Distribution Patterns of Egg Pods of Armoured Bush Cricket, *Acanthoplus discoidalis* (Walker) in the Ntsweletau Agricultural District in Gaborone Region, Botswana

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Received: August 2004 Accepted: April 2006

Resumé

Obopile, Motshwari & Manthe, Christopher S. *Mode de distributions de gousses d'oeuf de grillon de buisson blindé, Acanthoplus discoidalis (Walker) dans le quartier agricole Ntsweletau à la région Gaborone, Botswana.* Le grillon de buisson blindé *Acanthoplus discoidalis* (Walker) est reconnu comme le plus important ravageur de cultures au Botswana. Pourtant l'information sur son écologie au Botswana est inégale. La mode de distributions des gousses d'oeuf de buisson blindé était étudiée aux environs de terrains de culture à Gatukwe dans le quartier agricole Ntsweletau dans la région Gaborone en juin 1999. Les résultats ont montré que les femelles pondent normalenent dans les zones ombragées comme des clôtures de buisson, au-dessous d'arbres et les cultures céréales qui résultent en mode aggregée de distribution. Pour déterminer la mode de distribution on a employé la formule de régression Iwao et l'analyse Taylor de loi de courant. Toutes les deux méthodes ont décrit la mode des distributions de gousses d'oeuf comme agregée. La significance de la mode de distribution de gousses d'oeuf aggrégée pour contrôler la population dans la gestion de grillon de buisson blindé est discutée.

Mots clés: Gousse d'oeuf, mode de distribution, *Acanthoplus discoidalis*, contrôle de population.

Abstract

The armoured bush cricket *Acanthoplus discoidalis* (Walker) is recognised as the most important pest of field crops in Botswana. However the information on its ecology in Botswana is patchy. The distribution pattern of egg pods of armoured bush crickets was studied in and around crop fields at Gakutwe, in Ntsweletau Agricultural District, Gaborone region, in June 1999. The results showed that females deposited egg pods mostly in shaded areas like bush fences, underneath trees and cereal crops, which result in aggregated distribution patterns. Iwao's patchiness regression and Taylor's power law analysis were used to determine distribution patterns. Both methods described egg pod distribution pattern as aggregated. The significance of an aggregated egg pods distribution pattern for monitoring population in management

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of the armoured bush cricket is discussed.

Keywords: Egg pods, distribution patterns, *Acanthoplus discoidalis,* population monitoring, outbreaks.

Introduction

The armoured bush cricket, *Acanthoplus discoidalis* (Walker) (Orthoptera: Tettigoniidae, Hetrodinae) is a serious but sporadic pest of field crops in Botswana (Mosupi, 2003). The subfamily, Hetrodinae is endemic to Africa being most abundant in arid areas of Southern Africa (De Villiers, 1985). The most important economic species, *A. discoidalis* is distributed over much of the dry western areas of South Africa and the northern parts of Namibia, as well as Angola, Botswana and Zambia (Mitchell, 2001; Wohlleber, 1996; Mosupi, 2003). Research in Namibia showed that *A. discoidalis* deposited egg pods in the soil from April to May, at a depth of 5-7 cm and contained 3-15 eggs (Wohlleber, 2000). *Acanthoplus discoidalis* is monovotine insect that undergoes diapause in the egg stage at the beginning of winter (May to August) until early spring (September), after which the embryos of about 50% of the eggs develop between September and November (Wohlleber, 2000). During dry years, only that 50% will hatch after initial rains, and the rest of the eggs will remain in diapause until the next wet season (Wohlleber, 2000; Leuschner, 1995). The nymphs begin hatching from December to January during the main wet season (Leuschner, 1995). Major outbreaks of *A. discoidalis* occur when a season of good rainfall follows several years of drought (Mitchell, 2001). The reasons underlying these population fluctuations are still unknown.

Acanthoplus discoidalis feeds on several wild hosts during most stages of its development (Mitchell, 2001; Wohlleber, 1996). The early instar nymphs feed on the seeds and flowers of several wild species of grasses, herbs, and young leaves of the *Acacia* tree species (Mitchell, 2001; Mviha *et. al.*, 2001). It is the late nymphal instars (4-6th instar) and adult bush crickets that migrate into the fields and damage crops (Wohlleber, 2000). Leuschner (1995) showed the close synchronisation between the cereal crop cycle and the life-cycle of the bush cricket. Planting of cereal crops usually takes place after the first heavy rains of the summer season. This rainfall also stimulates the final development and hatching of the armoured bush cricket eggs (Leuschner, 1995). Adults of *A. discoidalis* feed more selectively on the developing cereal heads which are rich in proteins (Mitchell, 2001; Wohlleber, 1996). During outbreaks in Botswana, field crops such as sorghum, pearl millet, maize, cowpea and mungbean suffer high yield losses when *A. discoidalis* is not controlled (Mosupi, 2003). This happens especially during conditions of low rainfall when non-crop hosts are unavailable. Yield losses on sorghum attributed to armoured bush crickets in Botswana is estimated between 15 and 25% (Mosupi, 2003).

Monitoring the population of *A. discoidalis* can provide information on causes of outbreaks especially when related to climatic or weather conditions. Current information on the ecology of *A. discoidalis* is based on research done in Namibia. The recent work in Botswana by Mosupi (2003) on *A. discoidalis* concentrated on crop loss assessment and control with no coverage of the ecology of the pest. It is important to carry out similar work in Botswana because of ecological and climatic variation that exists between Namibia and Botswana. The eastern part of Botswana which includes the area where the current research was done lies in the hardveld while Namibia lies mostly in the sandveld. The egg stage is preferred stage for sampling because eggs are immobile and present in the soil from April to October. This is the period when eggs undergo diapause and then embryonic development before hatching during the early rains. Egg density and distribution patterns can provide timely and efficient detection system to allow sufficient time for planning, organizing and conducting control operations. The density and spatial distribution of the egg pods have not been undetermined in Botswana. The objective of this study, therefore, was to determine the density and distribution patterns of egg pods of armoured bush cricket in the Ntsweletau Agricultural District.

Materials and methods

Field layout and sampling procedures

The study was conducted on a crop field at Gakutwe, 30 km west of Gaborone in Ntsweletau Agricultural District in June 1999. The field, which measured about 300 x 100m, was subdivided into 15 subplots each measuring 50 x 40 m. The subplots were chosen at random from one edge of the field to the other. The state of the subplots was described as having bush fence, trees, crop plants, grasses or bare soil. From each subplot, 11 soil samples were taken at random about 3 metres from the edge of each adjacent subplot. This sampling procedure enabled stratified random technique (Snedecor and Cochran, 1967). The use of stratified sampling minimizes variance because the total variation is split into, within and between strata (Mead and Curnow, 1983).

Extraction of egg pods and eggs

Eleven soil samples were collected with a spade from $1m^2$ area dug to a depth of about 6 cm from each of the 15 subplots. The soil was put in a bucket and then transferred to a plastic bag and labelled. All samples were brought to the laboratory for dry sieving. Each soil sample was passed through a 2000μ-mesh sieve, and the egg pods removed and counted. The number of egg pods that contained no eggs was also recorded. The number of eggs per pod was determined after moistening the cemented soil that make up pods to loosen for separation of eggs from the pods. The number of eggs from each sample was recorded. The total number of eggs from each sample was divided by the number of pods to obtain the number of eggs per pod. In cases where the egg pods contained no eggs the number was recorded as zero. The grass species that were found at the sampling sites were not identified but the dominant tree species was *Acacia tortilis* (Forsk.) Hayne. The crops that were planted in the field were sorghum (*Sorghum bicolor* (L). Moench), maize (*Zea mays* L.) and cowpea (*Vigna unguiculata*) (L.) Walp.

Statistical analysis

The number of egg pods per square metre and number of eggs per pod were subjected to analysis of variance to test for significant differences between the subplots. Fisher protected LSD was used to compare means. The data was transformed to log (x + 1) prior to analysis to stabilise variance. The means and variances of egg counts were calculated. Variability among samples was examined by calculating the relative variation statistic (RV) (Pedigo, 1996):

$$\mathbf{RV = (SE\bar{x}) * 100} \quad \ldots \quad (1)$$

where SE = standard error of the mean and $\bar{x}$ = mean egg density (Pedigo *et al.*, 1972).

The RV values were used to measure sampling precision levels. Distribution or aggregation indices were calculated using two independent methods: Taylor's power law (Taylor, 1961) and Iwao's patchiness regression (Iwao, 1968). Taylor's power law relates variance (s^2) to mean density ($\bar{x}$).

$$\mathbf{Log\, s^2 = b \log \bar{x} + \log a} \quad \ldots \quad (2)$$

where $\bar{x}$ = mean density, s^2 = variance, a is considered to be a sampling factor, and b is an index of aggregation, which is constant for a species. Values of b range from $b<1$ for regular or uniform distribution through $b=1$ for random distribution to $b>1$ for an aggregated population (Taylor, 1961). Iwao's method is the regression of mean crowding (m*) on the mean ($\bar{x}$) in the linear model:

$$\mathbf{m^* = \alpha + \beta \bar{x}} \quad \ldots \quad (3)$$

where α and β are regression constants characteristic of respective distributions. The intercept β, which is the index of basic contagion, has a value of 0 for distribution where a single individual is the basic unit, but takes a positive value where the population exists as a group of individuals. The slope α, the density-contagiousness coefficient, describes how such individuals distribute themselves in the habitat and takes values of $\beta<1$, $\beta=1$ or $\beta>1$ for uniform, random and aggregated patterns respectively. The parameters α and β were calculated by computing Lloyd's (1967) mean crowding index (m*):

$$m^* = \bar{x} + [(s^2/\bar{x}) - 1] \quad \ldots \quad (4)$$

where $\bar{x}$ = mean density for egg pods. The mean crowding (m*) was then regressed linearly on mean density to obtain the least squares estimate of α and β.

Results

Larger numbers of egg pods per square metre and eggs per pods were collected from plots that had trees, bush fence and crop plants than in plots with grasses and bare soil (Table 1). The number of egg pods per square metre from each sample ranged from 0 to 21 across the 15 subplots. The mean number of egg pods per square meter ranged from 0.46 to 6.82 (Table 1). The overall mean number of egg pods per square metre was 3.44 (Table 1). A total of 7 egg pods that contained no eggs were recorded. The number of egg pods differed significantly (F= 2.52, P = 0.003) between the plots. The overall mean number of eggs per pod was 1.76 eggs per pod. The number of eggs per pod ranged from 0 to 9 while the mean ranged from 0.27 to 3.28 eggs per pods.

Table 1. The mean number ±SE of egg pods and eggs per pods from 15 sampled plots.

Plot	*n*	*Mean no eggpods* m^{-2} *±SE*	*Mean no eggs per pod ±SE*	*Description*
14	11	6.82±1.95a	3.28±0.86 a	Trees
5	11	6.09±1.42ab	3.28±0.68a	Bush fence
6	11	5.82±1.37ab	2.95±0.53ab	Crop plants
8	11	5.36±2.16abc	2.37±0.94abc	Trees
7	11	4.73±1.36a-d	2.41±0.66abc	Crop plants
9	11	4.45±1.90a-d	1.88±0.75abc	Crop plants
3	11	3.55±1.10a-d	1.88±0.56abc	Crop plants
13	11	3.27±0.88a-e	1.88±0.51abcd	Crop plants
15	11	2.45±1.05b-f	1.37±0.57bcd	Trees
1	11	2.27±1.02b-f	1.18±0.52bcd	Grasses
11	11	2.27±0.84c-f	1.25±0.46dc	Crop plants
4	11	2.00±0.84c-f	1.19±0.53dc	Bush fence
2	11	1.27±0.62def	0.84±0.42dc	Bare soil
10	11	0.73±0.73ef	0.32±0.32d	Grasses
12	11	0.46±0.31f	0.27±0.20d	Bare soil

Means followed by the same letter in a column are not significantly different (P>0.05).

The mean number of eggs per pods differed significantly (F = 2.63, P = 0.002) between the subplots.

Sampling precision

There was high variability among the samples as shown by high RV values (Fig. 1). Precision was greatest when egg pod densities were large and declined when densities were small (Fig 1). A significant linear relationship (r^2 = 0.57, P = 0.001) was detected between RV values and mean density of egg pods. The range of egg pods per square metre (0-21) and egg per pods (0-9) also indicate high variability between data. When considering all RV values in Fig. 1, 30% of data set had RV values close to 25% (Fig. 1). Southwood (1978) proposed that 25% precision was satisfactory for surveys and pest management decision-making.

Egg distribution patterns

Both the Taylor's power law and Iwao's patchiness regression models fitted the data well (Figs. 2 and 3). In both cases, there is close relationship between the

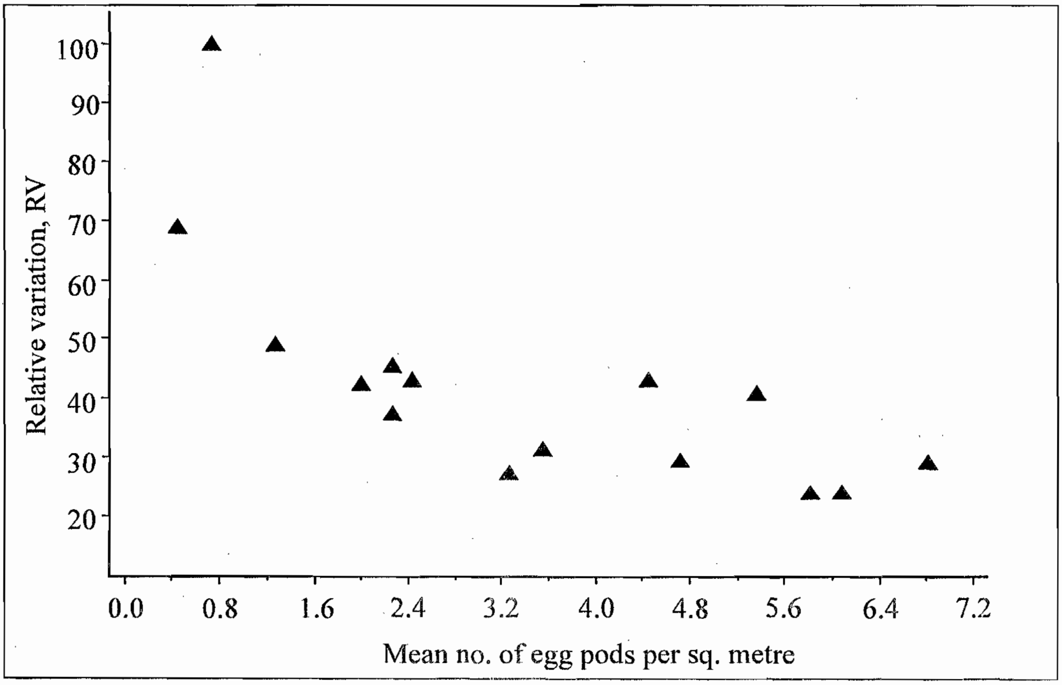

Figure 1. Relationship between sampling precision (expressed as relative variation) and mean number of egg pods per square metre. Each RV and mean value is based on 11 samples.

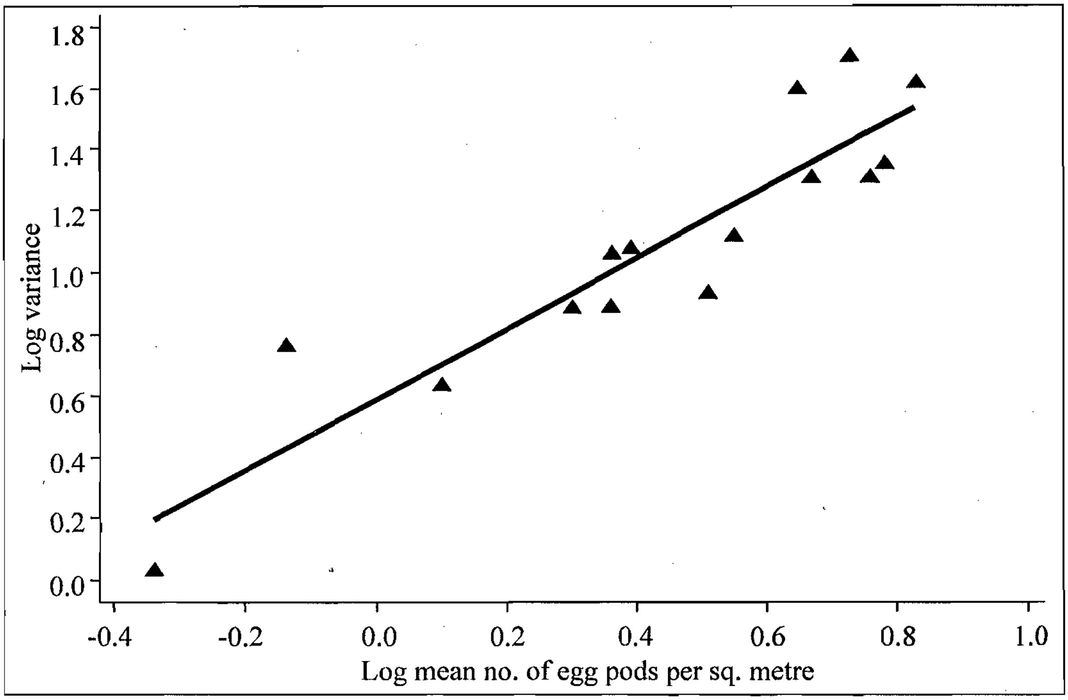

Figure 2. The spatial distribution of egg pods of *A. discoidalis* according to Taylor's (1961) power law. The logarithm of variance expressed as a function of the logarithm of mean egg pod density; Log $s^2 = 1.15 \log \bar{x} + 0.59$ ($r^2 = 0.83$).

logarithm of the mean and the logarithm of variance of the samples, with r^2 values of 0.83 for Taylor's power law model and 0.58 for Iwao's patchiness model. The results of Taylor's power law and Iwao's patchiness regression analysis are in Table 2. The dispersion parameter *b* of Taylor's power law was significantly greater than unit ($P < 0.001$), suggesting an aggregated distribution pattern of egg pods. The index of basic contagion α of Iwao's method and the density-contagiousness coefficient β were greater than zero ($P<0.001$) and unit ($P <0.001$) respectively (Table 2).

Discussion

The level of precision in making population estimates is important in pest management programmes (Pedigo, 1996). With RV value as a measure of precision, a good criterion for practical pest management is to obtain values near 25% (Pedigo, 1996; Southwood, 1978). In these results, only 30% of RV values for egg pod sampling were close to 25% (Fig. 1) indicating greater variability. The variability among the data was therefore large, indicating that

Table 2. Results of Iwao's patchiness regression and Taylor's power law analyses of egg samples of armoured bush cricket.

Iwao's regression				*Taylor's power law*		
n^c	R^2	α	β	R^2	*a*	*b*
15	0.58	2.95^{***d}	1.28^{***d}	0.83	0.59	1.15^{***d}

[c]number of data points in regression; each *n* based on 11 samples.
***d : significantly different at P = 0.001, Probability of a greater t statistic for H_o: α= 0, or H_o: β = 1 (Iwao's) or H_o: b = 1 (Taylor's).

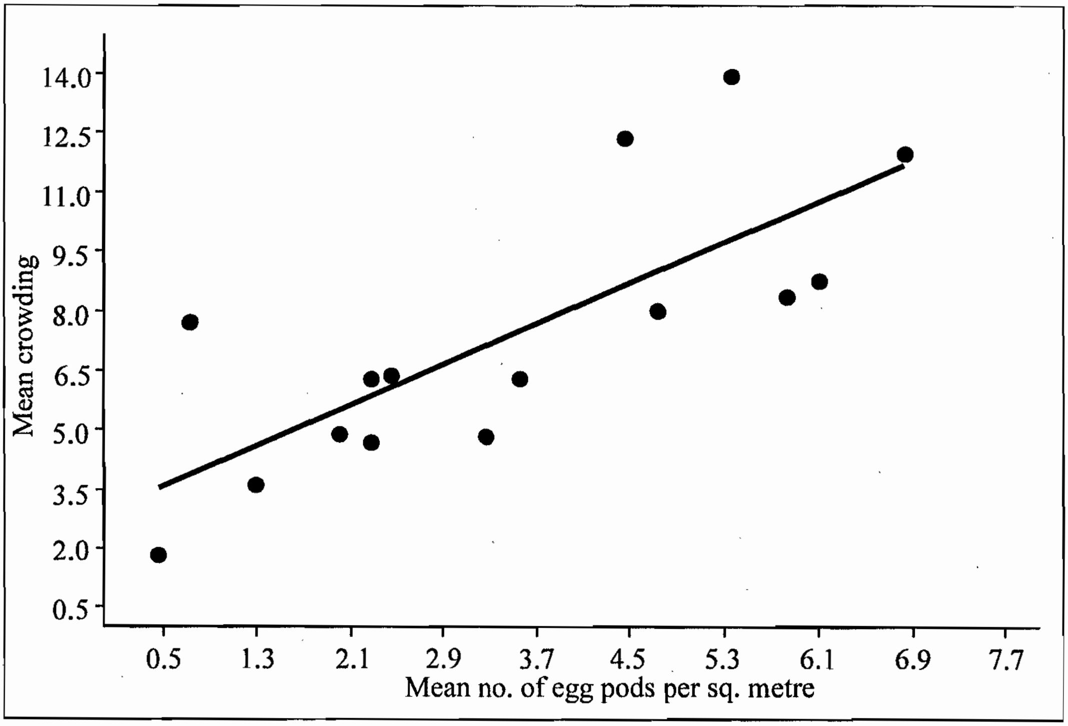

Figure 3. The spatial distribution of egg pods of *A. discoidalis* according to Iwao's patchiness regression (Iwao 1968). Mean crowding (m*) expressed as a function of the mean ($\bar{x}$) density. $m^* = 1.28\bar{x} + 2.95$ ($r^2 = 0.58$).

sampling procedures need improvement to increase precision. Because standard error decreases with increasing number of samples, sampling precision can be improved in future experiments by taking more samples and in wide areas and from different locations. In spite of this, large variation can still be expected because female armoured bush crickets deposit egg pods in aggregated rather than in uniform patterns. The indices of aggregation obtained from Taylor's power law and Iwao's patchiness regression results suggest an aggregated distribution pattern of egg pods of *A. discoidalis*. The values of α and β of Iwao's method strengthened the results of Taylor's power law analysis. Aggregates constituted the basic units and their spatial disposition conformed to an aggregated pattern. Iwao and Kuno (1971) interpreted α as the number of other individuals with which a typical individual lives (in the same habitat); thus judging from the present value of α, about 1 egg pod was enough to indicate the presence of other egg pods in the same sampling area.

The results showed that females deposited significantly higher egg pods on shaded areas like bush fences, trees, and cereal crops than on open areas (bare soil or grasses). The number of eggs per pod which ranged from 0-9 in this study was smaller than 3-15, reported by Wohlleber (1996) in Namibia. This could be attributed to fewer samples and small study area in the current study or the ecological variation between Botswana and Namibia. The oviposition site selection behaviour shown by gravid females in this study corroborates results of other workers elsewhere. Wohlleber (1996) showed that egg pods of *A. discoidalis* in Namibia were deposited in cleared areas adjacent to clearings in shades of millet crops. Musonda and Leuschner (1990) also reported that females of *A. speiseri* in Zambia preferred laying eggs within rows of sorghum, underneath shrubs, or trees to less shaded areas. Mviha *et. al.* (2001) reported that egg pod abundance was strongly related to soil particle size, but large egg pod abundance was most strongly associated with *Acacia scrub* habitat type. Gravid females were reported to avoid sandiest soil but prefer uncompacted, dry loam or sand for oviposition (Mviha *et al.*, 2001). The environmental conditions associated with shaded areas and their effects on oviposition selection by *A. discoidalis* remains to be explained.

For many of herbivorous insects, the selection of an oviposition site is a critical step in their life cycle because newly hatched larvae are generally slow in host searching (Singer, 1986). From a survival point of view, females could be laying their eggs at the base of crops, trees or bush fences that provide more favourable environmental condition (optimum temperatures, moisture) during embryonic development and allow for immediate access to food when nymphs hatch. During early nymphal stages, the crickets are greenish, resembling the colour of plant leaves, probably providing a camouflage to maximise protection from predators to increase chances of survival.

Since females prefer to deposit their egg pods on shaded areas it is likely to find egg pods of *A. discoidalis* on such places. Therefore, quick sampling for eggs pods of *A. discoidalis* for pest management purposes may be confined to the base of trees, bush fences or in the field where crops had established. This will be useful when predicting possible outbreaks during the season. This method provides simple and practical means of detecting the presence of eggs of *A. discoidalis*. These are preliminary results, therefore more research is needed that will focus on developing predictive models for pest management programmes. There is also a need to study factors that attract females to select ovipositing on shaded areas than on open areas.

Acknowledgement
Technical support of M. Chikumo, K. Siele and C. Moloi is highly appreciated. This study was fully funded by Botswana Government through the Department of Agricultural Research.

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