International Journal of Fauna and Biological Studies
Available online at www.faunajournal.com

IJFBS
International Journal of Fauna And Biological Studies

ISSN 2347-2677
IJFBS 2019; 6(5): 43-49
Received: 16-07-2019
Accepted: 21-08-2019

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Distribution of insects according to the phenological stages of apple cabbage *Brassica oleracea* var capitata (Brassicales: Brassicaceae) in Korhogo, northern Côte d'ivoire

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Abstract
The development of an efficient control of insect pests of cabbage requires the knowledge of these pests and their auxiliaries. To do this, an inventory of insects associated with cabbage cultivation was conducted from July to September 2016 and from February to April 2017 on three market gardening perimeters in Korhogo. The identification revealed the presence of 48 species grouped into 32 families and 10 orders. Twenty-five species have been identified as cabbage pests. *Lipaphis erisimy* (19.21%) and *Plutella xylostella* (11.20%) were classified as very abundant. Auxiliary fauna was dominated by six parasitoid Hymenoptera. *Cotesia vestalis* was the most abundant species. The distribution of species by phenological stage showed that there were 41 species present during the vegetative stage and during apples and 36 species at maturation. *C. vestalis, L. erisimy, P. xylostella* and *M. persicae* accounted for more than 50% of the insect population at each phenological stage.

Keywords: Cabbage, insects, distribution, phenological stages, Korhogo

1. Introduction
In sub-Saharan Africa, insects are the main pests of market gardening plants (Fening *et al.*, 2014, Martin *et al.*, 2015) [1, 2], both in terms of the quality and quantity of damage caused and their ability to mutate and adapt to environmental changes. In Côte d'Ivoire, these crops are grown in urban and peri-urban areas and provide markets with fresh vegetables (Fromageot, 2008, Tano *et al.*, 2011, Wognin *et al.*, 2013) [3, 4, 5]. Among these vegetable crops, cabbage ranks first in the northern region of Côte d'Ivoire (Tuo *et al.*, 2017) [6]. Unfortunately, like so many crops, cabbage is attacked by multiple insects (Amoako *et al.*, 2010) [7] including *Plutella xylostella*, *Hellula undalis, Spodoptera littoralis* and *Lipaphis erisimi*. These species are, to date, the main pests of cabbage in Côte d'Ivoire (N'Guessan-Kouassi *et al.*, 2012, Douan *et al.*, 2013, Ouali-N'Goran *et al.*, 2014) [8, 9, 10]. Although cabbage is the host of many insects that stay there for various reasons, their distribution according to the phenological stages of the plant remain unknown in Côte d'Ivoire. Hence the need to conduct the present study which has the general objective of characterizing the cabbage Entomofauna according to its phenological stages. Specifically, it will be an inventory of insects and study their distribution according to the phenological stages of cabbage.

2. Material and Methods
2.1 Study Sites
Three sites were selected in the urban and peri-urban area of Korhogo. These were the market gardening perimeters of the village of Waraniéné (9° 26'N, 5° 40'W), the District of Mongaha (9 ° 28'N, 5 ° 39'W) and the vegetable patch of Peleforo Gon Coulibaly University (9 ° 26'N, 5 ° 38'W). The criteria for selecting these sites were the intensity of the practice of cabbage culture, the accessibility and availability of producers. All these sites had sandy loam soil. The watering was manual. The climate was of the Sudanese tropical type. It was marked by a long dry season (November to May) and a long rainy season (June to October). The average monthly temperatures varied between 24 and 33 °C. The hottest months were February, March

and April with temperatures of up to 36 °C. The coldest months were December and January with minimum temperatures down to 16 °C. The average monthly humidity was around 20%. The average annual rainfall fluctuated between 1100 mm and 1600 mm while the duration of sunstroke was 2000 hours per year (Anonymous, 2007) [11].

2.2. Inventory of insects

The study took place from July to September 2016 and from February to April 2017. On each site, three 11 m^2 (5.5 m x 2 m) elementary plots were set up. Each plot contained 30 cabbage plants.

Data collection consisted of catching insects every seven days. The catches were made in three ways. The first method involved trapping insects with 6 yellow plastic plates 20 cm in diameter containing water and a few drops of detergent (Tingle, 2002) [12]. These trap plates were arranged at random on the plots. Twenty-four hours after application, the contents are sieved to collect insects. The second method consisted in sweeping the cabbage plants with the filleting net in order to dislodge the flying insects that colonize the plot. The last method was to harvest insects directly from cabbage plants. When populations were dense, individuals were harvested by washing contaminated leaves (Bochet *et al.*, 2017) [13].

In total, forty-eight surveys were conducted during the study. After each survey, the insects harvested are kept in jars containing alcohol at 70 ° and transferred to the laboratory. They are then sorted and classified according to the order and the species as well as the economic impact on the crop. Numbers are recorded for each species. The identification was made thanks to the dichotomous keys of Delvare and Alberlenc (1989) [14], Leclant (1999) [15] and Godin and Boivin (2002) [16]. The insects were identified from their morphological characters using an optico hand magnifier (6.5 D, 2.63 x) or a MOTIC binocular magnifier at 40x magnification.

2.3 Phenological stages of cabbage

Like all leafy vegetables, cabbage has eight main stages of development defined on the BBCH scale (Feller *et al.*, 1995) [17]. These stages range from germination to death of the plant. The observations took place on the main stages 1 and 4 redefined below:

- Main stage 1: development of 19 cabbage leaves; it is the vegetative stage.
- Main Stage 4 (1-8): formation of the apple; it is the apple house
- Main Stage 4 (9): hardening of the apple; it is the maturation (Figure 1).

Fig 1: Different phenological stages of cabbage apple (A: young cabbage plant with 5 real leaves; B: cabbage plant with early apple formation; C:. maturing cabbage apple)

In order to determine the distribution of species according to the phenological stages of the cabbage, the plants were observed over two crop cycles. The first cycle took place from July to September 2016 (average temperature: 25.2 °C, rainfall: 479 mm, relative humidity 89%). The second cycle took place from February to April 2017 (average temperature: 29.4 °C, rainfall: 17.5 mm, relative humidity: 48%). Observations began one week after plant emergence and occurred every seven days until apple maturation.

2.4. Data analysis

Ecological indices such as species richness, frequency of occurrence (F) and relative abundance (Ar) of different species were calculated. According to Dajoz (2000) [18], the frequency of occurrence represents the ratio between the number of surveys where the species is found (Pi) and the total number of surveys (P). F (%) = 100 x (Pi / P). Four groups of individuals are distinguished according to their frequency of occurrence:

- Constant species: $F \geq 50\%$
- Frequent species: $25\% < F < 50\%$
- Accessory species: $5\% \leq F < 25\%$
- Rare species: $F < 5\%$.

Relative abundance expresses, according to Zaime and Gautier (1989) [19], the ratio between the number of individuals of the species (Ni) taken into consideration and the total number of individuals of all the species taken together (N): Ar (%) = 100 x (Ni / N). Relative abundance also distinguishes four groups of individuals. Those are:

- Very abundant species: $Ar \geq 10$
- Quite abundant species: $5 \leq Ar < 10$
- Abundant species: $1 \leq Ar < 5$
- Low abundance species: $Ar < 1$.

The Shannon index or biodiversity index was used to express species diversity by taking into account the number of species and the abundance of individuals within each of these species. The index is minimal (= 0) if all individuals in the stand belong to a single family, or if each stand family is represented by a single individual except one family that is represented by all other individuals in the stand. The index is maximal when all individuals are evenly distributed across all families. The Simpson Index measures the probability that two randomly selected individuals belong to the same species.

3. Results

3.1 Insects inventoried

3.1.1 Specific wealth of cabbage insects

Over the two growing seasons, 156846 insects were harvested. These insects belonged to 48 species of which 52.1% were pests, 41.2% were auxiliaries and 6.25% were pollinators (Table 1). These species are distributed among 32 families and 10 orders. The order Hymenoptera was most represented with 9 families and 11 species. It is followed by Diptera with 6 families and 8 species and Lepidoptera with 4 families and 9 species. The Coleoptera order was rich in 3 families and 8 species. Hemiptera and Orthoptera are each represented with 3 families and 4 species. The orders of Dermaptera, Heteroptera, Neuroptera and Thysanoptera were least represented with one family and one species each.

Table 1: List of insects caught at Korhogo on apple cabbage

Orders	Families	Species	Caracteristics			
			Numbers	Status	Frequency	Abundance
Coleoptera	Chrysomelidae	*Aphthona flava*	217	pest	c	s
		Not identified	47	auxiliairy	f	s
		Phyllotreta nemorum	74	pest	f	s
	Coccinellidae	*Cheilomenes sulphurea*	178	auxiliary	c	s
		Coleomegilla spp.	171	pest	c	s
		Harmonia axyridis	22	auxiliary	a	s
		Henosepilachna elaterii	22	auxiliary	a	s
	Scarabaeidae	*Phyllophaga tristis*	57	auxiliary	f	s
Dermaptera	Forficulidae	*Forficula* spp.	43	auxiliary	a	s
Diptera	Calliphoridae	*Lucilia* spp.	936	pest	c	s
	Cecidomyiidae	*Cecidomyie* sp.	30	pest	r	s
	Muscidae	*Musca domestica*	1221	pest	c	s
	Sarcophagidae	*Sarcophaga* spp.	937	pest	c	s
	Stratiomyidae	*Hermetia illucens*	292	auxiliary	c	s
	Syrphidae	*Ischiodon aegyptius*	2377	auxiliary	c	a
		Scaeva pyrastri	2262	auxiliary	c	a
		Sphaerophoria scripta	1476	auxiliary	c	s
Hemiptera	Aleyrodidae	*Aleyrodes proletella*	5143	pest	c	a
	Aphididae	*Lipaphis erisymi*	30131	pest	c	va
		Myzus persicae	13008	pest	c	qa
	Pentatomidae	*Halyomorpha* spp	27	pest	r	s
Heteroptera	Pyrrhocoridae	*Dysdercus voelkeri*	11	pest	r	s
Hymenoptera	Apidae	*Apis* spp	151	pollinator	a	s
	Braconidae	*Apanteles litae*	8210	auxiliary	c	qa
		Cotesia vestalis	25474	auxiliary	c	va
		Microplitis spp.	8832	auxiliary	c	qa
	Chalcididae	*Brachymeria* spp	8725	auxiliary	c	qa
	Eulophidae	*Oomyzus sokolowskii*	9205	auxiliary	c	qa
	Formicidae	*Tapinoma* spp.	297	auxiliary	c	s
	Ichneumonidae	Not identified	1777	auxiliary	c	a
	Sphécidae	*Philanthus* sp.	159	auxiliary	a	s
	Tenthredinidae	*Athalia lugens*	117	pest	r	s
	Vespidae	*Polistes* sp.	193	pollinator	a	s
Lepidoptera	Crambidae	*Achyra nudalis*	567	pest	c	s
		Crocidolomia binotalis	926	pest	c	s
		Ebulea spp.	233	pest	c	s
		Hellula undalis	9378	pest	c	qa
		Hymenia recurvalis	274	pest	c	s
	Noctuidae	*Spodoptera littoralis*	4313	pest	c	a
		Trichoplusia ni	427	pest	c	s
	Nymphalidae	*Danaus* spp.	39	pollinator	a	s
	Plutellidae	*Plutella xyllostella*	17570	pest	c	va
Nevroptera	Chrysopidae	*Chrysoperla carnea*	11	auxiliary	r	s
Ortoptera	Acrididae	*Melanoplus sanguinipes*	197	pest	c	s
	Gryllidae	*Acheta domesticus*	49	auxiliary	f	s
	Pyrgomor-phidae	*Pyrgomorpha conica*	77	pest	c	s
		Zonocerus variegatus	39	pest	c	s
Thysanoptera	Thripidae	*Thrips* spp.	924	pest	r	s

c: constant; f: frequent; a: accessoiry; r: rare; va: very abundant; qa: quite abundant; a: abundant; s: scarce.

3.1.2 Frequency and abundance of identified insect species on cabbage

The distribution of insects according to frequency of occurrence and relative abundance resulted in 31 species (64.6%) being classified as constant. Of these species, 3 were very abundant (*Lipaphis erisymi* (19.21%), *Cotesia vestalis* (16.24%), *Plutella xyllostella* (11.20%)), 6 quite abundant (*Myzus persicae*, *Hellula undalis*, *Oomyzus sokolowskii*, *Microplitis spp*, *Brachymeria spp.*, *Apanteles litae*), 5 abundant (*Aleyrodes proletella*, *Spodoptera littoralis*, *Ischiodon aegyptius*, *Scaeva pyrastri*, unidentified Ichneumonidae) and 17 low abundant. Four frequent species (8.33%), seven accessory species (14.58%) and six rare species (12.5%) were also recorded, all of which were not abundant (Table 1).

3.2 Distribution of insects according to phenological stages of cabbage

The distribution of the orders according to the phenological stages showed that the Hymenoptera were the most abundant during the three stages (43%, 41% and 37% respectively). Dermaptera, Heteroptera and Neuroptera were minor in all

phenological stages (Figure 1). The study of biodiversity has shown that not all species are present at all phenological stages. The population is richer during the vegetative stage (41 species) and the apple house (41 species). The number of species decreases during the maturation phase (36 species). Shannon index values are low during all three phenological stages (Table 2). They indicate that there are dominant species. The high Simpson index (0.90 for all three stages) highlights the imbalance in the stand and the poor distribution of insects within species. Table 3 shows that *L. erisymi*, *C. vestalis* and *P. xyllostella* accounted for almost half of the total vegetatively grown population (49.3%). During pumping, these three species, together with *M. persicae*, represent 56.93% of the population. The maturation stage is dominated only by *L. erisymi* (24.2%) and *C. vestalis* (16.54%).

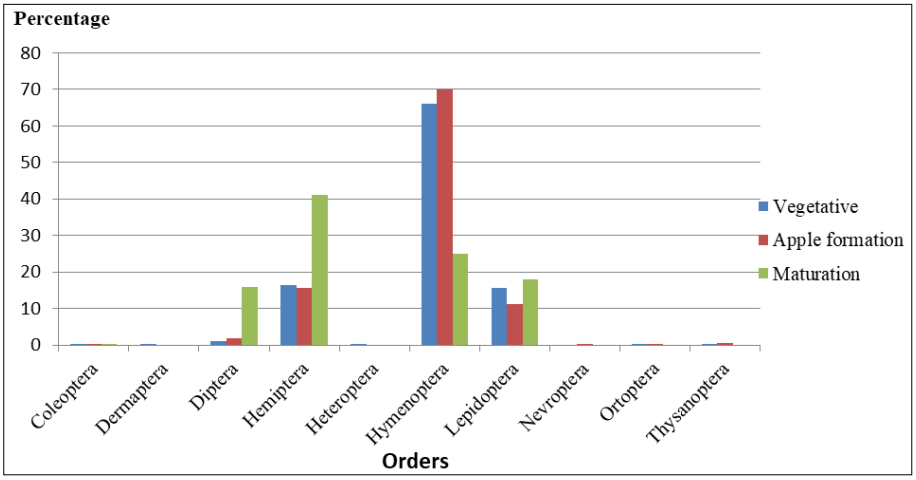

Fig 2: Distribution of Orders according to the phenological stages of apple cabbage

Table 2: Species diversity by phenological stage of apple cabbage

Phenological stages	Spécifique Health	Abundance	Index		
			Shannon	Simpson	Equitability
Végétative	41	67947	2,52	0,90	0,68
Apple formation	41	55673	2,60	0,90	0,70
Maturation	36	33226	2,61	0,89	0,73

Table 3: Distribution of species according to phenological stages of apple cabbage

Species	Percentage by phenological stage of cabbage		
	Végétative	Apple formation	Maturation
Aphthona flava	0,2	0,1	0
Not identified	0,02	0,05	0,01
Phyllotreta nemorum	0,1	0	0
cheilomenes sulphurea	0,1	0,2	0,07
Coleomegilla spp	0,1	0,2	0,04
Harmonia axyridis	0,03	0	0
Henosepilachna elaterii	0	0,04	0
Phyllophaga tristis	0,01	0,07	0,01
Forficula spp	0,02	0,03	0,02
Lucilia spp	0	0	2,8
Cecidomyie sp	0,04	0	0
Musca domestica	0	0	3,7
Sarcophaga spp	0	0	2,8
Hermetia illucens	0,15	0,18	0,3
Ischiodon aegyptius	1,2	1,8	1,7
Scaeva pyrastri	1,04	1,6	2
Sphaerophoria scripta	0,6	0,9	2
Aleyrodes proletella	3,4	4,5	1
Lipaphis erisymi	17,6	18,21	24,2
Myzus persicae	6	12,72	5,4
Halyomorpha spp	0,04	0	0
Dysdercus voelkeri	0,02	0	0
Apis spp	0	0,2	0,16
Apanteles litae	6,2	3,7	5,78
Cotesia vestalis	17,4	14,6	16,54
Microplitis spp	5,84	5,35	5,7
Brachymeria spp	5,9	6,3	3,6

Oomyzus sokolowskii	6,2	5	6,5
Tapinoma spp	0,2	0,2	0,14
Not identified	1	1	1,7
Philanthus sp	0,1	0,1	0,12
Athalia lugens	0	0,2	0
Polistes sp	0,05	0,06	0,4
Achyra nudalis	0,2	0,4	0,6
Crocidolomia binotalis	0,75	0,7	0
Ebulea spp	0,03	0,3	0,2
Hellula undalis	6,7	5	5,6
Hymenia recurvalis	0,2	0,3	0
Spodoptera littoralis	3,1	2,5	2,5
Trichoplusia ni	0,34	0,3	0,1
Danaus spp	0,01	0,03	0,04
Plutella xyllostella	14,3	11,4	4,4
Chrysoperla carnea	0	0,02	0
Melanoplus sanguinipes	0,08	0,2	0,1
Acheta domesticus	0,03	0,02	0,04
Pyrgomorpha conica	0,1	0,02	0
Zonocerus variegatus	0,02	0,04	0,02
Thrips spp	0,5	1	0,1

4. Discussion

4.1 Cabbage insects inventoried

Of 48 species identified on the cabbage, 31 were constant species. These species could be subservient to this crop. Twenty-five insect species have been identified as cabbage pests. Our results are similar to those of Assi *et al.* (2018) [20] and Obodji (2016) [21] which revealed in Côte d'Ivoire the presence of 28 cucumber-damaging species and 29 insect pest species on three cultivated varieties of eggplant. Choudourou *et al.* (2012) [22] identified 32 species considered as harmful to tomato cultivation in Benin. As for Tendeng *et al.* (2017) [23], they inventoried 35 species as pests of several vegetable crops in Senegal. These large numbers of pests could reflect the high parasite pressure on crops.

Of the 48 species identified in the study, 3 were observed on eggplant (Obodji, 2016) [21], 5 on cucumber (Assi *et al.*, 2018) [20], 6 on tomato (Choudourou *et al.* al., 2012) [22] and 7 on potato (Lamara, 2015) [24]. This observation could be explained by the fact that insects are usually polyphagous.

The dominant species was *L. erisimy*. This species of aphid colonizes several plants of the family Brassicaceae but it is not considered as an important pest (INRA, 2016) [25]. However, some individuals may transmit viruses in a non-persistent mode with turnip mosaic (TuMV) and semi-persistent with cauliflower mosaic (CaMV). *P. xylostella* was the third most abundant species in the study. It is known in Côte d'Ivoire as the most important pest of cabbage (Kouakou *et al.*, 2002, Douan *et al.*, 2013) [26, 8]. The species *H. undalis* was classified constant and quite abundant whereas Koné (2016) [27] did not identify it in the same study area. This absence could be justified by the biology of the pest. The latter sinks into the heart of young plants or leaf petioles (Sivapragasam and Chua, 1997) [28].

The results of this work have also shown that besides pests, predatory insects, parasitoids and pollinators have coexisted. The fauna of inventoried auxiliaries was dominated by the Hymenoptera of the family Braconidae, Chalcididae, Eulophidae and Syrphidae Diptera. Hymenoptera are parasitoids of *P. xylostella* and *S. littoralis* larvae (Monnerat *et al.*, 2002, Labou *et al.*, 2016) [29, 30] while Diptera are predators of aphids. Syrphe larvae are effective biological control agents against aphids (Djéto *et al.*, 2007) [31]. These larvae can consume hundreds of aphids in a few days. Adults, on the other hand, are floricultural and feed on nectar and pollen. They are very active pollinators (INRA, 2016) [25]. A species belonging to the family Ichneumonidae was collected. She has not been identified. It could be *Diadegma insulare*. This species has appeared in Senegal since 2014 with a high parasitism rate of 50 to 93.3% (Labou *et al.*, 2016) [30]. No such species had been observed previously in tropical areas (Monnerat *et al.*, 2002) [29]. The known parasitoids were *Oomyzus sokolowskii, Apanteles litae, Cotesia vestalis* and *Brachymeria citrae*. Identified saprophagous insects (Orthoptera, Coleoptera, Diptera) could feed on decomposing plant debris.

In addition, three pollinating insects were identified in cabbage plots. It is known that anthophile insects in general and bees in particular increase the fruit or seed yields of several plant species by pollinating the flowers during their browsing activities (Fluri and Frick 2005, Tchuenguem *et al.*, 2007) [32, 33]. Their presence may also be justified by the fact that cabbage is a self-fertilizing species.

4.2 Distribution of species according to phenological stages of cabbage

Hymenoptera were most abundant at all phenological stages. Six species were present. This simultaneous parasitism of Hymenoptera has been reported on *P. xylostella* by several authors (Talekar & Shelton, 1993, Ketipearchchi, 2002, Gad *et al.*, 2008) [34, 35, 36]. *P. xylostella* being a constant and very abundant species, the presence and the number of Hymenoptera could be related to the abundance of this prey.

Hemiptera were also abundant during the three phenological stages. These were mainly *L. erisimy* and *M. persicae*. These are aphids that develop into large colonies on the underside of leaves, on young shoots and flower buds (Hullé *et al.*, 1998) [37]. They swarm depending on the availability of sap that increases with the development of the plant. Contrary to our observations, Koné (2012) [27] mentioned that Hemiptera accounted for less than 3% of cabbage insects. This small size can be explained by the harvest method used, the duration of the study and the stage of the plant to which the study was carried out. The low presence of predatory Diptera may indicate a low parasitism of aphids. At the stage of apple

maturation, the Diptera predominantly present are species whose larvae could feed on organic matter such as decaying cabbage leaves. Other orders such as Coleoptera, Dermaptera, Orthoptera, Neuroptera and Thysanoptera were minor in cabbage during the three phenological stages.

More than 43% of the insects were vegetative on the leaves. During this stage, all the organs of the plant are tender and bursting with sap. They could therefore be a favorite food source and easy to exploit by stinging-sucking insects that suck the sap and grinding insects that devour the leaves. It is therefore likely that favorable environmental conditions have allowed many species to coexist. The action of pests during vegetation could seriously affect the good growth and development of the plant (Choudourou *et al*., 2012) [22].

The low values of the Shannon index (2.52, 2.60 and 2.61 for the three respective phenological stages) indicate that there are dominant species. These are *L. erisymi*, *C. vestalis* and *P. xyllostella*. These three species have been constant and very abundant.

This study has made it possible to target a number of cabbage pests. However, special attention should be given to *P. xylostella* which is a constant and very abundant species. It is known as the author of highly devastating damage that can reach up to 90% of crop losses (Zalucki *et al*., 2012) [38]. This damage is caused during the entire crop cycle, and can lead to the death of young shoots (Douan *et al*., 2013) [9].

5. Conclusion

The present study made it possible to know the entomofauna associated with the cultivation of cabbage in Korhogo. In total, 48 species of insects belonging to ten orders of insects have been recorded. The most represented orders were Hymenoptera, Lepidoptera and Diptera. Of the 48 species, 25 are known as cabbage pests. The most abundant were *L. erisymi, M. persicae, P. xyllostella, H. undalis* and *S. littoralis* and their main natural enemies were *I. aegyptius* (for aphids) and *C. vestalis* (for *P. xyllostella*). Insects were more abundant at the vegetative Stage (43.32%). The maturation stage recorded the least rich population (36 species) and the least abundant population (21.18%). A study of the dynamics of the auxiliaries and their biology with a view to mass rearing could make it possible to release them as part of a biological fight.

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