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Full Length Research Paper

Damage of stem borer species to *Zea mays* L., *Sorghum bicolor* L. and three refugia graminae

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ABSTRACT

This study aimed at determining the magnitude of damage inflicted by stem borer species to *Zea mays* L. and *Sorghum bicolor* L. and refugia graminae. It involved two growing gramineous crops: maize *Z.mays* L. and *S.bicolor* L. and three gramineous forages: Napier grass, Sudan grass and giant Setaria grass. These were planted both in pure and mixed stands and exposed to natural infestation in the field.Sampling for the borer infestation was done throughout the phenology of crops .Field and laboratory bioassays were conducted to determine biophysical efficacies of the control strategy from stem borer fecunditie.The type of the gramineous refugia had a significant ($p < 0.05$) effect to the magnitude of damage caused by the stem borers. The *B. fusca* was the most devastating species with a mean of 4.8800, 3.8800, 2.2400 and 1.4000 borers while *S. calamistis* was the devastating with a mean of 1.0600, 0.9200, 0.4600 and 0.6100 borers in maize, sorghum, Napier and Sudan grass. However *C. partellus* was the most devastating species in giant Setaria grass with a mean of 3.300 and *B.fusca* being the least devastating with a mean of 0.6800 borer. Maize was the most damaged host indicating that it provided the best geographical requisites and nutritional attributes. These were more attractive to *B. fusca.*This implies that it has desirable traits attractive to the stem borers especially the great devastating *B. fusca* as chemical and biophysical morphology and stem diameter. *B.fusca* was the most devastating both in the laboratory bioassays and field. Maize was the most damaged host and Napier grass was the most preferred forage refugia. *B.fusca* was the devastating stem borer species and it preferred hosts with larger stems..However, more research should be conducted to understand the moths better:their biology,seasonality dynamics and generations in different locations and natural enemies surviving on maize and sorghum for their biocontrol.

Keywords: Stem borer species, *Sorghum bicolor* L and refugia graminae.

INTRODUCTION

Cereal crops are grown widely throughout the world in a range of agro-ecological environments.About 50 environmental biotypes of *Z.mays* and *B.color* exist.

Both sorghum and maize yields in Africa are quite low by world standards and average,50% compared to the global average. Yields have increased only marginally over the last two decades. Most of the increase in production has come from expansion in the area harvested rather than from increases in yield on none expansive acreages (Ahmad *et al*., 2000).

Various species of stem borers rank as the most devastating maize pests in Sub-Saharan Africa (SSA). They can cause 20-40% losses during cultivation and 30-90% losses postharvest and during storage. Other pests in SSA include ear borers, armyworms, cutworms, grain moths, beetles, weevils, grain borers, rootworms, stem borers and white grubs. The parasitic striga weed is another maize pest. In fact, weed-related yield losses ranging from 65 to 92% have been recorded in the Nigerian savanna alone (Maddonni *et al*., 2006).

Maize diseases in SSA include downy mildew, rust, leaf blight, stalk and ear rots, leaf spot, and maize streak virus (MSV) (Muasya and Diallo, 2006).

Stalk borers cause serious losses when maize plants are particularly attacked at an early stage and in high densities (Amudavi *et al*., 2012). Ogemah (2003) gave the reasons for the increased damage in young plants as being due to tenderness of leaves and stem which aged and toughened and thus became unsuitable for newly hatched larvae. The first generation of the larvae was thus important in terms of causing yield loss and exceeded the second generation which attacked the crop when it was already advanced in age (Muasya and Diallo, 2006).

In East Africa, losses in cereal grain yield due to stem borers ranged from 44-50% (Mugo *et al*.,2005*)* when a single *B. fusca* larva developed in a healthy maize plant, it reduced its yield capacity by 28% (Tabashnik,2003), while elimination of single borers maximally enhanced yields by 35 1b/ha (Ahmed *et al*.,2000).Kingi and Burgess (2004) in a survey of estimation of grain yield losses in cereals attributed 27% and 18% losses due to stalk borers in Tanzania and Kenya respectively. In Kenya, Anonymous (2005) found that about 1.2% of the total yield was reduced whenever 1% of the plants were attacked. In the Kenyan Rift Valley region, Kingi and Burgress (2004) reported economic losses of Kshs217.20 per 90 kg in monetary terms. Kahumbu's (2012) studies yielded slightly different findings from those reported by Maddonni *et al.,* (2006). Later, Mulaa *et. al., (*2011) was of the opinion that Heiko (2009) studies left many variables uncontrolled and that their estimates were not convincing. The most important alternative hosts which could also serve as refugia for the four major stem borers are reportedly cultivated sorghum, *S. versicolor* Anderson, *S. arundinaceum* Stapf, Napier grass (*Pennisetum purpureum* Schumach*) and Hyperrhenia rufa* Nees, Sudan grass (*Sorghum vulgare Sudanese*) and giant Setaria grass molasses grass *(Melinis minutiflora*),desmodium (*Desmodium uncinatum* and *D. intortum*) *(*Nyukuri *et al.,* 2012*).*Napier grass and Sudan grass are used as refugia whereas molasses grass and desmodium repel ovipositing stem- borers. Although stem borers oviposit heavily on some grasses, only few species are favourable for them to complete their life cycles (Chabi – Olaye *et al*., 2006).

Africa is the declining harvested area during the period under review. Since a greater proportion in the patterns of change in maize production is explained by extensification rather than intensification, maize policy development in Africa needs to place greater emphasis on the development and dissemination of productivity-enhancing technologies. It is against this background of understanding that this study was conceived. The objective of this study was to elucidate the magnitude of damage and yield losses caused by stem borers in intercrops of maize,sorghum and three fodder grasses.

MATERIALS AND METHODS

Study Site

This study was conducted in Kenya Agricultural Research Institute (KARI), at Kitale Centre situated at latitude 1°01' N, longitude 35°7.5'E, at an elevation of 1,890 masl. It receives on average 1,143 mm annual rainfall and the soils are loamy. The centre is in Trans-Nzoia County, Kitale west district and is located 3km west of Kitale town. The Trans-Nzoia County is a continuation of the fertile Uasin Gishu Plateau beyond ("trans") the Nzoia River. The rainfall is bimodal occurring in two seasons. March to June/July and the second rain starts indistinctly around July to November. The rainfall peaks are at the end of April and end of July/August. The temperatures are relatively low due to high altitude and proximity to Mt. Elgon and Cherang'ani hills with average daily temperature of 22.5± 2 ^{0}C.

Experimental design and layout

The field under which studies were conducted was provided by KARI administration. As rainfall is bimodal, the duration of the trial was tagged to the 2011 long rain during the main cereal cropping season. A completely randomized block design with three replications of five treatments was used. Each plot measuring 6X6m with avenues of about 0.5 between plots were maintained to ensure accessibility and facilitate daily operations during the duration of the experiment.The study applied a survey method to investigate the damage of stem borer species caused to maize, *Z. mays* L. and sorghum, *S. bicolor*, Sudan grass, Napier grass, and giant setaria grass. The plots were planted at the beginning of the rains with commercial cultivar of hybrid maize H622 from Kenya Seed Company Ltd, local sorghum 9 red, Sudan grass, Napier grass Kakamega 1, KI and giant Setaria were obtain from KARI. Data was accumulated from the five treatments listed under various experiments as below:

Pure stands/monocropped agro - ecosystems

These consisted of: Three plots of 6x6m of maize with inter-row spacing of 75cm and inter-plant 30cm, three plots of 6x6m of sorghum drilled with an inter-row spacing of 45cm and thinned to 15cm intra-row spacing, three plots of 6x6m of Sudan grass drilled with an inter-row spacing of 45cm and thinned to 15cm intra-row spacing, three plots of 6x6m of Napier grass KI with inter-row spacing of 60cm and inter-plant 60cm and three plots of 6x6m of giant setaria with inter-row spacing of 60cm and inter-plant of 60cm.

Mixed stands/ intercropped agro - ecosystems

These consisted of: Three plots of maize with inter – row of 75cm and inter-plant spacing of 30cm intercropped with Napier grass with inter – row 30cm and inter- plant 30cm spacing, three plots of maize with an inter – row of 75cm and inter – plant 30cm intercropped with Sudan grass inter – row 30cm and thinned to 20cm inter – plant, three plots of maize with inter – of 75cm and inter – plant of 30cm intercropped with giant setaria grass inter – row 30cm and 30cm inter – plant spacing, three plots of sorghum drilled with an inter- row spacing of 45cm and thinned to 15cm inter-plant intercropped with Napier grass with inter – row and inter – plant spacing of 30cm, three plots of sorghum drilled with inter – row of 45cm and thinned to 15cm inter- plant spacing intercropped with Sudan grass of 30cm and 20cm spacing of inter- row and inter- plant spacing respectively and three plots of sorghum drilled with an inter- row spacing of 45cm and thinned to 15cm inter-plant intercropped with giant Setaria grass of 30cm inter- row and inter-plant spacing.

Elucidation of the magnitude of damage caused by stem borers

Laboratory bioassays

Bioassays were conducted measure damage rates of three stem borer species namely *C.partellus, B. fusca, S. calamistis*. Three treatments were arranged in randomized complete block design with three replications. The assays took place at the KARI laboratory in Kitale. Fresh stem cuttings of approximately 0.2 kg of each of the 10 host plants were placed into a 1 clean plastic jar, and 20 neonate larvae collected from the field were, starved for 12 hrs to standardize their physiological status then released in each jar, under ambient laboratory conditions (22-23℃ and 65-70 RH). The cuttings were measured by weighing machines model CI201J and accurate to 0.05g and their masses recorded and replaced every week, the jars cleaned. Days required for neonate larvae to reach pupation were recorded. At emergence, adult moths emerging from each assay were collected and transferred to a separate jar with paper wax to facilitate oviposition. The number of eggs laid was recorded daily until their fecundities were exhausted. Data collected was analyzed by analysis of variance (ANOVA) to determine the damaging economic rates of different species of stem borers relative to time.

Field evaluation

Four weeks after seedling emergence for maize and sorghum and 6 weeks after planting the forage gramineous plants, 20 stem borer pupae, kept on moist filter paper, were placed in each plot, so that the emerging moths would lay eggs on the seedlings. At physiological maturity,10 plants were randomly sampled per plot and assessed for tunnel length/ stem borer damage Plate 13, plants leaf damage, number of larvae and exit and entry holes, the stem diameter and dry matter yield. The leaf damage was assessed based on a 0 – 9 scale (whereby 0 was no damage and 9 very serious damage causing dead heart) scale as indicated below:

1 – 2 = slight damage
3 – 4 = moderate damage
5 – 7 = serious damage
8 – 9 = very serious damage
*An average of less than one was considered as none.

Assessment of yields and economic losses caused by stem borers to the gramineous hosts

To assess the yields and economic losses caused to the grains by the stem borers, an analytical method was used. This involved harvesting 15 infested and 15 uninfected maize and sorghum plants growing under identical conditions were harvested. The cobs and heads of maize and sorghum harvested respectively from infected and uninfected maize and sorghum were bagged separately. They were weighed before being manually shelled to weigh the grains. The stems were then split to reveal the extent of stem damage which was recorded in terms of the number of borer exit holes, extent of stem tunneling and borer population .

The coefficient of harmfulness was calculated as the yield loss per plant expressed as a percentage of yield from uninfected plants. Economic losses were assessed using Maddonni *et al.*, (2006) formula as represented below:

$$C = (a - b)/a$$
$$L = CP/100$$

Where:

a = mean yield of uninfected plants
b = mean yield of infested plants
C = Coefficient of harmfulness
P = % plants attacked
L =% economic loss

Table 1. Laboratory assay of damage of stem borers to maize

Entry	*B.fusca*	*C.partellus*	*S. calamistis*	Total
1	7.2^{a}	4.8^{ab}	2.2^{b}	
2	7.6^{b}	5.6^{a}	3.1^{c}	
3	6.3^{ab}	5.3^{a}	2.1^{b}	
4	7.5^{a}	3.7^{b}	3.4^{c}	
5	3.9^{c}	6.4^{c}	1.5^{ab}	
Mean	6.5000	5.1667	2.4667	4.7111
Std. Dev	.50000	1.10604	2.04042	2.13918
Std .Error	.28868	.63857	1.17804	.71306

Table 2. Laboratory assay of damage of stem borers to sorghum

Entry	*B.fusca*	*C.partellus*	*S.calamistis*	Total
1	6.7^{ab}	4.8^{ab}	3.2^{c}	
2	5.2^{a}	6.7^{a}	1.8^{a}	
3	7.1^{b}	5.3^{b}	1.7^{a}	
4	5.8^{a}	3.9^{c}	3.6^{b}	
5	5.2^{a}	3.3^{c}	0.9^{ab}	
Mean	6.0000	4.8000	2.2333	4.3444
Std. Dev	1.0000	1.21244	1.30512	1.95455
Std .Error	.57735	.70000	.75351	.65152

A simple micro – economic analysis was carried out on gathered data to depict cost – benefit ratios indicating the cost – effectiveness of using refugia gramineous plants to control stem borers and to estimate their complimentary valued attributes when incorporated in an IPM programme. The grain yields obtained from various treatments were converted into kg/ha and calculated in monetary

y terms at the prevailing average price of K.sh 35 and K.sh 40 per kg for maize and sorghum respectively. The cost benefit analysis was carried out by calculating the (C/B) which compared the control costs with the expected benefits derived from using each forage refugia.

The C/B ratio was calculated using a formula modified from suggested by Heiko (2009) as thus:

C/B = (CC +AC) NW/MV *RY

Where:

C/B = cost benefit ratio,

CC = cost of refugia (This include cost of seeds planting),

AC = cost of labour e.g. applying fertilizer, weeding the refugia etc

NW = number of times the refugia are weeded and fertilizer applied,

MV=Market value of the crop (Ksh/kg),

RY= Realised grain yield (kg/ha).

The cost incurred included: amount of labour used for planting, weeding and harvesting. This was measured in work - days of actual work done in the field including each operation carried out. The quantities of inputs used in particular, seeds, basal and top dress input fertilizers were recorded. The yields were measured and recorded. Local input and output prices were also recorded.

The production costs and revenue each refugia option was computed and extrapolated from plot level to per hectare basis for comparison.

The C/B was interpreted as follows:

If the ratio was >1, then the biocide and its costs of management was not economically favourable as the costs outweighed the benefits, and vice – versa.

RESULTS

Elucidation of the magnitude of damage caused to maize, sorghum and potential refugia by the stem borers

Bioassay in the laboratories

The magnitude to the gramineous hosts varied subject to nature of the graminae. *B.fusca* was the most devastating stem borer to maize,sorghum,napier and Sudan grass with a means of 6.500,6.000,5.6000 and 5.3330 respectively. *S.calamistis* was the least devastating in the same hosts with means of 2.4667, 2.2333, 2.667 and 3.2000 respectively. The *C.partellus* was the most devastating to giant setaria grass with a mean of 5.1000 and *B.fusca* being the with a mean of 3.5333 to the giant Setaria grass (Table 1 - 5).

Table 3. Laboratory assay of damage of stem borers to Napier grass

Entry	*B.fusca*	*C.partellus*	*S.Calamistis*	Total
1	5.2[a]	4.8[b]	1.9[ab]	
2	6.7[b]	6.9[a]	2.1[a]	
3	4.9[c]	6.9[ab]	2.3[a]	
4	5.3[a]	3.8[ab]	1.7[b]	
5	5.1[a]	2.1[c]	3.3[c]	
Mean	5.6000	4.3667	2.667	4.0778
Std. Dev	.80000	1.11505	1.42244	1.76265
Std .Error	.46188	.64377	.82125	.58755

Table 4. Laboratory assay of damage of stem borers to Sudan grass

Entry	*B.fusca*	*C.partellus*	*S. calamistis*	Total
1	3.8	7.2	3.8	
2	4.9	3.6	5.2	
3	3.4	6.8	1.7	
4	2.6	4.7	3.6	
5	3.0	3.2	2.4	
Mean	3.5333	5.1000	3.3333	3.9889
Std. Dev	.81445	.43589	.51316	.99051
Std .Error	.47022	.25166	.29627	.33017

Table 5. Laboratory assay of damage of stem borers to giant Setaria **grass**

Entry	*C.partellus*	*B.fusca*	*S.calamistis*	Total
1	3.8[a]	6.3[ab]	5.2[c]	
2	5.7[b]	7.1[ab]	1.9[a]	
3	43[c]	4.3[a]	3.3[b]	
4	3.9[a]	5.6[b]	4.3[ab]	
5	4.8[ab]	4.9[c]	1.3[a]	
Mean	4.5000	5.6333	3.2000	4.4444
Std. Dev	1.50997	.64291	.36056	1.34825
Std .Error	.87178	.37118	.20817	.44942

Field assessment

The magnitude of damage of the stem borers caused on hosts was significant ($p < 0.05$).The *B. fusca* was the most devastating stem borer in maize, sorghum, Napier grass and Sudan grass with means of 4.8800,3.8800 , 2.2400 and 1.4000 respectively (Tables 6 – 10) (Plate 1).However, it was the least damaging in giant Setaria grass with means of 0.6800. *C. partellus* was the most devastating stem borer in and giant Setaria grass with means of 3.300 (Table 11).However, S*. calamistis* was the least destructive species in maize, sorghum, Napier and Sudan grass with means of 1.0600, 0.9200, 0.4600 and 0.6100 respectively.

There were significant differences among the refugia crops and forages ($p < 0.05$) in all traits measured. Results from the field trials indicated higher stem borer damage rating and exit holes in maize and sorghum than in gramineous forages. The highest number of damaged plant was among maize and sorghum and Napier. However, it was notable that gramineous crops had the highest leaf damage scores although; Napier grass, Sudan grass and giant Setaria grass also showed some leaf damage scores. The highest numbers of larvae recovered per plant were from maize, sorghum and Napier grass and least in giant Setaria grass (Table 11).

DISCUSSION AND CONCUSION

The studies established that the damage of stem borer species to maize, sorghum and their refugia graminae

Table 6. Damage of stem borers to maize in the field

Entry	*B.fusca*	*C.partellus*	***S. calamistis* Total**
1	6.3^{a}	4.6^{a}	0.9^{a}
2	7.4^{a}	3.1^{b}	1.2^{a}
3	2.3^{b}	2.9^{b}	1.4^{b}
4	3.7^{C}	4.6^{a}	1.3^{b}
5	4.7^{A}	11.3^{c}	0.5^{c}
Mean	4.8800	3.3000	1.0600
			1.8133
Std. Dev	1.18659	1.63187	.80808
			1.28667
Std .Error	.53066	.72979	.36139
			.33222

Table 7. Damage of stem borers to sorghum in the field

Entry	*B.fusca*	*C.partellus*	*S.calamistis*	Total
1	4.3a	3.3a	0.9a	
2	5.1b	3.1a	1.3c	
3	2.3c	2.4b	0.7b	
4	2.5C	3.2a	0.9a	
5	5.5b	2.7c	0.8b	
Mean	3.8800	2.9400	.9200	3.0333
Std. Dev	4.72356	3.56861	.76616	3.60826
Std .Error	2.11244	1.59593	.34264	.93165

Table 8. Damage of stem borers to Napier in the field

Entry	*B.fusca*	*C.partellus*	*S.calamistis*	*Total*
1	3.1^{a}	2.5^{c}	0.5^{c}	
2	2.9^{b}	2.7^{c}	0.7^{b}	
3	0.7^{c}	0.9^{b}	0.4^{a}	
4	3.2^{a}	3.1^{a}	0.2^{a}	
5	1.3^{c}	1.5^{b}	0.5^{c}	
Mean	2.2400	2.1400	.4600	2.4267
Std. Dev	3.74192	3.17222	.42190	3.0260
Std .Error	1.67344	1.41866	.18868	.7813

Table 9. Damage of stem borers to Sudan grass in the field

Entry	*B.fusca*	*C.partellus*	*S.calamistis*	Total
1	0.9^{a}	0.3^{c}	1.2^{a}	
2	1.3^{a}	1.1^{b}	0.7^{b}	
3	0.7^{b}	1.1^{b}	0.6^{b}	
4	2.3^{c}	0.4^{c}	0.3^{c}	
5	1.8^{a}	1.0^{b}	0.3^{c}	
Mean	1.4000	0.7800	0.6100	2.5333
Std. Dev	.72595	6.04541	1.25100	3.9462
Std .Error	.32465	2.70359	.55946	1.0189

was substantially of a high magnitude.Many factors probably led to recorded damage.

The magnitude of damage of the stem borers to the gramineous host depended on the volatile compounds

Table 10. Damage of stem borers to giant Setaria grass in the field

Entry	*B.fusca*	*C.partellus*	*S .calamistis*	Total
1	0.7^{a}	3.5^{c}	2.2^{c}	
2	0.6^{a}	3.7^{c}	2.1^{c}	
3	0.3^{b}	2.3^{b}	1.3^{b}	
4	1.4^{c}	2.7^{b}	1.5^{b}	
5	0.4^{c}	4.5^{b}	0.9^{a}	
Mean	0.6800	3.3000	.1.6000	1.8600
Std. Dev	.63797	2.6488	1.28841	1.9741
Std .Error	.28531	1.19624	.57619	.5097

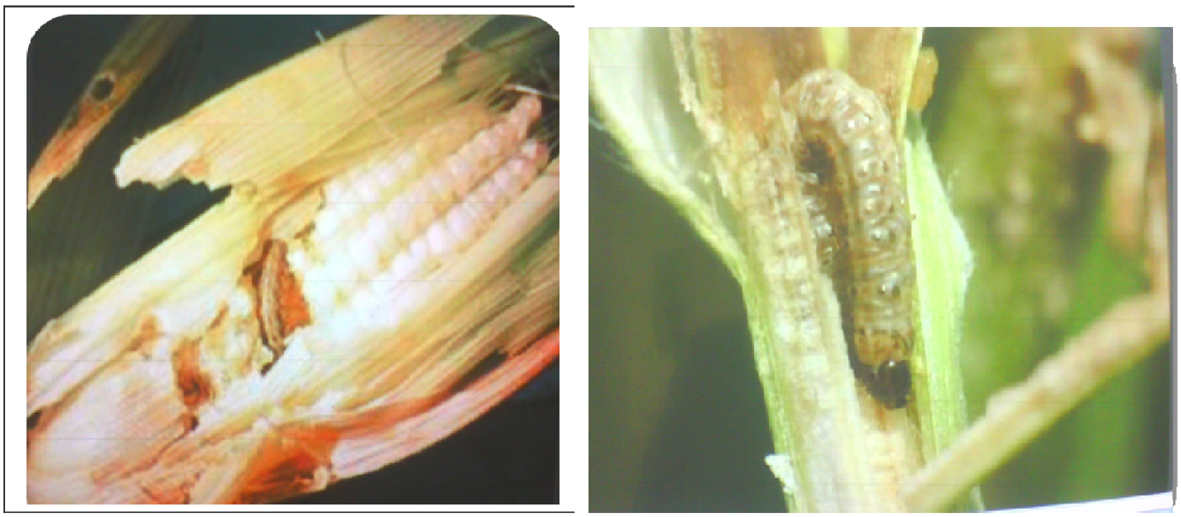

Plate 1. Damage of stem borer on maize grains

Table 11. Plant traits measured after infesting graminae species with stem borers

Entry	Host Plant	No. Of stems damaged	Stem Borer exit holes	Leaf damage score(1-5)	Larvae per plant (No.)	Stem diameter (Cm)	Dry matter yield (t/ha)
1	G.grass	5.43^{b}	0.52^{b}	0.77^{ab}	0.01^{a}	0.55^{ab}	0.89^{ab}
2	S.grass	8.72^{a}	0.56^{b}	1.03^{b}	0.06^{a}	1.02^{b}	1.67^{c}
3	Sorghum	13.27^{b}	1.36^{a}	1.36^{b}	0.11^{b}	1.25^{b}	1.82^{a}
4	Maize	14.84^{b}	2.34^{c}	2.61^{b}	0.16^{ab}	2.27^{a}	3.26^{b}
5	N. grass	12.58^{ab}	1.08^{a}	1.32^{a}	0.09^{a}	1.19^{b}	1.90^{a}

Key: G = Giant Setaria, S =Sudan ,N = Napier

they probably emitted in the first instance although they were not determined in these studies. The *Z. mays* L. emits the following volatile compounds identified by coupled gas chromatography – electro - antennographic detector (GC – EAD analysis): copaene, (Z)-3-hexenol, (E)-2- hexenol,3-hexenyl acetate , (Z) -3-hexenyl acetate, linalool, 4.8 – dimethyl – 1,3,7 – nonatriene,indole,a – *trans* – bergamotene,(E) – b –farnesene, (E) – nerolidol, (3E,7E) –4,8,12 – trimethyl – 1,3,7,11 – tridecatetraene (Adele et *al.*,2000), while the *S.bicolor* L. emits the following volatile compounds: tuolene,hexenol, (Z) – 3-hexenol, M – xylene, O –xylene (Z) – 3 – hexenol acetate, nonanal and decanal.

However, the refugia gramineous hosts : *P. purpureum* Schumach, Sudan grass and giant Setaria grass emit the following volatile compounds identified using Reverse phase/porapak and gas chromatography mass spectrometer (GC – MS) technique (Adele *et al.*,2000). This was confirmed by GC – co – injections .Octanal, decanol, octadecanol, *trans*–Caryophyllene,B–

fernesene,(a+B) Humulene,tridecanol, 1 – Pentacontal,cedrol, 2 – hexyldecanol, 3,7,11 – Trimethyl-2,6,10 – dodecatrienol and *bis (* 2-methoxyethyl)phthalate. It was possible that what was observed resulted from a conglomerate of complex air borne volatiles interacting and acting on borers (Kok and Kok, 2001).

Of these volatile compounds, those emitted by *Z. mays* L. are more attractive to *B.fusca* than they are to the *C.partellus* and *S. calamistis* as they have more electro -physiologically and behaviourally active compounds (Amudavi *et al*.,2009).Volatiles from *Sorghum bicolor a*re relatively attractive to *B. fusca* than to *C.partellus* and *S. calamistis* in comparison to the emissions from refugia gramineous hosts as they have less electro - physiologically active compounds (Mulaa *et al.,* 2011).This specifity suggests that the gramineous plants provides crucial cues for infestation by the stem borers. The cues lead to a greater propensity for searching maize perhaps spacing recommended for growing crops most appropriately facilitate an amenable pattern that confers protective properties to stem borers. More importantly, the preference of the *B.fusca* to *Z. mays* L. majorly is a reflection of the genetic adaptation to searching maize (KARI, 2012).Therefore, the emission of attractants to *B. fusca* by *Z. mays* L. resulted as it inflicted more injury to maize and other gramineous plants which in the descending order could be based on the type of volatiles released. Decreased attack was aligned to appropriate chemical emitted. Also, the *B. fusca* feeds more verociously accounting for a larger magnitude of damage comparative to the other stem borers in this study.

The morphological traits of the Z.*mays* was another trait led to its increased infestation by the *B.fusca* causing more overall damage such as its stem diameter and reduced trichomes which are known physical isolating mechanisms (Maddonni *et al*., 2006).Stem diameters of 1.25 – 2.27cm were appropriately preferred to those of the diameter range of 0.55- 1.19cm due to physical isolation.

The great magnitude of damage to maize could have been due to the biochemical factors. It has more of amino acids, sugars, than the other gramineous hosts (Souza,2002).

Sorghum bicolor L. had a lower damage in comparison to maize due to probably antibiosis. The survival of *B.fusca* in maize and sorghum compared to the three graminae hosts was 3.3 – 3.4, 2.8 – 2.9, and 5.6 – 4.9 times more than in Napier ,Sudan grass and giant setaria grass respectively. Consequently, survival appeared to be the main panacea that elucidated antibiosis since it forms a fundamental component for assessing the ability of the plant to deter attacks on them. It has co – existed with the stem borers for a relatively longer period leading to co – evolution resisting stem borer damages such as possessing more trichomes and the epicuticular wax layer which conspicuous and hampers climbing of the stem borers (Tollenaar *et al*., 2006). Antibiosis leads to high mortality in the early larval stages, low larval establishment, time interval between larval hatching and boring into the stem, larval mass and the survival rate (Nyamangara *et al*., 2003).

However, the forage gramineous refugia were less devastated by the stem borers compared to the forage refugia due to the biochemical factors such as acid detergent fibers, high lignin content,phenols,silica contents etc (Tollenaar *et al*.,2006).They cause non – preference to the stem borers to enter into the stems of these hosts. Also these have numerous trichomes on the leaves offering non – preference for oviposition curtailing the population from raising to the economic threshold nor economic injury level (Tollenaar *et al*.,2006).The Napier and Sudan grass secret a gummy substance that traps moths and prevents over 80% of the stem borer larvae from reaching the adulthood reducing their population growth (Granados,2000).The average damage of stem borers to the Napier and Sudan grass superceded that to the giant setaria due to physical isolation caused by their stem diameter (CAB,2002).The surface conformation of the studied plants had varied leaf smoothness and glossiness, the attributes that enabled their physical deterrence of stem borer attack to be aligned to these properties (Kok and Kok,2001).

The execution of the present studies facilitated the following inferences:

(i) The *B.fusca* was the most devastating stem borer species and it preferred hosts with larger stems thus its control is therefore of paramount importance.

(ii) When these pests are left unchecked, they are capable of causing a monetary loss of over Ksh.25, 438 per ha.

(iii) Bioassays results revealed that the stem borers were more destructive in the laboratory than in the field.

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