Effect of neem azal and neemol on survival, longevity, and development of cocoa shield bug, *Bathycoelia thalassina* (H.-S) (Heteroptera: Pentatomidae), attacking cocoa in Ghana

N. N. AMUNA, D. OBENG-OFORI, B. PADI & E. O. OWUSU

(N. N. A., D. O.-O. & E. O. O.: African Regional Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon; B. P.: Cocoa Research Institute of Ghana, P. O. Box 8, New Tafo, Akim, Ghana)

ABSTRACT

The study assessed the biological activity of neem azal and neemol against nymphs and adults of the shield bug, *Bathycoelia thalassina,* in the laboratory at the Cocoa Research Institute of Ghana. Toxicity of the neem products and their effect on moulting, nymphal survival, development time, adult longevity, and oviposition of the bug were determined at 2.0, 2.5, 3.0, 4.0, 5.0, 7.0 and 10 0 per cent v/v concentration. At 10 per cent v/v concentration, neem azal and neemol shortened the longevity of adult *B. thalassina* to 34 and 49 days, respectively. Neem azal delayed oviposition of the bug until after 26 days, but neemol did not have this effect. Egg laying was generally reduced by both neem products to as low as 12 eggs per female at 10 per cent v/v. Furthermore, neem azal and neemol extended the incubation period of the eggs by 4 days, and reduced percent egg hatchability by 30 and 17 per cent, respectively, compared to the control. Eggs that did not hatch gradually shrivelled and turned black. The neem products disrupted moulting, and nymphs emerging from neem-treated cocoa pods had flexed wings. Development time was prolonged and adult emergence was reduced. All insects exposed to 10 per cent v/v neem azal died after an extended period in the third and fourth instar stages. This study shows that neem azal and neemol can be used to effectively disrupt growth processes in *B. thalassina,* and may have great potential as a component of integrated management of the pest in cocoa production.

RÉSUMÉ

AMUNA, N. N., OBENG-OFORI, D., PADI, B. & OWUSU, E. O.: *Effets d'azal de margousier et de neemol sur la survie, la longévité et le développement du punaise de bois de cacao,* Bathycoelia thalassina *(H.-S.) (Heteroptera: Pentatomidae) attaquant le cacao au Ghana.* Les études au laboratoire se sont déroulées pour évaluer l'activité biologique d'azal de margousier et de neemol contre les nymphes et les adultes du punaise de bois, *Bathycoelia thalassina* à l'Institut de Recherche en Cacao du Ghana. La toxicité de produits de margousier et leur effet sur la mue, la survie de nymphe, la durée du développement, la longévité d'adulte et la ponte du punaise étaient déterminée à 2.0, 2.5, 3.0, 4.0, 5.0, 7.0 et 10.0 pour cent v/v de concentration. A 10 pour cent v/v de concentration, l'azal de margousier et neemol raccouraient la longévité d'adulte *B. thalassina* à 34 et 49 jours respectivement. L'azal de margousier retardait la mue du punaise jusqu'après 26 jours mais neemol n'avait pas cet effet. La ponte d'œuf était réduit en général pas les deux produits de margousier à une faible quantité de 12 œufs par femelle à 10 pour cent v/v. En outre, l'azal de margousier et neemol prolongeait la période d'incubation des œufs par 4 jours et reduisait le pourcentage de la capacité d'éclosion d'œuf respectivement par 30 et 17 pour cent par comparaison avec le contrôle. Les œufs qui ne sont pas éclot se ratatinaient et devenaient noirs graduellement. Les produits de margousier dérangeaient la mue et puis les nymphes sortant de cosse de cacao traitée de margousier avaient des ailes fléchies. Le temps de développement était prolongé et l'apparition d'adulte était reduite. Tous les insectes exposés à 10 pour cent v/v d'azal de margousier mouraient après une période supplémentaire au troisième et quatrième stades intermédiaires. Cette étude révèle que

Original scientific paper. Received 4 Jun 03; revised 9 Feb 04.

l'azal de margousier et neemol pourraient être utilisé pour déranger efficacement les processus de croissance en *B. thalassina* et pourraient avoir beaucoup de potentiel comme un élément de la gestion intégrée de l'insecte ravageur de la production du cacao.

Introduction

The cocoa industry provides employment to many people and brings revenue to countries engaged in its primary production and processing into numerous products (Sasson, 1993). In Ghana, the total area under cocoa production is currently estimated at 1.2 million hectares; and in 1998 and 1999, cocoa provided 26.2 per cent of Ghana's total export earnings (Anon, 2000).

The shield bug, *Bathycoelia thalassina* (H.-S) (Heteroptera: Pentatomidae), has become a serious pest of cocoa in Ghana (Lodos, 1967; Owusu-Manu, 1972, 1974; Padi, Osei Bonsu & Kumah, 1998). Damage to cocoa is restricted to the pods. The insect inserts its stylet through the epidermis of the pod into the developing bean, and the contents are sucked. Growth is arrested in developing pods fed on by *B. thalassina* adults and nymphs, and the pods gradually turn yellow and finally black. The damaged beans develop a characteristic brown colour and subsequently die, leaving empty shells.

National crop losses caused by *B. thalassina* damage have been estimated at 18 per cent (Owusu-Manu, 1972, 1974). However, on farmers' farms of Amazon and hybrid selections, considerable damage of up to 74 per cent can occur (Owusu-Manu, 1972). It has been suggested that the recent rise in the pest status of *B. thalassina* was due to the persistent use of lindane (Gammalin 20) to control cocoa mirids, which probably killed their natural enemies (Owusu-Manu, 1977a); and to the introduction of the Amazon and other hybrid cocoa which fruit all year round (Lodos, 1967; Marchart & Lodos, 1969; Padi *et al.*, 1998).

Lindane and propoxur (Unden 20) are insecticides registered for use against cocoa capsids, and are also presumed to control shield bugs. These chemicals are applied four times in a year in August, September, October, and December; and are alternated every 2 years to reduce the possibility of a pest developing resistance to either chemical. The current trend, however, is towards developing integrated control strategies involving the use of biological control agents, non-synthetic biopesticides, and other environmentally friendly methods combined with judicious use of synthetic pesticides.

Aqueous neem extracts have been tested intensively for use as natural insecticide against a wide range of field and storage pests (Schmutterer, 1995; Dreyer, 1987; Abbiw, 1990; Owusu-Akyaw, 1991; Tanzubil, 1992; Allotey & Dankwah, 1994; Adu-Acheampong, 1997). Home-made preparations of neem products have been used by farmers and researchers to control important field pests in different parts of Ghana (Tanzubil, 1992; Obeng-Ofori & Akuamoah, 1988; Afreh-Nuamah *et al.*, 1988; Akakpo, Obeng-Ofori & Wilson, 2001; Owusu-Ansah *et al.*, 2001; Obeng-Ofori & Ankrah, 2002). Commercial neem products are recent innovations which have been introduced into the Ghanaian market (Foerster & Moser, 2000). These products store well and do not lose their potency as rapidly as the home-made neem products (Foerster & Moser, 2000). Neem may have a potential for use in integrated management of cocoa pests (Adu-Acheampong *et al.*, 2000).

This study evaluates the efficacy of two neem products, neem azal-T/S (containing 1 % azadirachtin) and neemol (containing 0.15 % w/w azadirachtin), against *B. thalassina*. Neem azal was obtained from Trifolio-M GmbH of Germany, and neemol from Shree Minal Oil and Agro Industries Limited of India.

The main objective of the study was to investigate the biological activity of neem azal and neemol against nymphs and newly emerged adults of *B. thalassina*.

Materials and methods

Toxicity tests

The experimental cages were 2-l capacity plastic containers measuring 14 cm × 12.5 cm × 14.5 cm. The lids of the containers had "windows", measuring 5 cm × 4 cm, which were screened with polyvinyl gauze to ensure good ventilation in the cages. Each cage was lined with Whatman No.1 filter paper. Two fresh cocoa pods supported by office pins were placed in each cage to provide food for the insects. The experimental design was completely randomized block design with three replications. Seven concentrations of neemol and neem azal (2.0, 2.5, 3.0, 4.0, 5.0, 7.0 and 10.0 % v/v) were prepared by mixing required quantities of the products with the appropriate quantity of water. One millilitre of 1 per cent soap solution was added to each preparation as an emulsifier.

Ten fifth instar nymphs of *B. thalassina* were placed on the pods inside each cage. By means of a hand-held mist applicator, about 0.8 ml of insecticide solution was sprayed directly on the insects. Care was taken to ensure that each nymph received 0.8 ml of the insecticide solution. In the control treatment, the insects were sprayed with distilled water only. Immediately after the insecticide and distilled water had been applied, the cages were covered with the lids and kept in the insectary. Mortality was recorded after 24 and 30 h. An insect was considered dead when it showed no sign of movement when lightly touched by a camel's hair brush, or when it was found lying on its back without kicking. The experiment was repeated with first instar nymphs.

To assess the effect of neem products on adult longevity and oviposition, five pairs of newly emerged male and female *B. thalassina* were placed on pods inside each cage in the insectary. Different dosages of the products were applied to the insects. Each treatment had four replicates. In the control treatment, the insects were sprayed with distilled water only. Eggs laid by the female shield bugs were counted every 24 h until all the insects died. Mortality and longevity of the adult insects were recorded.

Effect of neem products on moulting of B. thalassina *nymphs*

The experiment was carried out in the insectary and consisted of a glass chimney resting on a Petri dish lined with Whatman No.1 filter paper, 9.0 cm in diameter. Fresh cocoa pods were placed in each chimney to provide food for the insects. To study the effect of the neem products on moulting, 10 newly emerged first instar nymphs of *B. thalassina* were placed in each chimney and sprayed with two squirts of the neem products at the concentrations outlined. In the control, the insects were sprayed with distilled water only. The replicates for each treatment were four. The insects were observed at 12 hourly intervals until all of them died. Mean nymphal longevity and development time from first instar nymph to adult was recorded. To study the effect of the neem-based insecticides on nymphal survival, the method was repeated with 10 insects per cage and replicated seven times.

Effect of insecticides on eggs of B. thalassina

Freshly laid eggs of *B. thalassina* were collected from rearing cages in the insectary with a camel's hair brush. The eggs were placed in a Petri dish lined with 9.0-cm Whatman's No.1 filter paper and sprayed with different concentrations of neem azal and neemol. Using a hand-held mist applicator, 15 eggs were used per treatment; each treatment was replicated three times. The incubation period and the percentage hatchability were recorded daily. Analysis of variance was applied to the data, and treatment means were compared using Fisher's protected Least Significant Difference (LSD).

Results

Toxicity of neem insecticides to nymphs

Table 1 shows the percent mortality of *B. thalassina* recorded by applying increasing doses of neem azal and neemol. Analysis of variance showed significant differences in nymphal mortality between the treatments and control ($P<$ 0.01). After 24 h of exposure of nymphs to the

TABLE 1

Percent Mortality of Nymphs of B. thalassina *24 and 30 h After Treating with Neem Azal and Neemol*

Dosage (% v/v)	*% mortality (h)*			
	First instar		*Fifth instar*	
	24	*30*	*24*	*30*
Neem azal				
2.0	9.4 ± 1.30[b]	22.0 ± 0.61[b]	2.8 ± 0.70[a]	3.6 ± 0.53[b]
2.5	10.9 ± 0.90[b]	22.0 ± 3.39[b]	3.0 ± 0.90[a]	5.0 ± 0.87[b]
3.0	15.3 ± 0.60[c]	34.0 ± 1.91[c]	5.5 ± 1.00[b]	7.5 ± 0.49[c]
4.0	20.2 ± 1.10[d]	48.8 ± 1.70[d]	6.2 ± 0.10[b]	8.0 ± 0.68[c]
5.0	21.3 ± 0.70[d]	66.3 ± 1.10[e]	8.0 ± 1.00[b]	11.7 ± 0.27[d]
7.0	29.3 ± 1.80[e]	68.7 ± 0.81[e]	12.7 ± 1.10[c]	16.3 ± 0.55[e]
10.0	37.5 ± 1.80[f]	73.0 ± 1.12[e]	17.8 ± 0.80[d]	19.0 ± 0.38[f]
Control	1.1 ± 1.20[a]	7.4 ± 1.45[a]	1.1 ± 1.10[a]	1.5 ± 0.96[a]
Neemol				
2.0	7.67 ± 0.60[a]	19.57 ± 0.82[b]	4.77 ± 0.90[b]	5.63 ± 1.42[a]
2.5	12.50 ± 0.60[b]	19.83 ± 0.23[b]	4.83 ± 1.20[b]	7.63 ± 1.12[a]
3.0	14.50 ± 0.50[b]	27.17 ± 0.82[c]	7.00 ± 1.50[b]	9.50 ± 1.71[a]
4.0	15.40 ± 2.60[b]	37.17 ± 0.73[d]	11.43 ± 1.80[b]	12.80 ± 1.99[b]
5.0	21.23 ± 1.10[c]	46.40 ± 0.61[c]	9.83 ± 0.90[b]	12.27 ± 1.19[b]
7.0	25.37 ± 1.60[d]	50.03 ± 1.20[f]	11.90 ± 0.70[b]	14.63 ± 1.87[b]
10.0	29.80 ± 2.20[d]	54.37 ± 0.29[g]	12.57 ± 1.50[b]	15.67 ± 0.84[b]
Control	5.67 ± 0.50[a]	4.13 ± 0.88[a]	0.67 ± 0.70[a]	4.27 ± 0.15[a]

Column means for each instar stage followed by different letter (s) differ significantly from one another ($P< 0.01$), LSD.

neem products, low mortality (2.8–37.5 %) were recorded for the first and fifth instar nymphs. Both neem products were more toxic to first instar nymphs than the fifth instar nymphs. After 30 h, unlike the fifth instar nymphs, mortality of first instar nymphs significantly increased with dosage for both products (Table 1). For example, when the nymphs were treated with 10 per cent v/v neem azal and neemol, 73 and 54 per cent of first instar nymphs were killed after 30 h, respectively. However, at the same concentration, only 19 and 16 per cent mortality were recorded for the fifth instar nymphs for neem azal and neemol, respectively. The LD_{50} values for the neem insecticides on first instar *B. thalassina* were 4.4 per cent v/v for neem azal (Fig. 1) and 7.1 per cent v/v for neemol (Fig. 2).

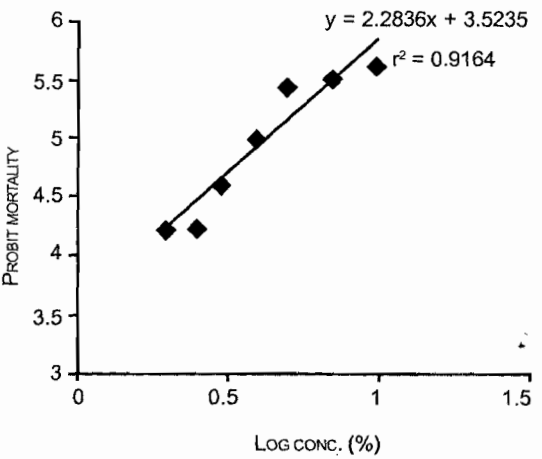

Fig. 1. Response of first instar *B. thalassina* nymphs to various levels of neem azal.

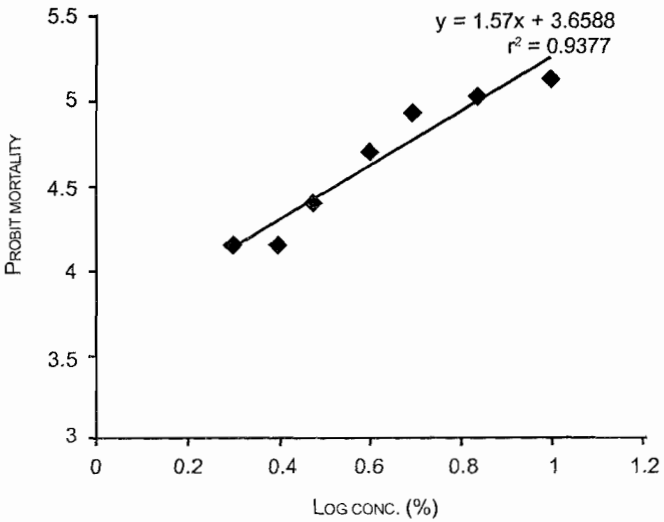

Fig. 2. Response of first instar *B. thalassina* to various levels of neemol.

Longevity and fecundity of B. thalassina

Table 2 shows the effect of the neem products on the longevity of adult *B. thalassina*. *Bathycoelia thalassina* exposed to 4 and 10 per cent v/v of neem azal had adult life span of 55 and 34 days, respectively, compared to mean survival period of 66 days for the control. Neem azal concentrations below 3 per cent v/v had no effect on adult longevity ($P > 0.01$). Neemol also had comparable effects on the longevity of adult *B. thalassina,* with neemol at 3.0 and 10 per cent v/v significantly reducing longevity to 51 and 44 days, respectively. Generally, the response of adult *B. thalassina* to the neem products was dosage-dependent. Furthermore, neem azal and neemol seemed to delay oviposition. Thus, at 10 per cent v/v, oviposition was delayed for nearly 5 and 7 days for neemol and neem azal, respectively (Table 2). Furthermore, neem azal and neemol significantly reduced laying of eggs. At the highest dose of 10 per cent v/v, the number of eggs per female was reduced to 12, and this was significantly different from 40 eggs/female recorded in the control (Table 2). However, the dose/response relationship was not clear-cut. The mean number of eggs laid by untreated *B. thalassina* in this study (40 eggs/female) was, however, lower than the 79 eggs/female reported by Owusu-Manu (1977b).

Ovicidal effect of neem insecticides on eggs of B. thalassina

Table 2 shows the ability of the neem products to prolong incubation period or inhibit hatching of eggs of *B. thalassina.* Generally, treatments with the neem compounds significantly ($P < 0.01$) extended the incubation period of eggs of *B. thalassina* and reduced egg hatchability. At 10 per cent v/v neem azal, 64 per cent of the eggs hatched into nymph, with mean incubation period of 9.9 days. In the control, 95 per cent of the eggs were viable and the incubation period was 5.7 days. Neemol also significantly reduced egg hatchability and extended the incubation period of the eggs.

Insect survival

Table 3 shows the effect of different concentrations of neem products on the survival of nymphs and adult emergence. The two neem products significantly reduced survival of *B. thalassina*, irrespective of the concentrations applied (Table 3). All *B. thalassina* nymphs treated with 7.0 and 10 per cent v/v neem azal died before the fifth and fourth instar stages, respectively (Table 3). Mortality during the first instar stage was higher. The dose/response relationship among the treatments was clear-cut. Many insects that did not survive died during moulting. Adult emergence in the treatments followed a similar pattern (Table 3). Analysis of variance showed that adult emergence was significantly ($P < 0.01$) reduced by the neem products. The effect of neem azal and neemol on *B. thalassina* was dosage-dependent (Table 3). Over 75 per cent of the adults emerged from the untreated control.

TABLE 2

Longevity and Oviposition of Adult B. thalassina *Treated with Different Concentrations of Neem Azal and Neemol*

Dosage (% v/v)	*Mean longevity (days)*	*Eggs/female*	*Pre-oviposition period*	*Mean incubation period*	*% hatchability*
Neem azal					
2.0	64.1 ± 0.9^{c}	32.9 ± 0.7^{d}	18.1 ± 0.4^{a}	6.5 ± 0.5^{b}	76.4 ± 5.7^{b}
2.5	64.6 ± 0.9^{c}	26.7 ± 0.7^{c}	18.1 ± 0.4^{a}	6.7 ± 0.2^{b}	78.8 ± 2.0^{b}
3.0	60.3 ± 4.2^{c}	18.4 ± 0.5^{ab}	19.4 ± 0.9^{ab}	6.9 ± 0.2^{b}	72.3 ± 1.1^{b}
4.0	54.9 ± 0.9^{b}	17.4 ± 0.3^{ab}	20.0 ± 0.9^{ab}	6.7 ± 0.3^{b}	79.0 ± 1.7^{b}
5.0	51.0 ± 0.7^{b}	18.8 ± 1.6^{ab}	22.6 ± 0.7^{bc}	7.6 ± 0.1^{c}	75.5 ± 1.1^{b}
7.0	47.4 ± 0.5^{b}	16.5 ± 0.4^{ab}	23.2 ± 0.6^{bc}	8.8 ± 0.1^{c}	63.1 ± 1.5^{a}
10.0	33.7 ± 0.7^{a}	12.0 ± 0.8^{a}	25.5 ± 1.2^{c}	9.9 ± 0.1^{d}	64.6 ± 1.1^{a}
Control	65.7 ± 2.2^{c}	40.3 ± 2.8^{e}	18.9 ± 1.2^{a}	5.7 ± 0.3^{a}	94.7 ± 2.7^{c}
Neemol					
2.0	63.1 ± 0.8^{c}	18.5 ± 1.6^{a}	18.1 ± 0.6^{a}	6.5 ± 0.3^{b}	93.7 ± 1.2^{c}
2.5	62.2 ± 0.9^{c}	17.5 ± 1.6^{a}	19.0 ± 1.1^{a}	6.7 ± 0.4^{b}	93.1 ± 2.9^{c}
3.0	50.6 ± 1.1^{b}	13.5 ± 1.5^{a}	18.7 ± 0.2^{a}	7.1 ± 0.3^{b}	95.5 ± 2.3^{c}
4.0	49.7 ± 1.8^{b}	12.2 ± 0.9^{a}	20.7 ± 2.1^{ab}	8.0 ± 0.2^{c}	89.3 ± 2.1^{bc}
5.0	49.3 ± 1.4^{b}	13.6 ± 2.5^{a}	20.4 ± 1.0^{ab}	7.9 ± 0.4^{c}	84.3 ± 2.0^{ab}
7.0	49.8 ± 2.2^{b}	12.2 ± 0.9^{a}	20.7 ± 1.2^{ab}	8.7 ± 0.4^{d}	83.1 ± 5.0^{ab}
10.0	43.6 ± 0.8^{a}	12.3 ± 1.3^{a}	23.4 ± 0.4^{b}	9.6 ± 0.2^{d}	77.8 ± 3.4^{a}
Control	62.2 ± 2.1^{c}	42.7 ± 2.9^{b}	18.6 ± 0.5^{a}	5.5 ± 0.3^{a}	95.0 ± 1.8^{c}

Column means followed by different letter(s) differ significantly from each other ($P < 0.01$)

TABLE 3

Survival of B. thalassina *Nymphs Treated with Neem Azal and Neemol*

Dosage (% v/v)	*No. of insects*	*Number of nymphs surviving*					*Nymphs reaching adult stage*	*% adult emergence*
		1st	*2nd*	*3rd*	*4th*	*5th*		
Neem azal								
2.0	70	51	46	44	42	39	37	52.9^{e}
2.5	70	44	41	36	31	28	28	40.0^{d}
3.0	70	34	31	26	21	17	16	22.9^{b}
4.0	70	24	18	15	11	8	7	10.0^{ab}
5.0	70	23	15	12	7	6	4	5.7^{a}
7.0	70	19	12	9	4	0	0	0.0^{a}
10.0	70	17	8	3	0	0	0	0.0^{a}
Control								
Neemol								
2.0	70	54	48	46	44	43	43	61.4^{a}
2.5	70	52	44	40	38	36	35	50.0^{de}
3.0	70	48	44	37	35	34	31	44.3^{de}
4.0	70	41	34	31	31	31	31	44.3^{de}
5.0	70	35	28	24	22	21	18	25.7^{c}
7.0	70	30	23	18	14	13	13	18.6^{bc}
10.0	70	28	19	13	10	11	10	14.3^{b}
Control	70	64	59	58	56	55	53	75.7^{f}

Column means for percent adult emergence followed by different letter (s) are significantly different at $P < 0.01$

Nymphal development

The increase in the development time of *B. thalassina* nymphs exposed to neem azal and neemol was significant ($P < 0.01$) (Table 4). Neem azal and neemol at 10 per cent v/v increased the total nymphal development time by 44 and 17 days, respectively, compared to the controls. Thus, at the higher concentrations, moulting and development to adult were seriously hampered.

Discussion

The results indicate that neem azal and neemol were less toxic to the fifth instar nymphs, but moderately toxic to the first instar nymphs of *B. thalassina*. After 24 h of exposure to neem azal and neemol, most insects had become less mobile and showed reduced activity. Generally, mortality in the neem-treated nymphs was gradual and delayed, and this confirms the findings of other workers that neem products lack the quick knock-down effect invoked by most synthetic pesticides (Arnason *et al.*, 1985; Schmutterer, 1990; Obeng-Ofori & Kelly, 2001; Obeng-Ofori & Ankrah, 2002).

It was also shown in this study that the neem products increased the incubation time of eggs of *B. thalassina* and reduced their percent viability. Neem azal and neemol can, therefore, be used in cocoa farms to reduce the build-up of populations of *B. thalassina*. Increased incubation time and reduction in egg viability by neem oils have been reported in other arthropods including the desert locust, *Schistocerca gregaria* (Schmutterer, 1990, 1995), and several pests of vegetables and fruit trees (Schmutterer & Ascher, 1984; Schmutterer & Hellpap, 1988; Oudejans, 1991).

Mordue & Blackwell (1993) observed that the regulatory effects of azadirachtin on insect growth are remarkably similar among species. Delay or complete inhibition of moulting has been noted in other species of insect nymphs or larvae treated

TABLE 4

Development Time of B. thalassina *Treated with Neem Azal and Neemol*

Dosage (% v/v)	*Duration of instar stages (days)*					*Total nymphal period*
	First	*Second*	*Third*	*Fourth*	*Fifth*	
Neem azal						
2.0	6.0 ± 0.1	8.1 ± 0.1	8.1 ± 0.1	9.8 ± 0.1	13.6 ± 0.1	45.6 ± 0.1^{b}
2.5	6.0 ± 0.1	8.3 ± 0.1	8.1 ± 0.1	10.1 ± 0.1	13.1 ± 0.2	45.6 ± 0.1^{b}
3.0	7.4 ± 0.2	9.1 ± 0.1	8.7 ± 0.1	10.2 ± 0.1	14.3 ± 0.1	49.7 ± 0.1^{c}
4.0	7.4 ± 0.2	10.1 ± 0.2	9.5 ± 0.1	11.9 ± 0.2	15.4 ± 0.4	54.4 ± 0.2^{d}
5.0	8.2 ± 0.1	13.0 ± 0.2	13.2 ± 0.2	14.1 ± 0.3	15.9 ± 0.2	64.4 ± 0.2^{f}
7.0	9.0 ± 0.2	15.0 ± 0.3	16.0 ± 0.1	16.9 ± 0.2	19.5 ± 0.4	76.4 ± 0.2^{g}
10.0	9.5 ± 0.3	15.8 ± 1.1	18.1 ± 0.2	18.3 ± 0.2	23.5 ± 0.4	85.2 ± 0.5^{h}
Control						
Neemol						
2.0	5.3 ± 0.2	6.3 ± 0.1	7.8 ± 0.1	8.5 ± 0.1	12.6 ± 0.3	40.5 ± 0.2^{a}
2.5	5.6 ± 0.1	7.5 ± 0.2	8.1 ± 0.4	8.5 ± 0.2	12.7 ± 0.6	42.4 ± 0.3^{ab}
3.0	6.5 ± 0.1	7.9 ± 0.1	8.2 ± 0.3	8.4 ± 0.2	13.0 ± 0.3	44.0 ± 0.2^{ab}
4.0	6.8 ± 0.3	8.2 ± 0.2	8.7 ± 0.1	8.7 ± 0.2	13.2 ± 0.3	45.6 ± 0.2^{b}
5.0	6.9 ± 0.1	9.0 ± 0.1	10.0 ± 0.3	8.7 ± 0.1	14.9 ± 0.1	49.5 ± 0.1^{c}
7.0	7.2 ± 0.2	12.3 ± 0.2	10.2 ± 0.2	8.9 ± 0.1	15.0 ± 0.4	53.6 ± 0.2^{d}
10.0	7.9 ± 0.2	12.7 ± 0.3	10.5 ± 0.1	10.4 ± 0.4	16.8 ± 0.7	58.3 ± 0.3^{e}
Control	5.5 ± 0.2	7.4 ± 0.1	7.3 ± 0.1	7.8 ± 0.2	13.3 ± 0.2	41.3 ± 0.2^{a}

Column means followed by different letter(s) differ significantly from each other ($P < 0.01$)

with azadirachtin. These insects include *Locusta migratoria* (R. & F) (Sieber & Rembold, 1983), *Periplaneta americana* (L.) (Qadri & Narsaiah, 1978), and *Manduca sexta* (L.) (Schluter, Bidmon & Grewe, 1985). The delay in moulting may be due to disruption of the neuroendocrine control of moulting mediated by azadirachtin and its derivatives (Rembold, 1984; Barnby & Klocke, 1987). It was also stated by Mordue & Blackwell (1993) that the effects of azadirachtin are dose and time-dependent, prevent ecdysis and apolysis, and can cause death before or during moulting and possibly induce "permanent" larvae. Although the nymphs of *B. thalassina* treated with 7.0 and 10.0 per cent v/v neem azal did not survive to reach adult stage, "permanent" nymphal stages were never induced.

It is important to assess the effectiveness of these compounds in the field on a larger scale before any conclusion can be drawn about their practical application. Field studies have shown that neem seed extracts are effective against cocoa mirids (Adu-Acheampong, 1997), but this was not extended to *B. thalassina*. Preliminary results from an ongoing study on the effect of neem azal on cocoa mirids have shown that the product is doing well at 5 per cent v/v (Padi & Adu-Acheampong, 2000; Padi, Adu-Acheampong & Nkansah, 2001).

In any field studies using neem azal and neemol against *B. thalassina*, higher concentrations could be applied and the application of the neem insecticides should be timed to coincide with the peak population of the first instar nymphs, which are most vulnerable. However, in a study of the life cycle of *B. thalassina*, Owusu-Manu (1977b) observed that mortality was highest among the second instar nymphs. Hence, the first and second instars could be targeted for any future studies. The use of neem insecticides against the older nymphs of *B. thalassina* may have little effect.

Field trials in the use of aqueous neem extracts for managing insect pests of cereals, legumes, vegetables, and fruits continue to be conducted by IPM trainers and farmers throughout the country. Farmers are rapidly adopting the use of neem extracts in a variety of crop production systems including irrigated rice, cowpea, pepper, cabbage, okra, eggplant, and onions (Youdeowei, 2000). Indeed, the potential for the use of neem products is high, and farmers need to be educated on the economic and environmental benefits of neem products. As neem seeds are unavailable throughout the year, the availability of potent commercial neem products in the Ghanaian market would facilitate their application to protect crops against pest infestation. It is, however, important to obtain the commercial neem products from a reputable source, as some so-called commercial neem products have been found not to contain the active ingredient, azadirachtin, and, therefore, showed no activity in field trials in Ghana.

In view of the rapid rise in pest status of *B. thalassina* (Owusu-Manu, 1972; Kumar, 1985; Padi *et al.*, 1998), new management strategies are required and these call for intensive research into botanical compounds. The results of this study show that neem insecticides have potential for managing *B. thalassina* attacking cocoa in Ghana. The promising potential for the use of neem seed extract in managing cocoa capsids was reported by Adu-Acheampong (1997) and Adu-Acheampong *et al.* (2000). The ability of neem azal and neemol to control economically important pests such as cocoa capsids and shield bugs is of considerable interest. It will be necessary to monitor the overall effects of neem products on damage of shield bugs, yield, and other factors in the field. Future field studies should also integrate other control strategies with neem azal and neemol to fully explore their practical use in managing *B. thalassina* attacking cocoa in Ghana.

Acknowledgement

The principal author was supported by DAAD, Germany, through the African Postgraduate Programme in Insect Science (ARPPIS), University of Ghana, Legon. The Cocoa Research Institute of Ghana (CRIG), Tafo, provided laboratory facilities and some materials for this work. The staff of CRIG and ARPPIS Office, Legon, assisted

in various ways, and the authors are most grateful to them. They are also thankful to Dr I. Ofori for statistical advice.

REFERENCES

Abbiw, D. K. (1990) *Useful plants of Ghana: West African uses of wild and cultivated plants.* Intermediate Technology Publications and the Royal Botanic Gardens, Kew, UK.

Adu-Acheampong, R. (1997) *Laboratory and field evaluation of neem* (Azadirachta indica *A. Juss) for the management of cocoa mirids (Heteroptera: Miridae)* (M Phil Thesis). University of Ghana, Legon. 66 pp.

Adu-Acheampong, R., Afreh-Nuamah, K., Owusu-Manu, E. & Padi, B. (2000) Field trials on the control of cocoa capsids with an aqueous neem (*Azadirachta indica* A. Juss) seed extract. *Proceedings of an Open Forum organized by the Goethe-Institute.* British Council Hall, Accra, pp. 45-47.

Afreh-Nuamah, K., Kortsen, C., Obeng-Ofori, D. & Ofosu-Budu, K. G. (1998) Laboratory evaluation of the effect of neem seed water extract on oviposition and developmental stages of fruit fly *Ceratitis capitata* Wiedemann (Diptera: Tephritidae). *Paper presented at the First Biennial Agricultural Research Systems (NARS) Workshop.* Accra International Conference Centre, Ghana, 16-20th November, 1998.

Akakpo, A., Obeng-Ofori, D. & Wilson, D. (2001) The use of biopesticides to control insect pests of papaya (*Carica papaya*). *J. Ghana Sci. Assoc.* **3** (3), 117-125.

Allotey, J. K. & Dankwah, J. (1994) Some aspects of the cowpea weevil *C. maculatus* (F.) on cowpea and Bambara groundnut. *Insect Science and Its Applications* **16**(2), 223-228.

Arnason, T. J., Philogene, B. J. R., Oonskov, N., Hudon, M., Mcdougall, C., Fortier, G., Morand, P., Gardne, D., Lambert, J., Morris, C. & Nozzolillo, C. (1985) Anti-feedant and insecticidal properties of azadirachtin to the European corn borer, *Ostrinia nubialis. Entomologia exp. appl.* **38,** 29-34.

Anonymous (2000) *The state of the Ghanaian economy in 1999.* ISSER, University of Ghana. 114 pp.

Barnby, M. A. & Klocke, J. A. (1987) Effects of azadirachtin on the nutrition and development of the tobacco budworm, *Heliothis virescens* (Fabr.) (Noctuidae). *J. Insect Physiol.* **33,** 69-75.

Dreyer, M. (1987) Field and laboratory trials with simple neem products against pests of vegetable and field crops in Togo. *Proceedings of 3rd International Neem Conference.* Nairobi, Kenya, 1986.

Foerster, P. & Moser, G. (2000) *Status report of global neem usage.* Deutsche Gesellschaft fur Technische Zusammenarbiet (GTZ) GmbH. 122 pp.

Kumar, R. (1985) *Insect pest control: With special reference to African agriculture.* Edward Arnold. London. 298 pp.

Lodos, N. (1967) Studies on *Bathycoelia thalassina* (H.-S) (Hemiptera: Pentatomidae), the cause of premature ripening of cocoa pods in Ghana. *Bull. ent. Res.* **57,** 289-299.

Marchart, H. & Lodos, N. (1969) The biology and insecticidal control of the cocoa pod pentatomid, *Bathycoelia thalassina* (H.-S) (Hemiptera: Pentatomidae). *Ghana Jnl agric. Sci.* **2,** 31-37.

Mordue, A. J. & Blackwell, A. (1993) Azadiractin: An update. *J. Insect Physiol.* **39,** 903- 924.

Obeng-Ofori, D. & Akuamoah, R. K. (1998) An overview of neem research in Ghana. *Proceedings of a Seminar on the Potentials of the Neem Tree in Ghana.* Dodowa. October, 1998. pp. 33-37.

Obeng-Ofori, D. & Kelly, M. P. (2001) Managing pests of fresh bean (*Phaseolus vulgaris* L.) with a non-synthetic insecticide. *J. Ghana Sci. Assoc.* **2**(3), 209-217.

Obeng-Ofori, D. & Ankrah, D. A. (2002) Effectiveness of aqueous neem extracts for the control of insect pests of cabbage (*Brassica oleracea* var. *capitata* L.) in the Accra Plains of Ghana. *Agric. Fd Sci. J. Ghana* **1,** 83-94.

Oudejans, J. K. (1991) *Agro-pesticides: Properties and functions in integrated crop protection.* United Nations Economic and Social Commission for Asia and the Pacific, Agriculture Division, Bangkok.

Owusu-Akyaw, M. (1991) Evaluation of plant products for the control of cowpea and maize storage insects. *Proceedings of Joint SAFGRAD Research Network Workshop.* Niamey, Niger. pp. 8-11.

Owusu-Ansah, F., Afreh-Nuamah, K., Obeng-Ofori, D. & Ofosu-Budu, K. G. (2001) Managing infestation levels of major insect pests of garden eggs (*Solanum integrifolium* L.) with aqueous neem seed extracts. *J. Ghana Sci. Assoc.* **3**(3), 70-84.

Owusu-Manu, E. (1972) The biology and control of *Bathycoelia thalassina* (H.-S) (Hemiptera: Pentatomidae): A pest of cocoa in Ghana. *Proceedings of the 4th International Cocoa Research Conference.* Trinidad, 1972. pp. 539-547.

Owusu-Manu, E. (1974) *Biology of* Bathycoelia thalassina *(H.-S) (Heteroptera: Pentatomidae), a pest of cocoa in Ghana* (Ph D Thesis). University of Ghana, Legon. 83 pp.

Owusu-Manu, E. (1977a) Possibilities of integrated control of *Bathycoelia thalassina. Proceedings of the 5th International Cocoa Research Conference,* 1975. pp. 485-490.

Owusu-Manu, E. (1977b) Notes on some factors influencing egg production and development in *Bathycoelia thalassina* (H.-S) (Hemiptera: Pentatomidae). *J. nat. Hist.* **11**(4), 425-444.

Padi, B., Osei Bonsu & Kumah, N. K. (1998) Relative abundance of *Bathycoelia thalassina* (H.-S) (Heteroptera: Pentatomidae) and *Pseudotheraptus devastans* (Dist.) (Heteroptera: Coreidae) and their damage on shaded and unshaded hybrid cocoa. *Proceedings of the 2nd Pests and Diseases Seminar.* Yamoussoukro, Cote d' Ivoire, 9 pp.

Padi, B. & Adu-Acheampong, R. (2000) *Preliminary results on laboratory and field tests on neem azal for cocoa capsid control in Ghana* (ed. A. K. Brimah). *Proceedings of the Open Forum organized by the Goethe-Institute.* British Council Hall, Accra. pp. 52 –53.

Padi, B., Adu-Acheampong, R. & Nkansah, A. (2001) Screening of botanical pesticides for the control of cocoa capsids (Heteroptera: Miridae). *Cocoa Research Institute of Ghana Progress Report for 2000–2001.* 4 pp.

Qadri, S. S. H. & Narsaiah, J. (1978) Effects of azadirachtin on the moulting process of last instar nymphs of *Periplaneta americana* (Linn). *Indian J. exp. Biol.* **16,** 1141-1143.

Rembold, H. (1984) Secondary plant products in insect control, with special reference to the azadirachtins. In *Advances in invertebrate reproduction* (ed. W. Engels *et al.*) **3,** 481-491. Elsevier, Amsterdam.

Sasson, A. (1993) Biotechnologies in developing countries: Present and future. *Vol. 1 UNESCO Publ.,* 764 pp.

Schluter, U., Bidmon, H.-J. & Grewe, S. (1985) Azadirachtin affects growth and endocrine events in larvae of the tobacco hornworm, *Manduca Sexta. J. Insect Physiol.* **31,** 773-777.

Schmutterer, H. & Ascher, K. R. S. (1984) Natural pesticides from the neem tree and other tropical plants. *Proceedings of the 2nd International Neem Conference.* Rauischholzhausen, Germany.

Schmutterer, H. & Hellpap, C. (1988) Effects of neem on pests of vegetables and fruit trees. In *The neem tree,* pp. 69-88.

Schmutterer, H. (1990) Properties and potential of natural pesticides from the neem tree, *Azadirachta indica. A. Rev. Ent.* **89,** 179-188.

Schmutterer, H. (1995) *The neem tree: Source of unique natural products for integrated pest management, medicine, industry and other purposes.* VCH Publ., Weinhein, New York, Basel, Cambridge, Tokyo, 696 pp.

Sieber, K. P. & Rembold, H. (1983) The effects of azadirachtin on the endocrine control of moulting in *Locusta migratoria. J. Insect Physiol.* **29,** 523-527.

Tanzubil, P. B. (1992) Control of some insect pests of cowpea (*Vigna unguiculata*) with neem, *Azadirachta indica*, in northern Ghana. *Trop. Pest Mgmt* **37,** 216-217.