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Efficacy of Selected Biopesticides and Botanical Extracts in Managing Rice Stem Borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) in Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author BJ designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Authors GMR and TT made conceptual contributions, corrections and objective criticisms. All authors read and approved the final manuscript.

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ABSTRACT

Stem borers have been reported as the most injurious insect pests of rice among the insects that attack rice crop globally. Management of stem borers has been relied on the use of synthetic insecticides but has been ineffective due to the cryptic nature of the attack, disruption of environment and unaffordability to purchase insecticides by small- scale farmers. The attempts to control insects have changed over time from chemicals to natural control methods. Among the various natural control methods, biopesticides and botanical extracts have received considerable

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attention as a viable alternative to chemical pesticides. This study was therefore aimed at evaluating the efficacy of fungi based biopesticides and botanical extracts in controlling rice stem borers in screen house under artificial infestation and in laboratory test condition at the Sokoine University of Agriculture, Morogoro, Tanzania between March 2017 and January 2018. The experiment was laid out in a randomised complete block design for screen house trial and a completely randomised design for laboratory trial. All the treatments in all two trials were replicated four times. The two trials involved six treatments which includes two commercial biopesticides (*Beauveria bassiana* and *Metarhizium anisopliae*), two botanical extracts (*Neorautanenia mitis* and *Derris elliptica*), and one synthetic insecticide (Amekan 344EC) which was the mixture of (Cypermethrin (144 g/L) + Imidacloprid (200 g/L)) and untreated control. The results showed a significant influence of biopesticides and botanical extract in reduction *Chillo partellus* damage incidences, increased mortality and increased rice grain yield (p < 0.01). Both biopesticides and botanical extracts reduced damage incidences from 45% - 64.28% dead heart, 42.01% - 76.19% whitehead and decreased yield loss from 60.01% - 19.7 % caused by *C. partellus*. Grain yield of treated samples (4.837 – 6.387 t/ha) with the stem borer mortality rate of 57.51% - 78.12% were higher than 0 - 2.837t/ha from untreated control plots. The control measures used has shown a great influence on grain yield due to a reduction of damage incidences and increased *C. partellus* mortality. The study, therefore, indicated the possibility of controlling rice stem borers using fungi based biopesticides and botanical extracts.

Keywords: Botanical extracts; damage incidences; fungi based biopesticides; management; stem borer and yield loss.

1. INTRODUCTION

Rice (*Oryza sativa* L), one of the major cereal crops in the world is attacked by various insect pests where lepidopteran stem borers have been reported as the most harmful [1]. About 21 lepidopterans, stem borers have been reported as an economically important insect pest of cultivated grasses in Africa including 12 crambids, 7 noctuids and 2 pyralids in which 7 of them are pests of rice [2]. Rice stem borers in Africa were primarily reported in West Africa in 1984 where rice crop was cultivated as an important food crop. In these area four stem borers were reported, they include African white borer (*Maliarpha separatella* Ragot (Lepidoptera: Pyralidae), African yellow stem borers (*Scirpophaga* spp. (Lepidoptera: Pyralidae), African striped stem borers (*Chilo* spp. (Lepidoptera: Pyralidae) and pink stem borers (*Sesamia* spp. (Lepidoptera: Noctuidae). These all are of African origin except for *M. separatella* which originated in Asia [3].

In East Africa, at least one species of each genus have been reported. *M. seperatella*, *S. calamistis* and *Chilo partellus* Swinhoe in Tanzania [4-5], *C. partellus, M. separatella and S. calamistis* in Kenya [6, 7]) and *Chilo* spp in Uganda [8]. Yield losses due to stem borers are attributed to their progressive feeding at larvae stage, which had a tunnelling effect in a stem. When larvae enter the stem, it causes several destructions including damage on growing point, early leaf senescence, interference with metabolite and nutrient translocation which results to stunting of the plant, stem breakage, lodging, grain deformity and ultimately yield loss [9,2]. Different loss estimates are expected concerning crop type, a country where the crop is cultivated and stem borer species. Estimated yield losses due to *C. partellus* in Sorghum crop exceed 50% and 70% in Maize in Zimbabwe [10]. In Tanzania, Maize grain yield loss due to *C. partellus* of up to 53% has been reported [11]. For rice crop, grain yield loss of up to 54% due to African striped borer has been reported in Nigeria [12] and up to 100% due to yellow stem borers have been reported in Kenya, a neighbouring country with the same climatic condition like Tanzania [13].

Management of stem borers has been relied on the use of synthetic insecticides but has been an ineffective technique due to the cryptic nature of stem borer attack, disruption of environment and unaffordability to purchase insecticides by small-scale farmers [14-15]. The attempts to control insects have changed over time from chemicals to natural control methods [16]. Among the various natural control methods, biopesticides [17] and botanical extracts [18] have received considerable attention as a viable alternative to chemical pesticides. When these natural methods are used in place of conventional insecticides they can minimise environmental pollution, preserve non-target organisms such as natural enemies and delay insecticide- induced pest resistance [14].

The study by [19] reported a mass reduction of stem borers and rice folders in their laboratory experiment using biopesticide based products like fungus *Metarhizium anisopliae* and bacteria *Bacillus thuringiensis* (Bt). Also, Teshome and Tefera [17] have reported *M. anisopliae* (PPRC-2, PPRC-14 and PPRC-51), and *Beauveria bassiana* (PPRC-GG and PPRC-HH) isolates as the most virulent biopesticides causing 84.4% to 98.3% mortality to maize weevil (*Sitophilus zeamais)* when tested in the laboratory. Further, the study by Tefera and Pringle [20] testifies the suppression of foliar damage, reduction of stem tunnelling and dead heart when the conidial suspension of *M. anisopliae* and *B. bassiana* isolates was sprayed onto 3 to 4-week-old maize plants infested with *C. partellus* larvae in the screen house. The use of biopesticides will benefit rice farmers; nevertheless, the efficacy of *M. anisopliae* and *B. bassiana* for rice stem borer control has not been reported.

The use of botanical extracts in the management of insect pests as an alternative to synthetic insecticides have been reported in crop protection for many centuries [21], but their potentials have not been fully evaluated. Some popular botanical extracts such as neem plant (*Azadirachta indica*), garlic (*Allium sativum*) and ginger (*Zingiber officinale*) have been used in the management of post-flowering insect pests in Nigeria [22]. Neem oil from neem plant has been reported by Islam et al. [23] as potential control measures against yellow stem borer damages in rice crop. On the other hand, Mulungu et al. [24] have reported the potential of *Neorautanenia mitis* in controlling bean bruchid (*Zabrotes subfasciatus* Boh) whereas Muro [25] has reported an increase in mortality of melon fly (*Bactocera cucurbitae* concuillet) when using *Derris elliptica* extracts. The potential of these effective botanicals in controlling the rice stem borers has not been reported. The current study reports on the efficacy of two commercial fungi based biopesticides (*M. anisopliae* and *B. bassiana*) and twobotanical water extracts (*N. mitis* and *D. elliptica*) in the control of rice stem borer.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

The study was conducted in screen house under artificial infestation and in the laboratory at the Sokoine University of Agriculture in Morogoro region located at Latitudes 6^{0}56'S, Longitudes 35^{0}37'E and Altitude of 525 m.a.s.l. from March to December 2017.

2.2 Evaluation of Fungi Based Biopesticide and Botanical Extracts against *Chilo partellus* in Screen House

2.2.1 Rice planting

The rice variety TXD 306 (a low land variety which is commonly grown by many farmers and susceptible to stem borers) was used. The treatment plots size was 4 m^2 (2 m x 2 m). Dibbling of seeds was done at 2 seeds per hole and later thinned to one seedling per hill at 14 days after planting. All necessary field management practice such as weeding and application of fertiliser were done as required. Fertilisers with nitrogen (N) in form of UREA, Phosphoras (P) in form of Triple supper phosphate and Potassium (K) in form of Muriate of potash (MOP) were applied at the rate of 80:40:40 as described by Mghase et al. [26].

2.2.2 Treatments

The experiment involved four treatments and two controls. The treatments include: two commercial biopesticides (*Beauveria bassiana* (Bals.) Vuill and *Metarhizium anisopliae* (Metsch.) Sorok), obtained from the Real IPM company (Arusha), and two botanicals (*Neorautanenia mitis* (A. Rich.) Verdc.*)* collected from Makambako and *Derris elliptica* (Wall.) Benth.collected from Handen Tanga Tanzania. The synthetic insecticide (Amekan 344EC) which was a mixture of (Cypermethrin (144 g/L + Imidacloprid 200 g/L) purchased from the local agro-vet shop in Morogoro, Tanzania, used as a positive control (treated control). Rice plot which received neither the biopesticides, botanical extracts nor insecticide served as untreated control (negative control). The experiment was laid out in a randomised complete block design (RCBD) with four replications.

2.2.3 Preparation of botanical extracts

Fresh roots of *D. elliptica* and *N. mitis* were washed with running tap water to remove soil materials, and rinsed with sterile distilled water (SDW) for three times. Samples were then chopped into small pieces and placed on benches at room temperature and allowed to dry for 3 to 4 weeks [27]. The dried materials of each plant species were made into powder separately using grinding machine at the Animal Science Department laboratory of the Sokoine University of Agriculture, then sieved with 1 mm sieve. The plant powder material was then packed separately in waterproof plastic bags well labelled and stored at 4°C until used [28]. Crude plant extracts were obtained by infusing 50 g of plant material in 100 ml sterile distilled water (SDW) to give 50% w/v in a 500 ml conical flask and the mixture was kept at 25°C-28°C for 20 hours [29]. The infusion was then filtered separately through sterile double-layered cheesecloth into a sterile 400 ml beaker and the resulting stock solution was ready for use [29]. A solution of bar soap obtained by dissolving 50 g in 250 ml of distilled water was also prepared to be used as sticker [30]. The solutions were used within the same day to avoid degradation of chemical ingredients.

2.2.4 Preparation of biopesticides and synthetic insecticide

The commercial biopesticides and synthetic insecticide were prepared following manufacturers recommendation shown on the label. The recommendation rates for *M. anisopliae* and *B. bassiana* was 1 ml/L whereas that of synthetic insecticide (Amekan 344EC) was 0.25 ml/L. These were prepared and used the same day of preparation.

2.2.5 Infestation of rice in screen house

Egg mass of *C. Partellus* was collected from insectary unit of the International Centre of Insect Physiology and Ecology (ICIPE), Kenya. The eggs masses were them placed in plastic containers with perforated lids at the top, lined with moist tissue paper inside and incubated at 28°C temperature at the Sokoine University Laboratory for two days to allow hatching prior seedling infestation. Using camel hair brush, each individual plant seedling of about 21 days old were infested with 10 neonate larvae of *C. partellus.* Infestation of plants was repeated 35 days after planting (2 weeks after the first infestation) to ensure sufficient damages to all treatments. Infested plants were left for about 3 days prior spraying to allow the insects to settle to natural condition [31].

2.2.6 Treatment application

Each botanical extracts (*N. mitis* and *D. elliptica*) were applied at the rate of 20 ml/L which includes 10 ml of crude plant extract and 10ml of sticker material (bar soap solution). The dosage was chosen based on [32-33] reports on the preparation of botanicals extracts for insect pest control. The two biopesticides (*M. anisopliae* and *B. bassiana* were applied at the rate of 1 ml/l and that of synthetic insecticide at the rate of 0.25 ml/l which were both according to the recommendations on label as per the manufacturers.

A hand sprayer of about 2 L in volume was used. Sprayer calibration was done to determine the amount of solution required to cover the treatment area by filling the sprayer with water and spray an area of 2 m × 2 m which was equivalent to the treatment area. The amount of water required to cover the entire treatment area was measured and the time was recorded. About 0.5 L was enough to cover the entire treatment area. This amount of spray (0.5 L) was again retested to the same area to find out the amount of spray which remains in the sprayer after spraying. The remaining amount was measured and added as additional to 0.5L of each treatment during application. The nozzle was adjusted accordingly to avoid wastage of chemicals. Spraying was done thrice (3, 21 and 42 days after infestation) to the respective treatment plots except for untreated control which was sprayed with water and sticker solution only. Spraying was done by targeting on runoff points of the leaves.

2.2.7 Data collection and analysis

Data for growth parameters (plant height and the number of tillers per hill for both infested and un-infested) was taken during the mid-grain filling stage of the rice crop in a 1 m^2 area sampled in every treatment plot. Plant height was measured as the distance from the soil level to the base of the flag leaf using a ruler. At harvest, a number of panicles and number of whiteheads were counted. Harvesting was done in every treatment plots from 1m^2 sampled areas for infested hills and un-infested hills separately for easy estimation of yield losses. Grain yield (t/ha) was calculated based on the harvested unit area at 14% moisture content.

The incidence was calculated using formula as described by Suresh et al. [34] as follows;

$$\text{Stem borer incidence \%} = \frac{\text{Number of dead hearts or white heads}}{\text{Total number of productive tillers}} \text{X100}$$

Percentage increase or reduction in damage incidences were calculated using the formula;

$$I = \frac{A - B}{A} X100$$

Where; I = percentage increase or decrease of the damage incidence, A = Incidence of the control treatment and B = Incidence of individual treatment.

The yield losses were also estimated using the method of Rahman et al. [35];

$$L = \frac{YP - Yo}{YP} X100$$

Where; L = percentage yield loss due to borer, YP = Yield per m^2 based solely on un-infested plants in the sampling area and Yo = Yield per m^2 based on both infested and non-infested plants in the sampling area. Percentage data were tested for normality and found not normally distributed and therefore arcsine transformed prior to analysis.

The collected data were subjected to R statistical software for analysis. Significant differences among means were separated using the Student Newman Keuls (SNK) at $p \leq 0.05$ level of significance. The analysis model was according to Gomez and Gomez [36] for RCBD i.e yij = μ +Ti + βj + Eij; where Yij = Response, μ= mean, Ti is the i^{th} treatment effect, βj is the j^{th} block effect, and Eij is the random error of the observation. Regression analyses were performed using Microsoft Excel to see the relationship between damage incidences and rice grain yield.

The daily temperature and relative humidity (RH) in the screen house were recorded throughout the experimental period. The recorded mean temperature and RH was ranged from 20°C–31°C and 60% respectively. The Temperature and RH were suitable for fungal and insect growth and disease development [37].

2.3 Effectiveness of Fungi Based Biopesticides and Botanical Extracts against *C. partellus* in Rice

2.3.1 Insect colony

Egg mass of *C. partellus* initially collected from insectary unit of the International Centre of Insect Physiology and Ecology (ICIPE) were placed in plastic containers with perforated lids at the top, lined with moist tissue paper inside and incubated at 28°C temperature at the Sokoine University Laboratory for two days to allow hatching. The first instar larvae were then reared on an artificial diet according to Tefera et al. [38]. The composition of the diet was, common bean powder 650 g, brewer's yeast 43 g, glucose 50 g, methyl paraben 8.5 g, ascorbic acid 11 g, sorbic acid 6 g, 3000 ml distilled water, 57 g of agar technology and 12.5 ml of formaldehyde. About 500 larvae were maintained on 250 g diet in a plastic bottle (5 cm x 11 cm). The plastic bottles containing the larvae in diet were then covered with perforated lids at the top and placed on benches at the Sokoine University of Agriculture, Entomology Laboratory at room temperature for larvae to grow. The newly moulted third instar larvae were fed with pieces of rice stem for 3 days before infestation, so that they become used to the natural conditions [31].

2.3.2 Bioassays

An experiment was conducted in Entomology laboratory at the Sokoine University of Agriculture aimed at evaluating the effectiveness of two commercial fungi based biopesticides *(M. anisopliae and B. bassiana*), two botanical extracts (*N. mitis* and *D. elliptica*), one synthetic insecticide, Amekan 344 EC (mixture of Cypermethrin (40 g/l) + immidacloprid (200 g/l)) which served as treated control and one as untreated control. Thirty third-instar *C. partellus* larvae were placed in 9 cm diameter Petri dishes. The larvae were treated with 3ml of each treatment using laboratory spray tower. The larvae in untreated controls were sprayed with 3mil of distilled water which contains neither the biopesticides or botanical extracts nor the insecticide. Petri dishes containing treated and control insects were sealed with masking tape and incubated at 25°C ± 1°C. All treatments and their controls were replicated four times arranged in a completely randomised design. The treated insects and controls were provided with pieces of rice stem daily after frass and debris had been removed. The whole experiment was repeated in 7 batches. The mortality was recorded every day for 7 days in such a way that every batch is recorded and discarded once every day for every treatment. Mortality data were corrected for control mortality according to Abbott [39] as follows;

$$\text{Corrected mortality }\% = \left(1 - \frac{\text{n in T after treatment}}{\text{n in CO after treatment}}\right)*100$$

Where: n = insect population, T = treatment, CO = control

3. RESULTS

Table 1 summarises the ANOVA results for the effect of rice stem bores on rice yield and yielding components when treated with and without fungi based biopesticides and botanical extracts. Fungi based biopesticides and botanical extracts applications differed significantly ($p < .001$) in all measured variables except on the number of tillers and a thousand seed weight.

3.1 Effects of Fungi Based Biopesticides and Botanical Extracts on Rice Growth and Incidence of Rice Stem Borers

The effects of fungi based biopesticides and botanical extracts on the growth and incidence of rice stem borers in rice are summarised in Table 2. Biopesticides and botanical extracts application had a significant ($p < .01$) effect on plant height, dead heart (DH) and white head (WH) incidences. Plots with high pest incidences had shorter plant and reduced number of tillers. There was no significant difference in plant height on plots treated with Amekan 344EC and *M. anisopliae* ($p > .05$). These plots had taller plants than height measured in other treatments. Shorter plants were observed in plots treated with *D. elliptica* and untreated control.

The incidence of 20% DH observed in untreated control were significantly ($p < .001$) higher than 4 to 5% in other treatments. The percentage incidence of 17% WH was in untreated plots. The percentage was higher than 1 to 4% observed in plots treated with biopesticides, botanical extracts and Amekan 344EC. However, the efficacy of these treatments varied significantly. Application of Amekan 344EC and *M. anissopliae* were more effective in reducing the incidence of WH than the other (Table 3). The percentage reduction of dead heart and white head damage were respectively ranged from 45 - 64 and 42.01 -76.19.

3.2 Effect of Botanical Extracts and Fungi Based Biopesticides on Rice Yield and Yielding Components

The effects of treatments on rice yield and yielding component are respectively summarised in Fig. 1 and Table 4. Significant variation in panicles/m^2 and number of whiteheads/m^2 were observed among different treatments ($p < .001$) except for 1000 grain weight which was insignificant ($p = 0.165$). The number of panicles varied significantly ($p < .001$) among treatments (Table 4). Plots treated with Amekan 344EC and *M. anisopliae* had many panicles than the others. Except control, other plots had an average number of panicles that ranged from 137 to 158. These plots had a smaller number of white heads incidences than in untreated control.

Rice grain yield in botanical extracts, Amekan 344EC and fungi based biopesticides treated plots differed significantly ($p < .01$) (Fig. 1). Grain yield ranging from 4.837 – 6.387t/ha recorded in either botanical or fungi based biopesticides treated plots were higher than 2.837t/ha recorded in un-treated control plots. Yield potential was in the order of Amekan 344EC (t ha^{-1}) > *M. anisopliae* (t ha^{-1}) >*B. bassiana* (t h^{-1})> *N. mitis* (t ha^{-1})> *D. elliptica* >Control (t ha^{-1}).

3.3 Relationship between Damage Incidences, Grain Yield and 100 Grain Weight

Figs. 2 and 3 summarise the relationship between rice stem borer damage incidences, rice grain yield and 1000-grain weight in plots with and without control measures. Grain yield and 1000 seed weight had a significant negative relationship with stem borer damage incidences. Their negative association was confirmed by low grain yield and 1000 seed weight in plots with greater dead heart and whitehead incidences, which had a significant contribution on grain weight reduction.

3.4 Percentage Yield Loss Due to Stem Borer (*C. partellus*) on Rice Crop Treated with Different biopesticides and Botanical Extracts

There was a significant difference in yield loss due to *C. partellus* in plots treated with different fungi based biopesticides (*M. anisopliae* and *B. bassiana*) and botanical extracts (*N. mitis* and *D. elliptica*) as compared to their untreated control ($p < .001$) (Table 5). The yield loss due to *C. partelus* in fungi based biopesticides and botanical extracts ranged from 19.7%-32.23%. This was lower than 60% recorded from untreated control. Plots treated with *B. bassiana* recorded the lowest yield loss followed by *M. anisopliae, N. mitis* and *D. elliptica* incomparable with untreated control. The regression analysis shows a positive relationship between yield loss and stem borer damage. Increase in dead heart or whitehead damage incidences leads to an increase in yield loss (Fig. 4).

Table 1. Mean squares and significance tests of the effect of fungi based biopesticides and botanical extracts in rice stem bores management

Analysis of variance	DF	PH	NT	DHC	WHC	DH	WH	NP	NWH	GW	Yield Loss
Replications	3	3.053	8.84	13.41	3.05	1664.9	90.7	60.4	0.5584	0.57	57.86
Treatments	5	144.89**	7.83^{ns}	167.801**	144.89**	1432.70**	1879.70**	2274.80**	10.45**	0.51^{ns}	1713.68**
Error	15	3.429	7.585	6.671	3.429	178	157.4	276	0.3916	0.2747	33.53
Total	23										

Notes: DF=degrees of freedom; PH= plant height; NT= number of tillers;
DHC = deadheart incidences; WHC = whitehead incidences; DH = number of dead heart; WH= number of whitehead; NP=number of panicles;
NWH = number of whitehead; GW = 1000 grain weight and YL = yield losses.
***Significant difference at 0.01 probability level; and ns = non-significant difference at 0.05*

Table 2. Effectiveness of biopesticides and botanical extracts on growth parameters and damage caused by *C. partellus* in rice crop under artificial infestation in screen house

Treatment	Dosage	Plant height ±SE	No. of tillers±SE	DH incidence%±SE	WH incidence%±SE
Amekan 344EC		130 ± 1.87c	5 ± 1.2a	4±1.5a	1 ± 0.71a
M. anisopliae	1mil/L	125 ± 1.9bc	6 ± 1.2a	4±1.5a	1 ± 0.71a
B. bassiana	1mil/L	123 ± 1.9b	6 ± 1.2a	4±1.5a	3 ± 0.71ab
N. mitis	10mil/L	119 ± 1.9ab	7 ± 1.2a	5±1.5a	4 ± 0.71b
D. elliptica	10mil/L	118 ± 1.87a	6 ± 1.2a	4±1.5a	3 ± 0.71ab
Control (Untreated)		115 ± 1.87a	9 ± 1.2a	20±1.5b	17 ± 0.71c
P-value		<.001	0.434	0.003	<.001
C.V		1.5	11.3	22.1	14.1

SE= standard error, C. V.= Coeffient of variation, DH = dead heart, WH = white head. Means followed by the same letters are not significantly different (P > 0.05) using Student Newman Keuls (SNK).

Table 3. Effects of biopesticides and botanical extracts on dead heart and white head damages reduction caused by *Chilo partellus* on rice crop over the control

Treatment	Dosage	% <DHD ± SE	%<WHD ± SE
Amekan 344EC	0.25 mil/L	-64.28 ± 1.6a	-76.19 ± 3.89b
Metarhizium anisopliae	1 mil/L	-60.62 ± 1.6a	-70.70 ± 3.89b
Beauveria bassiana	1 mil/L	-61.86 ± 1.6a	-51.17 ± 3.89a
Neorautanenia mitis	10 mil/L	-53.14 ± 1.6a	-49.28 ± 3.89a
Derris elliptica	10 mil/L	-45.00 ± 1.6a	-42.01 ± 3.89a
Control (Untreated)		+100 ± 1.6b	+100 ± 3.89c
$F_{3,5}$		9.35	5.80
P-value		<.001	<.001
C.V		26	6

DHD = dead heart damage, WHD = Whitehead damage, SE= standard error and C. V= Coeffient of variation. % Reduction / increase of DHD or WHD were calculated using the Control mean data of Dead heart or White head as 100% incidence. Negative sign (-) indicates % of reduction while positive sign (+) indicates % of increase in dead heart or whitehead. Means followed by the same letters are not significantly different (p > 0.05) using Student Newman Keuls (SNK)

Table 4. Effects of biopesticides and botanical extracts on yield components of rice crop infested with *C. partellus*

Treatment	Dosage	Panicles/m^2	White heads/m^2	1000 grain weight(g)
Control (Untreated)	-	119 ± 3.2a	33.5 ± 0.305d	28.07 ± 0.308a
Deris elliptica	10 mil/L	137 ± 3.2ab	7.5 ± 0.305c	28.98 ± 0.308ab
Neorautanenia mitis	10 mil/L	153 ± 3.2bc	5.25 ± 0.305abc	28.63 ± 0.308a
Beauveria bassiana	1 mil/L	158 ± 3.217bc	5.75 ± 0.305bc	28.9 ± 0.308ab
Metarhizium anisopliae	1 mil/L	172.2 ± 3.217cd	2.75 ± 0.305ab	28.88 ± 0.308ab
Amekan 344EC	0.25 mil/L	184.5 ± 3.217d	7.5 ± 0.305a	29.63 ± 0.308b
Mean		153.6	11.5	25
$F_{3,5}$		8.24	26.67	1.84
P- value		< .001	< .001	0.165
C.V		2.1	11.5	12.4

SE = standard error, C. V.= Coeffient of variation. Means followed by the same letters are not significantly different (P>0.05) using Student Newman Keuls (SNK)

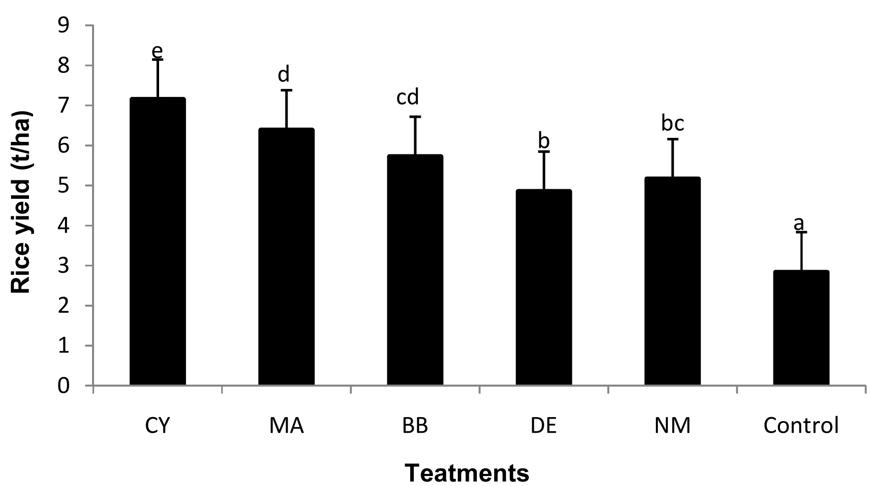

Fig. 1. Effects of treatments on rice grain yield

Cy = Synthetic insecticide (Amekan 344EC), MA = Metarhizium anisopliae, BB = Beauveria bassiana, DE = Derris elliptica, NM = Neorautanenia mitis. Error bars represent standard errors

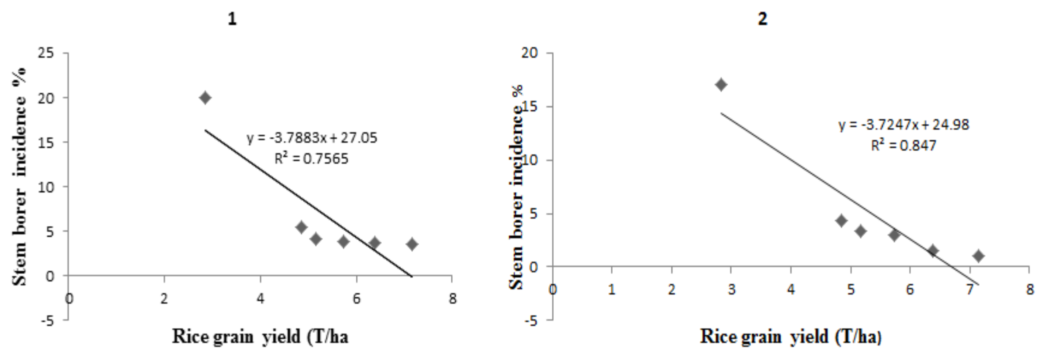

Fig. 2. Relationship between rice stem borer damage incidences, the Dead hearts (1) and white heads (2) and rice yield

The six- star dots represent six treatments (Amekan 344EC, D. elliptica, N. mitis, M. anisopliae, B. bassiana and control)

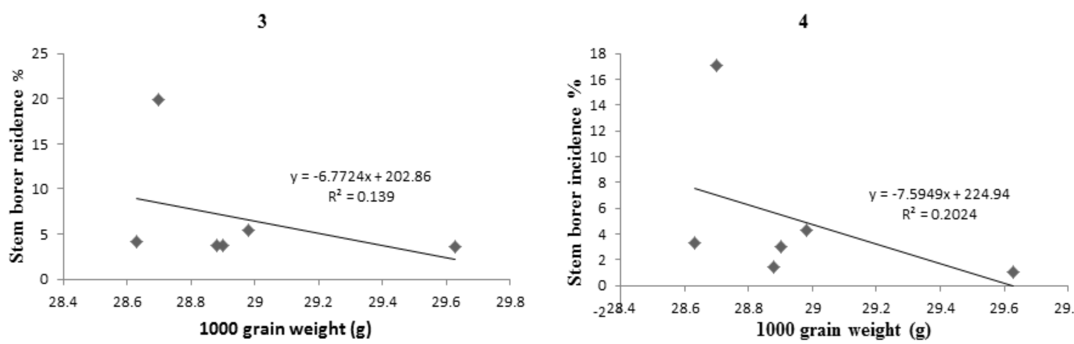

Fig. 3. Relationship between rice stem borer damage incidences, the Dead hearts (3) and white heads (4) and 1000 grain weight

The six- star dots represent six treatments (Amekan 344EC, D. elliptica, N. mitis, M. anisopliae, B. bassiana and control)

Table 5. Percentage yield loss due to *C. partellus* on rice crop treated with different biopesticides and botanical extracts

Treatment	Dosage	Yield loss % ± SE
Control (Untreated)		60.01 ± 3.11e
Deris elliptica	10 mil/L	32.23 ± 3.11d
Neorautanenia mitis	10 mil/L	27.58 ± 3.11cd
Beauveria bassiana	1 mil/L	19.7 ± 3.11c
Metarhizium anisopliae	1 mil/L	10.69 ± 3.11b
Amekan 344EC	0.25 mil/L	0 ± 3.11a
Mean		25
$F_{3,5}$		51.1
P-value		<.001
C.v		12.4

Yield loss was calculated based on the yield of synthetic pesticide Amekan 344EC (Cypermethrin+immidacloprid) which was a treated control. Means followed by the same letters are not significantly different ($P > 0.05$) using Student Newman Keuls (SNK).

3.5 Effects of Treatments on Stem Borer Mortality

There were significant differences in mean mortality ($F = 5.18$; $p < .01$) of stem borers (*C. partellus*) treated with different botanical extracts and fungi based biopesticides for 7 days (Table 6). The mortality rates of stem borer larvae ranged from 57.51%-78.12%. The highest mean mortality was recorded in *M. anisopliae* and *B. bassiana* followed by *N. mitis* and *D. elliptica* treated stem borer larvae which were closer to synthetic insecticide.

4. DISCUSSION

The findings of this study exhibited a clear effect of fungi based biopesticides (*M. anisopliae* and *B. bassiana*) and botanical extracts (*N. mitis* and *D. elliptica*) in the reduction of stem borer incidences as compared to their untreated control. This provides evidence for the potentiality of using these biopesticides and botanical extracts in controlling stem borers. Similar findings were reported by Chatterjee and Mondal [40] on the efficacy of fungi based biopesticides (*B. bassiana* and *B. thuringinensis)* and botanical extracts *(Azadirachta indica)* where rice yellow stem borer (*Scirpophaga incertulas* Walker*)* dead heart incidence was reduced by 57.3–62% using *M. anisopliae* and 3.48-4.44% by using *A. indica* extracts.

A significant influence of stem borer damage incidences to plant height and number of productive tillers per plant in different treatment indicated the variation in efficacy of these treatments in pest management. Reduction of plant height and number of tillers in treatments with higher infestations is attributed to the interference of this pest on both metabolic activity and physiology of the plant. The pest was found to feed on the inner part of the stem and affected nutrients uptake, water movement and thus the process of photosynthesis. The influence of stem borer infestations on the reduction of plant height is in line with the previous studies [41,42]. These studies reported plant height reduction due to *M. separatella* feeding at tillering stage of the rice crop. The number of tillers was observed to increase as stem borer infestation rates increased probably due to the ability of the rice crop of being able to compensate for the lost tillers at the early stages of stem borer infestation. This agrees with the studies by Van Den Berg et al. [43] and Sylvain [44], who stated that more stem borer attack can result into the formation of additional tillers. Further, the study by Kega et al. [13] suggested that enhancing plant compensation mechanism to stem borers damage may be a better approach for the management of stem borer than using insecticide.

Fungi based biopesticides (*M. anisopliae* and *B. bassiana*) and botanical extracts (*N. mitis* and *D. elliptica*) were found to possess a lethal effect that can be used to control rice stem borers. The comparable but significantly higher grain yield was produced by the treated than untreated control showing that fungi based biopesticides controlled rice stem borers as efficiently as chemical insecticides. The findings are consistent with the study by Chatterjee and Mondal [40] who reported an increase in rice yield using bio- rational insecticide like *M. anisopliae*, *B. thuringiensis* and *B. bassiana* in management of yellow stem borer *(Scirpophaga incertulas* Walker) as compared to untreated control and suggested it to be used as alternative to conventional synthetic organic insecticides by incorporating it in an integrated pest management programme.

Similarly, higher yield return recorded in plots treated with *N. mitis* and *D. elliptica* extracts indicated that plant extracts are also potential in managing stem borer problem remedy. Related findings on the potentiality of these botanical extracts used under this study are such as the study by Mulungu et al. [24] for bean bruchid (*Zabrotes subfascialatus*) control in stored common beans (*Phaseolus vulgaris* L.) using *N. mitis* and that of [25] for melon fly (*Bactocera cucurbitae* Coquillett) control in watermelons using extracts of *D. elliptica*. Botanicals may, therefore, include in an integrated pest management programmes for the management of stem borers in rice crop.

Low yield losses in plots treated with biopesticides, botanical extracts, and synthetic insecticide as compared to untreated control are in line with findings by Muralidharan and Pasalu [45] who reported high rice yield losses of up to 95% in treatments without any control measures as compared to protected plots. Similarly, the study by Way et al. [46] reported rice yield losses of 60% due to stem borers damage in the unprotected field in Texas. A positive relationship between yield loss and stem borer damage incidences was recorded under this study which is consistent with the findings of Sherawat et al. [47] who reported that rice yield losses were highly contributed by increased dead hearts and whiteheads. Further, the study by Krishanaiah [48] reported that for every per cent increase in whitehead incidence in rice crop leads to 1.3% grain yield loss.

Table 6. Effect of treatments on insect mortality

Treatments	Mortality rates (%) in different days ± SE							Mean ± SE
	Day 1	Day2	Day 3	DAY 4	Day 5	Day 6	Day 7	
CONTROL	0 ± 2.3a	0 ± 2.4a	0 ± 9.3a	0 ± 13.8a	0 ± 3.8a	0 ± 2.6a	0 ± 3.8a	0 ± 4a
D. elliptica	35 ± 2.3b	39 ± 2.4b	50.4 ± 9.32b	46 ± 13.8b	74 ± 3.8b	78 ± 2.6b	80 ± 3.8b	58 ± 4b
N. mitis	41 ± 23bc	45 ± 2.4b	60.41 ± 9.3bc	55 ± 13.8bc	86 ± 3.8c	94 ± 2.6c	95 ± 3.8c	68 ± 4c
B. bassiana	42 ± 2.3bc	53 ± 2.4c	68.33 ± 9.3c	70 ± 13.8cd	91 ± 3.8cd	95 ± 2.6c	100 ± 3.8c	74 ± 4cd
M. anisopliae	47 ± 2.3c	62 ± 2.4d	76.31 ± 9.3c	82 ± 13.8cd	97 ± 3.8d	100 ± 2.6c	100 ± 3.8c	78 ± 4d
Amekan 344EC	76 ± 2.3d	92 ± 2.4e	93.71 ± 9.3d	98 ± 13.8d	100 ± 3.8d	100 ± 2.6c	100 ± 3.8c	94 ± 4e
Mean	40.2	48.73	58.2	58.5	74.7	78.2	78.7	62.02
$F_{3,5}$	1.1	1.59	5.77	7.15	3.69	1.31	1.7	5.18
P-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
C.V	5.8	5	15.9	23.5	5.1	3.3	4.9	9.07

SE = standard error, C. V = Coeffient of variation. Means followed by the same letters are not significantly different (P>0.05) using Student Newman Keuls (SNK).

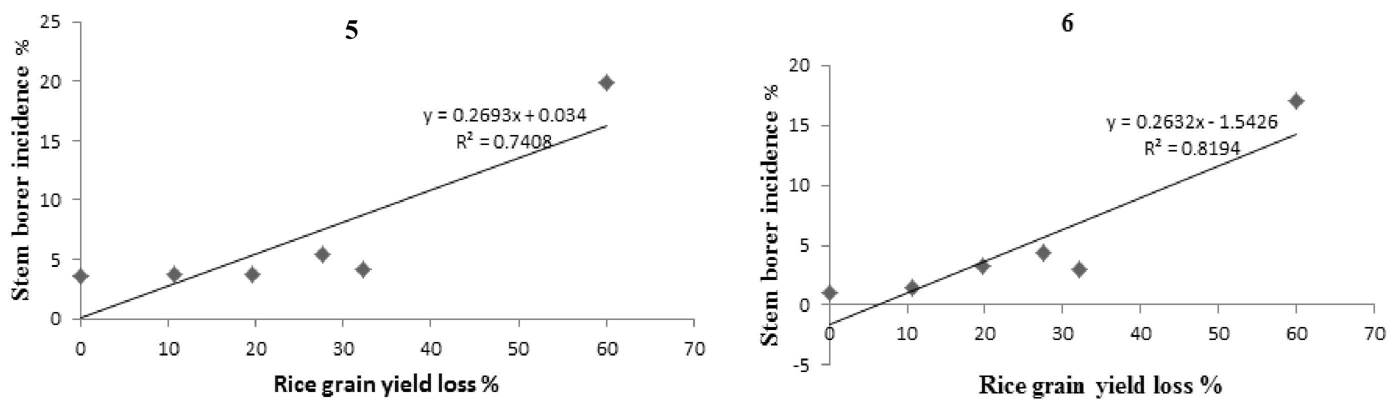

Fig. 4. Relationship between rice stem borer damage incidences, the Dead hearts (5) and white heads (6) and rice grain yield loss

The six- star dots represent six treatments (Amekan 344EC, D. elliptica, N. mitis, M. anisopliae, B. bassiana and Control).

The yield losses were due to an existence of negative correlation among grain yield and stem damage incidences. Stem damages occur when the larva tunnels the stem and makes internal feeding of the plant tissue where it interferes with soil nutrients and water uptake [49]. When this occurs during early stages of rice development, it results into drying of the central shoot (dead heart) which prevents panicle initiation and when occurs after panicle initiation, it can result into development of empty spikelets (white head) which consequently lead to grain yield disadvantage. The damage done by stem borers by tunnelling leads to a reduction of grain yield is parallel with the study by Singh et al. [50] who reported that loss of maize grain due to stem tunnelling was greater than losses incurred due to leaf feeding. Furthermore, the negative correlation of stem borer damage with yield and yield components is in line with studies by Kega et al. [13], Litsinger et al. [51], Asghar et al. [52] who describes grain yield to decreases with increasing stem borer infestation.

Findings of this study prove the efficacy of botanicals (*N. mitis and D. elliptica*) extracts in managing stem borer damages in rice. This protection can occur through repellent action of the extracts as insect ingests in attempting to feed on the crop leaves and for their larvae picking up the residues sprayed on leaves during spray or through foraging behaviour which ultimately suffer through feeding inhibition or high mortality, resulting in reduced crop damage [14]. Fungi based biopesticides have also been proved under this study as the potential remedy for rice stem borer control through reduction of stem borer damage incidence and high mortality of stem borer larvae. The fungi based biopesticides can affect the host as the insect cuticle comes in contact with the fungi during spray or during larvae movement. The fungi can then adhere to the host cuticle, germinates, form appressorium which penetrates to the insect body, colonise the haemolymph, extrudes and sporulates which finally lead to the death of the host [53]. High mortality rates of stem borer larvae were recorded in *B. bassiana* and *M. anisopliae* treated insects which were parallel with findings of Tefera [31], Terefe et al. [54] who respectively reported high mortality of *C. partellus* and *S. calamistis* larvae treated with natural isolates of *B. bassiana* and *M. anisopliae* under controlled conditions.

Generally, the present study reveal the potentiality of fungi based biopesticides (*M. anisopliae* and *B. bassiana*) and botanical extracts (*D. elliptica* and *N. mitis*) as natural insecticides in the control of rice stem borers as an alternative to synthetic insecticides. Rice grain yield increase in fungi based biopesticides and botanical extracts treated plots substantiates the potentiality of these natural insecticides. Stem borer infestations result in economic damage to rice crop in many African countries especially for small- scale farmers due to little knowledge on insecticide safety use and/or insecticides been very expensive. Therefore ideal stem borer control strategy that would suit the economy of rice cultivation at the smallholder sector level is the use of natural insecticides by including them in integrated rice stem borer management. Since the results from this study were obtained from the controlled environment, further studies under field conditions using the substances obtained from this study is important. This should be accompanied with studies on factors contributed to the production of more tillers in rice infested by stem borers.

5. CONCLUSIONS

The study was conducted to assess the efficacy of fungi based biopesticides (*M. anisopliae* and *B. bassiana*) and two botanicals (*D. elliptica* and *N. mitis*) in controlling rice stem borers. It was found that the use of biopesticides and botanicals were effective as chemical insecticides in controlling stem borer incidences. The highest grain yield and high stem borer mortality rates were recorded in plots treated with fungi based biopesticides and botanicals extracts indicating their potentiality in controlling rice stem borer. Future studies should rely on evaluating the active ingredients of the two botanicals used that can be made available to farmers. The availability of two biopesticides used or their relatives in natural habitats as potential for stem borer control should further be studied.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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