International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 21, No. 2, p. 34-42, 2022

RESEARCH PAPER OPEN ACCESS

Morphological description and population dynamic of *Spodoptera littoralis* (Boisduval, 1833) (Lepidoptera: Noctuidae)'s parasitoid on cabbage in South Côte d'Ivoire

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Key words: Cabbage, Population dynamic, *S. littotalis*, Parasitoids, Côte d'Ivoire.

http://dx.doi.org/10.12692/ijb/21.2.34-42 Article published on August 10, 2022

Abstract

The Egyptian cotton leafworm *Spodoptera littoralis* Boisduval (Lepidoptera: Noctuidae) is among the serious cabbage pests in tropical countries. It can lead an intensive chemical insecticides use in market gardening perimeters. Alternative control methods such as biological control are necessary for the integrated management of this pest. The laboratory rearing of *S. littoralis* larvae sampled in the cabbage fields has been undertaken and the presence of parasitoids has been noticed. The population dynamic of *S. littoralis* larvae and these parasitoids has been studied in two market gardening perimeters on two crop cycles. The parasitoids of *S. littoralis* larvae are *Apanteles* sp, the hymenopterans belonging to the Braconids family, and the Microgastrin subfamily. Strong populations of *Apanteles* sp. involve weak populations of *S. littoralis* and weak populations of *Apanteles* sp. involve strong populations of *S. littoralis*. However, the correlations between *Apanteles* sp. adult's number and *S. littoralis* larvae per ten plants are not significant for the crop cycles in all the sites. These parasitoids can be nevertheless taken to account for the integrated management program of *S. littoralis*. Identification of this insect up to the species could be undertaken for future studies.

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Introduction

The noctuid *Spodoptera littoralis* Boisduval (Lepidoptera: Noctuidae) is one of the most destructive insect pests of several crops in the Mediterranean region, Middle East, and Africa (El-Aswad *et al*., 2003). Over the past 25 years, the intensive use of broad-spectrum insecticides against *S. littoralis* has led to the development of resistance to many registered pesticides for its control (Smagghe *et al*., 1999, Aydin and Gürkan, 2006). Increasing concern about pesticide accumulation in the environment stimulates the search for alternatives that could replace synthetic insecticides in insect pest control. Biological control using braconid hymenopterans is a promising alternative control method against *S. littoralis* which is among the serious cabbage pests in Abidjan District in Ivory Coast (Douan *et al*., 2013). An increased interest in biological control using parasitoids has been noted in recent years. One example is the use of the parasitoid *Telenomus remus* against the armyworm *Spodoptera frugiperda* (Kenis *et al*., 2019). Microgastrin Braconid wasps are also abundant, diverse endoparasitoids of caterpillars throughout essentially all terrestrial habitats on the globe. As a consequence, they have figured strongly in countless ecological and agricultural studies including over 100 pest biological control projects (Whitfield *et al.,* 2009). *S. littoralis* is parasitized by braconids such as *Microplitis rufiventris* Kukujev (Hymenopera: Braconidae), *Apanteles* sp, *Glyptapanteles* sp (Hegazi and Führer, 1985; Ketipearchchi, 2002; Khafagi et Hegazi, 2004). Cases of parasitism of Lepidoptera caterpillars by Braconids are numerous (Cochereau, 1991, Shaw and Hurdleston, 1991cited by Johansen, 2010, Khafagi and Hegazi, 2004, Murúa *et al.,* 2006, Murúa *et al*., 2009, Whitfield *et al*., 2009). Microgastrins disrupt the biology of their host caterpillars in highly specific ways; they have also been used as tools for studying insect nutritional physiology, endocrinology, and immunology (Beckage and Gelman, 2004). Because of their relatively small body size (1.5 – 4.0mm), Microgastrins have, for the most part, been ignored by general entomologists. Thousands of species remain to be described. The situation is not different in west Africa in general and in Ivory in particular, where information concerning microgastrin wasps is rare.

Our objective for this research is to compare the population dynamic of *S. littoralis* and a Braconid Microgastrin Hymenoptera *Apanteles* sp., its larval parasitoid on cabbage on two market gardening perimeters in Abidjan District in South Côte d'Ivoire.

Material and methods

Number of S. littoralis larvae /10 plants

Direct and manual counting has been undertaken. It consists in counting the number of *S. littoralis* larvae on the sheets of ten seedlings taken randomly and marked according to a zig-zag line by plot (Fournier *et al*., 1994; Hines and Hutchison, 2001; Hamilton *et al*., 2004; Martin *et al*., 2006; Hamilton *et al*., 2009). Direct counting has been carried out once per week on each site (Keasar *et al*., 2005). The last nine visits of each plot are paid, 3 weeks after transplanting until harvest. Fifty plants are visited per week for 5 plots on each market gardening perimeter. A plot was a balk measuring 6 m in length and 1 m in width. We have three cabbage lines by plot and two cabbage plants are distant 40 cm or 39 plants per plot.

Trapping system

The trapping device was composed of two traps separated by 2 m on each plot. There were 20 traps. The traps are visited twice a week to record the number of trapped parasitoïds.

Rearing

The larvae collected on the ground were also brought to the laboratory and reared under environmental conditions. They were kept in bottles containing the cabbage leaves and closed with muslin to prevent the entry of any insect coming from outside. These larvae were observed daily and the presence of parasitoïds left in the larvae was noted (Ketipearachchi, 2002).

Conservation and Identification

The sampled parasitoïds were preserved in bottles and Eppendorfs in 70% alcohol. Each container carried indications of the study site and harvest day. A surmounted binocular magnifying glass of a camera of *AmScope* mark allowed the enlargement of the insects before identification.

The identification at the family and subfamily level has been undertaken. The identification keys used are those of Delvare et Aberlenc (1989), Sigwalt et Pointel (1980), Whitfield *et al.* (2001) et Whitfield *et al.* (2009) and Johansen (2010).

Statistical analysis

We had an ANOVA at an Intra-Subject factor (Week after transplanting) with 9 levels (3, 4, 5, 6, 7, 8, 9, 10, 11 weeks). The dependent variable in this study was the number of *S. littoralis* larvae per 10 plants. The Friedman ANOVA test, a nonparametric equivalent of the Intra-Subject ANOVA, was used in case of heterogeneity of the variances. It allowed the numbers of larvae to be grouped according to the weeks after transplanting.

These analyzes were done using the IBM SPSS Statistics 20 software. The diagrams and the equations of the regression lines and the correlation coefficients were made using Excel software.

Results

Parasitoid

The parasitoids that emerged from these larvae taken in the field and put in the breeding laboratory have been identified. Seen profile, the head has a black color and presents a round form at the level of the vertex and occiput. The oral parts seen under this angle are directed to the bottom perpendicular to the axis of the insect body.

Table 1. Relationship between the number of adults of trapped *Apanteles* sp. (y) and the number of *S. littoralis* larvae / 10 cabbage plants (x).

Crop cycle	Equation of the regression line	Coefficient of correlation (r)	Significance Degree (p)
C1 Bg1	y = - 33.47 x + 57.16	- 0.12	0.76 ns
C1 Bg2	y = - 0.004 x + 0.513	- 0.13	0.72 ns
C2 Bg1	y = 2.75 x + 0.927	0.58	0.1 ns
C2 Bg2	*	*	*

C1 Bg1 : First Crop cycle on Site 1 ; C1 Bg2 : First Crop cycle on Site 2; C2 Bg1 : Second Crop cycle on Site 1; C2 Bg2 : Second Crop cycle on Site 2.

* : no *Apanteles* sp. adult individuals of was trapped.

The head is thus orthognathous (Fig. 1). This sight of the head shows prominence due to the two compound eyes. The antennas are thread-like, of black color, and have 16 articles (Fig. 2).

The thorax has a black color, an ovoid form, and carries legs of yellow-brown color (Fig. 1). The former wings show ribs such as : a C + Sc + R rib which is the result of Costales (C), Subcostal (Sc), and Radial (R) ribs fusion; a M + Cu1 rib below the first is the result of Median and Cubital ribs fusion; a median rib (M) which forms a triangle with the first two cited; an Anal rib (1A) below the C + Sc + R and M + Cu1 ribs; mid rib (M) and Cu1, results of the bifurcation of the M + Cu1 rib; a Cubito-anal (Cu-a) rib which joins Cu1 and 1A ribs; a medio-cubital rib m-cu which is the continuity of the rib Cu1; a rib SR + M, resulting from M and Radial Sector (RS) ribs; a transverse radial rib (r), continuity of R rib. The r rib is longer than RS and both form an obtuse angle. There is also a brown triangular form ptérostigma with a black higher edge (Fig. 3).

The abdomen is oval and of brown color. It ends in a metasoma. It comes out from these studies that these parasitoïds are Hymenopterans belonging to the Braconids Family, the Microgastrin Subfamily, and *Apanteles* Genus. Those are *Apanteles* sp.

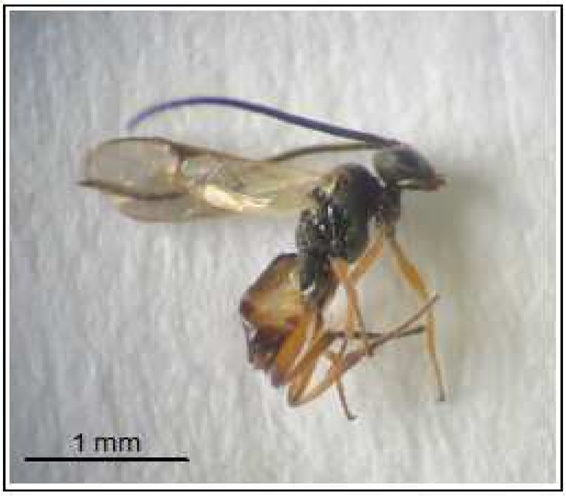

Fig. 1. *Apanteles sp*. profile view.

Study of population dynamics of S. littoralis and Apanteles sp.

On site I, during the first crop cycle, an impressive number of individuals of *Apanteles* sp. are trapped. A total of 481 individuals were trapped, including 225, nine weeks after transplanting. In contrast, a small number of S. *littoralis* larvae per ten statistically different plants (p> 0.05) was recorded. In the second cycle, a reduction in the number of individuals of *Apanteles* sp. trapped is noted in relation to the first crop cycle. 43 individuals of which 21 on the seventh day after transplanting are trapped. Larval numbers of *S. littoralis* up to 4 hoppers / 10 plants are observed but are not statistically significant (p > 0.05) (Fig. 4).

On site II, at the first crop cycle, only 4 individuals of *Apanteles* sp. are trapped, while a large population of *S. littoralis* larva is recorded up to 57.8 larvae / 10 plants. The numbers of *S. littoralis* larvae recorded at 6, 7, and 8 weeks after transplant were statistically equal (p> 0.05) but higher than those at 3, 4, 5, 9, 10, and 11 weeks after transplanting (p < 0.05). In the 2nd cycle, no individual of *Apanteles* sp. is not trapped. In addition, *S. littoralis* populations up to 2.4 larvae / 10 plants do not differ in weeks (p> 0.05) (Fig. 4).

The study of the relationship between the number of adults of the parasitoid trapped and the number of larvae of *S. littoralis* / 10 plants has shown that negative correlations exist between these two variables at the level of two of the four crop cycles.

The first two crop cycles recorded negative correlations (- 0.12 on Sites I and - 0.13 on Sites II). The correlation between these two variables is positive (0.58) for the second crop cycle on site I. However, these correlations are not significant (Table 1).

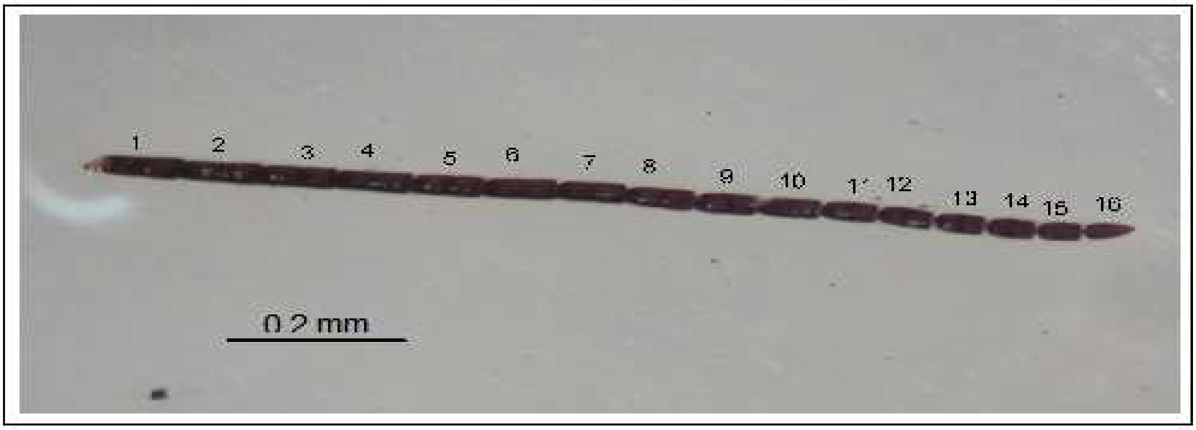

Fig. 2. Antenna of *Apanteles* sp.

Discussion

The identification key of Delvare and Aberlenc (1989) identified parasitoid I as belonging to the order Hymenoptera and the Braconids family. These same authors claim that Braconids are parasitoids of various insects. This confirms our data concerning the presence of this insect in some of our breeding jars of *S. littoralis*. This family is one of the richest with over 120,000 species, of which only 17532 belonging to 100 genera have been described to date. The tropical fauna of Braconids is poorly known (Delvare and Aberlenc, 1989 ; Ghahari *et al.*, 2006). This family has appeared since the Cretaceous (Ghahari *et al.*, 2006, Perrichot *et al.*, 2009). Cases of parasitism of Lepidoptera caterpillars by Braconidae are numerous (Cochereau, 1991 ; Shaw and Hurdleston, 1991 cited by Johansen, 2010 ; Khafagi and Hegazi, 2004 ; Murúa *et al.*, 2006 ; Murúa *et al.*, 2009 ; Whitfield *et al.*, 2009). The number of antennal items is 16 shows that this parasitoid is from the subfamily Microgastrinae (Johansen, 2010). The existence of a single copy of the RS or r-m rib instead of two on the anterior wing shows that parasitoid I belongs to the genus *Apanteles* (Whitfield *et al.*, 2009). It would be a solitary parasitoid because we found only one per jar containing a larva set in breeding.

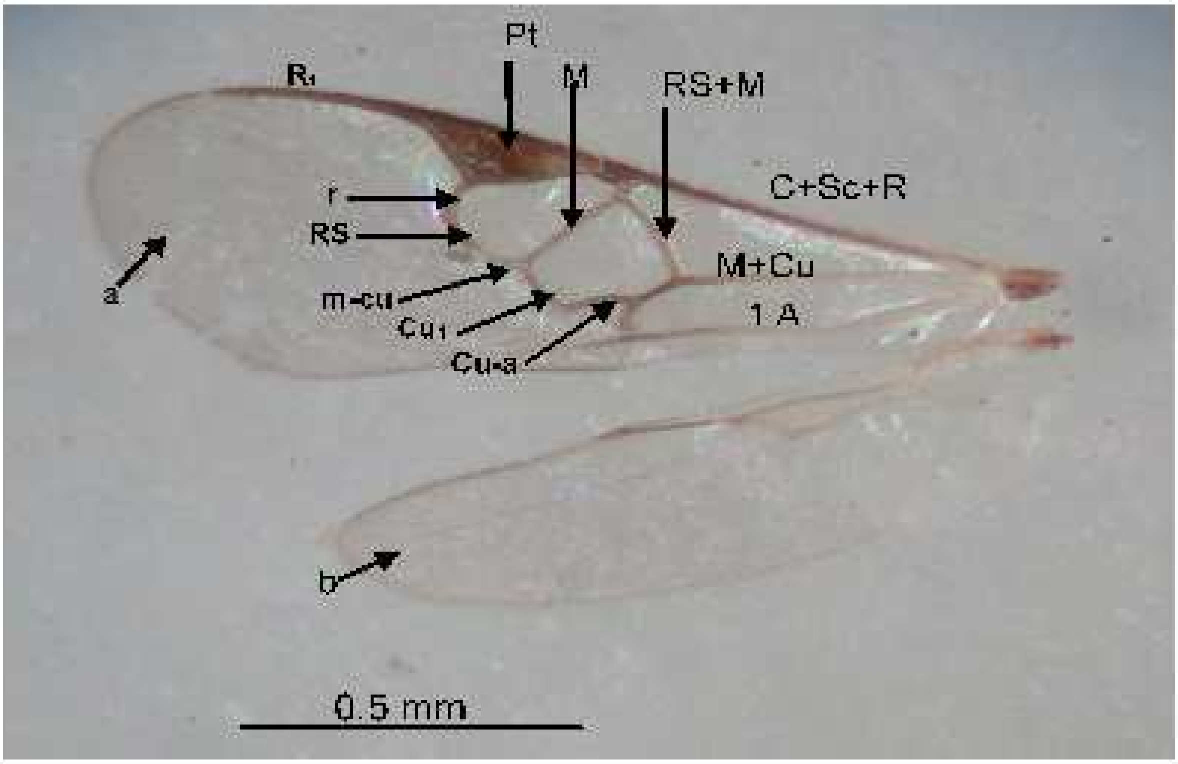

Fig. 3. Anterior and posterior wings of Apanteles sp.
Ribs (r : radial; SR : Radial Sector; M : Median ; Cu1 : Cubital ; cu-a : cubito anal ; C : Costal, Sc : Subcostal ; R1: Radial; Pt : Ptérostigma) ; a : Anterior wing ; b : Posterior wing.

The more or less dark coloration of pterostigma is, according to Whitfield *et al.* (2001), an element allowing a good distinction between different species of neotropical *Apanteles*. The pterostigma of *Apanteles* sp. is dark brown in color and uniform. In *A. nephoptericis* (Packard), pterostigma is more transparent at the base. The r rib is longer than RS one and both form an obtuse angle (Whitfield *et al.*, 2001). *A. galleriae* Wilkinson is a solitary parasitoid of several larval stages of Lepidoptera *Galleria melonella* (L.). It has an all-dark brown pterostigma (Whitfield *et al.*, 2001). In *A. nidophilus* Whitfield and Cameron (Hymenoptera: Braconidae), the center of the pterostigma is whitish and slightly more transparent. The r rib is also longer than RS here. *A. ephestiae* Baker has black-colored C + Sc + R and R_1 ribs while other ribs are brownish to varying degrees. Antennas are shorter than the body. Rib r is longer than RS (Whitfield *et al.*, 2001). *Apanteles* sp. has its ribs C + Sc + R and R_1 black, but its antennae are longer than the body. Our work revealed the presence of Braconid at the study sites in Bingerville in the District of Abidjan. Yellow traps in the different plots of cabbage from the study sites captured Braconidae Hymenoptera of the genus *Apanteles*. Our results are in agreement with those of Kwadjo (2012). Indeed, a study conducted by Kwadjo (2012) in southern Côte d'Ivoire, specifically in Grand Lahou, revealed the presence of Braconids on cabbage. He used yellow traps and pit traps and only yellow traps captured Braconids. Cases of control of Lepidoptera pests by Hymenoptera parasitoids of the genus *Apanteles* exist. 10% and 50% limitation of the cane driller *Chilo sacchariphagus* Bojer (Lepidoptera: Crambidae), respectively in Mauritius, Reunion and Madagascar is a striking example (Sigwalt and Pointel, 1980). According to the same authors, *A. sesamiae* Cameron, 1906, described in South Africa and widespread throughout tropical Africa, has allowed control of *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) in Mauritius and Reunion more than 60%. Other strains of this parasitoid originate from Côte d'Ivoire. *Apanteles machaeralis* Wilkinson attacks *Brachyama* sp. (Lepidoptera: Gelechidae) larvae. Lepidopteran pests of cabbage, such as *Spodoptera litura*, *P. xylostella,* and *Plusia sp.* are parasitized by Braconid *Microplitis similes* L. (Ketipaearachchi, 2002).

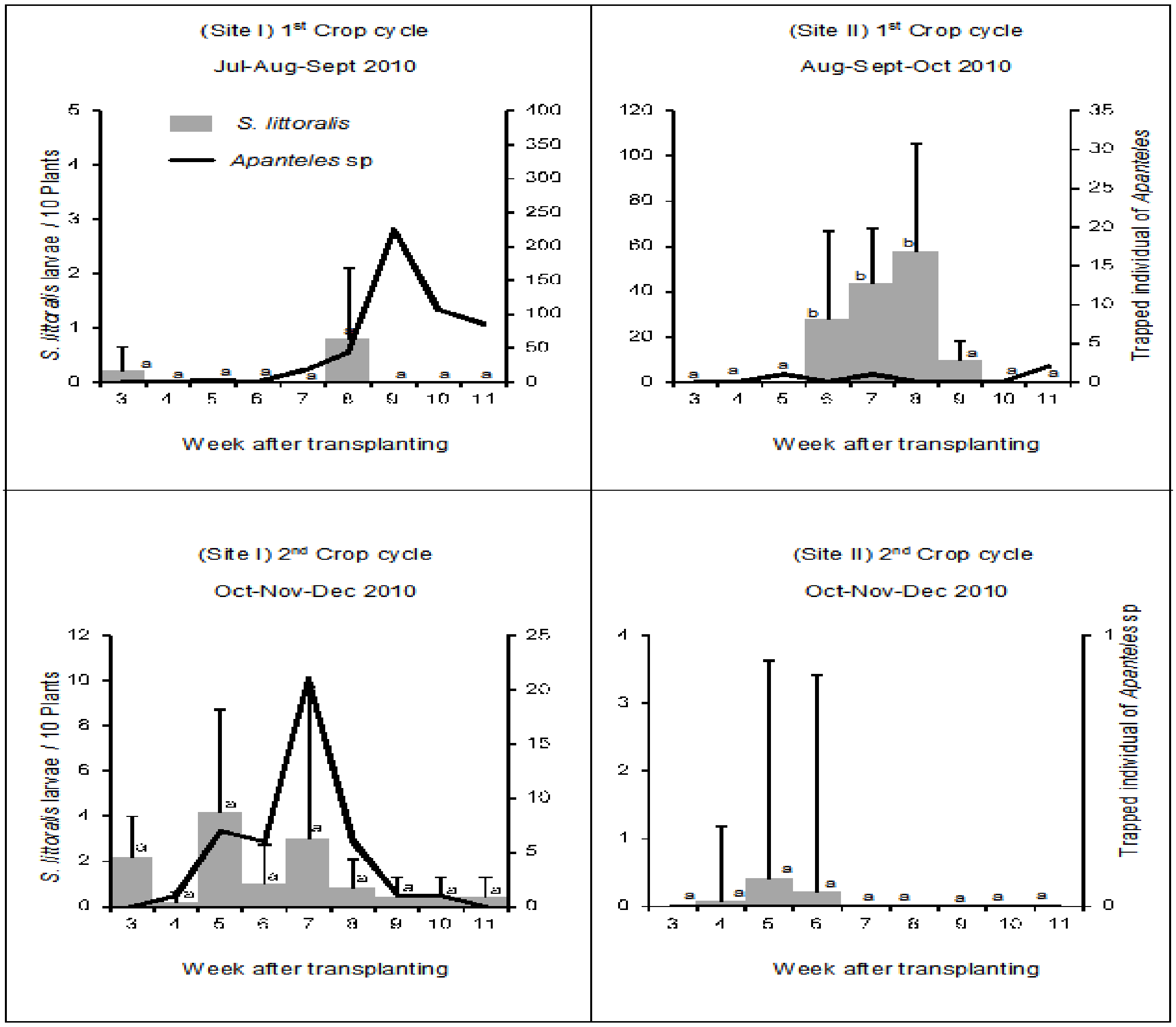

Fig. 4. Compared population Dynamic of S. littoralis and Apanteles sp.
Histograms with different letters are statistically different per Site and Cultural Cycle according to The Friedman test.

The most *S. littoralis* parasitic Braconid is *Microplitis rufiventris* Kok. (Hegazi and Fürer, 1985 ; Khafagi and Hegazi, 2004 ; Hegazi and Khafagi, 2005). Braconidae parasitoids Hymenoptera was trapped in Bingerville (Côte d'Ivoire) using yellow traps (Douan *et al.*, 2013). In Bingerville, small populations of *S. littoralis* give rise to high populations of *Apanteles* sp. on a given site. This difference in *S. littoralis* populations in relation to *Apanteles* sp. is thought to be due to the parasitism of S. *littoralis* by *Apanteles* sp. Beck and Cameron (1992) showed that pests parasitoid populations and the population of the latter evolve in the opposite direction and, therefore not synchronized. Our results are also similar to those of Pimentel *et al.* (1963) cited by Barbault (1992) who noted a weak synchronization between *Musca domestica* L. (Diptera: Muscidae) and its parasitoid *Nasonia vitripennis* Ashmead (Hymenoptera: Pteromalidae) with peaks of populations separated by 70 days in wild-type strains. Our results are, however, contrary to those of Diez *et al.* (2006). Their study of the Hymenoptera complex Eulophidae, parasitoids of the small leaf Lepidoptera Gracillariidae of citrus leaves *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) revealed that the two entities are moving in the same direction. This Lepidoptera and its parasitoids complex are synchronized. Our results differ from those of Diez *et al.* (2006). This could be due to the difference in parasitoid families, Lepidoptera, as well as the attacked plants. Attacks on cabbage plants by pests have caused emissions of volatile substances such as sesquiterpenes in attacked cabbage plants. These particularly attractive substances would be used as a defense by cabbage plants to alert *Apanteles* sp. Such reactions of the attacked plants are evidenced by Tumlinson *et al.* (1993) cited by Dugravot (2004). The affinity of *Apanteles* sp. for *Plutella xylostella* in addition to *S. littoralis* would explain this non-synchronization. Parasite pressure on *S. littoralis* from *Apanteles* sp. would be lower on-site II compared to site I.

The correlation between the number of adults of *Apanteles* sp traps and the number of larvae of *S. littoralis* / 10 cabbage plants is negative in two out of four crop cycles and not significant for all crop cycles. This non-significance is due to poor trapping of *Apanteles* sp individuals and low numbers of *S. littoralis* / plant larvae for a number of phenological stages of cabbage plants.

This study undertaken in Bingerville in Abidjan District in South Côte d'Ivoire shows that *S. littoralis,* a pest in the process of becoming major in market gardening perimeters, also has natural enemies that deserve to be studied in detail. This will allow us to consider methods of sustainable management of this pest.

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