[f]	3.27[b]	4.74[a]
NERICA 9	5.2[g]	3.23[b]	4.73[a]
NERICA 6	4.7[h]	3.04[bc]	4.81[a]
Abrekuku	3.3[i]	2.57[c]	3.91[b]
LSD (5%)	0.17	0.52	0.38

Column means followed by different letters are significantly different at P<0.05.

varieties. Among the NERICA varieties, percentage adult emergence ranged from 89.4% on NERICA 8 to 79.5% on NERICA 9, but the least (70.9%) was recorded in the control. Statistically, the percentage adult emergence was significantly higher on NERICA 8 and 3 than that of NERICA 9 and 6 (Table 3).

Seed weight loss and susceptibility index

The weight loss in seeds due to *S. oryzae* infestation was found to be significantly affected by the different NERICA varieties (P<0.002) (Table 4). The mean weight loss was highest (3.81) in NERICA 3 and lowest (3.04) in NERICA 6. Seed weight loss in the control was lowest (2.57) than any of NERICA varieties. There was a significant difference between the weight loss in NERICA 3 and 4, and the other moderately resistant varieties (NERICA 6 and 8). Also, a significant difference was observed among NERICAs 8, 6 and 9 but not in NERICA 4. *S. oryzae* bred more on soft kernel varieties than the hard kernel varieties, indicating varietal variability in resistance among cultivars. Table 4 presents the susceptibility indices (SI) of the different varieties to infestation by *S. oryzae*. SI ranged from 4.71 in NERICAs 1 and 5, to 4.94 in NERICAs 3 and 2. SI in the local Abrekuku variety was 3.91. There was a significant difference (P<0.001) among the treatment means in terms of susceptibility. However, SI did not vary significantly among the NERICAs. Furthermore, when the varieties were ranked in order of their relative susceptibilities using parameters such as oviposition, adult emergence, development period, seed weight loss and SI, it was observed that among the NERICA varieties, NERICAs 6, 9 and 4 proved to be the least susceptible while NERICAs 8, 3 and 5 were the most susceptible to *S*. *oryza* infestation (Table 5).

DISCUSSION

The results of the study showed that, egg oviposition and development of *S. oryzae* on rice is significantly affected by variety. Egg oviposition and development were significantly inhibited by NERICA 6 but was higher in NERICA 8 (Table 2). According to Campbell (2002), *S. oryzae* is able to reduce egg laying in the presence of

Table 5. Ranking of NERICA rice varieties in order of relative susceptibilities to *S. oryzae*.

Varieties	Eggs laid	Adults emergence	Seed weight loss (%)	Developmental period	SI	Rank total	Rank position
Abrekuku	1	1	1	9	1	13	1
NERICA 1	5	5	5	6	3	24	5
NERICA 2	6	7	6	2	8	29	6
NERICA 3	8	8	9	5	9	39	8
NERICA 4	4	4	4	3	5	20	4
NERICA 5	7	6	7	8	2	30	7
NERICA 6	2	3	2	1	6	14	2
NERICA 8	9	9	8	7	7	40	9
NERICA 9	3	2	3	4	4	16	3

Rank (1-9), 1 = Least susceptible and 9 = Most susceptible.

lower quality resources (that is, it lays fewer eggs when held with only small grains) and t his results from longer acceptance time for poorer quality and variation in seed quality and oviposition. The small seed size and quality of NERICA 6 explains why it performed best. However, for NERICA 8 it could be attributed to the larger grains size and is in agreement with earlier works by Stejskal and Kucerova (1996), who reported that *S. oryzae* prefer large grains for oviposition. Larger seeds were more likely to be parasitized or contain more than one egg than smaller grains. Nwanze et al. (1975) observed that the chemical composition of the seeds including colour of the seeds, thickness of the seed coat, and smoothness of seeds are major determinant for oviposition and development by *S. oryzae*. From these observations it would however appear that the inherent quality of the grain determines the developmental period. Also, mechanical grain damage or injury has been identified as a major factor affecting insect oviposition, kernel localization, survival, developmental time and fecundity on rice (Trematerra et al., 1999).

Weight loss resulting from the quantity of materials consumed by the developing larvae correlated positively with the seed susceptibility index. The variations in susceptibility indicated their suitability as host for oviposition, feeding and development of *S. oryzae*. Mbata (1993) reported that weight loss is generally highly correlated with susceptibility. Damaged grains correlated positively with the number of eggs laid, adult emergence and grain weight loss. This is in agreement with Singh et al. (1984) who stated that, the number of emerging adults determines the extent of damage, and consequently grains permitting more rapid and higher levels of adult emergence will be more extensively damaged. Furthermore, Mohammad et al. (1988) reported that, dry weight loss is dependent on number of adults emerged and damaged grains; if high number of emerged adults or damaged grains are more, it will result in more grain loss. Also, Swella and Mushobozy (2009) reported that SI has a positive correlation with emergence. Moreover, the high losses in weight can be attributed to the large flour extraction resulting from weevils feeding activity. The higher the flour extraction, the lower the protein, thus the endosperm cells (make the flour) which are packed with starch granules in a protein matrix. Available reports have also showed that, the vulnerability of the endosperm of common wheat cultivars with kernel hardness, accounts for the variability observed between cultivars for whole seed susceptibility (Sinha et al., 1988). It is well known that grain types and even varieties of the same grain differ in their susceptibility to attack and influence on life history characters of stored product insects (Bamaiyi et al., 2007; Ladang et al., 2008).

Conclusion

The results obtained from this study have indicated that *S. oryzae* infestation on stored NERICA grains leads to reduction in grain weight and number of damaged grains. The nature and intensity of damage caused by *S. oryzae* were different among the rice varieties. The control, Abrekuku variety recorded the least values with respect to susceptibility. Also, when the NERICAs were ranked in order of susceptibility, NERICA 6, 9 and 4 showed high resistance to *S. oryza* infestation and damage. NERICA 8 however, recorded the highest in terms of seed susceptibility. NERICA 6 consistently demonstrated high tolerance to the pest and should therefore, be promoted or incorporated into breeding programmes to help minimize the grain high losses incurred by farmers during storage. NERICAs 1, 2, 3, 5 and 8 will require more protection in storage in order to preserve grain quality.

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