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Research Article

Assessment of Yield Loss Caused by the African White Rice Stem Borer (*Maliarpha separatella* Rag (Lepidoptera: Pyralidae) at Mwea Irrigation Scheme, Kirinyaga County, Kenya

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Abstract

Information on losses caused by the African white rice stem borer, *Maliarpha separatella* rag, which is an important rice pest in Kenya is scanty. The development and implementation of effective pest management strategies relies on accurately defined Economic Injury Levels (EIL) for that pest. Investigations were, therefore, conducted to determine yield losses caused by *M. separatella* and economic injury level of the pest. The experiment was conducted in an insect proof screen house at Kenya Agricultural and Livestock Research Organization, Mwea station. The experiment was arranged as a (2×6) factorial design and each treatment replicated three times. First factor was time of infestation at two levels, early and late which was 3 and 6 weeks after transplant date, respectively. Second factor was infestation rate at six levels (0, 1, 2 4, 6 and 8 egg masses). Results indicated that infestation levels of 1, 2, 4, 6 and 8 *M. separatella* egg masses at early infestation resulted in grain yield losses of 59.8, 83.2, 84.8 90.2 and 90.9%, while losses of same infestation levels at late infestation was 34.3, 52.1, 63.4, 81.8 and 80.8%. There was a strong positive relationship between yield loss and *M. separatella* population levels ($y = -214.29x + 1693.4$, $r^2 = 0.8416$). On the basis of cost benefit ratio, the economic injury level was 6 and 8 egg masses per square meter in the early and late infestation, respectively. The action threshold for early infestation was 4 egg masses and 6 egg masses for late infestation.

Key words: Rice, *Maliarpha separatella*, infestation, economic injury levels

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Five stem borer species have been reported as pests on rice in Kenya. These are stalk eyed fly borer, *Diopsis thoracica* (Dipera: Diopsidae), Rice gall midge (Diptera: Ceceidomyidae), *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae), *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) and African white heads stem borer, *Maliarpha separatella* Ragonot (Lepidoptera: Pyralidae), (*M. separatella)* being the most important. Major incidences of the *M. separatella* are usually severe in the late planted rice and ratooned crop (WARDA., 2006). The development and implementation of effective pest management strategies relies on accurately defined Economic Injury Levels (EIL) and Economic Thresholds (ET) for that pest (RKMP., 2011). Applying insecticides against Yellow Stem Borer has been recommended if there is one adult stem borer moth per square meter of rice plants in a rice field or 5% "Dead hearts" at vegetative stage and moth or 1 egg kg m^{-2} in the heading stage of the rice plant (Paul, 2007; RKMP., 2011).

Litsinger *et al*. (2006) reported that the most effective action threshold for yellow stem borer (*Scirpophaga incertulas* (Walker)) and white stem borer (*S. innotata* (Walker)) was deadhearts. The respective percentages for different rice growth stages were 5% for vegetative stage 25% in reproductive and 10% in the ripening stages. Ritchie and Hunt (2009) found economic threshold for *Scircopophaga incertulas* to be 2 egg masses per 20 hills up to panicle initiation stage and one egg mass thereafter. The objective of this study therefore, was to determine yield loss caused by *M. separatella* in Kenya and economic injury level and action thresholds for the pest.

MATERIALS AND METHODS

The study was carried out in an insect proof screen house at Kenya Agricultural and Livestock Research Organization, Mwea station, (37.36502 E, 0.62153 S, 1210 m asl). The centre experiences bimodal rainfall with the main rains occurring between March and May, while the short rains fall between October and December. Basmati 370 (Pishori) a popular rice variety at Mwea irrigation scheme was used. Experiments were conducted in different compartments in a large outdoor screen house of size 8 m×5 m×6 m. The screen house was enclosed with fine netting to exclude natural enemies and other pests. Rice was seeded on raised beds in one of the compartments in the screen house and transplanted in plastic pails with a rim diameter of 30 and 32 cm high. A single seedling was transplanted in each pail. Seven days after transplant date, thinning was done leaving 25 tillers per bucket. This was equivalent to number of rice plants per square meter in the field when spaced at 20 cm ×20 cm. The plants were artificially inoculated with 0, 1, 2, 4, 6 and 8 *M. separatella* egg masses. One egg batch has approximately 50 eggs and hatch to approximately 50 neonates. Inoculation was done at two infestation times, early and late, that is 3 and 6 weeks after transplant date (WAT). The experiment was arranged in a 2×6 factorial design and each treatment replicated three times. Each treatment was housed in a different compartment in the screen house.

The effect of *M. separatella* on yield was assessed by weighing rice grain yields from the different infestation levels at 3 and 6 WAT infestation times. Yield per pail was weighed and monetary loss under different *M. separatella* infestation rates and times determined. Weight obtained from each pail was converted into kilogram per hector.

Yield loss due to *M. separatella* per meter square was determined following the method used by Katwijukye and Kyamanywa (1998) in Eq. 1:

$$w\ (\%) = \frac{P - A}{P} \times 100 \tag{1}$$

where, w is the percentage yield loss, P is the potential yield (without loss due to *M. separatella*) i.e., *M. separatella* free plants or the control and A is the actual yield loss (yield of infested plants at different infestation rates).

Yield loss of the plants was used to calculate the slope of the graph that was used to estimate loss per *M. separatella* egg mass. Before calculating EIL, the net monetary loss or gain due to the different *M. separatella* infestation rates in different infestation periods was calculated. The monetary loss took into account the monetary value if insecticide control was used at the recommended rates. Economic Injury Level was derived from the decision criterion in partial budget analysis:

$$R\ (N) \geq C\ (N)$$

where, R was the return if *M. separatella* pest population (N) was managed and (C) was the management cost (Pedigo *et al*., 1986). The underlying assumption was that loss was directly proportional to *M. separatella* infestation, that is, loss was a linear function of *M. separatella* population (N) and the economic injury levels were determined according to procedure outlined by Pedigo *et al*. (1986) by using the following equation:

$$EIL = \frac{C}{VID} \quad (2)$$

where, C is the cost of management per unit of production and was measured as total costs of inputs and management in shillings (Kenya currency, 1 US$ is equivalent to 80 shillings), the average Central Bank of Kenya exchange rate for 3rd in the month of August 2011 (CBK., 2011), I is the injury units per insect per production unit measured as *M. separatella* white heads per hectare, V is the market value per unit of produce, that is the utility per unit of produce and was measured as shillings per kilogram which was KES50 or US$ 0.63 per kilogram at time of study and D is the damage per unit of injury which was measured as reduction in yield (kg ha^{-1}).

Data on stem tunneling, white heads, yield components, yield and monetary value was subjected to analysis of variance. Correlation and regression analyses were conducted to establish the relationship between grain yield and monetary value with *M. separatella* infestation. All analyses were done by use of GENSTAT Version 12 statistical software (GENSTAT., 2009). Least Significant Difference (LSD) at 5% confidence interval was used to separate the means that were significant.

RESULTS

The effect of *M. separatella* damage on rice was represented by white heads, stem tunneling and number of empty grains per spikelet. Percentage of white heads, tunneled tillers and number of empty grains per spikelet increased with increasing levels of infestation. White heads increased from 0% at 0 infestation rate to 28.4% at 400 neonates (8 egg masses) infestation for early infestation. Similarly for late infestation percentage white heads increased from 0% at zero infestation rates to 22.5% in the 400 neonate infestation rate. Highest percentage number of white heads was in 400 neonate infestation in early infestation and the lowest was at zero infestation rates in both infestation periods (Fig. 1).

Percentage tunneled tillers followed a similar trend with the lowest tunneled tillers at zero infestation rate in both the two infestation periods. The number of empty grains per spikelet increased with increasing infestation in both infestation periods. Highest increase was in late infestation with an increase from 2.3% at zero infestation to 40%. There was significant effect on percent tunneled tillers by the rate of infestation ($p<0.03$) but this was not significant on percentage of white heads. There were no significant differences in the number of percent tunneled tillers between plants infested with one egg mass and those with no infestation in the two infestation periods (Table 1).

Table 1: Percentage of tunneled tillers and number of empty grains per spikelet in different *M. separatella* infestation rates and infestation times

Infestation time	Infestation rate (egg masses)	Tunneled tillers (%)	No. of empty grains per spikelet
Early	8	16.70[a]	39.97
Late	8	12.30[ab]	39.35
Late	6	9.70[b]	11.49
Early	6	9.70[b]	12.81
Late	2	4.30[c]	9.34
Early	4	4.00[c]	11.93
Late	4	3.30[cd]	10.64
Early	1	3.20[cd]	7.12
Early	2	1.20[e]	7.91
Late	1	1.00[e]	5.68
Early	0	0.00[e]	2.31
Late	0	0.00[e]	3.64
p-value		0.03	0.16[ns]
SE		0.96	2.70

Mean in a column followed by the same letter are not significantly different by Fishers protected LSD ($p<0.05$), DT: Days after transplant date, ns: Non significant

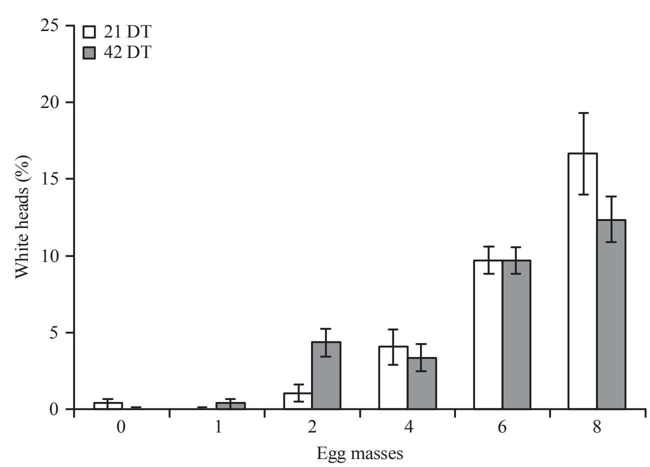

Fig. 1: Percentage of white heads in different egg mass infestation rates and 21 DT and 42 DT infestation periods

The pattern of change due to *M. separatella* infestation on rice yield and yield components namely, 1000 grains weight, number of filled grains per spikelet and number of productive panicles was similar to that described for damage characteristics. The productive tillers were 90 at zero infestation in early infestation (3 WAT) but increased to 100 at 1 egg mass infestation rate, possibly due to compensatory tillering. Number of filled grains decreased from 60 at 1 egg mass infestation to 2 in the 8 egg masses infestation rate.

Infestation by four egg masses at early infestation resulted in equal 1000 grain weight in plants infested late (6 WAT) with two egg masses. The weight of grains from plants infested with 8 egg masses in late infestation was not significantly different from the weight of those plants infested with 6 egg masses in early infestation period. Weight of 1000 grains dropped from 23.8 g at zero infestation to 19.1 in the 8 egg masses infestation rate at the early infestation period. The lowest 1000 grain weights occurred in late infested plants and the decrease was from 21.4 g at zero infestation to 19 g in the 8 egg masses infestation rate.

There were no differences in number of filled grains per spikelet and productive tillers in zero and one egg mass infestation rate in late infestation. Analysis of variance showed that treatments (number of egg masses) had significant effect on number of productive tillers (df = 5, 35, $p<0.05$), the number of filled grains per spikelet (df = 5, 35, $p<0.001$) and 1000 grain weight (df = 5, 35, $p<0.01$). There was also a significant effect by the period of infestation under different infestation rates on the number of productive tillers (df = 2, 35, $p<0.01$) (Table 2).

Overall *M. separatella* infestation levels had significant negative effects on grain yield and yield components. The number of white heads had a significant negative influence on yield, while number of productive panicles and 1000 grain weight had a significant positive influence. Number of empty grains had no significant effect on grain yield, but had a significant negative influence on 1000 grain weight (Table 3).

The effects of *M. separatella* infestation on rice grain yield and monetary value are presented in Table 4. In the early infestation, grain yield was significantly reduced from 2495 kg ha^{-1} in the un-infested plants to 1004, 418, 380, 245 and 227 kg ha^{-1} where 1, 2, 4, 6 and 8 *M. separatella* egg masses had been introduced, respectively. This corresponded with 59.8, 83.2, 84.8, 90.2 and 90.9% reductions in yield. For

Table 2: Grain weight, filled grains per spikelet and number of productive panicles per square meter in different *M. separatella* infestation rates and periods

Infestation period	Infestation rate (egg masses)	1000 grain weight (g)	Mean No. of filled grains per spikelet	Mean No. of productive tillers
3 WAT (early)	0	23.8[a]	59.70[a]	90.0[ab]
6 WAT (late)	0	23.5[a]	10.30[b]	81.0[abc]
6 WAT (late)	1	21.4[b]	10.00[b]	77.3[abc]
3 WAT (early)	1	21.4[b]	9.00[bc]	100.0[a]
6 WAT (late)	2	21.3[bc]	8.67[bc]	43.3[cd]
3 WAT (early)	4	21.1[bc]	6.33[cd]	84.7[ab]
6 WAT (late)	4	20.9[cd]	5.33[d]	62.7[abc]
3 WAT (early)	2	20.4[de]	5.33[d]	64.7[abc]
6 WAT (late)	6	20.2[e]	5.00[de]	75.7[abc]
3 WAT (early)	6	20.0[e]	4.0[def]	52.7[bcd]
6 WAT (late)	8	19.1[f]	2.33[f]	59.3[abc]
3 WAT (early)	8	19.1[f]	2.00[f]	14.7[d]
p-value		0.01	0.001	0.05
LSD		0.48	2.68	40.80

Mean in a column followed by the same letter are not significantly different from each other by Fishers protected LSD ($p<0.05$), WAT: Weeks after transplant date

Table 3: Correlations between white heads, yield components and grain yield

Correlations parameters	No. of white heads	1000 grains weight (g)	No. of productive panicles	No. of empty grains	Grain yield (kg ha^{-1})
Number of white heads	1				
1000 grains weight	0.-324 (0.099)	1			
No. of productive panicles	-0.270 (0.173)	0.253 (0.202)	1		
No. of empty grains	0.216 (0.280)	0.402* (0.038)	-0.181 (0.367)	1	
Grain yield	-0.280 (0.157)	0.302 (0.126)	0.998** (0.00)	-0.176 (0.379)	1

N = 36, significance level is indicated in brackets, *,**Correlation is significant at 5 and 1% level, respectively

Table 4: Grain yield and net value loss in different infestation rates and periods

Infestation period	Infestation rate (egg masses)	Grain yield (kg ha^{-1})	Net value (KES)	Reduction in grain yield (kg ha^{-1})	Yield (%) (reduction ha^{-1})	Net loss (KES ha^{-1})
3WAT (Early)	0	2495.00^{a}	124750.00^{a}	0.00^{a}	0.0	0.0
6 WAT (Late)	0	2072.00^{b}	103600.00^{b}	0.00^{a}	0.0	0.0
6 WAT (Late)	1	1361.00^{bc}	68050.00^{c}	711.00^{b}	34.3	35550.0
3 WAT (Early)	1	1004.00^{cd}	50200.00^{c}	1491.00^{bc}	59.8	74550.0
6 WAT (Late)	2	993.00^{cd}	49650.00^{d}	1079.00^{cd}	52.1	53950.0
6 WAT (Late)	4	758.00^{d}	37900.00^{e}	1314.00^{de}	63.4	65700.0
6 WAT (Late)	6	377.00^{e}	18850.00^{ef}	1695.00^{e}	81.8	84750.0
6 WAT (Late)	8	398.00^{e}	19900.00^{f}	1674.00^{f}	80.8	83700.0
3 WAT (Early)	2	418.00^{e}	20900.00^{f}	2077.00^{g}	83.2	103850.0
3 WAT (Early)	4	380.00^{e}	19000.00^{f}	2115.00^{g}	84.8	105750.0
3 WAT (Early)	6	245.00^{e}	12250.00^{f}	2250.00^{g}	90.2	112500.0
3 WAT (Early)	8	227.00^{e}	11350.00^{f}	2268.00^{g}	90.9	113400.0
p-value		0.01	0.01	0.01		
LSD		254.00	12.700	488.60		

Mean in a column followed by the same letter are not significantly different by Fishers LSD ($p<0.05$), WAT: Weeks after transplant date

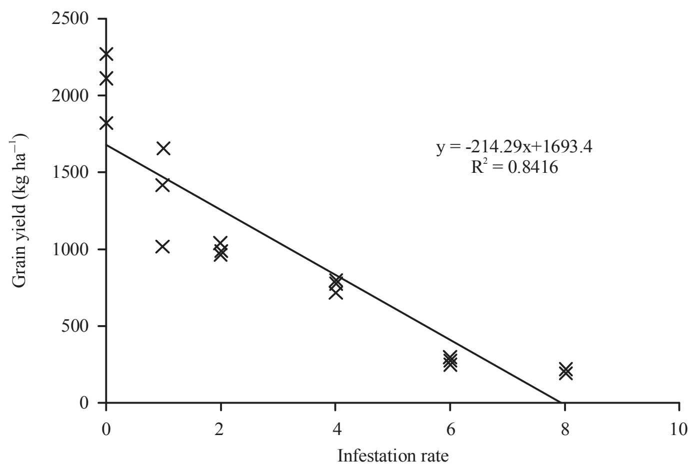

Fig. 2: Influence of *M. separatella* infestation rates on grain yield

the late infestation, yield was reduced from 2072 in the control with un-infested plants to 1361, 993, 758, 377 and 398 at 1, 2, 4, 6 and 8 *M. separatella* infestation rates and this corresponded to 34.3, 52.1, 63.4, 81.8 and 80.8% yield reductions.

Reduction in monetary value followed similar trend with no loss at zero infestation rate at the two infestation periods. The highest loss in net value was where the plants were infested with 8 egg masses in the early infestation (Table 4).

Data on grain yield at different infestation rates was used to calculate a regression in following equation:

$$y = -214.29x+1693.4, r^2 = 0.8416$$

where, y was the weight of paddy rice and x was the infestation level in number of egg masses. This described the overall relationship between yield and *M. separatella* infestation levels. There was a significant strong negative relationship between infestation levels and grain yield at different infestation levels. The linear relationship indicated that relatively high yield loss, up to 100% at infestation level of 8 egg masses was possible (Fig. 2).

Economic losses: The losses associated with different *M. separatella* population levels at different infestation times are presented in Table 5. The monetary loss increased with increasing *M. separatella* densities. The EIL derived from the current price of Basmati 370 variety rice and the current cost of chemicals was found to be 5.72 or approximately 6 and 7.80 or approximately 8 egg masses per 25 tillers for 3 and 6 WAT infestation times, respectively. Consequently the action thresholds is 4 and 6 egg masses per 25 tillers for 3 and 6 WAT, respectively.

Table 5: Monetary net loss of Basmati 370 rice caused by *Maliarpha separatella* infestation and economic injury levels

Time of infestation	Parameter	*M. separatella* infestation level in number of egg masses per twenty five tillers					
		0	1	2	4	6	8
3 WAT (Early)	Grain yield	2.495	1.004	418	380	245	227
3 WAT	Reduction in grain yield	0	1.491	2.077	2.115	2.250	2.268
3 WAT	Yield (%) reduction	0	59.8	83.2	84.3	90.5	90.9
3 WAT	Net revenue loss (KES ha^{-1})	0	40.666	103.850	105.750	112.500	113.400
3 WAT	Average loss per *M. separatella* egg batch				283.5 kg ha^{-1}		
6 WAT (Late)	Grain yield	2.072	1.361	993	758	377	398
6 WAT	Reduction in grain yield	0	711	1.079	1.314	1.695	1.674
6 WAT	Yield (%) reduction	0	34.3	52.1	63.4	81.8	80.8
6 WAT	Net revenue loss (KES ha^{-1})	0	35.550	53.950	65.700	84.750	83.700
6 WAT	Average loss per *M. separatella* egg batch	0			209.3 kg ha^{-1}		
	Type of cost	Labour					1.000
	Sprayer and depreciation						8.000
	Insecticide						1200
	Total (KES)						10.200
	EIL (21 DT)	5.72 or 6 egg masses/25 tillers					
	EIL (42 DT)	7.80 or 8 egg masses/25 tillers					

1KES: 0.0125USD (Central Bank of Kenya rates of 25th August, 2011)

DISCUSSION

The findings that number of productive tillers increased at low infestation levels in the early infestation period are in agreement with findings by Asghar *et al.* (2009) who found a corresponding increase in number of productive tillers at 1% white head infestation, but this was not evident at the late infestation period. This could be attributed to the fact, that the rice plant is able to compensate for low levels of stem borer attack, that occur during the early stages of the plant growth stage, by producing more tillers. It has been suggested that enhancing plant compensating mechanism to stem borer injury may be a better strategy for stem borer management compared with insecticide application (Asghar *et al.*, 2009). The results of two egg masses at early infestation periods causing an equal loss of productive tillers with 8 egg masses at late infestation are in agreement with Litsinger *et al.* (2011) who reported that compensatory tillering of the rice plant was low at high infestation rates in the late stages of the rice plant growth stage. The result of high grain yield at early infestation was suggestive of compensatory tillering and enhancement of the yield components by the rice plants, when infested young.

This is in agreement with Asghar *et al.* (2009) who reported an increase of grain yield at 1% white head infestation at the early stage of the rice plant growth. The decrease in the number of white heads as the rice plant aged into the reproductive and ripening phases is consistent with findings of Bandong and Litsinger (2005) which indicated that rice is resistant to stem borer damage when very young, at mid-growth and after panicle initiation, but is more susceptible at booting stage. They reported that during booting the stems swell and leaf husks loosen making it easy for stem borer neonates to gain entry into the rice plant. The number of filled grains per spikelet and 1000 grain weight were affected significantly in a negative way by increasing infestation levels. This effect may be attributed to the fact *M. separatella* damage disrupts translocation of nutrients to the growing floral parts as reported by Asghar *et al.* (2009).

The grain yield decrease with increase in infestation levels across the infestation periods is consistent with findings by Litsinger *et al.* (2011), Asghar *et al.* (2009) and Afzal *et al.* (2002), of negative correlation between grain yield and infestation levels. However there was a huge magnitude of losses and this is supported by reports that stem borers cause heavy losses. Grain yield losses of 3-95% due to Yellow Stem Borer (YSB) damage have been reported in India.

In Ganado, Texas rice yield losses of up to 60% were reported in untreated fields (Way *et al.*, 2006). The results of negative correlation of *M. separatella* damage with yield and yield components in this study was expected and is consistent with several reports from other authors (Litsinger *et al.*, 2006, 2011; Asghar *et al.*, 2009; Sherawat *et al.*, 2007) which indicate that grain yield decreases with increasing stem borer infestations.

The economic threshold of 4 egg masses/25 hills at early infestation in this study is consistent with recommendations by RKMP (2011) of applying insecticides against stem borers if there is one adult stem borer moth/25 hills per square meter of rice plants in a rice field. These results are also in agreement with findings of Muralidharan and Pasalu (2006) that one white head can cause 4.0% yield loss. Ritchie and Hunt (2009) found economic threshold for *Scircopophaga incertulas* to be 2 egg masses/20 hills up to panicle initiation stage and one egg mass thereafter. They recommended that egg masses be counted on 20 random hills along the diagonal of the field. When the threshold is reached the egg masses need to be collected and reared in vials or jars. If more parasitoids emerge than *S. incertulas* larvae there is no need to apply insecticides. However if the larvae are more numerous than the parasitoids then insecticides need to be applied. It has also been reported that *M. separatella* does not attack young leaves on tillers in the nursery and that adult moths oviposit eggs on mature leaves approximately 3 weeks after transplanting (Nwilene *et al*., 2008).

Results of this study suggest that pest monitoring of *M. separatella* by routine scouting for egg masses before 3 WAT equivalent to maximum tillering would aid in initiating insecticide control measures early enough. Further scouting up to 6 WAT will help in making decisions to spray against subsequent infestations at booting stage. Insecticides should be applied if 4 egg masses/25 tillers at 3 WAT (early infestation) are seen and a subsequent application if 6 egg masses/25 tillers is seen at 6 WAT (late infestation) for Basmati 370 variety at Mwea.

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