Agricultural Science Research Journal
ISSN 2026-6073
Fathelrahman I.E, Volume (8) Issue (7): 159 – 166 July – 2018. RESEARCH PAPER

Effect of ambient temperature and relative humidity on foraging activity of Termite Microtermes spp. (Isoptera: Microtermitinae) in Sinnar State, Sudan

Fathelrahman Ibrahim Elsiddig

Department of Plant Protection, Faculty of Agriculture, Sinnar University, Sudan

Email: elsiiddig@gmail.com

Author

Fathelrahman Ibrahim Elsiddig

Department of Plant Protection, Faculty of Agriculture, Sinnar University, Sudan

Email: elsiiddig@gmail.com

Abstract

Afield study was carried out at two experimental sites in Sinnar State during April- July 2014, to assess the effect of relative humidity and temperature on the foraging activities of termite species belonging to the Ganus *Microtermes* in tree canopy and open areas. The first site is located at the eastern bank of the Blue Nile River (Elsuki locality- Hilatsaeed) while the second site is located at the western bank of the Blue Nile River (Abuhujar locality- Sairo). Randomized Complete Block Design with four replicates was used to perform this study. Treatments in each site are executed in an area of four plots 10×10 m^2. Ten wood baits were placed horizontally along rows of 2 m a part, giving a total of 400 baits per two treatments. The baits were then examined for termite damage at two weekly intervals and the number of attacked baits was expressed as percentage. The collected data was subjected to statistical analysis using Statistical Analysis System (SAS) computer package. The results showed that there were fairly marked differences in the levels of infested wood baits laid in trees canopy compared to levels of infested wood baits laid in open-areas. The termites foraging activity in tree canopy is greater than that in open areas. It is worth noting that infestation of wood baits by termites increased as temperature decreased and relative humidity increased.

Key Words: Termites, Foraging activity, *Termites dynamics*, Isoptera

Introduction

Termites, a common name for numerous species of insects, comprising the order Isoptera, a latin term referring to the fact that adult termites have two pairs of wings that look very much alike. The infra order name is derived from the Greek wordsiso (equal) and Petra (winged), which refers to the nearly equal size of the fore- and hind-wings (Bignell, 2010).

Termites feed mainly on wood and other materials containing cellulose. This Termite predilection to feeding on wood has always put them in conflict with man. The Sudan is a vast country with a total area of about 2.5 million square kilometer. The country is populated by approximately 30.5 million (Elshafie, 2001). Eighty percent of the work force is engaged in agriculture and is living in the country side. The Sudan is climatically and geographically very divers, containing deserts, Semi-deserts, shrubby and woody savanna lands. The Sudan termite fauna also reflects this topological and climatologically diversity. Some Sudan termites are destructive feeders and can cause damage to agricultural crops and homes. Several published studies provide valuable overview of termites as pests of crops in Sudan (Schmutterer,1969;Kambal,1975; Abushama and kambal,1977;Wood and Kambal,1984; AbdElnour, 1985; Elbakri,1986;Tiben *et al*.,1990; Dawes-

Gromadzki,2005). The most economically important termite genera which attack crops in Africa are Microtermes, Odontotermes, Macrotermes and Trinervitermes (Pearce, 1997). In Sudan, at Kenana area, *Microtermes thoracalis* were reported attacking sugarcane (Elnour and Eljack, 2001). Groundnuts foliage, stems, roots and pods can also be attacked by termites. Termite damage to pods paved the way for fungal infection and production of which aflatoxin is poisonous and carcinogenic, and therefore reduces the market price of groundnut (Hassan, 1995). In Sudan, the roots of cotton plants were penetrated by Microtermes (Pearce, 1997)

Both the worker and soldier castes lack wings and therefore never fly so termites are predominantly reliant upon their legs to move around (Bignell, 2010). Workers do not forage unprotected and are rarely found out in the open. They rely on sheeting and runways to protect them from predators (Bignell, 2010). Foraging workers use semi chemicals to communicate with each other (Costa-Leonardo *et al*., 2013). In one species, *Nasutitermes costalis*, there are three phases in a foraging expedition: first, soldiers scout an area. When they find a food source, they communicate to other soldiers and a small force of workers starts to emerge. In the second phase, workers appear in large numbers at the site. The third phase is marked by a decrease in the number of soldiers and an increase in the number of workers. The most efficient forager is able to build over non-woody material, to forage over long distances and have efficient defensive castes (Costa-Leonardo *et al*., 2013).

Daily and seasonal factors affect termite activity, distribution and population dynamics. Moisture is the major factor closely linked to temperature that affects termite activity. Changes in environmental conditions cause changes in termite behavior. The special structure of colonies depends on environmental conditions. Some termites are more tolerant to environmental factors, this can depend on the size or degree of sclerotization of the cuticle as well as on adaptations linked to their normal habitat (Cornelius and Osbrink, 2010).The termite's activity is associated with the temperature. It is high during the spring and summer. However, an increase in temperature, evening the winter months, can cause an increase in activity (Lewis *et al.*, 2011). Activity is also lowest during the morning, and peaking in the late afternoon. As the termites become more active, they have an increase in the release of CO_2 (Shelton, 2001). Turner (2001) mentioned that termites require relative humidity around 70% to 80%. However, the nest mean temperature is 26.16^{O}C ± 4.18^{O}C in winter and 31.73^{O}C ± 2.94 in summer. Temperature and relative humidity (RH) play a vital role in influencing foraging behavior of desiccation prone termites (Bignell*et al*., 2010). No previous studies were undertaken to determine the best combination of temperature and RH for foraging of termite in Sudan. The objective of the presents study is to assess the influence of temperature and relative humidity which prevail in trees canopy and in open areas on foraging activity of the termite (*Microtermisthoracalis*) in two different locations in Sinnar State.

Materials and Methods

The study area

This study was conducted in tow different sites during the period from April 2014 to July 2014 in Sinnar State. The first site was Siro (Abuhujar locality) orchard situated at western bank of the Blue Nile River (Latitude 12.49^{0} North, Longitude 33.59^{0} East and Altitude 429 meters above sea level).The second site was at Hilat Saeed (Suki locality) orchard situated at the eastern bank of the Blue Nile River (Latitude13.15^{0} North, Longitude 33.94^{0} East, and Altitude 436 meters above sea level). The soil of the research site is predominately loamy soil composed of loam, sand and organic matter (Annony., 2015).The climate of the region is described as tropical savanna where annual rainfalls range from 350 to 450 mm The mean maximum and minimum monthly temperature range from 40.9° C in April to 33.2°Cin July and from 25.4° c in April to 23° c in July, respectively (Annony., 2015)..

Experiment and sampling

An area of 25 X 25 m^2 was marked out in Abuhujar and in Elsoki. In each site plant leaves, twigs and other organic matters were cleaned to avoid competition with the experimental baits in the attraction of termites. The area was subsequently divided into four equal size plots each measuring 10m X10 m^2 with a 3 m between each two adjacent plots. In each plot 10 parallel rows, 1 m a part were measured, ten popular wood baits 10X2X2 cm were laid horizontally along each row at 1 m spacing, thus making 100 baits on each of four replicate plots total 400 baits per treatment under shade (the major plant community consist of adult *Acacia sp*. trees) and / or open space (receives direct sunlight for almost the entire day). The ten wooden baits along each row were examined for termite damage at 2-weeks intervals. Attacked baits were replaced by new baits on each monitoring occasion. The number of attacked baits was expressed as percentage of the initial number. Average monthly temperature and RH for Siro site taken from Abunaama Metrological Station, 7km distanced from the experiment site.

Statistical Analysis

The data collected were subjected to arcsine transformation and analysis was carried out using (SAS/ STAT, 1999) method of analysis. Means were compared according to Duncan's Multiple Range Test (DMRT).Results of analysis was presented as Means ± standard Error (SE).

Result and Discussion

Foraging activity in various termite species is influenced by an array of biotic and a biotic factor. Of the a biotic factors, RH and temperature, play a vital role in affecting foraging behavior that ultimately determines their survival (Evans and Gleason 2001; Daves-Gromadski and Spain 2003; Potter, 2004; Mesenger and Su 2005; Moura et

al. 2006)).The present study sought to assess the influence of ambient temperature and relative humidity on the foraging activities of termite in Siro and Hillatsaeid- Sinnar state in the Sudan.

Termites foraging activity at Siro site

The lowest mean damage to wood baits placed on the soil surface in trees canopy occurred in15thMay (48.85) (Table 2) where the ambient temperature was34.4°c and RH of 51% (Figure 1). On the other hand, the highest mean damage was recorded in 15thJune (57.99) (Table 2) with temperature at 31.3°c and RH at 58% (Figure 1). This result suggested that the small decrease in ambient temperature accompanied by a moderate rise in relative humidity added advantage for termites' activity. However, Abdul Sattar et al. (2013) stated that foraging activity of *Microtermes obesi* and *Odontotermes lokanandi termites* colonies appeared to be dependent on temperature. They found that on average, greater percentage of wooden stakes were attacked in summer than in winter. They continued that analysis of the number of termites captures by termites trap and environmental factors indicated that maximum temperature and precipitation influenced the foraging activity of either mentioned species of termites, while relative humidity did not influence the foraging activity. Termite attack, temperature and humidity data can be seen in table 1.

Table 1: Termite attack, temperature and humidity during 3 months exposure period (15thApril-15thJuly, 2014)

	trees canopy			open area		
	Termite attack	Temperature (^{0}C)	RH (%)	termite attck	Temperature (^{0}C)	RH (%)
15th/April	55.35	36.5	34	51.96	40.9	32
1st/May	55.59	34.4	51	40.89	39.8	49
15th/May	48.85			48.51		
1st/June	55.12	31.3	58	40.91	37.8	62
15th June	57.99			37.9		
1st/July	57.99	29	78	35.44	33.2	80
15th/July	54.5			39.98		

At low relativity humidity, mean attack on wood baits in the open area tend to be high. At high temperature in the open area, mean attack on wood baits tend to be high. But there isn't correlation between mean attack on wood baits and climate (temperature and relativity humidity) under trees canopy. This is not in line with Shanbhang and Sundararaj (2011), who reported that the correlation of termite catch with climatic conditions indicated that the activity of *Odontotermes. obesus*, *Odontotermes. horni* and *Odontotermes. feae* was significantly correlated with minimum temperature, maximum soil temperature, minimum relative humidity, total rainfall and number of rainy days. However, Evans and Gleason (2001) stated that foraging activities of termites have been correlated with both temperature and rainfall.

Table 2: Mean attack on wood baits placed in trees canopy in Abuhujar site (Sairo) during 3 months exposure period (15thApril-15thJuly, 2014)

Rows of wood baits	1	2	3	4	5	6	7	8	9	10	Mean
15th/April	58.28ab (70)	51.34ab (60)	64.18ab (80)	38.67ab (40)	32.90b (30)	41.99ab (45)	73.40a (85)	50.90ab (60)	57.11ab (70)	50.90ab (60)	55.35
1st/May	45.00a (50)	47.88a (55)	57.10a (70)	50.89a (60)	35.33b (70)	64.17a (80)	67.50a (85)	45.00a (50)	53.78a (65)	67.50a (85)	55.59
15th/May	63.83a (80)	57.10a (70)	42.11bc (45)	47.88abc (55)	36.22c (35)	53.84ab (45)	56.79ab (70)	50.77abc (60)	35.78c (35)	56.79ab (70)	48.85
1st/June	57.10ab (70)	67.50a (85)	54.22ab (85)	56.79ab (70)	45.00b (50)	50.89ab (60)	54.22ab (65)	54.22ab (65)	63.44ab (80)	47.88ab (35)	55.12
15th June	63.44a (80)	56.79a (70)	50.77a (60)	64.17a (80)	45.00a (50)	63.44a (80)	56.79a (70)	61.16a (75)	60.11a (75)	58.28a (70)	57.99
1st/July	64.18ab (80)	50.77ab (60)	54.22ab (65)	53.78ab (65)	54.22ab (65)	48.01ab (55)	48.01ab (55)	47.99b (45)	53.79ab (65)	71.56a (90)	57.99
15th/July	54.22a (65)	54.22a (60)	56.79a (70)	57.11a (70)	61.17a (75)	64.18a (80)	50.90a (60)	48.01a (55)	48.01a (55)	61.17a (75)	54.5
Mean	58.01	55.09	56.10	52.76	44.26	55.22	58.23	51.15	53.15	59.16	

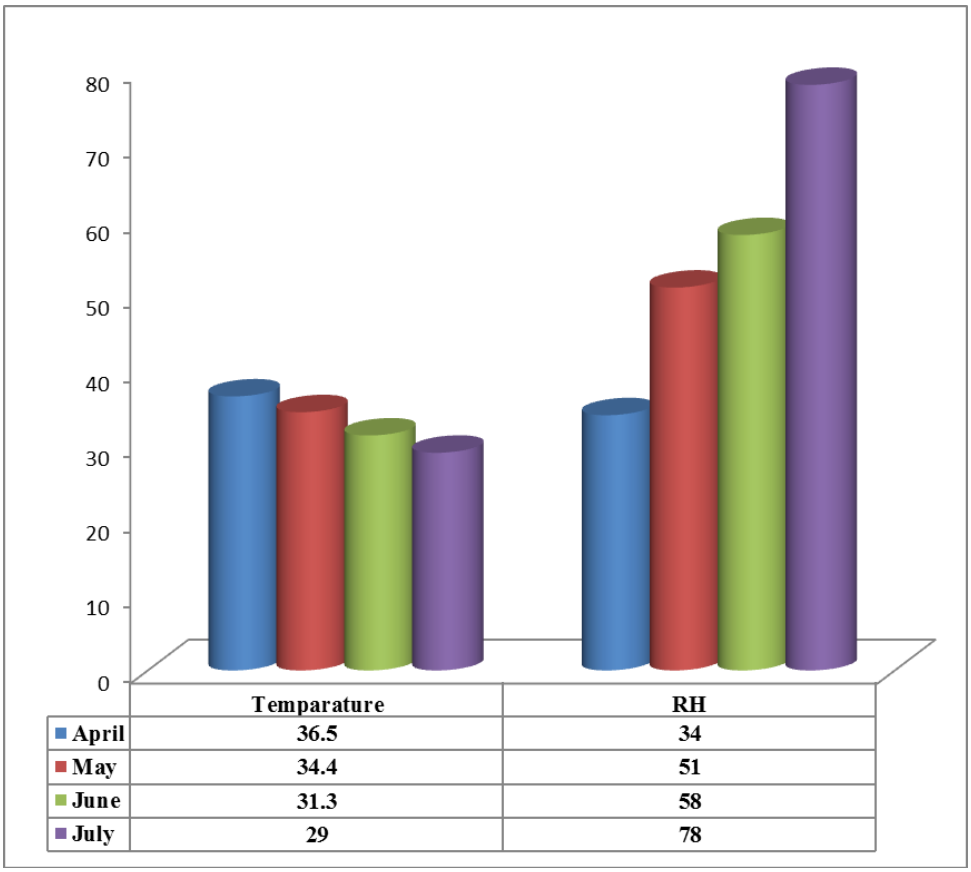
Means with same letter (letters) along a horizontal column are not significant at (0.05) probability level according to Duncan's Multiple Range Test (DMRT); data between parentheses are the actual data

Levels of foraging activity on wood baits placed in the open area are shown in (Table 3), where baits were attacked throughout the exposure period which extended from 15thApril to 15thJuly.The maximum mean damage was recorded in 15thApril (51.96) with temperature at 36.5°c and RH at 34 % (Figure 1).The lowest mean damage occurred in 1stJuly (35.44) with temperature at 29.0°c and RH 78% (Figure1). This result indicated that the combination of low temperature (29.0°c) and high relative humidity (78%) in July did not enhance foraging and this was not expected and was not in consistent with Potter (2004) who stated that low temperature and high relative humidity influence foraging behavior of termites. He continued that subterranean termites are very vulnerable to desiccation and require a constant supply of moisture, in addition temperature has strong influence on termites foraging and seasonal activity. Furthermore Mao et al. (2005) and Scharf et al. (2007) reported that caste composition in social insects can be influenced by environmental factors such as temperature.

Table 3: Mean attack on wood baits placed in open areas at Abuhujar site (Sairo) during 3 months exposure period (15th April-15th July, 2014)

Rows of wood baits	1	2	3	4	5	6	7	8	9	10	Mean
15th/april	48.33a (70)	61.61a (60)	45.00a (80)	45.00a (40)	57.11a (30)	36.44a (45)	61.17a (85)	52.39a (60)	80.78a (70)	38.67a (60)	51.96
1st/may	45.00a (50)	41.68a (45)	45.00a (50)	45.00a (50)	41.68a (45)	41.61a (35)	54.22a (65)	29.89a (25)	38.67a (40)	33.21a (30)	40.89
15th/may	51.76ab (65)	50.89ab (60)	47.88ab (55)	45.00ab (50)	57.10ab (70)	50.74ab (60)	60.10a (75)	45.00ab (50)	46.22ab (35)	38.66ab (40)	48.51
1st/june	51.33a (60)	33.21a (30)	39.10a (40)	39.33a (40)	32.89a (30)	45.00a (50)	45.00a (50)	45.00a (50)	39.10a (40)	39.23a (40)	40.91
15th june	39.00ab (25)	47.88ab (50)	53.78a (65)	29.88b (25)	39.23ab (40)	29.00b (15)	47.88ab (55)	32.82b (20)	47.88ab (55)	41.61ab (45)	37.90
1st/july	33.32bc (20)	33.71bc (15)	45.00ab (50)	50.77a (60)	39.10abc (40)	26.50bc (20)	42.11ab (45)	44.11ab (40)	45.00ab (50)	32.32bc (20)	35.44
15th/july	50.89a (60)	45.00a (50)	47.88a (55)	29.88a (25)	45.00a (50)	45.00a (25)	29.88a (55)	48.01a (35)	35.78a (50)	45.00a (15)	39.98
Mean	45.66	44.85	46.23	40.69	44.58	39.18	48.62	42.46	47.63	38.38	

Means with same letter (letters) along a horizontal column are not significant at (0.05) probability level according to Duncan's Multiple Range Test (DMRT); data between parentheses are the actual data.



Termites foraging activity at Helat Saeed site

Foraging by termites in the tree canopy at this site followed a fluctuating pattern (up and down) throughout the experimental period (Table 4). The lowest mean damaged baits occurred in15th April (45.79) with temperature at 40.9°c and RH at 32% (Figure 2).On the other hand, the highest damage was recorded in 15th May (58.32) with temperature at 39.8°c and RH at 49 %(Figure 2). It is interesting to notice that a decrease in temperature as small as 1% (40.9°c to 39.8°c) was adequate to increase foraging activity of termites resulting in high damage to wood baits. This result agreed with that of Nakayama et.al (2004) and Fie and Henderson (2002), they reported that the highest feeding rate of another species of subterranean termites *Coptotermes formosanus,* was observed at a temperature of 30°C.

Foraging activity by termite in open area at the same site followed an increasing pattern during April and early May, then followed by a sudden decline in mid-May and continued steadily thereafter up to the end of the experimental period. The lowest mean damage to wood baits (37.10) (Table 5) was found in 1st July with temperature at 33.2°c and RH at 80% (Figure 2), whereas , the highest damage to wood baits (55.51) (Table 5) was recorded in 1st May with temperature at 39.8°c and RH at 49% (Figure 2). The results of foraging activity in the open area indicated that some termite species might have a wide range of acceptable temperature and relative humidity levels. Generally the findings of this study suggested that foraging by termites in tree canopies was influenced by temperature and relative humidity. This approves the statement mentioned by Renaud *et al*. (2011) that tree canopy and tree transpiration has moderating effect on meteorological parameters such temperature and relative humidity. However, Gautam and Hnderson (2011) revealed that *Coptotermes formosanus* showed a tendency of higher survival at higher relative humidity (98%) and medium temperature (28°C).

Table 4: Mean attack on wood baits placed in trees canopy in Elsuki site (Hilatsaeed) during 3 months exposure period (15th April-15th July, 2014)

Rows of wood baits	1	2	3	4	5	6	7	8	9	10	Mean
15th/April	45.00^{a} (50)	45.00^{a} (50)	33.21^{a} (30)	51.34^{a} (60)	51.44^{a} (50)	55.40^{a} (55)	52.39^{a} (60)	41.68^{a} (45)	39.34^{a} (25)	67.50^{a} (85)	47.90
1st/May	56.79^{ab} (70)	50.77^{b} (60)	50.22^{b} (65)	46.18^{ab} (80)	60.12^{ab} (75)	61.17^{ab} (75)	42.12^{b} (45)	39..11^{b} (40)	51.34^{b} (60)	80.78^{a} (95)	56.10
15th/May	53.78^{a} (65)	51.34^{a} (60)	54.22^{a} (65)	64.18^{a} (80)	64.18^{a} (80)	58.28^{a} (60)	48.01^{a} (55)	55.40^{a} (65)	63.44^{a} (80)	70.39^{a} (80)	58.30
1st/June	42.12^{a} (45)	36.22^{a} (35)	50.77^{a} (60)	45.00^{a} (50)	63.44^{a} (80)	53.78^{a} (65)	47.89^{a} (55)	45.00^{a} (50)	52.50^{a} (50)	47.89^{a} (55)	47.70
15th June	67.50^{a} (85)	56.79^{cde} (70)	63.44^{bc} (80)	53.78^{def} (65)	47.88^{f} (55)	50.77^{ef} (60)	56.79^{def} (70)	71.56^{a} (90)	60.10^{bcd} (80)	47.88^{f} (55)	57.70
1st/July	60.12^{a} (75)	60.17^{ab} (75)	53.78^{ab} (65)	48.01^{ab} (55)	61.17^{ab} (75)	60.12^{ab} (75)	45.00^{ab} (50)	39.11^{b} (40)	42.12^{b} (45)	73.40^{a} (85)	54.40
15th/July	61.16^{a} (75)	57.10^{ab} (70)	45.00^{ab} (50)	45.00^{ab} (50)	45.00^{ab} (50)	57.10^{ab} (70)	64.17^{a} (80)	53.79^{ab} (65)	63.44^{a} (80)	36.22^{b} (35)	52.80
Mean	55.22	51.05	50.09	50.49	56.17	56.66	50.91	49.37	53.18	60.58	

Means with same letter (letters) along a horizontal column are not significant at (0.05) probability level according to Duncan's Multiple Range Test (DMRT); data between parentheses are the actual data.

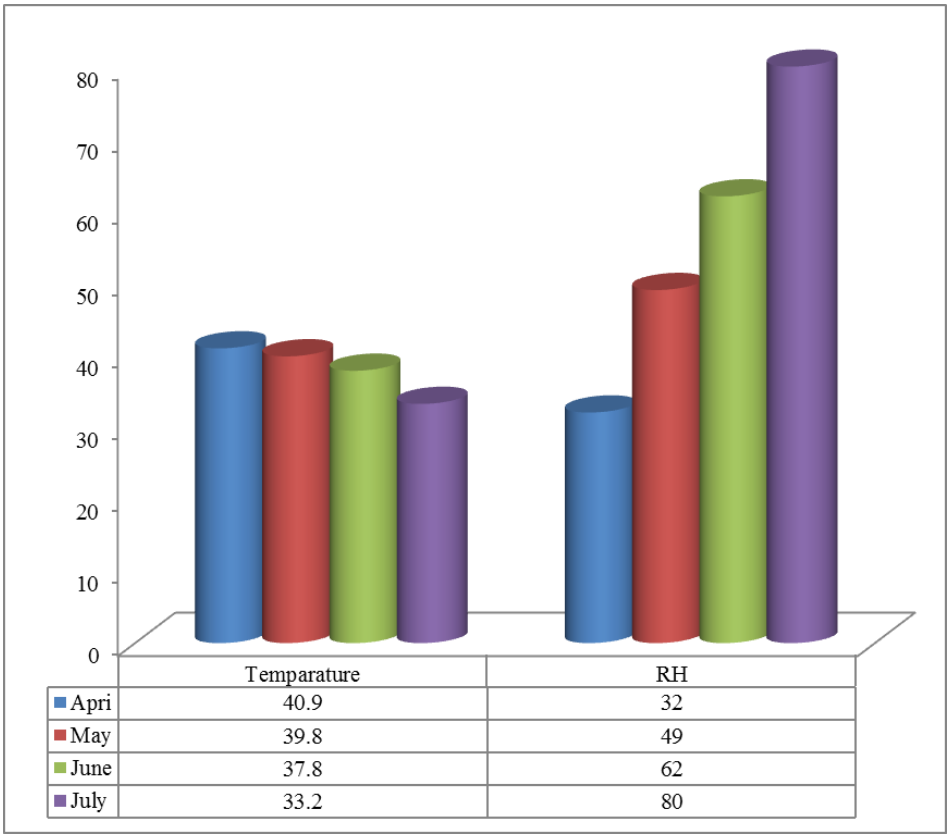


Table 5: Mean attack on wood baits placed in open area in Elsuki site (Hilatsaeed) during 3 months exposure period (15th April-15th July, 2014)

Rows of wood baits	1	2	3	4	5	6	7	8	9	10	Mean
15th/April	45.00^{abc} (50)	50.77^{ab} (60)	29.89^{bc} (25)	29.89^{bc} (25)	23.50^{c} (15)	35.61^{abc} (35)	35.78^{abc} (35)	47.89^{abc} (55)	61.17^{a} (75)	39.11^{ab} (40)	39.76
1st/May	56.79^{a} (70)	63.44^{a} (80)	61.17^{a} (75)	47.89^{a} (55)	57.11^{a} (70)	56.79^{a} (70)	57.11^{a} (70)	60.12^{a} (75)	38.62^{a} (40)	57.11^{a} (70)	55.50
15th/May	41.68^{abc} (45)	36.22^{abc} (35)	26.56^{bc} (20)	38.33^{ab} (55)	54.22^{a} (65)	20.44^{c} (10)	50.90^{ab} (60)	45.00^{abc} (50)	36.22^{abc} (35)	48.01^{ab} (55)	42.40
1st/June	48.01^{a} (55)	29.84^{a} (25)	29.89^{a} (25)	35.78^{a} (35)	33.21^{a} (30)	41.68^{a} (45)	42.12^{a} (45)	33.21^{a} (30)	50.77^{a} (60)	53.78^{a} (65)	39.70
15th June	36.22^{abc} (35)	53.78^{a} (65)	54.22^{a} (65)	38.66^{abc} (40)	45.00^{abc} (50)	26.82^{bc} (20)	47.88^{ab} (55)	25.82^{c} (20)	42.11^{abc} (45)	29.88^{bc} (25)	39.90
1st/July	29.88^{a} (25)	42.11^{a} (45)	42.11^{a} (45)	39..23^{a} (35)	41.99^{a} (60)	38.66^{a} (35)	36.22^{a} (35)	31.72^{a} (25)	18.44^{a} (10)	41.99^{a} (45)	37.10
15th/July	36.22^{a} (35)	45.00^{a} (50)	41.68^{a} (45)	45.00^{a} (50)	35.78^{a} (35)	33.21^{a} (30)	45.00^{a} (50)	25.83^{a} (20)	50.90^{a} (60)	32.90^{a} (30)	39..20
Mean	41.97	45.88	40.78	44.96	40.25	36.17	40.00	38.51	42.60	42.82	

Means with same letter (letters) alonga horizontal column are not significant at (0.05) probability level according to Duncan's Multiple Range Test (DMRT); data between parentheses are the actual data.

Conclusions

The ecological considerations to know the minimum, maximum and optimum temperature and relative humidity, that enable termites to maximize their foraging activity, was very important in suggestion of termites control strategies. Accordingly, conclusions could be drawn that termites damage increases with the increase of relative humidity, whereas it decreases as temperature increases. However the termites foraging activity in tree canopy is greater than that in open area.

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