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Diversity of hymenoptera and lepidoptera in cashew (*Anacardium occidentale*) orchards in Northern Cote D'Ivoire: The case of the bagoue

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Abstract
Cashew nuts remain one of the main sources of income for farmers in the Bagoué region. Generally, the increase in production depends on the extension of cashew plantations. However, this process is detrimental to biodiversity and in particular to animals. With the aim of increasing cashew nut production, this work aims to inventory the hymenoptera and lepidoptera families. To do this in 20 fields that were 10 and 15 years old and older en 2021 and 2022 by captured with yellow traps, insects were collected in the departments of Boundiali and Kouto. The trials lasted 6 months and were conducted every weeks in different orchards in the two locations. The results indicate that Hymenoptera and Lepidoptera visiting the cashew orchard belong to 9 families including 6 families (Hymenoptera) and 3 families (Lepidoptera). The order Hymenoptera (73.20%) was more abundant than the order Lepidoptera (26.80%) in the study area. Thus, the abundance of these insect families has been established on Anacardium occidentale. It appears that Formicidae (34.67%) and Apidae (21.83%) were more abundant. At the departmental level, Boundiali is the most abundant.

Keywords: Anacardium occidentale, hymenoptera, lepidoptera, Family, orchard.

Introduction
The cashew tree is a tree native to the northeastern coast of Brazil where it was cultivated by indigenous peoples long before it was discovered by the Portuguese who later introduced it to some of their colonies in Africa and Asia (Lacroix, 2003) [1]. Cashew cultivation was introduced in northern Côte d'Ivoire in 1960 with the aim of slowing down deforestation and combating soil erosion (Goujon et al., 1973; Adeigbe et al., 2015) [2, 3]. In addition, the cashew tree provides marketable products such as cashew apples and cashews (Agboton et al. 2014) [4]. In 2010, the latter became Côte d'Ivoire's third largest agricultural export product after cocoa and rubber (Koné, 2010) [5]. Côte d'Ivoire is the world's leading cashew nut producer and exporter (Diop, 2016) [6]. However, the annual yield of Ivorian orchards, between 350 kg and 500 kg per hectare, remains low (Djaha et al. 2010) [7]. Indeed, the expected average yield is estimated at between 1,080 t/ha and 2,950 t/ha per year (Goujon et al., 1973) [8]. The main causes are the use of unimproved plant material, archaic traditional production techniques, phytosanitary problems (Viana et al., 2007) [9] and the lack of pollination of cashew flowers (Bhattacharya, 2004) [10]. In agriculture, entomophilous pollination is remarkable in terms of quantity and quality (Bernard, 2015) [11]. For example, a recent study showed that in production plots, pollination by bees contributes to 66% of the production of quality seeds (Bernard, 2015) [11]. In Ghana, a high yield (1250 kg/ha), directly correlated with a high diversity and abundance of pollinators, favoured by the sustainable management of the cashew agroecosystem (Aidoo, 2009) [12]. Unfortunately, very few data exist on insects visiting cashew orchards in Côte d'Ivoire (Kouadio et al., 2017) [13].
This is the subject of this study, which has the general objective of knowing the diversity of hymenoptera and Lepidoptera of cashew orchards in the Bagoué in order to provide a more complete scientific database of pollinators of this plant.

2. Materiel and Methology
2.1. Study area: This study was carried out in the dry season, corresponding to the flowering period of cashew nuts in the Bagoué region belonging to the savannah district.

It belongs to the dry tropical climate regime of the Sudano-Sahelian type, the rhythm of the seasons of which is regulated by the movement of the Intertropical Front Jourda et al (2005) [14]. The climate is characterized by a rainy season that extends from May to October with maximum rainfall in September and a dry season from November to April, characterized by the harmattan that occurs from December to February. The average annual temperature varies between 25 °C and 35 °C Kouakou et al (2012) [15]. The trials were carried out over two years from 2020 to 2021 in the departments of Boundiali and Kouto. The study was carried out in plots during the dry season, i.e. at the time of the flowering of the cashew tree. For comparisons, each collection was an observation.

2.2 Methodology

2.2.1 Data Collection

The study was carried out on fields (20) aged 10 and 15 years and over. The cashew tree reaches its production potential in this period. The plots are chosen to cover all the cashew production sites of the Two Departments in the Bagoué. The insects were collected using the traps with coloured cups (yellow). In the plots. chosen, a perimeter of 100m^2 was delimited and five yellow traps were placed high up due to two traps at each end and one in the middle. Inside the yellow plates was soapy water that prevented the captured insects from escaping. After a period of 24 hours, the insects caught by the traps were collected and stored in 10% alcohol. Sampling was done every weeks in each cashew field due to the flowering period of the cashew tree. Insect samples were identified using a Motic binocular loupe at 10x20 magnification using the order and family identification keys (Delvare and Aberlenc, 1989) [16] and Atlas Hymenoptera (Pauly, 1979, 1984) [17, 18]. The coloured cups were chosen on the basis of the work of Southwood (1978). According to this author, this method provides an estimate of the relative abundance of particular insect taxa and has the potential to produce species richness estimates. According to the same author, coloured cups can be used for both qualitative and quantitative sampling of insects in many ecological studies.

2.2.2 Statistical analysis

Using the past 3 software, insect diversity and structure were described through taxonomic composition, rarefied richness, abundance, Shannon-Weaver diversity index (H'), equitability. The Shannon-Weaver Diversity Index was used to assess the taxonomic diversity of insects. As for equitability, it was used to examine the level of organization of the entomofaunal population. In this study, one-way analyses of variance (ANOVA, $p<0.05$) were performed and then homogeneous means were pooled using Duncan tests using the Statisca software. They made it possible to determine separately whether certain average numbers per taxonomic group are significantly different.

3. Results and Discussion

3.1 Results

3.1.1 Taxonomic richness of Hymenoptera and Lepidoptera

The insects of the two orders (Hymenoptera and Lepidoptera) recorded in the cashew orchards in the Bagoué included nine (9) families. The order Hymenoptera was richer in families with six (6) families and three (3) families for the order Lepidoptera which was less rich (Table I).

A total of 7705 insect specimens were recorded. The relative abundance of Hymenoptera (73.20%) was greater than that of Lepidoptera (26.80%). One-way analyses of variance revealed a significant difference between the relative abundance of the two insect orders ($p<0.05$). At the family level, the Formicidae (34.67%) represented the most abundant family. Apidae (21.83%) and Papilonidae (10.49%) were moderately abundant. With rates below 10%, the other six (6) insect families were considered to have low abundance. The one-way analysis of variance, followed by the Duncan test, also revealed a significant difference in the relative abundance of insect families ($p<0.05$) (Table I).

Table 1: Specific richness of Hymenoptera and Lepidoptera in cashew orchards in the Bagoué

Orders	Relative Abundance (%)	Families	Relative Abundance (%)
Hyménoptera	73,20^a	Formicidae	34,67^a
		Apidae	21,83^a
		vespidae	6,29^{cd}
		Sphécidae	4,80^d
		Halictidae	3,85^d
		Megachilidae	1,75^d
Lépidoptera	26,80^b	Piéridae	8,81^{cd}
		Noctuidae	7,50^{cd}
		Papilonidae	10,49^c

3.1.2 Diversity of Hymenoptera and Lepidoptera in the Bagoué

The analysis shows that there is no difference between the Shannon index of the two departments. The index (H' = 3.60) is the same for the departments of Kouto and Boundiali. The same families were collected in both departments.

The equitability index was the same 0.91 (Boundiali) and 0.90 (Kouto). Overall, the entomofaunal population is well organized and well structured at both locations. In terms of scarce wealth, by reducing the two departments to the same abundance, the departments have the same number of families (8.64).

3.1.3. Insect abundance by study department

In the two departments sampled, the orders Hymenoptera (531.83±31.24) and Lepidoptera (212.83±15.66) recorded the highest average abundance in the Kouto department. Low abundances were recorded in the department of Kouto with 408,167±129.28 for Hymenoptera and 131,33±42,65 for Lepidoptera.

The one-way analysis of variance, followed by the Duncan test, also revealed a significant difference between the mean abundance of the two orders of insects (P=0.00254) (Figure 2).

At the family level, families belonging to the order Hymenoptera recorded the high average abundances in the department of Boundiali. The department of Kouto was less abundant. The family Formicidae and Apidae were the most abundant in both localities, but they were more important in Boundiali (Formicidae=255.33±34.891 and Apidae=49.33± 26.70) than in Kouto (Formicidae=189.83±61.73 and Apidae=131±42.73). The two families in the two localities were followed by the Vespidae, Sphecidae, Halictidae, Megachilidae with an average abundance between 15.17±5.22 and 46.5±8.25 for the locality of Boundiali and between 7.33±3.80 and 34.33±11.71 for the the locality of Kouto. The ANOVA analysis of variance revealed a significant difference between the mean abundance of the families of the two departments (P=0.000001) followed by the Newman-Keuls test revealed homogeneous groups at the mean level (Table 2).

As far as Lepidoptera are concerned, the three (3) families Pieridae, Noctuidae, Papilonidae have been observed more in Boundiali than in Kouto. The mean abundances of these families for Boundiali ranged from 51.88±3.43 to 80.83±12.72 and from 33±11.15 to 53.83±17.43. The ANOVA analysis of variance revealed a significant difference between the mean abundance of families in the two departments (P=0.000001) followed by the Duncan test revealing homogeneous groups at the mean level (Table II). The department of Boundiali is more abundant.

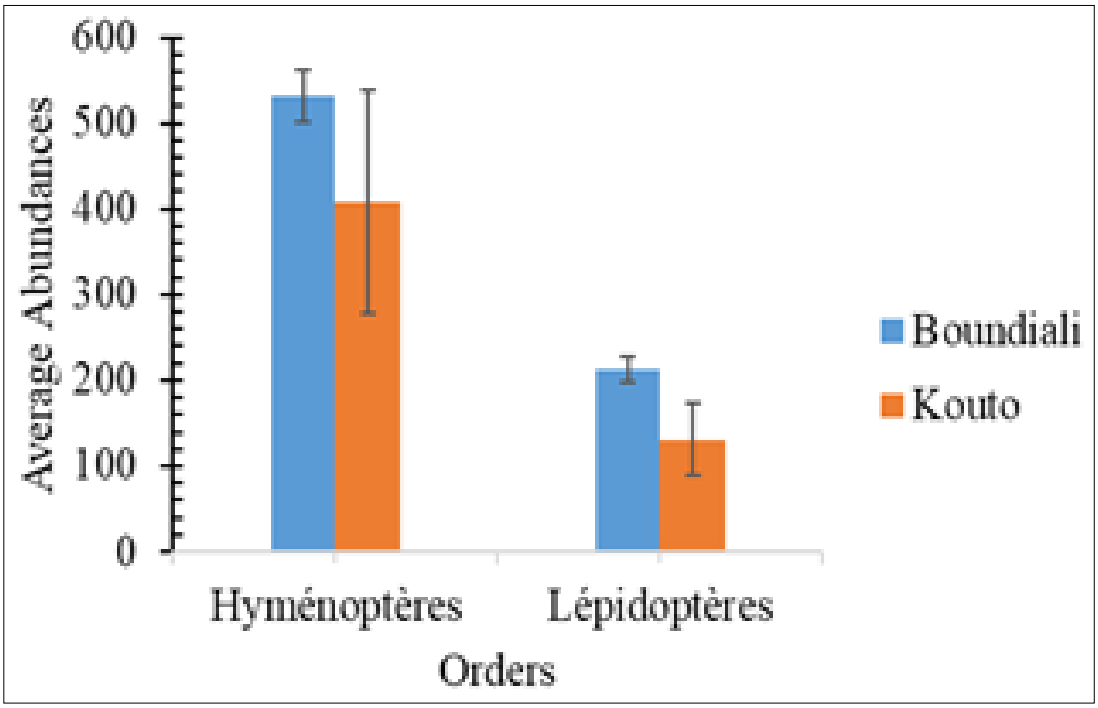

Fig 1: Average abundances of orders by department

Table 2: Average family abundances

Familles	Boundiali	Kouto
Apidae	149,33±26,70[a]	131±42,73[a]
Formicidae	255,33±34,89[a]	189,83±61,73a
Sphécidae	36,5±3,56[c]	25,17±8,79[c]
vespidae	46,5±8,25[c]	34,33±11,71[c]
Halictidae	29±7,07[c]	20,5±8,06[c]
Megachilidae	15,17±5,22d	7,33±3,80[d]
Piéridae	80,16±9,19[b]	33±11,15[b]
Noctuidae	51,88±3,43[b]	44,5±15,66[b]
Papilonidae	80,83±12,72[b]	53,83±17,43[b]

3.2 Discussion

From the analysis of the data collected in the cashew orchards, it appears that the order of Hymenoptera was richer in families. Indeed, this result could be explained by the fact that several families of bees and other families of Hymenoptera were the main visitors to cashew orchards. This result is similar to a study carried out in northeastern Brazil by Freitas and Paxton, (1996) [19] which showed by direct observations on cashew inflorescences and the count of pollen grains adhering to insects that Hymenoptera were the most diverse order. These insects are antophiles and are constantly looking for food (nectar and pollen) on the inflorescences of the cashew tree. As for the order Lepidoptera, which is less rich, shows 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) [19] who show that insects belonging to these above-mentioned orders do not distinguish young flowers with fresh pollen or receptive pistils from those already too old. They visit flowers only when they have some viable pollen, or show no consistency in visiting the cashew blossoms. Bhattacharya, (2004) [9] had shown that these insects visit the flowers but, less frequently, irregularly and without touching the pistil.

Regarding the abundance of orders, Hymenoptera was the most abundant order on the cashew trees studied and in the entire 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 have as their main food source the nectar and pollen from the cashew tree. This result is similar to that of Bhattacharya, (2004) [9] who showed in a study in Brazil that the insects that visit the cashew tree are mainly hymenoptera. Tuo et al, 2021[20] in a study carried out in northern Côte d'Ivoire on four varieties of cashew trees showed that insects belonging to the order Hymenoptera were more abundant on

the inflorescences of these different varieties.

Regarding insect families, our results showed that Apidae and Formicidae were the most abundant in terms of number of specimens. These results could be explained by the fact that Apidae and Formicidae include several species of insects visiting the flowers of the cashew tree. Coulibaly, (2019) [21] showed in the north of Côte d'Ivoire 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).

In the two departments of the study area (Boundiali, Kouto), the Formicidae and Apidae families recorded the greatest abundance. These results could be explained by the fact that Apidae and specifically the species Apis mellifera are abundant on the inflorescences. Coulibaly, (2019) [21] showed in northern Côte d'Ivoire 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[22] and Tuo et al, 2021[20] on cashew tree inflorescences in Côte D'Ivoire. These authors obtained that the family Apidae was made up of a great diversity of species visiting the flowers of the cashew tree, which would be at the origin of a significant abundance of this family on the flowers.

4. Conclusion

Insects can allow cashew plantations to have very good yields. However, the abundance and diversity of these differ greatly between localities. An improvement in the health status of these orchards will allow insects to become more involved in the pollination of these plantations. Also, the training of growers in the use of pesticides in plots could help to preserve not only the health of these agents, the usefulness of which is still unknown to producers, but also that of producers, consumers and the environment.

5. Thanks

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