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Effect of the Lepidoptera Stem Borers, *Busseola fusca* (Fuller) and *Chilo partellus* (Swinhoe) on Green Mealies Production

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Abstract:
The maize stem borers, Busseola fusca and Chilo partellus cause qualitative and quantitative losses on green mealies as they attack maize from seedling up to harvesting. A study was conducted to evaluate stem borer damage and management in green mealies on maize varieties SC 608, PHB 30B50 and SC 513. Two field trials similar in set-up and treatments were conducted. The first trial was planted on the 4th/August/2014 and the second was planted on the 4th/ October/ 2014. The essence of staggering planting was to determine whether B. fusca and C. partellus were problematic in the first part or second part of the dry season before the onset of the rain. For each variety, four treatments were applied, namely; whorl applications of ammonium nitrate (AN), Bulldock® 0.05GR (beta- cyfluthrin), Dipterex® 2.5 GR (trichloforn) and untreated control. The treatments were applied at 6 and 4 weeks after crop emergence (WAE) in the first and second trials, respectively and subsequently at 14 day intervals up to tasseling. The parameters assessed were; plant heights, number of plants with windowed leaves, number of plants with dead- hearts, plant biomass (t/ha), fresh cob weights (t/ha), number of damaged cobs and stem borer parasitism and predation. Results showed that the October planting was less infested with B. fusca and C. partellus than the August planting. Dipterex® 2.5 GR and Bulldock® 0.05 GR were effective to manage B. fusca and C. partellus infestations in green mealies. The effectiveness of the two granular insecticides was not significantly different ($P>0.05$) on the assessed parameters. A stem borer larval parasitoid recorded in the August planting was Schembria eldana Barraclough (Diptera: Tachinidae) with 5.9% parasitism on both stem borer species. For the October planting, the parasitoids that were recovered from both stem borer species were S. eldana Barraclough and Cotesia sesamiae Cameron (Hymenoptera: Braconidae) with parasitism levels of 13.5 and 21.6% respectively. Recovered species preying on stem borer larvae and pupae included earwigs (Dermaptera: Forficulidae), wasps (Hymenoptera: Vespidae) and ants (Hymenoptera: Formicidae) Overall, applying AN in the funnel was not effective in managing B. fusca and C. partellus. Farmers are therefore encouraged to use Dipterex® 2.5 GR and Bulldock® 0.05 GR with other IPM methods such as planting period manipulation, to manage B. fusca and C. partellus infestation in green mealies.

Keywords: *Busseola fusca, Chilo partellus, damage, management, green mealies.*

1. Introduction

Maize is the main staple food crop in Sub-Saharan Africa (Pingali, 2001). In Zimbabwe, maize is an important cereal crop grown by both smallholder and commercial farmers (Gwara, 2011; GOZ, 2012; Mudita *et al.*, 2014).

There are several insect pests that are a major constraint on maize yield within smallholder and commercial sectors of Zimbabwe (Chinwada and Overholt, 2001; Chinwada, 2003; Chinwada *et al.*, 2008). The larvae of the Lepidoptera stem borers *Busseola fusca* (Fuller) (African maize stalk borer) (Lepidoptera: Noctuidae), *Chilo partellus* (Swinhoe) (spotted stem borer) (Lepidoptera: Crambidae) and *Sesamia calamistis* (Hampson) (pink stem borer) (Lepidoptera: Noctuidae) contribute significantly to yield losses (Chinwada and Overholt, 2001; Chinwada, 2003; Mushore, 2005). Among the three, *B. fusca* and *C. partellus* are the most economically important species in Zimbabwe (Chinwada and Overholt, 2001; Chinwada *et al.*, 2001; Chinwada, 2003). They cause yield losses in quantity and quality as they attack the maize plants from the seedling stage up to harvesting. Increased damage in young plants is due to tenderness of leaves and stem since aged and toughened leaves are unsuitable for newly hatched larvae (Nyukuri *et al.,* 2014).

Among cereal crops, maize is the most damaged host because it provides the best geographical requisites and nutritional attributes that attract stem borers. Relatively high losses can occur at the smallholder level where suppression of stem borers by chemicals is seldom practiced (Chinwada *et al.,* 2001). Yield losses due to their damage range from 10 – 45%, depending on the levels of infestation in a geographical location (Sithole, 1995). Foliar damage by the insects results in a reduction of the total leaf area and photosynthetic capacity of the maize plant. Stem tunneling by the larvae weakens the stem and reduces the flow of water, nutrients and metabolites throughout the plant, thereby reducing yields. Stem tunneling also reduces plant vitality and the grain filling process, and promotes breakage and lodging of plants as they mature. Their feeding habit into maize cobs deforms them and these are disliked by consumers (Rice and David, 2010). In addition, cob feeding habit creates an environment suitable for infection by fungi such as *Fusarium* spp. leading to the production of mycotoxins (Keetch *et al*., 2005; Pray *et al*., 2009).

The distribution of Lepidoptera stem borers pests in Zimbabwe follows a defined pattern, with *B. fusca*, dominating in the highlands (>1200 m above sea level) while *C. partellus* is the most abundant and widely distributed species, but predominates in the low-level (<600 m) and middle-level (600- 1200m).*Sesamia calamistis* is found in all agroecological zones, but in very low proportions compared to the other two (Chinwada *et al.,* 2001, Chinwada, 2003).

Farmers use various methods to control stem borers. Several insecticides, formulated as either granules or spray applications are registered for stem borer control in Zimbabwe. The most common ones include carbaryl, endosulfan, dipterex® (trichlorfon), and carbofuran. Dipterex® 2.5 GR is commonly used throughout Zimbabwe (Chinwada *et al.,* 2001; Chandiposha and Chivende, 2014).These chemicals have been screened in both maize and sorghum in various agro-ecological regions and found to provide effective control. Cultural practices such as burning crop residues, removal of alternative hosts, intercropping and management of sowing dates have been recommended for the control of these pests (Chinwada *et al.,* 2001; Cugala, 2002). However, despite of use of these chemicals' insects continue to cause severe damage on green mealies within the smallholder sector. It is well known that the use of insecticides can be detrimental to the natural enemies that are involved in the regulation of the natural population of these pests (Godfray, 1994). In this context, the aim of this study was to study the Lepidopterous stem borers complex, their natural enemies and to find effective solutions in green mealies production.

2. Materials and Methods

2.1. Description of the Study Site

A set of trials to evaluate the effect of maize stem borers and their management in green mealies was conducted at Africa University farms (18^{o}53'70, 3'' S: 32^o 36'27.9'' E, 1,131 m above sea level), Mutare, Zimbabwe during the 2014-2015 farming season. Average day length is 14 hours in summer and 11 hours in winter and annual rainfall ranges from 750 mm to 1,200 mm. Rainfalls mostly in the months of December to February although heavy showers are possible before and after this period. The average maximum temperature ranges from 18 ^{o}C in July to 32 ^{o}C in October. The soils are classified as sandy clay loam of the red Fersiallitic 5E series according to the Zimbabwe soil classification (Nyamapfene, 1991).

- Field treatments Early maturing variety, SC 513; medium to late maturing varieties SC 608 and PHB 30B50 were evaluated for their responses to stem borer's infestation in a field experiment laid out in a Randomized Complete Block Design (RCBD) with three replicates. The distance between the blocks was 1.5m and the distance between plots in a block was 1 m. Each plot was 4m x 3.6 m with five rows. Each row had 13 plant spaced 30 cm apart.

The field experiment was prepared with a total land area of 1,152 m^2 (0.1152 hectare). Maize seeds of each variety were planted in August, 2014 for the first trial and in October, 2014 for the second trial. The second trial was similar to the first one, but planted two months after the first trial to determine whether stem borers were a problem in the first part or the second part of the dry season before the rains. For each trial, at 12 days after planting, Lambda- cyhalothrin® 2.5 EC insecticide was applied within the rows to control cutworms. Basal fertilizer of N: P2O5:K2O (8 – 14 -7) was applied at a rate of 300 kg per hectare. Ammonium nitrate was first top dressed at 49 days after planting at the rate of 300 kg/ha. The second top dressing was applied at 63 days after planting at the rate of 150 kg/ha. Sprinkler irrigation was applied at 48 mm/12 hrs. as a net discharge per cycle. Weeding was carried out three, six and nine week after emergence. The common weeds were gallant soldier, wandering Jew, couch grasses, upright starbur, black jack and nutsedge.

For each trial and each maize variety, four treatments were applied: (1) placing ammonium nitrate (AN) (34.5% N) in the maize funnel, (2) funnel applications of Bulldock® 0.05 GR granules (a.i. beta-cyfluthrin 0.5 g/kg) at 3-4 kg/ha, (3) funnel applications of Dipterex® 2.5 GR granules (a.i. trichloforn 2.5 g/kg) at 3-4 kg/ha and (4) untreated (= control). The treatments were applied at 42 and 28 days after planting in the first and second trials, respectivelyand subsequently at 14 day intervals up to tasseling. For each planting period, green mealies were harvested at 16 weeks after planting.

Data was collected on weekly basis starting from week 5 and 3 when infestation started to build up in the first trial and second trial, respectively. Plant heights, number of plants with windowed leaves, number of plants with dead – heart, plant biomass (t/ha), fresh cob weights (t/ha), damage scores and parasitism of stem borer larvae were recorded. The cob damage was assessed based on a score of 0 – 5 scale (whereby 0 was no damage and 5 severe damage) as indicated below:

The leaf damage was assessed based on a 0 – 9 scale whereby 0 was no damage and 9 very serious damage causing dead – heart. Visual examination for symptoms of funnel feeding, presence of dead – hearts and/ or stem tunneling was done to establish whether crops have been attacked. Samples of infested stems were removed and dissected to retrieve larvae and pupae. The larvae collected were put individually in a glass vial containing artificial diet, and were kept in a laboratory under ambient conditions for two weeks to observe the emergence of any parasitoids or to obtain the pupation of non- parasitized larvae for further identification using the protocol of Polaszek (1998) and Le Ru*et al.* (2006). In case of any parasitoid emergence, the parasitoids were identified using taxonomic keys.

2.2. Data Analysis

Least significance difference following a multivariate ANOVA was used to analyze difference in plant heights, plant biomass, windowed leaves, plant damage score, cob weight, and dead – heart score among varieties, treatments and between planting dates. Data were analyzed using the General Linear Model in SPSS 20 (IBM Statistics, 2011) with dead – heart and damage scores taken as ordinal variables. The significance level was set to $P < 0.05$

3. Results

3.1. Plant Height in Relation to Field Treatment and Varieties

For each maize variety and each trial, the plant heights were significantly higher when the plots have been treated by the two insecticides used as compared to the control plots and the plots amended by ammonium nitrate (Tables 1).

Field Treatments	Maize Variety					
	SC 608		PHB 30B50		SC 513	
	Aug	Oct	Aug	Oct	Aug	Oct
Control	176.3 ± 1.15^{a}	179.2 ± 0.3^{a}	175.7 ± 0.59^{a}	175.0 ± 0.00^{a}	172.0 ± 1.00^{a}	172.0±1.00^{a}
Dipterex® 2.5 GR	179.9 ± 0.36^{b}	182.4 ± 0.51^{b}	183.4 ± 1.15^{b}	177.9 ± 1.46^{b}	179.1 ± 1.06^{b}	179.1± 1.61^{b}
Bulldock® 0.05 GR	181.6 ± 1.80^{b}	181.7 ± 2.55^{b}	182.1 ± 1.65^{b}	177.8 ± 0.81^{b}	178.6 ± 0.46^{b}	178.8 ± 0.10^{b}
AN in the funnel	175.3 ± 0.53^{a}	178.1 ± 1.79^{a}	177.1 ± 0.90^{a}	173.8 ± 0.69^{a}	174.8 ± 1.25^{a}	174.5 ± 0.46^{a}

Table 1: Plant heights (in cm) of three maize varieties for August and October trials 10 weeks after planting (mean ± s.d.; n = 72)
^{a,b}Means followed by the different letters in a column are significantly different at 5 % level according to the LSD's test followed ANOVA

Aug: August; Oct: October; s.d.: Standard deviation

3.2. Leaves Panning in Relation to Field Treatment and Maize Variety

For each maize variety and each trial, plants in Dipterex® 2.5 GR and Bulldock® 0.05 GR treatments had a number of window panning that was significantly less as compared to the control plots and the plots amended by ammonium nitrate (Tables 2)

Field Treatments	Maize Variety					
	SC 608		PHB 30B50		SC 513	
	Aug	Oct	Aug	Oct	Aug	Oct
Control	11.0 ± 1.0^{b}	4.0 ± 1.0^{b}	11.3 ± 0.8^{b}	6.7 ± 0.8^{b}	10.0.± 0.0^{b}	4.0 ± 1.7^{b}
Dipterex® 2.5 GR	3.7 ± 0.3^{a}	1.7 ± 0.6^{b}	3.7 ± 0.3^{a}	1.3 ± 0.6^{a}	2.7 ± 0.3^{a}	1.7 ± 1.2^{a}
Bulldock® 0.05 GR	2.0 ± 0.0^{a}	1.3 ± 0.6^{a}	2.0 ± 0.0^{a}	1.0 ± 0.0^{a}	1.3 ± 0.6^{a}	1.3 ± 0.6^{a}
AN in the funnel	10.0 ± 1.0^{b}	3.3 ± 0.6^{b}	10.0 ± 1.0^{b}	3.7 ± 0.6^{b}	8.0 ± 0.0^{b}	3.3 ± 0.6^{b}

Table 2: Number of plants with windowed leaves of three maize varieties for August and October trials 10 weeks after planting (mean ± s.d.; n = 72)
^{a}Means followed by different letters in a column are significantly different at 5 % level according to the LSD's test followed ANOVA

3.3. Dead – Heart in Relation to Field Treatment and Maize Variety

For each maize variety and each trial, Bulldock® 0.05 GR and Dipterex® 2.5 GR significantly reduced dead – heart formation as compared to the AN application which did not differ from the untreated control (Table 3).

Field Treatments	Maize Variety					
	SC 608		PHB 30B50		SC 513	
	Aug	Oct	Aug	Oct	Aug	Oct
Control	3.0± 1.0^{b}	2.7± 0.6^{b}	3.3± 0.6^{b}	2.0± 0.0^{b}	3.3 ± 0.6^{b}	2.7 ± 0.6^{b}
Dipterex® 2.5 GR	1.7± 0.6^{a}	1.0 ± 0.0^{a}	1.7± 0.6^{a}	1.0± 0.0^{a}	1.7± 0.6^{a}	1.0± 0.6^{a}
Bulldock® 0.05 GR	1.3 ± 0.6^{a}	1.7 ± 0.6^{a}	2.3± 0.6^{a}	1.0± 0.0^{a}	1.7± 0.6^{a}	1.7 ± 0.6^{a}
AN in the funnel	3.3± 0.6^{b}	2.3± 0.6^{b}	4.0± 0.6^{b}	3.3± 0.6^{b}	2.7± 0.6^{b}	3.7± 0.6^{b}

Table 3: Number of plants with dead - heart of three maize varieties for August and October 10 weeks after planting (mean ± s.d.; n = 72)
^{a}Means followed by the different letters in a column are significantly different at 5 % level according to the LSD's following ANOVA

3.4. Plant Biomass (T/Ha) In Relation to Field Treatment and Maize Variety

For each maize variety and each trial, Bulldock® 0.05 GR and Dipterex® 2.5 GR significantly increased plant biomass compared to the AN application which did not differ from the untreated control. In general, the October planting yielded more biomass than the August planting (Table 4)

Field Treatments	**Maize Variety**					
	SC 608		PHB 30B50		SC 513	
	Aug	Oct	Aug	Oct	Aug	Oct
Control	52.0 ± 1.0^{a}	66.5± 0.8a	53.0 ± 1.0^{a}	53.8± 0.7^{a}	51.1± 0.9^{a}	53.1± 0.8^{a}
Dipterex® 2.5 GR	62.0 ± 1.0^{b}	69.4± 0.9^{b}	62.7± 1.1^{b}	58.7± 0.8^{b}	54.4± 0.7^{b}	60.9± 0.1^{b}
Bulldock® 0.05 GR	68.0 ± 1.0^{b}	68.9± 0.8^{b}	59.2± 0.9^{b}	64.3± 2.3^{b}	54.9± 0.4^{b}	62.3± 1.2^{b}
AN in the funnel	51.0 ± 1.0^{a}	62.3± 0.6^{a}	49.7± 0.9^{a}	54.3± 0.1^{a}	49.6±0.9^{a}	51.1± 0.9^{a}

Table 4: Plant biomass (t/ha)of three maize varieties for August and October trials 16 weeks after planting (mean ± s.d.; n = 72)
^{a}Means followed by the different letters in a column are significantly different at 5 % level according to the LSD's following ANOVA

3.5. Fresh Cob Weights (T/Ha) in Relation to Field Treatment and Maize Variety

For each maize variety and each trial, whorl applications of Dipterex® 2.5 GR and Bulldock® GR significantly increased fresh cob weights (t/ha) as compared to the whorl application of AN which did not differ from the untreated control. In general there was an increase in fresh cob weights in the October planting as compared to the August planting (Table 5)

Field Treatments	**Maize Variety**					
	SC 608		PHB 30B50		SC 513	
	Aug	Oct	Aug	Oct	Aug	Oct
Control	17.4± 1.2^{a}	19.2± 0.9^{a}	16.9± 1.1^{a}	18.3± 0.6^{a}	16.4± 1.1^{a}	19.2± 0.6^{a}
Dipterex® 2.5 GR	20.1± 0.2	^{b}23.1± 1.0^{b}	19.8± 0.5^{b}	20.3± 0.8^{b}	17.8± 1.8^{b}	23.1± 1.0^{b}
Bulldock® 0.05 GR	19.4 ± 0.2	^{b}24.1± 0.8^{b}	18.4± 1.2^{b}	19.6± 0.6^{b}	17.8± 0.9^{b}	24.1±0.9^{b}
AN in the funnel	16.4± 0.5^{a}	20.1± 0.3^{a}	15.9± 1.4^{a}	17.9± 1.2^{a}	16.4± 0.4^{a}	20.1± 0.8^{a}

Table 5: Fresh cob weights (t/ha) of three maize varieties for August (A) and October (O) trials 16 weeks after planting (mean ± s.d.; n = 72)
^{a}Means followed by the different letters in a column are significantly different at 5 % level according to the LSD's following ANOVA

3.6. Plant Damage Scores in Relation to Field Treatment and Maize Variety

For each maize variety and each trial, Dipterex® 2.5 GR and Bulldock® 0.05 GR had less damage scores as compared to that recorded from application of AN in whorl which did not differ from the control. In general the damage scores for October planting of maize treated with AN in the funnel and the control were higher than the August planting (Table 6).

Field Treatments	**Maize Variety**					
	SC 608		PHB 30B50		SC 513	
	Aug	Oct	Aug	Oct	A	Oct
Control	2.0 ± 0.0^{a}	3.0 ± 1.0^{a}	1.7 ± 0.6^{a}	2.3 ± 0.6^{a}	2.0 ± 0.0^{a}	3.0 ± 1.0^{a}
Dipterex® 2.5 GR	1.3 ± 0.6^{b}	1.7 ± 1.2^{b}	1.0 ± 0.0^{b}	1.3 ± 0.6^{b}	1.0 ± 0.0^{b}	1.3 ± 0.6^{b}
Bulldock® 0.05 GR	1.0 ± 0.0^{b}	1.3 ± 0.6^{b}	1.0 ± 0.0^{b}	1.0 ± 0.0^{b}	10. ± 0.0^{b}	1.0 ± 0.0^{b}
AN in the funnel	2.3 ± 0.6^{a}	3.3 ± 0.6^{a}	1.7 ± 1.2^{a}	3.3 ± 0.6^{a}	1.7 ± 1.2^{a}	2.7 ± 0.6^{a}

Table 6: Damage scores of three maize varieties for August and October trials 16 weeks after planting (mean ± s.d.;n = 72)
^{a}Means followed by the different letters in a column are significantly different at 5 % level according to the LSD's following ANOVA

3.7. Stem Borers and Parasitoids Species

In all experimental plots, the insects pests collected from infested maize plants were belonging to *Busseola fusca* and *Chilo partellus*.*Busseola fusca* and and *C. partellus* were found to be parasitized only by *Schembria eldana* Barraclough (Diptera: Tachnidae) and by *Cotesia sesamiae* (Hymenoptera: Braconidae) during August and October trials and on control plots (the relative percentages of larvae parasitized are also given). Earwigs (Dermaptera: forficulidae), wasps (Hymenoptera: Vespidae) and ants (Hymenoptera: Formicidae) were observed also preying *B. fusca* and *C. partellus* larvae.

August Planting						October Planting				
Variety	Larvae found		Parasitoids found			Larvae found		Parasitoids found		
	Species	No	Species	No	%	Species	No	Species	No	%
SC 608	*B.fusca* *C.partellus*	20 11	*S.eldana* -	2 -	10 -	*C.partellus* *B. fusca*	10 7	*S.eldana* *S.eldana*	1 4	10 57.1
SC 513	*C.partellus*	9	-	-	-	*B. fusca*	9	*C.sesamiae*	4	44.4
PHB 30B50	*B.fusca* *C.partellus*	18 10	*S.eldana* -	2 -	11.1 -	*B.fusca* *C.partellus*	5 6	*C.sesamiae* *C.sesamiae*	3 1	60 16.7

Table 7: Stem borers and parasitoids species collected during the study
-= Nothing; % paras = Percentage parasitism; No = Number

4. Discussion

Stem borer species identified at Africa University farm The studies established that the damage of *Busseola fusca* and *Chilo partellus* to green mealies was substantially of a high magnitude especially on the uncontrolled plots. Chinwada and Overholt (2001) suggested that the Lepidopteran stem borer *B. fusca* and *C. partellus* are by far the most important stem borer species that attack maize and Sorghum in Zimbabwe. No *S. calamistis* was found in the study area. Chinwada *et al.*(2001) also suggested that *S. calamistis* does attack Poaceae crops in Zimbabwe.

4.1. Effectiveness of Granular Insecticides and Ammonium Nitrate in Managing Stem Bores in Green Mealies

The granular insecticides used in the August and October trials are all registered for stem borer control and are used by farmers to control stem borers in Zimbabwe. In the current study, Dipterex® 2.5 GR and Bulldock® 0.05 GR granular insecticides were effective against *B. fusca* and *C.partellus* infestation in green mealies. These insecticides had active ingredients that act on different components of the nervous system of stem borers with different modes of actions. Beta – cyfluthrin, the active ingredient in Bulldock® 0.05 GR, acts on the axonal membrane by causing its permanent depolarization (Thatheyus and Selvam, 2013; Brown, 2013), and affects both the peripheral and central nervous system of the insect (Hetrick *et al.*, 2013. Trichlorfon, the active ingredient in Dipterex® 2.5 GR, acts as inhibitor of acetyl cholinesterase enzyme (Čolović *et al.*, 2013).

Both insecticides have contact and stomach action on the targeted insect pests (Brown, 2013) with no penetrating effects within the plants. The degree of survival of a pest depends upon the residual characteristics of an insecticide (Brown, 2013). Pyrethroids (such as Bulldock® 0.05 GR) have long (14 days in plants) residual activity and are applied at low rates, but they are not photo - stable as they degrade in sunlight while organophosphates (such as Dipterex® 2.5 GR) have short (7 - 10 days in plants) residual activity (Thatheyus and Selvam, 2013). However, the protective effects of Bulldock® 0.05 GR and Dipterex® 2.5 GR were the same. Plants treated with both chemicals had significantly more biomass, more cob weights, less windowed leaves and less damage scores compared to AN-treated maize and the control. The chemical concentration of an insecticide can also determine the level of survival of a pest (Brown, 2013). For example, granular formulation of Beta – cyfluthrin were found to be highly effective against *C. partellus* in South Africa at a very low concentration per hectare. Granular formulations of trichlorfon were also found to be the most economic insecticides against *C. partellus* control in maize in Kenya (Polaszek, 1998).

The effectiveness of the granular insecticides used in the experiment concurs with Polaszek (1998) who suggested that granular application of insecticides in whorls of maize plants is the most effective and economic method for control of stem borer species which feed in whorls.

These insecticide formulations have several advantages for borer control in maize as they are easy and safe to handle, can be applied by hand and can be applied accurately in a controlled manner. Once applied, the granules disintegrate in water that is often found in maize funnels and are retained there under conditions of wind and water. The recommended rates of application on the labels of the insecticides used in the trials contributed to the efficacy of the insecticides against *B. fusca* and *C. partellus* infestation in green mealies. Although insecticide use can be of benefit to farmers in the short term, their use thereof has not been without problems. For example, foliar applications of pyrethroids were found affecting epiphytic predators than epigealpredators on maize and sorghum under commercial farming systems in South Africa. On the other hand, granular formulations of insecticides applied in plant whorls were found to have no deleterious effects on natural enemies of stem borers (Du Toit, 1995). Therefore, for a successful reduction in insect populations, timing of control measures is crucial as the larval stages feed deep within plant tissues. Granular application must be applied when larvae are still feeding outside on maize leaves.

The use of AN in the funnel as a control method against stem borer larvae was ineffective as it had no effect on the infestations of *B.fusca* and *C.partellus* in the trials. The maize varieties used in the trials were not resistant to *B.fusca* and *C.partellus* attack as observed from the untreated plots. The study by Juma *et al.*, (2015) revealed that silicon in plant epidermal cells provide a physical barrier by increasing leaf abrasion, which subsequently increases wearing off of the mandibles of *B.fusca* larvae, which physically deter larval feeding.

The assessment of windowed leaves showed that maize plots treated with AN in the funnel as well as the controls had high damage mean than those treated with insecticides especially in the August trial. It was also observed that plants treated with AN in the funnel and the control were shorter than those treated with insecticides. These results concur with Songa *et al.*(2001) who also observed a decrease in plant height from 145 to 140 cm due to high borer density in maize.

During the reproductive growth stage, *B. fusca* and *C. partellus* larvae were occasionally found feeding on maize cobs of plots treated with AN in the funnel as well as the control with higher damage scores in the October planting than the August planting. The tunnels of stem borers significantly affected yield as was the case on fresh cob weights of maize treated with AN in the funnel and the control. These results concur with Songa *et al.* (2001) who also observed that one centimeter of stem borer tunnel reduces maize yield by 3g/plant. There are risks that arise from using AN in the funnel by smallholder farmers. Over application of AN in the funnel burns terminal bud of maize and the plant may die completely. In addition, application to a water stressed plant causes more damage that may lead to plants death.

4.2. Planting Period in Relation to Planting Season of Green Mealies

Regarding the planting period, the August planting was more attacked than the October planting. The rainfall season started when the October planting was not yet ready for harvesting resulting in low stem borer infestation on maize plants. Probable explanations for the deleterious effect of rainfall on stem borers include hindrance of adults from flying for mating, stopping or depressing egg laying, and causing high mortality in whorl-feeding early instars and moths (Chinwada *et al.*, 2001;Niyibigira *et al.*, 2001). Washed away larvae are unlikely to survive on the ground due to starvation, desiccation and predation (Bonhof and Overholt,2001).

A drought spell which occurred from December to January when the October planting was still immature resulted in high damage scores on the October planting than the August one. The higher damage could have been influenced by high temperature and low rainfall which are favorable conditions for stem borer multiplication. These results are in agreement with Kisimoto and Dyck (1976) who suggested that high temperature and low rainfall can cause a severe stem borer infestation. Sithole (1989) also suggested that in Zimbabwe, two distinct generations emerge in November and January-February and a third generation occurs only when conditions are favorable. Manipulation of planting date is commonly recommended for *B.fusca* control in South Africa and Zimbabwe, since this borer has a distinct moth flight with months being virtually absent for a period of 2-4 weeks between the first and second generation moth flight (Van den Berg and Rensburg, 1993; Sithole, 1995).

In order to efficiently utilize planting date as a means of escaping borer damage, it is crucial to define what should be regarded as early or late planting within an agro ecological region and to know the local seasonal patterns of stem borer life cycles. Planting dates can then be planned to ensure that the most susceptible stage of crop growth does not coincide with periods of peak moth activity (Polaszek, 1998). According to the local farmers, stem bores do not infest the late sown crop (October) much as they are affected by rainfall during plant growth as compared to those planted early under irrigation in August. Later sowing of maize is less affected by stem borer larvae than earlier sowings (ISU, 2012). Therefore, the findings of the present study are also in agreement with the local farmers cultivating maize in the study area.

4.3. Diversity of Stem Borer Natural Enemies

The larval parasitoid which bore resemblance to *S. parasitica* was identified to be *Schembria eldana* Barraclough. In the trials, parasitism due to the tachinid was5.9 and 13.5% in the August and October planting respectively. *S. eldana* was first collected in the Tongaat area of the South African sugarcane belt attacking E. *saccharina* in *Cyperus papyrus* umbels, also in Kenya and Ethiopia (Barraclough, 1991; Assefa *et al.*, 2006). In South Africa, it was recorded with 5.26% at the time of surveys (Assefa *et al.*, 2006). Apart from *E. saccharina,* the species has never been reported attacking other species of stem borers.

It is of interest to note that this is the first time in Zimbabwe to report on S. *eldana* parasitizing *B. fusca* and *C. partellus*. The parasitism was more evident on *B. fusca* than *C. partellus* larvae. The biology of this parasitoidand the suitability of cereal stem borers in Zimbabwe for its development need to be investigated. The recovery of *S. eldana* on *B. fusca* and *C. partellus* contradicted the studies by Barraclough (1991) who recovered it on *E. saccharina* only.

Though the *S. eldana* resembles *S. parasitica,* the latter is found in abundance in the Harare area and it would seem more likely that there are unknown abiotic or biotic factors that favors this particular parasitoid in the area (Chinwada *et al.*, 2004). In addition, in Zimbabwe, *S. parasitica* is carried over from one cropping season to the next by synchronizing its larval development with that of diapausing *B. fusca* larvae (Chinwada and Overholt, 2001). This carryover mechanism has never been reported with *S. eldana.* Therefore, careful identification with a specialist tachinidae is required when a larval dipteran tachinidae is recovered on stem borer larvae.

Cotesia sesamiae was another parasitoid identified in the trials with relative percent parasitism of 21.6 % in October plantings. In the August planting no *C. sesamiae* was recovered from sampled larvae. It is a gregarious endoparasitoid of medium and large-instar larvae of lepidopterous stem borers in the families Noctuidae and Pyralidae including *B. fusca, C. partellus, C.orichalcociliellus, E. saccharina* and *S. calamistis* that feed on maize and sorghum in sub-Saharan Africa (Mochiah *et al.,* 2001; Ngi-Song *et al.,* 2001; Mochiah *et al.,* 2002).

In order to ensure synchrony between their life cycles and host stem borers, the indigenous parasitoids must have mechanisms of synchronizing themselves in diapausing larvae to survive through to the next cropping season. For example, in Zimbabwe, *S. parasitica* overwinters by going into a synchronous diapause inside diapausing larvae of *B. fusca* (Chinwada and Overholt, 2001). The current study, however, did not elucidate seasonal carryover mechanisms of *S. eldana* and *C. sesamiae.*

In this study, *C.sesamiae* parasitized more from *B.fusca* than *C.partellus.* Chinwada*et al.* (2003) also found that *C. sesamiae* prefers *B. fusca* and *S. calamistis* to *C. partellus* for oviposition, possibly reflecting its long co-evolutionary history with the noctuids in Zimbabwe.

However, the findings of the present study contradicts the results obtained by Machiah *et al*. (2001), who suggested that *C. sesamiae* did not successfully develop in *C. partellus*. Probably, the population origin of *C. sesamiae* used in that particular study was different from the one detected in the trials at Africa University farm in Zimbabwe. In the trials it was observed that stem borers were pupating close to the tunnel exit or even partly outside the stem. This pupation behavior increases their accessibility to parasitoid attacks (Zhou *et al.*, 2003).

Predators are valuable components of Integrated Pest Management. Ants (Hymenoptera: Formicidae), wasps (Hymenoptera: Vespidae) and Earwigs (Dermaptera:Forficulidae) were found preying on the larvae and pupae of *B. fusca* and *C. partellus* in the current study. The observation was that bored maize stems had no stem borer larvae in them when the ants or earwigs were present on the maize plants. These findings are in agreement with Bonhof (2000) in Kenya, Ebenebe *et al*. (2001) in Lesotho and Wale *et al*. (2006) in Kenya, who also observed ants (Hymenoptera: Formicidae) and earwigs (Dermaptera: Forficulidae) preying on larvae and pupae of stem borers in maize fields. *Componotus* spp. and *Pheidole* spp. appear to be the most important and common species that prey on stem borer larvae and pupae. Ants of the genus *Lepisiota* can prey on stem borer eggs and pupae (Bonhof, 2000).

5. Conclusion

The Lepidoptera stem borers, *B. fusca* and *C. partellus* caused yield losses and cob quality reduction of green mealies as they attacked maize plants from the seedling stage up to the harvesting stage. When insecticides were not applied, there were qualitative and quantitative losses of green mealies than when an insecticide like Bulldock® 0.05 GR and Dipterex® 2.5 GR was applied. The use of AN in the funnel as a cultural control method should be discouraged as its application did not have any effect in terms of controlling infestations by *B. fusca* and *C. partellus*. Breeding maize varieties that are tolerant to stem borers is crucial as the present study did not reveal any tolerant variety. This will help smallholder farmers who generally cannot afford to buy insecticides. Renewed research efforts on chemical control, with smallholder farmers as the targeted group, are clearly necessary. There is a need to adopt reliable stem borer management methods through the use of registered granular insecticides such as Bulldock® 0.05 GR and Dipterex 2.5® GR in combination with cultural control. Combining whorl-applied granular insecticides with cultural practices such as planting date manipulation, crop rotation, tillage practices, and intercropping and crop residue management practices will help to reduce the damage caused by *B. fusca* and *C. partellus* in green mealies production. The current study established that *B. fusca* and *C. partellus* are the predominant stem borer species at Africa University farm and possibly the Old Mutare valley. The study also established the presence of some parasitoids of stem borers namely a *S. eldana* Barraclough (Diptera: Tachinidae) and*C. sesamiae* in the Old Mutare valley.

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6. References

i. Assefa, Y., Conlong, D.E. and Mitchell, A., 2006. Status of Eldana saccharina Walker(Lepidoptera: Pyralidae), its host plants and natural enemies in Ethiopia. Bulletin of Entomological Research,96: 497-504.
ii. Barraclough, D. A., 1991. A new species of Tachinidae (Diptera) parasitic on the sugarcane borer Eldana saccharina (Lepidoptera: Pyralidae) in Natal, South Africa. Bulletin of Entomological Research,81: 133-136.
iii. Bonhof, M.J., 2000. The impact of predators on maize stem borers in coastal Kenya. PhD Thesis, Wagenigen University. pp. 181.
iv. Bonhof, M.J. and Overholt, W.A., 2001. Impact of solar radiation, rainfall and cannibalism on disappearance of maize stem borers in Kenya. International Journal of Tropical Insect Science,21(4):403-407.
v. Brown, A.E., 2013. Mode of Action of insecticides and related pest control chemicals for production agriculture, ornamentals, and turf. University of Maryland Extension, Department of Entomology. pp. 4-13.
vi. Chandiposha, M. and Chivende, F., 2014.Effect of ethephon and planting density on lodged plant percentage and crop yield in maize (Zea mays L.). African Journal of Plant Science,8 (2):113-117.
vii. Chinwada, P., 2003. Stem borer parasitism by Cotesia sesamiae and Sturmiopsis parasitica and an assessment of the need to introduce Cotesia flavipes in Zimbabwe. PhD. Thesis, Kenyatta University. pp. 44-162.
viii. Chinwada, P. and Overholt, W.A., 2001. Natural enemies of maize stem borers on the highveld of Zimbabwe. African Entomology, 9: 67-75.
ix. Chinwada, P., Omwega, C.O. and Overholt, W. A., 2001. Stem borer research in Zimbabwe: prospects for the establishment of CotesiaflavipesCameron. Insect Science and its Application, 21(4): 327-334.
x. Chinwada, P., Overholt, W.A., Omwega, C.O. and Mueke, J.M., 2003. Geographic differences in host acceptance and suitability of two Cotesia sesamiae populations In Zimbabwe. Biological Control,28: 354-359.
xi. Chinwada, P., Overholt, W.A., Omwega, C.O. and Mueke, J.M., 2004. Biology of Sturmiopsis parasitica (Diptera: Tachinidae) and suitability of three cereal stem borers (Lepidoptera: Crambidae, Noctuidae) for its development. Annals of the Entomological Society of America,97(1): 153-160.
xii. Chinwada, P., Schulthess, F., Overholt, W.A., Jowah, P. and Omwega, C.O., 2008. Release and establishment of Cotesia flavipesfor biological control of maize stemborers in Zimbabwe. Phytoparasitica, 39 (2): 160-167
xiii. Čolović, M.B., Krstić, D.Z., Lazarević- Pašti, T.D., Bondžić, A.M. and Vasić, V.M., 2013.Acetycholinesterase Inhibitors: Pharmacology and Toxicology. Current Neuropharmacology,11: 315-335.

xiv. Cugala, D., 2002. Introduction and establishment of Cotesia flavipes Cameron (Hymenoptera: Braconidae) in Mozambique as a biological control agent against cereal stem borers in Mozambique. M Phil. thesis. University of Zimbabwe, Harare, Zimbabwe.

xv. Du Toit, H., 1995. Die natuurlikepredatorkompleks van somergraanplaeen die invloed van chemise plaagbeheerplaagbeheerdaarop. Msc. thesis, University of Potchefstroom, South Africa.

xvi. Ebenebe, A.A., van den Berg, J. and Van der Linde, T.C., 2001. The incidence of Dorylushelvolus(Linnaeus) (Hymenoptera: Formicidae) and parasitoids (Hymenoptera: Braconidae) as mortality factors of Busseola fusca, Fuller (Lepidoptera: Noctuidae) and Chilo partellus (Swinhoe) (Lepidoptera: Crambidae) in Lesotho. African Entomology, 9: 77-84.

xvii. Godfray, H.C.J., 1994. Parasitoids: Behavioural and Evolutionary Ecology. Princeton University Press, New Jersey

xviii. GOZ (Government of Zimbabwe)., 2012. Zhovhe small scale irrigation project Zimbabwe Appraisal report, Ministry of Agriculture, Mechanization and Irrigation Development. pp. 11-30.

xix. Gwara, S.,2011. An estimation of price and non price factors affecting maize supply response in Zimbabwe, Msc. thesis, Zimbabwe University.

xx. Hetrick, J., Juzwiak, R.L. and Spatz, D., 2013. Risks of cyfluthrinand beta- cyfluthrinUse, environmental fate and effects Division Office of Pesticide Programs Washington, D.C. pp. 36-164.

xxi. IBM SPSS statistics, 2011. Statistical Package for Social Sciences. Version 20.

xxii. ISU (Iowa State University).,2012. Field Crop insects. Iowa Soybean Association. pp. 4-5

xxiii. Juma, G., Ahuya, P.O., Ong' amo, G., Le Rü, B., Magoma, G., Silvain, J.F. and Calatayud, P.A., 2015. Influence of plant silicon in Busseola fusca (Lepidoptera: Noctuidae) larvae- Poaceae interactions. Bulletin of Entomological Research,105(2): 253-258

xxiv. Kisimoto, R. and Dyck, V.A., 1976. Climate and rice insects. International Rice Research Symptoms (IRRI) Rice. pp. 371-391

xxv. Keetch, D.P., Webster, J.W., Ngqaka, A., Akanbi, R. and Mahlanga, P., 2005. Bt maize for small scale farmers: A case study. African Journal of Biotechnology,12(4): 1505 – 1509

xxvi. Le Rü, B.P., Ong'amo, G.O., Moyal, P., Ngala, L., Musyoka, B., Abdullah, Z., Cugala, D., Defabachew, B., Haile, T.A., KaumaMatama, T., Lada, V.Y., Negassi, B., Pallangyo, K., Ravolonandrianina, J., Sidumo, A., Omwega, C.O., Schulthess, F., Calatayud, P.A. and Silvain, J.F., 2006. Diversity of lepidopteran stem borers on monocotyledonous plants in eastern Africa and the islands of Madagascar and Zanzibar revisited. Bulletin of Entomological Research, 96: 555–563.

xxvii. Mochiah, M.B., Ngi-Song, A.J., Overholt, W.A. and Botchey, M., 2001. Host suitability of four cereal stem borers (Lepidoptera: Crambidae, Noctuidae) for different geographic populations of Cotesia sesamia(Cameron) (Hymenoptera: Braconidae) In Kenya. Biological Control,21:285-292.

xxviii. Mochiah, M.B., Ngi-Song, A.J., Overholt, W.A. and Botchey, M., 2002. Effects of calyx fluid from a population of Cotesia sesamiae (Cameron) (Hymenoptera: Braconidae) on the immune Response of its host Busseola fusca Fuller (Lepidoptera: Noctuidae). Insect Science and its Application,1: 81-85.

xxix. Mudita, I.I., Chipfiko, T., Mapfumo, P. and Tigere, T.A., 2014. Effects of foliar fertilizer on yield and quality of green mealies (Zea mays L.). Journal of Agronomy, 13(1):35-39.

xxx. Mushore, K., 2005. Assessment of suitability of different populations of stem borer species for the development of Cotesia flavipes(Hymenoptera: Braconidae) and the establishment of the latter in Zimbabwe. Msc. thesis, University of Zimbabwe

xxxi. Ngi-Song, A., Kimani-Ngogu, S. and Overholt, W.A., 2001. Multiple parasitism by Cotesia sesamiae and Cotesia flavipes(Hymenoptera: Braconidae) on Buseeola fusca (Lepidoptera: Noctudae). Biocontrol Science Technology,11: 381-390.

xxxii. Niyibigira, E.I., Abdallah, Z.S., Overholt, W.A., Lada, V.Y. and Van Huis, A., 2001. Distribution and abundance, in maize and sorghum, of lepidopteran stem borers and associated indigenous parasitoids in Zanzibar. Insect Science and its Application,21(4): 335-346.

xxxiii. Nyamapfene, K., 1991. The soils of Zimbabwe. Nehanda Publishers (Pvt) Ltd, Harare, Zimbabwe.

xxxiv. Nyukuri, R.W., Kirui, S.C., Cheramgoi, E., Chirchir, E. and Mwale, R., 2014.Damage of stem borer species to Zea mays L., Sorghum bicolor L. and three refugiagraminae. Africa Journal of Food Science and Technology,5(2):37-45.

xxxv. Pingali, P.L., 2001. CIMMYT 1999-2000 World Maize Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector. Mexicon, D.F. CIMMYT. 60 pp.

xxxvi. Polaszek, A (ed.)., 1998. African cereal stem borers, economic importance, taxonomy, natural enemies and control, CAB International CTA. pp. 271-273.

xxxvii. Pray, C., Rheeder, J., Gouse, M., Volkwyn, Y., van der Westhuizen, L. and Shephard, G. S., 2009. Can Bt maize reduce exposure to the mycotoxin fumonisin in South Africa?.International Association of Agricultural Economists, Conference, Beijing, China. pp. 1-12

xxxviii. Rice, M. and Davis, P., 2010. Stalk borer (Lepidoptera: Noctuidae) ecology and Integrated Pest Management in corn. Journal of Integrated Pest Management, 1:1-6.

xxxix. Sithole, S.Z., 1989. Sorghum stem borers in southern Africa, pp.41-47. In Proceedings of the International Workshop on Sorghum stem borers, 17-20 November, 1987, ICRISAT Center, India, ICRISAT Patancheru.

xl. Sithole, S.Z., 1995. Distribution and economic importance of sorghum stem borers in Zimbabwe. PhD thesis, University of Zimbabwe, Harare, Zimbabwe

xli. Songa, J.M., Guofa, Z. and Overholt, W.A., 2001. Relationships of stem borer damage and plant physiological conditions of eastern Kenya. Insect Science and its Application,21(3): 243-249.

xlii. Thatheyus, A.J. and Selvam, A.D.G., 2013. Synthetic Pyrethroids: Toxicity and Biodegradation. Applied Ecology and Environmental Sciences,1(3): 33-36.

xliii. Van den Berg, J. and Rensburg, J.B.J., 1993. Importance of persistence and synergistic effects in the chemical control of Chilo partellus (Lepidoptera: Pyralidae) of grain sorghum. Applied Plant Science, 7: 5-7.

xliv. Wale, M., Schulthess, F., Kairu, E.W. and Omwega, C.O., 2006. Cereal yield losses caused by lepidopterous stem borers at different nitrogen fertilizer rates in Ethiopia. Journal of Applied Entomology,130 (4): 220-229.

xlv. Zhou, G., Overholt, W.A. and Kimani-Njogu, SW., 2003. Species richness and parasitism in assemblage of parasitoids attacking maize stem borers in Coastal Kenya. Ecological Entomology,28: 109-118.