Parasitism of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) Populations on Cabbage *Brassica oleracea* var. *capitata* (L.) by *Cotesia plutellae* (Kurdjumov) (Hymenoptera: Braconidae) in Ghana

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Abstract

The study was carried out at the Weija Irrigation Company site at Weija, in the Greater Accra Region of Ghana, to determine the seasonal abundance of the major parasitoid of *Plutella xylostella* (L.) populations on cabbage, *Brassica oleracea* var. *capitata* (L.) during the rainy and the dry seasons. The results indicated that *Cotesia plutellae* (Kurdjumov) was the most abundant and important parasitoid of *P. xylostella* on cabbage. It accounted for about 92% of the parasitoids, and occurred in all the three seasons of planting. The rest consisted of four facultative hyperparasitoids: *Oomyzus sokolowskii, Aphanogmus reticulatus, Elasmus* sp. and a *Trichomalopsis* sp., and two primary parasitoids, *Pediobius* sp. and *Hockeria* sp. A significantly higher rate of parasitism (68.6 ± 12.9%, $P < 0.05$) of *P. xylostella* by *C. plutellae* occurred during the major rainy season and the least (9.9 ± 7.1) in the minor rainy season. *Cotesia plutellae* acted in a density dependent manner, and its numbers increased as that of the host in all three seasons. The coefficient of correlation was highest in the major rainy season ($r = 0.97$) with a coefficient of determination of 0.97. In the minor rainy season $r = 0.55$, and in the dry season $r = 0.66$. The annual coefficient of correlation was $r = 0.51$ and the coefficient of determination = 0.262. Hence, in an annual production of cabbage, 26.2% of the variation in parasitism was due to the variation in the number of *P. xylostella*. The results, therefore, indicate that *C. plutellae* can be used in the development of an integrated pest management programme (IPMP), against *P. xylostella* in Ghana.

Introduction

The most damaging pests of the crucifer *Brassica oleracea* (L.) are the Lepidopteran species: *Plutella xylostella* (L.), *Pieris rapae* (L.), *Trichoplusia ni* (Hbn.) and *Hellula undalis* (F.) (Anene & Dike, 1996; Pratisolli *et al*., 2008). However, *P. xylostella,* commonly known as the diamondback moth, is cosmopolitan, and it is considered the most important worldwide, causing production losses of up to 60% (Obeng-Ofori *et al*., 2007; Pratissoli *et al.,* 2008). For this reason, insecticides are frequently applied on cabbage in order to produce marketable heads. This practice has led to the development of multiple resistance by *P. xylostella* to virtually every insecticide in use worldwide (Abdel-Razek *et al.,* 2006).

In order to address this problem, the use of biological control agents and the development of integrated pest management (IPM) programmes are considered as options to reduce insecticide use in the control of this pest (Hill & Foster, 2000; Abdel-Razek *et al.,* 2006; Pratissoli *et al.,* 2008).

There is no documented evidence as to

when cabbage was introduced into Ghana. It is, however, believed to have been cultivated in the country as far back as the 1940's by the British (Sinnadurai, 1992). It is produced throughout the country, but of less importance in the Upper East Region (Timbilla & Nyarko, 2004). In the forest zone, it tends to grow better in the minor rainy season, but on the Accra Plains, better yields are obtained during the major rainy season. It does remarkably well at cooler mountainous areas of the country such as Akwapim and Kwahu, and the moist high elevations around Tarkwa in the Western Region (Bangnikon, 1996).

Cultivars suitable for production in Ghana are Copenhagen Market, Drumhead, Suttons Tropical, Japanese Hybrid Cabbage, Golden Acre, Suttons Pride of the Market, KK Cross, Oxylus and Marion. The yield can vary from 18,000 kg ha^{-1} for an early maturing variety and 26,000 kg ha^{-1} for late cultivar (Obeng-Ofori *et al.,* 2007). Despite the intensive use of insecticides in the cabbage ecosystem, there is very little control. There are several instances when whole crops had been lost to *P. xylostella,* and farmers have had to prematurely harvest their cabbage or abandon their farms (Cobblah, unpublished).

There is increasing evidence of significant pest control by biological control agents in various countries (Liu *et al.,* 2002; Mahar *et al.,* 2004). There have been attempts at combining various strategies centred on biopesticides and plant products to control *P. xylostella* in Ghana (Obeng-Ofori & Ankrah, 2002; Youdeowei, 2002). However, there has been no development and implementation of biological control-based IPM of *P. xylostella* on cabbage, and very little is known regarding its parasitoids in Ghana (Obeng-Ofori, 2000).

The objective of the study was to determine the importance and seasonal abundance of the major parasitoid of *P. xylostella* populations, on the common cabbage *Brassica oleracea* var. capitata (L.) in Ghana to form the basis for development of an IPMP for *P. xylostella.*

Materials and methods

The experimental site was at the Weija Irrigation Company (WEICO) near Weija in the Greater Accra Region, situated at 5° 31' N and 0° 21' W near the coast of the Atlantic Ocean. The average minimum and maximum temperatures were 23 °C and 31 °C, respectively, and relative humidity ranged from 31% to 62%, with an average of 44%.

The experiments were carried out from April 1996 to April 1997. Four weeks old cabbage seedlings of the variety K.K cross were planted three times during the period in the major rainy season (May–July), minor rainy season (October–December) and the dry season (January–March) in Ghana. The plants were grown under irrigation. Fertiliser use included a split application of 450 kg/ha of 15:15:15 NPK at 7 days and 27 days after transplanting as recommended by Sinnadurai (1992). A single dose of sulphate of ammonium at 250 kg/ha was applied 34 days after transplanting. There were four plots and each plot measured 4.2 m by 2.3 m. Each plot had three rows of cabbage plants with seven per row. The plant spacing was 60 cm within rows and 75 cm between rows. No insecticides were applied on the plots.

Sampling of insects

Weekly sampling of *Plutella xylostella* was done 18–19 days after transplanting till maturity of the cabbage. The five upper leaves, the bud and the two leaves surrounding it were sampled for each of the seven central plants per plot. A Camel's hair brush was used to collect all *P. xylostella* larvae into petri dishes, lined with filter paper and a piece of cabbage leaf. Each week's sample was transported to the laboratory, and the numbers were recorded.

In the laboratory, the larvae were separated singly into petri-dishes and a fresh piece of cabbage leaf added. The leaves and petri-dishes were replaced every day until pupation of *P. xylostella* or the parasitoid larvae emerged from the host. Pupae of *P. xylostella* and those of the parasitoid were put singly in glass tubes plugged with cotton wool until emergence of moths or adult parasitoids. The duration from when the larvae of *P. xylostella* were collected and the larvae of the parasitoid emerged was recorded for each season.

In addition, the interval between the collection of host larvae and pupation was recorded. The pupal periods and the adult emergence rates of the parasitoid were calculated for each season. Dead host larvae were dissected daily to determine whether they were parasitized or not. Thus, parasitism was obtained from both rearing and dissections of hosts ((Waage & Cherry, 1992; Day, 1994). All insects, were maintained at a temperature of 23 ± 2 °C and relative humidity of 45 ± 1.0% in the laboratory.

Weekly percentage parasitism of *P. xylostella* was calculated for all samples using the conventional methods (Waage & Cherry, 1992) as opposed to the recruitment method, suggested by Van Driesche *et al.* (1991). The parasitoids were identified at CABI Bioscience, United Kingdom. Voucher specimens have been deposited in the Entomology Museum of the Department of Animal Biology and Conservation Science, University of Ghana.

Statistical analysis

ANOVA was used to analyse the data on seasonal abundance and parasitism of *P. xylostella* by *C. plutellae* and pupal duration as well as adult emergence rates of the latter. Duncans' multiple range test was used for mean separation. Pearson correlation was used to determine the relationship between *P. xylostella* and *C. plutellae*. All analyses were done at 0.05 confidence level. The analyses were done with the Statistical Programme for the Social Sciences (SPSS) version16 software.

Results and discussion

The number of *Plutella xylostella* larvae sampled varied from 0–30 per week depending upon the season and the age of the cabbage plants. During the major rainy season and the minor rainy season, 68 and 70 larvae were sampled, respectively. In the dry season, a total of 108 larvae were sampled. A total of seven species of parasitoids and hyperparasitoids were recorded from *P. xylostella*.

Cotesia plutellae was the most abundant parasitoid in all the three seasons and accounted for about 92% of all parasitoids recorded from *P. xylostella* on cabbage at the experimental site. The rest consisted of facultative hyperparasitoids (7%) such as *Oomyzus sokolowskii, Aphanogmus reticulatus, Elasmus* sp. and a *Trichomalopsis* sp., and two primary parasitoids, *Pediobius* sp. and *Hockeria* sp.

Morallo-Rejesus & Sayaboc (1992) noted that hyperparasitoids could reduce effectiveness of *C. plutellae*. However, other workers (Mustata, 1992; Liu *et al.,* 2000; Mahmood, 2004) observed that hyperparasitoids are of little significance and of no economic impact. Thus, the hyperparasitoids recorded in this study may not negatively affect the importance of *C. plutellae* in regulating *P. xylostella* populations on cabbage, as their occurrence was low, and they were facultative species.

The duration for *Cotesia plutellae* larvae to emerge from *Plutella xylostella* larvae ranged between 1 and 10 days (Table 1). In the major and minor rainy seasons, most of the parasitoid larvae emerged after day one (61% and 43%, respectively). In the dry season, the highest emergence (38%) was on day 2. *Cotesia plutellae* larvae pupated within 24 h after emergence from the host. Mean duration of parasitoid pupal stage was 4.66 ± 0.21, 4.71 ± 0.13 and 4.60 ± 0.23 days for the major rainy, minor rainy and dry seasons, respectively, with no significant difference ($P > 0.05$). The proportion of *C. plutellae* adults that eventually emerged from the field parasitized *P. xylostella* was high in all the three seasons (major rainy season, 79.17 ± 10.63; minor rainy season, 75.00 ± 25.00; dry season, 80.18 ± 10.49). There was no significant difference ($P > 0.05$) among them. These results suggest that the parasitoid can be quite easily obtained from field samples of the host and a method for mass production developed for release to control *P. xylostella* on cabbage in Ghana. In parts of Asia and Central America, *C. plutellae* has been reared and introduced in combination with other methods to control the pest (Talekar, 1992). Depending upon the age of *P. xylostella* larvae collected from the field, pupation started from between 2–12 days in the laboratory.

Cotesia plutellae exhibited a wide seasonal variation in parasitism of *P. xylostella* (Fig. 1). This was also observed by Liu *et al*. (2000) in China, and Rowell *et al* (2005) in Thailand. Mean percentage parasitism of *P. xylostella* was significantly higher during the major rainy season (68.6% ± 6, $P < 0.05$) and least during the minor rainy season (9.9% ± 7.1), and not significantly different ($P > 0.05$) between major rainy season and the dry season contrary to findings by Yadav *et al* (1974). Problems with estimates of rates of parasitism of *P. xylostella* were discussed by Waage & Cherry (1992). The conventional method of determining rates of parasitism used in this study as opposed to the

TABLE 1

Emergence of Cotesia plutellae *larvae from field collected* Plutella xylostella *larvae in the three seasons*

	Parasitoid emergence from host larvae		
Season	*Earliest emergence*	*Latest emergence*	*Highest emergence*
Major rainy (N=28)	1 (61%)	5 (4%)	1 (61%)
Minor rainy (N=21)	1 (43%)	5 (19%)	1 (43%)
Dry (N=23)	1 (25%)	10 (4%)	2 (38%)

Values in parentheses are percentage emergence on those days.

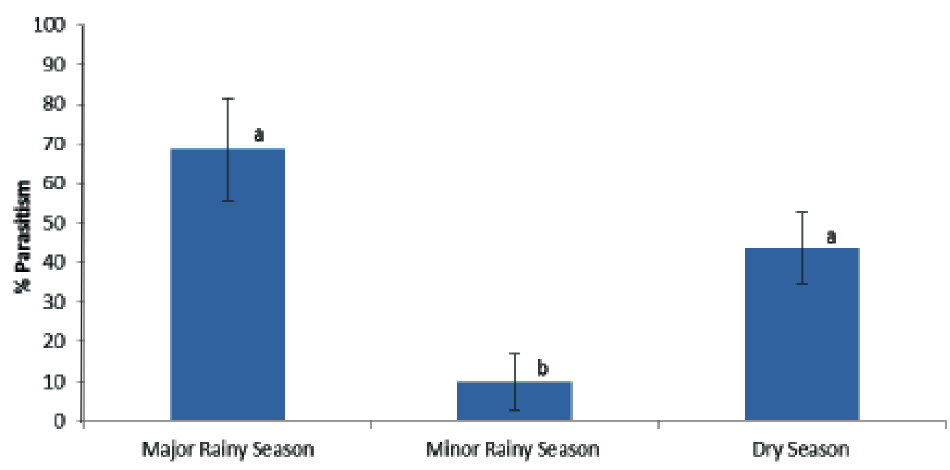

Fig. 1. Seasonal variation in mean percentage parasitism rates of *P. xylostella* by *C. plutellae.* Bars with same alphabets are not significantly different at the 5% confidence level, Duncan's multiple range test.

recruitment method suggested by Van Driesch (1991) has been thoroughly discussed by Liu *et al.* (2000) and shown to provide a good indicator of general pattern of seasonal abundance.

Population build-up of *C. plutellae* in relation to the diamondback moth on cabbage was density dependent relationship as observed by Goodwin (1979). Cock (1985), and Alam (1992), where increase in diamondback moth numbers resulted in corresponding increase in parasitism. There was a distinct time lag of 1–2 weeks in the major rainy and minor rainy seasons (Fig**.** 2 and 3) after which parasitism became closely synchronized with host numbers from 25 days after transplanting (DAT) in the former season.

Apart from the effects of parasitism, drowning in water collected on cabbage leaves after rains or washing off of larvae contributed to the lower densities of the larvae in the major rainy season. Sampling after rainy days yielded no larvae. Rains have been reported to be an important mortality factor in diamondback moth populations (Hardy, 1938; Harcourt, 1963; Wakisaka *et al*., 1992; Capinera, 2005). The initial time lag between *C. plutellae* and the Ghanaian populations of the diamondback moth during the two rainy seasons could be attributed to the very low numbers of the diamondback moth early in the crop season.

Hu *et al.* (1997) and Mitchell *et al.* (1997) considered this parasitoid inefficient because of its poor searching ability when pest populations were low. Nevertheless, the ability of *C. plutellae* to increase with increasing pest numbers makes it a good candidate for biological control and development of an integrated pest management programme for *P. xylostella* on cabbage in Ghana. In the dry season, there was no time lag between host numbers and parasitism (Fig. 4), and parasitism rates also increased as diamondback numbers increased.

The association between diamondback

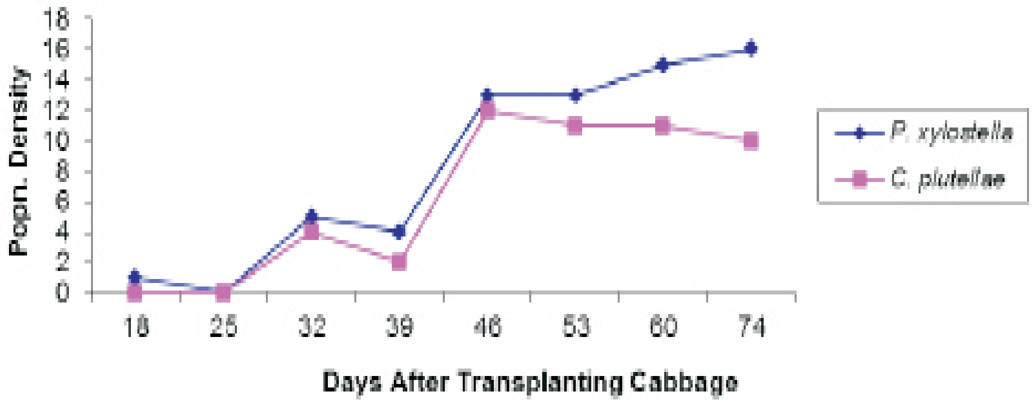

Fig 2. Population dynamics of *C. plutellae* in relation to *P. xylostella* in the major rainy season

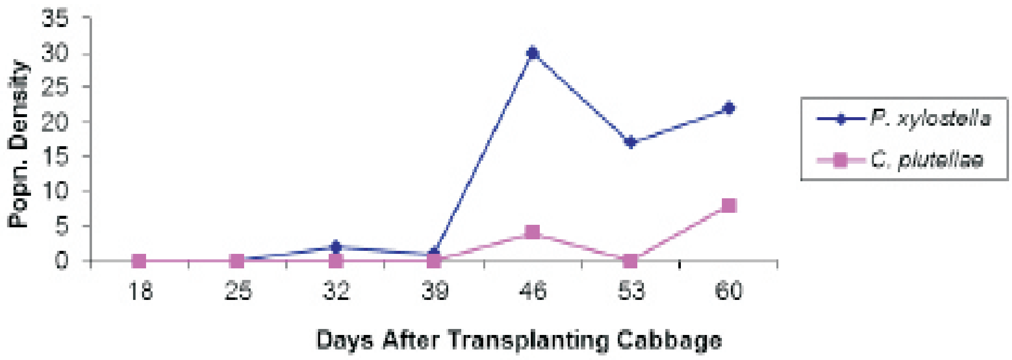

Fig. 3. Population dynamics of *C. plutellae* in relation to *P. xylostella* in the minor rainy season

moth numbers and parasitism was strongest in the major rainy season (Table 2). The correlation coefficient, *r,* between diamondback moth numbers and parasitism during the major rainy season was 0.97 whilst in the minor season it was 0.55. In the dry season the correlation coefficient was 0.66. The coefficient of determination ($R^2 = r^2$), which is defined as the variation in parasitism that is dependent on the variation in diamondback moth numbers, was 0.94 in the major rainy season, signifying that 94.3% of the variation in parasitism were due to the variation in diamondback moth numbers. In the minor rainy season and dry season 30.8% and 44.0% of the variation in parasitism were due to variation in diamondback moth numbers, respectively. The correlation coefficient between diamondback moth numbers and parasitism in the three seasons was 0.51. The positive correlation between diamondback moth populations and

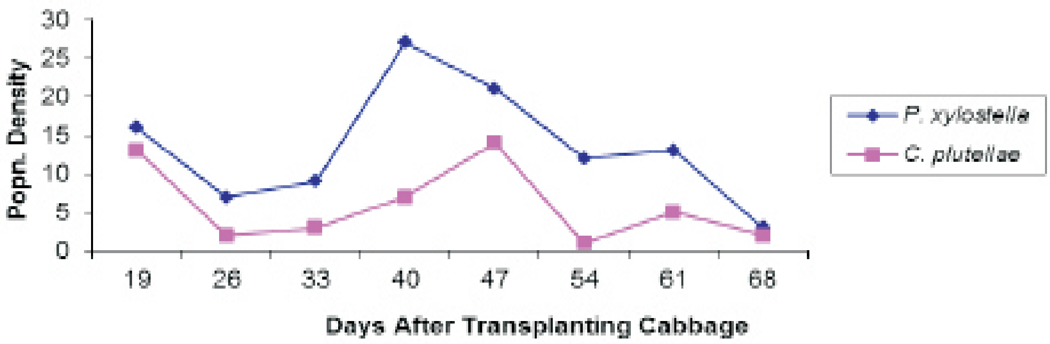

Fig. 4. Population dynamics of *C. plutellae* in relation to *P. xylostella* in the dry season

TABLE 2

Correlation between parasitism of P. xylostella populations by C. plutellae in the three seasons

Season	*Coefficient of correlation*	*Coefficient of determination*
Major rainy	0.97*	0.94
Minor rainy	0.55*	0.31
Dry	0.66*	0.44
All three seasons	0.51*	0.26

* Significant difference at the 0.05 confidence level. Pearson's correlation

parasitism by *C. plutellae* in all three seasons of planting, undoubtedly, suggests that an IPM strategy can be developed for *P. xylostella* in Ghana.

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