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Insect diversity of coffee beans (*Coffea spp*) in the Haut-Sassandra region and their impacts (Daloa, Côte d'Ivoire)

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Abstract
Coffee storage is a potential opportunity for insect infestation. The aim of this study was to identify coffee beans insects and to assess their damage on stored coffee beans from the Haut-Sassandra region. To do this, 3 samples of 3 kg of coffee beans were formed per locality. These samples were stored for 30 days in jute bags and then sieved every 15 days for 120 days. Adults harvested from each lot were observed, counted and identified. In total, 378 individuals divided into 02 orders, 09 families and 10 species were inventoried. The most abundant species is *Tribolium castaneum* (38.36%) followed by *Ahasverus advena* with 24.40%. The damage estimate indicated a relative weight loss of the coffee beans of 7.33% at the 120th day of storage. Coleoptera are the main pests.

Keywords: Insects, stocks of coffee beans, diversity, Côte d'Ivoire

Introduction
Coffee cultivation supports about 100 million people through the world, mostly in tropical countries (Haler, 2013) [15]. With an average $ 15 billions traded annually, coffee is the leading agricultural commodity and the second most traded raw material in the world, after oil (Anonymous, 2018) [2]. Two-thirds of the world's inhabitants consume coffee, mainly in Europe. World coffee production is about 7.4 million tonnes by year (Anonymous, 2018) [2]. Since independence, Côte d'Ivoire's economic performance has been based on the export of agricultural raw materials, mainly the coffee-cocoa combination (Esso, 2009) [11]. Agriculture remains a key sector of the Ivorian economy, occupying more than two-thirds of the population and accounting for 33% of GDP and 66% of national export returns (Sangaré *et al.*, 2009) [22]. Ranked as the world's third-largest coffee producer for nearly thirty years, Côte d'Ivoire recorded a drop in production from 250,000 tonnes in 1990 to 106,000 tonnes in 2017 (OIC, 2017) [19]. This drop in production makes Côte d'Ivoire the world's fourteenth coffee producer (OIC, 2017) [19]. Most coffee is produced by Haut-Sassandra (25.8%), Bas-Sassandra (15.2%), the Mountains region (10.3%) and Moyen-Cavally (10%). Other areas in the south of the country provide the rest of the production (Sangaré *et al.*, 2009) [22]. In Côte d'Ivoire, coffee production employs about 440 000 farmers, mostly small producers, who derive their income directly (FAO, 2005) [12]. The decline in coffee production follows the drastic decrease in purchase prices of coffee on the field leading to the abandonment of coffee cultivation in favor of that of cocoa from the year 1980 (Leonard, 1997) [18]. Another cause of this decline is attributed to the action of insect pests and diseases (Phthiriose, Anthracnose berries, Fusarium fruit) (Kébé *et al.*, 2005) [16]. One of the major concerns regarding coffee growing is insect management (Delobel and Tran, 1993; Kébé *et al.*, 2005; Rubabura *et al.*, 2015) [8, 16, 20]. According to the practices of the phytosanitary inspection service of the Autonomous Port of Abidjan, the presence of a single typical insect pest (larval and / or adult form) of the coffee in the analysis samples during the checks after unpacking the coffee batch treaty, led to postpone boarding. Lot treatment is required by fumigation (Doumbia and Kouassi, 2009) [10]. In order to cope with the problem upstream, an inventory of insects in the coffee stocks of the Haut-Sassandra region is needed. The aim of this study was to identify coffee beans insects and to assess their damage on stored coffee beans from the Haut-Sassandra region.

Study site

The coffee bean samples of 2017-2018 were collected from farmers in 6 localities (Bédiala, Djipri, Gadouan, Issia, Vavoua and Zoukougbeu) in the Haut-Sassandra region, Center-West of Côte d'Ivoire (Fig 1). These localities were chosen for their high production. The samples were sent to the Jean Lorougnon Guédé University of Daloa for the study. The city of Daloa is located at 6°53 North latitude and 6°27 West longitude of Côte d'Ivoire. During the study period, temperature of storage room varied between 28.2 to 30.2°C and the relative humidity between 67.64 to 82.31%.

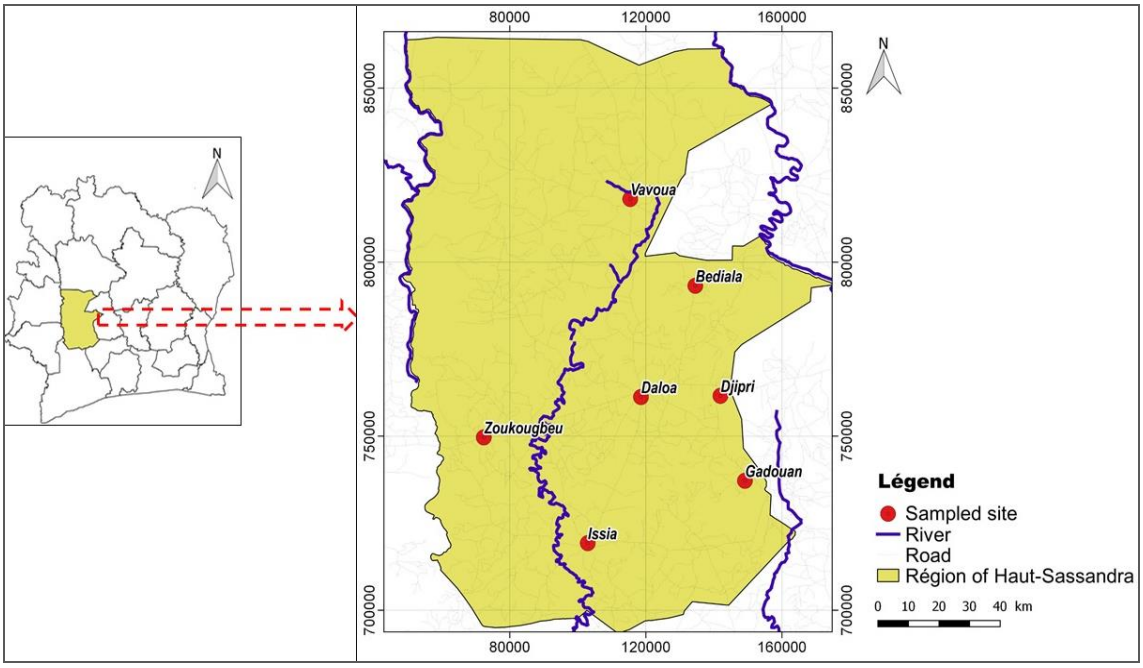

Fig 1: Presentation of the localities of the collected samples

Materials and Methods

Inventory and insect dynamics of coffee bean stocks

Inventory of stock insects were carried out on the lots of field coffee beans which had not undergone any chemical treatment. These bean were collected from 6 localities in the Haut- Sassandra region. In each locality, a 2 kg lot was taken from the stocks of coffee of 5 producers. The beans were removed at different locations from the coffee bags (two ends and in the center) according to regulation N° 401/2006 (CE) (Commission of the European Communities, 2006) [7]. These 5 elementary samples were grouped together to form an overall sample of 10 kg (Regulation No. 401/2006). From this overall homogenized sample, 3 samples of 3 kg of coffee beans were made per locality. These batches were stored for one month to allow the hatching of any insect eggs. After one month of storage, each sample was sieved every 15 days in a muslin observation cage for 120 days. Live or dead adults insects harvested in each lot were observed under binocular magnifying glass and counted. The living are returned to the lots from which they were removed. Counting is done directly by species after sorting. The number of adults per species has been noted. Species identification was done using identification key (Weidner and Rack 1984; Delobel and Tran 1993) [25, 8].

Evaluation of damage during storage time

The estimate of damage to coffee beans is done by evaluating the proportion of beans carrying pest attack holes in a sample. It is made according to the counting and weighing method (MCP). Thus, three samples of 1 kg of coffee beans not bearing holes were made. The number of beans corresponding to 1 kg has been account. Each month, after the sieving session, each sample was divided into two fractions: the first consisting of perforated beans and the second consisting of beans without holes. The damage of each fraction was estimated as a percentage after counting. The evaluation was done monthly, for four months. The estimate of damages was done by the following formula (Boxall,1998) [5]:

$$\text{Domages } (\%) = \frac{B}{A} X\ 100$$

With: A: total number of coffee beans; B: number of coffee beans with holes

Estimate the relative weight loss of coffee beans

Relative loss is the degree of transformation of a grain following a pest's infestation by comparing it to an intact grain. It is evaluated every month for four months. The Counting and Weighing (MCP) method is used to determine the relative weight loss of coffee beans. It ignores the determination of the beans moisture content; then it compares the standard internal value of the intact coffee beans with that of the damaged coffee beans. The sample removed from the stock after sieving is divided into two batches: on the one hand the intact coffee beans and on the other hand the infested coffee beans. The beans of each batch are weighed and counted. The relative weight loss is then evaluated according to the formula of Adams and Schulten (1978) [1]:

$$P(\%) = \frac{(ExB) - (CxD)}{ExA} x\ 100$$

A: total number of coffee beans; B: number of damaged beans
C: number of intact beans; D: weight of the damaged beans
E : weight of intact beans; P: relative weight loss
After each survey, the counted coffee bean samples are returned to the bags of the corresponding batches.

Data analysis

Data processing was performed using the software Statistica 7.1 version. The variance analysis followed by the Newman-Keuls test at the 5% threshold allowed to compare the average number of insects of the cofee beans of each batch, the number of coffee bean bearing or no holes, the damage and the relative weight loss of coffee beans. The XLSTAT 7.5 software was used to perform factorial correspondence analysis (AFC) between insect species and localities in the region to highlight the characteristic species of the region. The relative abundance of the species was determined by the formula of Zame and Gautier (1989) [26]:

$$\mathbf{Ar\ (\%) = \frac{Ni}{N} X\ 100}$$

Ni: number of species' individuals considered; N: total number of all species' individuals combined; Ar (%): relative abundance.

Results and Discussion

Results

Insects identified in the six localities

The identification of the collected specimens revealed in all 6 localities two orders (Coleoptera and Lepidoptera) with 9 families and 10 species. Of these 10 species, only one *Ephestia cautella* belonging to Lepidoptera's order and Pyralidae's family was collected.

Bédiala's locality

From 30th to 120th day, the insects collected in coffee beans of this locality was represented by four species: *Ahasverus advena* (Silvanidae), *Oryzaephilus surinamensis* (Silvanidae) *Sitophilus zeamais* (Curculionidae) and *Tribolium castaneum* (Tenebrionidae) (Table 1). The *S. zeamais* species appears on the 45th day of storage with an average number of 4 ± 1 individuals to disappear from stocks on the 90th day. As for the other three species, they were present throughout the storage with populations ranging from 0.33 ± 0.57 to 11.33 ± 2.52 individuals. The most abundant species was *T. castaneum*, whose number of individuals was 46, whether 44.66% of the total number of insects harvested (103 individuals). The *A. advena* species comes in second place with 33 individuals, whether 32.04%. The variance analysis followed by Newmans-Keuls test at the 5% threshold showed a significant difference (P-value < 0.05) between numbers of species identified.

Table 1: Average number of insects counted in the coffee beans in Bédiala's locality during 120 days of storage

Insect species	Storage time (Days)						
	30	45	60	75	90	105	120
A. advena	1.33±0.57^{d}	5.66±1.15^{bc}	2.33±1.52^{cd}	1.33±0.57^{d}	6.66±1.52^{b}	3.33±0.57^{cd}	2.33±1.52^{cd}
O. surinamensis	3±1^{cd}	1.33±0.57^{d}	0.66±0.57^{e}	0.66±0.57^{e}	1±1de	0.33±0.57^{e}	0.33±0.57^{e}
S. zeamais	0±0^{f}	4±1^{c}	0.66±0.57^{e}	0.33±0.57^{e}	0±0^{f}	0±0^{f}	0±0^{f}
T. castaneum	2.66±0.57^{cd}	11.33±2.52^{a}	7±2^{b}	5.66±1.15^{bc}	3±1^{cd}	6.66±1.15^{b}	7.66±1.52^{b}

F = 23.39; df = 27; P-value = 0.00001. The averages numbers which behave the same letters are not significantly different according to the Newman-Keuls test at 5% threshold.

Gadouan's locality

From 30th day to 120th day, seven (7) species of insects were collected in this locality. They are represented by *Ahasverus advena* (Silvanidae), *Araecerus fasciculatus* (Anthribidae), *Ephestia cautella* (Pyralidae), *Lasioderma serricorne* (Anobiidae), *Oryzaephilus surinamensis* (Silvanidae), *Sitophilus zeamais* (Curculionidae) and *Tribolium castaneum* (Tenebrionidae) (Table 2). On the 30th day of storage, four species (*A. advena*, *L. serricorne*, *O. surinamensis* and *T. castaneum*) were present at the control with populations ranging from 1.33 ± 0.57 to 6.33 ± 1.52 individuals (Table 2). The species *E. cautella*, *L. serricorne*, *O. surinamensis* and *S. zeamais* disappeared from the stocks from the 90th day. The both species (*A. advena* and *T. castaneum*) were present throughout the storage period. *T. castaneum* was the most abundant species with 31 individuals, whether 30.69% of the total number of insects harvested (101 individuals). The variance analysis followed by Newmans-Keuls' test at 5% threshold revealed a significant difference (P-value < 0.05) between species numbers collected during storage time.

Table 2: Average number of insects identified in the coffee beans in Gadouan's locality for 120 days of storage

Insects species	Storage time (Days)						
	30	45	60	75	90	105	120
A. advena	4.66 ± 0.57^{c}	5±1^{b}	6.66±1.52^{a}	2.66±0.57^{d}	0.66±0.57^{ef}	1.33±0.57^{e}	1±0^{e}
A. fasciculatus	0 ± 0^{f}	2±1de	1.33±0.57^{e}	4.66±0.57^{c}	0.33±0.57^{ef}	0±0^{f}	0±0^{f}
E. cautella	0 ± 0^{f}	0.33±0.57^{ef}	1.33±0.57^{e}	0±0^{f}	0±0^{f}	0±0^{f}	0±0^{f}
L. serricorne	1.33 ± 0.57^{e}	1.66±0.57^{e}	0.66±0.57^{ef}	0±0^{f}	0±0^{f}	0±0^{f}	0±0^{f}
O. surinamensis	3.66±1.15^{cd}	2.66±0.57^{d}	1.33±0.57^{e}	0.33±0.57^{ef}	0±0^{f}	0±0^{f}	0±0^{f}
S. zeamais	0±0^{f}	4.33±0.57^{c}	1.66±1.15^{e}	0.33±0.57^{ef}	0±0^{f}	0±0^{f}	0±0^{f}
T. castaneum	6.33±1.52^{a}	4.33±0.57^{c}	6±1^{d}	3.66±1.15^{cd}	5.33±2.08^{b}	5±1^{d}	4±1^{d}

F = 28.18; df = 48; P-value = 0.00001. The averages numbers which behave the same letters are not significantly different according to the Newman-Keuls test at 5% threshold.

Issia's locality

On 30th day of storage, the insects were represented by five species: *A. advena*, *Cryptolestes ferrugineus* (Cucujidae), *L. serricorne*, *O. surinamensis* and *T. castaneum* with averages numbers varying from 0.66 ± 0.57 to 5.66 ± 1.15 of individuals (Table 3). Species *C. ferrugineus* and *L. serricorne* have disappeared from stocks since 90th day. *O. surinamensis* and *T. castaneum* species were present throughout the stock control period. The variance analysis followed by the Newmans-Keuls test at 5% threshold revealed a significant difference (P-value < 0.001) between averages numbers of species collected.

Table 3: Average number of insects registered on coffee beans in the Issia's locality for 120 days of storage

Insects species	Storage time (Days)						
	30	45	60	75	90	105	120
A. advena	1.33±0.57^{de}	6.33±2.08^{b}	4±1^{c}	8.66±1.15^{a}	1.67±0.57^{de}	0.66±0.57^{de}	0±0^{f}
C. ferrugineus	2±1^{d}	2.66±1.15^{d}	2.33±0.57^{d}	1±0de	0±0^{f}	0±0^{f}	0±0^{f}
L. serricorne	0.66±0.57^{de}	1±1de	0.66±0.57^{de}	0.66±0.57^{de}	0±0^{f}	0±0^{f}	0±0^{f}
O. surinamensis	5.66±1.15^{bc}	4.66±1.15^{bc}	2.66±1.15^{d}	0.66±0.57^{de}	1.66±0.57^{de}	4.33±1.15^{bc}	1±0de
T. castaneum	4±1^{c}	6.33±1.52^{b}	2±1^{d}	1.33±0.57^{de}	1±0de	2.66±0.57^{d}	1.33±0.57^{de}

F = 21.10; df = 34; P-value = 0.00001. The averages numbers which behave the same letters are not significantly different according to the Newman-Keuls test at 5% threshold.

Zoukougbeu's locality

From 30th to 120th day, the insects recorded in coffee beans of this locality are represented by three species: *Carpophilus hemipterus* (Nitudilidae), *Oryzaephilus surinamensis* (Silvanidae) and *Tribolium castaneum* (Tenebrionidae) (Table 4). At the end of the first 30 days, only one species: *T. castaneum* was present in the stock with an average number of 1.66 ± 0.57 (Table 4). From the 30th to the 60th day, a new species appears (*C. hemipterus*) and disappears from the 75th to the 120th day of storage. *Oryzaephilus surinamensis* appears on the 105th day of storage with an average number of 0.66 ± 0.57 individuals. The most abundant species was *T. castaneum*, whose number of individuals was 11, whether 61.11% of the total number of insects harvested (18 individuals). The species *C. hemipterus* comes in second place with 5 individuals, whether 27.78% and finally *O. surinamensis* with 2 individuals, whether 11.11%. The variance analysis followed by Newmans-Keuls test at 5% threshold showed a significant difference (P-value < 0.05) between averages numbers of species collected during storage.

Table 4: Average number of insects identified coffee beans in Zoukougbeu's locality for 120 days of storage

Insects species	Storage time (Days)						
	30	45	60	75	90	105	120
C. hemipterus	0±0^{c}	1.66±1.52^{ab}	1.33±1.52^{ab}	0±0^{c}	0±0^{c}	0±0^{c}	0±0^{c}
O. surinamensis	0±0^{c}	0±0^{c}	0±0^{c}	0±0^{c}	0±0^{c}	0.66±0.57^{b}	0.66±0.57^{b}
T. castaenum	1.66±0.57^{ab}	1.33±1.52^{ab}	0±0^{c}	0±0^{c}	2±1^{a}	0±0^{c}	0±0^{c}

F = 29.14 df = 20 ; P-value = 0.00001. The averages numbers which behave the same letters are not significantly different according to the Newman-Keuls test at 5% threshold.

Djipri's locality

From 30th day to 120th day, two species of insect were harvested in this locality. They are represented by *A. advena* and *T. castaneum* (Table 5). At the end of the first 30 days, *A. advena* and *T. castaneum* have respective average numbers of 1.33 ± 1.15 and 0.33 ± 0.57 (Table 5). The relative abundance of these two species was substantially equal. The species *T. castaneum* has 11 individuals whether 55% and *A. advena* 9 individuals, whether 45% of the total number (20 individuals). From the 75th to the 120th day, the species *A. advena* disappeared from the stock. The variance analysis followed by the Newmans-keuls test at the 5% threshold shows that there is no significant difference (p-value = 0.34) between the numbers of the listed species.

Table 5: Average number of insects identified on coffee beans in the locality of Djipri for 120 days of storage

Insects species	Storage time (Days)						
	30	45	60	75	90	105	120
A. advena	1.33±1.15^{a}	1.33±1.52^{a}	1±1^{a}	0±0^{a}	0±0^{a}	0±0^{a}	0±0^{a}
T. castaneum	0.67±0.57^{a}	1±1^{a}	0±0^{a}	0±0^{a}	0.67±0.57^{a}	1.33±1.52^{a}	1.33±1.15^{a}

F = 13.26 df = 13 ; P-value = 0.34. The averages numbers which behave the same letters are not significantly different according to the Newman-Keuls test at 5% threshold.

Vavoua's locality

On 30th day storage, insects were represented by three species which are: *C. hemipterus*, *Rhysopertha dominica* (Bostrichidae) and *T. castaneum* with respectively average individual numbers of 3.33 ± 0.57; 1 ± 1 and 4.33 ± 1.52 (Table 6). On the 75th day of monitoring, the species *C. hemipterus* disappears from the stock and a new species appears *Sitophilus zeamais* (Cuurculionidae) The most abundant species was *T. castaneum* with 23 individuals whether 58.97% of the total number harvested (39 individuals). It is followed by *C. hemipterus* with 10 individuals whether 25.64%. The variance analysis followed by the Newmans-Keuls test at 5% threshold revealed a significant difference (P-value < 0.001) between the average numbers of species collected.

Table 6: Average number of registered insects of coffee beans in the Vavoua's locality during 120 days of storage

Insects species	Storage time (Days)						
	30	45	60	75	90	105	120
C. hemipterus	3.33±0.57^{ab}	2±0^{c}	1.66±1.15^{cd}	0±0^{e}	0±0^{e}	0±0^{e}	0±0^{e}
R. dominica	1±1^{d}	0±0^{e}	0±0^{e}	1.33±0.57^{d}	0±0^{e}	0±0^{e}	0±0^{e}
S. zeamais	0±0^{e}	0±0^{e}	0±0^{e}	1.66±1.15^{cd}	0.66±0.57^{d}	0±0^{e}	0±0^{e}
T. castaneum	4.33±1.52^{a}	3.33±1.52^{ab}	2.33±0.57^{c}	1.66±1.15^{cd}	2±1^{c}	0.66±0.57^{d}	1.33±0.57^{d}

F = 161.48; df = 27; P-value = 0.000001. The averages numbers which behave the same letters are not significantly different according to the Newman-Keuls test at 5% threshold.

Relative abundance of species in the Haut-Sassandra region

The insects encountered during all the sampling in the coffee stock of the Haut-Sassandra region were 378 individuals represented by 10 species (Fig 2). The most abundant species was *T. castaneum* with 145 individuals whether 38.36%, followed by *A. advena* with 96 individuals whether 24.40%. The least abundant species was *R. dominica* with 7 individuals. Factorial correspondence analysis revealed that three species, *T. castaneum*, *A. advena* and *C. hemipterus* are characteristic of the Haut-Sassandra region (Fig 3). The species *T. castaneum* is more abundant in the localities of Vavoua, Djibri, Bédiala, Gadouan and Zoukougbeu. As for *A. advena*, it has a very high stock in Bediala, Djibri, Gadouan and Issia. Concerning the species *C. hemipterus*, it is very abundant in the localities of Vavoua and Zoukougbeu.

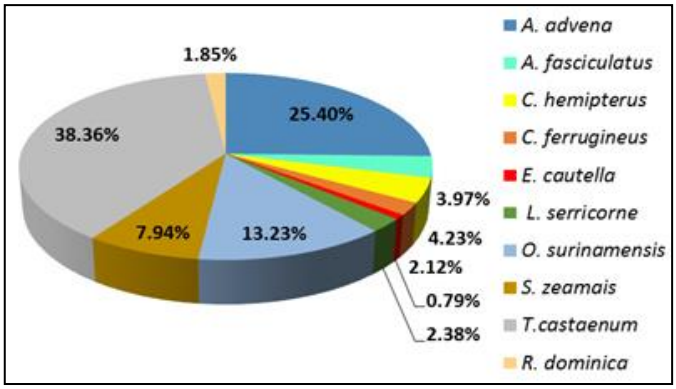

Fig 2: Relative abundance of species in the Haut-Sassandra region.

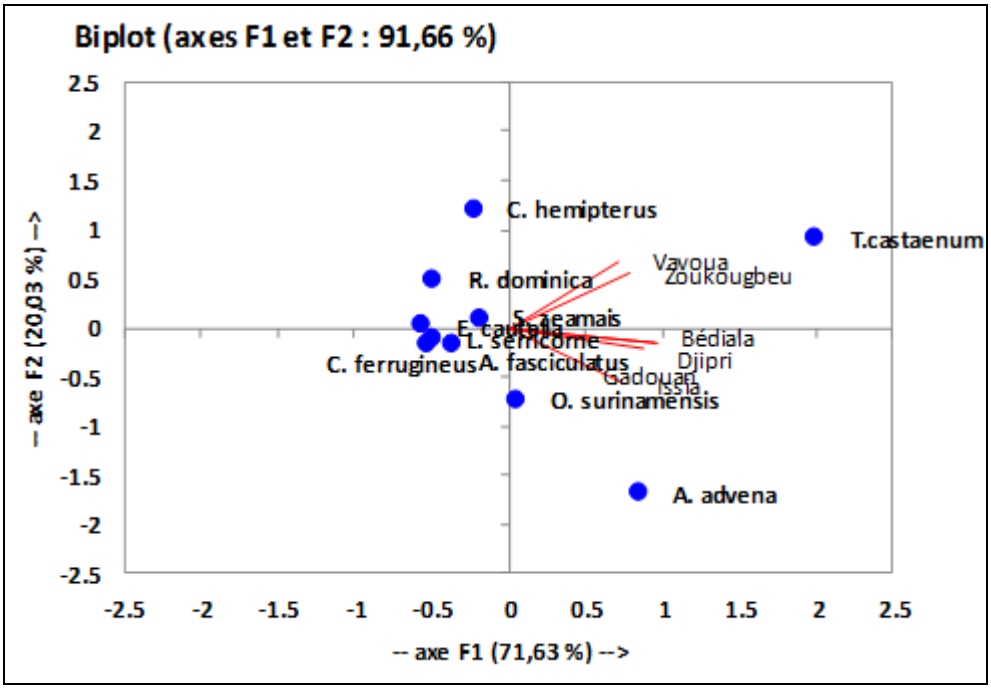

Fig 3: Factorial analysis of the correspondences representing the characteristics in the Cartesian plane of the insects' species in the Haut-Sassandra

Estimation of damage and relative weight loss of the coffee beans during storage time

The number of coffee beans carrying a hole increases as a function of the storage duration. After a month of monitoring, an average total of 11032.33 ± 9.29 coffee beans, only 35.67 ± 4.73 of them carry at least one hole. At the 120th day of storage, the average number of beans carrying at least one hole was 485.33 ± 11.02. The significance of the damage was 2.28 ± 0.07% and 4.40 ± 0.10% respectively in the third and fourth months of storage (Table 7). The statistical analysis revealed a significant difference (P-value = 0.00001) between the damage observed during the storage time. The relative weight loss of the coffee beans was very low (0.41 ± 0.04%) at the end of the first month of storage. It increases to 2.64 ± 0.07% at the second month of storage. Beyond this time, the relative weight loss becomes a little more significant (P-value = 0.00001) with 7.33 ± 0.27% at the fourth month of storage (Table 7).

Table 7: Relative weight loss caused by insect pests on 1kg of coffee beans during storage time

Storage time (Days)	Total number of coffee beans	Number of coffee beans carrying hole	Number of coffe beans without hole	Damage (%)	Relatives weigth loss of coffee beans (%)
0	11032.33±9.29	0.00^{e}	11032.33±9.29$^{a'}$	0.00^{e}	0.00$^{e'}$
30	11032.33±9.29	35.67±4.73^{d}	10996.67±1.41$^{b'}$	0.32±0.04^{d}	0.41±0.04$^{d'}$
60	11032.33±9.29	170.67±3.06^{c}	10861.67±0.71$^{c'}$	1.55±0.03^{c}	2.64±0.07$^{c'}$
90	11032.33±9.29	252±8.19^{b}	10780.33±4.24$^{d'}$	2.28±0.07^{b}	5.73±0.21$^{b'}$
120	11032.33±9.29	485.33±11.02^{a}	10547±9.19$^{e'}$	4.40±0.10^{a}	7.33±0.27$^{a'}$

Number winnings with at least one hole: F = 927.34; df = 4; P-value = 0.00001
Number of grains not bearing holes: F = 2461.52; df = 4; P-value = 0.00001
Damage: F = 2715.27; df = 4; P-value = 0.00001
Relatives losses grain weight: F = 1229.51; df = 4; P-value = 0.00001
Note: The average numbers followed by the same letter in a column are not significantly different according to the Newman Keuls test at the 5% threshold.

Discussion

The inventory of coffee bean stocks insects in the Haut-Sassandra region recorded a total of 10 insect species (*A. advena, A. fasciculatus, C. hemipterus, C. ferrugineus, E. cautella, L. serricorne, O. surinamensis, S. zeamais, T.castaenum* and *R. dominica*). These ten listed species are among the species listed(*Ptinus tectus, Tribolium castaneum, Carpophilus sp., Oryzaephilus surinamensis, Araecerus fasciculatus, Tribolium confusum, Alphitobius piceus, Lasioderma sierricorne, Carpophilus hemipterus, Dinoderus minutus, Ephestia cautella, Ephestia elutella* and *Corcyra cephalonica*) by Lavabre (1961) [17] on coffee beans and cocoa beans in different parts of the tropics. Our work took place only in Côte d'Ivoire, in the Haut- Sassandra region, unlike this author. This difference would be attributable to the extent of the experimental areas (Tah, 2017) [23].The results obtained differ from those of Sadia-Kacou *et al*. (2015) [21] who recorded 9 insect species (*L. sierricorne, R. dominica, A. fasciculatus, C. ferrugineus, A. advena, T. castaneum, T. confusum, E. elutella and Pladiaunter punctella*) in stocks of coffee at the Autonomous Port of Abidjan. They also differ from those of Tah *et al*. (2011) [24] who also listed 9 insect species (*T. castaneum, A. fasciculatus, A. advena, C. hemipetrus, C. ferrugineus, Necrobia rufipes, S. zeamais, E. cautella* and *Tenebroides mauritanicus*) in the stocks of cocoa beans. Although our work took place in Côte d'Ivoire like those of Tah *et al*. (2011) [24] and Sadia-Kacou *et al*. (2015) [21] only 4 species are common to the three repertories (*A. advena, A. fasciculatus, C. ferrugineus* and *T. castaneum*). The difference would be related to the storage conditions including temperature, relative humidity, the firmness of grains and the way in which grains are dried by farmers. Some farmers would use black plastic sheeting for beans drying instead of fixed or moving racks. This method would promote the increasing of grain moisture which the insect growth and moldy growth (Djossou, 2011) [9]. The drying on the racks allows the destruction of the eggs by the solar rays. The duration of drying, which depends on sunshine, is in the order of 3 to 4 weeks which decrease the grain moisture from 60% to 12% (Kébé *et al*., 2005) [16]. The pests best adapted to the mechanical disturbances that occur during storage live inside the grains. They are the primary pests (*S. zeamais*), because these insects are unable to carry out their complete development outside of foodstuffs as indicated by Fleurat-Lessard (1982) [13] and Bekon (1986) [4]. Others eat the beans from the outside. Most often, they attack the germ or are content with grains with a hollow or crack or beans broken. Their diet can evolve, at least at some stages of their development, to a food other than the stored beans. They are so-called secondary pests (*A. advena, T. castaneum* and *O. surinamensis*) because of their appearance often subsequent to that of primary pests, according to Fleurat-Lessard (1982) [13] and Bekon (1986) [4]. Individuals of *C. hemipterus* first devour the integument. Then, they dig the small holes in the beans while consuming the cotyledon. In search of the embryo, they dig a gallery by the consumption of a small part of the cotyledon then consume the embryo. The bean retains its shape but its content is degraded. The species *C. hemipterus* is described as a primary pest. Individuals of *A. advena* and *T. castaneum* benefit from cracks on the integument and damage caused by the species that emerged first to dig a hole and then a gallery. They dig the small holes in the beans while consuming the cotyledon. The individuals of *A. advena* and *T. castaneum* are classified as secondary pests. Of a total of 11032.33 healthy beans observed at the beginning of storage, 485.33 had at least one hole after 120 days of storage. This is bound to the gradual reinfestation of coffee beans. This reinfestation could be the consequence of long time storage. Indeed, a long time conservation seems to favor the setting up of the high mold and the mustiness which allow both the development of insects already existing in the stock, as well as the appearance of new species. The presence of holes and galleries outside as inside the bean is the fact of the mouthpieces-type grinder of the insects pest listed. This type of oral appliance is found in both Lepidoptera larvae and Coleoptera larvae as adults (Beaumont and Cassier, 1983) [3]. Of the 10 listed insect species, 7 (*A advena, C hemipterus, C ferrugineus, E cautella, O. surinamensis,* and *T castaneum*) have well-developed mandibles, which allow them to eat coffee beans. In the other three (*A. fasciculatus, S. zeamais* and *R. dominica*), the mandibles are worn at the end of a rostrum which allows them to dig the holes. These 10 species of insect pests feed by gnawing the grain, either on the surface or deeply by digging holes and / or galleries, and reject their droppings outside as mentioned Fleurat-Lessard (1982) [13] and (Delobel and Tran, 1993) [8]. Two species (*A. advena* and *T.castaenum*) were present during the 120 days of storage in two of the localities (Bédiala and Gadouan). This presence of these two species could be explained by their biological parameters. *A. advena* and *T.castaenum* are two prolific species whose females can lay between 100 to 300 eggs (Delobel and Tran, 1993; Goergen *et al.*, 2005) [8, 14]. The presence of *A. Advena* is indicative of the high moisture content characteristic of weathered crops due to high moisture content (Delobel and Tran 1993) [8]. *T. castaenum* was the most abundant species with 145 individuals, whether 38.36%. This abundance could also be due to the longevity of the insect which is 2 to 8 months following the abiotic conditions and to a duration of the development cycle which lasts approximately one month (Camara, 2009) [6].

Conclusion

This study sallowed to do an inventory the insect especies of coffee beans in the Haut- Sassandra region. The monitoring of coffee beans lots showed that all the lots coming from the fields are infested by insects. The identification of the collected specimens revealed 10 species, 9 families and two orders that are Coleoptera and Lepidoptera. The species encountered during all sampling in the coffee stock were: *A. advena, A. fasciculatus, C. hemipterus, C. ferrugineus, E. cautella, L. serricorne, O. surinamensis, S. zeamais, T. castaenum* and *R. dominica.* The most abundant species was *T. castaneum* (38.36%). Two species (*A. advena* and *T. castaenum*) were present during the 120 days of storage. Factorial analysis of the correspondences indicated that three species (*T. castaneum, A. advena* and *C. hemipterus*) are characteristic of the Haut Sassandra region. The relative weight loss of coffee beans was 7.33 ± 0.27% at 120th day of storage. This inventory will help to better target pests in order to develop an appropriate response.

6. References

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