**Entomofauna of inflorescences of *Anacardium occidentale* L., 1753 in the north of the ivory coast: case of the bagoue region**

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**Abstract**

In Ivory Coast, several agronomic research works are conducted to improve the production of cashew trees. However, very few studies have been devoted to pollinating insects. This study aims to identify the insects visiting the inflorescences of the cashew tree in order to improve the fruit setting of this plant. To do this, insects visiting the flowers were observed and then captured 4 times a month during the flowering period (December 2021 to April 2022) using sweep nets in the three departments of Bagoué throughout the flowering period. Thus, before flowering, thirty (30) cashew trees of the same diameter were chosen randomly in each orchard and then marked with a ribbon. The findings indicate that the insects visiting cashew tree inflorescences belong to 25 families and 53 species split into seven orders. The order of Hymenoptera, Diptera, Heteroptera and Lepidoptera are the most diverse in each department. As for families, Apidae, Megachillidae, Hallictidae and Noctuidae are the richest families in species in these localities. Regarding abundance, 25,035 specimens were collected. The order Hymenoptera (85.48%), the family Apidae (68.64%) and the species Apis mellifera (38.42%) were the most abundant taxonomic groups. some species (Ammophila sabulosa, Ectommius literates, Glypsus erubescens and Leptinotarsa ​​decenlineata) were present in the department of Boundiali but absent in the ones of Kouto and Tingréla.

**Keywords**: inflorescences, pollinators, cashew trees, Apidae, taxonomic

**INTRODUCTION**

Cashew cultivation was introduced to the north of Ivory Coast in 1960, with the aim of curbing deforestation and combating soil erosion Goujon *et al*. (1973). It has also enabled populations to increase their income through the marketing of associated products such as apples and cashew nuts Agboton *et a*l (2014). In 2010, cashew nuts became Côte d'Ivoire's third agricultural export product after cocoa and Koné rubber (2010). This performance ranked the country first among cashew nut producing and exporting countries in the world Diop (2016). Despite the achievements recorded, the current annual yield of Ivorian orchards, estimated between 350 kg and 500 kg per hectare, still remains low because it should reach 1.6 tonnes / hectare Djaha *et al.* (2010). One of the main causes would be the lack of pollination of flowers Bhattacharya (2004). Several studies seeking to understand the low productivity of the cashew tree explain it in part by under-pollination Reddi (1987); Freitas and Paxton (2014). This is the case of a study carried out in India which measured and obtained that, 25 to 72% of the pistil was not pollinated due to the lack of pollinating insects Reddi (1987). It is easy to understand that insects are the essential pollinators of the cashew tree and under-pollination would directly impact its production. Freitas and Paxton (2014) showed that the domestic bee (Apis mellifera), although not native to the area, is the most effective pollinator of the cashew tree in Northeast Brazil. In India, observations have shown that the insects that visit the cashew tree are mainly ants and bees Bhattacharya (2004). According to these authors, bees visit and forage on flowers more actively during the day, when the pollen and stigmas are receptive, while other insects in particular, Diptera, Lepidoptera and Coleoptera do so but less frequently and irregularly without touch the pistil. They only collect nectar and therefore do not participate in the transfer of pollen. Furthermore, in Ivory Coast (the world's leading cashew producing country), very little data exists on insects visiting the inflorescences of this speculation. It is therefore to compensate for this data gap that the present study was carried out. The general objective of this work is to improve the fruit setting rate of the cashew tree by managing the entomofauna of the inflorescences of this Anacardiaceae. More specifically, the aim was to inventory the insects visiting the inflorescences of the cashew tree and to evaluate their diversity.

**Materials and methods**

**Study area and sampling stations**

This study was carried out in the Bagoue region in the north of Ivory Coast. It belongs to the dry tropical climate regime of the Sudano-Sahelian type whose rhythm of seasons is regulated by the movement of the Intertropical Front Jourda *et al.* (2005). The climate is characterized by a rainy season which extends from May to October with maximum precipitation in September and a dry season from November to April, characterized by the harmattan which sets in from December to February. The average annual temperature varies between 25°C and 35°C Kouakou *et al.* (2012).

**Data collection**

Observations were carried out in fifteen (15) orchards of the same age, five (5) per department (Boundiali, Kouto and Tengrela). Three (3) capture techniques were used. This involves capture using fingers after direct observation, the use of the sweep net and the use of colored plates. In each cashew orchard, insect collection was carried out once a week on blooming inflorescences of 30 feet of the same diameter throughout the flowering period (December-April). After capture, the insects were preserved in pill boxes containing alcohol diluted to 70% and then transported to the laboratory. The insects collected were identified down to the species using the identification keys (Atlas Hymenoptera and Atlas Lepidoptera) Pauly (1979; 1984; 1998; 2009 and 2010) as well as the manual Phytophagous Heteroptera and Predators of West Africa Wiyao *et al.* (2011).

**Data analysis**

Insect diversity and structure have been described through taxonomic composition, rarefied richness, abundance, Shannon-Weaver diversity index (H') (Quinn & Hickey, 1990) and evenness € (Piélou, 1969). The Shannon-Weaver diversity index was used to assess insect taxonomic diversity. The Shannon-Weaver diversity index was used to assess insect taxonomic diversity. As for equitability, it was used to examine the level of organization of the entomofaunal population. All these analyzes were possible thanks to the vegan package (Oksanen et al., 2013) of the R software version 3.0.2 (R Core Team, 2013). Insect abundance was obtained by counting all individuals per taxon and per sample.

**Results**

Taxonomic composition of the entomofauna of cashew tree inflorescences in the Bagoué region

In the Boundiali department, the insects collected consisted of 46 species divided into 24 families and 6 orders. In Tingréla, the entomofauna was composed of 44 species belonging to 24 families and 6 orders. In the Kouto department, 50 species were collected divided into 25 families and 7 orders. Five (5) orders were common to the three departments of the study area. These are the orders of Hymenoptera, Lepidoptera, Diptera, Hemiptera and Coleoptera. The order of Neuroptera was specific to the departments of Kouto and Tingréla while the Blattoptera was collected in Boundiali and Kouto. The orders of Hymenoptera, Lepidoptera, Diptera, Hemiptera were the orders richest in species and families at the three localities (Table I). The families Apidae, Megachilidae, Hallictidae, Formicidae, Sphecidae, Vespidae, Noctuidae, Péridae, Papillonidae, Lycaenidae, Muscidae, Sarcophagidae, Syrphidae, Calliphoridae, Stratiomyidae, Ciccadelidae, Coréidae, Miridae, Pentatomidae, Carabidae, Coccinellidae, and Chrysomellidae were common to the three departments (boundiali, kouto and tingréla). On the other hand, the family Pyrrhocoridae and Blattidae were specific to the localities of Boundiali and Kouto. The Chrysopidae were more specific to the localities of Kouto and Tingréla. The Apidae with eight (8) species followed by the Noctuidae with five (5) species and the Halictidae with four (4) species were the families richest in species in all departments (Table I). In terms of species, some were observed only in the locality of Boundiali and Kouto. These are *Amonphila. sabulosa* and E. literates in the locality of Boundiali and *Glypsus erubescens* and *Leptinotarsa decenlineata* in the locality of Kouto. Species such as *Dactylurina staudingeri*, *Amegilla sp*, *Dysdercus volkéri*, *Coccinelila sp* and *Ectobus pallidus* were recorded in the localities of Boundiali and Kouto, whereas *Anthidiini sp*, *Ancistrocerus trifaciatus*, *Chrysoperla carnea*, *Chrysoperla affinis* were observed in kouto and Tingréla (Table I). The Kouto department was the richest with a population of 50 specie.

**Table I:** Taxonomic list of the entomofauna of cashew tree inflorescences in the Bagoué region

|  |  |  |
| --- | --- | --- |
| Orders | Families | Taxa |
| **Hymenoptera**  | Apidae | *Apis mellifera\*\*\** |
|  *Dactylurina staudingeri\*\** |
| *Xylocopa sp\*\*\** |
| *Amegilla sp\*\** |
| *Meliponula ferrufinea\*\*\** |
| *Meliponula bocandei\*\*\** |
| *Meliponula togoensis\*\*\** |
| *Xylocopa olivacea\*\*\** |
| Megachilidae | *Heriades sp\*\*\** |
| *Anthidiini sp\*\** |
| *Megachile sp\*\*\** |
| Hallictidae | *Stictonomia schubotzi\*\*\** |
| *Pseudapis sp\*\*\** |
| *Halictus sp\*\*\** |
| *Lasioglossum sp\*\*\** |
| Formicidae | *Camponotus sp\*\*\** |
| *Formica sp\*\*\** |
| *Crematogaster scutellaris\*\*\** |
| Sphecidae |  *Isodontia mexicana\*\*\** |
| *Ammophila sabulosa\** |
| Vespidae | *Ectommius literates\** |
| *Ancistrocerus trifaciatus\*\** |
| *Vespa sp\*\*\** |
| **Lepidoptera** | Noctuidae | *Heliophis viriplaca\*\*\** |
| *Chrisodeix chalcites\*\*\** |
| *Mythimna sp\*\*\** |
| *Mythimna albipuncta\*\*\**  |
| *Diarsia sp\*\*\** |
| Péridae | *Pieris napi\*\*\** |
| *Colias sp\*\*\** |
| Papillonidae | *Papilloni machon\*\*\** |
| Lycaenidae | *Lycaeni virgaureae\*\*\** |
| **Diptera** | Muscidae | *Musca automnalis\*\*\** |
| Sarcophagidae | *Sarcophaga canaria\*\*\** |
| Syrphidae | *Cheilosia sp\*\*\** |
|  *Episyrphus balteatus\*\*\** |
| Calliphoridae | *Calliphorissa vicina\*\*\** |
| Stratiomyidae | *Exairata spingera\*\*\** |
| **Hemiptera** | Ciccadelidae | *Ciccadelelila sp\*\*\** |
| Coréidae | *Anoplocnemis curvipes\*\*\** |
| Pyrrhocoridae | *Dysdercus volkeri\*\** |
| Miridae  | *Taylaridygus sp\*\*\** |
| Pentatomidae | *Spavia sp\*\*\** |
| *Glypsus erubescens\*\** |
| *Cléptus sp\*\*\** |
| **Coleoptera** | Carabidae | *Croscherichia sangunolenta\*\*\** |
| Coccinellidae | *Leptinotarsa decenlineata\** |
| *Coccinelila sp\*\** |
| Chrysomellidae | *Lamprocopa occidentallis\*\*\** |
| **Nevroptera** | Chrysopidae | *Chrysoperla carnea\*\** |
| *Chrysoperla affinis\*\** |
| **Blattoptera** | Blattidae | *Ectobus pallidus\*\** |
| **7** | **25** | **53** |

(\*\*\*): Species present in three departments

(\*\*): Species specific in two departments;

(\*): Species specific in one department

**Diversity of the entomofauna of cashew tree inflorescences in the Bagoué region**

There is a difference between the Shannon index of the three departments. The index (H’ = 3.26) of the Kouto department is higher than those of the Tingréla departments (H’ = 2.58) and Boundiali (H’ = 2.38). The Kouto department therefore appears to be the most diverse. The Kruskal-Willis test shows that the difference between the Shannon indices is not significant (P = 0.36) (Figure 1a). The fairness index varies between 0.62 (Boundiali) and 0.69 (Kouto and Tingréla). Overall, the entomofaunal population is well organized and well structured in the three departments. The Kruskal-Wallis test shows that there is no significant difference between the equitability index of the departments (P = 0.35) (Figure 1b). In terms of rarefied richness, by bringing the three departments to the same abundance, the Kouto department recorded 49.9 species followed by the Boundiali department 46 species and the Kouto department 45 species. No significant difference was observed between rarefied richness according to Kruskal-Wallis (P = 0.24) (Figure 1c).



**Figure1**: Box plots indicating variations in the Shannon-Weaver, Equitability and Rarefied Wealth indices between the departments of the Bagoué region (1a: Shannon-weaver; 1b: Equitability; 1c: Rarefied Wealth).

**Relative abundance of insects dependent on cashew tree inflorescences in the Bagoué region**

A total of 25,072 were collected, the most abundant orders of insects on the inflorescences of the cashew tree in Bagoué are Hymenoptera, Lepidoptera, Diptera with respective proportions of 85.48%, 7.14% and 4.40 % of total abundance. These three orders of insects total 96.64% of the total number of insects. The order Heteroptera, Blattoptera, Coleoptera and Neuvroptera are the least abundant orders on the inflorescences of the cashew tree. The respective numbers of these three orders are 2.64%; 0.44%; 0.30%; 0.12%. The cumulative number of these orders is 3.36% of the total number (Figure 2).

At the family level, the highest numbers are observed in Apidae (68.64% of individuals), Formicidae (8.49% of individuals), Hallictidae (5.25% of individuals), Noctuidae (4 .80% of individuals). These families constitute 87.19% of the total number of insects collected from the inflorescences of the cashew tree. The families of Péridae, Sarcophagidae, Megachilidae, Syrphidae, Stratiomyidae followed with 1.78%, 1.59%, 1.56%, 1.24%, 1.10% respectively. The least abundant families on cashew tree inflorescences are Coreidae and Pentatomidae (0.95% each), Ciccadelidae (0.50%), Vespidae (0.48%), Blattidae (0.47%), Muscidae (0.46%), Papillonidae (0.43%), Calliphoridae (0.30%), Sphecidae (0.27%), Chrysomellidae (0.18%), Pyrrhocoridae (0.14%). The families Lycaenidae, Carabidae and Chrysopidae recorded 0.13% each. The lowest proportions were recorded in Lygaeidae (0.10%) and Miridae (0.01%) (Table II). Regarding the species, the most abundant species on the inflorescences of the cashew tree is Apis mellifera with 38.42% of the total population. It is followed by the species Meliponula bocandei (18.73%), Camponatus vagus (10.14%), Meliponula togoensis (4.69%) and Stictonomia schubotzi (2.87%). The other species recorded the lowest abundances on the inflorescences of the cashew tree (Table II).

**Figure 2:** Relative abundance of orders of insects dependent on cashew tree inflorescences in the Bagoué region

**Table II:** Relative abundance of families and species of insects in the inflorescences of cashew tree

|  |  |  |
| --- | --- | --- |
| **Families** | **Taxa** |  **Percentages** |
| **Apidae** | *Apis mellifera* | 38,42 |
| *Dactylurina staudingeri* | 0,82 |
| *Xylocopa olivacea* | 0,48 |
| *Xylocopa sp* | 0,20 |
| *Amegella sp* | 0,32 |
| *Meliponula ferrufinea* | 4,21 |
| *Meliponula bocandei* | 18,73 |
| *Meliponula togoensis* | 5,46 |
|  | 68,65 |
| **Megachillidae** | *Heriades sp* | 0,99 |
| *Anthidiini sp.* | 0,06 |
| *Megachile sp* | 0,52 |
|  | 1,56 |
| **Halictidae** | *Stictonomia schubotzi* | 2,99 |
| *Pseudapis sp* | 1,39 |
| *Halictus sp* | 0,41 |
| *Lasioglossum sp* | 0,46 |
|  | 5,25 |
| **Formicidae** | *Camponotus sp* | 10,14 |
| *Formica sp* | 1,74 |
| *Crematogaster scutellaris* | 1,36 |
|  | 13,25 |
| **Sphécidae** | *Isodontia mexicana* | 0,23 |
| *Ammophila sabulosa* | 0,04 |
|  | 0,27 |
| **Vespidae** | *Ectommius literates* | 0,03 |
| *Ancistrocerus trifaciatus* | 0,08 |
| *Vespa sp* | 0,34 |
|  | 0,45 |
| **Noctuidae** | *Chrisodeix chalcites**Mythimna sp* | 1,410,65 |
| *Heliophis viriplaca* | 1,71 |
| *Mythimna albipuncta* | 0,94 |
| *Diarsia sp* | 0,09 |
|  | 4,80 |
| **Piéridae** | *Pieris napi* | 2,47 |
| *Colias sp* | 0,17 |
|  | 2,64 |
| **Papillonidae** | *Papilloni machon* | 0,40 |
|  | 0,40 |
| **Lycaenidae** | *Lycaeni virgaureae* | 0,12 |
|  | 0,12 |
| **Muscidae** | *Musca automnalis* | 0,43 |
|  | 0,43 |
| **Sarcophagidae** | *Sarcophaga canaria* | 1,50 |
|  | 1,50 |
| **Syrphidae** | *Cheilosia sp* | 0,29 |
| *Episyrphus balteatus* | 0,95 |
|  | 1,24 |
| **Calliphoridae** | *Calliphorissa vicina* | 0,29 |
|  | 0,29 |
| **Stratiomyidae** | *Exairata spingera* | 1,01 |
|  | 1,01 |
| **Ciccadellidae** | *Ciccadelelila sp* | 0,47 |
|  | 0,47 |
| **Coréidae** | *Anoplocnemis curvipes* | 0,90 |
|  | 0,90 |
| **Pyrrhocoridae** | *Dysdercus volkeri* | 0,13 |
|  | 0,13 |
| **Lygaéidae** | *Aspilocoryplus sp*  | 0,10 |
| **Miridae** | *Taylaridygus sp* | 0,02 |
|  | 0,02 |
| **Pentatomidae** | *Spavia sp* |  0,19 |
| *Spavia sp* | 0,19 |
| *Clétus sp* | 0,71 |
| *Glypsus erubescens* | 0,12 |
|  | 1,03 |
| **Blattidae** | *Ectobus pallidus* | 0,44 |
|  | 0,44 |
| **Carabidae** | *Croscherichia sangunolenta* | 0,12 |
|  | 0,12 |
| **Coccinellidae** | *Leptinotarsa decenlineata* | 0,05 |
| *Coccinelila sp* | 0,09 |
|  | 0,13 |
| **Chrysomellidae** | *Lamprocopa occidentallis* | 0,17 |
|  | 0,17 |
| **Chrysopidae** | *Chrysoperla carnea* | 0,08 |
| *Chrysoperla affinis* | 0,05 |
|  | 0,12 |

**Discussion**

 From the analysis of the data collected on the genotypes of cashew trees and in all the localities of the study area it appears that 53 species of insects regularly visit the inflorescences of the cashew tree. These species are distributed among seven orders and 25 families. The orders Hymenoptera, Heteroptera, Diptera and Lepidoptera dominate this diversity. This high diversity could be explained by the fact that cultivated plants are conducive to the proliferation of insects. Indeed, the cashew tree produces mainly in the dry season. Due to the scarcity of wild plants during this period, cashew flowers represent a source of food and a refuge plant for many insects. The cashew tree is a flowering plant that produces fruit. All of these organs constitute a food source for different groups of insects. This high diversity of insects could also be explained by the favorable ecological conditions offered by the cashew tree. Indeed, with the foliage, the cashew tree could create a microclimate favorable to the proliferation of many insects. This result is similar to that of a study conducted by Tuo *et al.* (2021) on four varieties of cashew tree in Ivory Coast in the Poro region. These authors showed that the orders Hymenoptera, Heteroptera and Diptera were more diversified in families on the inflorescences of the four cashew genotypes. On the other hand, Freitas and Paxton (1996) during a study carried out in the North-East of Brazil, showed by direct observations on the inflorescences of the cashew tree and the counting of pollen grains adhering to insects that, hymenoptera were the most diverse order. These insects are anthophilous and are constantly looking for food (nectar and pollen) on the inflorescences of the cashew tree. This difference in results could be linked to the climate and geographical location and also to the slight difference observed in the methodology.

 As for the orders of Neuroptera, Coleoptera and Blattoptera which are less diversified show that these insects visit the flowers of the cashew tree less or that they have another source of food other than the nectar and pollen from the cashew tree. This result is similar to that of Freitas and Paxton (1996) who show that insects belonging to these orders do not distinguish young flowers with fresh pollen or receptive pistils from those that are already too old. They only visit the flowers when they have a little viable pollen, or they do not show any consistency in visiting the cashew tree flowers. Bhattacharya (2004) showed that these insects visit flowers but, less frequently, irregularly and without touching the pistil.

 At the family level, the family Apidae, Megachillidae, Hallictidae, Noctuidae were the families with the most diversity in species on the inflorescences and in all localities. These results could be explained by the fact that these different families bring together the majority of insect species that visit cashew tree flowers. The cashew tree being a flowering plant, these inflorescences constitute a food reservoir for visiting insects. This result is similar to those obtained by Silué *et al.* (2022) on cashew flowers in cashew production regions in Ivory Coast. They showed that the Apidae, Hallictidae and Megachillidae families were the most species-diverse families.

 Certain species were present in one department or two departments and absent in the other. The absence or presence of these insects could be explained by differences in climatology between the two departments. Our study was carried out in the Bagoué region which has three departments (Boundiali, Kouto and Tingréla). The department of Tingréla, which borders Mali, has vegetative and pedological characteristics different from the other two departments. When we move from Tingréla to Boundiali, the vegetation changes and becomes increasingly dense. This gradient of heterogeneity can impact the taxonomic distribution of species in the region. Our results corroborate those of Acapovi *et al.* (2001) in the Kabadougou region where they showed that insect species were in one department and absent in the other.

 Regarding the abundance of orders, Hymenoptera was the most abundant order on the cashew trees studied and throughout the study area. This result could be explained by the fact that the order Hymenoptera is an order made up of a diversity of insects visiting the inflorescences of the cashew tree. These insects' main source of food is nectar and pollen from the cashew tree. This result is similar to that of Bhattacharya (2004) who showed in a study in Brazil that the insects which visit the cashew tree are mainly Hymenoptera. Tuo *et al.* (2021) in a study carried out in northern Ivory Coast on four varieties of cashew tree showed that insects belonging to the order Hymenoptera were more abundant on the inflorescences of these different varieties.

 In Bagoué (Boundiali, Kouto and Tingréla), the Apidae family recorded the greatest relative abundance. These results could be explained by the fact that the Apidae and specifically, the Apis mellifera species are abundant on the inflorescences. Coulibaly (2019) showed in northern Ivory Coast that Apis mellifera is more abundant on the inflorescences of the mango tree, which is a plant close to the cashew tree since it belongs to the same family (Anacardiaceae). This result is similar to those obtained by Silué *et al*. (2022) and Tuo *et al.* (2021) on the inflorescences of the cashew tree in Ivory Coast. These authors obtained that the Apidae family was made up of a great diversity of species visiting the flowers of the cashew tree, which would be the cause of a significant abundance of this family on the flowers.

 Regarding the abundance of species, the species *A. mellifera* is the most abundant. This result may be due to constant visitation of the species to cashew orchards. Indeed, the bee *A. mellifera* can form colonies of 25,000 individuals Walters and Taylor (2006). This number could directly affect the number of individuals visiting the cashew tree inflorescences. This result is similar to that obtained by Silué *et al* (2022) who showed that the species A. mellifera is more abundant on the inflorescences of the cashew tree in production areas in Ivory Coast.

**Conclusion**

This study made it possible to identify 53 species of insects which visit the inflorescences of cashew trees in the north of Côte d'Ivoire, in the Bagoué region. It appears that the order Hymenoptera, Diptera, Heteroptera and Lepidoptera are the most diverse. At the family level, Apidae, Megachillidae, Hallictidae and Noctuidae were the most species-rich families on inflorescences in all localities. The greatest abundances are recorded by the order Hymenoptera, the family Apidae and the species *Apis mellifera.*

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