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The Effect of Inflorescence Density of Grain Amaranth (*Amaranthus* spp) on *Cletus fuscescens* (Walker) (*Hemiptera: Coreidae*) Infestation

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Authors' contributions

This work was carried out in collaboration between all authors. Author OAO designed the study, managed the experimental process, managed the literature searches, analyzed the data and wrote the first draft of the manuscript. Authors TIO and CAO read, corrected and approved the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To reveal the inflorescence morphological characters affecting *Cletus fuscescens* (Walker) (*Hemiptera: Coreidae*) infestation.
Study Design: Field experiments were laid out in a randomized complete block design while the laboratory experiments were laid out in a completely randomized design.
Place and Duration of Study: Experiments were conducted at the vegetable field and entomology laboratory of the National Horticultural Research Institute, Ibadan, Nigeria, during the rainy seasons of 2009 and 2010.
Methodology: Nine accessions of grain amaranth comprising of 3 accessions with lax inflorescence (RRC 646, P 373 and Oscar Blanco), 3 accessions with intermediate inflorescence (RRC 1027, Tibet and Niqua) and 3 accessions with dense inflorescence (D70-1, RRC 551 and Zhen Ping) were planted in the field. Weekly visual counts of *C. fuscescens* adults and nymphs on

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six middle plants randomly selected and tagged per plot were made in the morning, a week after transplanting through grain maturity. At grain maturity the inflorescence morphological characters, inflorescence color, inflorescence density index, inflorescence shape were rated. Seed viability test of the harvested grain was conducted in the entomology laboratory.

Result: Accessions with intermediate inflorescence had highest *C. fuscescens* populations/ plant and least viability percentage implying susceptibility to *C. fuscescens* attack while accessions with dense inflorescence had lowest *C. fuscescens* populations/ plant and highest seed viability percentage (*P=.05*) due to compactness of the inflorescence which inhibited feeding by the insect, exhibiting an antixenosis resistance. *C. fuscescens* populations/ plant correlated negatively with only seed viability percentage (*P=.05*). Also stepwise regression analysis selected viability percentage as the most important variable reflecting *C. fuscescens* infestation (*P=.05*).

Conclusion: Dense inflorescence in amaranth accessions could be a source for conferment of antixenosis resistance to *C. fuscescens* attack while high yielding intermediate inflorescence density index though susceptible to *C. fuscescens* attack could be utilized for yield improvement in breeding programme.

Keywords: Grain amaranth; Cletus fuscescens; inflorescence density; antixenosis resistance; seed viability.

1. INTRODUCTION

Seeds of grain amaranth belongs to a nutritious class of pseudo cereals which has been identified as a very promising food because of its exceptional nutritive value as judged by its protein and lipid content, as well as for its essential amino acid composition that has relatively high lysine content [1] Consumption of grain amaranth is reported to have nutritional and health benefits, ranging from a general improvement of specific ailments and symptoms including recovery of severely malnourished children and an increase in the body mass index of people formerly wasted by Human immunodeficiency virus infection/ acquired immunodeficiency syndrome (HIV/AIDS) [2,3].

As many other vegetables, sustainable production of viable seeds of grain amaranth is threatened by pest infestation *Cletus fuscescens* (Walker) is the most prevalent bug infesting grain amaranth [4] and has been reported that its population fluctuated relatively to over-all phenological stages of grain amaranth with the peak population coinciding with the grain milky seed stage when the grains provided the most suitable quality and quantity of food for the bugs [5]. Indiscriminate use of synthetic pesticides in the control of pests of vegetables causes several pesticide related complications and toxic residues in vegetables. It is therefore pertinent to develop an alternative non-insecticide method for the control of this pest. The use of resistant varieties usually classified as antixenosis (non-preference) whereby a plant is unattractive to an insect for food, shelter or reproduction; antibiosis whereby a plant adversely affects the growth and multiplication of an insect; and tolerance, whereby a plant withstands insect attack more effectively than a susceptible plant is a component of integrated pest management. Resistant cultivars remain the most economic method of insect control because of the reduction in the costs and quantity of pesticide use and build-up of insect resistance. It also reduces the exposure of humans and environment to toxins, consequently result in production of safe food. Plant characters are known to contribute towards host plant resistance [6]. More density of glandular hair was observed in local cultivars of cucumber as one of the resistant factors to *Liriomyza sativae* (Blanchard) (*Diptera: Agromyzidae*) [7] Thus, this study was undertakento investigate the inflorescence morphological characters affecting *C. fuscescens* infestation, and yield. Findings from this study would assist plant breeders and entomologists in their selection of bug resistant high yielding accessions to diversify the basis of resistance to this pest.

2. MATERIALS AND METHODS

2.1 Planting Materials and Experimental Sites

Nine accessions of grain amaranth comprising of 3 accessions with lax inflorescence density index (RRC 646, P 373 and Oscar Blanco), 3 accessions with intermediate inflorescence density index (RRC 1027, Tibet and Niqua) and 3 accessions with dense inflorescence density index (D70-1, RRC 551 and Zhen Ping) were used in this experiment. The accessions were obtained from the North Central Regional Plant Introduction Station of the United States National Plant Germplasm System and supplied to the National Horticultural Research Institute, Ibadan, Nigeria, where the field experiments were carried out at the vegetable field of the Institute, (3°5´E, 7°3´N, 168m above sea level) and the laboratory studies carried out in the entomology laboratory of the institute during the rainy seasons of 2009 and 2010.

2.2 Assessment of the Effect of Inflorescence Density Index on *Cletus fuscescens* Infestation

Each accessions were established in sterilized sandy loam soil in nursery tray (38 × 38 cm) kept in a netted nursery house. Soil was moistened with water every 48 hrs. Pesticide and fertilizer were not applied. Seedlings weretransplanted into the field 3 weeks after germination at spacing of 50cm within row and between rows. Plot size was 2 × 2 m with 1m between plots. There were three replications laid out in a Randomized Complete Block Design. There was no pesticide treatment and the plots were weeded by hand when necessary. Six middle plants were randomly selected and tagged per plot for weekly observation of bugs which commenced a week after transplanting continuing through grain maturity. Visual counts of *C. fuscescens* adults and nymphs on tagged plants were made in the morning between 7.00am and 10.00am when the insects were relatively less active [8].

At plant maturity the inflorescence morphological characters were rated on the following scales:

Inflorescence color was rated on a scale of 1 – 4: Green = 1; golden yellow = 2; orange = 3; wine = 4. Inflorescence density index was rated on a scale of 1 – 3: Lax = 1; intermediate = 2; dense = 3. Inflorescence shape was rated on a scale of 1 – 3: Spike linking chains = 1; panicle with short branches = 2; panicle with long branches = 3. The rating scales were treated as dummy variables [9]. The rating scales were determined visually while the inflorescence color, inflorescence density index and inflorescence shape were determined according to [10].

Data were subjected to analysis of variance significantly different treatment means were separated using Student Newman Keuls (SNK) [11] (*P=.05*). Pearson's correlation and stepwise regression analyses [11] (*P=.05*) were used to investigate the relationship between the population of *C. fuscescens,* inflorescence morphological characters and yield parameters.

2.3 Viability Test

Four tagged plants were selected per accession and 100 seed/plant counted and spread on filter paper in the Petri dishes for 7 days and replicated 3 times. Petri dishes were arranged on a work bench in the laboratory at room temperature (24-28℃) relative humidity of 79–92% and a 12hr photoperiod. The filter papers were moistened with distilled water as necessary. Numbers of germinated seed were counted.

3. RESULTS

The 3 accessions with lax inflorescence had scanty inflorescence with exposed seeds. The 3 accessions with intermediate inflorescence had heavy inflorescence with exposed seeds while the other 3 accessions with dense inflorescence had compact inflorescence with hidden seeds.

In 2009 and 2010 field experiments, the 3 accessions: Niqua, RRC 1027 and Tibet which had intermediate inflorescence density index had the highest *Cletus fuscescens* population/ plant while Zhen Ping, D 70-1 and RRC 551 which all had dense inflorescence density index had significant lowest *C. fuscescens* populations/ plant (Table 1 and 2). The accessions (RRC 1027, Tibet and Niqua) with intermediate inflorescence density index and highest *C. fuscescens* population/ plant had the least viability percentage: which determined the effect of the feeding activities of bug on grain, in the 2 planting seasons. On the other hand, the accessions (Zhen Ping, D 70-1 and RRC 551) with dense inflorescence density index and lowest *C. fuscescens* population/plant had the highest viability percentage in the 2 planting season also (Table 1 and 2).

It was observed in the 2 planting seasons that the means of 1000 seed weights of the 3 accessions with lax inflorescence density index (P 373, RRC 646 and Oscar Blanco) were significantly smaller than the accessions with intermediate and dense inflorescence density index (Tables 1and 2).

Although the 3 accessions with intermediate inflorescence density index (Niqua, RRC 1027 and Tibet) had the highest C. fuscescens infestation, they still had significantly highest seed yield in the two planting seasons (Tables 1 and 2).

The accessions Niqua, RRC 1027, Tibet, Zhen Ping and D 70-1 which had high seed yield ranging from 97.9g – 176.4g (2009), 95.50g – 188.60g (2010) and high 1000 seed weight ranging from 0.711g – 0.886g (2009), 0.731g – 0.866g (2010) all had terminal inflorescence shape of panicle with long branches (Tables 1 and 2).

Pearson's correlation coefficients revealed similar trend between *C. fuscescens* infestation, inflorescence morphological characters and yield parameters in the 2 planting seasons. *C. fuscescens* population/plant had a strong negative relationship only with viability percentage. Terminal inflorescence shape showed positive relationship with 1000 seed weight and seed yield/ plant. Inflorescence density index showed a positive relationship only with 1000 seed weight. Seed yield/plant showed a positive relationship with 1000 seed weight. However inflorescence color did not show relationship with the other inflorescence morphological characters, yield parameters and *C. fuscescens* infestation (Tables 3 and 4).

Stepwise regression analysis selected viability percentage as the most important variable in the model reflecting the effect of *C. fuscescens* infestation (R^2=0.8753, F=55.15, *P=.0002*) in 2009 (Table 5) and (R^2=0.9138, F=74.20, *P=.0001*) in 2010 (Table 6).

Although seed yield did not correlate with *C. fuscescens* population/ plant it improved the stepwise regression in the 2 planting seasons. Also inflorescence density index though did not correlate with *C. fuscescens* population/ plant but it improved the stepwise regression in 2009.

4. DISCUSSION

The inflorescence morphological characters and yield parameters investigated in this study are important due to their direct and indirect effects on *Cletus fuscescens* (Walker) (*Hemiptera: Coreidae*) infestation in the 2 planting seasons. The highest *C. fuscescens* populations/plant observed on the 3 accessions with intermediate inflorescence could be related to the heavy inflorescence with exposed seeds which provided enough food to support the development and feeding of the bugs. This implies that accessions with intermediate inflorescence are susceptible to *C. fuscescens* attack. Similarly, the high *C. fuscescens* populations/ plant observed in accessions with lax inflorescence although had few but exposed seeds suggest that the bugs readily had access to grain and could easily suck the embryo, also revealing susceptibility to *C. fuscescens* attack. However the significant lowest *C. fuscescens* populations/ plant observed in accessions with dense inflorescence could be that the compactness of the inflorescence inhibited penetration of the insect stylets to the grain which resulted to the highest seed viability percentage observed. This suggests that dense inflorescence made plant unattractive to bug attack exhibiting an antixenosis resistance (non-preferential) to the accessions. The exhibition of physical characters of plants conferring resistance to pests has been reported by [12] that Jumki, a brinjal variety was less susceptible to brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (*Lepidoptera: Crambidae*) due to its small, round, less fleshy and smooth of fruits and presence of spines on leaves and shoots. Also [13] reported that high plant height and thick stem diameter of brinjal plants increased infestation of *L. orbonalis* while more branches/ plant reduced infestation due to reduced stem diameter which was not favorable for infestation.

The negative correlation of *C. fuscescens* populations/ plant with seed viability percentage indicated that as *C. fuscescens* populations increases seed viability decreases, resulting in unfilled grains or as *C. fuscescens* populations decreases seed viability increases resulting in more viable grains. Negative correlation was also observed by [14] between head bug *Eurystylus oldi* (Poppius) (*Hemiptera: Miridae*) and germination percentage of *Sorghum bicolor* (L.) (Moench). According to the study, the high seed viability observed in the accessions: Zhen Ping, D 70-1 and RRC 551 with the lowest *C. fuscescens* population/ plant and the lowest seed viability observed in the accessions: Niqua, RRC 1027 and Tibet with the highest *C. fuscescens* population/ plant suggests that feeding activities of the bugs on inflorescence caused death of seeds and lowered quality of grain especially. This is in agreement with the observation of [15] that infestation of 6 rice bugs per plant resulted in significant reduction in seed germination in all the lines tested.

Table 1. Inflorescence morphological characters, yield parameters and *Cletus fuscescens* infestation on grain amaranth accessions in 2009

Plant name	Inflorescence color	Inflorescence density index	Terminal inflorescence shape	Seed yield /plant (g) (Mean)	1000 seed weight (g) (Mean)	Viability % (Mean)	Number of *C. fuscescens*/ plant (Mean)
Niqua	Green	I	PL	176.4a	0.814b	63.1d	15.4a
RRC 1027	Orange	I	PL	158.1a	0.819b	58.7d	13.6b
Tibet	Wine	I	PL	105.7b	0.711c	61.9d	12.1b
Zhen Ping	Green	D	PL	101.2b	0.886a	95.8a	3.4d
D 70-1	Wine	D	PL	97.9b	0.801b	95.5a	2.9d
RRC 551	Golden yellow	D	SL	63.8c	0.652d	93.3a	2.0d
P 373	Green	L	PS	71.1c	0.617e	80.7b	8.4c
RRC 646	Green	L	PS	49.9d	0.592e	77.4c	8.1c
Oscar Blanco	Green	L	PS	25.1d	0.589e	76.1c	7.4c

Means in the same column followed by the same letters are not significantly different (P=.05; SNK); I = Intermediate, D = Dense, L = Lax; PL = Panicle with long branches, SL = Spike linking chains, PS = Panicle with short branches

Table 2. Inflorescence morphological characters, yield parameters and *Cletus fuscescens* infestation on grain amaranth accessions in 2010

Plant name	Inflorescence color	Inflorescence density index	Terminal inflorescence shape	Seed yield /plant (g) (Mean)	1000 seed weight (g) (Mean)	Viability % (Mean)	Number of *C. fuscescens*/ plant (Mean)
Niqua	Green	I	PL	169.70a	0.824b	61.2e	14.44a
RRC 1027	Orange	I	PL	188.60a	0.817b	64.5d	15.53a
Tibet	Wine	I	PL	99.90b	0.731c	55.1e	15.07a
Zhen Ping	Green	D	PL	102.30b	0.866a	94.1ab	3.76c
D70-1	Wine	D	PL	95.50b	0.810b	96.3a	2.41cd
RRC 551	Golden yellow	D	SL	59.80c	0.644d	91.7b	2.03d
P 373	Green	L	PS	66.40c	0.610e	79.9c	8.73b
RRC 646	Green	L	PS	57.30c	0.602e	78.4c	9.85b
Oscar Blanco	Green	L	PS	21.10d	0.580e	75.9c	8.60b

Means in the same column followed by the same letters are not significantly different (P=.05; SNK); I = Intermediate, D = Dense, L = Lax; PL = Panicle with long branches, SL = Spike linking chains, PS = Panicle with short branches

Table 3. Pearson's correlation coefficients between *Cletus fuscescens*, inflorescence morphological characters and yield parameters of grain Amaranth accessions in 2009

Variables	*Cletus fuscescens*	Terminal inflorescence shape	Inflorescence color	Inflorescence density index	Seed yield/ plant	1000 seed weight
	Correlation coefficient					
Terminal inflorescence shape	0.45 (.22)	-				
Inflorescence color	0.01 (.98)	0.20 (.60)	-			
Inflorescence density index	-0.47 (.20)	0.20 (.20)	0.10 (.79)	-		
Seed yield/plant	0.62 (.08)	0.70 (.04)*	0.01 (.97)	0.34 (.36)	-	
1000 seed weight	0.10 (.79)	0.76 (.02)*	-0.03 (.94)	0.69 (.04)*	0.78 (.01)*	-
Viability percentage	-0.94 (.0002)*	-0.25 (.51)	-0.10 (.80)	0.64 (.06)	-0.34 (.37)	0.18 (.65)

*Value in bracket is probability of r.; * Correlation level of significant at P=.05*

Table 4. Pearson's correlation coefficients between *Cletus fuscescens*, inflorescence morphological characters and yield parameters of grain Amaranth accessions in 2010

Variables	*Cletus fuscescens*	Terminal inflorescence shape	Inflorescence color	Inflorescence density index	Seed yield/ plant	1000 seed weight
	Correlation coefficient					
Terminal inflorescence shape	0.43 (.25)	-				
Inflorescence color	0.13 (.74)	0.20 (.60)	-			
Inflorescence density index	-0.51 (.16)	0.20 (.61)	0.10 (.79)	-		
Seed yield/ plant	0.54 (.13)	0.68 (.04)*	0.08 (.84)	0.30 (.43)	-	
1000 seed weight	0.09 (.81)	0.80 (.01)*	0.05 (.90)	0.68 (.05)*	0.80 (.01)*	-
Viability percentage	-0.96 (.0001)*	-0.26 (.51)	-0.06 (.87)	0.57 (.11)	-0.35 (.36)	0.10 (.80)

*Value in bracket is probability of r.; *Correlation level of significant at P=.05*

Table 5. Stepwise regression analysis of *Cletus fuscescens* with inflorescence morphological characters and yield parameters of grain Amaranth accessions in 2009

Variables	R^2	F value
Viability percentage	0.88	55.15(.0002)*
Seed yield/plant	0.98	26.33(.002)*
Inflorescence density index	0.99	9.31(.03)*

*Value in bracket is probability of F.; *Stepwise regression level of significant (P=.05)*

Table 6. Stepwise regression analysis of *Cletus fuscescens* with inflorescence morphological characters and yield parameters of grain Amaranth accessions in 2010

Variables	R^2	F value
Viability percentage	0.91	74.20(.0001)*
Seed yield/ plant	0.96	8.08(.03)*

*Value in bracket is probability of F.*Stepwise regression level of significant (P=.05)*

[16] suggested that if jewel bug, *Agonosoma trilineatum* (F.) (*Heteroptera: Scutelleridae*) on bellyache bush, *Jatropha gossypiifolia* (L.) is present at sufficiently high numbers it has the potential to reduce the quantity of viable bellyache bush seeds entering the soil seed bank through promotion of capsule abortion or through mortality of individual seeds held within capsules. [17] observed a similar occurrence on *Jatropha curcas*(L.) where a fruit-feeding bug, *Leptoglossus zonatus* (Dallas) (Hemiptera: Coreidae) caused up to 100% capsule abortion. [18] demonstrated that green stink bugs, *Acrosternum hilare* (Say) (*Hemiptera: Pentatomidae*) significantly reduced germination of seed harvested from bolls that were infested for 12 - 24 days.

Although 1000 seed weight did not correlate with bug infestation of inflorescence, however bug feeding caused seeds discoloration, shriveling and premature drying. The positive correlation of 1000 seed weight with seed yield, terminal inflorescence shape and inflorescence density index is an indication that the feeding activities of bugs did not affect seed weight; rather the plant genotype affects the inherent big size of seeds. This is in agreement with the report of [19] that seed weight of rice was not influenced by *Leptocorisa oratorius* (F.) (*Hemiptera: Alydidae*) adult density.

The positive correlation between seed yield/ plant and 1000 seed weight suggests that the large seed size of the high yielding accessions enabled them to exhibit high grain yield. Since seed yield/ plant correlated positively with terminal inflorescence shape and all the accessions having panicle with long branches terminal inflorescence shape had high yield then it could be inferred that terminal inflorescence shape is the most important inflorescence morphological character that affects seed yield. Although there was no correlation between *C. fuscescens* population/ plant and seed yield/plant but the selection for seed yield/ plant brought about an improvement of the stepwise regression indicating that in the absence of the other variables such as inflorescence color, terminal inflorescence shape, inflorescence density index and 1000 seed weight, *C. fuscescens* has the potential to reduce yield. Inflorescence color was of least importance among the inflorescence morphology characters since it did not correlate with any variable.

5. CONCLUSION

According to this study we can conclude that seed viability percentage is the most important variable that reflected the effect of *C. fuscescens* infestation on grain amaranth. Amaranth accessions with dense inflorescence exhibited an antixenosis resistance to *C. fuscescens* attack. This resistance appeared to be related to the compactness of the inflorescence while high yielding intermediate inflorescence though susceptible could be utilized for yield improvement in breeding programme.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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