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Evaluation of Damage Induced by *Aspavia armigera* Fabricius on Different Rice (*Oryza sativa* Linn.) Varieties

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Abstract

Yield-related responses of rice plants to artificial infestation of 5 adult *Aspavia armigera* per peduncle at 0, 7, 14, 21 days after flowering were examined to determine the critical stage of rice for *Aspavia armigera* infestation. Damage was also assessed at 7 days after flowering, which was the critical stage of rice, under different bug densities - 0, 2, 4, and 8 bugs per peduncle. The highest grain weight loss of 70.0%, which was significantly different from those recorded at 14 days after planting (DAF) and 21 DAF (40% and 39.7%, respectively), occurred at 7 DAF which was the milk stage. Similarly, significantly lower paddy and head weights which were about 48% of that of the control were obtained at 7 DAF, while higher percentage of floating grains caused by *A. armigera* infestation was obtained at 7 and 14 DAF compared to other times. With increasing insect density there was a corresponding significant increase ($P < 0.05$) in floating grains and grain weight loss, and reduction in head weight, paddy weight and grain weight. At 2 bugs per peduncle caused a significant reduction in rice yield parameters in both upland and lowland varieties and is therefore the damage threshold for the varieties tested.

Keywords: rice, critical phenological stage, *Aspavia armigera*, infestation density, damage, yield

1. Introduction

Rice (*Oryza sativa* Linn.) is grown for human consumption for its cheap source of carbohydrates. It is estimated that 40% of the world population utilize rice as a major source of energy (Heinrichs & Barrion, 2004). Rice is grown not only as a source of carbohydrate but also of valuable nutritive materials such as mineral elements and vitamins (Oyenuga, 1968; Wibberley, 1989). Yield of rice is generally low, 1.3t/ha in West Africa and 2.0 t/ha in Nigeria (West Africa Rice Development Association, WARDA, 1996). This low productivity on rice farms is often caused by harsh environmental conditions which determine the type and intensity rice diseases and pests that reduce the yield of rice (Food and Agriculture Organization, FAO, 1994). Moreover, poor grain yield has been attributed partly to insect pest attack on grains in the field (Agyen-Sampong, 1982).

All parts of the plant, from the root to the developing grains, are attacked by various species. In West Africa, major rice insect pests include the stem borers - *Chilo zacconius* Bleszynski, *Diopsis longicornis* Macquart, *Maliarpha separatella* Ragonot and *Sesamia calamistis* Hampson, caseworm - *Nymphula depunctalis* (Guenée), African rice gall midge - *Orseolia oryzivora* Harris and Gagne, and the grain-sucking bugs - *Aspavia armigera* (Fabricius).

In Nigeria, rice bugs used to be considered next in rank to the stem-borers (Alam & Lowe, 1989) until the International Institute for Tropical Agriculture (IITA) (1986) reported the increasing incidence of *A, armigera* as causing great damage in Nigeria when it sucks rice panicles at the milk/dough stage. Severity of *A. armigera* damage depends on the stage of grain development and on the number of punctures in the grain (Ewete & Olagbaju, 1990). It is believed that *Aspavia* spp. feeding contributes to the incidence of the 'dirty panicle' syndrome. Both nymphs and adults prefer rice at the milk stage but will also feed on soft and hard dough rice grains. Removal of the liquid milky white endosperm results in small and unfilled grains. When the bugs feed on soft or hard dough endosperm, they inject enzymes to predigest the carbohydrate. In the process, they contaminate the grain with microorganisms that cause grain discoloration or "pecky" rice. Damage from feeding at this stage reduces grain quality rather than weight. Pecky rice grains are prone to break during milling (Heinrichs & Barrion, 2004).

Although many insect species have been recorded to occur on rice in West Africa, their economic importance, especially the grain-sucking bugs, and role as pests are not well understood (Heinrichs & Barrion, 2004). This information is needed to guide researchers as they develop effective integrated pest management strategies. In this study, therefore, the damage potential of *A. amigera* on four rice varieties and four alternative hosts as well as the most critical phenological stage of rice for *A. amigera* infestation was investigated.

2. Materials and Methods

There were two experiments which were carried out at the Plant Biology Laboratory, Olabisi Onabanjo University, Ago-Iwoye, Nigeria.

2.1 Sources of Seeds

From earlier studies, ten rice varieties comprising five upland and lowland that were found to be resistant to *A. armigera* were used for the study. The upland varieties were ITA 321 and ITA 315 from IITA, Ibadan, Nigeria, IRAT 169 (Institute des Gerdart, IRAT station, Bouake), FAROX 41 (Federal Department of Agriculture, Nigeria) and M 55 (Macros Agricultural Research Institute, Indonesia). The lowland varieties were: ITA 230, TOX 3561-56-2-3-2, TOX 3100-32-2-1-3-5, TOX 3107-1-2-1-3-1 and TOX 3226-2-2-2 from IITA.

2.2 Mass Rearing of A. armigera

Aspavia armigera mass rearing method was adapted from Nilakhem (1976), Bowling (1979a, 1979b) and Heinrichs et al. (1985). Thirteen cages which were constructed using water-resistant wood and aluminum wire mesh were placed in a trench of about 15 cm deep outside the Plant Biology Laboratory, Olabisi Onabanjo University, Ago-Iwoye, Nigeria. Carbofuran (1.0 kg a. i/ha) was applied to the trench while permethrin powder was applied round each cage to trap ants and other crawling insects. The 13 cages were shared into 3 sets - Oviposition cages (3), Culture Maintenance cages (3), and Test cages (7). Potted rice variety ITA 257 which served as food source for the insect was planted in 30 plastic pots (20 cm diameter) filled with sieved top soil. Granules of NPK were incorporated into the soil before planting, and six seeds were sown per pot each week before thinning to two plants per pot at two weeks after planting. The potted rice plants were watered everyday during the dry season and every other day during the rainy season.

Adult *A. armigera* were collected from the field, sexed and placed in one of the oviposition cages containing two potted milk-stage and six potted booting-stage ITA 257 plants. After 7 days, the potted plants at booting stage containing eggs were transferred to one of the Culture Maintenance cages. At the same time, another six potted plants were placed near the already egg-laden rice plants so that the newly hatched nymphs could easily transfer to the panicle of the new food plants. This arrangement was left for one week after which the six potted plants (now with nymphs) were transferred into the Test cages where they were reared to adults. Only the newly emerged adults were used in all the experiments. Food materials were changed in the Test cages twice weekly and all contacts with the rearing cages were in the cool hours of the day (7.00 – 9.00 hrs and 16.30 – 18.00 hrs local time).

2.3 Experiment I: Determination of the Most Critical Rice Phenological Stage for Aspavia Armigera Infestation

Twenty plastic pots (20 cm diameter) filled with sieved top soil and planted to IRAT 169 were arranged five per row. These pots were watered as required. Five bugs/panicle (2 Male: 3 Female) (Ewete & Olagbaju, 1990) was introduced at three different stages of rice reproductive phase - 7, 14 and 21 days after flowering (DAF) into the nylon sleeves (30 cm × 15 cm) which accommodated the panicles up to the flag leaf. A treatment was a rice reproductive phase allotted to the panicles using completely randomized design with five replicates, while the control was insect-free. There was one panicle per nylon mesh bag. The bugs were introduced from a corner of the sleeves after which the bag was tied close to the insect with a jute thread. Then the panicle at the desired stage was enclosed in the nylon mesh bag, tied to the panicle stalk near the flag leaf. Thereafter, the first part previously tied was removed to allow the insects attack the panicle.

Cages were inspected daily to remove eggs and nymphs, while dead bugs were replaced with appropriate sexes and approximately the same age. After two weeks, the cages were removed and the panicles each in a separate paper bag were carried to the laboratory for bug damage evaluation. The panicles were oven-dried at 50 ^oC for one week after which they were weighed using Metlers Balance. Two methods of insect damage assessment were used - the percentage weight loss and unfilled grain floatation techniques. In the percentage weight loss, the difference in weight between grains from the control and the infested panicles were determined. Thus, if A represents the average weight of panicles on the control panicles and B is the average weight of panicles on infested panicles, the percentage grain weight loss is therefore:

$$\% \text{ Grain Weight Loss} = \frac{A - B}{A} \times 100$$

Percentage weight losses were then separated among the treatments using Duncan's Multiple Range Test.

In unfilled grain floatation techniques of evaluating bug feeding activity, the panicles used when determining the percentage grains weight loss were used. A saturated salt solution was prepared by dissolving NaCl in distilled water until it no longer dissolved. The supernatant was decanted and placed in a graduated cylinder, and shaken vigorously. Bug-damaged empty grains floated and filled undamaged grains sank to the bottom of the cylinder. If the volume occupied by unfilled grains is X and that of filled grains is Y, the estimate of the percentage of floating grains is:

$$\% \text{ Floating Grains} = \frac{X}{X+Y} \times 100$$

(Heinrichs et al., 1985).

2.4 Experiment II: Damage Assessment of Aspavia Armigera Under Artificial Infestation on Rice Varieties at the Most Critical Phenological Stage

Six seeds of each of the 10 rice varieties were sown each week per pot (20 cm diameter) filled with sieved top soil for four weeks and were thinned to two plants at 2 WAP. Six potted rice plants were so established per variety per week, and were watered daily. Granules of NPK fertilizer were broadcast on the soil to improve its fertility.

When about one-fourth of the grains reached the milk stage, the following different bug populations collected from the laboratory-maintained insect culture were confined on the panicle using muslin cloth bags/sleeves (15 cm × 30 cm) in five replications: 0 bugs/panicle (control); 2 bugs/panicle - (1M: IF); 4 bugs/panicle (2M: 2F); and 8 bugs/panicle (4M: 4F). The bugs were introduced into each bag from to a corner and the sleeve was tied with a rope. Then a jute thread was used to hold the sleeves onto the panicle towards the flag leaf. Thereafter, the insects were allowed to attack the panicle when the thread restricting them was removed. The cages were inspected daily to remove eggs laid and to replace dead bugs with those of the same age and appropriate sex.

At grain maturity, the bases of the panicles were cut while the cages containing the cut panicles were taken to the laboratory for evaluation. The panicles were oven-dried separately in paper bags (well-labeled) at 50 ^{o}C for 7 days, and later hand-threshed. Panicle and head weights were recorded, while the percentage weight loss and unfilled grain floatation techniques of evaluating bug feeding activity described earlier were used to assess insect damage.

3. Results

Variations in IRAT 169 head weight, paddy weight, threshing, floating grains and grain weight were observed when five adult *A. armigera* were artificially introduced per panicle at different DAF. The highest grain weight loss of 70.0%, which was significantly different from those recorded at 14 DAF and 21 DAF (40% and 39.7%, respectively), occurred at 7 DAF which was the milk stage. Similarly, significantly lower paddy and head weights which were about 48% of that of the control were obtained at 7 DAF, while higher percentage of floating grains caused by *A. armigera* infestation was obtained at 7 and 14 DAF compared to other times (Table 1). However, the lowest damage impact of the bug, which was significantly higher than the control, was recorded at 21 DAF.

Table 1. Head and paddy weights and panicle weight loss of rice artificially infested with *Aspavia armigera* at different days after flowering

Daf*	Head Weight (G)	Paddy Weight (G)	Threshing (%)	100-Grain Weight (G)	Floating Grains (%)	Grain-Weight Loss
0	1.9a	1.5a	78.9a	1.9a	12.2c	0.0c
7	0.9c	0.7c	77.8a	0.6c	100.0a	70.4a
14	1.6b	1.3b	81.3a	1.1b	95.3a	40.1b
21	1.6b	1.4b	88.5a	1.1b	25.7b	39.7b

Means followed by same letter along a column are not significantly different using DMRT ($P < 0.05$); *DAF = Days after flowering when caging were made; Head weight = total weight of the inflorescence; Paddy weight = weight of rice grains with hulk intact.

At different bug population pressures, the degree of losses recorded on upland rice varieties varied significantly. Head weight, paddy weight and 100-grain weights recorded on the panicles of these varieties infested with 2, 4, and 8 bugs per panicle were significantly lower (P < 0.05) relative to the control, while weight loss ranged from 0.5 to 2.6 (Table 2). The mean percentage floating grains was significantly higher than the control at 4 bugs and 8 bugs per panicle. However, at 8 bugs per panicle, 100% floating grain was obtained for IRAT 169. Grain weight loss was 73.3% and 25% at 8 bugs per panicle on IRAT 169 and FAROX 41, respectively (Table 3).

Table 2. Head, paddy and grain weights of five upland rice varieties after artificial infestation of *Aspavia armigera* at different population densities in screen cages

Bugs/Panicle	ITA 321			ITA 315			IRAT 169			FAROX 41			M 55		
	HW	PW	GW	HW	PW	GW	HW	PW	GW	HW	PW	GW	HW	PW	GW
0	2.7a	2.3a	2.5a	4.0a	3.7a	2.0a	1.7a	1.5a	1.9a	4.0a	3.7a	3.0a	2.9a	2.6a	2.8a
2	1.7b	1.6b	1.7b	2.2b	1.8b	1.9a	1.2b	1.1b	1.0b	3.7a	3.3a	2.9a	2.2b	2.0b	2.5a
4	1.7b	1.5b	1.1c	2.0b	1.9b	1.4b	1.2b	0.9b	1.0b	3.0b	2.9b	2.6b	2.0b	1.6b	1.0b
8	0.9c	0.7c	0.9c	1.9b	1.8b	1.1b	1.0b	0.7b	0.5c	2.6c	2.4c	2.3b	1.6c	1.5b	2.0b

Means followed by same letter along a column are not significantly different using DMRT (P<0.05); HW= head weight; PW= paddy weight; GW=100-grain weight; weights (g).

Table 3. Percentage floating grains and grain weight loss of five upland rice varieties infested with three population levels of *Aspavia armigera* in screen cages

Bugs/Panicle	Floating Grains (%)					Grain Weight Loss (%)				
	ITA 321	ITA 315	FAROX 41	IRAT 169	M 55	ITA 321	ITA 315	FAROX 41	IRAT 169	M 55
0	40.0c	26.3c	21.0c	12.2c	29.2c	0.0C	0.0D	0.0C	0.0C	0.0C
2	60.5b	47.5b	45.0b	82.2b	58.2b	29.2B	6.6C	12.7B	45.3B	11.2B
4	76.9a	78.4a	51.1b	87.8ab	71.9a	54.3A	30.0B	22.2A	47.3B	28.5A
8	79.2a	87.9a	78.7a	100.0a	80.0a	62.3A	41.5A	25.0A	73.3A	31.2A

Means followed by same letter along a column are not significantly different using DMRT (P < 0.05).

A. armigera feeding on lowland rice elicited a pronounced loss in head weight, paddy weight and 100-grain weight under different insect densities. At 2 bugs per panicle, TOX 3107-39-1-2-3-1 had the highest head weight (3.1) while the least value (1.8) was obtained on TOX 3226-5-2-2-2. Similarly, paddy weight was higher on TOX 3107-56-2-3-2 relative to others while 0.5 was recorded on TOX 3100-32-2-1-3-5. At 2 bugs per panicle, the mean percentage floating grains ranged from 35 on TOX 3226-5-2-2-2 to 60.6 on TOX 3561-56-2-3-2 (Table 4). At 8 bugs per panicle, 62.5% floating grains was recorded on TOX 3107-39-1-2-3-1 and both TOX 3100-32-1-3-5 and ITA 230 scored 100%. At 4 bugs per panicle, a significantly higher grain weight loss was recorded on TOX 3562-56-2-3-2 than others (Table 5).

The relationships between the population density of *A. armigera* and grain yield loss on the ten rice varieties were third-degree polynomial except on FAROX 41 and TOX 3226-5-2-2-2 which was a second-degree polynomial relationship (Table 6).

Table 4. Head, paddy and grain weights of five lowland rice varieties after artificial infestation of *Aspavia armigera* at different population densities in screen cages

Bugs/ Panicle	ITA 230			TOX 3561-56-2-3-2			TOX 3100-32-2-1-3-5			TOX 3107-39-1-2-3-1			TOX 3226-5-2-2-2		
	HW	PW	GW	HW	PW	GW	HW	PW	GW	HW	PW	GW	HW	PW	GW
0	2.9a	2.7a	1.9a	2.5a	2.3a	1.8a	3.3a	3.1a	2.2a	3.5a	3.3a	2.4a	2.5a	2.3a	2.4a
2	2.2b	2.0ab	1.6a	2.0b	1.8b	1.1bc	2.5b	2.2b	1.6b	3.1a	2.9a	1.6b	1.8b	1.6b	1.7b
4	2.0b	1.9b	1.6a	1.9b	1.7b	1.0bc	1.8c	1.6c	1.5b	2.3b	2.0b	1.3bc	1.5bc	1.4bc	1.6bc
8	0.9c	0.8c	0.9b	1.8b	1.6b	0.9b	0.7d	0.5d	0.7c	1.5c	1.5c	1.2c	1.4c	1.2c	0.9c

Means followed by same letter along a column are not significantly different using DMRT ($P < 0.05$); HW = head weight; PW = paddy weight; GW = 100-grain weight; weights (g).

Table 5. Percentage floating grains and grain weight loss of five lowland rice varieties infested with three population levels of *Aspavia armigera* in screen cages

Bugs/Panicle	Floating Grains (%)					Grain Weight Loss (%)				
	ITA	TO2	TO3	TO4	TO5	ITA	TO2	TO3	TO4	TO5
0	16.3c	11.9c	22.1d	7.4b	18.8d	0.0c	0.0c	0.0c	0.0c	0.0c
2	45.8b	60.6b	49.5c	47.8b	35.0c	20.7b	38.3b	33.8b	28.1b	22.6b
4	52.4b	69.6a	65.2b	54.3ab	48.5b	21.1b	41.3b	36.31b	35.2b	33.1b
8	100.0a	75.8a	100.0a	62.5a	80.0a	47.0a	50.0a	47.1a	74.9a	54.2a

Means followed by same letter along a column are not significantly different using DMRT ($P < 0.05$);

ITA = ITA 230;

TO2 = TOX 3562-56-2-3-2;

TO3 = TOX 3100-32-2-1-3-5;

TO4 = TOX 3107-39-1-2-3-1;

TO5 = TOX 3226-5-2-2-2.

Table 6. Relationships between the density of *Aspavia armigera* and grain yield on different upland and lowland rice varieties

Rice variety	Regression equation	R^2-value
Upland		
ITA 321	$y = -0.155x^3 + 0.421x^2 + 14.37x + 4E-14$	1.0
ITA 315	$y = -0.446x^3 + 4.778x^2 - 4.470x + 2E-13$	1.0
IRAT 169	$y = 0.791x^3 - 10.15x^2 + 39.80x + 2E-13$	1.0
FAROX 41	$y = -0.587x^2 + 7.855x - 0.18$	0.9
M 55	$y = -0.261x^3 + 2.331x^2 + 1.983x + 1E-13$	1.0
Lowland		
ITA 2302-2	$y = 0.447x^3 - 5.225x^2 + 19.00x + 1E-13$	1.0
TOX 3561-56-2-3-2	$y = 0.565x^3 - 7.806x^2 + 32.5x + 2E-13$	1.0
TOX 3100-32-2-1-3-5	$y = 0.519x^3 - 7.025x^2 + 28.87x + 2E-13$	1.0
TOX 3107-39-1-2-3-1	$y = 0.460x^3 - 5.390x^2 + 22.98x + 4E-13$	1.0
TOX 3226-5-2-2-2	$y = -0.478x^2 + 10.43x + 0.992$	0.9

4. Discussion

In this study, the most vulnerable stage of rice crop to *A. armigera* was 7 DAF which was the early grain filling stage. The results clearly indicated that the soft/milky panicle is more suitable as food for *A. armigera*. This result is similar to that of Price et al. (1981) who reported that young pods of cowpea abscised when attacked by bugs. The lowest weight loss recorded at 21 DAF implies that *A. armigera* is likely not to be able to digest hard rice panicles externally before sucking.

Similarly, the feeding effect of the bug on head weight, paddy weight and 100-grain weight varied with the rice varieties at different insect densities. In particular, the highest percentage (100%) of grains that floated in upland rice varieties clearly indicated that more severe damage was caused to the upland rice varieties than to the lowland varieties and hence more susceptible to *A. armigera* infestation. The 45.7% grain weight loss recorded on IRAT 169 at 2 bugs/panicle showed that susceptible varieties will record appreciable loss in weight even at very low population pressure. Rice variety FAROX 41, therefore, was the most non-preferred to *A. armigera* of the upland rice varieties tested having had the highest head weight (2.6), lowest mean percentage floating grains (49) and 25% grain weight loss at the highest population of 8 bugs per peduncle.

From these results and those of others, there appear to be varietal differences in the effect of *A. armigera* feeding on the extent of grain damage. In studies by Ewete and Olagbaju (1990), 4 bugs panicle^{-1} caused significant grain damage on cultivar ITA 257 while 8 bugs panicle^{-1} were required to cause significant grain damage on ITA 128. Mean percentage grain damage at 4 bugs panicle^{-1} was 14 and 39% for ITA 128 and ITA 257, respectively. Similar results have been reported by Pitan et al. (2007) for the same bug caged at varying population levels on cowpea and 2 bugs/10 cowpea plants caused a significant reduction in yield.

Based on the percentage weight loss recorded on these upland rice varieties, non-preference among the test varieties were in the following order: FAROX 41, ITA 321, ITA 315, M 55 and IRAT 169. Similar varietal responses to *A. armigera* infestation were recorded on the five lowland rice varieties with the following non-preference order: TOX 3100-32-1-3-5, TOX 3226-5-2-2-2, and others. Also, 2 bugs per peduncle caused a significant reduction in rice yield parameters in both upland and lowland varieties and is therefore the damage threshold for the varieties tested.

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