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Effect of arena sizes on intra- and inter-specific agonism in the termites, *Microcerotermes fuscotibialis* Sjostedt and *M. edentatus* Wasman (Termitidae: Termitinae)

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Abstract
Agonistic behavior in the termites, *Microcerotermes fuscotibialis* Sjostedt and *Microcerotermes edentatus* Wasmann were studied. 10 individuals each from same and different species of these termites were paired and observed for mortality 24h after, using different arena sizes. Workers of *M. fuscotibialis* exhibited agonistic behavior towards each other in pairings in smaller arena sizes, while agonism leading to equivocal mortality occurred in the larger arena sizes. However, workers of *M. edentatus* showed no aggression towards one another in all the arena sizes. Pairing workers of *M. fuscotibialis* with workers of *M. edentatus* resulted in significant aggressive behavior leading to high mortality of the individuals in the smaller arena sizes. Equivocal mortality was observed in the larger arena size of 12.0cm. These two termite species therefore demonstrated contrasting aggressive behavior in inter-colony pairings. Foraging space delineated by distance may be an important factor that could reduce fatal encounters among termite species with agonistic tendencies within a given foraging area.

Keywords: Termitidae, *Microcerotermes*, agonistic behavior, termite encounters, mortality

Introduction
The genus *Microcerotermes* Silvestri, are subterranean termites that build their nest on the trunks of various tree species within the rainforest and savanna zones in Nigeria [1, 2, 3]. *M. fuscotibialis* Sjostedt and *M. edentates* Wasman occurs in similar but distinct ecological zones wherever they are found.

M. fuscotibialis is the predominant species within and around the Campus of the Federal University of Technology, Akure, (FUTA) Nigeria, while *M. edentatus* is more prevalent within and around the premises of the Federal Secretariat complex, Akure, Nigeria (about 25km away from FUTA).

Several studies have reported aggressive or agonistic behavior in intra- and inter-specific encounters between different groups of termites [4, 5, 6, 7].

Agonism was defined as all behaviors displayed by individuals during contests, to include both defensive and offensive behaviors of the attacker and defender [8]. This may occur when certain termite castes attempt to acquire nest or food resources, protect those resources or compete for mates [7]. Although the soldier caste is better equipped to exhibit aggression, the workers are also capable of demonstrating agonism [4, 6, 9, 10].

Aggression among different groups of termites has been investigated as a means of deducing relationships among colonies of termites [7, 11] and has been used to infer colony affiliation of foraging groups or satellite groups of the subterranean termite, *Heterotermes aureus* Snyder [4, 6], *Reticulitermes spp*. Holmgren [12], *Reticulitermes* (l) *banyulensis* Clement [13], *Reticulitermes* (l) *grassei* Clement and *Reticulitermes* (l) *lucifugus* Rossi [14].

It has however been pointed out that not all distinct colonies of subterranean termites react aggressively towards one another and that certain pairings of distinct colonies sometimes results in high levels of mortality and sometimes they do not [7, 14, 15, 16]. Studies [17] involving pairing termite workers from cultures obtained from same colony of *Microcerotermes fuscotibialis* did not result in agonistic behavior or mortality of the paired individuals. However, pairings from different colonies located at different distances resulted in serious encounters and aggressive behavior leading to significant mortality of the individuals.

Observations showed that mixing workers from different foraging groups of the same colony

of *Reticulitermes spp.* from Northern California [18] never resulted in agonistic behavior, and seldom resulted in significant mortality. Intermingling workers from different colonies of the same cuticular hydrocarbon phenotype normally does not result to immediate aggression, but mortality was high after 24h. Attempts to mix workers from colonies of different cuticular hydrocarbon phenotype resulted in significant aggression and high mortality all the time [17, 18]. However termites separated and maintained in the laboratory for over 18 months still recognized colony mates from the field and vice versa.

Subterranean termites cooperate with conspecifics in order to efficiently utilize food resources. In *Coptotermes formosanus* Shiraki, intra- and intercolonial tube sharing was observed in a laboratory setting in this termite species [19], while no significant difference in the degree of aggression within a species of *Reticulitermes flavipes* Kollar and *R. virginicus* Kollar was found, as compared to aggression between the two species

In *C. formosanus*, aggression was not shown towards individuals from other colonies when raised in the laboratory, while low temperatures has been shown to inhibit the factors stimulating aggressive behavior [21].

Work on agonism among *Reticulitermes* [11] in Northern California, suggests variation in colony structure at the species and population levels. *Reticultitermes (l) banyulensis*, a typically monogynous species, shows distinct intra- and inter-specific agonism [14, 22], while aggression within *R. (l) grassei* and *R. (l) lucifugus* varies seasonally [14].

This study therefore seeks to investigate aggressive behavior within and among two species of *Microcerotermes*, with the hypothesis that termite workers would only fight when placed with workers from another colony. The effect of arena size on agonistic behavior in these two termite species was carried out to determine whether this has any influence on aggressive behavior in these termite species. The results will lead to a further understanding of this aspect of behavior in *Microcerotermes* species vis –a vis their relationship with one another, especially during foraging expeditions in the field.

Materials and Methods

Termites

Four colony nests of *Microcerotermes fuscotibialis* were collected from the trunks of *Terminalia catapa* Linn, *Mangifera indica* L, *Gmelina arborea* Robx ex Sm. and *Eucalyptus sp*. L'Her at the Federal University of Technology, Akure (FUTA), Western Nigeria, and brought to the laboratory.

Similarly, four colony nests of *Microcerotermes edentatus* were collected from the trunks of *Mangifera indica*, *Cocos nucifera* L, *Cassia sp.* L, *and Khaya anthotheca* Welw within the premises of the Federal Secretariat, Igbatoro Road, Akure, Western Nigeria. These two locations are about 25km apart from one another.

Each of the colony nests were kept in eight different plastic boxes and kept damp with a water-filled cotton-capped small bottles attached to the sides of the boxes. Cut pieces (2mm x 4cm x 20cm) of the tree species from where the termites were collected from, were placed in each of the corresponding boxes as food. These colony nests were maintained in the laboratory at a temperature of 29°c±4°c and relative humidity of 75mmHg±3mmHg.

Experimental colonies were made out of these boxes after being kept in the laboratory for at least one month. Colonies from Federal University of Technology are labeled FUT 1-4, while those from the Federal secretariat were labeled FED 1-4.

Bioassay

Termite pairing combinations of workers from the eight colonies were placed in 3.5cm, 6.0cm, 9.0 and 12.0cm diameter petri dish arenas. Each of these arenas was lined with a single Whatman #1 filter paper that had been moistened with a measured amount of distilled water (52% w/w).

The methods [18, 12, 20, 17] adapted for this bioassay were carried out as follows: two groups of 10 termite workers from two different colonies of same and different species were placed into each of the covered arenas, and observed for mortality and survivors after 24h. Extreme care was taken to use only workers that appeared healthy and not injured for the bioassays. The time taken to add workers of the other colony into the test arena was usually within 2 to 4 minutes. Preliminary studies showed that this time differential did not confer undue advantage on any of the termite individuals used for the assay. Each combination of the termite pairings with the appropriate arena sizes were replicated 5 times, using new arenas each time.

These pairings include, FUT_1 vs FUT_2; FUT_1 vs FUT_3; FUT_1 vs FUT_4; FUT_2 vs FUT_3, etc for 3.5cm, 6.0cm, 9.0cm and 12.0cm arenas; Similarly pairings of FED_1 vs FED_2; FED_1 vs FED_3; FED_1 vs FED_4; FED_2 vs FED_3, etc for same arena sizes; Then pairings of FUT_1 vs FED_1; FUT_1 vs FED_2; FUT_1 vs FED_3, etc for all the arena sizes.

Data Analysis

Mortality was considered high if 10 or fewer live termites remained, low if 17 or more remained and equivocal if 11-16 termites remained after 24h [12, 17].

In addition, the mean percentage mortality values between the smaller and larger arenas were compared, using the simple t-test at 0.05 level of significance. The assumption is to accept the Null hypothesis, H_o and assume no significant difference in mortality values if the calculated t_c <tabulated t_t. In the same vein if $t_c > t_t$, then H_o is rejected and significant difference is assumed.

Results

Intra-colony pairings in *Microcerotermes fuscotibialis* showed neither aggressive behavior towards one another nor mortality recorded in all the arena size combinations 24h after pairing (Table 1).

Agonistic behavior resulting in differential mortality levels was however observed in inter-colony pairings involving this termite species in all the arenas. In the 3.5cm arena, mortality was high, with values ranging between 69% and 80%, while survivors ranged between 3 and 8 individuals out of 20 (Table 1). Mortality in the 6.0cm arena was between 66% and 76%, with survivors ranging between 4 and 8 termite workers (Table 1).

In the 9.0cm arena, agonistic encounters were not as fierce as was observed in the 3.5cm and 6.0cm arenas, as lower mortality values were obtained. Mortality rate of 44% -49% occurred, with survivor values being in the range of 9-13 termites (Table 1).

A further reduction in aggressive behavior occurred in the 12.0cm arena, with encounters recording mortality values of 36%-44%, while survivor rates of 10-14 was recorded (Table

1). There was significant reduction in mortality rates as arena sizes increases except for arena sizes of 3.5cm and 6.0cm where mortality values were not significantly different from one another ($t_c<t_{t0.05}$ (5 df); t_c= 1.76; $t_{t0.05}$= 2.015). Comparing the mean percentage mortality values between arena sizes of 3.5cm and 9.0cm, a significant reduction in agonistic behavior of these termites was obtained ($t_c>t_{t0.05}$ (5 df); t_c= 15.88; t_t= 2.015). Similar significant reduction in agonistic behavior was obtained when percentage mortality rates between arena sizes 3.5cm and 12.0cm were compared ($t_c>t_{t0.05}$ (5 df); t_c= 15.55; t_t= 2.015) (Table 1).

Table 1: Number of survivors (Mean of 5 replicates each) from pairings of two groups of 10 worker termites from same and different colonies of *Microcerotermes fuscotibialis* with different Arena sizes.

Pairings*	No. of Survivors	% Mortality	No. of Survivors	% Mortality	No. of Survivors	% Mortality	No. of Survivors	% Mortality
	3.5cm Arena		6.0cm Arena		9.0cm Arena		12.0cm Arena	
FUT_1 vs FUT_1	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20,	-	20, 20, 20, 20,20	-
FUT_2 vs FUT_2	20, 20, 20, 20, 2	-	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-	20, 20, 20, 20,20	-
FUT_3 vs FUT_3	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-
FUT_4 vs FUT_4	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-	20, 20, 20, 20, 20	-	20, 20, 20 ,20, 20	-
FUT_1 vs FUT_2	5, 7, 4, 6, 5	73	4, 5, 5, 6, 4	76	11, 9, 12, 10, 9	49	13, 10, 13, 12, 10	42
FUT_1 vs FUT_3	4, 6, 6, 6, 5	73	6, 7, 5, 5, 4	73	8, 12, 10, 10, 13	47	11, 10, 14, 11, 10	44
FUT_1 vs FUT_4	5, 6, 5, 7, 8	69	7, 7, 8, 5, 7	66	10, 12, 10, 9, 11	48	14, 12, 15, 11, 12	36
FUT_2 vs FUT_3	4, 3, 4, 6, 6	77	5, 5, 6, 8, 6	70	9, 12, 11, 10, 10	48	10, 12, 11, 10, 14	43
FUT_2 vs FUT_4	6, 4, 7, 4, 4	75	5, 6, 6, 7, 5	71	12, 10, 13, 11, 10	44	12, 12, 11, 10, 14	41
FUT_3 vs FUT_4	3, 5, 3, 5, 4	80	7, 6, 8, 5, 5	69	10, 11, 10, 9, 12	48	11, 11, 12, 10, 10	46

*Termite colonies from the Federal University of Technology, Akure, denoted by FUT. Trees from where these termite colonies were taken from are denoted by the following: FUT_1 (*Terminalia* catapa); FUT_2 (*Mangifera indica*); FUT_3 (*Gmelina arborea*); FUT_4 (*Eucalyptus sp*.). Intercolony mortality was high in the 3.5cm and 6.0cm arenas, while it was equivocal in the 9.0cm and 12.0cm arenas. No agonism was recorded in the intracolony pairings. Percentage mortality was not significantly different in the 3.5cm and 6.0cm arenas when their mean percentage mortality values were compared ($t_c<t_{t0.05}$: $t_{t0.05}$ (5df)= 2.015; t_c = 1.76). However it was significantly reduced in the 9.0cm arena compared to the 3.5cm arena ($t_c>t_{t0.05}$: $t_{t0.05}$ (5df) = 2.015; t_c = 15.88). Similarly, percentage mortality was significantly reduced in the 12cm arena than in the 3.5cm arena ($t_c>t_{t0.05}$: $t_{t0.05}$ (5df) = 2.015; t_c = 15.55).

However, intra and inter-colony pairings of workers of *Microcerotermes edentatus* in all the arena sizes, showed no agonistic behavior, as no mortality was recorded in all the pairings except in one, where only 2 out of the 20 termite individuals died (Table 2). The termites were seen co-mingling with one another, and performing such acts as allogrooming, trophallaxis, and making frequent contact with one another and those they come in contact with.

Table 2: Number of survivors from pairings of two groups of 10 worker termites from same and different colonies of *Microcerotermes edentatus* with different Arena sizes.

No. of survivors in the various Arena Sizes (mean of 5 Replicates each)				
Pairings*	**3.5cm Arena**	**6.0cm Arena**	**9.0cm Arena**	**12.0cm Arena**
FED_1 vs FED_1	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20,20, 20	20, 20, 20, 20, 20
FED_2 vs FED_2	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_3 vs FED_3	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_4 vs FED_4	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_1 vs FED_2	20, 18, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_1 vs FED_3	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_1 vs FED_4	20, 20, 20, 20, 20	20, 20 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_2 vs FED_3	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_2 vs FED_4	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20
FED_3 vs FED_4	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20	20, 20, 20, 20, 20

*Termite colonies from the Federal Secretariat complex, Akure,denoted by FED. Trees from where these termite colonies were taken from are denoted by the following: FED_1 (*Mangifera indica*); FED_2 (*Cocos nucifera*); FED_3 (*Cassia sp*.); FED_4 (*khaya anthotheca*). Agonistic behavior was not demonstrated by these termites in all pairing combinations. Interspecific agonism was significant in termite pairings involving *M. fuscotibialis* and *M. edentatus* in the smaller arenas than in the larger 12.0cm Arena (Table 3).

In the 3.5cm arena, mortality was between 86%-94%, while a low survivor value of 1-4 individuals was obtained. In the 6.0cm arena, between 81%-85% casualties were recorded, while the number of termites surviving ranged between 2-5 termites.

Mortality rate in the 9.0cm Arena was between 50%-58%, while survivors were 7-12 termite workers. In the 12.0cm arena, a mortality value of 41%-49% was observed. Termites surviving ranged between 7 and 13 termites per 20 individuals (Table 3).

Therefore arena sizes of 3.5cm and 6.0cm recorded high termite mortality, while a moderately high mortality was achieved in the 9.0cm arena. Equivocal mortality occurred in the 12.0cm arena. A comparative analysis of the mean percentage values, using the one-tailed student t-test, showed a significant reduction in percentage mortality in the 6.0cm arena compared with the 3.5cm arena ($t_c>t_{t0.05}$ (15 df); t_c= 12.54; $t_{t0.05}$= 1.75). Percentage mortality also decreased significantly in the 9.0cm arena compared with 3.5cm arena ($t_c>t_{t0.05}$ (15 df); t_c= 32.26; $t_{t0.05}$= 1.75). A further significant reduction in percentage mortalities was obtained when the means from the 3.5cm and 12.0cm arenas were compared ($t_c>t_{t0.05}$ (15 df); t_c= 59.23; $t_{t0.05}$= 1.75) (Table 3). Aggressive

encounters in these termites often resulted in broken limbs, decapitated head and torn body parts, which ultimately lead to the death of the injured combatants.

Table 3: Number of survivors (Mean of 5 replicates each) in the interspecific pairings of two groups of 10 worker termites from *Microcerotermes fuscotibialis* and *M. edentatus* using different Arena sizes.

Pairings*	No. of Survivors	% Mortality	No. of Survivors	% Mortality	No. of Survivors	% Mortality	No. of Survivors	% Mortality
	3.5cm Arena		6.0cm Arena		9.0cm Arena		12.0cm Arena	
FUT_1 vs FED_1	2, 1, 3, 2, 1	91	2, 4, 3, 5, 2	84	7, 9, 12, 8, 9	55	11, 7, 12, 10, 11	49
FUT_1 vs FED_2	3, 1, 3, 2, 1	90	4, 3, 4, 2, 5	82	10, 12, 9, 11, 8	50	12, 10, 11, 12, 13	42
FUT_1 vs FED_3	2, 2, 1, 3, 2	90	3, 5, 3, 4, 4	81	8, 10, 9, 12, 9	52	11, 11, 10, 12, 11	45
FUT_1 vs FED_4	1, 2, 3, 1, 1	92	2, 5, 4, 4, 3	82	8, 7, 11, 9, 7	58	10, 10, 12, 12, 8	48
FUT_2 vs FED_1	3, 3, 3, 2, 1	88	4, 2, 3, 3, 4	84	9, 12, 10, 9, 9	51	13, 11, 13, 10, 11	42
FUT_2 vs FED_2	1, 3, 1, 3, 2	90	4, 5, 4, 3, 3	81	8, 12, 8, 10, 9	53	11, 12, 10, 11, 12	44
FUT_2 vs FED_3	2, 2, 3, 3, 2	88	4, 2, 4, 3, 4	83	7, 12, 9, 9, 11	52	10, 12, 13, 11, 10	44
FUT_2 vs FED_4	4, 3, 2, 3, 2	86	2, 2, 3, 5,3	85	9, 8, 11, 9, 10	53	10, 12, 11, 10, 14	43
FUT_3 vs FED_1	1, 1, 3, 2, 3	90	3, 5, 4 4, 2	82	9, 6, 10, 11, 9	55	12, 12, 10, 10, 12	41
FUT_3 vs FED_2	3, 2, 3, 1, 2	89	2, 4, 4, 3, 4	83	10, 7, 10, 9, 8	56	8, 11, 9, 12, 10	44
FUT_3 vs FED_3	1, 1, 2, 1, 1	94	4, 3, 4, 4, 3	82	12, 10, 8, 9, 9	52	10, 10, 13, 10, 12	45
FUT_3 vs FED_4	2, 1, 3, 2, 4	88	2, 5, 3, 3, 4	83	10, 7, 9, 7, 9	58	10, 10, 10, 11, 10	49
FUT_4 vs FED_1	3, 2, 1, 1, 1	92	5, 3, 1, 3, 5	83	8, 8, 10, 12, 9	53	11, 9, 12, 11, 10	47
FUT_4 vs FED_2	2, 1, 3, 1, 1	92	3, 4, 4, 3, 4	82	11, 8, 9, 9, 9	54	9, 12,10, 10 12	47
FUT_4 vs FED_3	1,3, 2, 1, 2	91	4, 3, 4, 5, 3	81	9, 12, 11, 10, 8	50	13, 10, 11, 11, 12	43
FUT_4 vs FED_4	1, 2, 1, 1, 3	92	3, 2, 4, 3, 3	85	7, 11, 9, 10, 10	53	10, 9, 12, 11, 13	45

*FUT for termite colonies from Federal University of Technology; FED for termite colonies from the Federal Secretariat, Akure, Nigeria.Subscript1-4 denotes the trees from which the colonies were collected from (see Materials and Methods). Mortality was high in the 3.5cm, 6.0cm and 9.0cm arenas, while it was equivocal in the 12.0cm

arena. Comparing the mean percentage mortality values, significant reduction was observed as arena sizes increases Mean percentage mortality was significantly reduced in the 6.0cm arena than in the 3.5cm arena ($t_c > t_{t0.05}$ (15 df): t_c = 12.54; $t_{t0.05}$ (15 df) = 1.75). Agonistic behavior was significantly reduced in the 9.0cm arena compared to the 3.5cm arena ($t_c > t_{t0.05}$ (15 df): t_c = 32.26; t_t= 1.75). A further significant reduction in percentage mortality was obtained in the 12.0cm arena when compared with values from the 3.5cm arena ($t_c > t_{t0.05}$ (15 df): t_c= 59.23; t_t= 1.75)

Discussion

Results from this study have shown different agonistic reactions between and among two different species of *Microcerotermes*. *M. fuscotibialis* showed significant agonism towards individuals of the same species which are from other colonies. Mortality was significantly higher, especially in the smaller arenas than in the larger ones. However, in *M. edentatus*, no agonism was observed in all the pairings and arena sizes. Similar lack of agonism was observed among the population of *Reticulitermes flavipes* [23, 24], while variability in occurrence of agonism among populations of other termite species had been recorded [9, 25, 26].

Occurrence of agonism in termites may therefore be contingent upon the species, colonies, nests, individuals, as well as the operating climatic conditions [7]. It is also known that altering termite's environment may greatly influence the way they will typically behave, while termites placed in an unfamiliar environment may not react to stimuli as they would in field conditions [20].

Studies has shown that workers of *Reticulitermes* could recognize differences at the colony level as demonstrated by both significant immediate aggression and 24h mortality following pairings of workers from different colonies of the same phenotype [12, 17]. However, reports had been made of lack of, or minimal aggressive behavior between colonies of *R. flavipes* and/or *R. virginicus*, on the one hand [20] and *Coptotermes formosanus* on the other hand [11, 15].

Studies of intraspecific agonism In some termite species revealed a complex suite of responses [12], which may be consistently aggressive as in *R. (l) banyulensis* [13], *M. fuscotibialis* [17] or always passive as found in *R. santonensis* Feynaud [14], or mostly passive as in *R. flavipes* and *R. virginicus* [16, 20], or vary seasonally as with *R. (l) grassei* and *R. (l) lucifugus* [14].

Aggressive behavior and mortality with respect to arena sizes showed that arena size may impact some effect among interspecific colony pairings. In the smaller arena sizes of 3.5cm and 6.0cm, mortality was high, while in the 9.0cm arena, mortality was moderately high. In the larger arena size of 12.0cm, equivocal mortality was observed. This result agrees with other studies [13], which reported that soldier and worker encounters decreased with an increase in arena sizes, making escape easier in larger arenas.

Thus, in view of the inconsistent display of overt agonism in intra and interspecific pairings in two *Reticulitermes* species [20], it was suggested that agonism may not be an innate behavioral response, but rather, kin recognition which is governed by a series of behavioral and chemical cues [15].

It must be noted however, that these assays are artificial, in that they involved forced encounters among the termite pairings, which left the workers only two choices: either to fight or not to fight, giving no option to either leave or avoid an encounter. In natural settings, other behavioral strategies such as avoidance may occur [12].

Agonistic behavioral studies are becoming useful tools in determining whether a foraging termite population belongs to the same colony [4, 12, 17] or being used to ascertain colony affiliation [18] appearing in monitoring devices within a foraging area occupied by a colony that was apparently eliminated or suppressed by baiting. In addition, agonistic behavioral bioassays could be used to determine whether a termite colony that had been suppressed subsequently resurged or if a newly collected termite is from a different colony that has now become established in the territory

previously occupied by a different colony or colonies [18].

Conclusion

This study has shown that agonistic behaviors vary within and among two species of *Microcerotermes*. In *M. fuscotibialis*, agonistic behavior leading to significant mortality occurred among the different inter- colony pairs, while no agonism was observed in *M. edentatus*.

The effect of arena size on agonistic behavior in these termite species also revealed a marked reduction in encounters and mortality as arena sizes increases

Intraspecific encounters between workers from different colonies of *M. fuscotibialis* recorded significant agonistic behavior, leading to high mortality in the smaller arenas, while equivocal mortality occurred in the larger arenas.

In the interspecific pairings between workers of *M. fuscotibialis* and *M. edentatus*, significant mortality was also recorded in the smaller arenas, while a moderately high mortality was achieved in the 9.0cm arena. In the larger 12.0cm arena, equivocal mortality was obtained.

Therefore agonistic behavior between two same but antagonistic species or two or more unrelated termite species may be prevented or reduced by virtue of space or keeping safe distances from one another during foraging in the field.

References

1. Olugbemi BO, Malaka SLO. Effect of food on recruitment activities in the termite, *Microcerotermes fuscotibialis* Sjostedt 1896 (Isoptera: Termitidae: Termitinae). Journal of Scientific Research and Development. 1994; 1(1):69-73.
2. Olugbemi BO, Malaka SLO. The effect of food on pheromonal communication in the termite, *Microcerotermes fuscotibialis* Sjostedt. African Journal of Ecology. 2007; 45(2):216-218.
3. Olugbemi BO. Influence of food on recruitment pattern in the termite, *Microceroterme fuscotibialis.* Journal of Insect Science. 2010; 10:165.
4. Binder BF. Intercolonial aggression in the subterranean termite, *Heterotermes aureus* (Isoptera: Rhinotermitidae). *Psyche.* 1988; 95:123-137.
5. Su NY, Scheffrahn RH. Foraging population and territory of the Formosan subterranean termite (Isoptera: Rhinotermitidae) in an urban environment. Sociobiology. 1988; 14:353-359.
6. Haverty MI, Thorne BL. Agonistic behavior correlated with hydrocarbon phenotypes in dampwood termite, *Zootermopsis* (Isoptera: Termopsidea). Journal of Insect Behavior. 1989; 2:523-543.
7. Thorne BL, Haverty MI. A review of intracolony, intraspecific and interspecific agonism in termites. Sociobiology. 1991; 19:115-145.
8. King JA. The ecology of aggressive behavior. Annual Review of Ecology and Systematics. 1973; 4:117-138.
9. Thorne BL. Termite-termite interactions: workers as an agonistic caste. Psyche. 1982; 89:133-150.
10. Delaplane KS. Tests for intraspecific agonism in a Louisiana population of *Coptotermes formosanus* (Isoptera: Rhinotermitidae). Journal of Entomological Science. 1991; 26:357-359.
11. Shelton TG, Grace JK. Review of agonistic behaviors in the Isoptera. Sociobiology 1996; 28:155-176.
12. Grace JK. Absence of overt agonistic behavior in a northern population of *Reticulitermes flavipes* (Isoptera: Rhinotermitidae) from Canada. *Sociobiology.* 1996; 28:103-110.
13. Clement J. Aggression intra- et interspecifique dans le genre *Reticulitermes* (Isoptera). Sequences comportementales de reconnaissance colonial. Congres sur les Societies d' Insectes Senangue. Biologia Ecologia Mediterranean. 1980; 7:157-158.
14. Clement J. Open and closed societies in *Reticulitermes* termites (Isoptera: Rhinotermitidae): geographic and seasonal variations. Sociobiology. 1986; 11:311- 323.
15. Su N-Y, Haverty MI. Agonistic behavior among colonies of the \Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae) from Florida and Hawaii: lack of correlation with cuticular hydrocarbon composition. Journal of Insect Behavior. 1991; 4:115-128.
16. Shelton TG. Factors affecting colony recognition in *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). M.S Thesis, University of Hawaii at Manoa, Hawaii, 1996.
17. Olugbemi BO. Intra- and Inter-colonial Agonistic Behavior in the Termite, *Microcerotermes fuscotibialis* Sjostedt (Isoptera: Termitidae: Termitinae. Journal of Insect Bahavior. 2012. DOI 10.1007/s10905-012-9336-6
18. Jones SC. Delineation of *Heterotermes aureus* (Isoptera: Rhinotermitidae) foraging territories in a Sonoran desert grassland. Environmental Entomology. 1990; 19:1047-1054.
19. Chen J, Henderson G. Tunnel and Tube Convergence of Formosan Subterranean Termites (Isoptera: Rhinotermitidae) in the Laboratory. Sociobiology. 1997; 30:305-318.
20. Polizzi JM, Forschler BT. Intra- and interspecific agonism in *Reticuliterms flavipes* (Kollar) and *R. virginicus* (Banks) and effects of arena and group size in laboratory assays. Insectes Sociaux. 1998; 45:43-49.
21. Shelton TG, Grace JK. Suggestion of an Environmental Influence on Intercolony Agonism of Formosan Subterranean Termites (Ispotera, Rhinotermitidae). Environmental Entomology. 1997; 26:632-637.
22. Bagneres AG, Killian A, Clement JL, Lange C. Interspecific recognition among termites of the genus *Reticulitermes*: evidence for a role for the cuticular hydrocarbons. Journal Chemical Ecology. 1991; 17:2397-2420.
23. Traniello JFA, Thorne BL. Termite baits in theory and practice. Proceedings of the National Conference. on Urban Entomology, Atlanta GA. 1994, 28-40.
24. Getty GM, Haverty MI, Lewis VR. Agonistic Behavior Between Recently Collected and Laboratory Cultured *Reticulitermes Spp*. (Isoptera; Rhinotermitidae) From Northern California. Pan- Pacific Entomology. 2000; 76(4):243-250.
25. Pearce MJ, Cowie RH, Pack AS, Reavey D. Intraspecific aggression, colony identity and foraging distances in Sudanese *Microtermes spp*. (Isoptera: Termitidae: Macrotermitinae). Ecological Entomology. 1990; 15:71-77.
26. Haverty MI, Copren K, Getty GM, Lewis VR. Agonistic behavior and cuticular hydrocarbon phenotypes of colonies of *Reticulitermes* (Isoptera: Rhinotermitidae) from northern California. Annals of Entomological Society of America. 1999; 92:269-277.