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Preliminary data on the bio-ecology of pest birds of sorghum (*Sorghum bicolour* (L.) Moench) (Korhogo, Côte d'Ivoire)

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Abstract
Sorghum is for the north of Côte d'Ivoire the staple food of the population because of its good protein value. Production efforts are hindranced by losses caused by pests and especially birds. However, no data is available concerning these pests. The present study represents the first analysis approach with regard to bio-ecology of sorghum pest birds in Korhogo locality (Northern Côte d'Ivoire). Thirty sessions of direct observations of that birds through binoculars based on line transects method with 15 minutes interval each, were carried out on sorghum panicles at the milky and grain stages from October to November 2016. We were able to discriminate nine species of sorghum pest birds, including seven families clustered in three orders. The main recorded sorghum pest bird species were *Ploceus cucullatus* (Muller, 1776) and *Crithagra mozambica* (Statius, 1776). The sorghum panicles phenological development stage as influencing sorghum pest birds' distribution.

Keywords: Sorghum cultivation, panicles phenological stage, pest birds, distribution, sustainable development

1. Introduction
Agriculture is the mainstay of the least-developed countries economies, underpinning their food security, export earnings and rural development. However, the poor performance of agriculture in least-developed countries is related to the many internal and external difficulties that these countries face as they seek to develop this sector and achieve their objectives of improving food security and increasing export earnings. Hence we believe that agriculture improvement in that regions can strongly contributes to the achievement of the Millennium Development Goals on hunger and poverty [1].

In Côte d'Ivoire a Western Africa country, food production contributes to the Gross Domestic Product (7% or 14,000,000 USD) [2]. Several typologies of crop are practiced in that country. Preeminence have given to cereal crop for local consummation. Then, main cereal crops englobe and/or include (i) rice, (ii) millet and (iii) sorghum. However, cereal crops yield in this area is low for covering population food need, making necessary importation filling that gap [3].

Furthermore, Northern of Côte d'Ivoire exhibits climatic and seasonal advantages allowing several cereal crops culture practices. Indeed, sorghum is traditionally grown in northern in Côte d'Ivoire [3, 4]. This speculation is strategic. Indeed, its culture requires a low rainfall, an important characteristic in the current climate change environment, with the consequent scarcity of precipitation [5-7]. In addition, sorghum grains exhibit interesting and health nutritive advantages including proteins, lipids, and carbohydrates, as well as weak fat amount. Sorghum plants and/or grains derivatives are used for various and/or multiple purpose such as, feed of livestock and poultry, collar, oil and construction equipment and as well traditional beer [7].

The attainment of food self-sufficiency is due to the intensification of cereal production. Cereals are in many developing countries the staple food of the population because of its good protein value (11% to 12%) [6]. However, production efforts are hindranced by losses caused by pests [3, 4, 8-10], reaching 60% of the annual production [11, 12]. In Korhogo (Northern of Côte d'Ivoire), cereals are cultivated by women communities for consumption and have incomes

for the satisfaction of their primary needs. However, the enormous losses caused by the sorghum pests have incited these communities to abandon this speculation [5, 10].

Data available on cereals pests are related to rice, wheat and barley [10, 11]. With the exception of the entomofauna [13, 14], there is no data on sorghum bird pests. But, grain fields in production are a regular source of food for pest birds, some species which may pose a risk to production [8, 12, 15-18]. It is an attempt to fill this information gap, that this research was initiated.

The present study, is a contribution to a better knowledge of birds' ecology in order to ensure a rational and sustainable management. It is specifically designed to (i) identify the sorghum pest bird's community and (ii) analyses the influence of the phenological stages of the panicles on its distribution with the purpose to draw a practical applications for the intensification of this speculation.

2. Materials and Methods

2.1 Study Area

The Department of Korhogo (9° 34' N-5° 37'W) is located in the north of the Côte d'Ivoire, in the Poro Region, which is located in the Savannah District. This Commune is subject to a Sudanese-type climate, which consists of two seasons: a dry season (November to April) and a rainy season (May to October).

2.2 Materials

Sorghum is a high-stem tropical grass (Fig 1 a). Seedlings were made in June 2016 after the first rains. The seeds germinated and developed until October 2016, the month of the first panicles at the milky stage (Fig 1 b). The panicles gradually matured to reach the grain stage in November 2016 (Fig 1 c), the month at the end of which the harvest occurred.

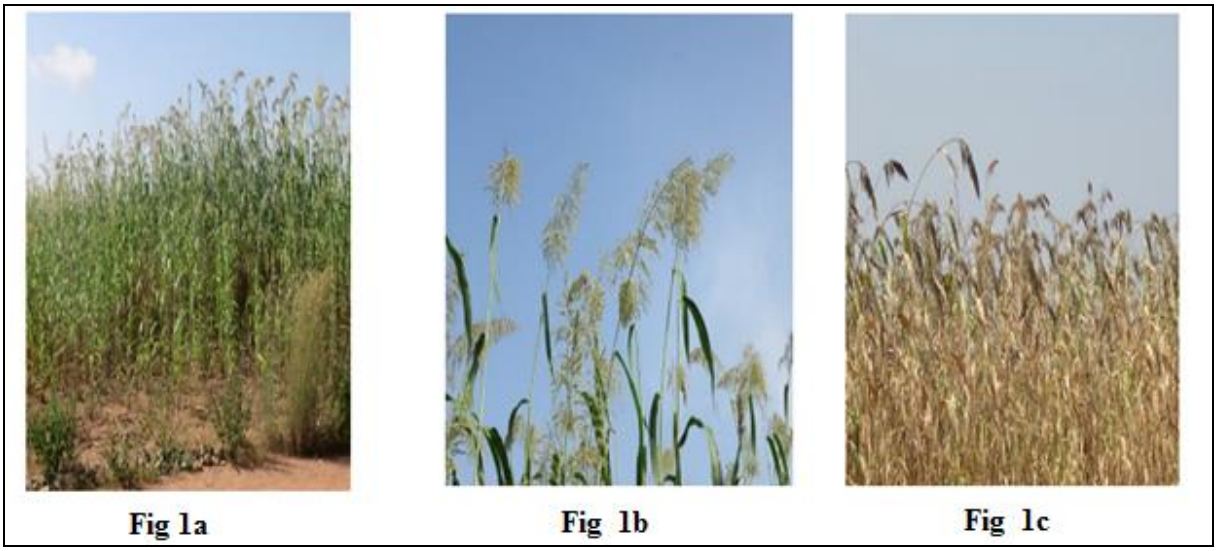

Fig 1: Sorghum field (1a) with the phenological stages of panicles in the milky stage (1b) and in the Grain stage (1c) from October 2016 to November 2016 in the Commune of Korhogo

2.3 Methods

2.3.1 Pest birds' inventory

The inventory of the sorghum pest bird's community was carried out in Korhogo locality from October 2016 to November 2016, corresponding to sorghum panicles development and maturation stages [9]. Thirty sessions of direct observations of birds by binoculars based on the method of line transects with a 15 minutes points count were carried out [19, 20]. The inventories were carried out from sorghum panicles milky stage to the harvest (grain stage) [11, 21]. For this purpose, we walked along the trails bordering the sorghum field to identify and count bird species. 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 [19, 20]. All birds on sorghum plants were observed through binoculars and identified using the West African Birds Identification Guide [22].

2.3.2 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 panicles. 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 panicles in which diversity and numbers were highest. The distribution of bird species related to the phenological stage of sorghum panicles was tested using the Generalized Linear Model. The qualitative and quantitative distributions of bird species based on the phenological stages of sorghum panicles were highlighted using the "Z-Score". All these analyses were performed using the software *STATISTICA* (version 7.1) and *R* (version 3.3.1).

3. Results

3.1 Qualitative composition

Surveys of pest birds (N = 1515 individuals) carried out on sorghum from October 2016 to November 2016 during the 30 sessions of observations identified nine species of birds (Fig 2) grouped into seven families and classified in three orders (Table 1).

Fig 2: Photographs of some pest bird species of sorghum panicles from October 2016 to November 2016 in the Commune of Korhogo

Globally, the orders observed are Columbiformes, Psittaciformes and Passeriformes. The Passeriformes with five families constitute the best represented order (78%). The other orders contain only one family (11%) (Table 1).
Seven families have been determined. These are the families of Columbidae, Psittacidae, Ploceidae, Estrildidae, Fringillidae, Passeridae and Pycnonotidae (Table 1). The families of the Ploceidae and Estrildidae are the most important with two species (22.22%). Other families are equally important with only one species (11.11%) (Table 1).

3.2 Variation in the composition of the bird's community in relation to the phenological stage of sorghum panicles

3.2.1 Panicles at the milky stage

Qualitatively, three orders were observed: Columbiformes, Psittaciformes and Passeriformes. The order of Passeriformes is best represented (72%). The remaining orders represent 28 % of the total (Table 1).

Table 1: Results of qualitative inventories of the pest birds of sorghum in relation to the phenological stage of sorghum panicles from October 2016 to November 2016 in the Commune of Korhogo (+: present, -: absent)

Orders	Families	Species	Milky stage	Grain stage
Columbiformes	Columbidae	*Streptopelia senegalensis* (Linné, 1766)	+	+
Psittaciformes	Psittacidae	*Poicephalus senegalus* (Linné, 1766)	+	-
Passeriformes	Ploceidae	*Ploceus cucullatus* (Muller, 1776)	+	-
		Ploceus luteolus (Lichtenstein, 1823)	+	-
	Estrildidae	*Lonchura cucullata* (Swainson, 1837)	+	-
		Lonchura fringilloides (Lafresnaye, 1835)	+	-
	Fringillidae	*Crithagra mozambica* (Statius, 1776)	+	+
	Passeridae	*Passer griseus* (Vieillot, 1817)	-	+
	Pycnonotidae	*Pycnonotus barbatus* (Desfontaines, 1789)	+	-

Five families were determined when sorghum panicles were in the milky stage. These are the families of Columbidae, Psittacidae, Ploceidae, Estrildidae, Fringillidae and Pycnonotidae. The family of Ploceidae and Estrildidae are the richest with two species (29%). The other families contain only one species (14%) (Table 1).

3.2.2 Panicles at the grain stage

Qualitatively, two orders were determined. These are the orders of Columbiformes and Passeriformes. The order of Passeriformes is the most important (83%). Columbiformes represent only 17% of the birds' qualitative composition (Table 1).
Six families, with one species, were identified. These are families of Columbideae, Ploceidae, Estrildidae, Fringilidae, Passeridae and Pycnonotidae (Table 1).
The number of sorghum pest bird species varies with phenological stage of the panicles according to the analysis of variances (ddl = 1; F = 16.07; $p < 0.05$). 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 stage (Fig 3).
The phenological stage of sorghum panicles influenced the distribution of pest birds species (GLM: ddl = 1; W = 7.08; $p < 0.05$). Furthermore, the Generalized Linear Model shows a significant effect of the season on the distribution of sorghum pest bird species (GLM: ddl = 1; W = 9.90; $p < 0.001$). The association between phenological stage of sorghum panicles-season also influenced the distribution of pest bird species (GLM: ddl = 1; W = 9.84; $p < 0.05$).
The number of pest bird species varies with the phenological stage of sorghum according to the analysis of variances (ddl = 1; F = 16.07; $p < 0.05$). The Newman-Keuls comparison and classification test reveals that the largest number of bird species has been observed at the milky stage and low at the grain stage (Fig 4).

3.3 Classification of sorghum panicles pest birds

3.3.1 Global classification

The average numbers of sorghum pest bird species varied significantly (ddl = 8; F = 15.39; $p < 0.001$). The Newman-Keuls comparison and classification test applied to these data reveals that *Ploceus cuculatus* was the primary pest. *Crithagra mozambica* is the secondary pest and the remainder of the species are minor pests (Fig 5). *Ploceus cuculatus* therefore presents a high risk for sorghum production while a mean risk is highlighted for *Crithagra mozambica*.

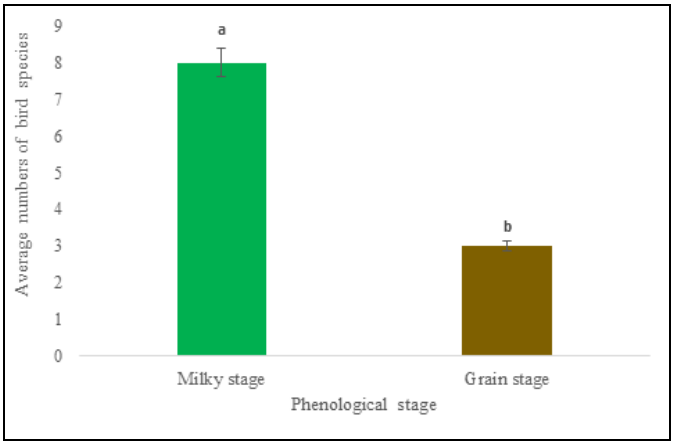

Fig 3: Changes in the number of species of pest birds based on the phenological stages of sorghum panicles from October 2016 to November 2016 in the Commune of Korhogo (a: panicle stage with large species of birds and b: panicle stage with weak species of birds)

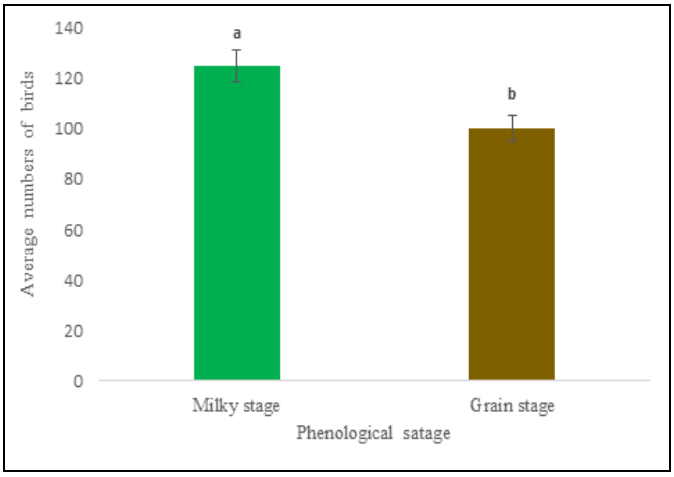

Fig 4: Changes in the average number of pest birds according to the phenological stage of sorghum panicles from October 2016 to November 2016 in the Commune of Korhogo (a: panicle stage with large numbers of birds and b: panicle stage with weak numbers of birds)

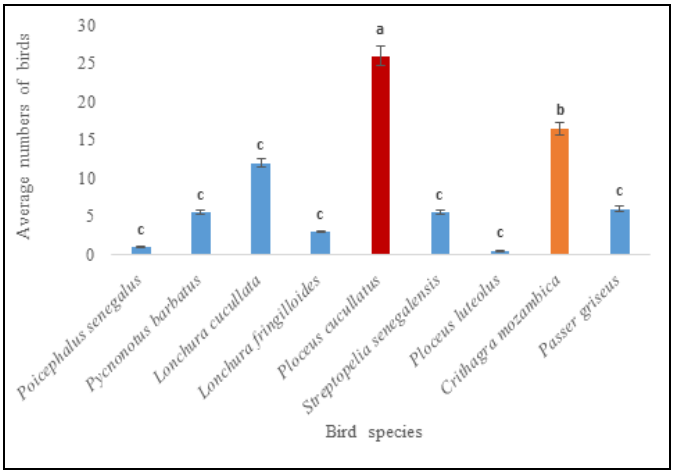

Fig 5: Global classification of pest bird species of sorghum panicles from October 2016 to November 2016 in the Commune of Korhogo (a: main pest, b: secondary pest and c: accessory pest)

3.3.2 Distribution of sorghum pest birds

The study of the qualitative and quantitative distribution of the pest bird species at the different stages of sorghum panicles made from the "Z-Score analysis" gave Figure 4. When considering the phenological stages of sorghum panicles from a qualitative or quantitative point of view, two groups are distinguished: the quantitative milky phenological stage (Qt-MSP) and the quantitative grain stage (Qt-GSP); the qualitative milky stage (Ql-MSP) and the qualitative grain stage (Ql-GSP). Moreover, from a specific point of view of the pest birds, two sets are also distinguished. The first consists of two species, *Ploceus cucullatus* (Pc) and *Lonchura cucullata* (Lc). The second group contains the remainder of the seven species (Figure 4).

The association of the different phenological stages of sorghum panicles with the presence or absence of pest bird species highlights three clusters. Thus, in the first grouping, the species *Passer griseus* (Pg), *Streptopelia senegalensis* (Ss) and *Crithagra mozambica* (Cm) are the most important pests of sorghum panicles at the grain stage (Ql-MSP and Qt-GSP). In the second group, with the exception of *Passer griseus* (Pg) which is absent, the other species of birds are less important ones. Finally, in the last set, the species *Streptopelia senegalensis* (Ss) and *Ploceus cucullatus* (Pc) are the main pests (Fig 6). Qualitative (GLM: ddl = 1; W = 16, 12; $p < 0.001$) and quantitative distribution (GLM: ddl = 1; W = 40.68; $p < 0.001$) of pests bird species of sorghum panicles varied with the phenological stage.

3.3.3 Classification according to the phenological stage of panicles

The numbers of pest bird species in the panicles of sorghum at the milky stage vary significantly (ddl = 7; F = 19.82; $p < 0.001$). The test of Newman-Keuls reveals that *Ploceus cucullatus* is the primary pest. Secondary pests are *Lonchura cucullata* and *Crithagra mozambica*. Other species are less important (Fig 7). *Ploceus cucullatus* presented a high risk for sorghum cultivation when panicles were at the milky stage.

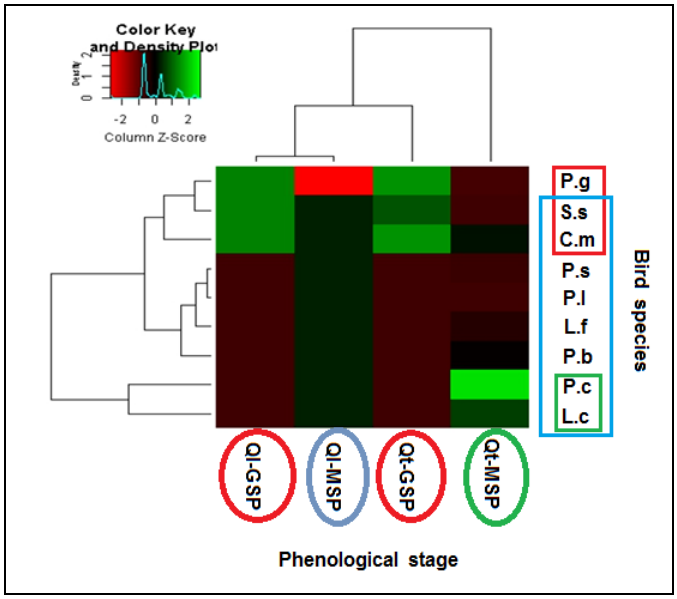

Fig 6: Qualitative and quantitative distribution of the pest bird species of sorghum panicles according to the phenological stage from October 2016 to November 2016 realized from the "Z Score analysis" (Ps: *Poicephalus senegalus*, Pb: *Pycnonotus barbatus*, Lc: *Lonchura cucullata*, Lf: *Lonchura fringilloides*, Pc: *Ploceus cucullatus*, Ss: *Streptopelia senegalensis*, Pl: *Ploceus luteolus*, Sm: *Crithagra mozambica* and Pg: *Passer griseus*; Ql-GSP: Sorghum panicle at the qualitative grain stage, Ql-MSP: Sorghum panicle at the qualitative milk stage, Qt-GSP: Sorghum panicle at the quantitative grain stage, Qt-MSP: Sorghum panicle at the quantitative milk stage)

Comparison of the numbers of sorghum pest bird species with panicles at the grain stage shows a very significant difference (ddl = 2; F = 24.74; p < 0.001). *Crithagra mozambica* is the primary pest while *Passer griseus* and *Streptopelia senegalensis* are secondary pests (Figure 7). *Crithagra mozambica* presented a high risk for sorghum cultivation when panicles are at the grain stage.

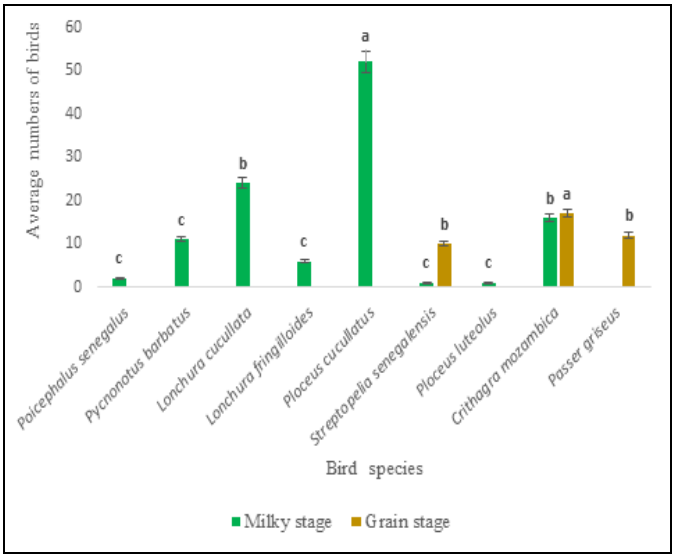

Fig 7: Classification of pest bird species of sorghum panicles according to phenological stage from October 2016 to November 2016 in the Commune of Korhogo (a: main pest, b: secondary pest and c: accessory pest)

4. Discussion

Results of qualitative surveys carried out on sorghum in the Commune of Korhogo (Côte d'Ivoire) from October 2016 to November 2016 identified nine species of pest birds. This number is comparable to the 11 bird species observed in the paddy fields of Kagogo-Gisumo in Burundi [11].

The families of Ploceidae and Estrildidae were best represented during our study. Similar observations relating to the Ploceidae family were respectively made in Mali, Burundi and Côte d'Ivoire on rice [5, 11, 19].

The distribution of species and numbers of birds according to phenological stages showed that the most abundant pest birds were observed at the milky stage. This fact suggested that the damage caused was the most important at this stage. Indeed, these large numbers seemed to be linked to the high energy demand due to reproduction [5, 10]. In fact, the concentrations of total protein and free amino acids measured during this stage were the most important, and thus provided a good calorific value for the satisfaction of their high energy need [10, 11, 19, 23]. This is the case of *Lonchura cucullata* and *Ploceus cucullatus*, which have reproduced during the milky stage of sorghum panicles. In fact, birds adapted to the availability of the new regular food source made up of cereal fields [9, 10, 11, 17, 19, 23]. In contrast, *Passer griseus* reproduced at the grain stage of sorghum panicles. This would aim at an adaptation, which would be to coincide its period of reproduction with the phenological stage of sorghum where the competition level was low in order to guarantee its reproductive success [10, 19, 23]. The lowest numbers of birds were observed at the grain stage, the state of maturity of sorghum. That same observation was made on paddy field [11].

Ploceus cucullatus (Ploceidae) and *Crithagra mozambica* (Fringillidae) were the main pests of sorghum panicles in milky and grain stages, respectively. However, the most important pests of paddy belonged to the families of Ploceidae, Estrildidae and Passeridae [11]. Compared to previous studies on cereals [10, 11, 12, 19, 21], our study revealed for the first time that *Crithagra mozambica* (Fringillidae) is a major pest of cereals. *Ploceus cucullatus* has been reported as a major pest of rice cultivation [19, 21]. Indeed, these birds' fed at all phenological stages of sorghum panicles, and due to their gregarious behavior, would constitute a serious threat to the production of that basic and economical food [8]. *Crithagra mozambica* has been reported as low-risk pest of rice [21]. Whereas, our study revealed that this species is a major pest of sorghum at the grain stage. This could be explained by its habitat and behavior, which were linked to agro-ecosystems such as cereal fields [22].

5. Conclusions

The study of the pest birds' community of sorghum panicles, the basic and economical food of Korhogo populations, has allowed to inventory nine species of birds, grouped into seven families and classified in three orders. Overall, the order of Passeriformes as well as the families of Ploceidae and Estrildidae were the most important. The largest numbers of pest birds and the highest diversity were observed at the milky stage of sorghum panicles. During the study period, *Ploceus cuculatus* was the main high-risk pest for sorghum cultivation. At the milky stage of sorghum panicles, *Ploceus cuculatus* remained the most important pest, whereas at the panicles grain stage, *Crithagra mozambica* has been the major pest. To ensure the intensification of sorghum cultivation in order to increase the production of this strategic speculation, the fight should focus on these main pests, with particular attention to *Ploceus cuculatus* because of its gregarious behavior, which would impact efforts. Besides, predatory bird species of seedlings should also be identified to determine all categories of pests at different stages. This will contribute to sustainable management of biodiversity, to ensure the profitability of production and thus to guarantee the social well-being of vulnerable rural women's communities, dependent on cereal crops in the current context of poverty in developing countries.

6. Références

1. Banque Mondiale. L'agriculture au service du développement. Rapport sur le développement dans le monde, Bruxelle, 2008; 1-20.
2. CNRA. Programme de recherche: Présentation des résultats 2004. CNRA, Abidjan, 2004; 1-59.
3. Tuo Y, Koné K, Yapo ML, Koua KH. Evaluation of the entomofauna of Millet (Cyperales: Poaceae) in the north of Côte d'Ivoire. International Journal of Current Research in Life Sciences. 2018; 7(7):2416-2422.
4. Djè Y, Heuertz M, Ater M, Lefebvre C, Vekemans X. Évaluation de la diversité morphologique des variétés traditionnelles de sorgho du Nord-ouest du Maroc. Biotechnologie, Agronomie et Société Environnementale. 2007; 11(1):39-46.
5. Billet F. L'impact des oiseaux granivores sur les cultures céréalières dans le delta du Niger au Mali. Tropicultura. 1983; 1(4):133-135.
6. El Naim A, Hamoda M, Ibrahim SM, Zaied EA, Ibrahim EB. Performance of In-situ Rain Water Harvesting on Yield of Grain Sorghum in Graded Soil of North Kordofan. International Journal of Agriculture and

Forestry. 2018; 8(2):77-82.
7. Suleman NN, El Naim AM, Ahmed MF. Agronomic Evaluation of Groundnut and Two Varieties of Grain Sorghum Intercropped at Different Spatial Arrangements. International Journal of Agriculture and Forestry. 2018; 8(5):171-175.
8. Fayenuwo JO, Olakojo SA, Akande M, Amusa NA, Olujimi OA. Comparative Evaluation of vertebrate pest damage on some newly developed quality protein maize (QPM) varieties in south western Nigeria. African Journal of Agricultural Research. 2007; 2(11):592-595.
9. Behidji-Benyounes N, Doumandji S. Les attaques journalières de trois parcelles d'orge Hordeum vulgae L. par le moineau hybriqde *Passer domesticus* x *Passer hispaniolensis* dans la Matidja orientale. Lebanese Science Journal. 2009; 10(1):55-62.
10. Madagh MA. Bioévaluation des dégâts dus aux oiseaux (moineau hybride) dans les agroécosystèmes aux environs d'Alger. Congress of the population and animal communities: "Dynamics and biodiversity of the terrestrial and aquatic Ecosystem". Algeria, 2013.
11. Nasasagare RP, Ntakimazi G, Libois R. Etude des facteurs influençant la visite des oiseaux dans les champs de riz. Bulletin scientifique de l'Institut national pour l'environnement et la conservation de la nature. 2014; 13:28-34.
12. Gros-Désormeaux JR, Picard R, Siblet S. Perspectives pour l'intégration des comportements de l'avifaune dans la gestion d'agroécosystèmes insulaires tropicaux: le cas de cultures vivrières à la Martinique. Cahiers Agricole. 2015; 24(3):177-185.
13. Teetes GL, Young WR, Jotwani MG. Insectes ennemis du sorgho. Introduction à la lutte intégrée contre les ennemis du sorgho. Etude de la FAO. Production Végétale et Protection des Plantes. 1980; 19:5-13.
14. Douan BG. Evaluation de l'efficacité de la «terre diatomée » sur trois coléoptères ravageurs des stocks de maïs (*Zea mays* L.) et de sorgho (*Sorghum bicolor* L.) en Côte d'Ivoire. Mémoire de DEA d'Ecologie Tropicale, Université de Cocody, 2009, 64.
15. Clergeau P. Le contrôle des oiseaux ravageurs des cultures: de la destruction à la gestion. Ibex Journal of Mountain Ecology. 2000; 5:219-227.
16. Clergeau P, Mandon-Dalger I, Georger S. Mise en place d'une gestion intégrée d'un oiseau ravageur des cultures à la Réunion. Ingénieries. 2002; 30:71-80.
17. Reader SM, Morand-Ferron J, Côté I, Lefebvre L. Unusual feeding behaviors in five species of Barbadian birds. El Pitirre. 2002; 15:117-23.
18. Borad CK, Parasharya BM. Community structure of birds in wheat crop fields of Central Gujarat. Journal of Entomology and Zoology. 2018; 6(5):19-24.
19. Odoukpé KSG, Yaokokoré-Béibro KH, Kouadio KP, Konan EM. Dynamique du peuplement des Oiseaux d'une riziculture et ses environs dans la zone humide d'importance internationale de Grand-Bassam. Journal of Applied Biosciences. 2014; 79:6909-6925.
20. Yaokokoré-Béibro KH, Koné YS, Odoukpé KSG. Avifaune d'un milieu marécageux urbain dans la commune de Cocody. International Journal of Innovation and Scientific Research. 2015; 18(1):99-108.
21. Nasasagare RP, Ndayisaba ED, Libois R. La déprédation non aléatoire chez les oiseaux granivores du marais de Kagogo-Gisumo au Burundi. Bulletin scientifique sur l'environnement et la biodiversité. 2017; 2:1-8.
22. Borrow N, Demey R. Guide des Oiseaux de l'Afrique de l'Ouest. Delachaux et Niestlé, Black publishers, Paris, 2008, 510.
23. Tréca B. Les risques de dégâts d'Oiseaux sur les rizières sahéliennes. Eldin M. et Milleville, Paris, 1989, 167-175.