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Preliminary data on the distribution and damage of the community of granivorous pest birds of sorghum (*Sorghum bicolour* (L.) Moench) (Korhogo, Côte d'Ivoire)

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Abstract

Sorghum (*Sorghum bicolour* (L.) Moench), a cereal rich in protein, is cultivated by the people of northern Côte d'Ivoire as a staple food and for income. However, because of the important losses due to birds, the culture of this strategic speculation is neglected. In order to better understand the impact of these pests and improve food security, a study was carried out from June 2017 to December 2017 on the experimental site of the University Peleforo Gon Coulibaly in Korhogo (Côte d'Ivoire). Forty sessions of direct observations with the binoculars of the avifauna were carried out from seedlings to harvest, and their damage was identified. A total of 2,065 birds belonging to four orders, nine families and 16 species have been identified. Bird diversity was highest during the milky panicle stage. The primary pests in sorghum cultivation were *Ploceus cucullatus* (Muller, 1776), *Francolinus bicalcaratus* (Linné, 1766), *Psittacula krameri* (Scopoli, 1769), *Poicephalus senegalus* (Linné, 1766) and *Crithagra mozambica* (Statius, 1776). Three categories of pest birds were determined based on damage: seedling predators, panicle seed depredators and panicle cutters. The phenological stage of sorghum cultivation has influenced the distribution of pest birds. To ensure the well-being of vulnerable rural women's communities dependent on this speculation, these data must serve as a scientific basis to address the fight in order to reduce the impacts of pests and thus, increase production and fight poverty.

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Introduction

Cereals are important food and cash crops for the livelihoods of millions of people in Sub-Saharan Africa (Hiron *et al.*, 2014). Indeed, in developing countries, people depend directly or indirectly on food for their livelihoods. Agriculture thus contributes to the achievement of sustainable development goals relating to hunger and poverty (Banque Mondiale, 2008).

In Côte d'Ivoire, food production contributes to 7% of Gross Domestic Product (GDP), or 14,000,000 USD. The main cereal crops are rice, millet and sorghum, which are mainly used for local consumption. However, this production is insufficient to cover population food need. As a result, imports are made to fill this gap (Tuo *et al.*, 2018).

Achieving food self-sufficiency requires the intensification of food production, particularly cereals. In many developing countries, cereals are the staple food of populations (El Naim *et al.*, 2018; Niamien *et al.*, 2019). However, production efforts are hindranced by losses caused by pests (Fayenuwo *et al.*, 2007; Abdou *et al.*, 2013; Hiron *et al.*, 2014; Odoukpé and Yaokokoré-Béibro, 2016; Niamien *et al.*, 2019). These losses can reach 60% of annual production (Nasasagare *et al.*, 2014; Gros-Désormeaux *et al.*, 2015).

Among the cereals, sorghum is a strategic speculation. Indeed, its cultivation requires low rainfall, an important characteristic in the current climate change context, which could result in decrease or the scarcity of precipitation (El Naim *et al.*, 2018; Suleman *et al.*, 2018). In addition, sorghum grains exhibit interesting and health nutritive advantages including proteins, lipids and carbohydrates, as well as weak fat amount. Finally, Sorghum plants and/or grains derivatives are used for various and/or multiple purposes such as, feed of livestock and poultry, collar, oil and construction equipment and as well traditional beer (dolo) (Suleman *et al.*, 2018).

In Côte d'Ivoire, most of the cereals are grown in the north (Tuo *et al.*, 2018; Niamien *et al.*, 2019).

Grain fields in production are a regular source of food for pest birds, with the impact of permanent pressure, some species which may pose a risk to production and food security (Hiron *et al.*, 2014; Gros-Désormeaux *et al.*, 2015; Odoukpé and Yaokokoré-Béibro, 2016; Niamien *et al.*, 2019).

In Korhogo, cereals are cultived by women's communities for household consumption and for the satisfaction of their primary needs through the sale. However, the enormous losses caused by the sorghum pests have incited these communities to abandon this speculation, with the consequences of reduced production and the financial resources necessary to ensure their subsistence (Niamien *et al.*, 2019). In Côte d'Ivoire, data available relate only to the community of sorghum panicle pest birds (Niamien *et al.*, 2019). No data is available on damage caused by birds in sorghum fields. It is an attempt to fill this information gap, that this study was carried out.

The present study, is a contribution to a better knowledge of the bio-ecology of sorghum avifauna, strategic speculation, in order to make recommendations for its intensification. It is specifically designed to (i) inventory the sorghum pest birds community from seedlings to harvest, (ii) analyses the influence of the phenological stages (seedling, milky stage and grain stage of panicles) on its distribution and (iii) identify and characterize the damage with the purpose to draw practical applications for the intensification of this speculation for food security.

Materials and methods

Experimental site

The present study was conducted in the Commune of Korhogo, situated between latitude $8^0$26 and $10^0$27 North and longitude $5^0$17 and $6^0$19 West. This Commune is at 600 Km from Abidjan (Northern of Côte d'Ivoire). That climate is characterized by two seasons. The rainy season from May to October and the dry season from November to April, characterized by the Harmattan which comes from December to February (Boko-Koiadja *et al.*, 2016).

The present study was conducted at the experimental site of Peleforo Gon Coulibaly University in Korhogo (Côte d'Ivoire) (Fig. 1). The experimental plot has an area of 400 m². On this plot, 15 elementary plots and five furrows per elementary plot were made. Each groove is made up of 12 pockets, the distance between two consecutive pockets is 0.5 m. Each pocket housed two sorghum plants, or 120 feet per elementary plot for a total of 900 pockets housing 1,800 feet of sorghum on the experimental area. This plot is bordered by the tree savannah.

The plots were made after weeding. The seedling was carried out on 23 June 2017 after the first rains and the lifting took place a week later on 30 June 2017. Another seedling phase was carried out in early July after the action of the seedling predators. The "milky" and "grain" phenologies of panicles were observed in October, November and December respectively. The harvest took place on 10 December 2017, approximately six months after seedling and emergence.

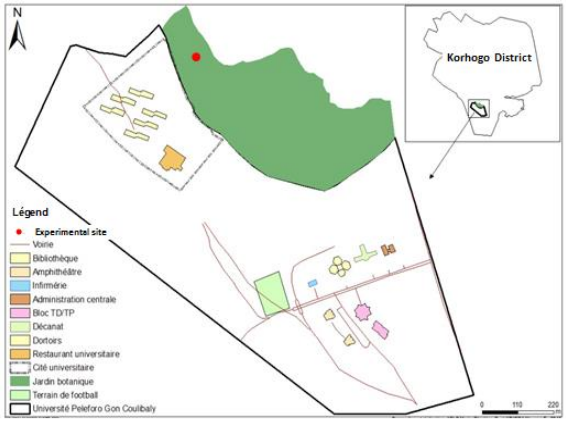

Fig. 1. Location of the experimental site of Peleforo Gon Coulibaly University in Korhogo.

Data collection

The inventory of the sorghum pest bird's community was carried out during the different phases of the sorghum development cycle, from June 2017 to December 2017. These are the seedling phase (June-July 2017), the milky panicle phase (October 2017) and the grain panicle stage (November and December 2017). Forty sessions of direct observations of birds by binoculars were carried out. To do this, we walked silently and discreetly along the trails bordering the experimental plot of the sorghum field to identify and count bird species (Nasasagare *et al.*, 2014, 2017; Odoukpé and Yaokokoré-Béibro, 2016; Niamien *et al.*, 2019). The observations were made from 07:30 Am to 11:00 Am and from 02 Pm to 04 Pm, time-slots, which corresponds to a period of high activity (Hiron *et al.*, 2014 ; Odoukpé *et al.*, 2014 ; Yaokokoré-Béibro *et al.*, 2015). All birds on ground after seedling, or laid on sorghum plants with phenological phases "milky" or "grain" were observed through binoculars and identified using the West African Birds Identification Guide (Borrow and Demey, 2008, 2012).

In addition, bird species that feed on the ground by stirring the soil after seedling or that feed on sorghum panicles at different phenological stages (milky or grain) were counted in order to characterize their damage.

Statistical analysis

Prior to any analysis, the normal distribution of data was verified using the Shapiro-Wilk normality test. Analysis of variances compared the number of individuals and species of birds according to the phenological stages of sorghum. Differences were considered significant when p-values were < 0.05. In addition, the Newman-Keuls Post-Hoc comparison and classification test was made to determine the phenological stage of sorghum in which diversity and numbers were highest. The distribution and characterisation of bird species based on the phenological stages of sorghum were highlighted using the principal component analysis. The distribution of bird species related to the phenological stage of sorghum panicles was tested using the Generalized Linear Model. All these analyses were performed using the software *STATISTICA* (Version 7.1) and *PAST* (Version 1.0).

Results

Global qualitative composition

Inventories of the sorghum bird community (N = 2,065 individuals) identified 16 species belonging to nine families and four orders (Table 1). Overall, the order of Passeriformes is the largest with six (6) families containing 11 species (66.66%). The other orders contain only one family each (11.11%) (Table 1).

Table 1. Results of qualitative inventories of the pest birds of sorghum in relation to the phenological stage in the experimental site of Peleforo Gon Coulibaly University in Korhogo from June 2017 to December 2017 (+: present, -: absent).

Orders/Families/Species	Seedling	Milky stage	Grain stage
Galliformes			
Phasianidae			
Francolinus bicalcaratus (Linné, 1766)	+	-	-
COLUMBIFORMES			
Columbidae			
Streptopelia semitorquata (Ruppell, 1837)	+	-	-
Streptopelia senegalensis (Linné, 1766)	+	-	+
PSITTACIFORMES			
Psittacidae			
Psittacula krameri (Scopoli, 1769)	-	+	+
Poicephalus senegalus (Linné, 1766)	-	+	+
PASSERIFORMES			
Pycnonotidae			
Pycnonotus barbatus (Desfontaines, 1789)	-	+	+
Atimastillas flavicollis (Swainson, 1837)	-	+	-
Sturnidae			
Lamprotornis caudatus (Müller, 1776)	+	-	-
Passeridae			
Passer griseus (Vieillot, 1817)	-	+	-
Ploceidae			
Ploceus vitellinus (Lichtenstein, 1823)	-	+	-
Ploceus cucullatus (Muller, 1776)	-	+	+
Malimbus scutatus (Cassin, 1849)	-	+	-
Euplectes franciscanus (Isert, 1789)	-	+	-
Estrildidae			
Uraeginthus bengalus (Linné, 1766)	-	+	-
Lonchura cucullata (Swainson, 1837)	-	+	-
Fringillidae			
Crithagra mozambica (Statius, 1776)	-	+	+

The ploceidae family is the best represented with four species followed by Estrildidae, Pycnonotidae, Psittacidae and Columbidae with two species each (12.5%). The other families (Phasianidae, Sturnidae, Passeridae and Fringillidae) are the least important with one species each (6.25%) (Table 1).

Variations in the composition of bird's community in relation to the phenological stage of sorghum

Seedling stage

Three orders of birds of equal importance in number of families are observed at the seedling stage of sorghum. These are Galliformes (N = 1: 33.33%), Columbiformes (N = 1: 33.33%) and Passeriformes (N = 1: 33.33%) (Table 1).

Milky stage

Three families are observed. These are the Phasianidae, the Columbidae and the Sturnidae. The Columbidae family is the richest with two species (50%), the other families contain only one species each (25%) (Table 1).

At the milky stage, two orders are inventoried : Psittaciformes and Passeriformes. The order of Passeriformes is the best represented with five families out of a total of six (83.33%) while that Psittaciformes is the least represented with a single family (16.67%) (Table 1).

Six families were determined when sorghum panicles were in the milky stage. Among them, the Ploceidae family is the richest with four species out of a total of 12 species (33.33%). It is followed by the families of Psittacidae, Pycnonotidae and Estrildidae with each two species (16.66%). The rest of the families (Passeridae and Fringillidae) contain only one species each (8.36%) (Table 1).

Grain stage

Three orders are identified at the grain stage of sorghum panicles. These are the orders of Columbiformes, Psittaciformes and Passeriformes. The Passeriformes order is best represented with Three (3) families out of a total of five (60%). The other orders contain only a single family (20%) (Table 1).

A total of five families are observed : Columbidae, Psittacidae, Pycnonotidae, Ploceidae and Fringillidae. The family of Fringillidae is the best represented with two (2) species (33.33%). The remaining families contain only one species each (16.66%).

Specific qualitative composition in relation to the phenological stage

At the seedling stage, three species of birds were inventoried. These species are *Francolinus bicalcaratus* (Linné, 1766), *Streptopelia semitorquata* (Ruppell, 1837) and *Lamprotornis caudatus* (Muller, 1776) (Table 1).

At the milky stage of panicles, seven species of birds were identified: *Atimastillas flavicollis* (Swainson, 1837), *Passer griseus* (Vieillot, 1817), *Ploceus vitellinus* (Lichtenstein, 1823), *Malimbus scutatus* (Cassin, 1849), *Euplectes franciscanus* (Isert, 1789), *Uraeginthus bengalus* (Linné, 1766) and *Lonchura cucullata* (Swainson, 1837) (Table 1).

No specific bird species of panicle grain stage was observed during this study (Table 1).

The number of sorghum pest bird species varies highly significantly with phenological stage according to the analysis of variances (ddl = 2; F = 13; p < 0.001). Indeed, the test of Newman-Keuls reveals that the most high numbers of bird species were observed at the milky stage of sorghum panicles and weak at the grain and seedlind stage respectively (Fig. 2).

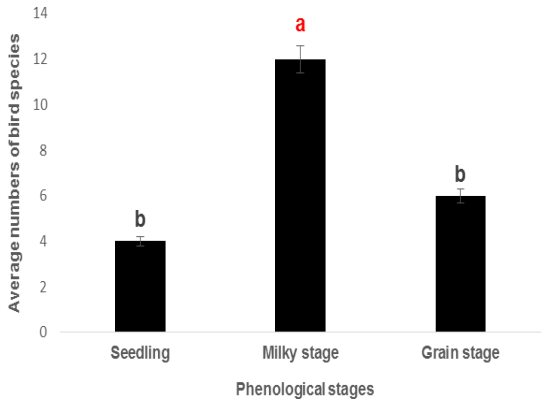

Fig. 2. Changes in the number of pest bird species based on the phenological stages of sorghum from June 2017 to Decembre 2017 in the experimental site of Peleforo Gon Coulibaly University in Korhogo (a: stage with large bird species and b: stage with weak bird species).

In addition, a comparison of the number of pest bird species according to the phenological stages of sorghum reveals highly significant differences respectively between the associations seedling stage and milky stage ; and milky stage with grain stage ($p < 0.001$). In contrast, no significant difference was observed between the seedling and grain stage ($p > 0.05$).

Changes in pest birds number according to the phenological stages of sorghum

Global variation

The numbers of sorghum pest bird species varied significantly with the phenological stage (ddl = 2; F = 64.8; p < 0.0001). The Newman-Keuls comparison and classification test applied to these data reveals that the highest numbers of pest birds are observed at the milky stage of sorghum panicules. Average numbers are recorded during seedling, while the lowest numbers of birds are counted at the grain stage of sorghum panicles (Fig. 3).

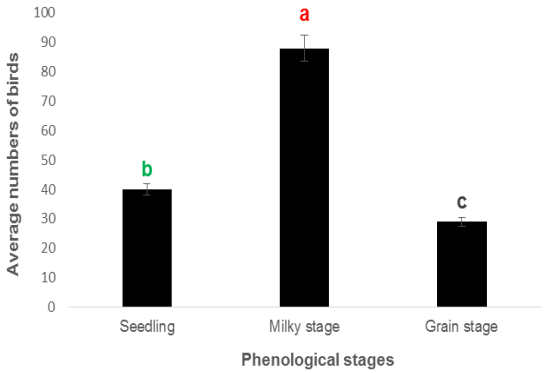

Fig. 3. Global variations in numbers of pest birds according to phenological stages of sorghum in the experimental site of Peleforo Gon Coulibaly University in Korhogo from June 2017 to December 2017 (a : panicle stage with large number of pest birds; b: panicle stage with average number of pest birds and c: panicle stage with low number of pest birds).

Global classification of sorghum pest bird species

The numbers of sorghum pest bird species varied significantly (ddl = 15; F = 15.91; p < 0.001). Following this analysis, the Newman-Keuls comparison and classification test reveals that *Ploceus cucullatus* is the primary pest. *Francolinus bicalcaratus* and *Psittacula krameri* are the secondary pests while the other species are minor pests (Fig. 4).

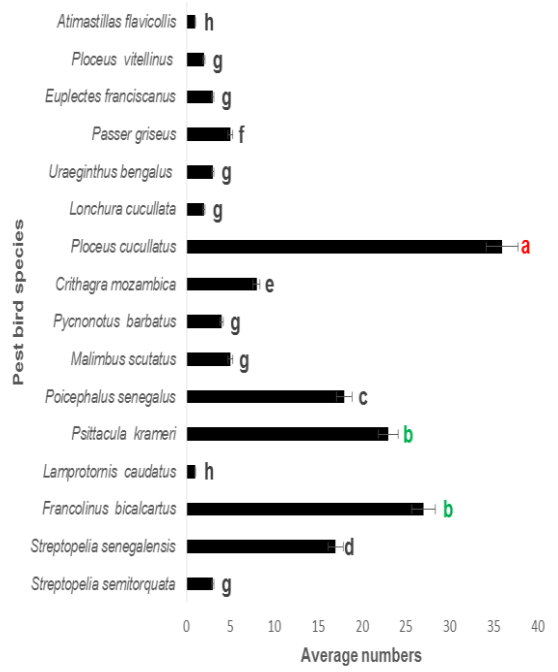

Fig. 4. Global classification of pest bird species of sorghum from June 2017 to December 2017 in the experimental site of Peleforo Gon Coulibaly University in Korhogo (a: main pest, b: secondary pest and c: accessory pest).

Distribution of pest bird species according to the phenological stages of sorghum

The study of the characterization of pest bird species of sorghum according to the different phenological stages carried out from a principal component analysis (Fig. 5), makes it possible to distinguish two main groups when we consider the first axis (62, 48%). The first group is positively correlated with this axis and includes the milky and grain phenological stages of sorghum while the seedling stage is negatively correlated with this first axis. The bird species characteristic of the milky stage are *Ploceus cucullatus* and *Psittacula krameri* while *Poicephalus senegalus* is linked to the grain stage of panicles. At the seedling stage, the characteristic pest bird species are *Francolinus bicalcaratus* and *Streptopelia senegalensis*. The rest of the bird species are not associated with different phenological stages (Fig. 5). The Generalized Linear Model confirms this observation by noting that the phenological stage of sorghum has a very significant effect on pest bird species distribution (ddl = 2; W = 24.34; p <0.0001).

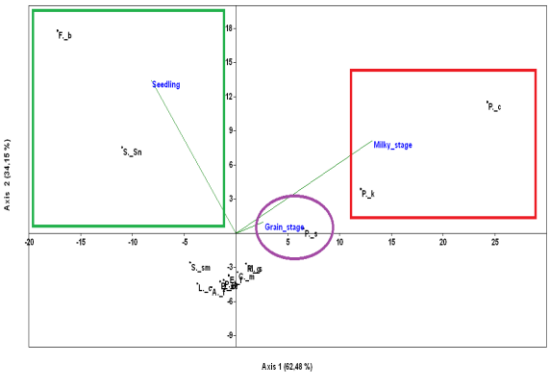

Fig. 5. Distribution of pest granivorous bird species based on sorghum phenological stages in the Peleforo Gon Coulibaly University experimental site in Korhogo from June 2017 to December 2017

(A. f : *Atimastillas flavicollis*; C. m : *Crithagra mozambica*; E. f : *Euplectes franciscanus*; F. b : *Francolinus bicalcartus*; L. c : *Lamprotornis caudatus*; L. cc : *Lonchura cucullata*; M. s : *Malimbus scutatus*; P. b : *Pycnonotus barbatus*; P. c : *Ploceus cucullatus*; P. g : *Passer griseus*; P. k : *Psittacula krameri*; P.s : *Poicephalus senegalus*; P. v : *Ploceus vitellinus*; S. sm : *Streptopelia semitorquata*; S. Sn : *Streptopelia senegalensis* and U. b : *Uraeginthus bengalus*).

Classification of pest bird species according to the phenological stages of sorghum

At the seeding stage, the numbers of pest bird species vary significantly (ddl = 3; F = 18.67; p < 0.0001). The test of Newman-Keuls reveals that *Francolinus bicalcaratus* is the primary pest of sorghum seedlings. *Streptopelia senegalensis* is the secondary pest, while *Lamprotornis caudatus* and *Streptopelia semitorquata* are the minor pests (Fig. 6).

The numbers of the pest bird species vary significantly with the milky stage of sorghum panicles (ddl = 11; F = 19.58; p <0.001). The Newman-Keuls test reveals that *Ploceus cucullatus* is the primary pest of sorghum panicles at this stage. The secondary pest is *Psittacula krameri* while the other species are minor pests (Fig. 6).

Based on the variance analysis, the numbers of sorghum pest bird species varied significantly

with sorghum panicles grain stage (ddl = 4; F = 6.6; P <0.001). According to the Newman-Keuls test, the species *Crithagra mozambica*, *Psittacula krameri* and *Poicephalus senegalus* are primary pests while the other species are minor pests (Fig. 6).

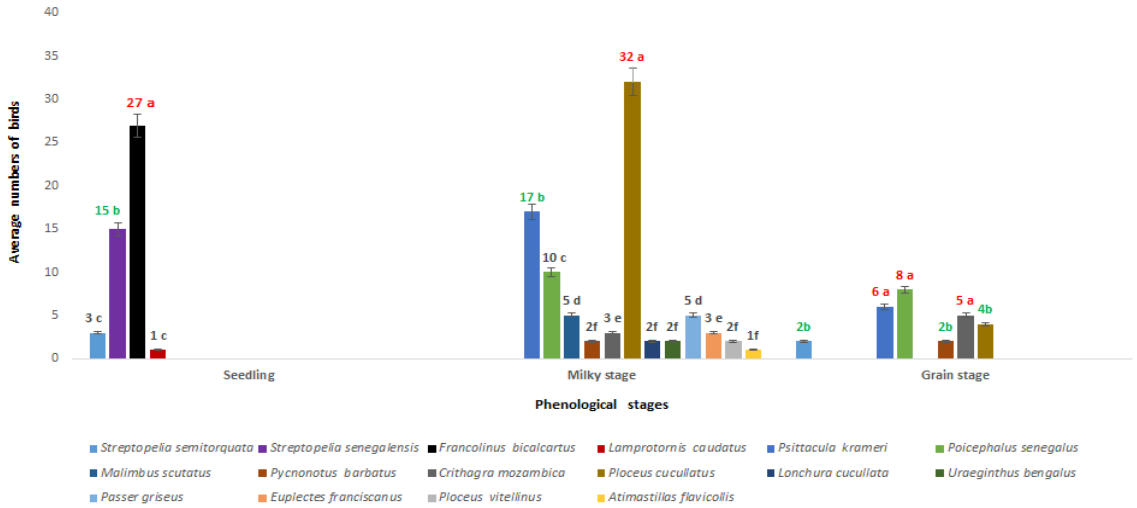

Fig. 6. Classification of granivorous pest bird species according to the phenological stages of sorghum in the experimental site of Peleforo Gon Coulibaly University in Korhogo from June 2017 to December 2017 (a: Primary pest; b: secondary pest and c, d, e, f: minor pest).

Damage identification and characterization

The damage is caused by three groups of pest birds, namely, seedling predators, panicle seed eaters (Fig. 7 a) and sorghum panicle cutters (Fig. 7 b).

a) b)

Fig. 7. Damage of granivorous pest birds of sorghum panicles in the experimental site of Peleforo Gon Coulibaly University in Korhogo from June 2017 to December 2017 (a: depredation of sorghum panicles and b: cutting of sorghum panicles).

The characterization of bird species according to their damage carried out from a principal component analysis (Fig. 8), allows to distinguish three main groups. *Francolinus bicalcaratus* is the only seedling predator. Bird species responsible for the depredation of sorghum seed panicles are *Crithagra mozambica*, *Psittacula krameri* and *Ploceus cucullatus* (Fig. 9 a), while the last set of "panicula cutters" is exclusively represented by *Poicephalus senegalus* (Fig. 9 b). The Generalized Linear Model confirms this observation by noting that the damage caused by pest bird species varies very significantly with phenological stage of sorghum (ddl = 2; W = 14.34; p <0.0001).

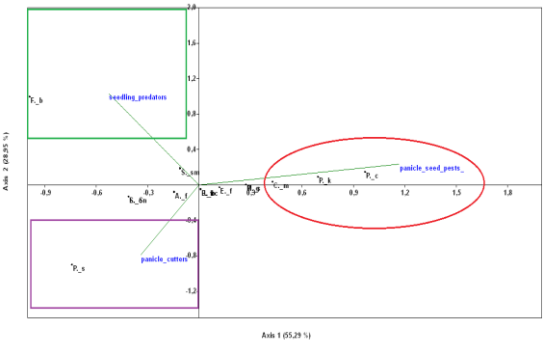

Fig. 8. Characterization of the damage of pest bird species according to the phenological stages of sorghum in the experimental site of the Peleforo Gon Coulibaly University in Korhogo from June 2017 to December 2017

(A. f : *Atimastillas flavicollis* ; C. m : *Crithagra mozambica* ; E. f : *Euplectes franciscanus* ; F. b : *Francolinus bicalcartus* ; L. c : *Lamprotornis*

caudatus ; L. cc : *Lonchura cucullata* ; M. s : *Malimbus scutatus* ; P. b : *Pycnonotus barbatus* ; P. c : *Ploceus cucullatus* ; P. g : *Passer griseus* ; P. k : *Psittacula krameri* ; P.s : *Poicephalus senegalus* ; P. v : *Ploceus vitellinus* ; S. sm : *Streptopelia semitorquata* ; S. Sn : *Streptopelia senegalensis* and U. b : *Uraeginthus bengalus*).

a) b) c)

Fig. 9. Predatory birds and sorghum panicle "cutters" birds in the experimental site of Peleforo Gon Coulibaly University in Korhogo from July 2017 to December 2017 (a and b: Depredation of sorghum panicles (*Psittacula krameri* and *Ploceus cucullatus*) and c : sorghum panicle cutter (*Poicephalus senegalus*)).

Discussion

Inventories of the community of sorghum pest birds carried out from seedlings to harvest have identified 16 species. This number is higher than the nine (9) bird species identified exclusively at the milky and grain stages of panicles in sorghum cultivation observed in the municipality of Korhogo (Niamien *et al.*, 2019). This difference could be linked respectively to the fact that the seedling stage was taken into account on the one hand, and to the duration of the present study (six months against two months for the previous study) on the other hand. Compared to the previous study (Niamien *et al.*, 2019), nine species are observed for the first time in sorghum cultivation in Côte d'Ivoire. These are *Francolinus bicalcaratus*, *Streptopelia semitorquata*, *Psittacula krameri*, *Atimastillas flavicollis*, *Lamprotornis caudatus*, *Ploceus vitellinus*, *Malimbus scutatus*, *Euplectes franciscanus* and *Uraeginthus bengalus*. Their presence would be linked to the food resources constituted by the sorghum field, which will attract them because of their good energy value necessary to cover their need (El Naim *et al.*, 2018; Arain *et al.*, 2019; Niamien *et al.*, 2919).

The order of Passeriformes and the family of Ploceidae were the most important. Our results are similar to the sorghum study in Korhogo (Niamien *et al.*, 2919). In addition, studies on rice in Côte d'Ivoire, Mali and Burundi confirm this observation (Nasasagare *et al.*, 2014; Odoukpé *et al.*, 2014; Odoukpé and Yaokokoré-Béibro, 2016).

The largest number of species and individuals were recorded during the milky phenological stage of sorghum panicles. This fact suggested that the damage caused was the most important at this stage. In addition, these large numbers seemed to be linked to the high energy demand due to reproduction (Nasasagare *et al.*, 2014 ; Niamien *et al.*, 2019). Indeed, the concentrations of total protein and free amino acids measured during this stage were the most important, and thus provided a nutritional intakes necessary to cover the high calorific demand of breeding individuals (Nasasagare *et al.*, 2014; El Naim *et al.*, 2018; Suleman *et al.*, 2018; Arain *et al.*, 2019). Furthermore, birds adapt to these food sources constituted by the fields of cereals in production (Sax *et al.*, 2007; Nasasagare *et al.*, 2014; Hiron *et al.*, 2014; Odoukpé and Yaokokoré-Béibro, 2016; Niamien *et al.*, 2019).

The bird species *Francolinus bicalcaratus*; *Ploceus cucullatus*; *Psittacula krameri*, *Poicephalus senegalus* and *Crithagra mozambica* were the most important pests during seedling, milky panicles and grain panicles, respectively. Compared to previous studies, which identified *Ploceus cucullatus* and *Crithagra mozambica* as the main pests of sorghum in Kenya and Côte d'Ivoire (Hiron *et al.*, 2014; Niamien *et al.*, 2019), this study reveals for the first time three new primary pests in sorghum cultivation in Côte d'Ivoire. These are *Francolinus bicalcaratus*, *Psittacula krameri* and *Poicephalus senegalus*. Their presence could be linked to their habitat and their behavior related to agro-ecosystems and particularly to cereal fields (Borrow and Demey, 2008, 2012). In addition, the presence of *Francolinus bicalcaratus* would be related to the seedling stage considered in this study as opposed to the previous study (Niamien *et al.*, 2019).

Conclusion

The study of the pest birds' community of sorghum, the staple and economical food of Korhogo populations identified 16 species from nine families and four orders. Nine pest species have been observed for the first time in Côte d'Ivoire. These are *Francolinus bicalcaratus*, *Streptopelia semitorquata*, *Psittacula krameri*, *Atimastillas flavicollis*, *Lamprotornis caudatus*, *Ploceus vitellinus*, *Malimbus scutatus*, *Euplectes franciscanus* and *Uraeginthus bengalus*. The specific richness and abundances were most important during the milky phenological stage of the sorghum panicles. Overall, *Ploceus cucullatus* was the primary pest of sorghum. During the seedling, *Francolinus bicalcaratus* was the main pest. At the milky stage of sorghum panicles, *Ploceus cucullatus* remained the primary pest while the species *Poicephalus senegalus*, *Psittacula krameri* and *Crithagra mozambica* were the most important pests at the panicles grain stage. Characterization of pests according to their damage has helped distinguish seedling predators (*Francolinus bicalcaratus*), depredators of sorghum panicle (*Crithagra mozambica*, *Psittacula krameri* and *Ploceus cucullatus*) and panicle cutters (*Poicephalus senegalus*). Therefore, control should target these primary pests. In addition, special attention should be paid to the parrot *Poicephalus senegalus*, due to the significant damage it causes, related to the cutting of panicles. Thereby, this would enable to decrease its impacts and increase crop, and thus to remotivate the rural women's communities for the recovery of sorghum cultivation in order to contribute to food security and increase their income.

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