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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 15 (3): 108-120, 2012
ISSN 1028-8880 / DOI: 10.3923/pjbs.2012.108.120
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Biodiversity of Termite (Insecta: Isoptera) in Tropical Peat Land Cultivated with Oil Palms

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Abstract: Termites are the major decomposers in tropical region but yet their occurrences in oil palm plantation especially in peat soil are generally treated as pest. Study of termite species in peat land was conducted in selected oil palm plantations in North Sarawak with 5-7 years old palms and South Sarawak with 13-15 years old palms with two sites in each area. Results of quadrate (25×25×30 cm) sampling showed termite was significantly higher in relative density with increasing depth of soil (0-10 = 21.23, 10-20 = 42.52 and 20-30 cm = 81.12%) which could be advantaged from being predated by ants (Hymenoptera: Formicidae) which were higher in density from soil surface to 10 cm soil depth with relative density of 31.84%. Modified transect sampling (50×6 m) had successfully sampled 18 species of termites from 2 families (Rhinotermitidae and Termitidae), 5 subfamilies (Rhinotermitinae, Coptotermitinae, Termitinae, Macrotermitinae and Nasutitermitinae) and 11 genera (*Coptotermes, Schedorhinotermes, Termes, Macrotermes, Nasutitermes, Globitermes, Amitermes, Parrhinotermes, Pericapritermes, Havilanditermes* and *Prohamitermes*). Both plantation sites have termite dominantly feeding on rotten wood as a result of abundant dead woods. However, *Coptotermes curvignathus* Holmgren was identified to feed on the living tissues of oil palm causing damage or death of the tree. Study showed higher encounter of soil-feeding termite in longer established plantation. It indicates the gradually shifting of soil condition towards a stabilized environment which favors the successful settlement of soil feeder termite species. Termite control should be more targets specific to avoid harming beneficial termites.

Key words: Termite diversity, isoptera, oil palm, peat, *Coptotermes curvignathus*

INTRODUCTION

Soil is one of the most complex and poorly studied habitats of terrestrial ecosystem. Organisms in the soil comprises a wide range of life-forms and functions involved in a large number of ecological processes and provide key ecosystem services for human population (Lavelle *et al*., 2006). To date, we still know very little about the taxonomy, systematic and biogeography as soil organisms have only weakly attracted attention of taxonomist compared to others like plants and vertebrates (Decaens *et al*., 2006). Decaens (2010) who reviews published evidence regarding the soil organisms reveals that soil animals are poorly represented both on the internet and in the scientific literature.

Being a member of soil invertebrates, termites (Insecta: Isoptera) are the most dominant invertebrate in tropical ecosystem. This particular group of soil organism was recognized as destructive pest as they damage the wooden structure of building, compete with other beneficial organisms (Sorokin and Whitaker, 2008), destroy tree crops (oil palms, *Acacia mangium*) and even rice (Agunbiade *et al*., 2009). Despite their deleterious effects, termites are important in the decomposition of organic matter which plays a major role in carbon cycle, nutrient cycling, amend soil physical properties by increases soil water infiltration rate (Robert *et al*., 2007; Patrick, 1994). Study by Khucharoenphaisan *et al*. (2012) discovered actinomycetes isolated from termite of *Termes* sp. have showed inhibition effect on both Gram-positive and Gram-negative human pathogen. Termite has also been consumed by people as protein source (Agbidye *et al*., 2009) as well as being utilized as bio-indicator to land conversion as they are sensitive to habitat disturbance, vegetation type and habitat fragmentation.

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Due to dwindling area of mineral soil land in Malaysia as a consequence of rapid development of oil palm cultivation, peat soil had been utilized to cultivate oil palm where land prices are cheaper. According to Wahid *et al.* (2010), oil palm cultivation covered 5.01 million hectare and 13.3% of which were on peat soils throughout Malaysia. In the state of Sarawak, more than 37% or 0.44 million hectare of oil palm were planted on peat.

In Peninsular Malaysia alone, there were about 175 species of termite representing 42 genera (Tho, 1992). Lee *et al.* (2004) conducted a study on termite diversity on Pantai Acheh forest reserve of Penang Island found 24 species of termites which represented 17-29% of those species found in Peninsular Malaysia. Meanwhile, Thapa (1981) reported 103 termite species in Sabah, Malaysia. Survey of termite species diversity in Maliau Basin, Sabah yielded 18 termite species in the upper Montane forest, compared to 34 species in the lower Montane forest (Jones, 2000; Jones and Eggleton, 2000). Eggleton *et al.* (1997) concluded that 66 species of termite were collected from primary and regenerating lowland dipterocarp forest in Sabah. They found that termite of subfamily Termitinae and Nasutitermitinae dominated the whole transects carried out. Study of soil macrofauna by Collins (1980) at Mulu National Park, Sarawak revealed the dominant component of soil macrofauna in mixed dipterocarp forest was the termites. The study of termites in peat was carried out by Vaessen *et al.* (2011) where, they concluded that land conversion in peat area has resulted in shifting termite assemblages and declining of termite species density. Bong *et al.* (2012) has identified wood-feeder termites are the most dominant species. However, no termite study has been carried out in different age of mature oil palm plantations in peat.

Several species of termite have been identified as pests which cause damage to oil palm trees namely *C. curvignathus*, *Schedorhinotermes longirostris*, *Schedorhinotermes malaccensis* (Holmgren), *Globitermes globosus* (Haviland) and *Globosus sulphurous* (Haviland) (Harris, 1971). Turner *et al.* (2008) stressed the lack of publication on biodiversity and species conservation particularly in oil palm plantation. Most of the oil palm publication was related to mammals and birds but insects which comprises majority of the living species was less in biodiversity study (Turner *et al.*, 2008). Hence this study was aimed to survey the termite species composition and richness with different age of oil palm establishment together with other soil macroinvertebrate community in an oil palm plantation on peat soil. This study was intended to provide a better understanding of termite occurring in peat that will eventually contribute towards oil palm management strategies as well as biodiversity conservation of fauna in peat area plantation.

MATERIALS AND METHODS

Sampling site: Two oil palm plantations cultivated in peat soil in Sarawak, Malaysia were selected. The North Sarawak site (coordinate: N03°01’0.6”, E112°52’51.7”) at Kuala Tatau (here after referred to as KT) had 5000 ha of 5-7 years old palm while the South Sarawak site (Coordinate: N03°00’41.7”, E112°52’47.2”) at Saratok (hereafter referred to as SS) had 2000 ha of 13-15 years old palm. This gave an insight into the termite diversity in different ages of oil palm tree in peat.

Sampling method: A modified transect method was designed to sample termites in between two rows of oil palm trees (50×6 m). Two sampling sites were randomly selected and sampled in each plantation. The transect was then subdivided into 15 grids measuring 10×2 m. Basically investigation was carried out from 20 cm below the ground until 2 m up each oil palm tree. Each grid was thoroughly searched for any termite mud trails on the tree trunk, infested fallen oil palm rachis, buried rotting wood logs, tree stumps and rooting zone of ground vegetations. Any visible termite mounds on the ground and nests were also removed or broken using a hoe or machete to sample the termites inside. All termites were hand sorted according to different castes and were collected in 70% alcohol and brought back to laboratory for further identification. Information such as date, caste, grid and occurrence of the termites were recorded.

Soil macro-invertebrates were sampled from 10 sample points randomly located within a 50×50 m quadrate each site. At each point, one soil block measured 25×25×30 cm was collected and sorted according to standard method used by the Tropical Biology and Fertility Institute (TSBF). A trench was excavated to 30 cm depth around the quadrate of 25×25 cm. The soil block was removed from the ground, divided into 3 layers of 10 cm depth (0-9.9, 10-19.9 and 20-30 cm) and hand-sorted for soil macro- invertebrates. Collected soil invertebrates were preserved in 70% alcohol. Collected earthworms and larvae were preserved in 4% formalin. Invertebrates were identified to genus level and counted.

Identification of termites: The termites were examined under a real-time imaging dissecting microscope

(Nikon SMZ800). Photos of termite were taken and analyse through installed photo analysing programme (NIS-element). Identification of termites were based on description from Thapa (1981) and Tho (1992). Features of termite soldier include (1) Head length, width and height (2) pro- and mesonotum length and width (3) body length (4) shape and segment number of antenna (5) Postmentum length and width (6) mandible length (7) distance among marginal tooth of mandible (8) tibia length (9) femur length (10) segment number of tarsi (11) fontanelle width and length (12) nasus length (13) tibia spur and (14) labrum. Prestwich (1983) classification was used to classify the soldier mandible type. Same features of soldier termites were studied on worker termites except the fontanelle and nasus length. Features of termite eggs, termite alates and reproductive pairs encountered were also being studied to provide a general profile for that particular termite species colony. Number of termite specimens used in morphological study depends on availability of termites sampled in the field. Reading of measurements was in millimeter.

The identified termite species were assigned to a functional feeding group and nesting group based on literature available and field observations (Decaens *et al*., 2006). The main feeding groups are: (1) Wood-feeder (fresh or rotten wood); (2) Soil-wood interface feeders; (3) wood-litter feeders; and (4) soil-feeder. Whereas nesting groups are: (1) Wood-nesting, (2) Arboreal, (3) subterranean; (4) Epigeal; (5) Hypogeal and (6) Inquilines.

Data analysis: Termite was semi-quantitatively assessed based on the number of encounters or hits of termite genus in each sites to provide relative frequency of occurrence (Dawes-Gromadzki, 2005; Jones, 2000). Jones *et al.* (2003) defined the term encounter as the recorded presence of a species in one section and gave no measure of the absolute abundance per unit area. Species accumulation curve was measured using biodiversity software EstimateS version 8.2 using sample-based technique with 50 runs (Colwell, 2009). Biodiversity data of invertebrate was generated by Shannon index H', Evenness E and Simpson index D and ANOVA test was used to test the invertebrate density among soil depths.

RESULTS

A total of 24 groups of soil invertebrates were recorded in this study (Table 1). Shannon index revealed the highest value of diversity for soil level 0-10 cm (H' = 2.25). Followed by second soil level (10-20 cm)

Table 1: Soil invertebrate density (individual m^{-2}) and relative density (%) at different soil depth level in KT site

		Soil depth (cm)					
		0-10		10-20		20-30	
Group	TL	Density (ind. m^{-2})	Relative density (%)	Density (ind. m^{-2})	Relative density (%)	Density (ind. m^{-2})	Relative density (%)
Gryllotalpidae	Family	5.6	1.96				
Pseudoscorpionida	Class	3.2	1.12	1.6	1.57		
Geophilidae	Family	5.6	1.96	3.2	3.15		
Isoptera	Order						
Rhinotermitidae	Family	24.0^{a}	8.38	43.2^{b}	42.52	92.8^{c}	81.12
Termitidae	Family	36.8	12.85				
Araneae	Class	17.6^{a}	6.15	1.6^{b}	1.57	3.2^{b}	2.80
Hymenoptera	Order	91.2^{a}	31.84	24.0^{b}	23.62	6.4^{c}	5.59
Coleoptera	Order	4.8	1.68			0.8	0.70
Protura	Order	2.4	0.84				
Enchytraeid	Family	12.0	4.19	4.0	3.94		
Diptera	Order	1.6	0.56				
Symphyla	Class	2.4	0.84				
Dermaptera	Order	4.0	1.40				
Acari	Subclass	1.6	0.56				
Diplopoda	Class	0.8	0.28				
Gastropoda	Class			0.8	0.79		
Oligochaeta	Subclass	56.0^{a}	19.55	23.2^{b}	22.83	9.6^{c}	8.39
Blattidae	Order	0.8	0.28				
Collembola	Subclass	2.4	0.84			0.8	0.70
Diplura	Order	1.6	0.56				
Isopoda	Order	4.8	1.68				
Buthidae	Family	0.8	0.28				
Unidentified		6.4	2.24			0.8	0.70
Shannon index H'		2.25		1.45		0.74	
Evenness E		0.72		0.70		0.38	
Simpson index D		0.82		0.71		0.33	

Density values followed by same alphabet in the same row were not significantly different at p = 0.05 by ANOVA test, TL = Taxonomic level

Table 2: List of termite species collected from oil palm plantation in peat soil

Sampling location	Genus	Species	Feeding group	Nesting group	No. of hit of genus	No. of encounter
KT site (5-7 years old palm)	*Coptotermes*	*curvignathus*	Fresh wood	Wood	12	2
		sepangeusis Krishna	Rotten wood	Wood		8
		borneensis Oshima	Rotten wood	Wood		2
	Schedorhinotermes	*sarawakensis* (Holmgren)	Rotten wood	Wood	33	2
		medioobscurus (Holmgren)	Rotten wood	Wood		4
		javanicus (Kemner)	Rotten wood	Wood		27
	Nasutitermes	*havilandi* (Desneux)	Rotten wood	Arboreal	5	2
		rectangularis (Thapa)	Rotten wood	Arboreal		1
		matangeusiformis (Holmgren)	Rotten wood	Arboreal		2
	Pericapritermes	*nitobei* (Shiraki)	Soil feeder	Subterranean	16	14
		paraspeciosus (Thapa)	Soil feeder	Subterranean		2
	Parrhinotermes	*aequalis* (Haviland)	Rotten wood	Subterranean	5	5
	Havilanditermes	*proatripennis* (Ahmad)	Wood-litter interface	Subterranean	1	1
SS site (13-15 years old palm)	*Coptotermes*	*sepangeusis*	Rotten wood	Wood	4	2
		borneensis	Rotten wood	Wood		2
	Schedorhinotermes	*sarawakeusis*	Rotten wood	Wood	2	1
		javanicus	Rotten wood	Wood		1
	Nasutitermes	*rectangularis*	Rotten wood	Arboreal	8	5
		havilandi	Rotten wood	Arboreal		1
		matangeusiformis	Rotten wood	Arboreal		2
	Pericapritermes	*nitobei*	Soil feeder	Subterranean/Wood	2	2
	Parrhinotermes	*aequalis*	Rotten wood	Subterranean/Wood	2	2
	Amitermes	*dentatus* (Haviland)	Soil-wood interface	Inquilines-*Macrotermes* mound	1	1
	Globitermes	*globosus*	Rotten wood	Subterranean/ Wood	16	16
	Prohamitermes	*mirabilis* (Haviland)	Soil-wood interface	Hypogeal	5	5
	Termes	*rostratus* (Haviland)	Soil-wood interface	Epigeal	2	2
	Macrotermes	*gilvus* (Hagen)	Wood-litter interface	Epigeal mound	4	4

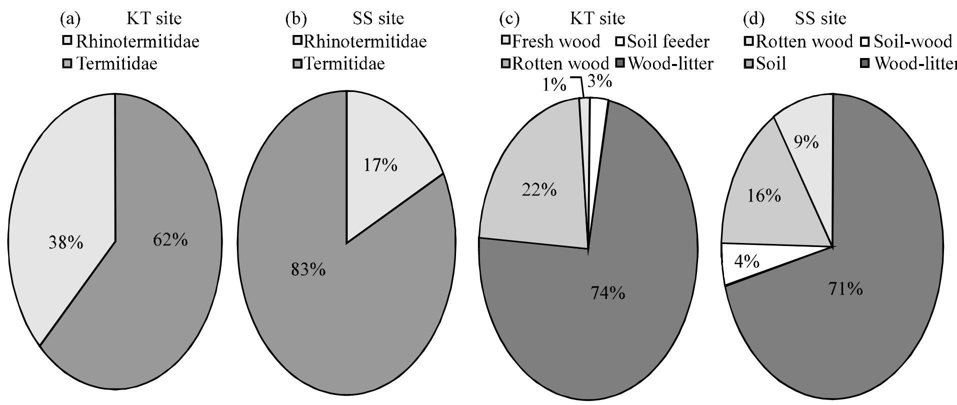

Fig. 1(a-d): Composition of termite based on family (a) and (b) and feeding group (c) and (d) in Kuala Tatau (KT site) and Saratok (SS site)

(H' = 1.45) and third soil level (20-30 cm) (H' = 0.74). In terms of evenness, top soil level and second soil level were more even on species number distribution across all groups of invertebrates. Highest value of Simpson's index was recorded for soil level 0-10 cm (D = 0.82). Followed by 10-20 cm (D = 0.71) and 20-30 cm (D = 0.33). Unevenness of species number on third soil level was evidenced by large number of termites being collected. All groups of invertebrate decreased in density or abundance (individual m^{-2}) when moved deeper into the peat except termites of family Rhinotermitidae. The termite showed significantly highest in relative density in the soil level of 20-30 cm.

A total of 18 species termites from 2 families, 5 subfamilies and 11 genera (*Coptotermes*, *Schedorhinotermes*, *Termes*, *Macrotermes*, *Nasutitermes*, *Globitermes*, *Amitermes*, *Parrhinotermes*, *Pericapritermes*, *Havilanditermes* and *Prohamitermes*) were collected from both plantation sites (Table 2). Thirteen species of termite were collected from KT site whereas SS site yielded 14 species. Both plantations have a distinct difference in term of termite family. Family Rhinotermitidae was the major group of termite found in KT site at 62% of the total while family Termitidae occupied 83% of the total termite group in SS site (Fig. 1). The termite assemblage comprised of five feeding groups with rotten wood dominating both sampling areas at 74% of the total species at KT site and 71% at SS site (Fig. 1). Species accumulation curves indicate sampling was relatively complete at KT site as the curve showed trend of approaching an asymptote (Fig. 2). However, it is

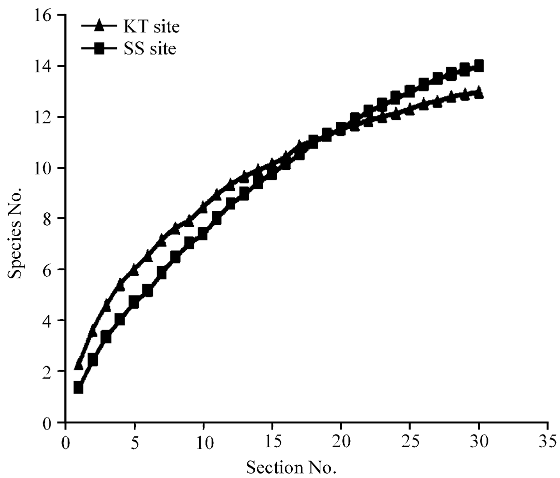

Fig. 2: Species accumulation curves for termite sampling at KT and SS site against the unit sampling effort (per section) by pooling 30 sections per site and each section measures 10×2 m

probable that given greater sampling effort at site SS, more species of termite may be uncovered as the curve shown the trend of increasing toward asymptote (Fig. 2).

Termite workers of family Rhinotermitidae generally characterized by their wood feeding behaviour have more marginal tooth on their left mandible as compared to termites from family Termitidae which generally are litter and soil feeder (Fig. 3). *Globitermes globosus* from family Termitidae, however, do not meet these criteria as it was found foraging on the rotten wood log buried underground. Prestwich's classification of soldier mandible yielded 7 species of piercing (BI), 4 species of glue squirting (GS), 3 species of daubing brush (DB), 2 species of asymmetrical snap (ASN), 1 species of symmetrical snap (SSN) and 1 species of crushing mandibles (CM) (Fig. 4).

There were 4 nesting groups represented in both sampling sites, with 33.3% of the species nesting in wood buried underground as well as nesting underground. Wood-nesting was dominant in both sites in the present study. Species that constructed epigeal mound as their nest were *T. rostratus* and *M. gilvus*. Nest of *T. rostratus* was discovered to be building on exposed oil palm roots as the tree lean over due to soft peat soil (Fig. 5a). The mound of *M. gilvus* was constructed on the ground with

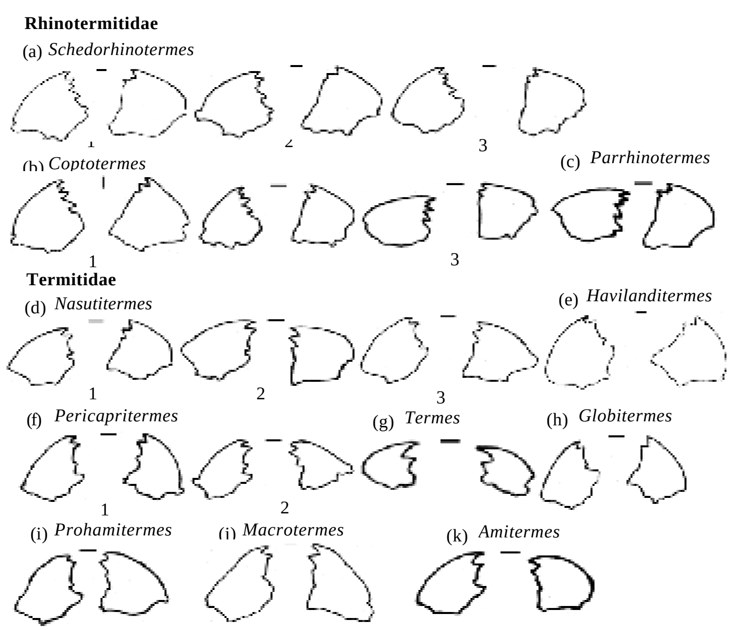

Fig. 3(a-k): Mandibles of worker termite: (a:1) *S. sarawakensis* (2) *S. medioobscurus* (3) *S. javanicus* (b:1) *C. curvignathus* (2) *C. sepangensis* (3) *C. borneensis* (c) *P. aequalis* (d:1) *N. havilandi* (2) *N. matangensiformis* (3) *N. rectangularis* (e) *H. proatripennis* (f:1) *P. nitobei* (m) *P. paraspeciosus* (g) *T. rostratus* (h) *G. globosus* (i) *P. mirabilis* (j) *M. gilvus* and (K) *A. dentatus*. The bar above each mandible represents 0.1 mm scale

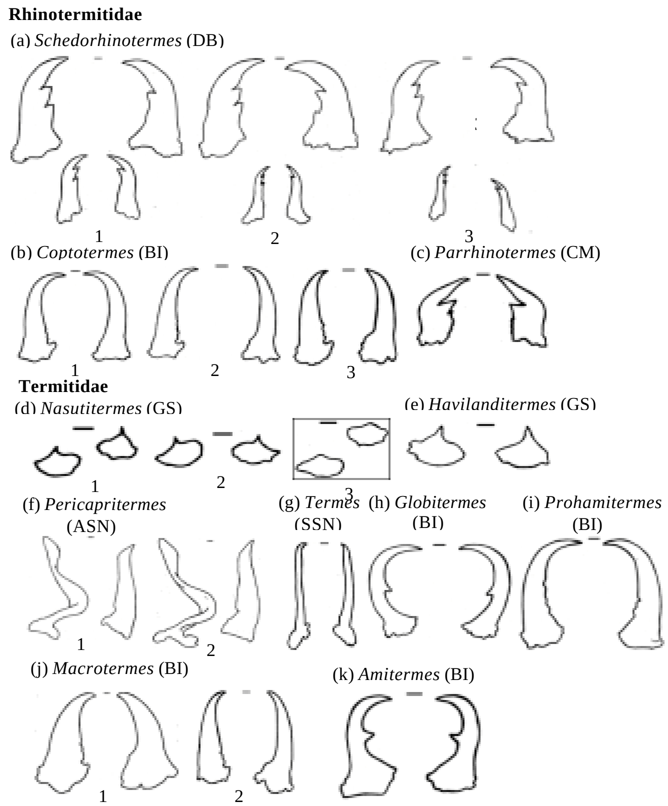

Fig. 4(a-k): Mandibles of soldier termite: (a:1) *S. sarawakensis*, major soldier (above), minor soldier (below) (2) *S. medioobscurus,* major soldier (above), minor soldier (below) (3) *S. javanicus*, major soldier (above), minor soldier (below) (b:1) *C. curvignathus,* (2) *C. sepangensis*, (3) *C. borneensis,* (c) *P. aequalis*, (d:1) *N. havilandi*, (2) *N. matangensiformis*, (3) *N. rectangularis*, (e) *H. proatripennis*, (f:1) *P. nitobei*, (2) *P. paraspeciosus*, (g) *T. rostratus*, (h) *G. globosus*, (i) *P. mirabilis*, (j:1) *M. gilvus* (major soldier), (2) *M. gilvus* (minor soldier) and (k) *A. dentatus*. Prestwich's classification of soldier mandible is indicated in the bracket. DB = daubing brush, BI = piercing, CM = crushing mandibles, GS = glue squirting, ASN = asymmetrical snap and SSN = symmetrical snap. The bar above each mandible represents 0.1 mm scale

whitish clayey soil (Fig. 5b). No mound-building species were found in the KT site. Nest of *P. mirabilis* was located underground with a lump-like structure and dark black in color (Fig. 5c). Arboreal nests were mainly constructed by termite of genus *Nasutitermes* inside oil palm frond (Fig. 5d) while foraging on dead laying oil palm fronds (Fig. 5e). Nesting site of *C. sepangensis* was found to be building in a decaying wood log buried underground (Fig. 5f).

Most of these termites were found to be consuming dead wood material buried underground. Fresh wood eater of species *C. curvignathus* was found in KT site consuming living palm tissue. *Coptotermes sepangensis* and *C. borneensis* were found foraging on the decaying wood logs buried underground rather than feeding on living palm tissue, even though these termite species were also found forming mud work up to the oil palm shoot as with *C. curvignathus* adjacent to the sampling plot. The termites of *Schedorhinotermes* were the dominant species at KT site and constituted about 49% of the total number of termite encountered, whereas *G. globosus* was dominant in SS site and constituted 35.7% of the total number of encounters. Reproductive castes were found in 7 out of 18 termite species founded in both plantations (Fig. 6a-g) and only secondary queens were found on *P. mirabilis* (Fig. 6c).

Coptotermes curvignathus was rare in the sampling location considering it had only one encounter in two transects in KT site. Its cryptic behavior as it tunneled underground and as a living tissue consumer made the sampling of this species more difficult. However the bait station being set up

Fig. 5(a-f): Mound of *T. Rostratus* on the palm roots, (b) *Macrotermes gilvus* mound beside oil palm tree, (c) *Prohamitermes mirabilis* nest dug from the peat ground, (d) *Nasutitermes* sp. Nesting inside frond, (e) *Nasutitermes* sp.consuming the dead frond that laid on the ground and (f) *Coptotermes sepangensis* devouring the decaying wood log

Fig. 6(a-g): Queen of termite species (a) *Termes rostratus*, (b) *Macrotermes gilvus*, (c) Secondary reproductive of *Prohamitermes mirabilis*, (d) *Parrhinotermes aequalis*, (e) *Coptotermes curvignathus*, (f) *Pericapritermes nitobei* and (g) *Nasutitermes matangensiformis* nearby using fresh rubber wood as bait successfully attracted a high number of *C. curvignathus*.

DISCUSSION

Invertebrate study: Several management practices like pesticide and fertilizer application could affect the soil community in cultivated field (Pappoe *et al*., 2009). Abe and Mastumoto (1979) in their study of lowland rainforest termite discovered the higher tendency of finding termites in the top 0-15 cm of the soil. This was in contradicting with results of KT site which showed that higher relative density of termite was located between soil depths of 20-30 cm. The relatively abundant of dead wood logs buried underground may have contributed to the higher abundance of termite at that particular soil depth. Susceptibility of termite to desiccation can be prevented by nesting and tunneling underground and also being preyed by predators like ants (Lee and Wood, 1971), as indicated on higher abundance of Hymenopteran or ants on the top layer of the soil. The ants forage above soil layer and trees and nest in top layer of soil or any rotting oil palm fronds that lay between rows of oil palm trees. These predator ants were observed to attack termites as the latter were exposed during sampling.

Termite species diversity and biology: The results of the transect sampling clearly indicate that both plantations are quite similar in term of species number but different in species composition. Comparison with works done by Vaessen *et al*. (2011) in 28 months old oil palm plantation showed higher species abundance in present study (Table 3) indicating the colonization of new adaptable termite species to the homogenized environment in plantation. The study of termite species diversity in KT site showed in support with previous finding by Bong *et al*. (2012) where 13 species of termite were found in that plantation.

Both plantations shared the same genera of termite which are *Coptotermes*, *Schedorhinotermes*, *Nasutitermes*, *Parrhinotermes* and *Pericapritermes*. KT site has *Havilanditermes* which was not found in SS site.

Table 3: Relative encounter of termite species collected in KT and SS site with oil palm aged 5-7 years and 13-15 years respectively compared with works done by Vaessen *et al*. (2011) in near peat swamp forest and 28 months old oil palm in peat soil

			Study site			
			Vaessen *et al*. (2011)		Present study	
Family	Genus	Species	NF	26 months	5-7 years	13-15 years
Kalotermitidae	*Glyptotermes*	*paracaudomunitus* (Thapa)	1	-	-	-
Rhinotermitidae	*Coptotermes*	*curvignathus*	4	-	2	-
		sepangensis	-	-	8	2
		borneensis	-	-	2	2
	Schedorhinotermes	*sarawakensis*	1	7	2	1
		medioobscurns	-	4	4	-
		javauicns	-	-	27	1
		brevialatus (Haviland)	-	16	-	-
		tarakanensis (Oshima)	1	-	-	-
Termitidae	*Nasutitermes*	*havilaudi*	2	-	2	1
		rectangularis	-	-	1	5
		matangensiformis	-	-	2	2
	Bulbitermes	*borneensis* (Haviland)	1	1	-	-
		constrictns (Haviland)	-	1	-	-
		sarawakensis (Haviland)	2	-	-	-
	Lacessititermes	*kolapisensis* (Thapa)	1	-	-	-
	Oriensubulitermes	sp. A (Emerson)	-	-	-	-
	Pericapritermes	*nitobei*	-	-	14	2
		paraspeciosns	-	-	2	-
	Parrhinotermes	*aequalis*	-	-	5	2
		near *minor* Thapa	1	-	-	-
		pygmaens (John)	1	-	-	-
		microdentiformisoides (Thapa)	1	-	-	-
	Havilauditermes	*proatripennis*	-	-	1	-
	Amitermes	*dentatus*	-	-	-	1
	Prohamitermes	*mirabilis*	-	2	-	5
	Globitermes	*globosns*	-	-	-	16
	Termes	*rostratns*	-	-	-	2
	Macrotermes	*gilvns*	-	-	-	4
Total			16	31	72	46

NF: Near-natural peat swamp forest

Meanwhile 5 genera of termite which were not found in KT site were found in SS site and there were *Prohamitermes*, *Amitermes*, *Termes*, *Macrotermes* and *Globitermes*.

The family Rhinotermitidae with subfamily Coptotermitinae was represented by 3 species of genus *Coptotermes* (*C. curvignathus, C. sepangensis* and *C. borneensis*). Of these, *C. curvignathus* was identified as a serious pest to oil palm industry as they feed on living plant tissue eventually killing the palm (Chan *et al*., 2011). Attacked palm is easily recognized by mud works extending from the basal part of the tree up to the shoot and causing the shoot to break. Generally, young palms aged 7-8 months after planting were susceptible to *C. curvignathus* attack. This might explain the existence of this termite pest at KT site which had 5-7 years old palms. The nesting site of termite pest *C. curvignathus* was found in an old tree stump with layers of crispy mineral soil carton forming a honeycomb structure. *Coptotermes curvignathus* is morphologically similar to but larger than *C. sepangensis,* a structural pest as *C. curvignathus* (Lee, 2002a, b) and *C. borneensis*. Soldier of *C. borneensis* meanwhile has a straighter mandible shape compared to other *Coptotermes* species. Site KT was dominated by *Schedorhinotermes* particularly *S. javanicus*. Dominance of this genus was also reported in 28 months oil palm plantation in peat (Vaessen *et al*., 2011). Three species of genus *Schedorhinotermes* (*S. sarawakensis*, *S. medioobscurus* and *S. javanicus*) of the same family but of subfamily Rhinotermitinae were also being found foraging on decaying wood logs buried in the soil. Irritated scent was immediately released by the termite when disturbed which contained volatile component of vinyl ketones that served as repelling signal to enemy (Chuah *et al*., 1990). Similar scent was also being released by termite species *Parrhinotermes* of family Rhinotermitidae when termite was collected from decaying wood logs buried under the ground. The well-developed labrum with tiny hairs as 'brushes' as in *Schedorhinotermes* sp. and defense secretion similarity have proved the close phylogeny relationship between these 2 termite genera (Prestwich, 1983).

The family Termitidae composed of subfamilies Termitinae, Macrotermitinae and Nasutitermitinae. *Nasutitermes* species were generally characterized by its conical, nozzle-shaped sharp projection of termite soldier which would secrete a gluey secretion once disturbed (Chuah *et al*., 1989). Similar characteristics were exhibited by the termite *Havilanditermes* except for the larger size. This termite species was found scavenging on dead plant materials like decaying fronds. *Macrotermes gilvus*, a termite species which often occurred in well drained mineral soil area was found in peat plantation of SS site. Practice of water table control which was normally being utilized in plantation favors the existence of this termite species in which it can build epigeal mound. This species with dimorphic soldiers was not observed to damage the oil palm although it had been reported to be a pest that fed on the plant root (Lee and Wood, 1971). *Termes rostratus* was found to build mound on the oil palm roots. Apparently, the oil palm roots were being utilized by this termite as structural support. *Macrotermes* build large mound in SS site and was found throughout the peat area near to oil palm trees and made of whitish clayey soil probably excavated from the substratum. Round oval shaped royal chamber was found inside the mound located at the bottom part near to the soil with royal pairs inside guarded by lots of major soldier. *Amitermes dentatus* was found living in the wall of the mound of *M. gilvus*. This species of termite has a feeding habit of soil-wood interface and alates of this species was found within the thick wall of *Macrotermes* mound. The genus *Globitermes*, characterized by its semi-circle curved mandibles and milky white abdomen were found scavenging on the dead wood logs buried under the ground. Small holes were found in the chambers of *P. mirabilis* nest with black pellets. These black pellets were referred to as prefabricated plugs by Tho and Maschwitz (1988) as a defense strategy for emergency sealing of the holes. Termites of genus *Nasutitermes* (*N. havilandi* and *N. rectangularis*) were found on the oil palm tree trunk with covered runways. *Nasutitermes matangensiformis* were generally found foraging on the decaying oil palm frond lying on the ground and also on oil palm frond base. Queen of *N. matangensiformis* was found in the frond base of oil palm. This termite species, however, was discovered did not causing damage into the oil palm trunk. Termites of *Pericapritermes* with soil feeding habit were generally found forage under the mosses that grow on the ground in the plantation. However some of these termites were also found foraging on the buried wood logs.

Feeding group diversity: When soil-feeder species are grouped with soil-wood interface feeder, SS site has greater richness of species (4 spp.) compared with KT site (2 spp.). High organic matter content in peat soil may have contributed to the existence of soil-feeder and soil-wood interface termite species in both sites. Jones and Prasetyo (2002) have related factor of low, open canopy of *Gmelina* plantation which lead to fluctuations of temperature and moisture level and cause the absent of soil-feeding termites. As water table of peat plantation was well controlled to avoid irreversible drying of peat soil, the relatively low and open canopy of oil palm compared to older oil palm trees may have led to a considerable lower recovery of soil-feeder or soil-wood interface termite species probably as a result of temperature fluctuation. The abundant of dead wood buried underground in peat soil which provide food source and wood-nesting microsites may have contributed to the higher frequency of occurrence of wood-feeding termites in both sites. This was in contrast with findings by Eggleton (2000) in dipterocarp forest in Sabah, where termite of family Rhinotermitidae was less dominant than *Termes*-group soil feeders and *Nasutitermes*. The gradual decline in density of wood-feeding termites in older palm site (SS) may be due to amount of dead wood which decreases over time. Although study by Kumar and Pardeshi (2011) revealed the pest termite species were common and dominant in agroecosystem and had wider niche breadth as compared to other species, present study did not come out with similar conclusion as higher dominance of a termite species do not necessary be a pest.

Although present study discovered *C. sepangensis* and *C. borneensis* do exist on the oil palm tree as *C. curvignathus*, the biology of these two species as a pest to oil palm tree has not yet being thoroughly studied. Further studies are needed to assess the destructive behavior of these two termite species and their impact on the oil palm tree. The absence of grass-feeding termite species at both sites may reflect a low plant richness of the ground layer (Dawes-Gromadzki, 2008). Above ground vegetation was generally occupied by fern species *Nephrolepis biserrata* (Swartz) Schott at both sites.

Peat swamp forest conversion to oil palm was reported to cause a decline in termite species density and shifting community structure (Vaessen *et al*., 2011). However, present study has shown that with the increasing of oil palm age, termite species richness gradually increases and feeding habit was being replaced from wood-feeding to soil-feeding. As the oil palm industry has been receiving attention and criticism pertaining to biodiversity issue from Non-government Organizations from other countries, this study provides significant and informative breakthrough in the biodiversity issue. Nevertheless, thorough study on the biodiversity constitution of other faunas in the oil palm plantation should be carried out in the future to give a better understanding pertaining to the effect of oil plantation on biodiversity. Koh and Wilcove (2007) however have suggested a win-win idea between oil palm grower and NGOs, to implement a new strategy of using palm oil revenue to fund the acquisition of land for the establishment of private nature reserve.

Presence of an abundant soil macrofauna community may have important effects on aspects of soil quality to agricultural practices (Pauli *et al*., 2011). Conservation of soil biodiversity becomes an important key aspect to sustainable agriculture. Clearing of peat soil for agricultural purposes like oil palm should take into account of conserving the biodiversity for sustainability. More efforts should be put by the oil palm grower to conserve these non-pest termite species as termite contribute a lot to nutrient recycling which is beneficial to the crops. Monoculture practice of oil palm plantation which greatly reduces the variability of food source has changed fresh wood eater like *C. curvignathus* into a pest as they feed on living oil palm tissue. Practices of pest control should be carefully formulated so that only targeted group of insect like the pest termite *C. curvignathus* is eliminated. Pest control should go towards eco-friendly by utilizing biological control method like entomopathogenic fungus *Metarhizium anisopliae* and termiticidal plant extract like neem (Sotannde *et al*., 2011) and castor (Babarinde *et al*., 2008) More studies are needed to evaluate the impact of oil palm replanting on termite in the future.

ACKNOWLEDGMENT

This study was supported by Fundamental Research Grant Scheme (FRGS) 07-04-10-911FR of the Ministry of Higher Education, Malaysia.

REFERENCES

Abe, T. and T. Mastumoto, 1979. Studies on destruction and ecological role of termites in lowland rainforest of West Malaysia, distribution and abundance of termites in Pasoh forest reserve. Jap. J. Ecol., 29: 337-351.

Agbidye, F.S., T.I. Ofuya and S.O. Akindele, 2009. Some edible insect species consumed by the people of Benue State, Nigeria. Pak. J. Nutr., 8: 946-950.

Agunbiade, T.A., F.E. Nwilene, A. Onasanya, M. Semon, A. Togola, M. Tamo and O.O. Falola, 2009. Resistance status of upland NERICA rice varieties to termite damage in Northcentral Nigeria. J. Applied Sci., 9: 3864-3869.

Babarinde, S.A., O.O.R. Pitan and F.A. Iyiola, 2008. A prescreen of termiticidal potentials of aerial parts of castor *Ricinus communis* (Euphorbiaceae). J. Entomol., 5: 218-223.

Bong, C.F.J., P.J.H. King, K.H. Ong and N.M. Mahadi, 2012. Termite assemblages in oil palm plantation in Sarawak, Malaysia. J. Entomol., 9: 68-78.

Chan, S.P., C.F.J. Bong and W.H. Lau, 2011. Damage pattern and nesting characteristics of *Coptotermes curvignathus* (Isoptera: Rhinotermitidae) in oil palm on peat. Am. J. Appl. Sci., 8: 420-427.

Chuah, C.H., S.H. Goh and Y.P. Tho, 1989. Interspecific variation in defence secretions of Malaysia termites from the genus *Nasutitermes* (Isoptera, Nasutitermitinae). J. Chem. Ecol., 15 : 549-563.

Chuah, C.H., S.H. Goh and Y.P. Tho, 1990. Chemical defence secretions of some species of Malaysian Rhinotermitidae (Isoptera, Rhinotermitidae). J. Chem. Ecol., 16: 685-692.

Collins, N.M., 1980. The distribution of soil macrofauna on the west ridge of Gunung (Mount) Mulu, Sarawak. Oecologia (Berl.), 44: 263-275.

Colwell, R.K., 2009. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.2- User's Guide and application. http://purl.oclc.org/estimates

Dawes-Gromadzki, T.Z., 2005. The termite (Isoptera) fauna of a monsoonal rainforest near Darwin, Northern Australia. Aust. J. Entomol., 44: 152-157.

Dawes-Gromadzki, T.Z., 2008. Abundance and diversity of termites in a savanna woodland reserve in tropical Australia. Aust. J. Entomol., 47: 307-314.

Decaens, T., 2010. Macroecological patterns in soil communities. Global Ecol. Biogeogr., 19: 287-302.

Decaens, T., J.J. Jimenez, C. Gioia, G.J. Measey and P. Lavelle, 2006. The values of soil animals for conservation biology. Eur. J. Soil Biol., 42: S23-S38.

Eggleton, P., R. Homathevi, D. Jeeva, D.T. Jones, R.G. Davies and M. Maryati, 1997. The species richness and composition of termites (Isoptera) in primary and regenerating lowland dipterocarp forest in Sabah, East Malaysia. ECOTROPICA, 3: 119-128.

Eggleton, P., 2000. Global Patterns of Termite Diversity. In: Termites: Evolution, Sociality, Symbioses, Ecology, Abe, T., D.E. Bignell and M. Higasi (Eds)., Kluwer Academic Publishers, Dordrecht, pp: 25-51.

Harris, W.V., 1971. Termite Injurious to Agriculture. In: Termites their Recognition and Control, Hickin N.E. (Ed.). Longman Group Limited, London, Pages: 186.

Jones, D.T., 2000. Termite assemblages in two distinct montane forest types at 1000 m elevation in the Maliau Basin, Sabah. J. Trop. Ecol., 16: 271-286.

Jones, D.T. and P. Eggleton, 2000. Sampling termite assemblages in tropical forests: Testing a rapid biodiversity assessment protocol. J. Applied Ecol., 37: 191-203.

Jones, D.T. and A.H. Prasetyo, 2002. A survey of the termites (Insecta: Isoptera) of Tabalong District, South Kalimantan, Indonesia. Raffles Bull. Zool., 50: 117-128.

Jones, D.T., F.X. Susilo, D.E. Bignell, S. Hardiwinoto, A.N. Gillison and P. Eggleton, 2003. Termite assemblage collapse along a land-use intensification gradient in lowland central Sumatra, Indonesia. J. Applied Ecol., 40: 380-391.

Khucharoenphaisan, K., N. Sripairoj and K. Sinma, 2012. Isolation and identification of actinomycetes from termite's gut against human pathogen. Asian J. Anim. Vet. Adv., 7: 68-73.

Koh, L.P. and D.S. Wilcove, 2007. Cashing in palm oil for conservation. Nature, 448: 993-994.

Kumar, D. and M. Pardeshi, 2011. Biodiversity of termites in agro-ecosystem and relation between their niche breadth and pest status. J. Entomol., 8: 250-258.

Lavelle, P., T. Decaens, M. Aubert, S. Barot and M. Blouin *et al*., 2006. Soil invertebrates and ecosystem services. Eur. J. Soil. Biol., 42: S3-S15.

Lee, C.Y., 2002a. Control of foraging colonies of subterranean termites, *Coptotermes travians* (Isoptera: Rhinotermitidae) in Malaysia using hexaflumuron baits. Sociobiology, 39: 411-416.

Lee, C.Y., 2002b. Subterranean termite pests and their control in the urban environment in Malaysia. Sociobiology, 40: 3-9.

Lee, C.Y., P.S. Ngee, L.C. Lee and J.P.S. Na, 2004. Survey of termite diversity in Pantai Acheh forest reserve, Penang Island, Malaysia. J. Biosains, 15: 91-99.

Lee, K.E. and T.G. Wood, 1971. Termites and Soils. Academic Press, New York, USA., Pages: 251.

Pappoe, A.N.M., F.A. Armah and H.K. Akotoye, 2009. Diversity of soil surface invertebrates in cultivated and uncultivated fields in coastal savanna zone of Ghana. Res. J. Soil Biol., 1: 37-44.

Patrick, B., 1994. The importance of invertebrate biodiversity: An Otago conservancy review. Conservation Advisory Science Notes No. 53, Department of Conservation, Wellington, Pages: 13, http://www.doc.govt.nz/upload/documents/science-and-technical/casn053.pdf

Pauli, N., E. Barrios, A.J. Conacher and T. Oberthur, 2011. Soil macrofauna in agricultural landscapes dominated by the Quesungual Slash-and-Mulch Agroforestry System, western Honduras. Applied Soil Ecol., 47: 119-132.

Prestwich, G.D., 1983. Chemical systematics of termite exocrine secretions. Annu. Rev. Ecol. Syst., 14: 287-311.

Robert, O.E., U.O. Frank and O.U. Agbonsalo, 2007. Influence of activities of termites on some physical and chemical properties of soils under different land use patterns: A review. Int. J. Soil Sci., 2: 1-14.

Sorokin, N. and J. Whitaker, 2008. The Impacts of Selected Natural Plant Chemicals on Terrestrial Invertebrates. In: Secondary Metabolites in Soil Ecology, Karlovsky, P. (Ed.). Springer-Verlag, Berlin, Heidelberg, Germany, pp: 255-268.

Sotannde, O.A., G.O. Yager, B.D. Zira and A. Usman, 2011. Termiticidal effect of neem extracts on the wood of *Khaya senegalensis*. Res. J. For., 5: 128-138.

Thapa, R.S., 1981. Termites of Sabah (East Malaysia). Sabah Forest Department, Sandakan, Malaysia, Pages: 374.

Tho, Y.P. and U. Maschwitz, 1988. The use of prefabricated plugs for emergency entrance sealing. Naturwissenschaften, 75: 527-528.

Tho, Y.P., 1992. Termites of Peninsular Malaysia. Forest Research Institute Malaysia, Malaysia, Kepong, Malaysia.

Turner, E.C., J.L. Snaddon, T.M. Fayle and W.A. Foster, 2008. Oil palm research in context: identifying the need for biodiversity assessment. PLoS ONE, Vol. 3, 10.1371/journal.pone.0001572.

Vaessen, T., C. Verwer, M. Demies, H. Kaliang and P.J. Van Der Meer, 2011. Comparison of termite assemblages along a landuse gradient on peat areas in Sarawak, Malaysia. J. Trop. For. Sci., 23: 196-203.

Wahid, O., A.A. Nordiana, T.M. Ahmad, H.H. Mohd and K.D. Ahmad, 2010. Mapping of oil palm cultivation on peatland in Malaysia. MPOB Information Series No. 529, pp: 4.