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Specific Diversity and Damage of Termites on Upland Rice in Benin

[1]A. Togola, [2]E.A. Kotoklo, [3]F.E. Nwilene, [2]K. Amevoin, [2]I.A. Glitho, [3]O.E. Oyetunji and [4]P. Kiepe

[1]Africa Rice Center (AfricaRice), 01 B.P. 2031, Cotonou, Benin
[2]Laboratory of Applied Entomology, Faculty of Science, University of Lomé, B.P. 1515, Lomé, Togo
[3]Africa Rice Center (AfricaRice), P.M.B. 5320, Ibadan, Oyo State, Nigeria
[4]Africa Rice Center (AfricaRice), P.O. Box 33581, Dar es Salam, Tanzania

Corresponding Author: Abou Togola, Africa Rice Center (AfricaRice), 01 B.P. 2031, Cotonou, Benin Tel: +229 21 35 01 88

ABSTRACT

Termites are considered useful insects in natural savannah because of their role in soil fertility regulation, soil aeration and soil porosity. However, they are perceived as a serious threat for tropical agriculture. Due to the complexity of their populations and habitats, they cause high losses on dryland crops, especially upland rice. The present study aimed to analyze the specific diversity of termites on rice (*Oryza*) in rainfed upland conditions in Benin and to assess the damage they cause. Sampling was carried out in natural savannah and rice fields with 10 upland varieties to evaluate the population of termites. Specific damage was located on the susceptible organs of rice plants. The study allowed the identification of four termite species in the shrub savannah and six species in rice field. The commonest species on rice were *Microcerotermes parvus*, *Microtermes* sp., *Pseudacanthotermes militaris* and *Amitermes evuncifer*. Termite attack was diverse, but mainly affected roots and stems. The results of this study contributed to the identification of the diversity of termite species on rainfed upland rice and also to the identification of the damage they cause in order to undertake targeted measures against the key species.

Key words: Biodiversity, savannah, upland rice, attack mode, termites

INTRODUCTION

Termites are soil-living arthropods that cause serious losses to most dryland crops, including rainfed upland rice (Wood and Cowie, 1988). They dig underground tunnels with minimum connection to the above-ground environment (Noirot and Darlington, 2000) through which they reach and attack host plants. Since the major constituent of the diet of termites is cellulose, they can cause damage directly in many ways to the host (Femi-Ola *et al.*, 2007; Kumar and Pardeshi, 2011). In Africa, most of the termite species that cause serious damage to crops belong to the subfamily Macrotermitinae (Wood *et al.*, 1980). In the dry and semi-arid tropics, many food and industrial crops and many forest trees are attacked by termites leading to economic losses. In general, the level of damage depends on termite species and population size. It can also depend on the susceptibility of the host plants. Factors such as drought, cellulosic food availability, soil aeration and soil moisture stability increase the proliferation of Isoptera. Also, the presence of biotic and abiotic elements in the ecosystem plays a major role in the abundance and distribution of termites (Bong *et al.*, 2012). Aslam *et al.* (2000) report that the presence of termites in a region depends on the vegetation type. Taking into account this basic knowledge from previous research, the present study investigated the biodiversity of termites in an upland rice ecosystem, including seeking to establish the periods of their occurrence and the level of damage inflicted on rice varieties. Many studies report high levels of damage due to termites on upland rice (Heinrichs and Barrion, 2004; Nwilene *et al.*, 2008; Agunbiade *et al.*, 2009), but the species responsible are not indicated in all cases. Knowledge of termite diversity associated with upland rice and the exact situation concerning their damage will constitute an important base for better control of these pests. Furthermore, information on the occurrence of each species would be crucial for deciding the appropriate period of applying control measures against these insects.

MATERIAL AND METHODS

Site of experiment: The experiment was carried out in Niaouli (Benin), identified as a hot spot for termites. This site is characterized by bimodal rainfall with an average annual of 1200 mm per year. The main rainy season runs from March to July and the short rainy season from September to November. The soil is a ferralitic upland that is sandy in its upper horizon (0-25 cm) and clayey in the lower horizon (25-50 cm). The vegetation type is Guinean humid savannah covered with monocotyledons and dicotyledonous weeds, with some forest trees.

Planting techniques: Ten upland rice varieties - 7 NERICA varieties (1, 2, 3, 4, 6, 7 and 10), one *Oryza glaberrima* (CG14, African parent of the NERICA lines), two *Oryza sativa* (WAB56-104, Asian parent and LAC23, a variety resistant to many biotic stress) were sown at random on individual plots separated from each other by a 2-m alley.

The varieties were sown at a plant spacing of 20×20 cm, and gaps were filled at 7 days after emergence. Three seedlings per hill were kept throughout the experiment. A basal dose of NPK (15-15-15) at a rate of 150 kg ha^{-1} was applied before sowing. A top-dressing of urea (50 kg ha^{-1}) was applied twice during the weeding periods at 21 and 42 Days After Sowing (DAS). The experimental design was a randomized complete block with three replications.

Sampling of population and damage parameters: Termite populations and damage were sampled at three phenological stages of rice: tillering (40 DAS), heading (60 DAS) and maturation (90 DAS). Population sampling was carried out in two environments - (1) the rice field and (2) the surrounding natural savannah-while damage was recorded only in rice plots.

In rice plots, five sampling points 0.5 m apart were chosen following plot diagonals. Holes of 0.25×0.25 m (0.06 m^2) surface area were made between hills. For each new sampling period new holes were dug a few centimeters from the previous sampling points. Damage sampling consisted of harvesting 10 hills within the rice plot. For selected hills, all plant organs were checked to identify termite species and their damage.

The sampling in natural savannah consisted of evaluating the termite populations in the landscape surrounding the experimental field. Sampling holes of 0.25×0.25 m (0.06 m^2) surface area were dug at random in the delimited space at the same time as the field sampling. A distance of 2 m was maintained between holes.

The extracted soils were placed in plastic bags for laboratory investigation, during which termite species were separated and conserved in vials containing 70% alcohol.

Identification of termites species: Termites species were identified in the laboratory using several identification methods (Sands, 1965; Harris, 1968; Pearce *et al.*, 1992).

Data collection and statistical analysis: The specific diversity in both rice field and natural savannah was calculated from the diversity index formula established by Simpson (1949):

$$D = \frac{\sum_{i=1}^{S} n_i (n_i - 1)}{N(N-1)}$$

where, S represents the number of termite species (species richness), N represents the total population and n represents the total number of individuals per species.

This index is negatively correlated with the diversity, i.e. diversity is higher when D = 0 and lower when D = 1. From this formula we can calculate the Derived Index of Simpson (Es) as:

$$Es = 1\text{-}D$$

Mean termite population per plot was analyzed by analysis of variance (ANOVA) with SAS statistical software 8.2 (SAS Institute, 2002). Significant differences between termite populations were compared by the Student Newman-Keuls (SNK) test at 5% probability level.

RESULTS

Six termite species were identified namely: *Microtermes* sp., *Microcerotermes parvus* Haviland, 1898; *Pseudacanthotermes militaris* Hagen, 1858; *Amitermes evuncifer* Silvestri, 1912; *Trinervitermes oeconomus* Trägardh, 1904 and *Macrotermes bellicosus* Smeathman, 1781. These species belong to the family of Termitidae and the subfamilies Macrotermitinae, Termitinae and Nasutitermitinae (Table 1).

Specific diversity and abundance of termites: The abundance and diversity of termite species varied across infested environments and according to phonological stage of rice.

Six termite species were recorded in the rice field, while four species were found in the natural savannah (Table 2). The termite population was also denser in the rice field than in the natural savannah. In rice, six species of termite were observed at tillering and heading stages, while five species were inventoried at maturity. The specific diversity was greater at heading stage (D = 0.23; Es = 0.77) than at tillering (D = 0.31; Es = 0.69) and maturity stages (D = 0.34; Es = 0.66) (Table 3).

At tillering stage six termite species were present on rice. While NERICA 10 and NERICA 6 had the highest specific richness of termites (5 species), population densities on these varieties were moderately low (3.8 and 7.9 individuals per sampling hole, respectively). The lowest specific

Table 1: Termite species found in upland ecology at Niaouli, Benin

Family	Subfamily	Species
Termitidae	Macrotermitinae	*Pseudacanthotermes militaris* Hagen
		Microtermes sp.,
		Macrotermes bellicosus Smeathman
	Termitinae	*Amitermes evuncifer* Silvestri
		Microcerotermes parvus Haviland
	Nasutitermitinae	*Trinervitermes oeconomus* Trägardh

Table 2: Termite specific diversity in rice field and natural savannah

	Mean No. of termites per sampling hole	
Termite species	Natural savannah	Rice field
Microtermes sp.	4±0.2	158±2.7
Microcerotermes parvus	3±0.3	163±2.4
Pseudacanthotermes militaris	0±0	96±1.7
Amitermes evuncifer	4±1.1	71±0.6
Trinervitermes oeconomus	2±0.3	5±0.3
Macrotermes bellicosus	0±0	26±0.3
Population abundance	13	519
Specific richness (S)	4	6
Simpson diversity index (D)	0.27	0.25
Derived index diversity (Es)	0.73	0.75

Table 3: Termite specific diversity in each stage of rice phenology

	Mean No. of termites per sampling hole		
Termite species	Tillering	Heading	Maturity
Microtermes sp.	13±0.4	32±2.4	113±2.6
Microcerotermes parvus	51±0.1	62±1.2	50±1.4
Pseudacanthotermes militaris	36±0.2	39±0.5	21±0.7
Amitermes evuncifer	11±1.3	32±1.6	28±1.3
Trinervitermes oeconomus	2±0.1	3±0.3	0±0
Macrotermes bellicosus	4±0.1	12±1.1	10±0.1
Population abundance	117	180	222
Specific richness (S)	6	6	5
Simpson diversity index (D)	0.31	0.23	0.34
Derived index diversity (Es)	0.69	0.77	0.66

Table 4: Population of termites on rice varieties at tillering stage

	Mean No. of termite per sampling hole						
Rice variety	*Microtermes* sp.	*M. parvus*	*P. militaris*	*A. evuncifer*	*T. oeconomus*	*M. bellicosus*	Total
NERICA 1	0.4±0.2	1.2±1.2	1.1±0.7	0.7±0.7	0.0±0.0	0.0±0.0	4.1
NERICA 2	0.5±0.3	5.9±2.7	0.1±0.1	1.3±0.3	0.0±0.0	0.0±0.0	7.7
NERICA 3	0.0±0.0	6.4±2.2	3.7±1.2	0.3±0.2	0.0±0.0	2.5±0.2	12.8
NERICA 4	0.8±0.4	6.1±2.0	1.3±0.2	0.0±0.0	0.0±0.0	0.3±0.2	8.5
NERICA 6	0.3±0.2	0.7±0.5	1.9±0.3	0.9±0.4	4.2±1.2	0.0±0.0	7.9
NERICA 7	0.5±0.2	4.5±1.4	0.5±0.3	0.0±0.0	0.0±0.0	0.0±0.0	5.5
NERICA 1	0.2±0.1	1.9±1.5	1.3±0.1	0.2±0.2	0.0±0.0	0.3±0.2	3.8
LAC23	0.3±0.1	6.1±2.4	4.6±1.3	2.5±0.9	0.0±0.0	0.0±0.0	13.5
CG14	0.0±0.0	3.7±1.2	2.5±0.5	0.4±0.4	1.5±0.5	0.0±0.0	8.1
WAB56-104	0.0±0.0	4.9±2.5	7.4±2.3	1.8±0.3	0.0±0.0	0.0±0.0	14.1

richness was found on WAB56-104 (3 species), but the total density on this variety was moderately high (14.1 individuals per sampling hole). The dominant species were *M. parvus*, followed by *P. militaris* and *Microtermes* sp. (Table 4).

Table 5: Population of termites on rice varieties at heading stage

Rice variety	Mean No. of termite per sampling hole *Microtermes* sp.	*M. parvus*	*P. militaris*	*A. evuncifer*	*T. oeconomus*	*M. bellicosus*	Total
NERICA 1	0.25±0.2[a]	1.58±1.01[a]	0.66±0.4[a]	1.58±0.7[a]	0.00±0.0[a]	0.25±0.3[a]	4.3
NERICA 2	0.50±0.3[a]	5.16±2.9[ab]	0.16±0.2[a]	2.58±1.5[a]	0.16±0.2[a]	0.33±0.2[a]	8.9
NERICA 3	1.58±0.4[ab]	4.16±1.9[ab]	4.33±1.6[a]	8.75±3.6[a]	0.00±0.0[a]	0.00±0.0[a]	18.8
NERICA 4	0.75±0.5[a]	8.16±3.1[b]	1.33±0.1[a]	2.08±1.4[a]	0.00±0.0[a]	0.00±0.0[a]	12.3
NERICA 6	0.00±0.0[a]	4.83±1.7[ab]	1.00±0.4[a]	3.75±1.8[ab]	0.00±0.0[a]	1.16±0.8[a]	10.7
NERICA 7	0.33±0.3[a]	3.75±0.7[ab]	2.41±1.1[a]	3.91±1.6[ab]	0.00±0.0[a]	1.25±0.8[a]	11.6
NERICA 10	4.41±1.3[b]	6.50±2.9[b]	4.00±1.3[a]	2.16±0.2[a]	4.25±2.9[b]	0.00±0.0[a]	21.3
LAC23	2.25±1.1[ab]	4.66±1.7[ab]	1.91±1.1[a]	0.58±0.4[a]	0.00±0.0[a]	0.00±0.0[a]	9.4
CG14	11.58±4.3[c]	9.16±3.4[b]	3.25±1.2[a]	2.08±1.1[a]	0.00±0.0[a]	2.58±2.2[a]	28.7
WAB56-104	0.58±0.4[a]	3.41±1.6[ab]	5.33±2.02[a]	3.83±1.8[ab]	0.00±0.0[a]	0.00±0.0[a]	13.2

Means followed by the same letter are not significantly different at the 5% level according to SNK test

Table 6: Population of termites on rice varieties at maturity

Rice variety	Mean No. of termites per sampling hole *Microtermes* sp.	*M. parvus*	*P. militaris*	*A. evuncifer*	*T. oeconomus*	*M. bellicosus*	Total
NERICA 1	13.8±2.8[bc]	0.7±0.7[a]	3.0±1.8[a]	8.0±2.4[b]	0.0±0.0[a]	0.8±0.7[a]	26.3
NERICA 2	10.6±3.3[b]	0.8±0.6[a]	0.5±0.5[a]	1.2±1.2[a]	0.0±0.0[a]	0.0±0.0[a]	12.6
NERICA 3	3.7±1.2[a]	2.7±1.2[a]	0.0±0.0[a]	1.2±0.6[a]	0.0±0.0[a]	1.5±0.6[a]	9.0
NERICA 4	19.5±4.9[c]	8.4±1.9[b]	0.6±0.3[a]	2.1±1.2[a]	0.0±0.0[a]	0.5±0.5[a]	31.1
NERICA 6	0.5±0.4[a]	0.2±0.2[a]	0.0±0.0[a]	0.0±0.0[a]	0.0±0.0[a]	0.4±0.4[a]	0.7
NERICA 7	9.5±2.8[b]	8.4±2.8[b]	1.0±0.7[a]	3.9±2.1[a]	0.0±0.0[a]	0.0±0.0[a]	22.4
NERICA 10	3.5±1.2[a]	0.2±0.1[a]	0.4±0.4[a]	0.6±0.6[a]	0.0±0.0[a]	0.0±0.0[a]	4.3
LAC23	12.3±4.5[b]	11.1±3.1[b]	1.7±0.6[a]	0.8±0.8[a]	0.0±0.0[a]	0.4±0.4[a]	25.4
CG14	1.8±1.1[a]	1.9±1.1[a]	1.1±0.6[a]	0.0±0.0[a]	0.0±0.0[a]	0.0±0.0[a]	4.8
WAB56-104	10.3±2.9[b]	2.0±1.1[a]	0.8±0.8[a]	0.0±0.0[a]	0.0±0.0[a]	0.0±0.0[a]	13.1

Means with the same letter are not significantly different at the 5% level according to SNK test

At heading stage, six termite species were present on rice, but the specific diversity and density differed considerably among rice varieties. However, the populations of the various termite species increased (compared to tillering stage) on all varieties except WAB56-104 and LAC23 (Table 5).

Finally, at maturity stage the density of termites was greater than at the two earlier stages but at that stage only five species infested rice (Table 6). *Microtermes* sp. was by far the most abundant species overall. It was followed by *M. parvus* and *A. evuncifer*. Populations of *P. militaris* and *M. bellicosus* were less important at this stage.

Mode of attack and damage on rice: The site of termite attack was highly dependent on the species of termites (Table 7). In most of the cases, the presence of a specific termite species was coincident with evidence of severe damage on rice, but in a few cases the termite was present without the associated damage. The occurrence of termite species varied according to rice phenological stages and the symptoms of damage were specific for each type of termite.

Microtermes sp. occurred at all phenological stages, but its damage was very low at the beginning of the crop growth cycle and gradually increased to maturity stage, except NERICA 10 and CG14 on which species peaked at heading. The species was found in the ground especially in

Table 7: Termite damage localization and plant status

Termite species	Root	Collar	Stem	Leaf	Panicle	Lodged plant	Fresh plant	Dried plant	Wilted plant
Microtermes sp.	+++	+++	+++	-	-	+++	-	+++	+++
Microcerotermes parvus	+++	+++	+++	-	-	+++	+	+++	+++
Pseudocanthotermes militaris	-	+	+	-	-	+++	-	-	-
Amitermes evuncifer	+++	+++	+++	-	-	-	-	+	+
Trinervitermes oeconomus	-	+	+	+	+	-	+	+	+
Macrotermes bellicosus	+++	+++	+++	-	-	+++	+	+	+

Damage level: - = low or nothing; + = medium; +++ = high

the rhizosphere (root area). The damage was primarily cutting of roots and making tunnels along the stems. The tunnels were often filled with soil. The attack was more frequent on wilted and dry plants.

Microcerotermes parvus was also found at all cropping stages. Its damage increased from tillering to maturity. It was not only found in the rhizosphere, but also on the dried plants. Its damage was either stem cutting, especially on the collar leaving characteristic furrows at the end of the stems, or root cutting and making tunnels along the stems. Its attack was particularly evident on wilted and dried plants and a little on fresh seedlings.

Amitermes evuncifer was uniformly present in the rice field throughout the growth period. It was often found in built nests or in underground galleries. It was also found in the nest of *T. oeconomus*. Its presence was strongly associated with damage, recognized by black furrows inside the infested organs (stems or roots). The attack also took place outside the stem especially on the external cortex of the collar.

Pseudocanthotermes militaris was present in the field throughout the cropping cycle, but its population was abundant only at tillering and heading stages. This species was also found in the soil surface (without apparent nests) as well in underground horizon. Its presence in the field was rarely associated with damage. Dried grasses (in natural savannah) and lodged rice stems were primarily infested and damage was minor on normal rice plants. In a few cases, small furrows were observed on the base of rice seedlings without any serious impact.

Trinervitermes oeconomus was present in the field at low densities from tillering to heading, and absent at maturity stage. An abundant colony of this species was found in a nest built 10-30 cm above the soil. It was also seen in small groups in underground galleries. Its presence was not related to any serious damage. Only a few furrows were noted on the stems, leaves and panicles, leaving small openings on these organs without any severe consequences. Some nests were built next to rice hills creating a physical constraint to seedling growth.

Finally, *M. bellicosus*, like the previous species, was present at low density in the field throughout the cropping cycle. However, its presence was very often associated with damage. Indeed, in the infested hills, all the stems were cut on the side of the collar. The infested seedlings lodged and dried out.

DISCUSSION

The study revealed the presence of six species of termite in the rice field and only four species in the natural savannah. All the species found in natural savannah were found on rice. This suggests that field infestation can originate from natural savannah. Akpesse *et al.* (2008) reports that termites found in natural vegetation are able to colonize crops and fruit trees. Litsinger *et al.*

(1987) found that termites have some preference for rice over perennial vegetation. This could explain the greater diversity of termites in the rice field than in the natural environment. Among the species collected on rice, the fungus-growing termites (*Microtermes* sp. and *P. militaris*) and the dry-wood termites (*M. parvus* and *A. evuncifer*) were the most abundant. These termites constitute the main part of soil macrofauna attacking dryland crops (Akpesse *et al.*, 2001). The establishment of their colonies in cropping areas should be favored by the availability of food that promotes the termites' activity (Kumar and Pardeshi, 2011). *Microtermes* sp., *A. evuncifer* and *P. militaris* have been identified on rice in Côte d'Ivoire (Akpesse *et al.*, 2008), while *M. bellicosus*, *Microtermes* sp. and *T. oeconomus* have been found on rice in Nigeria (Harris, 1969; International Institute of Tropical Agriculture, IITA, 1971; Malaka, 1973). Also, most of the species recorded in our study have also been found on other tropical crops such as yam and cassava (Atu, 1993), sugar cane (Sands, 1977), groundnut (Johnson and Gumel, 1981), sorghum (Logan *et al.*, 1990), maize (Wood *et al.*, 1980; Akpesse *et al.*, 2008), as well as many forest trees (Anani Kotoklo *et al.*, 2010).

Microcerotermes parvus and *P. militaris* were the most abundant species at tillering stage, *M. parvus*, *A. evuncifer*, *P. militaris* and *Microtermes* sp. the most abundant at heading stage, and *Microtermes* sp., *M. parvus* and *A. evuncifer* were the most common at maturity. The termite population was not very important at the beginning of the cropping cycle (tillering), but increased during heading and maturity stages, probably because of the abundance of the cellulosic resources (wilted and dried plants) in that period. Agunbiade *et al.* (2009) report that termites attack living rice when dead material is not available. Heinrichs and Barrion (2004) explain that termites are attracted by plants being stressed by biotic or abiotic factors such as drought, diseases and nutrient deficiency. *Microtermes* sp. appeared to be the dominant and most harmful species at maturity. Indeed, this species builds underground nests located in the deep soil horizon (Wood, 1996), where it stores food to feed a growing population over a long period of time.

All of the rice varieties were infested by the six termite species, but the specific densities were different among varieties. NERICA 6, CG14, NERICA 10 and NERICA 3 were less infested even at maturity, while NERICA 4 and LAC23 were heavily infested at maturity.

The attack modes of termite species were also specific. The three most harmful species were *Microtermes* sp., *M. parvus* and *A. evuncifer*. These species are known to be responsible for major damage on dryland crops (Akpesse *et al.*, 2008). Their attack is commonly made on roots and stems. The attack of *P. militaris* and *M. bellicosus* was sporadic and very low. *Trinervitermes oeconomus* had no effect on upland rice, contrary to what is reported by Wood and Cowie (1988) on its role in rice damage.

Finally, it is important to know that termites can be secondary pests on plants that are primarily stressed by other biotic or abiotic constraints. So, not all the damage met in the field is caused by termites.

CONCLUSION

This study has identified the main termite species that attack upland rice. A total of six species was found on rice against four in the natural savannah. The dominant species were xylophagous termites (fungus-growing termites and dry-wood termites). The specific diversity varied not only according to the environment, but also according to rice phenological stage. These results can be useful to undertake targeted measures against key termite species.

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