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Study of Foraging Behaviour of *Coptotermes heimi* (Wasmann) by Mark-Release-Recapture Method

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Abstract.- In this study we have investigated the foraging activity and territory of *Coptotermes heimi* (Wasmann) in Jallo Forest Park, Lahore during the period when there was maximum termite activity by mark-release-recapture method, using proper concentration of Nile Blue A as a marking dye. The activities of *C. heimi* were observed in three colonies marked as A, B and C setup at considerable distances and variable depths. It was observed that foraging activities of *C. heimi* were different in each colony and also varied with respect to foraging depth and distances. It was also observed that most of the foraging activity was carried out by worker caste and maximum foraging activity was attained by *C. heimi* (Wasmann) workers at the depth of 45cm under soil surface. Total population of *C. heimi* (Wasmann) was positively correlated with the relative humidity and the soil temperature, but negatively correlated with atmospheric temperature.

Keywords: Mark-release-recapture method, marking dye, foraging.

INTRODUCTION

Pakistan's climate ranges from tropical to temperate. Such diversity in physical and climatic features of the country provides favorable conditions to support rich and varied termite fauna. *Coptotermes heimi* (Wasmann) has been reported from urban and agricultural fields of Pakistan as serious pest (Manzoor and Mir, 2010; Manzoor *et al.*, 2011). Subterranean termites tend to search for food in soil by constructing underground tunnels. Once the food is discovered, it is then transferred by individual termites moving within the existing tunnels that lead to multiple existing food sources. These two elements deal with vastly different behaviors of subterranean termites. Termites work together in a large group in order to find food in soil. Individual termites remove one bite of soil at a time yet they produce a relatively predictable pattern of tunneling geometry (Puche and Su, 2001a).

Foraging behavior of termites is a social process in which groups of individuals explore new food sources in organized patterns (Traniello *et al*., 2000). The procedure by which termites make tunnels in the soil and the mechanism of tunnels to encounter food source is still unknown and very mystifying. Based on the observation of small two dimensional foraging arenas Robson *et al.* (1995) suggested that tunnel distribution of the eastern subterranean termites was optimized for food searching efficiency. Similarly, Hedlund and Henderson (1999) indicated that food size affected tunnel volume and length of the Formosan subterranean termite. Puche and Su (2001b) also reported that tunneling geometry of termites in laboratory arenas was not affected by the presence of food but tunneling activity increases towards a positive moisture gradient. Likewise to moisture, decayed wood is also one of the major attractants of termites. Temperature plays important role in termite foraging behavior. Apart form seasonal fluctuations, daily fluctuations of temperature also influence the termite activity. If top layer of the soil is either too hot or too cold the termites would not live there and would move deeper into the soil. Subterranean termites are among the most abundant but cryptic of animals; a factor that makes in the behavioral studies very difficult. Consequently little is known about their foraging behavior or general activity patterns (Emerson, 1955; Araujo, 1970; Wood and Johnson, 1986; Eggleton *et al.*, 1996).

Previous studies have been restricted mainly to mound builders or harvesters which forage openly on the soil surface. A few estimates of

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subterranean termite populations have been based on baiting with attractive materials or soil core sampling (Sands, 1965). As termites are active insects throughout life so all castes move from one place to another for finding food and shelter. As termites find any food source, all move towards that source and move freely forming galleries. All food sources are connected by galleries and then form a nest. Inside nest all caste lives together but due to continuous movement of termite colony there can be no permanent area for nest. As food moisture and temperature vary, the termite foraging behavior may also vary in days or weeks (Hewitt *et al.*, 1972).

The present study was carried out with the objective to study the foraging activity of *C. heimi* under field conditions at different depths and to find its correlation with soil and atmosphere temperature and Humidity.

MATERIALS AND METHODS

Subterranean termite species, *Coptotermes heimi* (Wasmann) was selected for studying the foraging behavior. Workers of *C. heimi* were obtained from the collection traps setup in Lahore College for Women University, Lahore. For the assessment of underground foraging activity of *C. heimi* (Wasmann), Jallo Forest Park, Lahore was selected as experimental site. Collection traps were established in a specific area reserved for entomology research purpose by joint collaboration of LCWU and FMC (corporation). Three colonies were selected in that area, marked as colonies A, B and C. A commercial dye, Nile Blue A (87%) was selected as marking stain, with distilled water as its solvent, as described by Sornnuwat (1996).

Application of Nile Blue A for marking C. heimi *(Wasmann)*

Nile Blue A (87%) was dissolved in distilled water and three concentrations (0.01%, 0.05% and 0.20%) of dyeing solution were prepared. Filter paper (Whatman No.1) was placed into the petri plates (90mm x 15mm) and was dipped in each concentration solution for 20 seconds. These stained filter papers were air dried over night prior to force-feeding by termites. Approximately 100 workers were released into a petri dish having moist dyed filter paper. After 3 and 5 days feeding period, 30 stained workers were transferred into another petri dish having moist unstained filter papers. For comparison of soldier and worker castes, 5 soldiers were added to stained worker group. Observations were made after 2, 4, 6 and 10 days to record the number of stained termites and survivors. Control unit was composed of un-dyed filter papers and three replicates were prepared for each concentration and feeding period.

Establishment of collection trap units

The collection trap units were comprised of plastic buckets having moistened rolled corrugated cardboards. A small piece of sugar cane was placed at the core of each collection trap to provide optimum condition for the activity of termites. The collection trap unit was buried in ground at the depths of 10, 30, 45, 60, 70, 85, 100 and 115 cm for determining the underground foraging depth. Traps were set randomly at distances ranging from 50 cm to 100 cm for each of these colonies. Following the procedure described by Grace (1989), a mark release recapture method was used from April-May 2010, during dry hot season. First collection was gathered from colony A and termites were allowed to feed on filter paper marked with 0.05% (w/w) Nile Blue A solution for up to 3 days and then released back to the same colony. This pattern was followed by two other recapture cycles, each after two weeks. Number of termites and soldiers collected from the traps were determined by weighing the termites. The calculation of individual body weight of worker and soldier was made by measuring 100 termites three times at each recapture cycle.

RESULTS

Application of Nile Blue A to C. heimi *(Wasmann)*

Results represented in Table I shows applicability of the dye to the termites. Filter paper with 0.05% Nile Blue A for 20 seconds, with three days forced feeding was found to be most suitable for marking *C. heimi* (Wasmann). This concentration offered high marking rate with negligible mortality. Even after 10 days, marking was easily identified in this case. Filter papers dyed

Table I.- Mortality of termites after feeding on filter paper treated with Nile Blue A at three concentrations.

Feeding period (days)	Nile Blue A concentration (%)	Mortality of workers (%)			
		3 days	5 days	7 days	10 days
3	0.01	3.85*	7.5*	13.75*	19.75*
	0.05	6.0*	9.75*	14.0*	20.25*
	0.25	10.0*	17.75*	25.25*	33.5*
5	0.01	4.0*	9.75*	16.0*	20.25*
	0.05	4.0*	10.25*	15.50*	23.50*
	0.25	15.0*	23.75*	33.5*	40.0*
Control		1.0*	8.50*	17.25*	22.75*

* Clear marking of all individuals was observed.

Table II.- Termite activity of *Coptotermes heimi* (Wasmann) from three colonies in Jallo Forest Park, Lahore.

Trap depth (cm)	Colony A		Colony B		Colony C		Means of 3 colonies	
	Number of workers	% soldiers	Number of workers	% soldiers	Number of workers	% soldiers	Number of workers	% soldiers
10	550	9.2	510	10.5	510	11.5	557	10.4
30	870	8.5	795	5.0	820	6.5	828	6.66
45	590	8.0	688	5.5	710	7.0	663	6.83

with lowest concentration of 0.01%, though, resulted in maximum marking with low mortality but this concentration was not selected for further experiment as the marking was not clear as compared with that of 0.05%. The highest concentration (0.20%) did not serve as good marking solution because of the highest mortality in comparison to control. As far as feeding period is concerned, a highest mortality rate at each concentration was observed with 5 days period. The mortality, however, remained the same level as that of control, at lower concentrations of 0.01% and 0.05%. In light of these results, the later field experiment was conducted by dyeing the termites with 0.05% solution of Nile Blue A for 3 days.

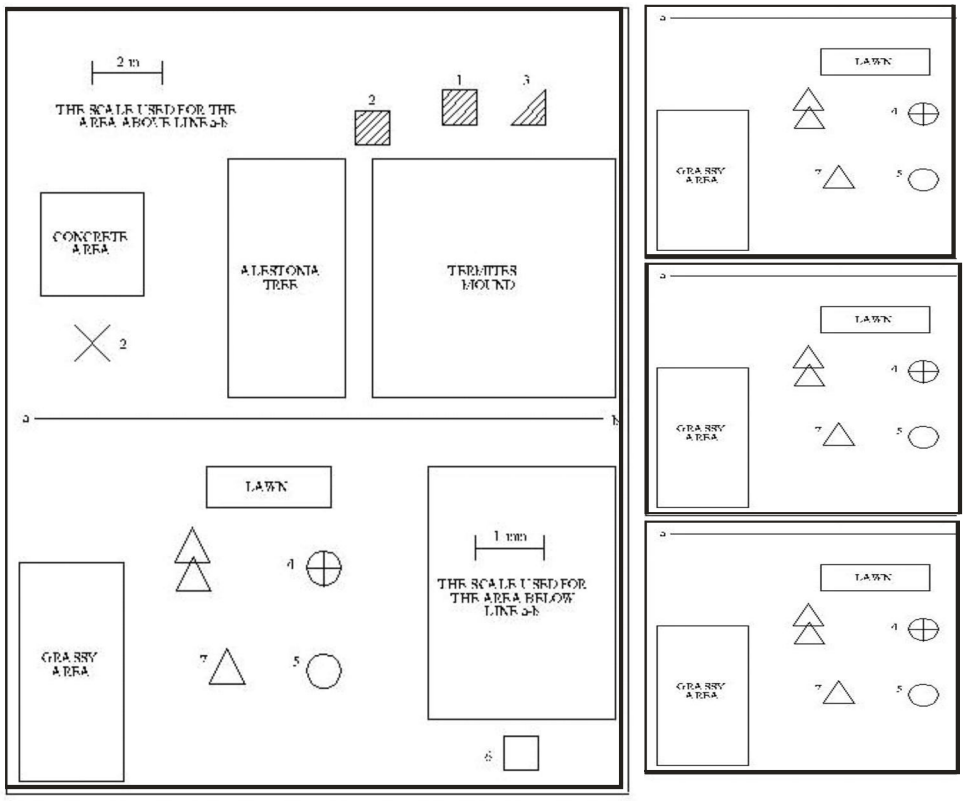
Foraging activity of C. heimi *(Wasmann) in three colonies*

In colony A, maximum marked termites were found in 2 and 3 collection traps. During three recapture cycles, the maximum distance and underground foraging depth was observed. The underground foraging activity was observed in the traps which were set up at the depth of 10, 30 and 45 cm. No observable activity was found in remaining traps. Furthermore, the highest foraging population (870) was observed at the depth of 30 cm (Table II). It was indicated by mean number of foragers collected from each depth. The presence of maximum number of soldiers (9.2%) was observed at the depth of 10 cm. As indicated in Table III, mean body weights of individual worker and soldier were 2.72±0.03 mg and 2.35±0.01 mg (mean±SD), respectively. As far as foraging activity in colony B is concerned, marked termites were found in 4, 5 and 7 monitoring collection traps.

Table III.- Mean individual body weight of workers and soldiers of three colonies of subterranean termite *Coptotermes heimi* (Wasmann).

Colonies	Mean individual body weights (mg ± SD)	
	Workers	Soldiers
A	2.72± 0.03	2.35±0.01
B	2.71 ±0.02	2.42 ±0.03
C	2.77±0.03	2.40±0.08

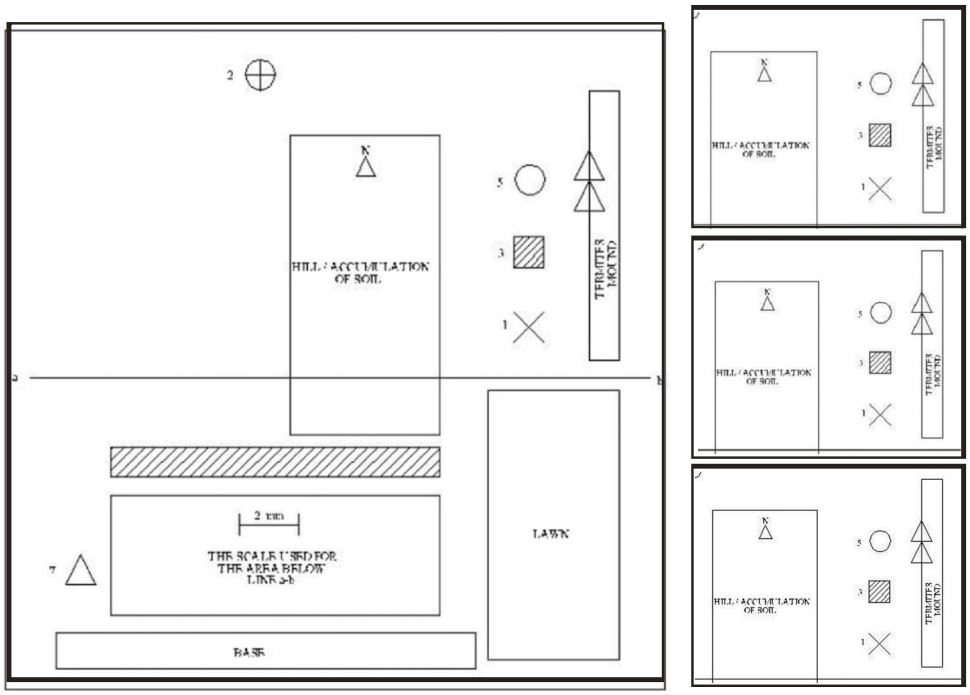
On the basis of observation, it was indicated that foraging distance was found to be up to maximum of 30 cm, with highest activity of foragers (approximately 795) at the depth of 30 cm



SYMBOL		TRAP DISTANCE (cm)	NO		TRAP DEPTH (cm)
×	=	50	1	=	30
○	=	100	2	=	45
△	=	150	3	=	60
▨	=	200	4	=	70
◢	=	300	5	=	85
□	=	500	6	=	100
⊕	=	1000	7	=	115

Fig. 1.Observation of foraging territory of *C. heimi* (Wasmann) (Colony A) at Jallo Forest , Lahore. B, C, D are parallel magnification of the foraging territory. A, Initial setup of 8 traps; B, first observation; C, second observation; D, third observation.

and at the depth of 10 cm, highest soldier proportion was 10.5% (Table II). As indicated in table 3, mean body weights of individual worker and soldier were 2.71±0.02mg and 2.42±0.03mg (Mean±SD), respectively. A slightly different result was observed with 3, 6 and 7 monitory collection traps in colony C. With regard to maximum foraging distance and foraging depth, colonies B and C gave almost similar results. The highest number of foragers (approximately 820) was found to be actively present at the depth of 30 cm with highest soldier proportion (11.5%) at the depth of 10 cm. The results clearly demonstrated that there was positive correlation between temperature and relative humidity of the soil whereas negative correlation was observed between population and atmospheric temperature.



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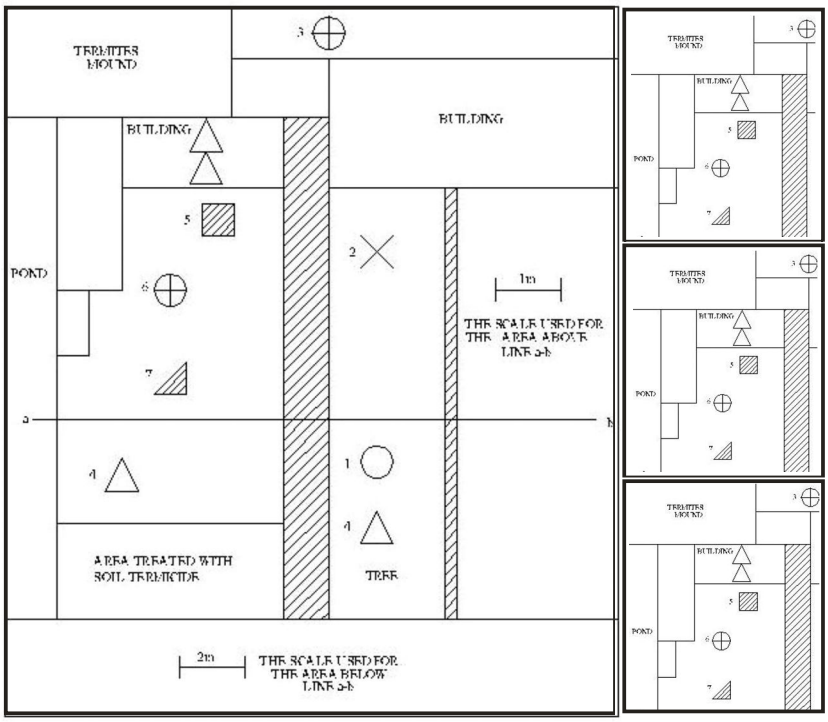
⊕	=	1000	7	=	115

Fig. 2. Observation of foraging territory of *C. heimi* (Wasmann) (Colony B) at Jallo Forest , Lahore. B, C, D are parallel magnification of foraging territory. A, initial setup of 7 traps; B, first observation; C, second observation; D, third observation.

DISCUSSION

The foraging patterns of termite species have been investigated by many investigators (Su *et al*., 1984; Su and Scheffrahn, 1988; Grace *et al*., 1989; Sornnuwat *et al*., 1996; Costa-Leonardo *et al*., 2005; Casarin *et al*., 2008). The present study demonstrated that foraging territory of *C. heimi* (Wasmann) was very small as compared with that of other subterranean termite species. Su and Scheffrahn (1988) investigated the foraging activity of Formosan subterranean termite, *C. formosanus* (Shiraki). The results of their studies indicated that this species extended its galleries up to 100m and its foraging territory ranged from about 126 to 3, 5712 per colony. On the other hand, findings of Grace *et al.* (1989) and Grace (1990) showed that western subterranean termite, *Reticulitermes flavipes* (Kollar), extended foraging distance up to 41 – 79m and covered an area of approximately 285-1,091m^2.



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△	=	150	3	=	60
▨	=	200	4	=	70
◿	=	300	5	=	85
□	=	500	6	=	100
⊕	=	1000	7	=	115

Fig. 3.Observation of foraging territory of *C. heimi* (Colony C) at Jallo Forest , Lahore. B, C, D are parallel magnification of oraging territory. A, initial setup of 8 traps; B, first observation; C, second observation; D, third observation.

Mean individual worker weight of three colonies of *C. heimi* (Wasmann) was 2.72 - 2.77mg (Table III) which were smaller than those 2.9 to 6.0mg of *C. formosanus*, as investigated by Su and Scheffrahn (1988). From the results of present study, it can be assumed that suitable environmental conditions for *C.* (Wasmann) feeding activity are provided at the depth of 300mm below ground surface. These findings are well supported by studies of La Fage *et al.* (1976) with respect to desert subterranean termite, *Gnanthamitermes perplexus*. Studies on foraging territory by Sornnuwat (1996) showed that percent soldier proportion was relatively higher at the depth of 150mm or 300mm, in case of *C. gestroi* (Wasmann). However, a contradiction was observed at 10mm depth rather than 300mm or 450mm with *C. heimi* (Wasmann) in our study.

As regard with the depth of foraging patterns, table 3 indicated that maximum availability of

workers and soldiers of *C. heimi* (Wasmann) was observed at the depths of 10cm, 30cm and 45cm. Similar findings were reported by Chutibhapakorn *et al.* (2000) while working on different termite species. According to their findings, maximum depth of foraging activity of *Coptotermes gestroi, Macrotermes gilves* and *Odontotermes feae* (Wasmann) could reach the depth of 90cm, while *Microtermes obesi* (Holmgren), *Hypotermes wakhamensis* and *Odontotermes proformosanus* were having maximum depth of 60cm. *Globitermes sulphureus* was able to forage at the depth of 45cm under soil surface, and this distance was also attained by *C. heimi* (Wasmann) workers, in our study. The variation in depth of foraging activity might be due to the accessibility of food source and soil moisture requirements of the particular species. As soldier caste is only 10% of the entire termite colony, most of the foraging activity is carried out by worker caste, which constitutes about 90% of the whole termite colony. These observations were clearly noticed while studying the foraging patterns of *C. heimi* (Wasmann) (as indicated in Table II). These findings are further supported by Grace (1989) and Casarin *et al.* (2008). Haverty *et al.* (1999) also studied the effect of environmental factors and also observed the variation in the population of termites in different seasons of the year. Fei and Henderison (2004) also supported the present study and also concluded that soil temperature affected the foraging activities. All literature reviewed papers support the present study that relative humidity, soil temperature and total population of termites were found positive but non significantly correlated while atmospheric temperature had negative but nonsignificant impact on population of termites.

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