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Inventory of the entomofauna associated with *Tamarindus indica* flowers and fruits and their damage in Hauts-Bassins' region of Burkina Faso

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Abstract
Insects are essential to the development of flowering plants, but they also cause huge damage to plants and their by-products. The tamarind tree, a plant with many virtues, is subject to attack by some insects. The aim of our study was to determine the abundance and diversity of insects associated with tamarind (*Tamarindus indica*) from flowering to maturity. Plastic bottles were used as traps to capture insects during the plant's flowering period in five localities in the Upper Basin region of Burkina Faso. Each trap contained a mixture of fruit juices (mango, orange and pineapple). For insects associated with *T. indica* fruits, forty samples were taken per locality to obtain emergences 45 days later. Pods from each batch bearing at least one insect emergence hole were counted before and after 45 days. Insects were preserved in vials containing 70 °C alcohol. Identification was carried out using a LEICA EZ4HD binocular loupe. For flowering insects, the species richness was 23, divided into 5 orders. The Shannon diversity index was highest at Nasso (2.98). The theoretical value calculated (H' max = 4.52) is high. Piélou's equitability indices was low, varying from 0.48 to 0.66 depending on locality. For insects emerging from fruit, *Caryedon serratus* was present in every locality, while *Sitophilus linearis* and *Luprops badius* were only recorded in Dindérèsso and Farakoba. Shannon diversity index was zero in 3 localities, whereas it was 1.55 in Dindérèsso and 1.58 in Farakoba, and the theoretical value calculated (H' max = 1.58). The perforation rate showed a clear difference between Dindérèsso and Kiri 45 days later.

Keywords: Inventory, entomofauna, *Tamarindus indica*, damage, Burkina Faso

1. Introduction

Tamarind (*T. indica* L.), is one of the cultivated and familiar plants worldwide [1, 2]. It serves as a medicinal plant for the treatment of several diseases and nutritional for malnutrition. Tamarind is a large tree found throughout semi-arid Africa, Madagascar and India [3].

T. indica L. contains highly essential phytochemicals, including phenolics, uronic acid, tartaric acid, malic acid, pectin and glucose [3]. It contains vital elements including copper, calcium, iron, manganese, sodium, magnesium, phosphorus, potassium and zinc [4, 5]. *T. indica* has been used in Ayurveda to treat gastrointestinal, inflammatory, neurological and digestive problems [6, 7]. It has anti-ulcer, healing, anti-inflammatory and antipyretic properties [8]. This makes it useful in the treatment of a variety of clinical problems, including diseases of the gastrointestinal tract.

Tamarind (*T. indica* L.) could contribute to Burkina Faso's economic growth. The ripe, dried and shelled fruit is used in the industrial production of sweet non-alcoholic beverages and various traditional juices. It is a traditional household product. It is processed both by craftsmen and industrially [9]. The leaves are rich in vitamin C and contain 14.1% protein. Leaves and flowers are used in soups and sauces. Leaves are used in the cooking of "tô" [10]. Bark is used to treat wounds, while leaves are used as antibiotics and in the cooking of local porridges [11]. Non-timber tamarind products can be found on the country's various markets. Tamarind fruit, juice (Soft drink), syrup and many other products can be found in various markets. The share of income from the tamarind sector in the PICOFA zone contributes more to household NTFP income [12]. Value added per tonne (VA/t) of tamarind fruit is 43, 704 FCFA for the sector in the PDRD zone and 23, 389 FCFA in the PICOFA zone.

monetary income per tonne (NMI/t) of tamarind fruit in the PDRD and PICOFA zones is 36,711 FCFA and 5,586 FCFA respectively [12]. Despite this high socio-economic importance, this NTFP is still undervalued. According to [13, 14], the fruit of *T. indica* is a curved pod containing a brownish, sweet pulp and a few hard seeds that can be stored without constraint. However, the problem of entomofauna hinders the development of tamarind by damaging the pods during the storage. However, the insects that attack tamarind stocks could be present well before the harvest time. It was with this in mind that we carried out this study to analyze insect damage to tamarind. For this purpose, we need to assess the abundance and diversity of insects associated with *T. indica*, in order to put effective control strategies in place. More specifically, we will first assess the abundance and diversity of insects interacting with *T. indica* during the flowering period, then evaluate the insects associated with tamarind fruit, and finally determine the rate of initial infestation of pods by insect at harvest.

2. Material and methods

2.1 Description of the study site and collection period

Data collection took place in the commune of Bobo-Dioulasso, one of the major tamarind harvesting and consumption areas. More specifically, in the localities of Dindérèsso, Farakoba, Kiri, Logofourousso and Nasso. Bobo-Dioulasso is located in the south-western part of Burkina Faso, in the southern Sudanian zone. It has an annual rainfall of over 1,000 millimeters and a rainy season lasting around 6 months [15]. Flowering insects were collected from April to May 2022, and ripe fruits in November 2022.

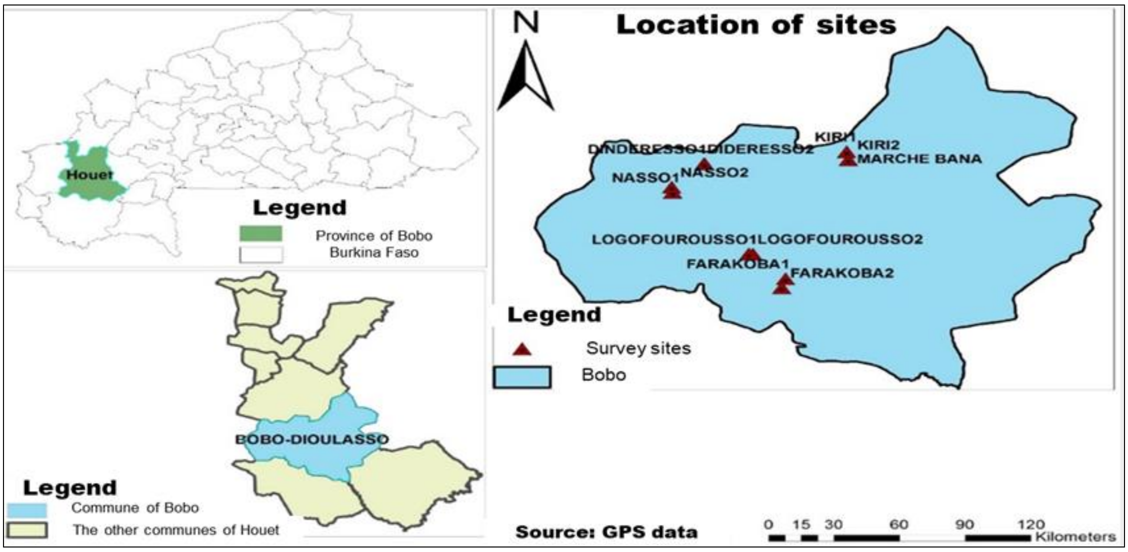

Fig 1: Map of Bobo-Dioulasso commune showing sampling zones

2.2 Insects' sampling

2.2.1 Sampling during the flowering period

We drew inspiration from the sampling procedure used by [16] and [17] and adapted it to our study. Traps with plastic bottles were used to capture flowering insects in the five localities, based on the protocol implemented by [18]. We hung two traps per tree, an opening was made in the upper middle of the bottles, which contained a mixture of fruit juices, namely mango, orange and pineapple. There is no set recipe for preparing a bait, but it should smell of light alcohols and esters, which are products of fermentation [19]. When insects came to forage on the flowers, they were attracted by the juice. Once inside the bottles, the insects could not get out. The trapped insects were taken to the Laboratory of Fundamental and Applied Entomology of Joseph KI-ZERBO University (Ouagadougou, Burkina Faso). Pre-sorting was performed to classify the insects captured according to their orders and families. After sorting, the samples were identified using a binocular loupe, and the insects were kept in vials containing alcohol at 70 °C.

2.2.2 Insects' sampling at fruiting stage

Harvesting took place in November. We used the same sampling procedure as in 2-2-1. In each of the 5 localities, four samples of dry *T. indica* pods were taken, placed in small cotton bags and brought back to the laboratory. Pods from each batch bearing at least one insect emergence hole were counted, then placed separately in a one-liter glass jar to monitor insect emergence. The opening of each jar was closed with a mosquito net held in place by a rubber strap. Monitoring lasted 45 days to allow the emergence of the first generation of insects from the eggs laid at harvest. To prevent re-infestation of the seeds, the contents of each jar were sieved daily using a 2.5 mm mesh sieve. The insects collected were stored in 40 cl bottles containing 70% alcohol for identification and counting at the end of the monitoring period. Immediately after sieving, each batch of pods was examined to count those bearing at least one insect emergence hole. At each harvest, the geographical position of each plant was recorded using GPS.

2.3 Insects' identification and parameters assessment

2.3.1 Specimen identification

Identification of the insects collected was carried out in Laboratory of Fundamental and Applied Entomology of Joseph KI-ZERBO University, using a LEICA EZ4HD binocular loupe and the identification keys of: [20-23].

2.3.2 Assessment of biodiversity indicators at flowering time: *Insect species richness* (Magurran, 2004) [24], equal to the total number of species recorded at each site;

Shannon Wiener diversity index, H' (Magurran, 2004) [24], which expresses the diversity of the stand. It is determined from the number of individuals per species and per site as a

function of time by the formula H' = - Σ ((qi/Q) log2 (qi/Q)); where *qi* represents the number of individuals of taxon *i* and *Q*, the total number of individuals in the stand.
Diversity is highest when all observed taxa have the same abundance. H' max = log2S; S is the total number of taxa in the stand. The Shannon Wiener diversity index ranges from 0 to Ln(S).
The equitability index by Pielou, J' (Magurran, 2004) [24], which evaluates the equi-repartition of numbers in the stand. It can be used to define regularity, i.e. recorded diversity in relation to maximum theoretical diversity, and to compare ecosystems with very different species richness. It also gives an idea of the quality of stand structuring. It is calculated by the formula: J' = H'/H' max;

$$H_{\max} = -\sum_{i=1}^{S} \frac{1}{S} \ln \frac{1}{S} = \ln S.$$

Values of (J') range from 0 to 1; low values of this index also indicate an unequal contribution of the different species to the constitution of the community.
Jaccard's similarity index (J) determines the similarity between the two sites**.** It is calculated using the following formula: [25] J = c / (a + b - c)
Where: a = species richness of group A; b = species richness of group B; c = number of species common to A and B.
Its value ranges from 0 (dissimilar communities) to 1 (maximum similarity).

Initial Pod Damage Rate (IDR)

$$\mathrm{IDR} = \frac{\text{Number of pods perforated at end of experiment}}{\text{Total number of pods}} \times 100$$

Initial Pod Damage Rate per Insect (IDRI)

$$\mathrm{IDRI} = \frac{\text{TDI} \times \text{relative \% of each insect species}}{100}$$

The relative percentage represents the ratio of the number of individuals of each insect species to the total number of insects counted.
The average abundance of each insect species: this is the average number of each insect species emerged.

2.3. Data analysis

Tests were carried out using R software. We used the Shapiro-Wilk test to check the normality of our data, then subjected them to an analysis of variance (ANOVA). The tests were considered significant at the 5% probability level.

3. Results

3.1 Overall abundance of insects sampled

Our study showed 315 individuals divided into 26 species, 23 genera and 13 families were collected (Table 1). The number of species and individuals was higher in Dindérèsso than in other localities.

Table 1: Abundance of insect species collected on different sites

Localities	Dindérèsso	Farakoba	Kiri	Logofourousso	Nasso	Total
Number of families	8	5	6	4	9	13
Number of genera	10	7	6	7	17	23
Number of species	10	7	6	7	18	26
Number of individuals	89	69	41	46	70	315

3.2 Overall distribution and richness of insect species per locality: All the insects recorded belong to 26 species. The Coleoptera order was the most important, with 6 families comprising 13 species (Table 2). Next come Diptera, Hemiptera and Hymenoptera. The highest percentages of families are represented by the Scarabaeidae (30.77%), followed by the Tephritidae (15.38%). Nasso had the highest species richness, with 18 different species, while Kiri has the lowest, with 6 species (Table 2).

Table 2: Specific richness per locality

Families	Genrera	Species	Localities				
			Dindérèsso	Farakoba	Kiri	Logofou rousso	Nasso
Apidae	*Apis* (Linnaeus, 1758)	*Apis mellifera* (Linnaeus, 1758)	+	−	+	−	−
Curculionidae	*Phyllobius* (Germar, 1824)	*phyllobius argentatus* (Linnaeus, 1758)	−	−	+	−	+
Drosophilidae	*Zaprionus* (Coquillett, 1902)	*Zaprionus indianus* (Gupta, 1970)	−	−	+	−	+
Formicidae	*Camponotus* (Mayr, 1861)	*Camponotus vagus* (Scopoli, 1763)	−	−	−	−	+
		Camponotus floridanus (Buckley, 1866)	+	−	−	−	−
Muscidae	*Chrysomya* (Robineau-Desvoldy, 1830)	*Chrysomya putoria* (Wiedemann, 1830)	−	+	−	−	−
	Musca (Linnaeus, 1758)	*Musca domestica* (Linnaeus, 1758)	+	+	−	−	+
	Phaonia (Robineau-Desvoldy, 1830)	*Phaonia pallida* (Fabricius, 1787)	+	+	+	−	+
Nitidulidae	*Epuraea* (Erichson, 1843)	*Epuraea ocularis* (Fairmaire, 1849)	−	−	−	+	−
Pyrrhocoridae	*Dysdercus* (Guérin-Méneville, 1931)	*Dysdercus voelkeri* (Schmidt, 1932)	+	−	+	+	+
Scarabaeidae	*Rhabdotis* (Burmeister, 1842)	*Rhabdotis sobrina* (Gory & Percheron, 1833)	−	−	−	+	+
	Chondroohina (Fabricius, 1792)	*Chondroohina abbreviata*	−	−	−	+	−
	Cyclocephalla (Dejean, 1821)	*Cyclocephalla* sp	−	−	−	−	+
		Cyclocephalla sp	+	−	−	−	+
	Oxythyrea (Mulsant, 1842)	*Oxythyrea funesta* (Poda, 1761)	−	−	−	−	+
	Pchnoda (Drury, 1773)	*P.marginata aurantia* (Herbst, 1790)	−	−	−	+	+
	Pchnoda (Burmeister, 1842)	*Pchnoda uelensis* (Burgeon, 1931)	−	−	−	−	+
	Pchnoda (Drury, 1773)	*Pachnoda cordata tigris* (Herbst, 1790)	+	−	−	+	+
Tephritidae	*Ceratitis* (Macleays, 1829)	*Ceratitis cosyra* (Walker, 1849)	−	−	−	−	+
		Ceratitis silvestrii (Bezzi, 1912)	−	+	−	−	−
	Bactocera (Macquart, 1835)	*Bactrocera dorsalis* (Hende, 1794)	−	−	−	−	+

	Anastrepha (Schiner, 1868)	*Anastrepha grandis* (Macquart, 1846)	-	-	-	-	+
Noctuidae	-	-	-	-	-	-	+
Chrysomelidae	*Caryedon* (Schoenherr, 1823)	*Caryedon serratus* (Olivier, 1760)	+	+	+	+	+
Tenebrionidae	Luprops (Hope, 1833)	*Luprops badius* (Muller, 1887)	+	+	-	-	-
Curculionidae	*Sitophilus* (Schonherr, 1838)	*Sitophilus linearis* (Herbst, 1797)	+	+	-	-	-
Specific richness	23	26	10	7	6	7	18

3.3 Distribution of insects collected at flowering period

3.3.1 Insects collected at flowering

23 species were recorded in the 5 localities where collections took place. The large majority of species were *Phaonia pallida* (38.58%) (Figure 2). Then *Dysdercus voelkeri* (9.47%), *Musca domestica* (7.09%), *Pachnoda cordata tigris* (7.09%) and *ceratitis silvestrii* (5.51%). The remaining 17 species fluctuated between 3.94 and 0.79%.

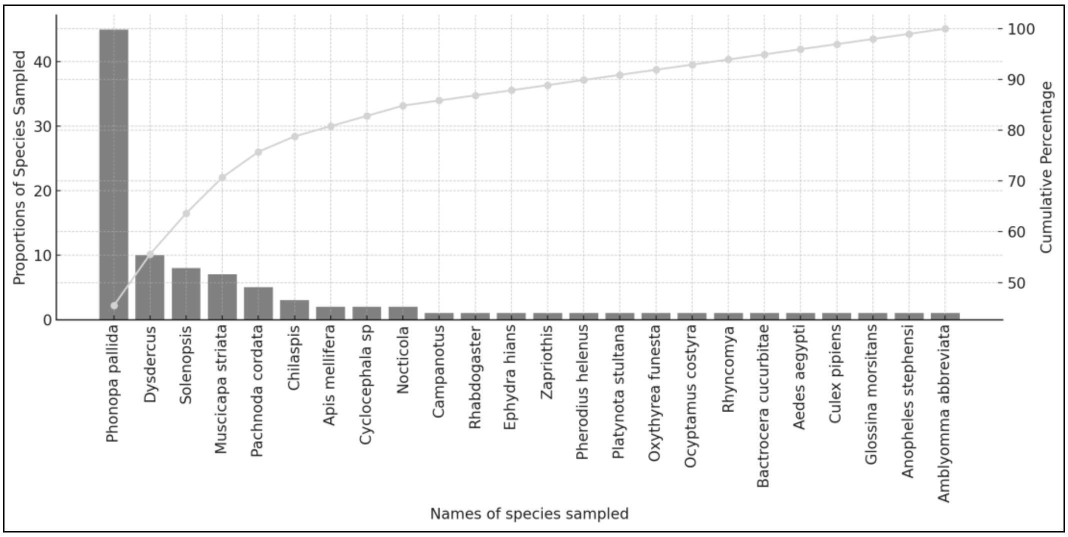

Fig 2: Proportion of species sampled at flowering

3.3.2 Richness and abundance of insects associated with *T. indica* pods at harvest

Insects associated with *T. indica* pods all belong to the Coleoptera order (Table 3). Three (3) species (*Caryedon serratus, Sitophilus linéaris* and *Luprops badius*) belonging to three (3) families including Chrysomelidae, Rhynchophorinae and lagriinae were recorded on the pods. *C. serratus* was found in all five (5) localities, while *S. linéaris* and *L. badius* were only found in Dindérèsso and Farakoba. *C. serratus* was the most abundant species in Kiri and Logofourousso, while *S. linearis* was the most abundant species in Dindérésso on *T. indica* pods.

Table 3: Insects associated with *T. indica* pods

Families	Species	Abundance				
		Dindérèsso	Farakoba	Kiri	Logofourousso	Nasso
Chrysomelidae	*C. serratus*	22	13	21	32	19
Tenebrionidae	*L. badius*	15	14	0	0	0
Curculionidae	*S. Linearis*	25	17	0	0	0

3.4 Shannon-Wienner (H'), Piélou equitability (J') and similarity indexes for collected insects

For flowering insects, the Shannon diversity index was highest at Nasso (2.98) and the lowest was calculated at Farakoba (1.57). Piélou's equitability indexes are low, ranging from 0.35 to 0.66 depending on the locality (Table 4). The theoretical value calculated (H' max = 4.52) was high compared to the different values in the localities.

As for insects collected during fruiting, the Shannon diversity index was zero in 3 localities, while it was 1.55 in Dindérèsso and 1.58 in Farakoba (Table 4). The theoretical value calculated (H' max = 1.58) and did not vary from the different values in the localities. The same was true for Piélou's equitability indexes in the 3 localities. However, it was 0.98 in Dindérèsso and 1 in Farakoba (Table 4).

Table 4: Shannon-Wienner index (H') and Piélou equitability index (J') by locality

Localities	Indice de Shannon-Wienner (H')		Indice d'équitabilité de Piélou (J')	
	Flowering	Fruiting	Flowering	Fruiting
Dindérèsso	2.00	1.55	0.44	0.98
Farakoba	1.57	1.58	0.35	1
Kiri	2.18	0	0.48	0.00
Logofourousso	2.70	0	0.60	0.00
Nasso	2.98	0	0.66	0.00

NB: The Shannon-Wienner diversity index varies between 0 and Ln(S) = 1.10 and the equitability index between 0 and 1.

The highest Jaccard similarity index was obtained in the Dindérèsso-Kiri localities where (J= 0.33) for flowering insects (Table 5). The lowest similarity was observed in the Farakoba-Logofourousso localities (J= 0).
The highest similarity value observed for fruiting insects was 1, while the lowest was 0.33 (Table 5).

Table 5: Jaccard Similarity Index per locality

Localities	Jaccard Similarity Index per locality (J)	
	Flowering	Fruiting
Dindérèsso-Farakoba	0.22	1.00
Dindérèsso-Nasso	0.26	0.33
Dindérèsso-Logofourousso	0.18	0.33
Dindérèsso-Kiri	0.33	0.33
Farakoba-Nasso	0.11	0.33
Farakoba-Logofourousso	0.00	0.33
Farakoba-Kiri	0.13	0.33
Nasso-Logofourousso	0.21	1.00
Nasso-Kiri	0.22	1.00
Logofourousso-Kiri	0.10	1.00

3.5 Assessment of damage (initial infestation rate) to *T. indica* pods at harvest

3.5.1 Initial pod infestation rate

On average in all localities, the rate of perforation doubled 45 days after the emergence of the first generation (Table 6). The perforation rate did not differ significantly at the start, but 45 days later there was a clear difference between Dindérèsso and Kiri.

Table 6: Pods' initial infestation rate per location

Localities	Perforation rate	Initial infestation
Dindérèsso	$16.23{\pm}0.78^{a}$	$46.41{\pm}\ 0.29^{a}$
Farakoba	$10.71{\pm}0.2^{a}$	$34.05{\pm}4.67^{ab}$
Kiri	$13.89{\pm}3.20^{a}$	$27.78{\pm}6.41^{b}$
Logofourousso	$12.78{\pm}4.49^{a}$	$38.33{\pm}13.47^{ab}$
Nasso	$14.64{\pm}0.41^{a}$	$33.06{\pm}3.71^{ab}$
p-value	P=0.721 F=2.682	P=0.0226 F=3.918

S. linearis caused most of the damage in the localities of Dindérèsso and Farakoba. However, *C. serratus* caused the majority of damage, as it was present in all localities (Table 7).

Table 7: Initial infestation rate of *T. indica* pods per species

Localities	Species	Relative percentage	Initial infestation rate
Dindérèsso	*C. serratus*	35.48	16.47
	L. badius	24.19	11.23
	S. linearis	40.32	18.71
Farakoba	*C. serratus*	29.55	10.06
	L. badius	31.82	10.83
	S. linearis	38.64	13.15
Kiri	*C. serratus*	100.00	27.78
	L. badius	0.00	0.00
	S. linearis	0.00	0.00
Logofourousso	*C. serratus*	100	38.33
	L. badius	0	0.00
	S. linearis	0	0.00
Nasso	*C. serratus*	100	33.06
	L. badius	0	0.00
	S. linearis	0	0.00

4. Discussion

Flowering of *T. indica* starts in March for early plants and around May-June for late season species. We captured 10 families of insects visiting tamarind flowers and belonging to 5 orders during our study. This biodiversity of insects in *T. indica* flowers means that this plant offers resources that attract several types of insects. Hence [26] description of the flower as a generalist or "appointment" flower. In fact, the simultaneous presence of 5 orders of insects, namely Hymenoptera, Diptera, Coleoptera, Hemiptera and Lepidoptera, has also been recorded in tamarind by [27] and in jujube by [28]. Among the orders of insects found on *T. indica* flowers, Diptera's order (Muscidae, Tephritidae and Drosophilinae) comes in second place, and the Coleoptera one (Scarabaeidae, Curculionidae, Nitidulidae) is the most diverse, with 12 species. These two orders rank second in terms of pollinators. A total of 23 species have been recorded, and this diversity of pollinators could be an advantage for *T. indica*, since although its flowers are said to be hermaphroditic, [27] asserts that this species is allogamous partially self-incompatible. This biodiversity of insects is an advantage for *T. indica* (A partially self-incompatible allogamist), given its contribution to the variety of allopollen. Indeed, according to [29], flower loss and grain abortion in flowering plants is due to self-incompatibility, cited as one of the main factors responsible. The Hymenoptera (Apidae and Formicidae) are among the orders least represented in our study. *Apis mellifera* was observed by [27] on tamarind, on jujube by [18] and on *Piliostigma reticulatum* by [17]. However, it could be a poor pollinator for cross-pollinated plants with a high level of self-incompatibility [30] such as *T. indica*. This would be due to its foraging method, which leads us to think that it spreads a high proportion of self-pollen, given its low mobility between trees [31] and its high capacity for mobility on the same tree [32]. However, among these insects (Coleoptera and Diptera) there are phytophagous insects that are potential pollinators, as they also feed on plant resources (nectar, pollen) [33], transporting pollen grains from one flower to another. However, the activity of the latter could more or less influence fruit yield. Indeed, [30] have shown that the drop in fruiting rate of most legumes, like *T. indica*, is due to the low success rate of fruiting. According to [34], a stand of more than 13 individuals per flower can cause 36% reduction in pod production. The greatest diversity was recorded in Nasso locality, with a shannon diversity index of 2.98. However, species similarity between localities is low, as Jaccard's highest similarity index value is 0.33, which was lesser than 0.5. Despite the damage caused to the plant by these phytophagous insects, it is their important role as pollinators that takes precedence, hence the mutualistic relationship that separates them from the pest group. Apart from nectar- and pollen-consuming insects, fruit-consuming insects are few in number, according to [23] and [35]. In fact, the insects most often attacking *T. indica* pods not for nutrition, but for reproduction. All the recorded insects after their emergence from the pods belong to the Coleoptera order (Chrysomelidae, Tenebrionidae, Curculionidae). The most representative species is *C. serratus*, which is present at all sampling sites, unlike *L. badius* and *S. linearis*, which are only present at Dindérèsso and Farakoba [16]. also recorded *C. serratus* on *T. indica* in Colombia. These insects are parasites that destroy *T. indica* fruits as they reproduce [36]. stated that *C. serratus* is a parasitic species that attacks certain pods of wild plants called host plants, all belonging to the Caesalpinioideae. The damage registered on *T. indica* pods is due not only to the attacks of frugivores, but also to those of insects such as *C. serratus*, *L. badius* and *S. linearis*. In fact, *S. linearis* is known to attack tamarind pods, causing enormous damage during storage. It has been recorded in Colombia as a phytophagous insect of *T. indica* crop damaging mainly seeds [16]. It should also be noted that *L. badius* is not known to infest tamarind pods. Its presence was only observed on plants where the majority of leaves and pods were dry, immature and rotten, which could be either the consequence of its activity, which halted pod ripening, or the cause of its presence, as insects of *Luprops* genus also feed on leaves and dead wood. According to [37], 79% of farmers in northern Uganda recognized *L. badius* as an insect that attacks *Cajanus cajan*, a new pest of pigeon pea. Shannon index for the localities of Kiri, Logofourousso and Dindérèsso were zero, as only one species was recorded in these localities. Our results show that perforation rates in the various localities do not differ significantly from one another. However, these rates doubled completely 45 days later, which could be due to the feeding activity of the larvae after their emergence. Analysis of our results in relation to the initial infestation rate of *T. indica* pods by species showed that the majority of damage could be caused by *C. serratus* because of its presence in all localities.

5. Conclusion

This study enabled us to sample 23 insect species involved in the pollination of *T. indica* flowers, belonging to 5 orders: Coleoptera, Lepidoptera, Diptera, Hemiptera and Hymenoptera. The greatest diversity was recorded in the Nasso. Three species are associated with fruit and all belong to the Coleoptera order. *S. linéaris* and *L. badius* were found in only two of the five localities, except *C. serratus*. The latter is the species that causes most damage to *T. indica*. The perforation rate doubled in all localities 45 days after harvesting.

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