2017 International Symposium on Cocoa Research (ISCR), Lima, Peru, 13-17 November 2017.

Reassessment of the temporal distribution and damage of *Bathycoelia thalassina* (Herrich-Schaeffer) on cocoa in Ghana

G. K. Awudzi[1*], R. Adu-Acheampong[1], S. K. Ahadzi[1], A. J. Daymond[2]
[1]Entomology Division, Cocoa Research Institute of Ghana, P. O. Box 8, New Tafo-Akim, Ghana.
[2] School of Agriculture, Policy and Development, University of Reading, Whiteknights, Reading, RG6 6AR, UK.

Abstract

In Ghana, insecticides are mainly used to control mirids the most important insect pest on cocoa. However, recent field observations show that *Bathycoelia thalassina* has also become a key pest. The present study was conducted to assess the current distribution and damage levels of *B. thalassina* with a view to developing an appropriate strategy for their control. Pest assessment involved visually inspecting *B. thalassina* inhabiting sites on cocoa trees to hand-height and recording their numbers between the hours of 6:30am and 9:00am. Immature but ripened pods, occasionally deformed were characterized as *B. thalassina* damaged pods. Ten farmers' farms were selected in each of Ashanti and Eastern regions of Ghana between January 2012 and April 2013. Three experimental plots at the Cocoa Research Institute of Ghana (CRIG) were also observed from September 2014 to September 2016. *B. thalassina* was present throughout the year in both the farmers' and CRIG plots. Peak population and damage occurred in April to June and again in September. Incidence of *B. thalassina* on hybrid cocoa was significantly higher than on the traditional Amelonado variety on some farmers' farms (p<0.01). The occurrence of the pest all year round might partly be explained by the presence of pods on hybrid varieties throughout the year given that *B. thalassina* are pod feeders. A significant positive relationship was observed between rainfall and number of *B. thalassina* per tree (r^2=0.35, p=0.001). High *B. thalassina* numbers and symptoms of their damage on pods between April and June suggest that the current recommendations for the spraying of insecticides on cocoa need revision and should include treatments in the first half of the year. Regular monitoring of pest numbers would also enable a more targeted pest control.

Key words: cocoa, *Bathycoelia thalassina*, population dynamics, pest control measures

Introduction

Bathycoelia thalassina (the "cocoa shield bug") is an important pest of cocoa in Ghana, and is reported to be responsible for 40% of premature ripening of immature pods and clumping of beans in older pods (Owusu-Manu, 1971). Owusu-Manu (1976a) further reported 18% loss in cocoa production annually due to damage by these bugs. A recent study of insect pest populations and damage levels on cocoa farms coupled with farmers' perception of their economic importance places *B. thalassina* as the second most important insect pest on cocoa after mirids (Awudzi et al., 2016a).

Control of insect pests on cocoa farms has primarily been achieved through the use of conventional insecticides, with mirids as the main target (Owusu-Manu, 1995). The carbamate and organochlorine-based insecticides used on cocoa in the 1970's and 80's are now banned due to their adverse effects on the environment, high mammalian toxicity, and increased residue levels in cocoa beans (Bateman, 2009, Matthews, 1999). Insecticides currently being used on cocoa are screened mainly against cocoa mirids, and post treatment data suggests they are effective in the management of *B. thalassina* (Awudzi et al., 2009). With the introduction of hybrid cocoa varieties which produce larger numbers of pods to a greater or lesser extent all year round, *B. thalassina*, which are strict pod feeders, are thus also present in cocoa farms all year round (Owusu-Manu, 1977). The continuous availability of feeding/breeding sites on hybrid cocoa varieties could have contributed to an increase in *B. thalassina* populations on cocoa farms, especially between January and July, when insecticide application is usually not carried out. Most farmers observe premature ripening of immature pods and clumping of beans in matured pods but are unable to relate it to attack by *B. thalassina* and therefore may underestimate cocoa yield losses caused by these bugs (Awudzi et al., 2016a).

Adu-Acheampong *et al.* (2014) suggested April or May/June as appropriate spraying times against insect pests on cocoa primarily based on data collected on mirid populations by making inferences based on field observations of *B. thalassina* numbers/damage. In order to address the lack of current field data on *B. thalassina*, the purpose of this study was to conduct a re-assessment of the temporal distribution of this pest and damage levels in order to critically evaluate existing control measures.

Materials and methods

Study sites and farm selection

Cocoa farms selected for the study were located in the Ashanti and Eastern regions of Ghana. The farms were organic certified and had not received conventional insecticide for at least five years. These farms were not less than six years old and categorised into six farms growing cocoa hybrids (bi-parental crosses developed by the Cocoa Research Institute of Ghana) and four farms cultivating the traditional Amelonado variety making a total of 10 farms for both regions. The Ashanti region had 3 farms that cultivated Amelonado and 3 that cultivated hybrids while the Eastern region had 2 farms that cultivated Amelonado and 2 that cultivated hybrids. A 0.4 hectare plot was demarcated within each selected farm for the 10 farms in the study. Three plots planted with mixed hybrids older than five years were also assessed to determine the population dynamics of insect pest species on cocoa on research plots at the Cocoa Research Institute of Ghana (CRIG), Tafo, Eastern Region, from September 2014 to September 2016. In both experiments, two linear transects at right angles to each other were marked within the demarcated area, dividing the area into four equal blocks. Twenty trees evenly spread within each demarcated area were chosen for data collection within these transects.

Temporal distribution of *B. thalassina* populations

The visual hand-height method was used to assess *B. thalassina* populations (Collingwood, 1971) over time. This involved visually inspecting inhabiting sites of *B. thalassina* (pods, pod peduncles, chupons, flower cushions, crevices on pods as well as the pod-stem interface) on trees and recording pest numbers observed. Assessment was carried out from the base of the tree up to the height of the stem that corresponded to the maximum hand stretch of the assessor between the hours of 6:30am and 9:00am, since *B. thalassina* are less active before sunrise (Entwistle, 1985). Data was collected every two weeks.

Damage and pod assessment

In addition to recorded numbers of *B. thalassina*, pods were assessed visually for their damage. Deformed, immature but ripened pods usually with a black point of attack were described as *B. thalassina* damage (Entwistle, 1985) and their numbers recorded. The number of pods at different developmental stages on tagged trees were also counted and recorded. Pods were categorised into small (up to 2 months old), medium (3 & 4 months old) and large (5 & 6 months old).

Meteorological data

Bi-weekly rainfall, temperature and relative humidity data were obtained from the nearest weather stations to the farms.

Data analysis

The number of *B. thalassina* counted to hand-height was analysed using the linear mixed-model approach for repeated measurements where the correlation within the subjects was modelled as first-order autocorrelation (AR) (1). The fixed effects in the model were specified to account for location and variety and the interaction between variety and location. This was carried out using the mixed-model procedure in GenStat. The relationship between *B. thalassina* numbers, their damage and climatic data was investigated by means of regression analysis in GenStat.

Results

Temporal distribution of *B. thalassina*

The population trends of *B. thalassina*, on Amelonado and hybrid cocoa and the temporal distribution of the pest in the Ashanti and Eastern regions in the 2012/2013 study are displayed in Figure 1. *B. thalassina* numbers on hybrid cocoa were significantly greater (p=0.01) than that observed on Amelonado trees. The differences were particularly marked during the first half of the year, with little difference observed during the second half of the year. The greatest numbers of *B. thalassina* were observed on Amelonado trees during July and between October and December, when numbers were lower on hybrid trees. Trends in *B. thalassina* numbers were similar for the two regions, although a larger initial peak was observed in the Eastern region between March and April 2012. Overall there were no significant differences in populations of *B. thalassina* between the two regions (Figure 1B). The population trend for *B. thalassina* in the 2014 to 2016 study at Tafo is presented in Figure 2. An initial peak in pest numbers was observed in September 2014 followed by a smaller peak in April 2015 and more prolonged peak between September 2015 and January 2016.

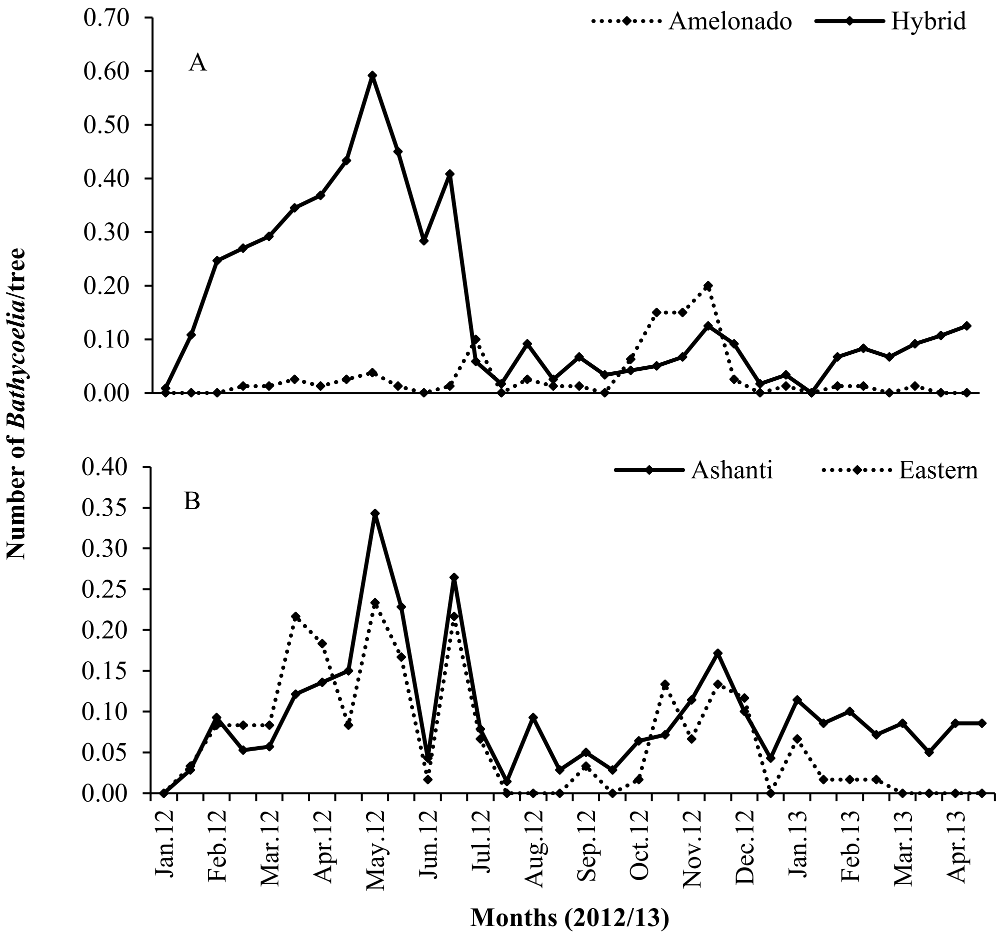

Figure 1: Temporal distribution of *Bathycoelia thalassina* on Amelonado and hybrid cocoa (A) and in the Ashanti and Eastern (B) regions of Ghana

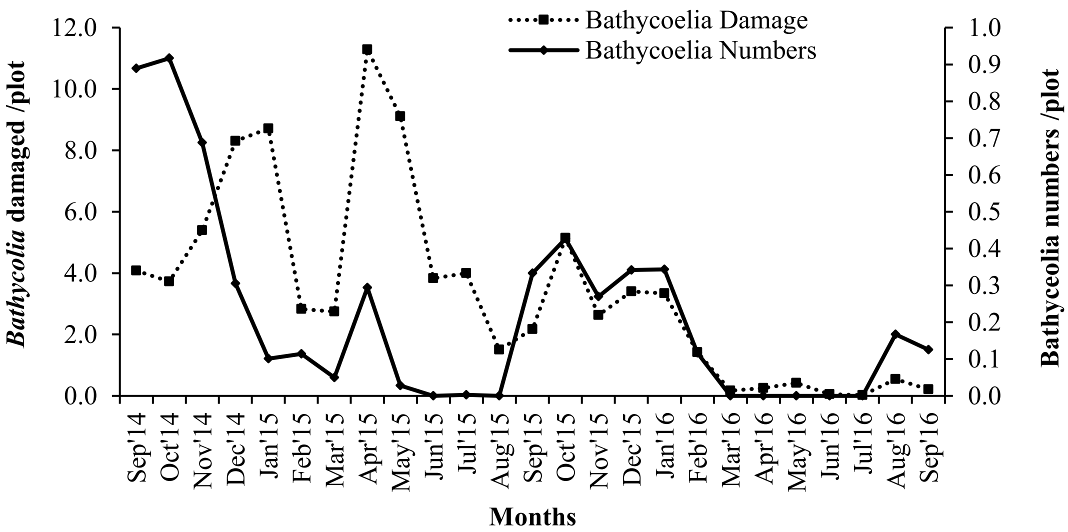

Figure 2: Temporal distribution and damage trends of *Bathycoelia thalassina* at the Cocoa Research Institute of Ghana, Tafo from 2014 to 2016

Damage trends of *B. thalassina*

Pest damage trends of *B. thalassina* on farm that cultivate Amelonado and hybrid cocoa and for farms in the Ashanti and Eastern regions are displayed in Figure 3. Even though pest damage trends of *B. thalassina* on Amelonado and hybrid cocoa differed in peak periods, there were no significant differences in the number of damaged pods between varieties (p=0.15). Similarly, there was no overall difference between locations in numbers of *B. thalassina* damaged pods. However, a peak in *B. thalassina* damage was observed in February 2013 for the Eastern Region. High *B. thalassina* damage was observed in both halves of the year (February, March, May and July, October). Damage trend of *B. thalassina* in the 2014 to 2016 study at Tafo is presented in Figure 2. There was a greater amount of damage observed in 2015, with peaks in January and April.

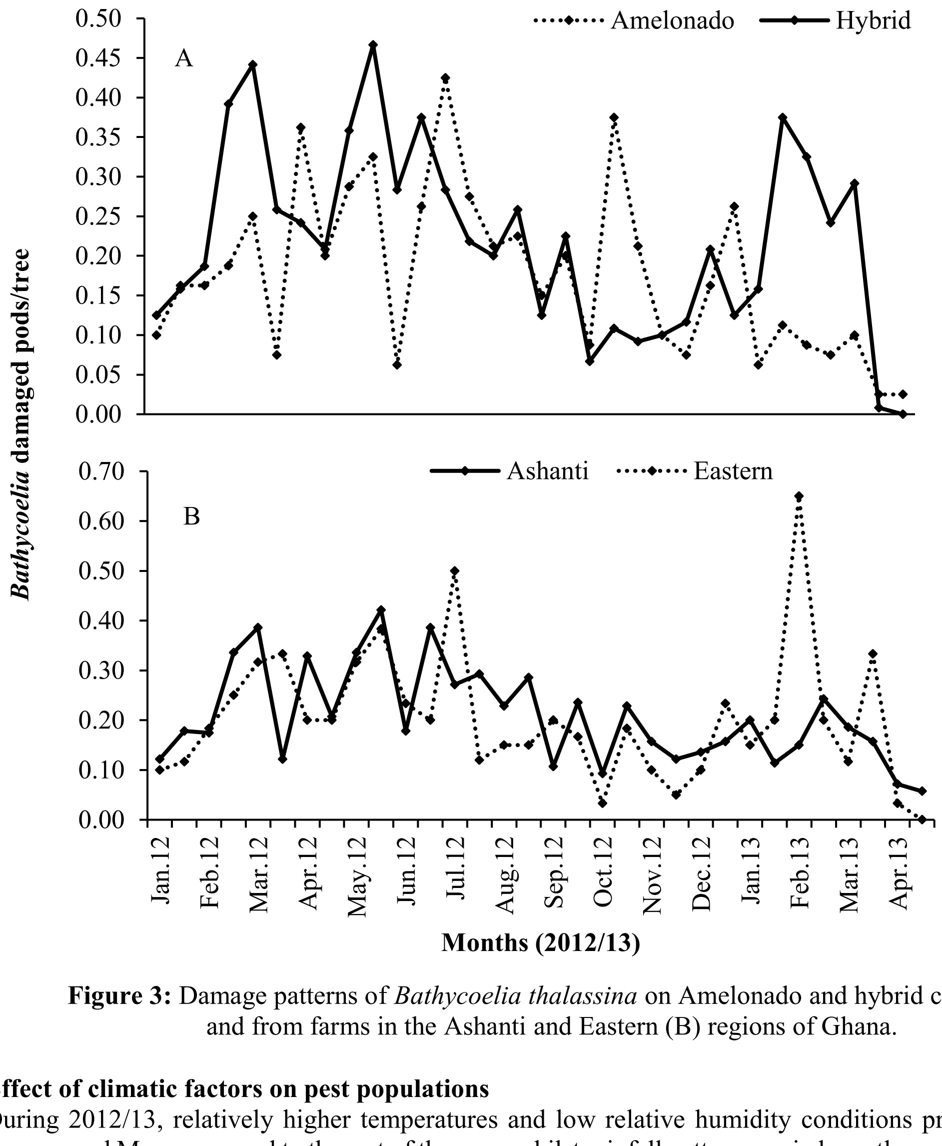

Figure 3: Damage patterns of *Bathycoelia thalassina* on Amelonado and hybrid cocoa (A) and from farms in the Ashanti and Eastern (B) regions of Ghana.

Effect of climatic factors on pest populations

During 2012/13, relatively higher temperatures and low relative humidity conditions prevailed between January and May compared to the rest of the year, whilst rainfall patterns varied greatly across the year with the highest rainfall figures recorded in June (Table 1). A weak but significant positive linear relationship was observed between temperature and the number of *B. thalassina* in the Eastern Region (r^2 =0.21; p=0.02; Fig. 4); however, no such relationship was observed in the Ashanti region. A significant linear relationship was also observed between rainfall and the number of *B. thalassina* in the Ashanti region (r^2=0.35, p=0.001; Fig. 5); no such relationship was observed in the Eastern region. No significant relationship was observed between relative humidity and *B. thalassina* numbers in both the Ashanti and Eastern regions in the 2012/13 study. No significant relationships were observed between *B. thalassina* in the trial at Tafo and any of the weather parameters measured from 2014 to 2016 (Table 2).

Table 1: A summary of the weather data collected with values representing means for the Ashanti and Eastern regions in the 2012/13 season

Months	Mean Temperature (°C)	Relative Humidity (%)	Rainfall (mm)
JAN.12	27	76	13
FEB.12	28	79	39
MAR.12	28	76	29
APR.12	28	83	72
MAY.12	26	84	113
JUN.12	26	88	128
JUL.12	25	91	33
AUG.12	24	87	6
SEP.12	26	89	79
OCT.12	26	91	12
NOV.12	26	86	22
DEC.12	26	88	17
JAN.13	25	80	1
FEB.13	25	86	32
MAR.13	26	87	69
APR.13	27	85	37

Table 2: A summary of the weather data collected with values representing means in Tafo (Eastern region) from 2014 to 2016

Month	Rainfall (mm)			Relative Humidity (%)			Temperature (oC)		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
JAN	50	63	3	70	61	52	26	24	25
FEB	173	47	29	70	67	55	26	27	27
MAR	95	98	150	67	69	69	26	27	28
APR	111	51	160	72	70	69	26	26	28
MAY	115	119	397	78	70	75	26	26	26
JUN	539	191	155	82	77	76	25	28	26
JUL	83	90	139	86	75	78	24	24	25
AUG	93	68	61	85	77	78	23	24	25
SEP	311	107	226	80	74	79	24	25	25
OCT	125	201	201	75	75	74	25	25	27
NOV	28	46	89	70	73	73	25	25	28
DEC	26	6	33	74	53	71	25	24	27

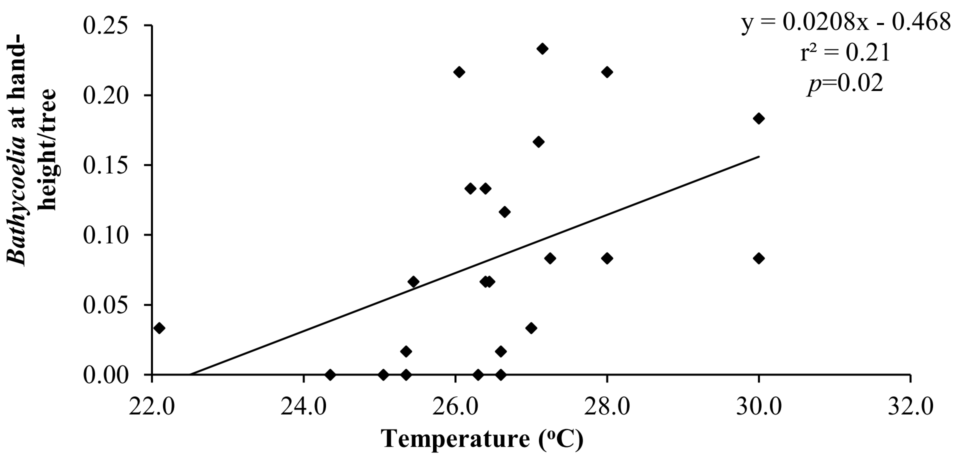

Figure 4: Linear relationship observed between temperature and the number of *B. thalassina* in the Eastern Region of Ghana (2012/13 season)

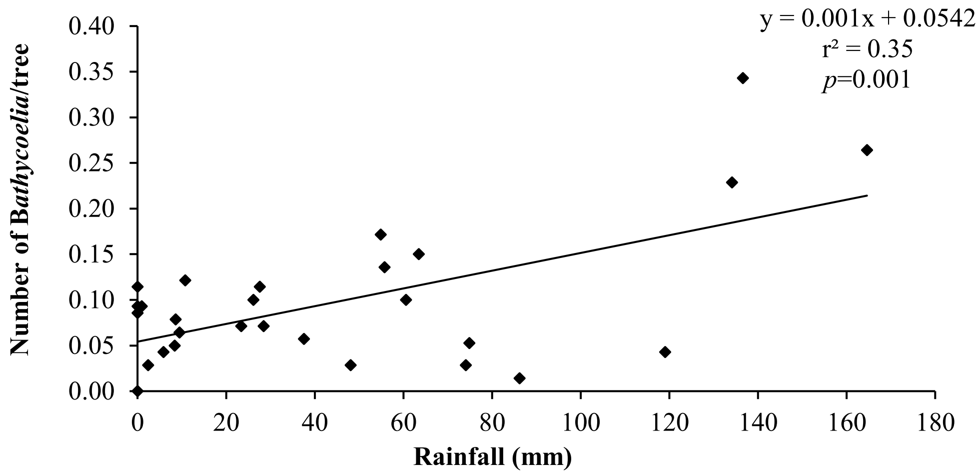

Figure 5: Linear relationship between rainfall and the number of *B. thalassina* in the Ashanti region of Ghana (2012/13 season)

Relationship between pod load and *B. thalassina* numbers

A significant positive relationship was observed between the number of *B. thalassina* sampled and the number of large pods (5-6months old) on hybrid cocoa, such that trees with the highest number of pods harboured significantly greater number of *B. thalassina* (Fig. 6; r^2=0.40, *p*<0.001). Two peak periods of large pods was observed between April/May and October/November. Even though the relationship between the number of *B. thalassina* sampled and the number of large pods on Amelonado cocoa was statistically significant, it only explained 17% of the relationship (y=0.039x – 0.0041; r^2=0.17; *p*=0.03). Relationship analysis between *B. thalassina* and other pod sizes (small=up to 2 months old and medium=3 & 4 months old) on both hybrid and Amelonado cocoa did not reveal any significant relationships.

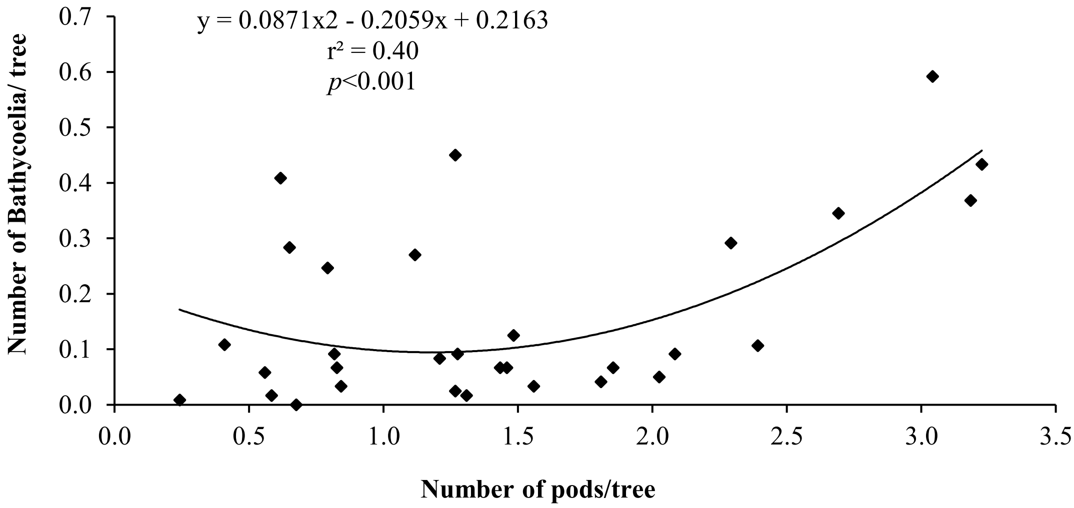

Figure 6: Relationship between the numbers of *B. thalassina* and the number of large (5-6 months) pods on hybrid cocoa

Discussion

B. thalassina assumed an important pest status on cocoa in the early 1970s (Owusu-Manu, 1971). Results from this study have shown that *B. thalassina* is present on cocoa throughout the year, although their numbers vary across the season. A similar trend was reported for mirids by Awudzi *et al.* (2016). The temporal distribution of *B. thalassina* was different for Amelonado and hybrid cocoa. There were also more of the bugs recorded on hybrid cocoa than on Amelonado varieties. This is consistent with findings by Owusu-Manu's (1971) and Lodos (1965) who reported that *B. thalassina* is present on cocoa throughout the year with higher numbers on hybrid and "Amazon" (early generation of hybrid) cocoa relative to their numbers on Amelonado trees. A possible explanation for this is that, *B. thalassina*, being a pod feeder, has access to pods on Amazon and hybrid cocoa all year round, compared with Amelonado (that has a lower yield potential) and thus is able to maintain a sufficiently large population to cause significant damage.

With the largest proportion of cocoa farms in Ghana now planted with hybrids, the problem of *B. thalassina* damage has increased.

No direct relationship was recorded between *B. thalassina* numbers and temperature. However, temperature may have an indirect effect on the bug population since flowering and pod development on cocoa is influenced by temperature (Alvim, 1966, Sale, 1968, Daymond and Hadley, 2008). As *B. thalassina* are strict pod feeders, factors that influence the availability of pods would be expected to then impact on their numbers (Owusu-Manu, 1981). Very low relative humidity levels, below 30%, have been reported to be lethal to *B. thalassina* (Owusu-Manu, 1976b); here no relationship was observed between relative humidity and *B. thalassina* numbers in the field, probably due to the fact that relative humidity rarely fell to such low levels. Owusu-Manu (1981) reported that rainfall was the most important physical factor regulating the abundance of *B. thalassina*, however no such association was observed in this study. According to Owusu-Manu (1981), rainfall washes away and drowns the first three developmental stages of the pest thus reducing their abundance when mean monthly rainfall figures exceed 100 mm. Our findings do not support this hypothesis as a weak but positive relationship was found between rainfall and *B. thalassina* numbers in the Ashanti region and relatively high numbers were recorded during months with rainfall figures exceeding 100 mm (May and June). Relationships between a pest and environmental factors are not always easy to quantify in part due to the complex interactions between the pest, its natural enemy complex and climate (Dudt and Shure, 1994, Owusu-Manu, 1981).

With the provision of hybrid cocoa seedlings for the establishment of new cocoa farms and replanting of old farms, it could be predicted that the majority of cocoa farms in Ghana would consist mainly of hybrids in the foreseeable future (COCOBOD, 2015) with a consequent impact on *B. thalassina* numbers. Therefore, the current spraying recommendation for cocoa farms in Ghana (where January to July is excluded) (Awudzi et al., 2016b) is likely to result in increased *B. thalassina* damage to pods if not reviewed. Furthermore, the observed shift in the onset of mirid population build-up from August to June (Adu-Acheampong et al. 2014; Awudzi et al. 2016), and the higher numbers of *B. thalassina* and damage observed within that period means pest control activities should include applications earlier in the year and not be confined to the second half of the year as the current recommendation suggests. It is possible that cocoa yield losses as a result of *B. thalassina* damage are higher than currently estimated. The data presented here therefore provides support for the recommendation by Adu-Acheampong *et al.* (2014) for a review of the current spraying calendar. Insecticides used for mirid control in the 1960s to the 1970's were reported not to be as effective against *B. thalassina* as they were against mirids (Owusu-Manu, 1971). The continuous use of these insecticides was believed to have destroyed most natural enemies of *B. thalassina* which kept the population of the pest below the economic injury level in preceding years (Owusu-Manu, 1971). With neonicotinoids currently in use for mirid control on cocoa, there is a need to evaluate their effectiveness as well as other permissible chemical groups against *B. thalassina*. Furthermore, studies on the biological control of *B. thalassina* should also be intensified to provide an integrated approach to their control (Owusu-Manu, 1976b). Effective and continuous pest monitoring is also required to monitor the population of these bugs in order to provide decision support for efficient use of insecticides and other control strategies. The reintroduction of cocoa extension in Ghana through the Cocoa Health and Extension Division (CHED) may serve as a vehicle to provide decision support for the management of cocoa insect pests in Ghana.

Acknowledgements
The authors would like to express their sincere gratitude to staff of the Entomology Division of CRIG, notably, Fiakegde Godson, Enoch Chawudzi, Ebenezer Obeng Mintah, Abraham Sowah and Dickson Ampadu for their help with data collection. This paper is published with the kind permission of the Executive Director of CRIG.

References

ADU-ACHEAMPONG, R., JIGGINS, J., VAN HUIS, A., CUDJOE, A. R., JOHNSON, V., SAKYI-DAWSON, O., OFORI-FRIMPONG, K., OSEI-FOSU, P., TEI-QUARTEY, E., JONFIA-ESSIEN, W., OWUSU-MANU, M., NANA KARIKARI ADDO, M. S., AFARI-MINTAH, C., AMUZU, M., NYARKO EKU-X, N. & QUARSHIE, E. T. N. 2014. The cocoa mirid (Hemiptera: Miridae) problem: evidence to support new recommendations on the timing of insecticide application on cocoa in Ghana. *International Journal of Tropical Insect Science,* 34**,** 58-71.

ALVIM, P. D. T. 1966. Factors affecting the flowering of cocoa tree. *Cocoa Growers Bulletin,* 7**,** 15-19.

AWUDZI, G. K., ACKONOR, J. B., CUDJOE, A. R., DWOMOH, E. A. & SARFO, J. E. 2009. *Manual for cocoa insect pests, symptoms of their damage and methods of their control,* New-Tafo, Akim, Cocoa Research Institute of Ghana.

AWUDZI, G. K., ASAMOAH, M., OWUSU-ANSAH, F., HADLEY, P., HATCHER, P. E. & DAYMOND, A. J. 2016a. Knowledge and perception of Ghanaian cocoa farmers on mirid control and their willingness to use forecasting systems. *International Journal of Tropical Insect Science,* 36**,** 22-31.

AWUDZI, G. K., CUDJOE, A. R., HADLEY, P., HATCHER, P. E. & DAYMOND, A. J. 2016b. Optimizing mirid control on cocoa farms through complementary monitoring systems. *Journal of Applied Entomology***,** n/a-n/a.

BATEMAN, R. 2009. *Pesticide Use in Cocoa: A Guide for Training Administrative and Research Staff,* London, ICCO.

COCOBOD. 2015. *Ghana cocoa board free seedlings project takes off* [Online]. Accra, Ghana: COCOBOD. Available: https://cocobod.gh/news.php?page=3&=&search= [Accessed 2/7/2015 2015].

COLLINGWOOD, C. A. 1971. A comparision of assessment methods in cocoa mirid count trials *3rd International Cocoa Research Conference.* Accra, Ghana,.

DAYMOND, A. J. & HADLEY, P. 2008. Differential effects of temperature on fruit development and bean quality of contrasting genotypes of cacao (*Theobroma cacao*). *Annals of Applied Biology,* 153**,** 175-185.

DUDT, J. F. & SHURE, D. J. 1994. The influence of light and nutrients on foliar phenolics and insect herbivory. *Ecology,* 75**,** 86-98.

ENTWISTLE, P. F. 1985. Insects and cocoa. *In:* WOOD, G. A. R. & LASS, R. A. (eds.) *Cocoa, pp. 366-409.* 4th ed.: Longman Group Limited.

LODOS, N. 1965. Studies on Bathycoelia thalassina (H.-S.) (Hemiptera; Pentatomidae), the cause of premature ripening of cocoa pods in Ghana. *Bulletin of Entomological Research,* 57**,** 289-299.

MATTHEWS, G. A. 1999. *Application of Pesticides to Crops,* London, Imperial College Press.

OWUSU-MANU, E. 1971. *Bathycoelia thalassina* - another serious pest of cocoa in Ghana. *CMB Newsletter***,** 12-14.

OWUSU-MANU, E. 1976a. Estimation of cocoa pod losses caused by *Bathycoelia thalassina* (Herrich - Schaeffer) (Hemiptera, Pentatomidae). *Ghana Journal of Agricultural Science***,** 81-83.

OWUSU-MANU, E. 1976b. Natural enemies of Bathycoelia thalassina (Herrich-Schaeffer) (Hemiptera: Pentatomidae), a pest of cocoa in Ghana. *Biological Journal of the Linnean Society,* 8**,** 217-244.

OWUSU-MANU, E. 1977. Distribution and abundance of the cocoa sheild bug, *Bathycoelia thalassina* (Hemiptera, Pentatomidae) in Ghana. *Journal of Applied Ecology***,** 331-341.

OWUSU-MANU, E. 1981. Effect of physical environment of the abundance of *Bathycoelia thalassina* (Herrich-Schaeffer) (Hemiptera: Pentatomidae), in Ghana. *International Cocoa Research Conference.* Proceedings, Douala, Cameroon, 463-468.

OWUSU-MANU, E. 1995. The need for chemical control of cocoa mirids in Ghana. *Cocoa Pests and Diseases Seminar.* Accra, Ghana.

SALE, P. J. M. 1968. Flushing and leaf growth of cacao under controlled temperature conditions. *Journal of Agricultural Science,* 43**,** 475-489.