



Arthropod Diversity and Assessment of Damage in Forage Crop Species Cultivated in Burkina Faso

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Abstract

In Burkina Faso, despite its socio-economic importance, livestock farming faces a number of constraints, including a shortage of animal feed. To cope with this shortage, several forage species are imported and cultivated. However, some producers note that fodder is increasingly subject to insect attack. The aim of this study was to determine the diversity and arthropod abundance associated with forages grown in Burkina Faso. A trapping system consisting in water traps was set up in seven fields where different fodder crops were cultivated to measure insect diversity and abundance. In addition, damage caused by arthropods on each fodder crops species was evaluated on 30 plants in each field. The arthropods specimens caught belonged to 67 families and 11 orders. The orders of Diptera, Hymenoptera and Coleoptera were the predominant. Regarding arthropods functional groups, predators and insect pests were the most dominant in fodder crop fields. The attack severity varied from 25 to 43.06% according the fodder crop species taken into account. Further studies are needed to identify the insect pests responsible for the damage observed on forages in order to develop control strategies.

Keywords: *Livestock, fodder, insects, functional groups, damage.*

Introduction

Burkina Faso, a Sahelian country located in the heart of West Africa, has an economy heavily dependent on the primary sector. The average annual contribution of the rural sector to the formation of Gross Domestic Product (GDP) during the period 2005-2015 is estimated at 32.46%.

The agriculture and livestock sectors account for over 86% of the working population (CILSS, 2006). The livestock sub-sector has always been an important pillar of the national economy. It contributes over 18% (MRAH, 2012) to the formation of national value added, including 12% for animals and 6% for hides and skins. It is the third most

important sub-sector in terms of export earnings, with an average contribution of 14.2% in 2009 (MRAH, 2012) and 38.8% to the incomes of rural households (MRA and UNDP, 2011). It also has the advantage of stabilizing populations in rural areas and avoiding migration for employment and income (FAO, 2018). Despite these advantages, livestock farming is faced with enormous difficulties, linked mainly to feed, which is one of the main factors limiting animal production.

In Burkina Faso, livestock farming is dominated by the extensive system, in which cattle feeding is based mainly on the

exploitation of natural pastures, which account for around 90% of the diet of domestic ruminants (Kagoné, 2001; Kiéma, *et al.*, 2015). The major constraint of this system is that forage availability is high during the rainy season, while during the longer dry season, herbaceous forage is insufficient and poor in nutrients. This situation has led breeders to develop a number of strategies: for many breeders, this involves transhumance (Kiéma, *et al.*, 2012), and for sedentary breeders, it involves building up feed reserves to cope with the dry period, by storing crop residues, mowing and conserving natural fodder (César, *et al.*, 2004 ; Hamadou, *et al.*, 2005 ; Toutain, *et al.*, 2009). Nowadays, the practice of transhumance and natural grazing are tending to disappear due to (i) the extension of cultivated land, (ii) the demographic explosion and galloping urbanization, (iii) and more recently, terrorist incursions which are causing a massive displacement of rural communities towards urban centers. Faced with this situation, new strategies are being considered to meet the animals' feed requirements during deficit periods. Forage crops cultivation appear to be an alternative for improving the quantity and quality of livestock feed.

To contribute to the development of forage production, several species have been introduced into Burkina Faso in recent years, with the sole aim of alleviating animal feed shortages. The cultivation of these exotic forage species has been successfully tested at the Farako-Ba research station, and some have been popularized among producers. However, in the field, some growers have noticed that their forage crops are subject to attack by insect pests. It is in this context that this study was carried out to help preserve the quantity and quality of forage species grown in Burkina Faso. Specifically, the aim was to (1) inventory the arthropod species associated with forage crops, (ii) determine the functional groups of insects present on forage production fields, and (iii) assess the damage caused by arthropods on cultivated forage species.

1. Materials and Methods

1.2. Study Site

The study was carried out at the Farako-Bâ research station, part of INERA's Direction Régionale Ouest, located 10 km south of Bobo-Dioulasso. The research station covers an area of 375 ha, 200 ha of which is developed. The geographical coordinates of the Farako-Bâ station are as follows: longitude 4°20' West, latitude 11°06' North and altitude 405 m (Somé, 2000). The site is located in the South Sudanian agro-ecological zone of Burkina Faso (Sawadogo, 2019). The climate is in zone A of Köppen's classification of climatic zones (Beck, *et al.*, 2018). The climate is characterized by a unimodal distribution of the rainy season from May to October and the dry season from November to April. Annual rainfall ranges from 900 to 1,200 mm (Sawadogo, 2019). Average monthly temperatures range from 20°C (minimum) in December to 35°C (maximum) in April, with an average annual temperature of 27°C. Soils at the station are mostly ferralitic, very sandy, slightly acidic, poor in clay and organic matter, resulting in a low cation exchange capacity (CEC) (Traoré, *et al.*, 2007). Vegetation is characterized by a fairly dense wooded and grassy savannah and an herbaceous carpet.

1.2. Methods

1.2.1. Arthropods' Mass Trapping

The trapping system was set up in early September 2022 at the Farako-Bâ research station. The experimental set-up used for the inventory of insects associated with forage crops was a scattered block with four treatments. The treatments consisted of six production fields of imported forage species and one field of local species. The forage production fields varied in size from 0.5 to 1 ha. In each field, four water traps were installed for insect trapping. The trap consisted of a yellow plastic bowl half-filled with odorless soapy water. The trap was suspended at a height of one meter from the ground and supported by three wooden beams. The traps were separated from each other by a distance of 20 meters. One liter of water was used to dilute 7 ml of soapy water

in each trap. The trapping system installed in each forage production field was monitored at five-day intervals to recover the insects caught and renew the soapy water contained in each trap. On each observation date, the insects caught in each trap were recovered

using a sieve and flexible forceps. The recovered insects were then placed in pillboxes containing 70% ethanol and returned to the laboratory for identification. **Table 1** gives details of each forage species cultivated.

Table 1: Details of treatments and fodder crops species

Treatments	Fodder crop species	Country of origin	Year of introduction
T1	<i>Panicum maximum</i> cv Tanzania	Tanzania	2018
T2	<i>Panicum maximum</i> cv Zuri	Tanzania	2018
T3	<i>Panicum maximum</i> cv Quênia	Kenya	2018
T4	<i>Panicum maximum</i> cv C1	Local	-
T5	<i>Brachiaria ruziziensis</i>	Congo, Rwanda, Burundi	2018
T6	<i>Brachiaria mulato</i> II	Colombia	2018
T7	<i>Brachiaria brizantha</i>	Côte d'Ivoire, Ethiopia, South Africa	2018

1.2.2. Arthropods' Identification

Arthropod specimens captured were identified at the laboratory of entomology of the Institute for Environmental and Agricultural Research (INERA) located at Farako-Bâ research station. Morphological characteristics were observed using a binocular magnifying glass. This made it possible to determine certain order and families. Identification at generic and specific levels was made using identification keys (Delvare and Aberleng 1989; Kirk-Spriggs and Sinclair 2017, 2021).

1.2.3. Assessment of Insect' Damage on Fodder Crop Species

$$\text{Infestation rate (IR) (\%)} = \frac{\text{number of infested plants}}{\text{total number of plants observed}} * 100$$

The severity of attacks was assessed in each forage production field. It was assessed by calculating the severity index in each field. It was assessed on a scale of 0 to 4, with 0 = no attack; 1= attack level between 1 and 25%; 2 = 26 to 50% of leaves attacked; 3= 51 to 75% of leaves attacked and 4 = 76 to 100% of leaves attacked.

1.3. Data Processing and Statistical Analysis

Damage was assessed by observing symptoms of insect attack on aerial parts, particularly leaves. In each forage production field, 30 plants were randomly selected along the diagonals. Observations were made on the leaves at two-weekly intervals. The parameters measured were infestation rate and damage level. The infestation rate (IR) corresponds to the number of attacked plants out of the total number of plants taken into account in the evaluation. The following formula was used to calculate this parameter.

The Microsoft office 2016 was used to enter and process the raw data collected during this study. It was also used to construct tables and certain figures.

Analysis of variance was used to analyze the different diversity indices of the forage fields, and the means were separated using Newman-Keul's test ($\alpha = 0.05$).

1.3.1. Diversity Indices

Specific richness is often insufficient to compare two communities, because it does not take into account the relative dominance of each species (Krebs, 1999). With this in mind, Shannon's diversity index (H) and Pielou's equitability coefficient (EH) were calculated. They provided information on the specific diversity between forage fields,

$$P_i = \frac{N_i}{N} \quad H = -\sum_{i=1}^S p_i \times \ln p_i \quad EH = \frac{H}{\ln S}$$

P_i is the relative density of individuals of species i ; N_i is the number of individuals of species i ; N is the total number of individuals and S is the total number of species. The Shannon diversity index (H) varies between 0 and $\ln(S)$. The higher the value of the H index, the greater the diversity. The equitability index (EH) is 0 when only one species is present and 1 when all species have the same abundance.

1.3.2. Average Catch Indices

The number of specimens was counted per trap and survey date on each forage field. This was used to calculate the daily capture index (DCI). This is equivalent to the number of specimens caught per trap per day. The DCI is calculated using the following formula:

DCI = Total number of specimens caught / (Number of days that traps were exposed in the field \times number of traps inspected). Analysis of variance (ANOVA) was

enabling a better understanding of the structure and composition of plant communities over time and space. Analysis of variance (ANOVA) was performed using Minitab software. Means were separated at the 5% probability threshold. The following formulas were used to calculate the various indices:

performed using Minitab software. Means were separated at the 5% probability level.

2. Results

2.1. Abundance and Arthropods Species Diversity

In the course of this study, 8760 arthropod specimens were captured and 8538 identified. The arthropods identified belonged to 11 orders, 67 families and 120 species (**Table 2**). Statistical analysis showed a highly significant difference ($P < 0.0001$) between the orders and families of arthropods captured. The order Diptera was the most represented (54.83% of arthropods caught), followed respectively by Hymenoptera (27.59% of arthropods caught) and Coleoptera (6.17% of arthropods caught). The main arthropod species captured during the study are shown in **Table 3**. These are the species whose the total number of specimens captured is greater than or equal to ten.

Table 2: Diversity and arthropod abundance in forage fields

Orders	Number of families	Numbers of specimens
Aranae	3	53
Blattodae	2	90
Coleoptera	17	536
Diptera	16	4676
Hemiptera	8	448
Hymenoptera	15	2354
Lepidoptera	1	289
Orthoptera	2	26
Trichoptera	1	64
Neuroptera	1	1
Julida	1	1
Total	67	8538

Table 3: Main insect species identified in forage fields

Orders	Families	Genera and species
Coleoptera	Meloidae	<i>Hycleus lugens</i> , <i>Mylabris oculata</i> , <i>Epicauta rufidorsum</i>
	Scarabaeidae	<i>Digitonthophagus gazella</i>
	Chrysomelidae	<i>Lilioceris lili</i> , <i>Xanthogaleruca luteola</i>
	Curculionidae	<i>Naupactus cervinus</i>
	Attelabidae	<i>Deporaus betulae</i>
Diptera	Calliphoridae	<i>Calliphora vomitoria</i> , <i>Chrysomya megacephala</i>
	Dolichopodidae	<i>Condyllostylus patibulatus</i> , <i>Dolichopus plumipes</i> <i>Neurigona</i> sp.
	Drosophilidae	<i>Drosophila melanogaster</i> , <i>Scaptomyza pallida</i>
	Muscidae	<i>Musca autumnalis</i> , <i>Musca domestica</i>
	Syrphidae	<i>Baccha</i> sp., <i>Eristalinus taeniops</i>
	Stratiomyidae	<i>Hermetia illucens</i>
	Diopsidae	<i>Diopsis apicalis</i>
Hymenoptera	Apidae	<i>Apis mellifera</i> , <i>Xylocopa</i> sp.
	Eulophidae	<i>Tetratichus</i> sp.
	Vespidae	<i>Polistes</i> sp.
	Braconidae	<i>Cotesia</i> sp.
	Formicidae	<i>Brachyponera atrata</i> , <i>Camponotus castaneus</i> , <i>Camponotus</i> sp., <i>Lasius</i> sp., <i>Messor barbarus</i> , <i>Myrmica rubra</i> , <i>Odontomachus</i> sp.
	Halictidae	<i>Halictus scabiosae</i>
	Pompilidae	<i>Auplopus carbonarius</i>
	Pteromalidae	<i>Pteromalus</i> sp.
	Megachilidae	<i>Megachile</i> sp.
	Sphécidae	<i>Sphex nudus</i> , <i>Sphex</i> sp.
Hemiptera	Pentatomidae	<i>Oebalus</i> sp.
	Membracidae	<i>Leptocentrus taurus</i>
	Alydidae	<i>Hyalymenus tarsatus</i>
	Cixiidae	<i>Tachycixius pilosus</i>
Lepidoptera	Nymphalidae	<i>Acraea admatha</i>
Orthoptera	Tettigoniidae	<i>Neoconocephalus triops</i>
Trichoptera	Limnephilidae	<i>Limnephilus</i> sp.

2.1.1. Relative Abundance of Arthropods Orders According to the Treatments

The relative abundance of each arthropod order depending on the seven forage species fields is shown in Figure 1. It can be seen that the Diptera order was the predominant in all forage fields followed in sequence by Hymenoptera and Coleoptera orders. The

lowest abundance was recorded in orders including Orthoptera, Neuroptera and Julida. Statistical analysis showed that there was a highly significant difference ($P < 0.0001$) between the relative abundance of arthropods orders captured in forage fields.

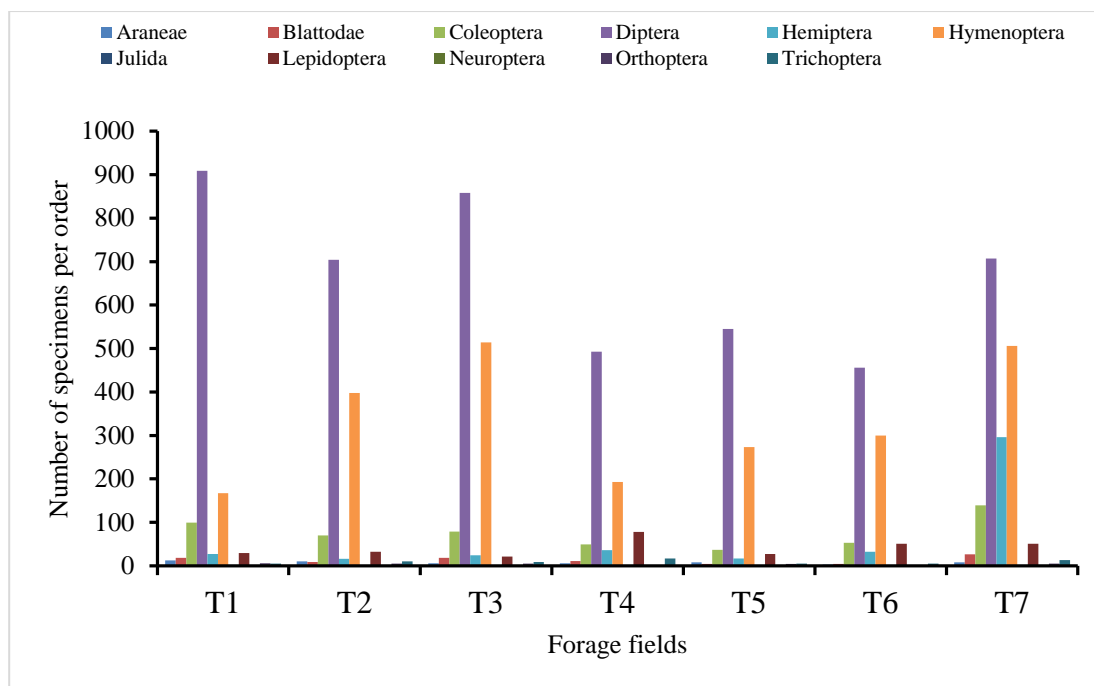


Figure 1: Relative abundance of arthropod orders according to the forage species field. **T1 :** *Panicum maximum* cv Tanzania ; **T2 :** *Panicum maximum* cv Zuri ; **T3 :** *Panicum maximum* cv Quênia ; **T4 :** *Panicum maximum* cv C1 ; **T5 :** *Brachiaria ruziziensis* ; **T6 :** *Brachiaria mulato* II ; **T7 :** *Brachiaria brizantha*

2.1.2. Average Catch Indices of the Arthropods

The average number of arthropods caught per trap per day is shown in Table 4. The *Brachiaria brizantha* plot recorded the highest daily capture index (7.30 ± 3.19 arthropods captured per trap per day), compared with

the *P. maximum* cv C1 plot, which recorded the lowest number (3.69 ± 1.82 arthropods captured per trap per day). Statistical analysis revealed a highly significant difference between the average capture indices recorded according to forage plot at the 5%.

Table 4: Arthropod diversity indices according to fodder crops species

Forage fields	Average catch indices (means \pm SD)
<i>Panicum maximum</i> cv Tanzania	$5.30 \pm 2.16ab$
<i>Panicum maximum</i> cv Zuri	$5.23 \pm 3.23ab$
<i>Panicum maximum</i> cv Quênia	$6.40 \pm 2.76a$
<i>Panicum maximum</i> cv C1	$3.69 \pm 1.82b$
<i>Brachiaria ruziziensis</i>	$3.83 \pm 1.84b$
<i>Brachiaria mulato</i> II	$3.77 \pm 2.17b$
<i>Brachiaria brizantha</i>	$7.30 \pm 3.19a$
F	3.77
P	0.002***

Means followed by the same letter are not statistically different at 5% threshold.

*** very highly significative

2.1.3. Diversity Indices of Arthropods

The species richness, Shannon diversity index and equitability index of the different forage plots are presented in Table 5. The *P. maximum* cv C1 and *B. brizantha* fields showed the highest species richness (75 species), while the

P. maximum cv Tanzania field showed the lowest (66 species). The Shannon diversity and equitability indices were roughly equal for all forage plots. Furthermore, the ANOVA did not reveal any significant differences for

the Shannon diversity index ($P = 0.997$) and the forage crops species

Table 5: Diversity indices depending on forage species

Forage fields	Richesse spécifique	Shannon diversity' index (H)	Pielou's Equitability Coefficient (EH)
<i>Panicum maximum</i> cv Tanzania	66	0.037 ± 0.066	0.009 ± 0.015
<i>Panicum maximum</i> cv Zuri	67	0.037 ± 0.066	0.008 ± 0.015
<i>Panicum maximum</i> cv Quênia	67	0.038 ± 0.068	0.009 ± 0.016
<i>Panicum maximum</i> cv C1	75	0.042 ± 0.058	0.009 ± 0.013
<i>Brachiaria ruziziensis</i>	73	0.041 ± 0.059	0.010 ± 0.013
<i>Brachiaria mulato II</i>	74	0.043 ± 0.059	0.009 ± 0.015
<i>Brachiaria brizantha</i>	75	0.041 ± 0.062	0.009 ± 0.014
F	-	0.010	0.06
P	-	0.997	0.999

2.2. Arthropod Functional Distribution

The various arthropods identified are belonged mainly to four functional groups. The abundance of these functional groups in each plot is shown in **Figure 2**. All the functional groups were observed in the seven forage crop species fields. Predators were the most dominant with 36.27% of arthropods

encountered in forage fields followed in sequence by followed by the phytophagous insects (21.44%), pollinators (11.42%) and parasitoids (4%). Statistical analysis showed a highly significant difference between arthropod functional groups according to fodder crop species fields ($P < 0.0001$).

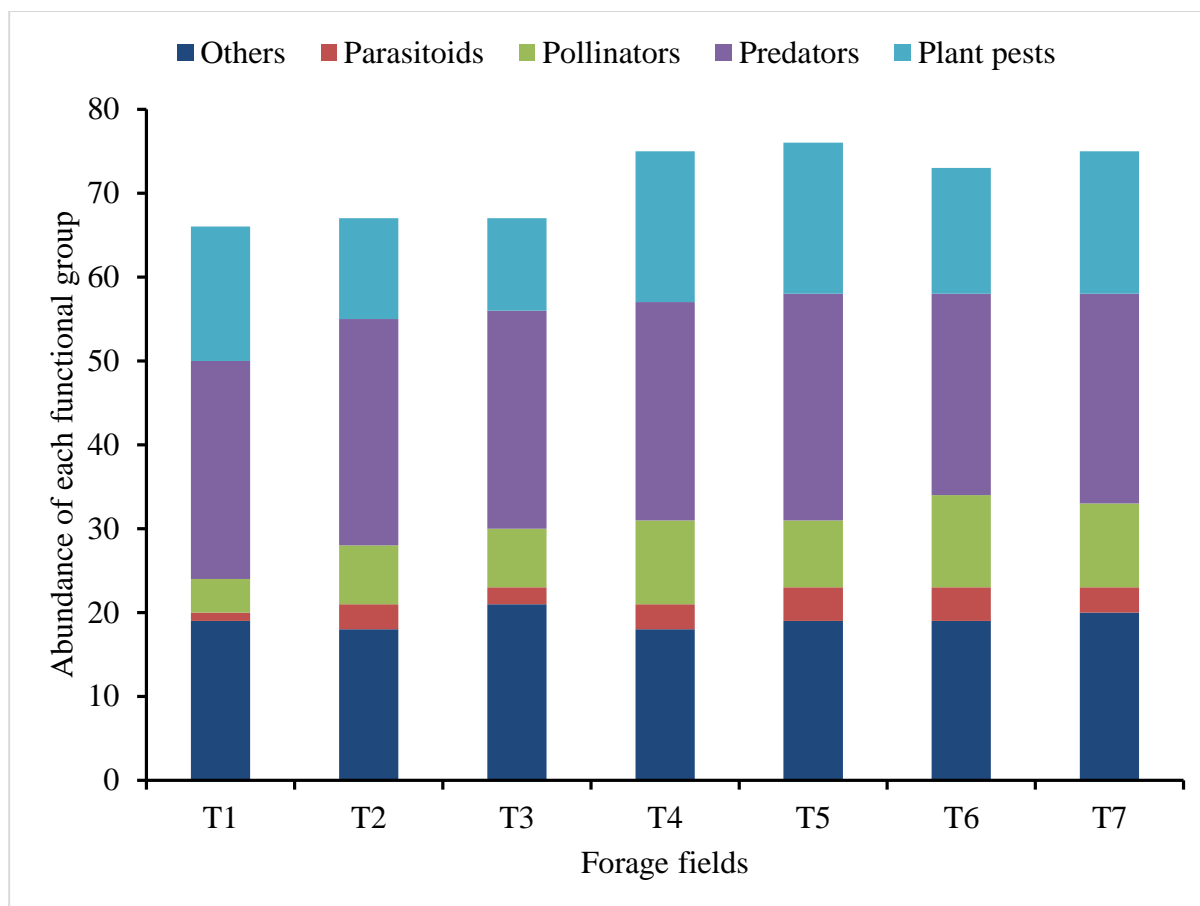


Figure 2: Diversity and abundance of arthropod functional groups according to fodder crop species fields. **T1** : *Panicum maximum* cv Tanzania ; **T2** : *Panicum maximum* cv Zuri ; **T3** : *Panicum maximum* cv Quênia ; **T4** : *Panicum maximum* cv C1 ; **T5** : *Brachiaria ruziziensis* ; **T6** : *Brachiaria mulato* II ; **T7** : *Brachiaria brizantha*.

2.3. Damage of Arthropods on Fodder Crops Species

The different forage species cultivated showed signs of attack caused by insect pests to varying degrees (**Table 6**). The highest rate of attack was observed in fields of *P. maximum* cv Tanzania, *P. maximum* cv Zuri, *P. maximum* cv Quênia and *B. ruziziensis* ($100 \pm 0.00\%$) ($P = 0.0001$). In contrast, the field of *B. brizantha* recorded the lowest attack rate ($72.22 \pm 45.04\%$).

The severity of attack varied from one forage species to another (**Table 6**). The plot of *P. maximum* cv Quênia recorded the highest severity of attack ($45.83 \pm 19.79\%$). In contrast, the *B. brizantha* plot recorded the lowest severity of attack ($25.00 \pm 0.00\%$). Analysis of variance revealed a highly significant difference between these attack rates ($P = 0.0001$).

Table 6: Average attack rates and severity attack rates according to the forage fields

Forage fields	Average attack rates (%)	Severity attack rates (%)
<i>Panicum maximum</i> cv Tanzania	100.00 ± 0.00a	41.67 ± 22.10b
<i>Panicum maximum</i> cv Zuri	100.00 ± 0.00a	41.67 ± 23.06b
<i>Panicum maximum</i> cv Quênia	100.00 ± 0.00a	45.83 ± 19.79a
<i>Panicum maximum</i> cv C1	98.89 ± 10.54b	40.00 ± 18.10b
<i>Brachiaria ruziziensis</i>	100.00 ± 0.00a	30.00 ± 13.77c
<i>Brachiaria mulato</i> II	95.56 ± 20.72b	28.33 ± 8.64c
<i>Brachiaria brizantha</i>	72.22 ± 45.04c	25.00 ± 0.00c
F	25.90	6.86
P	0.0001***	0.0001***

Means followed by the same letter are not statistically different at 5% threshold.

*** very highly significative

3. Discussion

The results of this study reveal the presence of 120 species belonging to 67 arthropod families divided into 11 orders, the main ones being Diptera, Hymenoptera and Coleoptera. The numerical importance of the insects captured reflects the attraction of forage crops for insects. In fact, the growth of the plants, favored by high tillering, could create a microclimate suitable for the development of most insects. These results show that forage crops provide an entomological niche. Not all the arthropods captured are harmful to forage crops. In fact, insects visit forage production plots either in search of refuge, to feed or to reproduce. The attractiveness of certain insect species is linked to the yellow color of the traps and the attraction of the water surface (Rabasse, 1981). The predominance of the orders of Diptera and Hymenoptera was also observed by Berchiche (2004) and Kellil (2010) in their study of a research station in Algeria.

The fields where *Brachiaria brizantha* was cultivated attracted large numbers of ants throughout the study. This particular abundance of ants could be explained by the fact that, in the vicinity of the *B. brizantha* field, there was a functional termite mound, and these termites would be potential prey for the ants. Also, the presence of aphids in the plots could justify the strong presence of ants. Indeed, some ant species can live in symbiosis with aphids (Verheggen, et al., 2009).

The higher species richness observed in the fields of *P. maximum* cv C1 and *B. brizantha* (75

species) could be explained by the fact that *P. maximum* cv C1 is a local species and was cultivated in Burkina Faso several years ago. In fact, over time, insects could have plenty of time to adapt to this forage species. The entomofauna observed in these two fields could also be influenced by the presence of crops located near the fields. In this study, the field of *P. maximum* cv Tanzania recorded the lowest species richness (65 species). This field was located next to a cowpea field, which can be considered a trap crop for insects. Indeed, as cowpea is considered a highly insect-attacked specie among crops (Singh and Jackai, 1985), it could help attract a maximum number of insect pests to the detriment of the nearby forage field.

No significant differences were observed between the diversity indices recorded in the forage fields. Our study showed that the Shannon diversity index and the equitability index were low. This can be explained by the fact that a few species were strongly represented in the fields, while the majority of species were present in very low numbers. In fact, the diversity index is high if all the species present are well represented (low dominance, high equitability) and low if a few species are predominant in terms of number of individuals (high dominance, low equitability). In the forage fields studied, not all species contributed equally to the formation of the insect community.

In terms of functional groups, the abundance of predators in the plots could be partly

linked to the presence of natural enemies (predators and parasitoids). Indeed, most of the predators were ants and spiders, which are generalist predators. Their presence would contribute significantly to the reduction of insect pest population (Gerling, et al., 2001; Chailleux, et al., 2013; Zappalà, et al., 2013). These natural enemies could also be attracted by the presence of flowers, as many predators and parasitoids feed on nectar and pollen, representing sweet and protein resources (van Rijn and Wäckers, 2016; Gillespie, et al., 2016).

With regard to damage caused by insect pests, the lowest attack rate ($25.00 \pm 0.00\%$) recorded in the *Brachiaria brizantha* field could be due to the high number of ants in this field and/or the high pubescence of the *B. brizantha* plants. Considered generalist predators for the most part, ants can have a negative impact on the population dynamics of an insect pest in a given biotope. The highest average attack rate recorded in the field of *Panicum maximum* cv Quênia could be due to its sensitivity to insects or its palatability. In fact, although no specific damage could be associated with a given insect, some insect pests associated with cereal crops were encountered during this study. Among the species identified, previous studies have shown that *Opomyza florum*, generally known as the yellow cereal fly, whose larvae develop in the stems of young grass shoots, is a pest of grasses. They also attack cereal crops such as wheat and barley (Lucien, 1961). According to Heinrichs and Barrion (2004), *Diopsis apicalis* is an insect species of pedunculate-eyed fly recognized as a devastating pest of rice throughout its growing season.

Conclusion

At the end of this study, it was found that several species of arthropods belonging to different families and orders are found in forage production fields on the Farako-Bâ research station. These arthropods belong to different functional groups, the most important of which are predators and insect pests. The latter are responsible for the damage observed in forage production,

although the present study was unable to associate the damage observed in forage fields with a specific insect pest. The investigations carried out showed that all the forage species studied were liable to be attacked by insects of varying degrees of severity. It was not possible to determine the impact of insect pest attacks on biomass quantity and forage quality. Taking these parameters into account in future studies will help optimize forage production.

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