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Role of refugia graminae in push - pull management of stem borer species of zea mays l. And sorghum bicolor l.

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A B S T R A C T

This study aimed at determining the role of graminae refugia in push – pull management of stem borer species of Zea mays L. and Sorghum bicolor L. and refugia graminae. It involved two growing gramineous crops: maize Zea mays L. and Sorghum bicolor L. and three gramineous forages: Napier grass Pennisetum purpureum Schumach, Sudan grass and giant Setaria grass. These were planted both in pure and mixed stands and sampling for the borer infestation done throughout the phenology of crops .Field and laboratory bioassays were conducted to determine biophysical efficacies of the control strategy from stem borer fecundities. P.purpruem was the most effective gramineous forage refugia with the potency of being utilized in the push – pull management strategy of the stem borers. It reduced damage caused by stem borers to 2.02% and 5.77% in maize and sorghum respectively. 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 The gramineous biocontrol agent had a significant ($F = 46.29^*$; $p < 0.05$) effect on the damage caused by stem borers to maize and sorghum. The Napier grass was the most preferred forage refugia. However, more research should be conducted to determine the augmention of Napier grass as the appropriate “push crop “when utilized in a push – pull management strategy.

Introduction

Maize, Zea mays L. and sorghum, Sorghum bicolor L. Moech are among the 50 biotypes cereal crops that are grown widely throughout the world in a range of agro-ecological environments.

James (2004) described the factors that limited maize production in Kenya and cited insect pest problems as being one of them. According to Spencer et. al., (2008), about 130 insect species cause varying degrees of damage to the crop in India. However, only about a dozen of these are important. Among the most serious insect pests of maize recoded in Kenya are the stalk borers (ICRISAT et al., 2006).

Stalk borers also attack maize and sorghum because of the stem morphology. The stem of the plant is solid and dry, succulent and sweet .Under favourable conditions more internodes develop, together with leaves, producing a longer stem. The stem consists of internodes and nodes. A cross section of the stem appears oval or round. The diameter of the stem varies between 5 and 30 mm. The internodes are covered by a thick waxy layer giving it a blue-white colour. The waxy layer reduces transpiration and increases the drought tolerance of the plants. The root band of nodes below or just above the soil surface develops prop roots.

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) (Mulaa et al., 2011).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., 2005).

There refugia plants drive them away from the main by emitting repellants. Both maize and sorghum stem borers are polyphagous and have many wild graminaceous alternative hosts (Kenya, MoA, 2005). The wild hosts are thought to be the original hosts of stem borers in their native ecosystems. The current dogma is that wild habitats constitute reservoirs for severe pest infestation on crops. This may not apply on all pest species due to differences in races adapted to different habitats. Research shows that the natural hosts of insects pests act as trap plants which keep pest populations away from cultivated hosts (Songa et al., 2000).Refugia grasses can compliment an integrated pest management (IPM) thus making the strategy less palliative. The current IPM could includes: early planting, use of pest and disease tolerant varieties, use of environmentally friendly methodologies which preserve natural enemies such as selective pesticides, natural plant products, and use of push-pull strategies (Nyukuri,2012)**.**

This strategy has contributed to food security immensely. Intercropping or mixed cropping of maize, grasses and fodder legumes has enabled farmers in Kenya to increase crop yields thus improving their food security and gross benefits. This feature of the technology is suitable for mixed farming conditions which are prevalent in Trans – Nzoia County and has increased maize yields by 20 %.(Mulaa et al., 2011).

The principles of this strategy maximize control efficacy, efficiency, sustainability and outputs while minimizing negative environmental effects. The efficacy is improved through tandem deployment of its components (Songa et al., 2000).
The push – pull components are generally non- toxic therefore the strategies are integrated with biocontrol (Chabi – Olaye et al., 2008)).

The refugia have boosted dairy farming as they serve as livestock farming especially the Napier grass. Desmodium is a nitrogen – fixing legume, improves soil fertility and is a quality fodder and also an effective stem borer repellant (Songa et al., 2000).

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 phytogeography and taxonomy of stem borer species of 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.

Fully established and grown phytogeographical patterns were as depicted in plates 1 – 3 below: The plates of photo – geographical depiction of refugia cropping design.

Figure1. Experimental plot of Sudan grass at flowering stage

Figure2. Experimental plot of luxuriant Napier grass,k1.

Figure3. . Experimental plot of giant Setaria grass nearing harvesting.

Evaluation of the host plants on stem borer survival, larval development and fecundity

Ten of 5 refugia crops and forages were tested in the field and laboratory. Insect bioassays were conducted to measure larval development rates and fecundity of the three stem borer species (B.fusca, C. partellus and S.calamistis).Ten treatments were arranged in randomized complete block design with three replicates. Fresh stem cuttings of approximately 0.5kg of each of the 5 host plants were placed into a clean plastic jar and 10 neonate larvae from KARI – Katumani stem borer rearing facility were released in each jar, under ambient laboratory conditions (22 – 23^{o}C and 65 – 70 RH).The cuttings were replaced every week, the jars cleaned and the larval weight recorded. 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. .

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, 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.

Establishment of the efficacy of using preferred refugia of stem borers in a pull-push pest management strategy

Six weeks after planting the forage gramineous hosts 20 stems borer pupae were kept on moist filter paper, and were placed in each plot, so that the emerging moths would lay eggs on the seedlings (Plate 4). At physiological maturity, 10 plants were randomly sampled per plot and assessed for tunnel length, leaf damage, number of larvae per grass species and exit and entry holes, stem diameter and to evaluate the most preferred host that can utilized pull or push pest management strategy.

The intercrop with forage gramineous maize and sorghum that recorded the least damage hence lowest yield loss was regarded the appropriate refugia**.**

The eggs, larvae, pupae and adults used in this experiment were managed in jars and vials as described by Cock's Protocol (2007).

Figure4. Adults moths emerging from pupae.

Results

Evaluation of the host plants on stem borer survival, larval development and fecundity

The laboratory studies revealed that there were significant differences ($p < 0.05$) between the crop host plants and graminae refugia hosts in life cycle, percentage survival and number of eggs produced by B.fusca, C.partellus and S. calamistis. Larvae reared on maize and sorghum had the shortest life cycle of 53.2 and 55.4 days with those reared on giant Setaria showing the longest development time of 65.4 (Table 1).Durations in Napier and Sudan grasses were 60.2 and 63.4 days respectively.

Egg production per female was highest for larvae reared on maize and lowest for giant Setaria. Percentage survival was significantly ($p < 0.05$) highest on maize with 37.8%, followed by sorghum with 32.8% while Napier, Sudan and giant setaria grasses provided nearly equal effects in borer survival which were 11.5%, 11.2% and 6.7% respectively.

The larval weight gain was generally greatest for the two preferred hosts, maize and sorghum for the prevalent species of stem borer: B.fusca and C.partellus (Table 2).The trend followed the same analogy as for survival.

Table 1. Life cycle, egg production and survival B.fusca and C.partellus reared on gramineous hosts

Host plant	Lifecycle (Days)	Survival (%)	No. of egg produced	Life Cycle (days)	Survival (%)	No. of eggs produced
Maize	53.2^{a}	37.8^{c}	215.0^{c}	55.9^{a}	25.3^{ab}	93.0^{ab}
Sorghum	55.4^{a}	32.8^{b}	184.8^{b}	56.5^{a}	13.3^{b}	67.0^{c}
Napier grass	60.2^{b}	11.5^{a}	146.6^{a}	60.7^{b}	27.5^{ab}	62.3^{b}
Sudan grass	63.4^{b}	11.2^{a}	140.2^{a}	65.3^{b}	18.4^{a}	60.1^{b}
Giant setaria	65.4^{b}	6.7^{ab}	135.4^{ab}	67.5^{ab}	15.7^{a}	55.7^{a}

B.fusca C.partellus

Table 2. Average larval weight of three species of stem borer on gramineous hosts.

Host plant	C. partellus	B. fusca	S.S. calamist
Maize	0.035^{c}	0.038^{a}	0.018^{a}
Napier grass	0.023^{a}	0.025^{b}	0.020^{b}
Sorghum	0.017^{c}	0.026^{a}	0.014^{c}
Sudan grass	0.024^{a}	0.025^{b}	0.021^{b}
Giant Setaria	0.025^{a}	0.012^{b}	0.025^{b}
Overall mean	0.0245	0.0252	0.0196

Table 3. 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

Assessment of effects of gramineous refugia to the grain yields and economic losses

The Table 4 Shows various yields of the grains maize and sorghum realized after intercropping them with the forage refugia used in study. It also shows the yields of grains obtained in the control experiment, pure stands of maize and sorghum agro - ecosystems. The lowest average was obtained in maize and sorghum protected by giant setaria grass. This was 106.6g/plant and 114g/plant respectively.

The table shows that the average grain realized from the biologically protected plots with gramineous refugia were significantly ($F = 46^{*}$; $p < 0.05$) different from the control experimental plots. The average grain loss in protected maize and sorghum plots was 4.92% and 7.12% respectively.

Table 4. Effects of different push –pull management strategy on grain yield loss

Treatment	Mean grain Weight / plant	Grain Yield Loss
Maize	106.6^{c}	22.94
Sorghum	123.47^{ab}	10.92
Maize*Napier grass	135.8^{a}	2.02
Maize*Sudan grass	131.9^{ab}	5.10
Maize*G.Setaria grass	128.0^{ab}	7.65
Sorghum*Napier grass	130.6^{ab}	5.77
Sorghum*Sudan grass	129.5^{ab}	6.51
Sorghum*Setaria grass	126.5^{ab}	9.1
F- value	46.29*	
CV	7.8	

The grain yield loss due to the stem borers in unprotected maize and sorghum as shown in the table 7 was 22.94% and 10.94% respectively. The protection of gramineous refugia to the grain crops was significant ($p < 0.05$).The maize yield reductions were 2.02%, 5.1% and 7.65% were realized when the maize crop was protected by Napier grass, Sudan grass and giant Setaria grass respectively.

The sorghum had grain loss was 5.77%, 6.5% and 9.1% when protected with Napier, Sudan grass and giant Setaria grass respectively.

The type of the gramineous refugia had a significant ($p < 0.05$) effect on the cereal crop protected. The Napier grass was the most effective refugia graminea. It reduced grain yield loss to 2.02% in maize and 5.77% in sorghum.
The giant Setaria grass was the least effective gramineous refugia. It reduced grain loss to 7.65% and 9.1% maize and sorghum respectively.

The efficacy of the most preferred gramineous refugia of stem borers in a push and pull management strategy.
Laboratory evaluation of the forage gramineous refugia.

There were significant differences ($p < 0.05$) among the forage refugia with regard to life cycle, percentage survival, and number of eggs produced by the devastating stem borers: B.fusca and C. partellus. The life cycles of the larvae B.fusca and C.partellus were shortest when reared on Napier grass with means of 60.2 and 60.7 days. They were longest when reared on giant Setaria with means of 65.4 and 67.5 days (Table 1). This showed the longest development time on giant Setaria.

Egg production per female was highest for larvae reared on Napier grass and lowest for giant Setaria with means of 146.6 and 135.4 eggs for B.fusca species, 60.1 and 55.7 eggs for C. partellus. The B.fusca species for management is a major concern, showed the highest survivorship on Napier grass with 11.5% followed by Sudan grass with 11.2% and lowest on giant setaria with 6.7%. The larval weight gain was generally greatest for the two preferred forage refugia hosts: Napier grass and Sudan grass for B.fusca had 25% while C.partellus had 23% and 20% respectively (Table 2) .This implied Napier grass has a greater ability to habour stem borers especially the most devastating B. fusca a principle ingredient in the pull and push management strategy.

Napier grass was the most preferred refugia for B.fusca whose devastation mean was 5.6000 followed by Sudan grass with a mean of 4.5000.However,giant Setaria was the least preferred host of B.fusca with a devastation mean of 3.5333. Giant Setaria was the most preferred refugia for C.partellus with damage mean of 5.1000 and least attractive to B.fusca whose damage mean was 3.5333.

Field evaluation of the forage gramineous refugia

There was a significant difference among the forage refugia ($p < 0.05$) in all traits measured (Table 3).The highest number of damaged plants was in Napier grass followed by Sudan grass and least in giant Setaria grass with means of 12.58, 8.72 and 5.43 respectively. This was the same with regard to the number of stem borer exit holes, leaf damage and the number of the larvae recovered from the dissected forage gramineous refugia.

Also, yield reduction was highest in maize intercropped with Napier grass and sorghum intercropped with Napier grass at 2.02% and 5.77% respectively. Least yield reduction was recorded in the mixed stands of maize, giant Setaria and sorghum, giant Setaria at 7.65% and 9.1% (Table 4).

Discussion

The studies established the efficacy of using refugia graminae in push- pull strategy of pest management. The stem borers that can be controlled by growing different potential refugia graminae in mixtures with maize and sorghum in any of the zones differed. Species diversity had not drastically altered meaning that continuous growing of maize and sorghum in juriposition with Napier, Sudan and giant Setaria grasses has led to highly variable regimes of survival and development of stem borers (Mulaa et al.,2011).

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 (Songa et al., 2000). 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).

The Napier grass K1 showed a greater potency of control stem borers both in maize and sorghum. Although it emits related chemical volatiles to those emitted by Sudan grass and giant setaria grass, Napier grass has a higher concentration of these volatiles with lower molecular weights hence their dispersion rates is more attracting more and even distant stem borers to it (James, 2004;KARI 2011).

Conclusion

The execution of the present studies facilitated the following inference: The Napier grass was the most effective forage gramineous refugia. When intercropped with maize it reduced stem borer damage to as low as 2.02% and 5.77% damage in sorghum. Also it was greatly damaged of three forage refugia investigated. Therefore this can as well be utilized in the push and pull strategy in stem borers' management and hence compliment further the IPM strategy.

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