International Journal of Entomology Research
ISSN: 2455-4758; Impact Factor: RJIF 5.24
Received: 25-08-2020; Accepted: 10-09-2020; Published: 26-09-2020
www.entomologyjournals.com
Volume 5; Issue 5; 2020; Page No. 91-96

Insect dynamics based on the phenological stages of cucumber (*Cucumis sativus*; Cucurbitacae) in the rainy season in daloa (Central West; Côte D'ivoire)

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Abstract
Cucumber (*Cucumis sativus*) is a vegetable belonging to the family of Cucurbitacae. Its growing is subject to many insects attacks damaging mostly the fruit. The objective of this study was to inventory insects in cucumber plots and to determine the dynamics of population. Sampling was carried out every two days, using coloured traps, mowing nets and incubation of decomposing fruits in a cucumber plot in Daloa. A farmer plot was used. The dynamics vary according to the phenological stages of the cucumber. A total of 24.327 insects belonging to 7 Orders, 37 families and 61 species were identified. These Orders are Diptera, Lepidoptera, Orthoptera, Coleoptera, Odonata, Hymenoptera and Heteroptera. Hymenoptera are the most present population with 55% of the total but not voracious like Coleoptera, Orthoptera and Heteroptera. 95.01% of insects were recorded from flowering.

Keywords: daloa, insects, voracious, phenological

1. Introduction
Market vegetable cultivation has been increase since food security has become a worldwide issue. In Africa, this type of agriculture employs a significant proportion of urban dwellers (Delamarche, 2007) [1]. In sub-Saharan Africa, market vegetable farming is practiced on plots of land that rarely reach one hectare (Mbaye and Moustier, 2000) [2]. Regarding West Africa, since its introduction during colonization, market farming has gained particular strength with the development of cities and the growing demand for fresh market vegetables (Koné *et al*. 2000) [3]. According to FAOSTAT data (2014) [4], world cucumber production is estimated at 71 365 573 tonnes and China is the world's largest producer with 76%. In 2002, Africa produced only 507.000 tonnes from 25.000 ha, which represents just under 1.5% of world production (FAO, 2003) [5]. Côte d'Ivoire, for its part, has developed more than 40 species of market vegetable crops (CNRA, 2008) [6]. Among these market vegetables that are developing in urban and peri-urban areas are exotic crops such as cucumber, cabbage and parsley. Cucumber (Cucumis sativus), belonging to the family Cucurbitacae along with melon, pistachio and watermelon, is extensively cultivated (Swaider *et al*. 2005) [7]. It is one of the most important market vegetables in the tropics (Okonmah, 2011) [8]. It is also one of the most important Cucurbitaceae vegetables grown worldwide (Plader *et al*. 2007) [9] with great economic importance (Harlan 1975) [10]. Côte d'Ivoire's cucumber production, which is mainly in urban areas, was estimated approximately at 30.000 tonnes in 2009 (Sangaré *et al*. 2009) [11]. However, the development of market vegetable in general faces important constraints, such as pest attacks, which cause huge production losses. Cucumbers are no exception; their growing is subject to major constraints such as disease and pest pressure that hamper production (Cissé *et al*. 2003; Williamson *et al*., 2008) [12, 13]. Insects can cause major problems, principally because they act as vectors for viruses or diseases (Jeffery, 2001) [14]. Damage caused by insects can lead to yield losses of up to 40% (Onovo, 1992) [15]. Therefore, the general objective of the present study is to carry out an insect inventory of the cucumber cultivated in the town of Daloa. This specifically leads to :
- Make an inventory of the insects of the cucumber crop;
- Establish the distribution of insects according to the phenological stages of the cucumber.

2. Material
The study was conducted in Daloa, Côte d'Ivoire. (06° 52'38" N and 06° 27'00" W), characterized by a sub-equatorial, hot and wet climate (ANADER 2017). During the sampling, the average temperature and relative humidity of the region were 25.6°C and 78% respectively. The average annual rainfall was 1317 mm.
The biologycal material is composed by the varieties of cucumber seed (Tokyo F1 and Poinsett 76 cucumber varieties.
Technical material is composed of sampling (mower net, yellow box and entomological forceps), conservation (jars containing 70% alcohol) and identification (binocular loupe, identification key: Barry Bolton, 1980; 1987, Lecoq 1988. Mike *et al*, 2004; Brian L. Fischer & Barry Bolton, 2016**)**

3. Method
The work was carried out on 150 m² (15m x 10 m), consisting of 16 ridges (lines) spaced at 1 m intervals. The bundles on each line are spaced 0.5 m apart. Plants population is 4 plants per square meter. Two coloured traps were placed along the edge in line spacing 1; 5; 9 and 13. A trap was set in the middle of line spacing 3; 7; 11 and 15. This makes a total of 12 coloured traps. To capture Diptera (flies), mature cucumber fruits were collected and grouped in small packets of 10 fruits on the ground. Each stack is covered with the 50 cm cubic shaped muslin on one side. The fruits were kept in incubation and after 12 days, flies

started emerging.

The observations were conducted according to two (2) identified phenological stages which are : Germination-Flowering (20 days) and from flowering to the end of the cycle (65 days). Sampling was done regularly every 2 (two) days from 3:00 p.m. to 5:00 p.m.

The samples of insects captured were conserved in ethanol (alcohol) diluted at 70% in 4 bottles: Data processing was done using R software (version 2.8).

4. Results

4.1 Inventory of insects collected on the cucumber plot

A total of 24.327 insects have been collected belonging to 7 Orders, 37 families and 61 species. Hymenoptera, Coleoptera, Heteroptera, Diptera, Lepidoptera, Odonata and Orthoptera are the Orders present in cucumber cultivation in Daloa (Table I). Individuals collected from flowering represent respectively 95.01% of the total numbers (Figure 1).

4.2 Numbers of insects captured by different methods

With the mowing net methode 15.078 insects have been captured, equivalent to 61.98% of the population, with a large number of Hymenoptera followed by Beetles.

Coloured traps captured 8.432 insects, equivalent to 34.66%. Hymenoptera are still the most numerous followed by Beetles. The Orders less captured by this method were the Odonates.

The cucumber fruit incubation method, specific to Diptera, allowed the capture of 817 spaces, equivalent to 3.36%.

4.3 Abundance of Insect Orders

The Order of Hymenoptera is the most abundant. This Order contains more than half of the insects collected with 55%. Beetles are far behind with 15%. As for the other Orders, they are scarcely present with abundances of less than 10% (Figure 2).

Table 1: Concumber entomofauna

Orders	Families	Spaces	Effectives
Diptera	Muscidae	*Musca domestica*	448
	Tephritidae	*Anastrepha striata*	386
		Zeugodacus cucurbitae	153
		Dacus bivittatus	141
		Dacus punctatifron	121
	Syrphidae	*Sercomyia selentis*	95
	Sarcophagidae	Sarcophago sp.	67
Coleoptera	Coccinellidae	*Cheilmones lunata*	116
		Henosepilachna sp.	214
	Chrysomelidae	*Acalymma vittatum*	1743
		Podagrica sjostedti	39
		Chrysolina polita	368
		Chrysolina coerulans	295
	Tenebrionidae	*Gnathocerus maxillosus*	126
		Lagria maxillosus	56
	Cerambycidae	*Pachydissus sartus*	24
		Monochamus scutellatus	113
		Arthopalus rusticus	21
	Nitidulidae	*Meligethe saeneus*	40
	Elateridae	*Melanotus punctolineatus*	213
	Carabidae	*Stenaptinus insignis*	75
	Scarabaeoidae	*Copris fricator*	34
	Meloidae	*Mylabris variabilis*	19
Heteroptera	Coreidae	*Leptoglossus membranacerus*	501
		Anoplocnemis curvipes	106
		Pseudotheraptus devastans	51
	Pentadomidae	*Nezara viridula*	89
	Pyrrhocoridae	*Dysdercus melanoderes*	550
	Miridae	*Deraeocoris ruber*	67
Hymenoptera	Formicidae	*Camponotus acvapimevsis*	2151
		Camponotus sp	665
		Camponotus maculatus	1306
		Lepisiota sp	1026
		Odontomachus troglodytes	1049
		Monomorium sp	1217
		Paltothyreus tarsatus	774
		Mesoponera brunoi	2281
		Pheidole sp	997
	Apidae	*Apis mellifera*	306
		Nomada goodeniana	434
	Chneumonidae	*Rhyssa persuasoria*	273
	Vespidae	*Vuscula vulgaris*	189
	Halictidae	*Pachynomia atrinervis*	506
	Braconidae	*Atanycolus sp,*	163

Lepidoptera	Pieridae	*Gonepteryx rhamni*	332
	Crambidae	*Diphania nitidalis*	486
	Nymphalidae	*Pyronia basthseba*	352
Odonates	Corduliidae	*Cordulia aenea*	209
	Gomphidae	*Onychogomphus forcipatus*	137
	Aeshnidae	*Brachyton basthseba*	117
	Coenagrionidae	*Ischnura pumilio*	96
		Ischnura senegalensis	140
	Libellulidae	*Orthetrum albistylum*	132
Orthoptera	Gryllidae	*Gryllus bimaculata*	169
		Gryllus Pennsylvanicus	142
	Pyrgomorphidae	*Zonocerus variegatus*	367
	Tettigoniidae	*Tettigonia virdissima*	428
	Acrididae	*Schistocerca gregaria*	440
		Arcyptera fusca	289
	Tetrigidae	*Tetrix subulata*	301
	Proscopiidae	*Pseudoproscopia scabra*	223

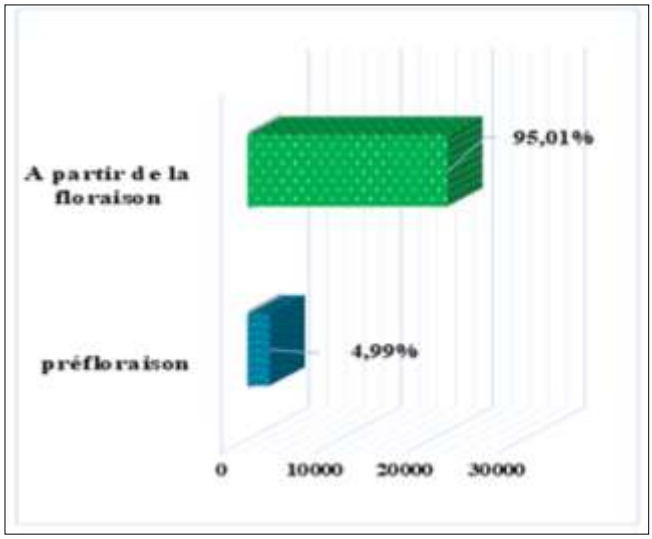

Fig 1: Abundance of insects depending on the phenology of the cucumber plant

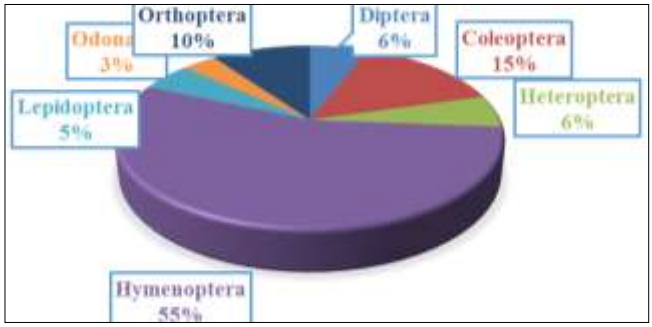

Fig 2: Abundance of Orders

4.4. Dynamics of insect Orders

As soon as germination begins, Hymenoptera are the most present. Orthopterans are also very present on young leaves and their numbers decrease with the rising maturity of the plants. One week later, several other Orders appear, but it is 15 days after germination (day 20) that the insects are abundant. At the end of this period, which corresponds to the beginning of flowering, the insects are attracted to the flowers. Lepidoptera, which are actively contributing to pollination, are now making their appearance. Hymenoptera, already present since germination, will continue to increase until the end of the plant cycle. Concerning Heteroptera, the specimens essentially prickly-suckers, swarm from the fruiting stage. Diptera appear at the end of the plant cycle. This period corresponds to the ripening of the fruits that have served as incubators for Diptera larvae. Hymenoptera are present during all phenological stages of the cucumber but reach their peak at the end of the cycle (Figure 3).

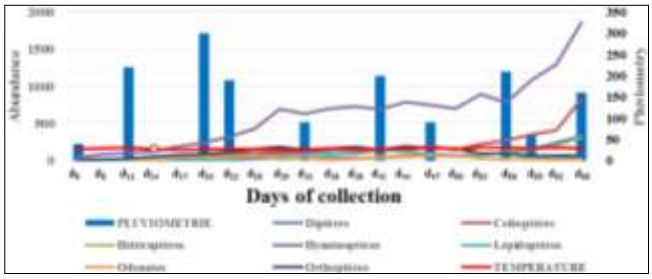

Fig 3: Dynamic of insects Orders according to the plant phenology

4. 5- Abundance of insect families

All the insects collected are divided into 37 Families.

Beetles: 9 families represent this Order, of which the Chrysomelidae family is the most collected and the Meloidae family the least present.

Diptera: Represented by 4 Families. The Family Muscidae is the most represented and that of Sarcophagidae the least present.

Heteroptera: This Order is represented by 4 Families; that of Pyrrhocoridae is more abundant.

Hymenoptera: 6 Families are present in this Order. The Formicidae are in the majority and the Vespidae in the minority.

Lepidoptera: The Families Pieridae, Crambidae and Nymphalidae represent this Order.

Odonates: 5 families represent this Order, the Corduliidae family is the most present.

Orthopterans: Represented by 6 Families. Pyrgomorphidae, Tettigoniidae and Acrididae are the majority.

4.6 Abundance of insect species

Some species such as, *Leptoglossus membranacerus* (Coreidae), *Camponotus acvapimensis* (Formicidae), *Mesoponera brunoi* (Formicidae), *Acalymma vittatum* (Coccinellidae), *Dysdercus melanoderes* (Pyrrhocoridae), *Pachynomia atrinervis* (Halictidae), *Apis mellifera* (Apidae), *Vuscula vulgaris* (Vespidae), *Schistocerca gregaria* (Acrididae) and *Chrysolina coerulans* (Tenebrionidae) are the most present in cucumber cultivation in Daloa region.

4.7 Pests and damages on cucumbers

During the first phenological stage, defoliating insects are the most present in this occurrence Beetles and Orthoptera. These Orthopterans consist of the families Acrididae (*Schistocerca sp*), Gryllidae (*Gryllus sp*), Tetrigidae (*Tetrix sp*), Tettigonidae (*Tettigonia sp*) and Pyrgomorphidae (*Zonocerus sp*) (Figure 4 A). Beetles are represented by the families Chrysomelidae (*Acalymma sp*); Tenebrionidae (*Gnathocerus sp*), Cerambycidae (*Pachydissus sp*), Meligethinae (*Meligethe sp*) and Coccinellidae (*Cheilmones sp*). This category of insects perforates the leaf blade of young plants causing a reduction in the photosynthetic leaf area. As for *Acalymma sp* (Chrysomelidae), adults and larvae attack cucumbers at all stages of plant development (Figure 4 B).

From the time of fruiting, Heteroptera, stinging-sucking insects, swarmed suddenly. They are represented by the families Pyrrhocoridae (Dysdercus), Pentadomidae (*Nezara sp*) and Coreidae (*Anoplocnemis sp* and *Leptoglossus sp*). This order was found in colonies on the underside of leaves and on fruits (Figure 4 C). The bites of these insects do not cause visible damage, but repeated collection of stem causes significant loss of energy to the host plant. Attacks can lead to deformation of the fruit (Figure 4 D).

Other defoliators such as Lepidoptera represented by Crambidae (*Diphania sp*) defoliate leaves by their larvae. These caterpillars also attack fruits by burrowing into the fruit to feed on the contents (Figure 4 E).

Fruit flies (Diptera) appear at the end of fruiting. Oviposition punctures lead to destruction of the vegetable, following intense activity of the young larvae that feed on the pulp (Figure 4 F)

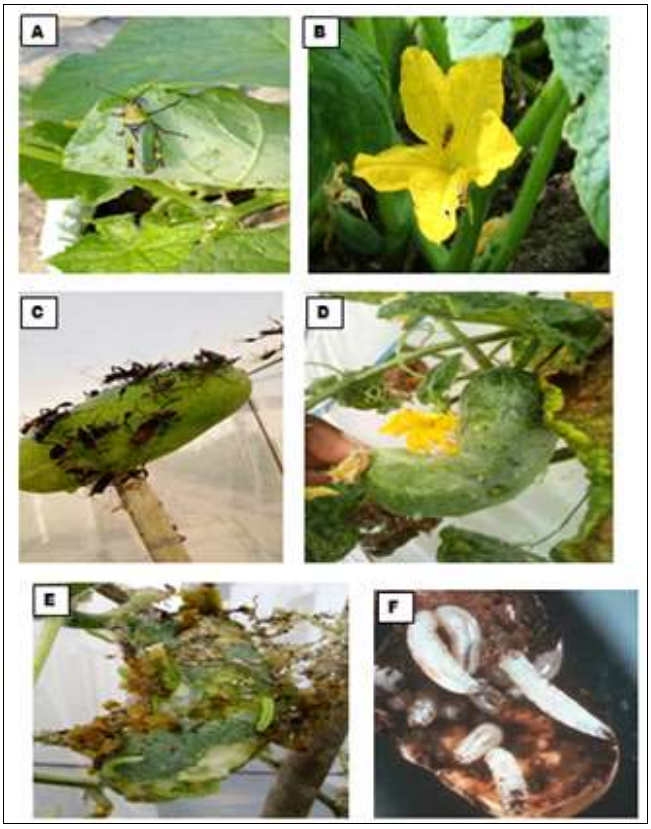

Fig 4: Insect damage on cucumber A: Z. *variegatus* B: *A. vittatum* C: *L. membranaceus* D: Deformed fruit due to repeated attacks of *L. membranaceus* E: Ledidoptera larvae F: Diptera larvae

5. Discussion

Inventory of insects associated to cucumber cultivation in Daloa region allowed to count a total of 36.501 individuals divided into 7 Orders, 37 Families and 61 species. These results are different from those obtained by Ouali *et al* (2019), who observed a total of 4 133 cucumbers in Bonoua (Côte d'Ivoire), grouped into 9 Orders, 27 families and 42 species. Koné *et al*. (2018) [16], recorded 6 976 insects, nine (9) orders and 48 families on courgette which is a Cucurbitacea in Korhogo (Côte d'Ivoire). This difference could be explained by the variation of climatic parameters in the study areas or the number of replicates. From a qualitative point of view, the insects harvested from flowering are the same as those identified during the pre-flowering stage. However, the relative abundance of insects collected is closely related to the phenology of the cucumber. These results are similar to those of Sadou *et al*. (2008) [17] and Soro *et al*. (2010) [18] who respectively observed the variation in insect abundance according to the phenological stages of tomato and yam. However, this parameter is more elevated in the late flowering stage of the cycle.

In fact, at fructification, fruits, flowers, and leaves are potential food sources for insect pests. The high fruiting numbers are also thought to be due to the activity of chemicals such as peroxidase, polyphenoloxidase and the amount of phenols contained in the fruit. This would result in the attraction of large numbers of insects at this stage (Bhattacharya *et al*., 2009) [19]. The abundance of insects at flowering stage was observed by Marie-José (1997) [20] who in her work indicated that the colour and odour of flowers play a role in attracting insect pests of Cucurbitaceae. Flowers mainly attract Hymenoptera (bees) and Lepidoptera (butterflies) which are specialists in pollination and nectar harvesting to feed their nectar, (Mathilde *et al*., 2011) [21]. According to Benachour and Louadi (2013) [22], flowers, particularly those of Cucurbitacea, attract insects for the concentrated sugar in the nectar. Hymenoptera is the most abundant order, particularly Formicidae with the species Mesoponera brunoi. But the species of this Order are not voracious, unlike the Beetles and Orthoptera. It appeared from this study that specimens belonging to the families Chrysomelidae, Coccinelidae, Crambidae, Coreidae and Tephritidae are main pests of cucumbers. These results are similar to those of Koné *et al*. (2018) [16] who reported that Chrysomelidae, Coccinelidae and Tephritidae are most voracious on courgette. These results are similar to those of Duval (1993) [23] who in his work in Canada observed that *Acalymma vittatum* (Chrysomelidae) is the main insect pest of Cucurbitacae. According to the work of Marie-José (1997) [20], Chrysomelidae of Cucurbitacae feed on cucurbitacin, kairomones and bitter substances derived from them, which explains their presence on Cucurbitacae. The ubiquitous presence of Beetles was also reported by Adja *et al*., (2014) [24] at all phenological stages of Cucurbitaceae. These insects attack the flowers, leaves, stems, fruits and even the roots of cucumbers. Similar results were also obtained by Ouali *et al*. (2019) [25] who reported that insects attack all parts of the cucumber. Lepidoptera represented by the cucurbit moth, in particular *Diphania sp* (Crambidae), by their larvae devour leaves and fruits. These larvae dig holes to feed on the contents. These results are in conformity with those obtained by Berthon (2015) [26] who

observed that larvae bore galleries in cucumber fruits and can also consume flowers, leaves and stems. Larval entry holes in the fruit are also entry points for various fungal or bacterial diseases. From flowering onwards, borers and borer-suckers cause the highest rate of attack. This may be explained by the fact that at this stage the plants attract a large number of Heteroptera adults for mating. Amoukou (2013) [27] made the same observation on sesame where he found that some Heteropterans such as Agonoscelis sp. And Piezodorus sp. (*Anoplecnemis curvipes* and *Spilosthetus sp*.) swarmed at flowering and sucked the flower buds. *Leptoglossus* (Heteroptera) in particular, is abundant during the last phenological stage of the cucumber and feeds on the sap of young stems, leaves and mainly on the fruit. This dehydrates the plant considerably and can lead to slower growth and even death. These results confirm those obtained by Chaput (1998) [28] who indicated that insect attacks cause fruit malformation, reduced flowering and delayed development of new shoots. Diptera also devastate cucumbers. This is justified by the fact that female fruitminer flies deposit eggs in fruit close to maturity. These results are in agreement with those of N'depo *et al.* (2009) [29] who observed that the development of pre-imaginal stages causes rotting and fall of attacked fruits resulting in considerable losses.

6. Conclusion

The study cucumber (*Cucumis sativus)* entomofauna in relation to the phenological stages of the plant provides a lot of information on cucumber pests. The study identified 24.327 insects divided into 7 Orders, 37 families and 61 species. Insects are more abundant from the flowering stage onwards. Individuals collected from flowering represent 95.01% of the population. The Orders are the Individual Beetles, Orthoptera, Hymenoptera, Heteroptera, Diptera, Odonata and Lepidoptera. Catching with the mowing n*et al*lowed to catch the largest number of insects. Hymenoptera are the most important, especially the species Mesoponera brunoi (Formicidae) which is present throughout the cucumber cycle. The families Chrysomelidae, Coccinelidae, Crambidae, Coreidae and Tephritidae are the main cucumber pests. This study will contribute to the knowledge of the entomofauna of cucumber cultivation in Daloa and may be used to design pest management strategies for this vegetable. This approach will make it possible to increase the production of cucumbers, whose marketing has become a source of foreign exchange and its consumption is beginning to become part of the population' habits in Côte d'Ivoire.

7. Acknowledgements

We sincerely thank Dr. N'dépo Ossey Robert and all the teacher-researchers in Entomology at the Université Jean Lorougon Guédé de Daloa for their advice. Finally our thanks to my nephew Fondjo Sifoly for his contribution in the realization of this work.

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