

Research Article

Laura Estelle Yêyinou Loko*, Azize Orobiyi, Joelle Toffa, Sédami Medegan Fagla, Dieudonné Martin Gavoedo, Tamò Manuele

Farmers' knowledge, perceptions and management practices for termite pests of maize in Southern Benin

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Abstract: Termite (Isoptera: Termitidae) infestation is an important constraint of maize production in Benin. A survey of 300 households was conducted in 2018 throughout 30 villages in Southern Benin to evaluate farmers' knowledge, perceptions and management practices of maize termite pests using focus group discussions and individual interviews with a semi-structured questionnaire. The results showed that for most of the farmers, maize is the most susceptible crop to termite attacks and the maturation developmental stage having the highest termite abundance and damage. A total of 43 different names of maize termite pests corresponding to 8 species were recorded in the study area. Size and colour were the main criteria used by farmers to classify and identify maize termite pests. *Amitermes evuncifer* was perceived as the most damaging to maize during vegetative and maturation stages, while *Macrotermes bellicosus* was perceived by farmers (32.5%) as most damaging during seedling and flowering maize development stages. Erratic rainfall was perceived by maize producers as the most important factor favouring termite infestation in maize fields. The majority of the local maize is considered by farmers as susceptible

to termites. The use of synthetic insecticides was the main method to control termites. Four of the 20 pesticides used by farmers have active ingredients that have been listed as highly hazardous (class Ib) by the World Health Organization (WHO). Farmers training on the danger and impact of misuse of insecticides on the development of termite insecticide resistance was recommended. The development of an integrated termite management strategy is discussed and the future research for its implementation identified.

Keywords: Benin; Indigenous knowledge; Maize; Management practices; Pesticides; Termites.

1 Introduction

Maize (*Zea mays* L.) is a crop that contributes to food security and poverty reduction in the Republic of Benin. It is the most widely grown cereal crop in the country and occupies about 70% of the total cereals in the cultivated area (MAEP 2010). Maize is produced in all regions of Benin with an estimated production to 1,376,683 tonnes in 2016 (FAO 2016). This cereal represents the main staple food of the population in Southern Benin (Van Den Akker 2000; Semassa et al. 2017), which is considered as the main area of production for maize (Babadankpodji and Dadou 2015). A national consumption level is estimated at 116.98 grams per capita per day in 2013, which places the Republic of Benin among the major maize consumers in West Africa (FAO 2016). Maize kernel is a great source of potassium, carbohydrates and several vitamins (Shah et al. 2016). In Benin, maize is also used as feed and as raw material for some food industries. Besides its function of food subsistence, it is also subject to trade both within the country and sub-regional markets (Boone et al. 2008). Unfortunately, maize production in Benin is subject to several constraints such as soil infertility, drought, insect attacks including

*Corresponding author: Laura Estelle Yêyinou Loko, Laboratory of Applied Entomology, Faculty of Sciences and Technology of Dassa (FAST-Dassa), National University of Sciences, Technologies, Engineering and Mathematics of Abomey (UNSTIM), BP 14 Dassa-Zoumé, Benin, E-mail: lokoestelle@yahoo.fr

Azize Orobiyi, Joelle Toffa, Alterra, Dieudonné Martin Gavoedo, Laboratory of Applied Entomology, Faculty of Sciences and Technology of Dassa (FAST-Dassa), National University of Sciences, Technologies, Engineering and Mathematics of Abomey (UNSTIM), BP 14 Dassa-Zoumé, Benin.

Sédami Medegan Fagla, Medicinal and organic chemistry Laboratory, Faculty of health Sciences, 01BP 188 Cotonou Benin

Tamò Manuele, International Institute of Tropical Agriculture (IITA), 08 BP 0932, Cotonou, Benin

termites that induce a significant decline in yield (Bonou-gbo et al. 2017; Loko et al. 2017).

Termites are known as one of the most important maize production constraints throughout the African continent (Sekamatte et al. 2001; Riekert and Van den Berg 2003; Sileshi et al. 2005; Sileshi et al. 2008; Faragalla and Al Qhtani 2013; Paul et al. 2018). Indeed, termites attack maize plants in their seedling stage to maturity and damage their roots, leading to deaths (Wood et al. 1980). Species within the genus *Odontotermes* and *Macrotermes* can defoliate maize seedlings, while *Microtermes* sp. attacks mature maize plants (Paul et al. 2018). The crop losses caused by these termites are enormous, range from 20% to 45% (Wood and Pearce 1991). Despite the importance of termite damage to maize fields, very little attention has been given to these pests in Benin. Therefore, the folk nomenclature and taxonomy of maize' termite pests are unknown. The taxonomic knowledge of these indigenous termites is important for the best communication between farmers, extension agents and scientists on termite pest problems (Akutse et al. 2012). Similarly, farmers' knowledge and perception of maize' termite pests are not well documented. The understanding of the indigenous knowledge on termite pests accumulated by farmers is not only crucial for their efficient management but also for the conservation of the non-pest termite species.

Worldwide, termite control is commonly based on the use of chemical insecticides that have a negative impact on the environment and human health (Logan et al. 1990; Verma et al. 2018). However, in Africa, farmers often use traditional pest management practices to control termites (Sileshi et al. 2005; Sileshi et al. 2008; Loko et al. 2017). In order to elaborate integrated pest management (IPM) strategies that suit small-scale maize producers in Benin, it is important to identify the appropriate and sustainable traditional control methods adopted by farmers (Nyeko et al. 2002; Sileshi et al. 2008; Akutse et al. 2012). This paper presents the results of a survey on termite pests of maize conducted in Southern Benin. The objectives of the survey were to (i) document farmers' perceptions, folk nomenclature, folk taxonomy, and damage of maize' termite pests; (ii) identify resistant maize varieties to termite attacks; and (iii) identify termite pest management practices, constraints and intervention opportunities for the development of an integrated termite management strategy that will contribute to the enhancement of maize production in Southern Benin.

2 Material and methods

2.1 Study area

The survey was carried out in 2018 in Southern Benin located between latitudes 6°20' N and 7°30' N and longitudes 1°35' E and 2°45' E (Figure 1), covering an area of 17,920 km². This region is among the main maize-growing areas in Benin (Babadankpodji and Dadou 2015). Six (Atlantique, Mono, Couffo, Oueme, Plateau and Zou) of the seven departments located in Southern Benin (Figure 1) were surveyed. Only the Littoral Department wasn't surveyed, because it is entirely formed by the economic capital of Benin, Cotonou, which is an urban area with little maize fields. The study area is characterised by a Sudano-Guinean climate with two dry seasons and two wet seasons. The mean annual rainfall range is from 800 to 1500 mm and the mean temperature is 27 °C (Table 1). The soils are either deeply ferrallitic or rich in clay, humus and minerals. The native vegetation consists of dense semi-deciduous forests and Guinean savannahs. In South Benin, farmers practice continuous cultivation or short duration fallows (Schulz et al., 2003). The main food crops are maize, cassava and cowpea while oil palm and groundnuts are major cash crops. The population of South Benin is estimated at 5,894,168 inhabitants (INSAE, 2013) and constitutes several socio-cultural groups, such as the Saxwè, Adja, Cotafo, Watchi, Mina, Nagot, Ouémègbé, Fon, Tori and Ayizo. Within each of the six departments, the surveyed villages were selected on the basis of the maize production statistics taken from agriculture and rural development office of each department (Figure 1).

2.2 Data collection

A survey was carried out between February and June 2018 in the 30 selected villages of Southern Benin (Figure 1). In each village, the data were collected using the tools (questionnaires) and the methods (household survey, focus group survey, and field visit) of participatory research (Kombo et al. 2012). In each village, 10 households were selected using the transect method described by Dansi et al. (2010) for an individual interview. A total of 300 (258 male and 42 female) household head farmers who grew maize were interviewed throughout the 30 surveyed villages. The number of surveyed farmers varied from one department to another, depending on the maize producers at the level of each surveyed village. The highest number of farmers interviewed was from the Zou Department (N =

Table 1: Basic information regarding the six surveyed departments in southern Benin

	Departments					
	Zou	Mono	Couffo	Plateau	Ouémé	Atlantique
Sociolinguistic groups surveyed	Fon	Saxwè, Mina, Watchi, Cotafo	Adja	Nagot	Ouémègbé, Tori	Ayizo, Fon
Number of districts	9	6	6	5	9	8
Population	851 580	497 243	745 328	622 372	1 100 404	1 398 229
Climate	Transitional climate between the sub-equatorial climate and Sudano-Guinean climate	Sub-equatorial climate	Sub-equatorial climate	Sudano-Guinean climate	Sub-equatorial climate	Sub-equatorial climate
Area (Km ²)	5 243	1 605	2 404	3 264	1 281	3 233
Annual rainfall (mm)	900-1200	850-1160	800-1200	800-1400	900-1500	800-1200
Annual temperature (°C)	27.7	27.4	27.8	27.4	27.4	27.2
Vegetation	Dominated by a natural palm grove and grasses with a few shreds of classified forests or sacred forests	Grassy savannah, marsh formations and some mangroves	Savannah with trees and grass	Dense semi-deciduous forest and treed or shrubby forest	Grassy savannah, grasslands, and so	Natural forest islands, plantations and forest classified
Soils	Sandy-clay ferrallitic soil. Lateritic and hydromorphic soils	Alluvial and colluvial type of valleys of rivers and lakes more or less hydromorphic	Tropical ferruginous, vertisols and clay soil	Tropical ferruginous, bar lands and clay soil	Ferrallitic, clay-sandy, alluvial and colluvial soils	Soils made of black clays green-soils.
Farming system	Maize, cassava, peanut	Maize, cassava, market gardening	Maize, cassava, cowpea, beans	Maize, cassava	Maize, cassava, peanut, oil palm	Maize, cassava, peanut
Number of surveyed villages	9	3	4	5	2	7

Data assembled from INSAE (2013).



Figure 1: Map of Southern Benin showing the geographical position of the surveyed villages

66), followed by Atlantique (N = 64) and Plateau (N = 56), and then Mono (N = 43), Couffo (N = 40) and Ouémé (N = 31). The interviews were conducted in local language with the help of a trained translator recruited in each village.

The data are collected during face-to-face interviews on the basis of a pre-tested and revised questionnaire (Loko *et al.* 2017). The socio-demographic profile of the surveyed household head (gender, age, household size, level of education, marital status, farming experience in maize production, farm size and purpose of maize production) was firstly recorded. Thereafter, the data relating to farmers' perception of the crops most attacked by termites, growth development stage of maize most damageable by termite attack, termite abundance in each maize growth stage and during storage, factors aggravating termites' infestation in maize fields, type of termite damages, estimated losses due to termite attack and termite management practices and constraints were recorded. According to Obopile *et al.* (2008), when farmers mentioned the use of pesticides, they were asked to name the pesticides or show them to the interviewer for recording. Similarly, plant samples used by farmers to control termites were collected and labelled (vernacular name of the plant, village name and method of use) for identification at the national herbarium of the University of Abomey-Calavi. Farmers' perception of termite pest damage severity was recorded as a categorical variable using a 4-point Likert scale rating (Khan *et al.* 2014). For that, a 4-point scale (0 = no severe, 1 = moderate severity, 2 = severe and 3 = very severe) was used by farmers to score the level of damage caused by termite pests (Munyuli *et al.* 2017). Farmers were also asked to list the maize' termite pest species they knew of. For each termite maize pest identified by farmers, the meaning of the vernacular name and folk taxonomy were recorded. Moreover, for each identified termite pest, the severity of the damage at each different development stage of the maize and during the storage were evaluated using a two-level scale (high and low). Lastly, farmers were asked to identify the constraints they face in termite management and propose possible solutions to overcome these constraints.

Farmers' knowledge of maize' termite pest was evaluated according to Midega *et al.* (2012), which is based on the ability of farmers to identify termite pests by their name, description and damages. The combinations of these three parameters (termite name, description and damage) were classified in 4 categories (Midega *et al.* 2012): (0) No knowledge (farmers wasn't able to mention a maize' termite pest by a name, its description or damage); (1) Low knowledge (farmers was able to give a name of only one maize' termite pest, one feature and one type

of damage); (2) Medium knowledge (farmers was able to give names of two maize' termite pests and describe at least one feature and damage of each termite pest); (3) High knowledge (farmers was able to name three or more maize' termite pests and describe one or more features and damages of each termite pest).

Samples of each maize' termite pest identified by farmers were collected and preserved in labelled boxes containing 70% alcohol for later identification at the Laboratory of Applied Entomology (LEnA) of the Faculty of Sciences and Technology of Dassa (Loko *et al.* 2015b). The specimens were identified to species level based on the caste soldiers by using various standard determination keys established by Sands (1959, 1965, 1972), Bouillon and Mathot (1965) and Ruelle (1970).

Focused group discussions were conducted using the methodology described by Loko *et al.* (2015a). In each village, the resistance of cultivated maize' local varieties to termite attacks was evaluated by a farmer group (10 to 20 maize producers of both sexes and of different ages). Focus group participants were identified and gathered with the help of the village chief and the heads of the peasant associations. According to Loko *et al.* (2015a), a two-level scoring scale was used: a variety is scored 1 when unanimously recognised by the farmers as resistant and 0 otherwise.

2.3 Data analysis

Survey data were analysed using descriptive and multivariate statistics. Chi-square analysis was used to compare the socio-demographic profile of surveyed farmers and farm characteristics. Before multivariate analysis, the data normality was tested using Levene's test. To achieve normality and homogeneity of variances, data were log-transformed ($\log(x + 1)$). The transformed data were then subjected to one-way ANOVA analysis to compare farmers' perception of termite severity damage and pest management practices used by farmers between the 6 prospected departments, using the Statistical Package for Social Sciences (IBM SPSS version 23.0). The level of significance was set at 0.05, and means were separated by Student Newman Keuls (SNK) test.

Ordinal regression with a logit link was used to identify factors determining farmers' level of knowledge of maize' termite pests in Southern Benin using StataMP 13 software. For that, the categorised farmers' knowledge of maize' termite pests were used as dependant variables, and the socio-demographic profile of the surveyed farmers and their farm characteristics were used as

explanatory variables. Similarly, the relationship between the damage severity of termite attacks on maize and the socio-demographic profile of the surveyed farmers and their farm characteristics was evaluated using an ordered probit regression model. However, for a simpler interpretation of results, marginal probabilities were estimated (Greene 2003; Midega et al. 2012).

3 Results

3.1 Household and farm characteristics

Most of the surveyed households were headed by male (86%) (Table 2). There was a significant difference between the surveyed departments in terms of the number of surveyed female household head. Indeed, the Mono Department had presented the high number of surveyed female household head (27.9%) while the Plateau Department the lowest (8.9%). A great majority of household heads were found to be illiterate (64%), while only 18.4% and 14.3% were found to have primary and secondary levels of education, respectively. The number of farmers with a university level of education varied between departments with a maximum of 7.5% in Couffo and null in Mono and Plateau (Table 2). The age of the surveyed household heads ranged from 18 to 78 years with an average of 46 years. The marital status of the surveyed household heads varied significantly across the departments with a great majority of monogamous (51.3%). The surveyed households had large families ranging from 1 to 30 individuals. Significant differences in household sizes were observed across departments, with average household sizes ranging from 6 individuals in the Mono Department to 8 in the Plateau Department (Table 2). The surveyed household heads were small holders with farm sizes averaging 3.5 ha and had in general several years of experience in maize production (an average of 23 years). These averages farm sizes significantly varied across departments (Table 2). Maize production in the study area is very little intended for consumption (12%), but both consumption and sale (78.3%).

3.2 Farmers' knowledge of maize' termite pests

In the study area, 18 crops were listed by farmers, as most attacked by termite pests (Table 3). In the Zou, Plateau and Atlantique departments respectively, 12 crops have been listed as the most attacked by termites, while only 3

crops have been listed in the Ouémé Department (Table 3). Maize was ranked by the surveyed farmers (46.4%) as the main crop attacked by termites, and this belief was found to be constant throughout all the prospected departments. Farmers identified groundnut as the second crop most attacked crop by termites in Zou (15.2%), Couffo (15.3%) and Ouémé (22.4%) departments while in Mono (11.6%), Plateau (16.2%) and Atlantique (15.9%) departments, it was cassava (Table 3). Beans were also ranked by farmers as the second most (22.4%) attacked crop by termites in the Ouémé Department.

The majority of the surveyed farmers (91%) knew at least one species of termites as pests of maize. Most of the farmers (82.1%) mentioned in their local language two species of maize' termite pests, followed by 10.6% of the farmers who listed 1 species and only 6.9% who identified three species. Very few farmers (0.4%) were able to identify four maize' termite pest species. No significant difference ($P \geq 0.05$) in terms of the number of termites listed by farmers was observed across the six departments. A total of 43 different names of maize' termite pests corresponding to 8 species were recorded in the study area (Table 4). Seven maize' termite pest species were recorded in the Couffo and the Atlantique departments, 6 species in the Mono, Plateau and Ouémé departments and only 4 species in the Zou Department (Table 4). *Amitermes evuncifer* Silvestri (32.1%), designated by 10 vernacular names, and *Macrotermes bellicosus* Smeathman (30.1%), designated by 9 vernacular names, were the most common maize' termite pests identified by farmers across departments (Table 4) in contrast to *Macrotermes ivorensis* Grasse and Noirot (1.7%), namely Ekon gba (Adja), and *Coptotermes sjostedti* Holmgren (0.2%), namely Kossou assiho (Fon), which were found to be the least cited maize' termite pests.

3.3 Vernacular and folk nomenclature of maize' termite pests

The great majority of names (95.4%) given to maize' termite pest species had a meaning (Table 5). Most of maize' termite pest names correspond to morphological aspect (82.4%) of termites, such as size (70.4%), colour (23.2%), shape of the head (4.7%) and presence of wings (1.7%). Termite caste (14.3%), type of damage caused by termites (2.2%), and gender (1.1%) were also among the criteria used by farmers to name maize' termite pests (Table 5). The folk taxonomy of maize' termite pest has a hierarchical structure with a low level of classification (two hierarchy levels), as found in several sociolinguistic groups (Fon, Adja, Mina, Kotafon, Nagot, Tori and Ayizo)

Table 2: Socio-demographic and farm characteristics of the maize producers in the six-surveyed departments of the southern Benin

Variables	Departments						Average for the region N = 300	X2-test	F-test
	Zou N = 66	Mono N = 43	Couffo N = 40	Plateau N = 56	Ouémé N = 31	Atlantique N = 64			
Gender (%)									
Male	90.9	72.1	80	91.1	87.1	89.1	86	11.150*	
Female	9.1	27.9	20	8.9	12.9	10.9	14		
Education level (%)									
None	59.1	60.5	62.5	75	64.5	62.5	64	29.527*	
Primary	18.2	7	20	19.6	29.1	18.8	18.4		
Secondary	18.2	32.5	10	5.4	3.2	14.0	14.3		
University	4.5	0	7.5	0	3.2	4.7	3.3		
Age (years)									
Average	45.5 ± 1.6	47.7 ± 2.6	46.5 ± 2.1	47.8 ± 1.8	44.7 ± 2.1	45.2 ± 1.6	46.1 ± 0.8	0.235ns	
Range	25-72	18-78	18-70	25-75	20-62	18-73	18-78		
Marital status (%)									
Single	4.6	16.3	2.5	1.8	0	1.6	4.3	28.073**	
Monogamous	43.9	46.5	42.5	50	74.2	57.8	51.3		
Polygamous	51.5	37.2	55	48.2	25.8	40.6	44.4		
Household size (number)									
Average	7.9 ± 0.5	5.9 ± 0.7	7.3 ± 0.8	8 ± 0.7	7.6 ± 1.1	7.7 ± 0.6	7.5 ± 0.3	2.376*	
Range	1-19	1-20	1-20	1-30	1-22	1-27	1-30		
Experience (years)									
Average	22.1 ± 1.4	23.7 ± 2.1	24.8 ± 1.8	24.1 ± 1.8	18.8 ± 1.5	21.7 ± 1.6	22.9 ± 0.7	0.873ns	
Range	3-54	3-52	2-52	3-56	3-34	2-56	2-56		
Farm size (hectare)									
Average	3.6 ± 0.3	4.4 ± 0.6	4.2 ± 0.6	1.9 ± 0.2	2.5 ± 0.2	3.9 ± 0.5	3.5 ± 0.2	5.703***	
Range	0.8-15	0.8-14	0.8-16	0.5-10	0.8-7	0.5-20	0.5-20		
Purpose of production (%)									
Consumption	1.5	11.6	27.5	3.6	16.1	18.8	12	29.276**	
Sale	9.1	16.3	15	7.1	6.45	6.2	9.7		
Consumption and sale	89.4	72.1	57.5	89.3	77.4	75	78.3		

Statistically significant at *P < 0.05, **P < 0.01, ***P < 0.001; ns = not significant. Means within a row followed by different letters are significantly different at P < 0.05 (Student Newman Keuls test). N = Number of surveyed maize producers.

of the study area. For example, in the Fon sociolinguistic group, the generic name of termites Kossou is subdivided into 7 infra-specific termite taxa (Kossou kpèvi, Kossou winiwin, Kossou kossihoi, Kossou wéwé, Kossou assiho, Kossou abgotra and Kossou vovo). Whereas in the Mina sociolinguistic group, the generic name Baba were subdivided in only 2 infra-specific termite taxa (Baba tagan and Baba vi). Farmers' identification of maize' termite pests was based on 6 criteria related to their morphological fea-

tures (83.3%) and damage (16.7%). Termite size (70.5%), colour (23.1%), shape of the body (4.5%), shape of head (1.2%) and presence of wings (0.7%) were the morphological features used by farmers to classify maize' termite pests.

Table 3: Farmers perceptions of crop most attacked by termites in southern Benin

Variables	Departments						Average for the region N = 300
	Zou N = 66	Mono N = 43	Couffo N = 40	Plateau N = 56	Ouémé N = 31	Atlantique N = 64	
Maize	47.1	45.3	36.1	53.4	51.7	47.6	46.4
Groundnut	15.2	8.4	15.3	4.8	22.4	3.9	10.9
Cassava	5.8	11.6	5.4	16.2	-	15.9	9.8
Beans	8	10.5	14.4	5.7	22.4	3.1	9.5
Cowpea	14.5	3.2	6.3	-	-	1.6	5.1
Pepper	1.5	3.2	5.4	7.6	-	7.2	4.4
Tomato	0.7	10.5	2.7	0.9	-	8.7	4.1
Okra	-	6.3	9.9	-	-	-	2.7
Sweetpotato	0.7	-	2.7	0.9	3.5	1.6	1.4
Soybean	2.9	1.0	1.8	0.9	-	-	1.2
Sugarcane	-	-	-	0.9	-	4.8	1.1
Pineapple	0.7	-	-	-	-	4	0.9
Yams	0.7	-	-	2.9	-	-	0.6
Cotton	2.2	-	-	-	-	-	0.5
Sesame	-	-	-	2.9	-	-	0.5
Cashew	-	-	-	2.9	-	-	0.5
Pigeon pea	-	-	-	-	-	0.8	0.2
Watermelon	-	-	-	-	-	0.8	0.2

N = Number of surveyed maize producers.

3.4 Factors determining farmers' knowledge on maize' termite pests

The model of ordinal regression of factors determining farmers' knowledge of maize' termite pests was statistically significant ($\text{Prob} > \chi^2 = 0.000$). The results in Table 6 showed that the sociodemographic parameters of the surveyed farmers and farm characteristics don't have a significant impact on the farmers' knowledge of maize' termite pests. However, the department variables were significant with the results showing the high and low knowledge of maize' termite pests by farmers belonging to the Plateau (coefficient = 1.089) and the Ouémé (coefficient = -2.153) departments compared to those belonging to the Atlantique Department, which was used as a reference variable. These tendencies were confirmed by the marginal effects which showed that farmers of the Plateau Department were less likely to have low and medium knowledge of maize' termite pests in contrast to farmers of the Ouémé Department.

3.5 Farmers' perception of maize' termite pest damages

Most of the farmers perceived that termites are more damageable in maize fields (84.3%) than in storage (15.7%). Termites' damage in maize fields was considered by a majority of the surveyed farmers (49.3%) as most critical during the maturation stage, and only 3.2% estimated that it is during the flowering stage (Figure 2). The maize maturation stage was also considered by most of the surveyed farmers (47.4%) as the maize development stage coinciding with high termite pest abundance, followed by vegetative crop stages (27.6%). No significant difference ($P \geq 0.05$) was observed between the six departments in terms of perception of termite abundance and damage critical according to the maize development stages. Farmers attributed four types of damages in maize to termite attacks: defoliation of seedlings (19.6% of the responses), cutting of roots during all maize stages (38.1% of the responses), cutting of the stem just above ground levels (36.9% of the responses) and seed consumption

Table 4: Maize pestiferous termite's species identified by farmers in southern Benin (N = 273)

Species of termites Vernacular name and corresponding sociolin- guistic groups	Scientific name	Percentage of responses by department						Average for the region
		Zou	Mono	Couffo	Plateau	Ouémé	Atlantique	
Baba tagan (Watchi, Mina), Ekon vi (Adja), Etoutou fougou (Nagot), Kokossou kpèvi (Fon), Kossou kpèvi (Fon), Kor kpé agbodri (Ayizo), Kossou winiwini (Fon), Kossou adjowé (Tori, Sahoué), Kossou kossihoin (Fon), Okor wéwé (Cotafon, Ayizo)	Amitermes evuncifer	48	13.3	32.5	26.6	5.9	40.1	32.1
Ekon ava (Adja), Etoutou elérilila (Nagot), Etoutou lakou (Nagot), Kossou agbotra (Fon), Tatawin (Sahoué), Kor flékoflé (Cotafon), Kor kpé daho (Ayizo), Kossifan (Ouémégbé), Konfli (Adja)	Macrotermes bellicosus	37.8	25.3	8.8	22	61.8	38.3	30.1
Cordou cordou (Ouémégbé), Ekon gagaton (Adja), Kossou baba (Tori, Adja), Okor fofu (Ayizo), Atchochrin (Cotafon), Kor daho (Cotafon), Baba gbagoue (Mina, Watchi), Etoutou ogan (Nagot)	Macrotermes subhyalanus	-	18.7	20	15.5	5.9	6.5	10.5
Baba vi (Watchi, Mina), Ekon kloklotu (Adja), Iyokin (Nagot), Kor adjala (Cotafon), Kor kpé kpèvi (Ayizo), Akpikpi (Tori)	Trinervitermes geminatus	-	25.3	11.2	14.8	5.9	8.4	10.3
Ekon houéhouéto (Adja), Etoutou kpikpa (Nagot), Kokossou Mèho (Fon, Ayizo), Kossou vovo (Fon, Tori)	Trinervitermes oeconomus	12.6	2.7	12.5	12.8	2.9	2.9	8.7
Etoutou wèwè (Nagot), Gbinkouhin (Sahoué), Ekon kpokpi (Adja), Kossou wéwé (Fon, Tori)	Ancistrotermes cavithorax	1.6	14.7	3.8	8.3	17.6	2.9	6.4
Ekon gba (Adja)	Macrotermes ivorensis	-	-	11.2	-	-	-	1.7
Kossou assiho (Fon)	Coptotermes sjostedti	-	-	-	-	-	0.9	0.2

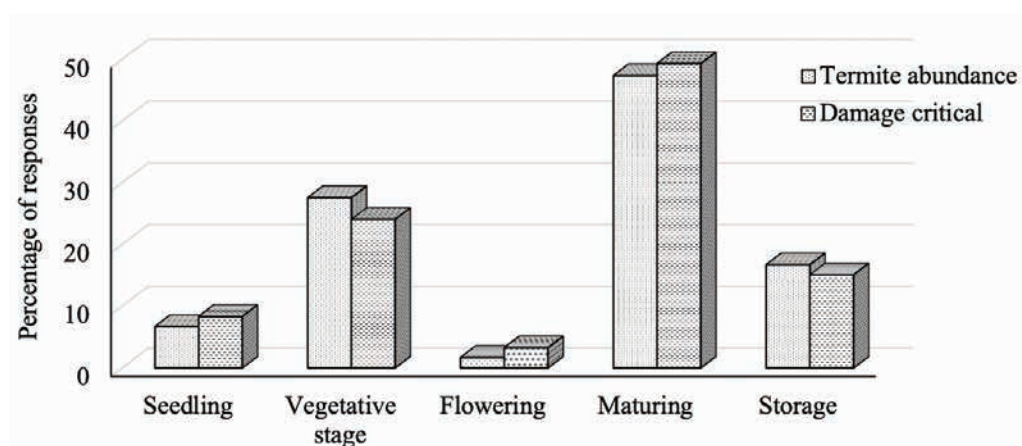
**Figure 2:** Farmers' perception of termite abundance and damage in relation to maize development stage as evaluated by surveyed farmers (N = 300)

Table 5: Meaning of termites vernacular names across study area (N =273)

Criteria of denomination	Percentage of responses	Vernacular names	Meaning of the vernacular name
Morphological aspects (colour, size, shape of head, and presence of wings)	82.4	Atchochrin, Baba gbagoue, Ekon gba, Ekon klokloto, Ekon Ava, Cordou cordou, Etoutou Lakou, Kor kpédaho, Kossifan, Kor daho	Big termite
		Kor kpé kpèvi, Ekon houéhouéto, Ekon kpokpi, Kossou kpèvi, Kossou winiwini	Small termite
		Etoutou pkipka, Ikan kpika, Kossou vovo	Red termite
		Kossou wéwé, Okor wéwé, Etoutou wèwè, Etoutou fougou, Ikan fougou	White termite
		Kossou Adjowé, lyokin	Small white termite
		Akpikpi, Kokossou mèho	Small red termite
		Ekon gagaton, Kossou abgotra, Kossou baba	Termite having a large head
		Etoutou elérilila	Termite having a large red head
		Kor flékoflé, Konfli	Termites with wings
		Okor fofo	Big brother termites
Termites caste	14.3	Baba vi, Ekon vi	Son of termites
		Baba tagan, Etoutou ogan	King of termites
		Gbinkouhin	King of the soil
Damage	2.2	Tatawin	Destroyer of cultures
Gender	1.1	Kor kpe agbodri	Female termite

during storage (8.4% of the responses). Most maize producers (52.5%) believed that termite attacks contributed to 25% of yield losses. Contrarily, some surveyed farmers (42.1%) estimated that the losses could reach up to 50%, and only 5.4% of the maize producers perceived that the losses could reach 75%. This trend has been observed across departments (Figure 3).

Among the eight termite species identified by farmers as pests of maize, *A. evuncifer* was perceived as the most damaging to maize during vegetative and maturation stages (Table 7) while *M. bellicosus* was perceived by farmers as most damaging during the seedling and flowering maize stages. *Trinervitermes geminatus* and *T. oeconomus* were also considered by some farmers as pests causing high damage to maize during vegetative stages. Contrarily, *C. sjostedti* was perceived by only one farmer as the pest causing high damage to maize during vegetative and maturation stages.

Erratic rainfall (76.5% of the responses) were perceived by maize producers as the most important factor

favouring termites' infestation in maize fields. The high soil humidity (15.7%) was also identified by farmers as an important factor of termites' proliferation in maize fields. However, a few maize producers revealed that the badly maintained fields (4.5%), maize maturity (3%) and the corpse of an animal (0.3%) served as factors favouring proliferation of termite pests in maize fields.

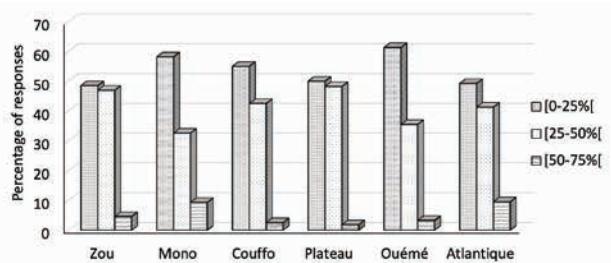
**Figure 3:** Farmers' perception of percentage of maize yield loss due to termite attacks

Table 6: Determinants of famers' level of knowledge of maize termite pests in southern Benin (N = 300)

Variables	Coefficient	Marginal effects ^a					
		Low knowledge		Medium knowledge		High knowledge	
		Coef.	Std. err.	dy/dx	Std. err.	dy/dx	Std. err.
Gender (0 = Female, 1 = Male)	0.203		0.448	-0.044	0.073	-0.013	0.021
bNo education (0 = No, 1 = Yes)	-1.222		0.802	0.214	0.143	0.062	0.043
Primary education level (0 = No, 1 = Yes)	-0.538		0.834	0.085	0.149	0.024	0.043
Secondary education level (0 = No, 1 = Yes)	-0.957		0.876	0.139	0.154	0.040	0.045
Age (years)	0.050		0.025	-0.008	0.004	-0.002	0.001
Family size (years)	-0.064		0.356	0.010	0.005	0.003	0.001
Farming experience (years)	-0.028		0.027	0.004	0.004	0.001	0.001
Land size (hectares)	0.038		0.061	-0.005	0.103	-0.001	0.003
cSingle (0 = No, 1 = Yes)	-0.085		0.796	0.136	0.141	0.040	0.042
Monogamous (0 = No, 1 = Yes)	0.628		0.360	0.118	0.600	0.034	0.018
dConsumption (0 = No, 1 = Yes)	-0.934		0.479	0.144	0.809	0.042	0.237
Sale (0 = No, 1 = Yes)	-0.314		0.599	0.059	0.100	0.017	0.029
eZou (0 = No, 1 = Yes)	0.298		0.463	-0.047	0.076	-0.013	0.022
Mono (0 = No, 1 = Yes)	0.736		0.552	-0.133	0.086	-0.039	0.026
Couffo (0 = No, 1 = Yes)	0.935		0.533	-0.165	0.883	-0.048	0.026
Plateau (0 = No, 1 = Yes)	1.089		0.518*	-0.175*	0.080	-0.051*	0.026
Ouémé (0 = No, 1 = Yes)	-2.153		0.462***	0.370***	0.093	0.108***	0.025
f/cut1	-2.161		1.059				
/cut2	-1.094		1.045				
/cut3	3.884		1.087				

LR $\chi^2(17) = 81.66$, Prob > $\chi^2 = 0.000$, Pseudo $R^2 = 0.1601$, Coef.: coefficient, Std. Err.: Standard Error. Statistically significant at * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

^aFor comparison purposes, "No knowledge" option was used as the base category. ^bUniversity education used as reference variable. ^cPolygamous marital status used as reference variable. ^dConsumption and sale purpose of maize production used as reference variable. ^eAtlantique department used as reference variable.

^f/cut1, /cut2 and /cut3 are cut-off points in the ordered probit analysis confirming the variables were ordered.

Table 7: Farmers perception of levels of damage caused by different termites species at different development stage of maize and storage (N = 300)

Termite species	Perceived level of damage										Total responses	
	Seedling		Vegetative stage		Flowering		Maturity		Storage			
	High	Low	High	Low	High	Low	High	Low	High	Low	Number	Percentage
Amitermes evuncifer	32	18	79	78	30	22	81	79	8	4	431	29.8
Macrotermes bellicosus	37	36	76	72	37	36	78	81	9	8	470	32.5
Macrotermes subhyalanus	9	10	17	28	9	10	17	27	6	2	135	9.3
Trinervitermes geminatus	12	12	24	31	13	11	21	29	4	8	165	11.4
Trinervitermes oeconomus	15	9	24	20	22	19	15	9	6	1	140	9.7
Ancistrotermes cavithorax	5	3	18	15	5	4	18	15	5	2	90	6.2
Macrotermes ivorensis	-	1	2	7	-	3	-	1	-	1	15	1.0
Coptotermes sjostedti	-	-	1	-	-	-	1	-	-	-	2	0.1
Total	110	89	241	251	116	105	231	241	38	26	1448	100

N = Number of surveyed maize producers.

3.6 Factors determining farmers' perception of termite' damage severity on maize

The model of ordinal regression of factors determining farmers' perception of termite' damage severity on maize was statistically significant (Prob > chi-squared = 0.016). The results showed that only the department variables had a significant impact on farmers' perception of termite' damage severity on maize (Table 8). Farmers belonging to the Zou (coefficient = 2.538) and Couffo (coefficient = 1.128) departments had a positive and significant effect on farmers' perception of severe termite' damage on maize. The corresponding significant marginal effects for the Zou department showed that farmers living in this department tend to perceive termite attacks severe compared to those belonging to the Atlantique Department, which was used as a reference variable.

3.7 Farmers' perceptions of maize varieties susceptibility to termite attacks

A total of 31 local maize varieties were evaluated throughout the study area. The great majority of maize producers' focus group (83.3%) notified that all the maize varieties cultivated in their villages were susceptible to termite attacks. No variety was registered as resistant to termite attacks in the surveyed villages in the Atlantique, Mono, and Couffo departments. Throughout the study zone, only five local maize varieties, of which 2 belonged to the

Plateau Department (Elèkpèrè (Oko-Akare village) and Igbado tchakpa (Kparouke village)), 2 in the Zou Department (Forkui (Atchia village) and Agbadé kouin winiwini (Monsourou village)), and 1 to the Ouémé Department (Korga (Zoundji village)), were registered by farmers as resistant to termite attacks.

3.8 Maize' termite pest management

The majority of farmers (90.9%) confirmed utilising at least one method to control maize' termite pests in the study area. Termite management methods used by maize farmers included chemical (44.8% of the responses), physical (28.7%), botanical (10.6%) and cultural (1.9%) control methods. Excluding cultural method, the remaining methods used by farmers to protect maize against termites varied significantly across the prospected departments (Table 9). The chemical insecticides were the most used in the Ouémé Department (65.8% of the responses), while botanical (20.9%) and physical (40.4%) methods were the most used in the Mono and Plateau departments, respectively. The results showed that the use of chemical insecticides was the main cited method of controlling maize' termite pests through prospected departments the chi-square test showed that there is no difference between male and female maize producers regarding the function of the type of the control method used against termite pests. However, the use of the botanical method was sig-

Table 8: Determinants of farmers' perception on damage severity of maize' termite pests of southern Benin (N = 300)

Variables	Coefficient		Marginal effects ^a			
	Coef.	Std. err.	Not severe	Severe	Very severe	
			Std. err.	Std. err.	Std. err.	dy/dx Std. err.
Gender (0 = Female, 1 = Male)	0.423	0.317	-0.074	0.056	0.049	-0.060 0.044
^b No education (0 = No, 1 = Yes)	-0.595	0.652	0.105	0.115	0.102	0.085 0.092
Primary education level (0 = No, 1 = Yes)	-0.088	0.677	0.015	0.119	0.106	0.013 0.096
Secondary education level (0 = No, 1 = Yes)	0.239	0.687	-0.042	0.121	0.108	-0.037 0.098
Age (years)	0.070	0.036	-0.125	0.006	0.005	-0.011 0.005
Family size (years)	0.022	0.025	-0.003	0.004	0.004	-0.003 0.003
Farming experience (years)	-0.016	0.020	0.002	0.003	0.003	0.002 0.002
Land size (hectares)	-0.044	0.039	0.007	0.007	0.006	0.006 0.005
^c Single (0 = No, 1 = Yes)	-0.399	0.608	0.070	0.107	0.095	0.062 0.086
Monogamous (0 = No, 1 = Yes)	-0.164	0.257	0.029	0.045	0.040	0.025 0.036
^d Consumption (0 = No, 1 = Yes)	-0.597	0.345	0.105	0.061	0.053	0.093 0.047
Sale (0 = No, 1 = Yes)	-0.288	0.431	0.050	0.076	0.067	0.045 0.061
^e Zou (0 = No, 1 = Yes)	2.538	1.151*	-0.448**	0.204	0.175	-0.398* 0.168
Mono (0 = No, 1 = Yes)	1.126	0.645	-0.198	0.115	0.098	-0.176 0.092
Couffo (0 = No, 1 = Yes)	1.128	0.524*	-0.199*	0.093	0.081	-0.177* 0.075
Plateau (0 = No, 1 = Yes)	1.275	0.868	-0.225	0.154	0.134	-0.200 0.126
Ouémé (0 = No, 1 = Yes)	1.344	0.760	-0.237	0.134	0.117	-0.211 0.109
^f /cut1	2.661	2.176				
/cut2	4.350	2.188				
/cut3	6.139	2.203				

LR χ^2 (17) = 22.49, Prob > χ^2 = 0.016, Pseudo R^2 = 0.0287 Coef.: coefficient, Std. Err.: Standard Error. Statistically significant at *P < 0.05, **P < 0.01, ***P < 0.001.

^a For comparison purposes, "No knowledge" option was used as the base category. ^b University education used as reference variable. ^c Polygamous marital status used as reference variable. ^d Consumption and sale purpose of maize production used as reference variable. ^e Atlantique department used as reference variable.

^f /cut1, /cut2 and /cut3 are cut-off points in the ordered probit analysis confirming the variables were ordered.

Table 9: Farmers termite pest management methods across departments, gender and education level in southern Benin (N = 300)

Control methods	Departments (Percentage of responses)								Gender				Education level			
	Zou	Mono	Couffo	Plateau	Ouémé	Atlantique	Mean	X ²	Male	Female	X ²	No	Pr	Se	Un	X ²
Chemical	47.1	37.3	48.2	44.2	65.8	38.3	44.8	14.2**	45.2	42.6	1.14ns	45.6	44.9	41.1	47.1	1.37ns
Cultural	3.9	1.5	-	0.9	2.6	2.2	1.9	3.7ns	2.2	-	1.51ns	2	2.5	1.4	-	0.46ns
Botanical	12.8	20.9	7.1	8.7	2.6	10.6	11.1	13.4**	10.7	13.1	0.14ns	10.2	10.3	16.4	5.8	4.46*
Physical	29.4	32.8	39.3	40.4	23.7	28.7	33.1	22.4***	32.7	36.1	-0.33ns	32	35.9	35.6	29.4	1.86ns
No control	6.8	7.5	5.4	5.8	5.3	20.2	9.1	17.3***	9.2	8.2	0.17ns	10.2	6.4	5.5	17.7	4.43ns

Statistically significant level (Chi-square analysis): *significant at 5%; ns: not significant.

No: No education, Pr: Primary; Se: Secondary, Un: University.

nificantly influenced by the educational level of the surveyed farmers.

Ten termite management practices were recorded for termite control in maize fields against nine practices for stock protection (Table 10). The results showed that compared to other departments, maize producers belonging to the Zou Department used most of the termite control methods to protect their maize fields (9 out of 10 recorded methods) and stored maize (8 out of 9 recorded methods). However, farmers in the Couffo and Mono departments were found to only use 3 methods to control termite pests in maize fields and one method to protect stored maize, respectively (Table 10). The use of synthetic insecticides, insecticide and repellent plants, motor oil, petroleum and salt were common for maize protection in fields and storage (Table 10). On the other hand, the use of palm wine, exposure to sun and detergent were the found approaches to protect stored maize against termites in the Ouémé, Atlantique and Plateau departments. Synthetic insecticides were the most used both for maize fields and storage protection as well as those across the 6 prospected departments (Table 10). The systematically destruction of termite mounds in and around maize fields was performed by many farmers (35.7%) in all prospected departments (Table 10). The majority of them destroyed large termite mounds (79.4%), and only 20.6% destroyed small termite mounds under construction. The majority of the maize producers who did not destroy termite mounds in their fields justified this by the fact that it's useless because termites are in the ground (82.9%), or termites quickly rebuild destroyed termite mounds (10%), or again they avoid the rapid multiplication of termites (7.1%). The use of repellent plants, such as cotton seed oils (6.9%) and hot botanical extract of neem leaves (93.1%), to control maize termite pests in fields was performed by many farmers (11.9%) through the six prospected departments (Table 10). However, neem leaves were the only plant powder used by the farmers to protect stored maize. The only cultural method used to control maize' termite pests was crop rotation practiced by few farmers in the Zou (4%), Mono (1.6%), Plateau (1%) and Atlantique (2.6%) departments. Motor oil and salt were used by some farmers in the Zou, Ouémé and Atlantique department for maize' termite pest control. The use of wood ash and petroleum was only registered in the Zou Department. Similarly, the use of hot water to control termite pests in maize fields was only found in the Atlantique Department.

In the study area, 20 different commercial pesticides corresponding to 15 active ingredients were used by farmers to control maize' termite pests both in the field and during storage (Table 11). Among these pesticides,

Table 10 : Farmers management practices for the control of maize termite pests in southern Benin

Maize	Management practices	Percentage of responses by departement						Mean
		Zou	Mono	Couffo	Plateau	Ouémé	Atlantique	
Fields (N = 283)	Synthetic insecticides	42.4	40.3	50.9	46.9	50.1	38.9	44.3
	Destruction of termite mounds	30.3	35.5	41.5	42.9	23.7	35.1	35.7
	Repellent plants	13.1	22.6	7.6	9.2	2.6	13	11.9
	Motor oil	2	-	-	-	18.4	7.8	3.5
	Petroleum	3.1	-	-	-	2.6	-	0.9
	Salt	3.1	-	-	-	2.6	1.3	1.2
	Wood ash	1.0	-	-	-	-	-	0.2
	Crop rotation	4.0	1.6	-	1.0	-	2.6	1.9
	Gazoil	10	-	-	-	-	-	0.2
	Hot water	-	-	-	-	-	1.3	0.2
Storage (N = 78)	Synthetic insecticides	43.5	100	60	21.4	43.8	28.6	42
	Plant powder	4.5	-	5.0	42.9	-	21.5	12.5
	Wood ash	17.4	-	25	7.1	-	7.1	12.5
	Palm wine	17.4	-	-	-	31.2	-	10.3
	Motor oil	4.3	-	10	21.5	12.5	-	9.1
	Exposure of maize to sun	4.3	-	-	-	-	35.7	6.8
	Petroleum	4.3	-	-	-	12.5	-	3.4
	Salt	4.3	-	-	-	-	7.1	2.3
	Detergent	-	-	-	7.1	-	-	1.1

we found 16 insecticides, 2 herbicides and 2 insecticides and acaricides (Table 11). The highest number of commercial pesticides used belonged to the Zou Department (12), followed by the Plateau and Atlantique (8 respectively), Mono and Ouémé (7 respectively) and Couffo (4) departments. Most of the active ingredients mentioned were organophosphates (50%), 41.4% pyrethroids, 8.3% carbamates and 2.8% avermetin and aryloxyacid, respectively. The insecticides with commercial name Lambda Super 2.5 EC (24.4% of the responses) and Termicot (13.3% of the responses) were the most used by the surveyed farmers trough study area to control maize' termite pests. However, Sniper 1000EC DDVP and Magic force were the most commercial pesticides used by farmers to control maize' termite pests in the Mono and Ouémé depart-

ments, respectively (Table 11). The most active ingredient commonly used by the maize producers was lambda-cyhalothrin (24%), followed by chloropyrphos, cyfluthrin, cypermethrin dichlorvos and dimethoate with 8% of the responses, respectively. The rest of the active ingredients represent 4% of the pesticides used (Table11). Four insecticides cited by farmers in the study area have active ingredients that have been listed as highly hazardous (class Ib) by the World Health Organisation (WHO, 2005) (Table 11).

Table 11: Pesticides used by maize producers of southern Benin to fight against termite pests (N = 205)

Commercial name	Active ingredient	Chemical class ^a	Toxicological class ^b	Main use ^c	Used by farmers in each department (% of farmers)						Average for the region
					Zou (N = 45)	Mono (N = 29)	Couffo (N = 27)	Plateau (N = 46)	Ouémé (N = 23)	Atlantique (N = 35)	
Lambda Super 2.5 EC	Lambda-Cyhalothrin	Pyr	II	Ins	13.7	10.3	57.2	42.6	-	23.7	24.4
Termicot	Chlorpyrifos	OP	II	Ins	21.6	24.1	-	4.3	15.1	13.2	13.3
Acarius 018 EC	Abamectin	Ave	Not listed	Ins/Aca	15.7	-	-	2.1	30.2	10.5	10.2
Magic force	Lambda-Cyhalothrin + Dimethoate	Pyr + OP	II	Ins/Aca	9.8	-	-	2.1	42.3	7.9	10.2
Pacha 25 EC	Acetamiprid + Lambda-Cyhalothrin	Pyr	II	Ins	-	-	-	25.5	-	10.5	7.1
Sniper 1000EC DDVP	Dichlorvos	OP	Ib	Ins	-	44.8	7.1	-	-	-	6.7
Calife 500 EC	Profenofos	OP	II	Ins	13.7	3.5	10.7	4.3	3.1	-	6.3
Lambdacal P 630 EC	Lambda-Cyhalothrin	Pyr + OP	II	Ins	6	13.8	25	-	-	-	6.3
Lamicom 2.5 EC	Lambda-Cyhalothrin	Pyr	II	Ins	-	-	-	17	-	-	3.7
Kinikini	Cyfluthrin + Malathion	Pyr + OP	Ib	Ins	1.9	-	-	-	-	18.4	3.7
Sumithion 1000 EC	Fenitrothion	OP	II	Ins	-	-	-	-	-	10.5	1.8
DD force 1000 EC	Dichlorvos	OP	Ib	Ins	1.9	-	-	-	-	5.3	1.3
New action	Cypermethrin	Pyr	II	Ins	6	-	-	-	-	-	1.3
Sofagrain	Deltamethrin + Pirimiphos-methyl	Pyr + OP	II	Ins	3.9	-	-	-	3.1	-	1.3
Kalach Extra 70 SG	Glyphosate	OP	III	Her	1.9	-	-	-	-	-	0.4
Cychlo 318 EC	Cyfluthrin + Chlorpyrifos	Pyr + OP	Ib + II	Ins	3.9	-	-	-	-	-	0.4
Cymetox super	Cypermethrin + Dimethoate	Pyr + OP	II	Ins	-	-	-	-	3.1	-	0.4
Herbextra 720 SL	2,4-D Dimethylamine salt	Ary	II	Her	-	-	-	-	3.1	-	0.4
Lara Force	Lambda-Cyhalothrin	Pyr	II	Ins	-	3.5	-	-	-	-	0.4
Sunprifos 48% EC	Chlorpyrifos-Ethyl	OP	II	Ins	-	-	-	2.1	-	-	0.4

^a Pyr = Pyrethroid; Ave = Avermetin; OP = Organophosphate; Ary = Aryloxyacid. ^b Ib = highly hazardous; II = moderately hazardous (WHO, 2005). ^c Ins = Insecticide; Aca = Acaricide; Her = Herbicide.

3.9 Farmers' perception of constraints of maize' termite management

Six constraints related to the control of maize' termite pest were recorded throughout the study area. Among them, the lack of specific insecticides targeting termite pests (69.4% of the responses) was the most important followed by the inefficiency of available chemical insecticides (25.8%) and the high cost of chemical insecticides (3% of the responses). The other constraints with a very low importance included the high multiplication rate of termites (0.6%), the toxicity of the treated maize with chemical insecticides (0.6%) and the lack of resistant varieties (0.6%).

4 Discussion

The results showed that among the 18 crops perceived by the surveyed farmers as the most attacked by termite pests, maize and groundnut were the most cited. A literature review showed that the surveyed farmers in this study have a good perception of the crops susceptible to termite attacks (Sands 1973; Nyeko and Olubayo 2005; Sileshi *et al.* 2009; Orikiriza *et al.* 2012). Indeed, maize is known to be very susceptible to termite attacks (Sekamatte *et al.* 2001; Riekert and Van den Berg 2003; Sileshi *et al.* 2005; Sileshi *et al.* 2008; Faragalla and Al Qhtani 2013; Paul *et al.* 2018). Similarly, some scientific papers revealed the susceptibility of groundnut to termite attacks (Logan *et al.* 1992; Abudulai *et al.* 2007). Moreover, maize and groundnut were also rated as highly susceptible to termite attacks in Zambia (Sileshi *et al.* 2008) and Uganda (Nyeko and Olubayo 2005). However, Sekamatte *et al.* (2003) demonstrated that intercropping between maize and groundnut was effective in the suppression of termite attacks by increasing the predatory activity of ants. Knowing this, the maize-legume intercropping system is recommended for a reduction of the termite damage (Sekamatte *et al.* 2003). It is also important to evaluate the effect of intercropping maize with cowpea, pigeon pea and sesame regarding the severity of termite attacks.

Most of the surveyed farmers were able to identify in local language at least one maize' termite pest. This ability to recognise maize' termite pests was also found in farmers in Uganda (Nyeko and Olubayo 2005; Mugerwa *et al.* 2011), Nigeria (Ogedegbe and Ogwu 2015), and Zambia and Malawi (Sileshi *et al.* 2008). However, very few farmers were able to identify the four maize' termite pests, showing that indigenous taxonomy skills are limited to a

few farmers; such is the case of farmers from the Tororo district in Uganda (Nyeko and Olubayo 2005). For a better control of termite pests, it is also important to elaborate an action plan for the propagation of these important indigenous knowledge.

Vernacular and folk nomenclature of maize' termite pests were majority based on the morphological aspects of termite pests. These characteristics were also used by the farmers in Uganda (Nyeko and Olubayo 2005; Sekamatte and Okwakol 2007; Mugerwa *et al.* 2011) and farmers in northwest Benin (Loko *et al.* 2017) to identify and classify termite pests. Knowing this, pest identification and recognition is crucial for a successful pest management program (Abteu *et al.* 2016). It is important to vulgarise the criteria used by maize producers to identify and classify termites to extension agents and to researchers in order to facilitate communication in the framework of the implementation of the integrated termite management programs. Moreover, a compilation of the 43 different names of maize' termite pests and corresponding 8 species recorded in the study area must be known by researchers and extension workers for better communication with farmers on a particular termite pest.

The eight termite species identified by farmers as maize pest are well known as the pests of several crops. In fact, these termite pests were also listed as the pests of maize (Wood *et al.* 1980; Umeh and Ivbijaro 1997; Debelo and Degaga 2014), yams (Loko *et al.* 2017) and rice (Akpesse *et al.* 2008). *Amitermes evuncifer* and *Macrotermes bellicosus* were perceived by farmers as the most damageable to maize. This perception is in line with result of Umeh and Ivbijaro (1997) who found that *Macrotermes* species inflicted maximum damage on maize crops. Similarly, Akpesse *et al.* (2008) found that *A. evuncifer* is responsible for maximum damage to the maize crop. However, some termite species, such as *Odontotermes* sp., *Reticulitermes* sp. and *Cubitermes sankurensis*, not listed by farmers in this study were the most abundant termites in maize fields in Burkina Faso (Ouédrago *et al.* 2015). It is also important to evaluate the diversity and abundance of the termites in the maize fields in Southern Benin to confirm or invalidate farmers' knowledge of maize' termite pests in the study area.

Unlike in Uganda (Orikiriza *et al.* 2012), where socio-demographic parameters of farmers, such as gender, age and education level influenced farmers' knowledge of termite pests, the knowledge of maize' termite pests in the study area was not influenced by these parameters. The fact that maize producers in the Ouémé and Plateau departments have significantly more knowledge of termite pests than those living in the Atlantique Department can

be explained by the fact that in both these departments that represent a pole of the agricultural development in Benin, the agricultural extension agents are active in sensitisation programmes about termite knowledge. It is so important to educate farmers belonging to the other prospective departments on the knowledge of maize' termite pests.

Like Kenyan farmers (Midega et al. 2016), maize producers in the study area perceived the damage of termites to be more important in maize fields than storage. The description of termite damages by surveyed the farmers was consistent with the scientific descriptions of the termite damage in maize fields (Sands 1973; van den Berg and Riekert 2003; Akpesse et al. 2008). Maize producers perceived that termites cause the most serious damage during the maturation stage of the maize crop. This perception is corroborated by Wood et al. (1980) who revealed that maize is more susceptible to termite attack at maturity. Surveyed farmers perceived *M. bellicosus* as the most damageable during seedling and flowering maize stages. This is in line with the results of Wood and Cowie (1988) who revealed that species of the genus *Macrotermes* cut maize seedlings just below soil surface, resulting in lodging. Similarly, *A. evuncifer* was ranked as most damaging to maize during the vegetative and maturation stages. This perception is contrary to Wood et al. (1980) who notified that the attack of the maize root system at maturity is rarely conducted by *A. evuncifer*. It is so important to identify the most damaging termite species in maize fields of Southern Benin in order to develop an efficient strategy against the key termite species that will be identified.

The losses estimated (25 to 50%) by the surveyed farmers are important and revealed the necessity to implement effective termite management program in the maize fields of Southern Benin. Like farmers in Central (Loko et al. 2015b) and Northwest Benin (Loko et al. 2017), the farmers in this study recognised several factors that favoured termite pest infestations. Erratic rainfall as the main important factor cited by a great majority of the surveyed farmers showed that they have adequate perception of the factors favouring the proliferation of termite pest in maize fields. In fact, it is known that in areas with erratic rainfall, termites become important maize' termite pests (Wence and Antipas 2018). Similarly, wet soil listed by farmers was observed by Famba et al. (2011) as a condition for intense termites' activities in maize fields.

The ordered regression results revealed that farmers' perception of termite damage severity in maize fields is not influenced by the sociodemographic characteristics of the surveyed farmers. This is contrary to the results of Orikiriza et al. (2012) that showed that age, sex and edu-

cation of the farmers in Uganda influenced their perception of termite damage. The results showed that farmers belonging to the Zou and Couffo departments tend to perceive termite attacks severe compared to those living in the Atlantique Department. To understand this difference in perception of termites' damage severity by surveyed farmers, it is therefore important to evaluate the impact of termites in the maize yields of these departments. Moreover, it is important to characterise the termite damages in maize fields in order to make farmers aware of a better recognition of termite attacks in their fields.

Throughout the study area, the majority of the maize varieties grown by farmers was considered very susceptible to termite attacks. This situation underlines the need to select and vulgarise the maize varieties resistant to termite attacks in Southern Benin. During the focused group discussions, farmers unanimously recognised three local maize varieties as resistant to termite attacks. It is important to test the resistance of these five local varieties to infirm or confirm this farmer's perception. However, these three local maize varieties identified as resistant to termite attacks can serve in breeding programs for the amelioration of the other maize varieties grown in the study area.

Contrary to the yam producers in Central Benin (Loko et al. 2015b), a great majority of the surveyed maize producers in Southern Benin used at least one method to control termites in their fields. As in Uganda (Nyeko and Olubayo 2005; Orikiriza et al. 2012), the use of synthetic insecticides by farmers in the study area was the main method to control termite pests both in maize fields and during storage. The main insecticide used by the surveyed farmers known as Lambda Super 2.5 EC, with lambda-cyhalothrin as an active ingredient, is intended for the protection of horticultural crops against aphids and moths. Su et al. (2004) showed that lambda-cyhalothrin can act as a repellent against termites. However, this synthetic insecticide does not target termites, so their use in the context of termite control is not adequate. It is therefore necessary to sensitise maize producers of Southern Benin on the consequences related to the use of inappropriate chemical insecticides on insect resistance development. Furthermore, a large number of pesticides recorded in the study area and the use of herbicide and acaricides for termite control underscores the need to vulgarise the only termite-specific insecticide found in the study area known as Termicot. It is also important that this research develops effective termiticides and that the plant protection service of Benin homologates new termiticides. Moreover, it is urgent to sensitise the maize producers of Southern Benin on the dangers of the use of synthetic insecticides

known as Sniper 1000EC DDVP, Kinikini, DD force 1000 EC and Cychlo 318 EC with active ingredients listed as highly hazardous (class Ib) by the World Health Organisation (WHO, 2005). According to Ewetola *et al.* (2018), training farmers on the use of integrated termite management is important to reduce the use of chemical insecticides.

The destruction of termite mounds was the second most important method used by farmers in the study area for termite control. However, Sileshi *et al.* (2009) revealed that the termite mounds destruction is inefficient because termite species that do not build mounds are not often targeted. Our results suggest that an integrated termite control strategy in Southern Benin should be based on botanical extracts and crop rotation used by farmers in the study area. Indeed, the use of neem extract to control termite, which is conducted by farmers in Malawi and Zimbabwe (Sileshi *et al.* 2008), has been shown to act as an efficient termiticide (Sileshi *et al.* 2008; Sotannde *et al.* 2011). However, a study should be conducted to evaluate the insecticidal or repellent effects of the cottonseed oil used by the surveyed maize producers on termite pests. Moreover, the effectiveness of palm wine in the control of termites in stored maize should be tested.

Our findings showed that the implementation of an integrated termite management (ITM) program is easier in the Zou Department where farmers used several methods to control termites than those in the Couffo and Mono departments. However, maize producers in the study area considered most of methods as inefficient. Other efficient termite control methods such that the use of protein-based baits (Sekamatte *et al.* 2003), granular formulation of *Metarhizium anisopliae* (Maniania *et al.* 2002) and nematodes (Zadji *et al.* 2014) should be promoted to maize producers through farmers' field schools.

5 Conclusion

Maize producers of Southern Benin have a good knowledge of maize' termite pests. However, this knowledge is restricted to a few producers. The elaboration of an action plan for the propagation of these important termite pest knowledge is important. Moreover, in the framework of the implementation of integrated termite management programs, the vulgarisation of maize' termite pests folk taxonomy and nomenclature to extension agents and researchers is important to facilitate communication. Farmers noted that termite damage cause important losses and identified *A. evuncifer* and *M. subhyalinus* as the most damageable during maturing and seedling maize devel-

opment stages, respectively. Among the strategies used by farmers to reduce termite damage both in maize fields and during storage, the use of synthetic insecticides was the most important. Four synthetic insecticides used by maize producers have an active ingredient listed as highly hazardous (class Ib) by the World Health Organisation underlines the urgent need to make producers aware of the dangers of using these insecticides. The development of alternative methods of termites control such as the use of botanicals is a necessity. Therefore, the use of neem extracts must be promoted, and the efficacy of cotton seed oil should be tested. This study reveals the existence of three local maize varieties perceived as resistant to termite attacks that can be used for research and development. However, the level of the perceived resistance of these varieties must be assessed.

Based on the results of this study, for the establishment of an integrated termite management programs for maize in Southern Benin, we recommend: (i) research on the diversity and abundance of termite pest both in maize fields and storage as well as the determination of economic threshold levels of the keys pests *A. evuncifer* and *M. subhyalinus*; (ii) identification of natural enemies of maize' termite pests in Southern Benin and training farmers on the principles and practices of biological termite control; and (iii) development and assessment of an integrated management package incorporating cultural, botanical and biological control methods.

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