Amaranth Pigweed Beetle Damage Level Correlates to Environmental Temperature Regimes

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ABSTRACT

Pigweed beetle *Hypolixus haerens* Boheman has been cited as a major insect pest of grain amaranth worldwide. This study evaluated injury level of both foliar and stem damage pests on eight varieties of *Amaranthus hypochondriacus* (L.) during two seasons of production at Katumani (LM4) and Kiboko ((LM5). Stem damage by beetle *H. haerens* correlates to environmental temperature. The hotter zone of low midlands five (LM5) was drier (43.7 ± 15.9 mm, 28 ± 2°C) than the cooler zone of low midlands four (LM4), which was relatively wetter (57.1 ± 13.8 mm, 24 ± 2°C). Beetle stem tunnel length inversely correlated with yield. The stem damage levels at the cooler zone were lower by 35, 42 and 47% in comparison to those from the hotter zone (LM5). Insect foliar damage level did not reflect direct grain loss. No variety was found resistant to *H. haerens* stem injury from the eight accessions evaluated. The wetter and cooler zone (LM4) was found to influence lower stem damage and subsequently 5-9 times higher grain yield than the hotter zone. In conclusion, considerations of the environmental factors in each agro-ecological zone would lead to right time of insecticide spray for management of the pests of grain amaranth to prevent yield loss.

Key words: *Amaranth; Agro-ecological zones; Low midlands; Foliar damage; Tunnel length; Pigweed beetle*

INTRODUCTION

Amaranthus hypochondriacus L. belongs to the grain group of Amaranthaceae and is increasingly being grown in Kenya after introduction from the Americas (Gupta and Thimba, 1992; Kaur et al 2010). As a grain crop amaranth has been reported to provide low cholesterol diet as staple food stuff (Berger et al, 2003; Kong et al., 2009; Escudero et al., 2011). Much research has been dedicated on the chemical composition and nutritive quality of the pseudo cereal amaranth, where several varieties of Amaranthus have been found superior to most other cereals (Gorinstein et al., 1991; Gonzalez et al., 2007; Milan et al., 2012). The importance of amaranth is increasingly being reported as an important food supplement for people living with HIV/AIDS in most Sub-Sahara Africa (Veeru et al., 2009; Schoenlechner et al., 2010; Kunyanga et al., 2012). The plant has been found to be a heavy feeder of nitrogen and microelements (Zheleznov et al., 1997; Skwaryło-Bednarz et al., 2011; Skwaryło-Bednarz, 2012). On pest occurrence, some sucking plant bugs and the pigweed beetle have been reported worldwide as the major agents constraining realization of variety genotype potential yield (FAO, 1988; Grubben et al., 2004). Some disease pathogens like Pythium can be a problem under some environmental conditions. Another disease fungus of Rhizoctonia genus, as well as stem canker, caused by Phorma or Rhizoctonia genus which colonizes leaves and stems and causes dieback has been highlighted in the Americas and Africa (van Rensburg et al., 2007). However, little information has been documented on the actual yield loss due to foliar and plant stem damage of specific pests. Farmers in Kenya have used various insecticides reporting no reduction of *Hypolixus haerens* Boheman, on amaranth as agro-chemical stockists experiment with farmers each season. The objective of this study was to evaluate both foliar pests and the stem damage by the pigweed beetle *H. haerens* as well as variety tolerance of other pests in two related agro-ecological zones in the low midlands region of Kenya, and the right time to spray against common pests was tested using Beta-cyfluthrin-Chlorpyrifos insecticide.

MATERIALS AND METHODS

Site Plot Establishment

Eight variety plots of amaranth were established on tractor ploughed and harrowed plots. The eight varieties were planted on the onset of the short and long rain seasons in April-June (2013) and January-March (2014). Using Jaezold et al (2007) agro-ecological zonation, the two plots were located at two low midlands ecological zone sites; at Kiboko, low midlands five (LM5) and Katumani, low midlands four (LM4) of the eastern region of Kenya. Plot design was randomized complete block design (RCBD). The eight varieties were planted in five rows of 90cm x 30cm spacing. The plot sizes were 18 plants in the five rows. Climate data (pooled) from the sites meteorological stations was analyzed for interpretation of plant development and final yield in consideration to biotic and physical factors during production periods. Kiboko site plot was drier, monthly rainfall of 43.7 ± 15.9mm at an altitude of 940m above sea level (asl). Katumani plot was within the wetter zone of monthly rainfall of 57.1 ± 13.8mm at an altitude of 1609 m asl. Site annual temperatures were 26-30ºC for Kiboko and 22-26ºC range for Katumani.

Treatments and Data Collection

One month after plant emergence, foliar damaging insects like bollworms and leaf miners showed windowed leaves and lamina mining. The stem pest pigweed beetle *H. haerens* damage symptoms was observed on most plant stems as pin hole-punches three weeks after plant germination. Bioassay studies on the efficacy level of Bulldock Star® 262.5 EC (pyrethroid-organophosphate) of Beta-cyfluthrin (12.5g/litre)-with-Chlorpyrifos (250g /litre) was carried out at the rate of 5ml /20-litre, 10ml /20-litre and 15ml/20-litre to determine dose effectiveness on the two pests.

Three different species of leaf miners, *Liriomyza sativae* Blanchard, *L. trifolii* Burgess and *L. huidobrensis* Blanchard were identified on amaranth leaves at the two sites. Composite manure was applied at the plots at planting at the rate of 2.7 t ha^{-1}. The variety blocks were treated with the insecticide together with the control plot treatments replicated four times at the two different field plots. Spray of Bulldock Star® 262.5 EC was carried out on the first three outer- most plant rows on all plant variety plots in two months' intervals to crop physiology maturity. The manufacturer's rate of recommendation of 10ml / 20-litre of water was followed. The total sprays were two at each site with the first one carried out after one month of crop emergency.

Insect foliar damage data was taken at the flowering stage (seven weeks after planting) of the crop and the pigweed stem tunnel length at harvest; nine weeks after planting (WAP). Other damage symptoms of beetle exit holes, tunnel length and number of beetles were scored for each treatment plot. This was to enable comparison of variety pest tolerance as well as insecticide efficacy under the prevailing agro-climatic conditions at the two sites. Log transformation (x +5) was carried out on the number of pests per plant to remove effect of zero values on parameter means. Analysis of variance (ANOVA) was carried out to determine significant difference of parameter mean values of plant height (cm), stem tunnel length (cm), exit holes and number of pigweed beetles (larvae) per plant stem. The analyses were carried out using General Linear Method (GLM) of Student-Newman Keuls (SNK) Post Hoc Test using SAS Version 8 (2001) at 5% significance level. Correlation (R^2) trend of yield response to increase of stem tunnel length was graphed for interpretation of the relationship between the two parameters at the two sites.

RESULTS

Foliar Damage

Mean bollworm infestation densities on varieties was not significantly ($P>0.05$) different on the unsprayed plots at Kiboko. At Katumani, varieties KAM 201, Kisii White, KAM 105 and KAM 106 indicated significant ($P<0.05$) increase of plant height with insecticide application (Table 1).

Bollworm larvae density difference on the varieties was insignificant (P>0.05) among unsprayed plots at Kiboko while at Katumani where KAM 115 led with 2.3 larvae / plant. Insecticide application lowered significantly (P<0.05) bollworm densities on the varieties at Kiboko but it did not effect significant (P>0.05) pest reduction at Katumani. Leaf miner pest density was significantly (P<0.001) different amongst the different varieties at the unsprayed plots at Kiboko. Likewise, leaf miner density was significantly (P<0.05) different among varieties at Katumani on the same unsprayed plots. Insecticide application did not significantly (P>0.05) decrease leaf miner densities on the varieties at both sites.

Beetle stem damage

The *H. haerens* beetle caused highest stem damage on amaranth at the hotter Kiboko site (28 ± 2 °C) than the cooler Katumani (24 ± 2 °C). The 4 °C difference in temperatures at Kiboko and Katumani resulted to twice tunnel length increase across most varieties at the former.

Yield at the sites

On unsprayed plots, variety yield tonnage / ha was significantly (P<0.001) different among the varieties at the two sites. Highest yield was recorded at Katumani on variety Kisii White (1,524.8 kg /ha) followed by Kisii Brown (1,323.3 kg/ha) as shown on Table 2. The least yield was on variety KAM 114 of 808.7 kg /ha at the same site. At the drier Kiboko, the highest yield was on variety KAM 201 with 238.4 kg /ha closely similar to Kisii Brown yield (237.1 kg/ha). All varieties at Katumani site had >100% yield increase in comparison to Kiboko site. Some varieties recorded over 400% (Kisii White, Kisii Brown, KAM 201 and KSC) grain yield increase.

Table 1: Mean (± SE) amaranth variety height and foliar pests' occurrence at two different agro-ecological zones under unsprayed and sprayed treatments at flowering stage

Sit e		Plant height (cm)		No. bollworm larvae / plant		No. Leaf miner larvae / plant	
Kiboko (LM5)	*Variety*	*Unspraye d*	*Sprayed*	*Unspraye d*	*Sprayed*	*Unspraye d*	*Sprayed*

	KAM 201	86 ± 3.9aA	86 ± 5.4aA	0.6 ± 0.2aA	0.2 ± 0.1bB	1.2 ± 0.4aA	0.2 ± 0.1bB
	Kisii Brown	64 ± 5.4bB	84 ± 4.6aA	0.5 ± 0.3aA	0.1 ± 0.0cA	0.2 ± 0.1bA	0.1 ± 0.0cA
	KSC	78 ± 4.2abB	93 ± 3.6aA	0.4 ± 0.2 aA	0.2 ± 0.1bA	0.5 ± 0.2bA	0.3 ± 0.1aA
	Kisii White	86 ± 3.4aB	104 ±2.5aA	0.7 ± 0.4aA	0.1 ± 0.0cA	0.6 ± 0.5bA	0.2 ± 0.1bA
	KAM 114	88 ± 4.6aA	94 ± 4.7aA	0.5 ± 0.1aA	0.3 ± 0.1aB	0.2 ± 0.0bA	0.2 ± 0.1bA
	KAM 105	81 ± 2.9abA	77 ± 2.75aA	0.4 ± 0.1aA	0.1 ± 0.0cB	0.1 ± 0.0bA	0.1 ± 0.0cA
	KAM 106	89 ± 2.3aA	90 ± 3.6aA	0.6 ± 0.5aA	0.2 ± 0.1bA	0.2 ± 0.1bA	0.1 ± 0.0cA
	KAM 115	81 ± 2.5abA	85 ± 1.6aA	0.4 ± 0.1aA	0.1 ± 0.0cB	0.3 ± 0.1bA	0.1 ± 0.0cA
	P-value	*0.028*	*0.727*	*0.375*	*0.003*	*<0.001*	*0.002*
Katumani (LM4)							
	KAM 201	125 ± 2.3ab A	130 ± 1.3abA	1.9 ± 1.3abA	1.8 ± 1.0aA	1.2 ± 0.8aA	0.8 ± 0.1aA
	Kisii Brown	127 ± 2.0abA	122 ± 2.3cB	1.3 ± 1.2abA	1.2 ± 1.0aA	1.0 ± 0.2abA	0.2 ± 0.1cA
	KSC	127 ± 3.6abA	129 ± 2.5cA	2.1 ± 1.8abA	1.4 ± 1.3aA	0.8 ± 0.2abA	0.4 ± 0.1bA
	Kisii White	127 ± 4.8abA	142 ± 2.9aA	1.1 ± 0.7abA	2.0 ± 1.3aA	0.7 ± 0.6abA	0.3 ± 0.1bA
	KAM 114	114 ± 3.4bA	124 ± 3.0cA	1.4 ± 1.3bA	1.7 ± 0.8aA	0.5 ± 0.2bA	0.1 ± 0.1dA
	KAM 105	113 ± 5.4bA	137 ± 3.6abA	0.8 ± 0.7abA	1.1 ± 1.0aA	0.8 ± 0.4abA	0.0 ± 0.0eA

KAM 106	138 ± 5.2aA	142 ± 4.5aA	2.2 ± 2.0abA	3.1 ± 2.6aA	1.1 ± 0.5aA	0.2 ± 0.1cA
KAM 115	120 ± 3.0abB	135 ± 2.9bA	2.3 ± 1.3aA	1.2 ± 1.0aA	0.9 ± 0.6abA	0.1 ± 1.0dA
P-value	*0.011*	*0.003*	*0.015*	*0.367*	*0.028*	*<0.001*

Similar lower case letters denote insignificant (P>0.05) mean value parameter difference among different amaranth varieties (SNK at 5% level). Different upper letters denote significant (P<0.05) difference between sprayed and unsprayed treatment within rows.

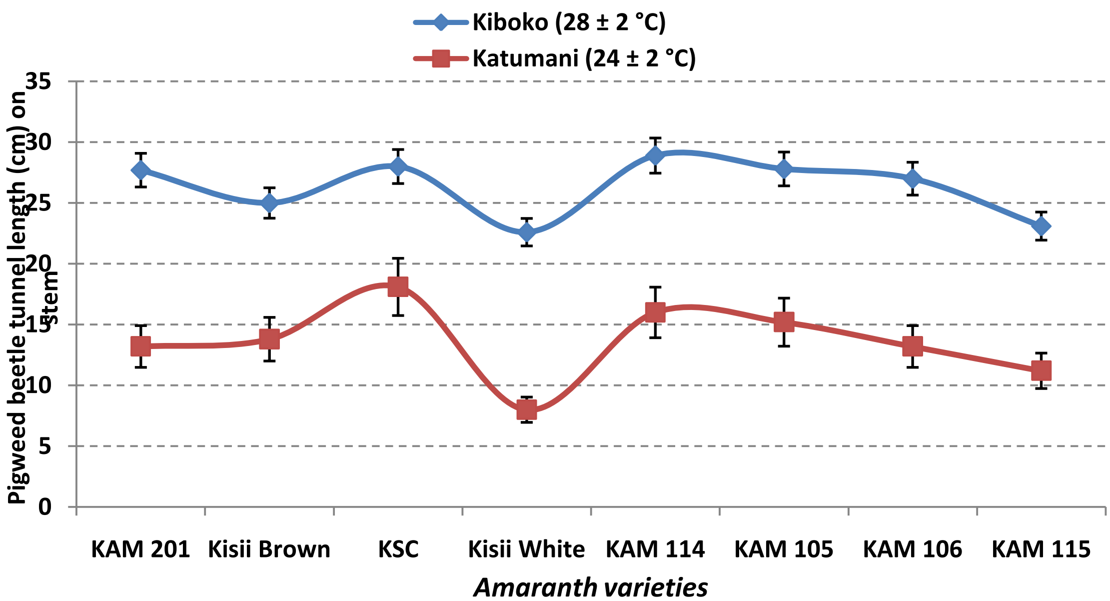

Fig. 1: Pigweed beetle tunnel length (cm) on different amaranth varieties at two varied site temperatures

On the insecticide treated plots at Katumani, Kisii Brown variety had highest yield at 2,113 kg /ha with KSC recording 1,735 kg /ha as the second highest (Table 3). At Kiboko insecticide treated plots, variety KAM 201 led with 628.1 kg /ha followed by Kisii White (618.9 kg /ha). Significant (P<0.001) yield difference was realized among the different varieties at both sites on control and insecticide treated plots. The cooler zone had 5-9 times higher yield than the hot and drier zone irrespective of treatment. The insecticide application effected significant (P<0.05) yield increase at Kiboko of between 23% (Kisii Brown) to 163% (KAM 201) but did not bring similar increase at Katumani plots as shown in Table 2. At Katumani low stem damage led to higher yield than at Kiboko plots. Grain yield (dependent variable) was influenced by other environmental factors (independent variables) besides stem damage level as Figure 2 shows at the two sites.

Table 2: Mean (±SE) amaranth variety grain yield (kg/ha) under treatments (unsprayed) plots

Site	Variety	Unsprayed: Kg ha^{-1}	Sprayed: Kg ha^{-1}	*F (df), p*
Kiboko (LM5)	KAM 201	238.4 ± 24.9abB	628.1 ± 33.5aA	*6231.2 (1,3), 0.001*
	Kisii Brown	237.1 ± 22.4abB	292.9 ± 18.3cA	*553.9 (1,3), 0.008*
	KSC	155.3 ± 24.5dB	291.7 ± 11.2cA	*1577.8 (1,3), 0.006*
	Kisii White	210.5 ± 21.9bcB	618.9 ± 91.5aA	*103.3 (1,3), 0.009*
	KAM 114	208.2 ± 25.9bcB	457.7 ± 38.8bA	*1147.8 (1,3), 0.001*
	KAM 105	189.3 ± 30.6bcdB	471.6 ± 150.8bA	*19.9 (1,3), 0.046*
	KAM 106	165.4 ± 13.3c	441.2 ± 45.2b	*244.3 (1,3), 0.044*
	KAM 115	264.3 ± 34.5a	349.1 ± 47.1bc	*215.9 (1,3), 0.041*
	F (df) , p	*10.2 (7,14), 0.001*	*17.2 (7,14), <0.001*	
Katumani (LM4)	KAM 201	1,230.8 ± 30.7cdA	1,572.9 ± 117.6cA	*7.1 (1,3), 0.116*
	Kisii Brown	1,323.3 ± 107.7bA	2,113 ± 112.5aA	*3.9 (1,3), 0.184*
	KSC	1,279.8 ± 74.4bcA	1,735.0 ± 108.1bA	*0.1(1,3), 0.835*
	Kisii White	1,524.8 ± 73.7aA	1,538.9 ± 76.7cA	*0.1 (1,3), 0.882*
	KAM 114	808.7 ± 80.6gB	1,461.2 ± 49.6dA	*20.6 (1,3), 0.045*
	KAM 105	1,168.5 ± 36.5edA	1,183.4 ± 104.3fA	*0.2 (1,3),0.754*
	KAM 106	914.5 ± 56.6fA	887.3 ± 41.2gA	*9.5 (1,3), 0.090*
	KAM 115	1,101.6 ± 25.9eA	1,265.2 ± 104.5eA	*13.2 (1,3), 0.068*
	F (df), p	*86.6 (7,14), <0.001*	*397.3 (7,14), <0.001*	

Different lower case letters denote significant (P<0.05) mean value parameter difference among different amaranth varieties (SNK at 5% level). Similarly, different upper letters denote significant (P<0.05) difference between sprayed and unsprayed treatment within rows.

DISCUSSION

Pest foliar damage of the grain amaranth was found to have no significant effect to the yield as in maize stem borers (Kfir et al., 2002; Beyene et al., 2011). The drier and hotter zone at Kiboko (LM5) had lesser foliar damage of bollworms and leaf miners than the cooler zone at Katumani (LM4). The indication was that foliar damage of bollworm and leaf miner pests on grain amaranth did not appear to reduce yield loss at Katumani. The spray of pyrethroid-organophosphate insecticide reduced plant stress and led to significant ($p<0.05$) height gain on the different varieties at Kiboko but less same effect at Katumani. There was no significant reduction of *H. haerens* beetle development at the two sites among varieties even where insecticide spray was used. Higher beetle density was recorded at the drier Kiboko than the cooler Katumani site. The pest control of foliar damage in the low midland zones led to increased plant height and this showed improved plant health, good for higher grain yield as found in other related studies (Gimplinger, et al., 2007).

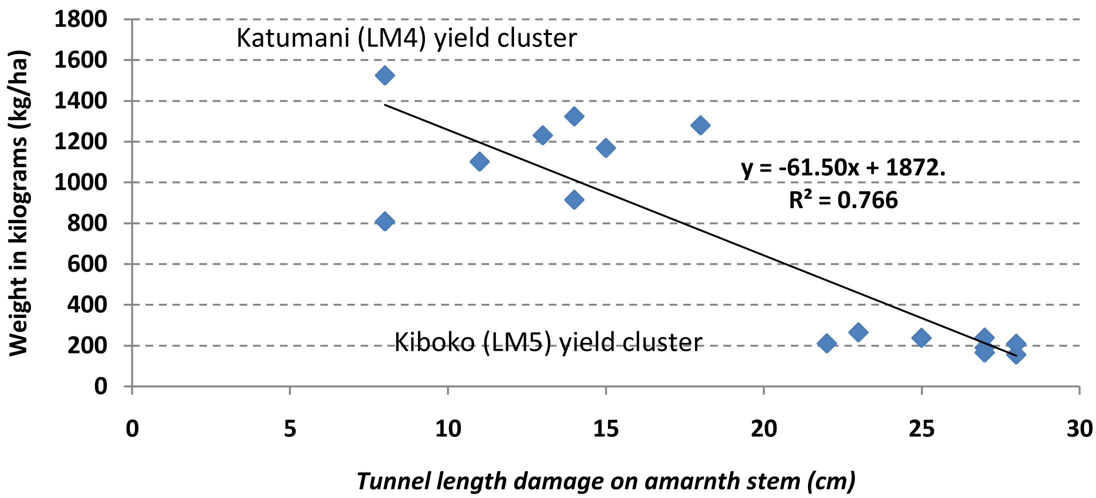

Fig. 2: Regression of amaranth yield at Katumani (LM4) and Kiboko (LM5) vs stem tunnel length (cm)

Bautista et al. (1997) has described a dipteran borer pest on grain amaranth in South America with close symptoms as *H. haerens*. Oliveira et al. (2012) recently presented similar tunnel length and exit holes of a moth, *Herpetogramma bipunctalis* Fabricius. The present study has analyzed the effect of *H. haerens* on grain amaranth at the two sites. Further comparison of environmental factors of rainfall amount and temperature influence to grain yield showed that higher tonnage of between 5-9 times was realized at the cooler/wetter zone (LM4-Katumani) than the hotter /drier LM5 (Kiboko) on almost all the varieties. Kunyanga et al. (2012) detailed amaranth ecological requirement for optimum production as medium soil fertility and rainfall amount of >100 mm per production season and medium pH level of 4.5-6.5. The present work has shown yield increase to over 400% with increase of monthly rainfall amount change from 43.7 mm to 57.1 mm in a higher altitude. The environmental effect to both plant development and yield was found a strong determinant to final effect of pests. Beetle stem tunnel length was found inversely correlated to yield as in maize (Beyene et al., 2011).

Further, a parallel comparable similarity damage traits of two different orders of insects; Lepidopteran and Coleoteran, respectively comes to the fore. As determined on maize recently, the tunnel length on the plant stem is the criteria for resistance on a crop variety (Bautista et al., 1997; Butron et al., 2014). All the evaluated eight amaranth varieties did not indicate resistance to *H. haerens* as they displayed high similar stem damage indicted by long tunnel lengths. Higher stem tunnel length led to lower yield tonnage on all varieties, as found in other studies (De Oliveira, et al. 2012). There was significant difference on tunnel length on the varieties where the hotter/drier zone site had higher lengths than the cooler/wetter zone on both insecticide sprayed and non-sprayed plots. Both tunnel lengths and number of beetles per stem parameters showed no significance difference between sprayed and unsprayed plots, leading to the conclusion that the insecticide pyrethroid-organophosphate was not effective in controlling *H. haerens* on grain amaranth. Being a contact insecticide no significant control was achieved on stem tunneling *H. haerens* as the beetle could lay its eggs between the one month or so period of spray application. One of the factors found to lead to high stem damage by *H. haerens* was hot-warm environment, while the wetter-cool conditions led to faster plant growth and better plant health leading to higher grain yield as reported on cereal stem borers (Abro et al., 2013; Bamaiyi and Ifejeola-Joan, 2011). Nevertheless, the timing of spray could have been done every 7-14 days but not at one month interval as farmers' were directed by agro-chemical dealers, with a systemic insecticide to protect amaranth crop from pests.

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