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Infestation and Parasitism of Banana Skipper (*Erionota thrax*) (Lepidoptera: Hesperiidae) in Relation to Banana Leaf Age, and Surface and Distance from Field Edge

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ABSTRACT

Studies were carried out in a commercial plantation of Cavendish bananas and a local variety Pisang Mas in Malaysia. The numbers of *Erionota thrax* life stages and those parasitized were quantified in relation to banana leaf age, leaf surface and distance from field edge. Irrespective of the observation period (low or high density), a significantly higher mean number of eggs and younger instar larvae were found on older leaves while highest mean numbers of older instar larvae were recorded on younger leaves only during the low-density period. Generally, parasitism of eggs was relatively higher on older leaves while that of larvae and pupae was higher on younger leaves. For both Pisang Mas and Cavendish, mean number of egg batches and individual eggs were significantly more on lower than on upper leaf surfaces. With the exception of mean number and percent parasitism of pupae, infestation and parasitism of eggs and larvae were not significantly different between interiors (50 and 100 m) and perimeters (10 m) of the field.

Keywords: banana, pest, parasitoid, within-field and plant distribution

INTRODUCTION

Musa species are very important to many people in Southeast Asia, the native area of the banana skipper (*Erionota thrax*). In these areas, although damage resulting from the larvae of this pest is usually below economic damaging levels, high populations have been recorded during the rainy seasons and even situations of 100% defoliation have been reported in some farms (Ashari and Eveleen 1974; Ahmad and Balasubramanian 1975; Abdullah *et al*. 1990; Khoo *et al*. 1990; Okolle *et al*. 2006a). Even though there are many reports on the use of classical insecticides (Waterhouse and Norris 1989; Waterhouse *et al*. 1998) and biological control agents such as parasitoids (Mau *et al*. 1980; Sands *et al*. 1993) for managing the pest, there seems to be inadequate research that has been carried out to study infestation and parasitism of the pest in relation to banana leaf age, surfaces and in relation to interiors/perimeters of banana fields. Such studies are very important for effective management of the pest.

Knowledge of within-field distribution of *E. thrax* and its parasitoid complex may help to identify parts of bananas or field sections that are most attractive to ovipositing adults of the pest and its parasitoids. Distribution of *E. thrax* in relation to leaf age may have a substantial effect on the accuracy of sampling to estimate population densities and on the efficacy of insecticides applied to control the pest. Several studies have shown the importance of plant phenology, foliage quality, and farm inputs on the within-plant and within-farm distribution of phytophagous insects (Pencoe and Lynch 1982; Snodderly and Lambdin 1982; Pitre *et al*. 1983; Legg and Chiang 1985; Eckel *et al*. 1992; Preszler and Price 1995; Inbar *et al*. 2001; Zarrabi *et al*. 2005; Okolle *et al*. 2006b). The only such studies carried out in a banana agroecosystem is that of Okolle *et al*. (2006b) that recorded distribution of *E. thrax* and its parasitism in relation to banana phenology and field management. Schoonhoven *et al*. (1998) emphasized that understanding the factors governing the relationships between plants and insects may help unravel the causes of insect plague development

The objective of this research was to quantify the within-field and within-plant distribution and parasitism of immature *E. thrax*. The specific questions addressed by this research are: (i) Which age of banana foliage (older, younger or newly emerged leaves) contains more eggs, younger or older instar larvae? (ii) Is parasitism of immature *E. thrax* significantly different between foliage of different ages? (iii) Does infestation and parasitism of immature *E. thrax* differ at the interior and edges of a field?

MATERIALS AND METHODS

Study site

The study was carried out in a commercial plantation of Cavendish bananas and a section consisting of a local variety (Pisang Mas). According to Yeo and Zakaria (2001), both Pisang Mas and Cavendish are dessert varieties, and were planted using tissue culture plantlets. However, the former is commonly found in medium farms or subsistence systems while the latter is mostly planted on large plantations. In addition, the Mas variety grows up to 2.2 m in height, takes about 8-10 months from planting to harvest and produces a mean bunch weight of 8-10 kg. Cavendish grows up to 2.5-3 m in height, takes 9-12 months from planting to harvest and produces mean bunch weight of 20-25 kg. The plantation is located in Ara Kuda, Daerah Seberang Prai – Penang State, Malaysia, positioned at 5° 30′ North and 100° 30′ East with an altitude of 52 m asl. The 176 acres consisted of about 60% Cavendish bananas and 40% assorted fruit orchards and wild flowers/weeds. The other non-banana crops planted in separate sections included guavas, jackfruits, coconuts, mangoes and pineapples. Wild flowers and various weeds were also found at the edges. About ¾ of the Cavendish bananas were surrounded by an oil palm plantation

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while ¼ shared boundary with a public road. In the Pisang Mas section, with the exception of weeds within the farm, there were no fruit trees or wild flowering plants even at the edges.

In the plantation, Okolle *et al*. (2006b) identified and categorized the main banana growth stages as follows: bunched plants (BP), flowering plants (FP), Preflowering plants (PF), broad leaf followers (BLF), and narrow leaf followers (NLF). BP were considered as plants with new bunches until when the bunches were harvested; FP were plants with newly emerged flowers until when the first fruits were formed, PF were plants without flowers, 4-5 months old and greater than 1.6 m in height; BLF were young plants 3-4 months old, broader leaves, greater than 1 m but less than 1.6 m in height; NLF were very young plants, 1-2 months old with very narrow leaves and less than 1 m in height. It is worth noting that plants at the edges were less vigorous, had fewer and smaller leaves, as well as had little or no chemical inputs (e.g. insecticides, fungicides).

Agronomic/agricultural management practices

The entire plantation was intensively managed including a monthly irrigation system carried out using a dripping pipeline system, fertilizers, pesticides and pruning. Fertilizers (organic and inorganic) were put into dug holes before planting and were also applied monthly after planting. The inorganic fertilizers used were: (i) NPK + MgO (12:6:22:3; 200 g/plant), (ii) Trace elements (B_2O_3, Mn, Cu, Fe, Zn; 30 g/plant), (iii) Ammonium sulfate (200 g/plant), (iv) NPK Green® (15:15:15; 200 g/plant). The organic fertilizers were: (i) Bioplus® (*Bacillus* spp., *Pseudomonas* spp., *Enterobacter* spp.; 2500 g/plant) and (ii) chicken dung (500 g/plant). Liquid fertilizer (N: P_2O_5: K_2O + MgO + chelated micronutrients at a ratio of 54: 25: 145 + 8) was applied on the leaves using a knapsack sprayer. The pesticides used in the plantation included: (i) Capture 605® (Cypermethrin; 200 ml/300 L water), (ii) Wesco Malathion 57® (Malathion; 135 ml/300 L water), (iii) Decis® (Deltamethrin; 135 ml/300 L water), (iv) Endotox 555® (Endosulfan; 530 ml/300 L water), (v) Dipel® (*Bacillus thuriengensis* Berl;), (vi) Tilt® (Propicanazole; 170-250 ml/300 L water), (vii) Topsin® (Thiophonate; 240 g/300 L water), (viii) Paraquat 25® (Paraquat dichloride; 140 ml/54 L water), and (ix) Zap-UP 410® (Glyphosate isopropylamine; 140 ml/54 L water). Insecticides and fungicides were sprayed monthly on the leaves of banana plants using tractor-drawn turbine air blast sprayers or motorized knapsack mist blowers. Weed management was carried out using herbicides, mound construction around the base of plants and mowing. Other phytosanitary measures applied in the plantation were pruning of diseased or senescent leaves as well as desuckering (reducing the number of suckers within a banana mat).

Distribution and parasitism of *E. thrax* in relation to banana leaf age

For this study, only NLF, BLF, and PF were considered for sampling. This was because it was easy to categorize the leaves according to age as follows: (i) Newly emerged leaves – the central leaf of the plant not completely expanded or unrolled (usually very fresh and soft). (ii) Young leaves – the first four leaves surrounding the newly emerged leaf (fresh and softer than older leaves). (iii) Old leaves – those leaves surrounding the younger leaves (not very fresh and usually hard/tough). During the low-density period (April and May) and a high-density period (October-December) of 2004, observations were carried out on 120 plants of each banana stage (NLF, BLF, and PF) chosen randomly in the farm. From each plant, eggs, young instar larvae, and older instar larvae were counted from old, young, and newly emerged leaves. In order to record parasitism, only *E. thrax* life stages from BLF and PF were reared in the laboratory. The young instar larvae were provided with young banana leaves daily while older instar larvae were provided with fresh leaves at 3-day intervals. These life stages were kept in the laboratory until they died or until adult *E. thrax* or parasitoids emerged. The numbers of eggs, larvae and pupae parasitized by the major parasitoids (*Ooencyrtus erionotae*, *Cotesia erionotae*, and *Brachymeria albotibialis*) were recorded. The NLF stages were not considered because the pilot study showed that parasitism of *E. thrax* on these stages was very low.

To quantify egg distribution on leaf surfaces, observations were carried out in April, August, and November 2004 on Cavendish bananas and Pisang Mas. Sixty plants of the BLF stage were sampled randomly each month. After every 10th row, a plant was selected and its upper and lower surfaces of all its leaves inspected carefully to count the number of egg batches and individual eggs. The BLF stages were chosen as sampling units because these stages have been reported to contain significantly more *E. thrax* life stages (Okolle *et al*. 2006b).

Infestation and parasitism of *E. thrax* at the perimeter and interior of the plantation

To find out whether infestation and parasitism were different at the perimeters (edges) and interiors of the plantation, four blocks in the plantation were chosen for this study. From the edges of each block, points at 10, 50 and 100 m intervals were marked. At each point, two banana rows were chosen and from each row, 20 plants were selected (10 for PLF and 10 for BLF giving a total of 120 plants) for sampling in April, August, and November 2004. All the leaves of the plants were carefully inspected to collect eggs, larvae, and pupae. These two banana stages were chosen for sampling because they were found to be the most preferred for adult *E. thrax* oviposition. Healthy life stages and those with signs of parasitism were taken to the laboratory. Eggs and pupae were placed into plastic vials while larvae were placed into cages and reared as previously mentioned. These life stages were kept in the laboratory until they transformed to the next stage or until adult parasitoids (*O. erionotae*, *C. erionotae*, and *B. albotibialis*) or *E. thrax* emerged. The total numbers of each life stage as well as the total number parasitized for each block at the different points were recorded.

Data analyses

Actual data of *E. thrax* life stages in relation to banana leaf ages and leaf surfaces were $\log_{10}$ (N+1) transformed in order to normalize them since the frequency distributions were highly skewed (N = density of the life stages). In the case of parasitism of the life stages, percentages or proportions were arcsine transformed and then subjected to a one-way analysis of variance (ANOVA). These transformations and analyses were done using the STATDISK software (Mario *et al*. 2003). Upon rejection of the null hypothesis (equal means), the means were further subjected to Tukey's Test of equal sample size (Fowler *et al*. 1998) to find out which means were significantly different at a significance level of $\alpha = 0.05$. Data of immatures in relation to farm-level management were not log-transformed because they were subjected to the *Z*-Test (Fowler *et al*. 1998) used to separate two sample means and this test does not require populations to be normally distributed. The *Z*-Test was used whenever sample sizes were greater than 30 and in all cases, untransformed means and standard errors are presented.

Besides, the Z-Test was used to determine if the number of eggs on the upper and lower leaf surfaces were significantly different. Mean number of individual eggs and batches on the leaf surfaces were also compared between Pisang Mas and Cavendish banana varieties. In the case of infestation and parasitism at the perimeters and interior of the plantation, for each point, and for each month, total percentage parasitism was calculated from values pooled from each block. The data were then subjected to a Kruskal-Wallis non-parametric test to find out if differences of infestation and parasitism at the different points (10, 50 and 100 m) were significant. This test was carried out using the software programme STATDISK (Mario *et al*. 2003).

RESULTS

For Cavendish, **Table 1a** (low-density period) and **Table 1b** (high-density period) show the mean number of immatures on different leaf ages for different banana stages. During the low-density period (**Table 2a**), for BLF, parasitism of eggs, larvae, and pupae were not significantly different for the leaf categories. During the high-density period (**Table 2b**), for BLF, parasitism of eggs from all leaf ages were statistically similar. Generally, parasitism of eggs was relatively

Table 1a Mean number (±S.E) of *Erionota thrax* stages within banana plants during the low-density period (April and May, 2004).

Leaf category	Plant Category or Stage								
	Preflowered (PF)			Broad leaf follower (BLF)			Narrow leaf follower (NLF)		
	E	YI	OI	E	YI	OI	E	YI	OI
Old leaves	3.8 ± 0.7 a	0.9 ± 0.3 a	1.5 ± 0.2 a	6.3 ± 0.9 a	1.0 ± 0.3 a	1.0 ± 0.2 a	0.0 ± 0.0 a	0.1 ± 0.5 a	0.3 ± 0.2 a
Young leaves	1.0 ± 0.4 b	1.0 ± 0.1 b	3.7 ± 0.2 b	2.9 ± 0.7 b	0.6 ± 0.2 a	4.2 ± 0.4 b	1.0 ± 0.3 b	0.6 ± 0.2 b	0.9 ± 0.1 b
Newly emerged leaves	0.8 ± 0.3 b	0.1 ± 0.1 b	0.3 ± 0.1 c	1.5 ± 0.5 b	0.1 ± 0.1 b	0.7 ± 0.1 a	1.1 ± 0.4 ab	0.2 ± 0.1 ab	0.2 ± 0.1 ab
F	12.38	7.60	56.02	13.21	9.73	64.39	4.61	8.00	42.51
F_1	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
P-Value	0.0000	0.006	0.0000	0.0000	0.0001	0.0000	0.011	0.0004	0.0000

E = Eggs. YI = 1st and 2nd instars. OI = 3rd to 5th instars. F = Test statistics. F_1 = Critical values.
Means followed by the same letters in a column are not significantly different (Tukey's Test)

Table 1b Mean number (±S.E) of *Erionota thrax* stages within banana plants during the high-density period (October-December, 2004).

Leaf category	Plant Category or Stage								
	Preflowered (PF)			Broad leaf follower (BLF)			Narrow leaf follower (NLF)		
	E	YI	OI	E	YI	OI	E	YI	OI
Old leaves	8.4 ± 0.3 a	2.9 ± 0.2 a	3.1 ± 0.2 a	15.1 ± 1.4 a	6.9 ± 0.7 a	5.1 ± 0.6 a	0.0 ± 0.0 a	0.1 ± 0.1 a	0.3 ± 0.1 a
Young leaves	3.9 ± 0.2 b	2.2 ± 0.1 a	3.1 ± 0.2 a	11.1 ± 1.2 a	4.7 ± 0.7 b	4.6 ± 0.5 a	1.4 ± 0.4 b	0.7 ± 0.2 a	0.4 ± 0.1 b
Newly emerged leaves	1.5 ± 0.1 bc	1.3 ± 0.1 ba	0.5 ± 0.1 bc	3.5 ± 0.2 bc	2.0 ± 0.5 c	2.3 ± 0.4 bc	0.6 ± 0.2 ab	0.7 ± 0.3 a	0.3 ± 0.1 ab
F	18.22	4.19	12.90	27.85	22.39	12.03	7.17	3.12	7.32
F_1	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
P-Value	0.0000	0.0159	0.0000	0.0000	0.0000	0.0000	0.0009	0.0455	0.0008

E = Eggs. YI = 1st and 2nd instars. OI = 3rd to 5th instars. F = Test statistics. F_1 = Critical values.
Means followed by the same lowercase letters in a column are not significantly different (Tukey's Test)

Table 2a Mean percent parasitism (±S.E) of *Erionota thrax* stages within banana plants (low density period) (April and May, 2004).

Leaf category	Plant stage					
	Broad Leaf Follower (BLF)			Preflowered (PF)		
	Eggs	Larvae	Pupae	Eggs	Larvae	Pupae
Old leaves	54.6 ± 5.4 a	15.9 ± 4.0 a	31.2 ± 5.1 a	52.5 ± 5.3 a	5.7 ± 2.6 a	22.9 ± 4.6 a
Young leaves	41.6 ± 5.5 a	12.8 ± 3.7 a	21.8 ± 4.6 a	50.1 ± 5.8 a	3.8 ± 1.6 a	33.0 ± 5.3 ab
Newly emerged leaves	40.4 ± 5.4 a	6.7 ± 2.8 a	13.9 ± 4.4 a	37.2 ± 5.4 a	3.1 ± 2.0 a	12.4 ± 3.4 ac
F	2.03	1.08	2.40	1.51	1.08	5.27
F_1	3.05	3.05	3.05	3.05	3.05	3.05
P-value	0.1346	0.3417	0.0939	0.2246	0.3427	0.006

Means followed by the same letters in a column are not significantly different (Tukey's Test). F = Test statistic. F_1 = Critical value

Table 2b Mean percent parasitism (±S.E) of *Erionota thrax* stages within banana plants (high density period) (October-December, 2004).

Leaf category	Plant stage					
	Broad Leaf Follower (BLF)			Preflowered (PF)		
	Eggs	Larvae	Pupae	Eggs	Larvae	Pupae
Old Leaves	48.0 ± 4.9 a	8.1 ± 3.1 a	15.2 ± 4.4 a	58.8 ± 5.2 a	6.9 ± 3.0 a	9.5 ± 3.6 a
Young Leaves	45.5 ± 4.9 a	17.2 ± 4.5 a	19.7 ± 4.3 a	50.2 ± 5.2 a	16.1 ± 4.1 b	13.4 ± 3.6 a
Newly Emerged Leaves	43.8 ± 5.3 a	5.3 ± 4.7 b	2.2 ± 1.8 b	32.7 ± 4.6 b	10.9 ± 3.1 ab	7.9 ± 3.1 a
F	0.21	3.25	6.52	6.55	4.05	0.74
F_1	3.05	3.05	3.05	3.05	3.05	3.05
P-value	0.8084	0.0411	0.0019	0.0018	0.0191	0.4805

Means followed by the same letters in a column are not significantly different (Tukey's Test). F = Test statistic. F_1 = Critical value.

Table 3a Mean number of *Erionota thrax* eggs (±S.E.) on leaf surfaces of Pisang Mas and Cavendish banana varieties.

Months	Sample size	Pisang Mas				Cavendish			
		Mean egg batches		Mean individual eggs		Mean egg batches		Mean individual eggs	
		Upper surface	Lower surface	Upper surface	Lower surface	Upper surface	Lower surface	Upper surface	Lower surface
April	60	2.1 ± 0.15 a	0.5 ± 0.09 b	18.9 ± 1.74 a	4.0 ± 0.92 b	2.2 ± 0.20 a	1.6 ± 0.16 b	24.4 ± 2.48 a	16.6 ± 1.96 b
August	60	2.0 ± 0.18 a	1.1 ± 0.13 b	20.4 ± 2.08 a	9.0 ± 1.46 b	1.8 ± 0.17 a	1.3 ± 0.14 b	18.1 ± 2.05 a	14.9 ± 1.95 a
November	60	2.4 ± 0.20 a	1.1 ± 0.13 b	23.1 ± 2.14 a	13.4 ± 1.84 b	2.1 ± 0.19 a	1.4 ± 0.15 b	25.4 ± 2.30 a	17.2 ± 2.01 b
Months pooled	180	2.2 ± 0.10 a	0.9 ± 0.07 b	20.8 ± 1.15 a	8.8 ± 0.89 b	2.0 ± 0.19 a	1.4 ± 0.15 b	22.6 ± 2.31 a	16.2 ± 2.00 b

Means with the same lowercase letters in the same row are not significantly different (*Z*-test).

Table 3b Mean number of *Erionota thrax* eggs (±S.E.) on leaf surfaces (comparison of Pisang Mas and Cavendish variety).

Banana variety	Sample size	Mean egg batches		Mean individual eggs	
		Upper surface	Lower surface	Upper surface	Lower surface
Cavendish	180	2.0 ± 0.19 a	1.4 ± 0.15 a	22.6 ± 2.31 a	16.2 ± 2.00 a
Pisang Mas	180	2.2 ± 0.10 a	0.9 ± 0.07 b	20.8 ± 1.15 a	8.8 ± 0.89 b
Z-score		1.40	6.3	1.0	5.1
Critical value		1.96	2.58	1.96	2.58
P-value		0.05	0.01	0.05	0.01

Means with the same lowercase letters in the same row are not significantly different (*Z*-test).

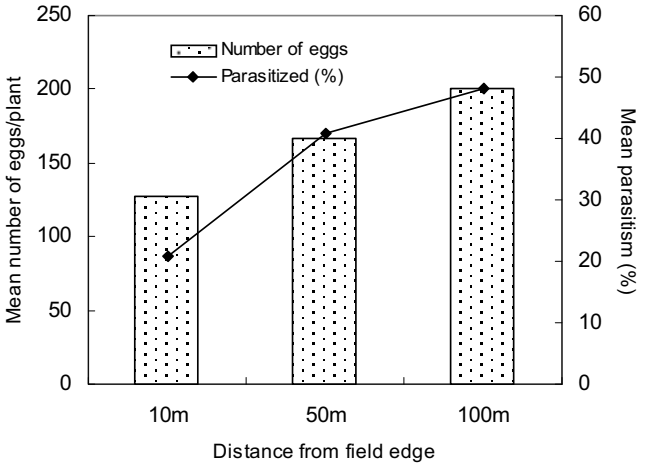

Fig. 1 Parasitism of *Erionota thrax* eggs at the interiors and perimeters of a Cavendish banana plantation, Penang, Malaysia.

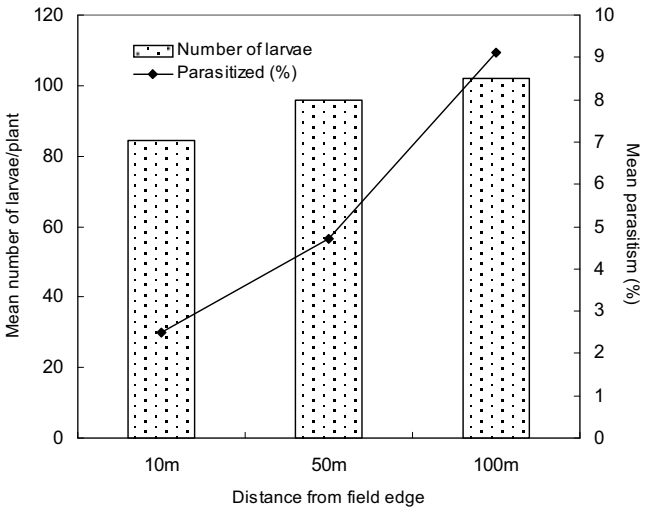

Fig. 2 Parasitism of *Erionota. thrax* larvae at the interiors and perimeters of a Cavendish banana plantation, Penang, Malaysia.

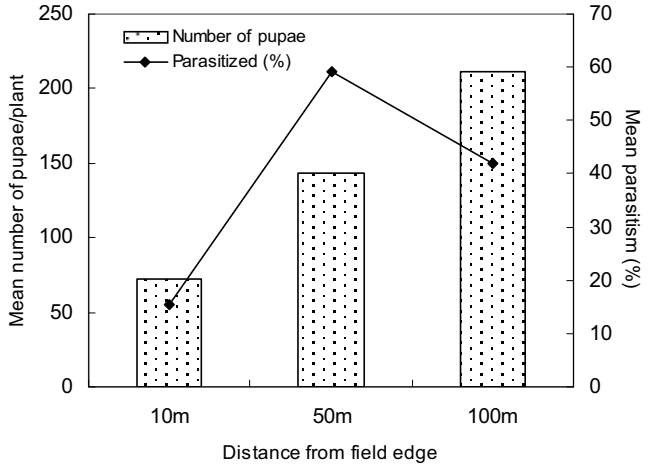

Fig. 3 Parasitism of *Erionota. thrax* pupae at the interiors and perimeters of a Cavendish banana plantation, Penang, Malaysia.

higher on older leaves while that of larvae and pupae were higher on younger leaves.

For Pisang Mas, for all the months, the mean number of egg batches and individual eggs were significantly different between upper and lower leaf surfaces (**Table 3a**). When values of the different months were pooled, mean number of egg batches and individual eggs were also significantly different (Z = 20, P = 0.01 and Z = 4.8, P = 0.01, respectively). Results for Cavendish (**Table 3a**) were similar to those of Pisang Mas and pooled values for egg batches and individual eggs on upper and lower leaf surfaces were significantly different (Z = 2.45, P = 0.05 and Z = 2.1, P = 0.05). Comparison of both varieties (**Table 3b**) showed that mean number of egg batches and individual eggs on lower surfaces were significantly more on Cavendish than on Pisang Mas.

Generally, mean number of eggs and percent parasitism of eggs were higher at the interiors (50 and 100 m) than in the perimeter (10 m) (**Fig. 1**). Nonetheless, Kruskal-Wallis Test showed that there were no significant differences in infestation and parasitism (H = 1.78 and H = 3.59, P = 0.05 respectively). From **Fig.** 2 mean number of larvae and percent parasitism of larvae were also relatively higher at the interiors than at the perimeters though the differences were not significant (Kruskal-Wallis Test: H = 0.26 and H = 0.21, P = 0.05, respectively). Mean number of pupae and percent parasitism of pupae were relatively higher in the interiors compared to the perimeters (**Fig. 3**) and Kruskal-Wallis Test showed significant differences at 10, 50 and 100 m (H = 15.1 and H = 6.19, P = 0.05, respectively).

DISCUSSION

For both periods, on PF and BLF, highest and significant mean numbers of eggs, young instar larvae and parasitism of eggs were recorded from older leaves while highest and significant mean numbers of older instars, parasitism of larvae and pupae were recorded from younger leaves (**Tables 1, 2**). Older leaves (lower canopy) probably provided a suitable microenvironment for the development and survival of eggs and younger instar larvae because the leaves of the upper canopy shade them. These results therefore support the optimum oviposition theory (Jaenike 1978) predicting that the oviposition site chosen within selected plants are more suitable for larval development and survival. However, control experiments using banana leaves are needed to confirm these for *E. thrax.* Significant parasitism of *E. thrax* on older and younger leaves show that the parasitoids are attracted to parts of the banana plants with higher numbers of the pest.

As the young instar larvae grow older, a significant number preferred younger leaves. This could be an indication that defense chemicals and nutrient composition vary with leaf age. Another factor that might cause such a switch is that of inadequate space for shelter-building or leaf-rolling. The higher number of younger instars on older leaves implies high competition for food and leaf-rolling space; forcing most of them to move upwards to the younger leaves. Further studies on the intra-plant distribution of chemicals/nutrients will lead to useful insights. There has been considerable variation on the distribution of lepidopteran eggs and larvae on different plant species (Pencoe and Lynch 1982; Fowler and Lawton 1984; Eckel *et al.* 1992). It appears that oviposition and larval preferences tend to vary with the insect as well as the plant species. However, in all cases including the current study on *E. thrax*, adult females will oviposit on plant stages or parts where eggs and subsequent young larvae would be safe (support of the optimum oviposition theory). From **Table 1**, on NLF, significant and highest mean numbers of all stages were recorded from younger and newly emerged leaves. The older leaves of this banana stage are very narrow and even if eggs are laid on these leaves, most young instar larvae will not survive due to inadequate food and space for construction of leaf rolls.

Generally, mean infestation and parasitism of *E. thrax* life stages were higher at the interiors of the plantation compared to the edges (**Fig. 1, 2, 3**). The higher densities of *E. thrax* in the interiors might have been due to the pattern of application of fertilizers. In the plantation, workers usually concentrated fertilizers in the first half of the blocks, leaving the second half especially plants at the edges with little or no fertilizers. Plants in the interior were more vigorous and therefore possibly attracted more *E. thrax* females.

Higher densities of larvae at the interiors cause higher damage of leaves that in turn could possibly increase concentration of chemical cues (plant volatiles) that easily attract the parasitoids (*O. erionotae*, *C. erionotae*, and *B. albotibialis*). An increase of larval frass (feces) within leaf rolls could possibly be another source of higher concentration of these chemical cues. Takabayashi *et al*. (1994) reported that herbivory releases plant volatiles that in turn attract natural enemies of herbivores.

In addition, the less vigorous plants at the edges were probably more exposed to sun light and therefore the BLF and PF plants at the edges were hotter compared to those in the interior (more shaded). The hotter environment at the edges could also probably discouraged *E. thrax* females from laying eggs. Contrary to these results, Veromann *et al*. (2006) reported significantly more larvae and larval parasitism of *Meligethes aeneus* per plant at the field edges than in the centers of both spring and winter oilseed rape fields. Furthermore, Jungman (2008) reported that stink bugs usually are not uniformly distributed in the fields but are more often found in 'hot spots' particularly at the field edges while Olson and Andow (2008) found significantly more *Rhopalosiphum maidis* at the field edges.

In conclusion, the numbers of *E. thrax* immature and their respective parasitism varies with banana leaf ages and leaf surfaces. However, infestation and parasitism of *E. thrax* life stages is higher on banana plants found at the interiors compared to the edges. Also, for any effective management of the pest, monitoring of the life stages prior to any insecticide application is necessary.

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