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Pest status and seasonal activity of termites in relation to abiotic factors in different field crops

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Abstract
Experiments were carried out to study the seasonal activity of termites in relation to abiotic factors in different field crops during 2016-18. Termite infestation to baits was maximum in the month of October IF (first fortnight) (46.67 %), October IF and May IIF (43.33%) and December IIF and June IF (43.33 %) in Maize, Sunflower and Finger millet ecosystems, respectively during 2016-17. Infestation to bait was maximum in the month of September IIF (56.67 %) in Maize, August IIF, October IF, March IIF, May IIF and July IIF (36.67 %) in Sunflower and September IIF, October IIF and June IF (43.33%) in Finger millet ecosystem during 2017-18. Correlation analysis of termite activity with abiotic factors in different cropping systems from 2016 to 2018 revealed that, total rain fall (r = 0.708), *in situ* soil moisture (r = 0.699) and minimum atmospheric temperature (r= 0.425) had a significantly positive correlation with the bait infestation under maize cropping system. Significant, positive correlation was observed between bait damage and total rainfall (r = 0.549), *in situ* soil moisture (r = 0.472), minimum atmosphere temperature (r = 0.351) and minimum soil temperature (r = 0.290) in Sunflower ecosystem. Termite activity was significant negative correlation with the maximum atmospheric temperature (r = -0.396), maximum soil temperature (r = -0.378), sunshine hours (r = - 0.360), minimum soil temperature (r = - 0.304) and *in situ* soil temperature (r = -0.299) in finger millet ecosystem.

Keywords: Seasonal, fort night, *in situ* and correlation

1. Introduction
Termites are highly organized social insects, distributed in tropical and subtropical regions of the world. They are known to live in the nests of their own construction. A colony of termites consists of different casts *viz*., functional reproductives (queen and king), sterile workers and soldiers which are morphologically and functionally distinct. Termites play an important role both as beneficial and harmful creatures in the agricultural, horticultural and forest ecosystems. They play a major role in the disintegration of wood and decomposition of organic matter and other cellulose materials. These are also known to cause significant and serious damages to crops, structures, buildings and forest plantations. Their damage to various crops and forest plantations is noticed throughout the tropics. Field crops such as pearl millet, barley, sorghum, maize, wheat, chickpea, pigeon pea, groundnut, niger, sunflower and cotton are severely attacked especially under rain fed cropping systems. Apart from these, they also cause damage to stored timbers, books, records, woodworks in the buildings and stored products containing cellulose (Rashmi and Sundararaj, 2013) [13].
In India, the losses due to termite have been estimated around 35.12 M US$ (Joshi *et al*. 2005) [6]. Roonwal (1958) [14] reported an entire township in India was gradually destroyed by the termite *Heterotermes indicola* (Wasmann). Annual losses caused by termites in the USA and Japan are 1000 and 800 M US$. Globally, the estimated loss due to termite damage is about 50 billion US$ annually (Subektia *et al*., 2015) [15], although estimates vary considerably by the cropping systems followed in different geographical regions.
With this background an attempt was made to analyze the foraging activity of termites and effect of abiotic factors on the foraging intensity of termites in the field crops during cropping and non-cropping period.

2. Materials and Methods
The experiment was conducted from 2016 to 2018 in the field crops of maize, sunflower and finger millet under rain fed conditions during cropping and non-cropping period to determine the pest status of termites and influence of abiotic factors on the activity of termites. The size of each experimental plot was 4 × 5 m.

2.1 Monitoring of termite activity

Naturally dried wooden sticks (bait) of silver oak measuring 7 cm long were used as baits for scouting termites. These baits were placed at 2 m apart along the bunds and at the centre of each plot during the cropping and non-cropping period. Termite activity was monitored at fortnight interval. Once the bait was infested it was replaced with new one and monitoring was continued. Termite workers along with the soldiers feeding on the baits were collected using camel hair brush and preserved in vials (5 × 1 cm) containing 70 per cent ethyl alcohol and labelled for identification. *In situ* soil temperature and moisture were recorded during observations.

$$\text{Per cent incidence} = \frac{\text{Number of baits infested}}{\text{Total number of baits placed}} \times 100$$

2.2 Impact of abiotic factors on the seasonal activity of termites in different crops

The influence of abiotic factor on the activity of termite was monitored in maize, sunflower and finger millet. Wooden baits of silver oak/ dung were used to monitor the termite activity. Termite infestation was recorded based on the construction of earthen sheeting and damage caused to baits. The sampling was done at the fortnightly interval to know the termite activity. Fortnightly weather data comprising of temperature (both maximum and minimum), rainfall, relative humidity (maximum and minimum) and sunshine hours was collected from the meteorological department of GKVK campus. SPSS 23 package was used to work out the simple correlation, regression and stepwise regression between termite activity and abiotic factor.

3. Results and Discussion

3.1 Incidence of termites on baits in maize, sunflower and finger millet ecosystems during 2016-17

3.1.1 Termites activity in maize field: The infestation recorded in the field ranged from 0.00 to 46.67 per cent. Maximum infestation of bait was recorded during October IF (first fortnight) (46.67 %) followed by December IF (43.33 %) and May IIF (40.00 %). Baits were free from damage during the month of January (I and IIF) and damage of 3.33 and 6.67 per cent was recorded during February (I and IIF) and August and September IF, respectively. Termite incidence was severe during May month with 26.67 and 40.00 per cent damage at IF and IIF, respectively. According to Sudhakar (1983) [16] reported *Microtermes obesi* and *Odontotermes obesus* were dominant causing 90 per cent of total incidence on wood and dung baits in maize cropping system and also noticed increased in termite activity after rain. Earlier reports from India, (Parihar, 1980 and Ashok kumar 1987) [11, 1] and Nigeria (Haverty *et al*., 1976 and Johnson *et al*., 1981) [4, 5] revealed that the termite species of *M. obsei* and *O. obesus* were more active during the months of May-August, which was coincided with maximum number of wet days (Table 1).

3.1.2 Termite activity in sunflower ecosystem: Maximum infestation to bait was recorded during October IF and May IIF with the bait damage of 43.33 per cent. This was followed by 36.67 per cent bait damage during April IF, May IF and July IF. Among these months, more bait damage was noticed in the month of May with 36.67 and 43.33 per cent during I and IIF, respectively. It was followed by October IF and IIF (43.33 and 16.67 % of damage). Baits were free from damage during the fortnights of August IIF, September IF, March IF and IIF. Minimum bait damage of 3.33 per cent was recorded in the standard fortnights of September IIF, November IF and February IF (Table 1). Earlier, Ashok kumar (1987) [1] also reported termite infestation during a short span of four months when there was intermittent rain and their activity slowed down drastically during rest of the year. The less infestation in sunflower ecosystem may be due to non-availability of previous crop residue and frequent inter cultivation also.

3.1.3 Termite activity in finger millet ecosystem: Highest bait damage (43.33 %) was observed during December IIF and June IF. These were followed by October IIF with the infestation of 40 and 36.67 per cent during November IIF. The baits were free from damage during February IIF, March IF, April IIF and June IIF (Table 1). Present findings are corroborate with the findings of Gupta *et al*. (1981) [3] where termite *O. gurdaspurensis* activity was continued throughout the year with its maximum activity during early winter months of October-November. Minimum bait damage of 3.33 per cent was observed during September IF, March IIF, April IF and May IIF and was followed by 6.67 per cent during August IF and February IF. Earlier studies conducted in GKVK, Bengaluru by Kumar (1991) [8] also revealed that distribution of *O. horni* (Wasman) was observed throughout the year in the cultivated crops, orchards, forests and also in the uncultivated fields except in summer months.

3.2 Incidence of termite on baits in maize, sunflower and finger millet fields during 2017-18.

3.2.1 Termite activity in maize ecosystem: Bait damage due to termite was maximum at September IIF (56.67 %) and was followed by September IF (46.67%), May IF (46.67%), October IF (36.67%), May IIF (36.67%) and July IF (36.67%).Baits were free from termite attack during November IIF and January IF. Least bait damage was observed during December IF, January IIF, February IF(3.33 %) and was followed by December IIF and June IIF with the bait damage of 6.67 per cent. Basappa (1984) [2] also reported the maximum termite infestation to dung bait during September and was least during January. Results of Mutsamba *et al*. (2016) [9] showed the activity of termite increased when the maize residues was applied to the field compared to the conventional mould board ploughing (Table 2).

3.2.2 Termite activity in sunflower ecosystem: The baits were free from termite attack at November IF, December IF, January IF, February IF and June IF. The minimum bait damage (3.33 %) was recorded in December IIF and June IIF and was followed by January IIF, May IF with 13.33 per cent damage. Bait damage was more (36.67 %) during the standard fortnights of August IIF, October IF, March IIF, May IIF and July IIF. It was followed by 26.67 per cent incidence during September I and IIF, April I and IIF and July IF (Table 2). Present observations were partial agreement with the study of Kalidas (1986) [7] who reported that foraging activity of *O. horni* occurred during October, November, February, April and May in the cultivated field, whereas it was found during all the months except during December and February under the uncultivated and forest ecosystems.

3.2.3 Termite activity in finger millet ecosystem: Bait damage was maximum (43.33%) during September IIF, October IIF and June IF and was followed by September IF

and June IIF with the infestation of 36.67 per cent. September and June months recorded higher bait damage. Least damage to baits (6.67%) was observed during February IIF and March IF (Table 2) and was followed by 10 per cent damage during January IF and April IIF. Baits were free from termite attack during January IIF and February IF.

3.3 Impact of abiotic factors on the seasonal activity of termites in different crops

3.3.1 Termite activity in maize ecosystem

Based on the relationship established through correlation studies indicated total rain fall (r = 0.708), *in situ* soil moisture (r = 0.699) and minimum atmospheric temperature (r= 0.425) had significant positive correlation with the bait infestation. However, minimum soil temperature (r = 0.253), maximum atmospheric temperature (r = 0.155) and minimum relative humidity (r = 0.095) had a positive correlation with the termite damage to baits. Sunshine hours (r = - 0.261), maximum soil temperature (r = - 0.091), *insitu* soil temperature (r = - 0.049) and maximum relative humidity (r = -0.014) had a negative relation with the bait damage (Table 3). Present findings are corroborate with the observation made by Parihar (1980) [11] where the population density of the termites *O. obesus* Rambur, *O. latiguloides* Roonwal and Verma, *M.obesi* Holmgren and *M. mycophagus* (Desneux) was higher during wet days compared to the non-wet days.

Influence of abiotic factors was 67.60 per cent on the termite activity (Table 4). Stepwise regression analysis showed that an unit increase in the total rain fall and *in situ* soil moisture leads to 0.134 and 1.40 unit increase in the bait damage, respectively. However, unit increase in maximum relative humidity leads to 0.81 unit decrease in the bait damage (Table 5).

3.3.2 Termite activity in sunflower ecosystem

Significant positive correlation was observed among bait damage and total rainfall (r = 0.549), *in situ* soil moisture (r = 0.472), minimum atmosphere temperature (r = 0.351) and minimum soil temperature (r = 0.290). Whereas maximum atmospheric temperature (r = 0.282), *in situ* soil temperature (r = 0.103), maximum relative humidity (r = 0.038) and maximum soil temperature (r = 0.037) were found positive relation with bait damage. Minimum relative humidity (r = -0.083) was found negative correlation with the termite activity (Table 3). When the data was subjected to multiple linear regression analysis, the results showed that the influence of abiotic factors on the bait damage was up to 38.40 per cent (Table 4). An unit increase in the total rain fall and maximum temperature leads to 0.15 and 1.69 unit increase in the bait damage (Table 5). The findings from present investigation is in conformity with the earlier report of Ohiagu (1979) [10] who stated that duration and daily pattern of foraging was partly dependent on temperature with a lower temperature threshold of 20 ^{O}C and an upper threshold of 35 ^{O}C below or above after which foraging was restricted.

3.3.3 Termite activity in finger millet ecosystem

Termite activity was significant and negatively correlated with the maximum atmospheric temperature (r = -0.396), maximum soil temperature (r = -0.378), sunshine hours (r = -0.360), minimum soil temperature (r = - 0.304) and *in situ* soil temperature (r = -0.299). However, minimum atmospheric temperature (r = -0.014) showed negative relation with termite activity. The present results corroborate with the findings of Rajagopal and Veeresh (1981) [12] where they observed reduced foraging activity of *O. wallonensis* with increase in atmospheric temperature and sun shine hours. Significant positive relation was also recorded with minimum and maximum relative humidity (r = 0.411 and r = 0.290). However, bait damage was positively related with *in situ* soil moisture (r = 0.252) and total rain fall (r = 0.142) (Table 3). Influence of abiotic factors on the termite activity was up to 26.20 per cent (Table 4). An unit increase in minimum relative humidity leads to 0.69 unit increase in the termite activity (Table 5). Abiotic factors play an important role in the activity and intensity of termite foraging during cropping and non-cropping period.

Table 1: Incidence of termites on baits in agro-ecosystem during different months of 2016-2017.

Months	Standard fortnight	Bait damage (%)		
		Agro-ecosystem		
		Maize	Sunflower	Finger millet
August -16	I	6.67	13.33	6.67
	II	10.00	0.00	20.00
September	I	6.67	0.00	3.33
	II	10.00	3.33	16.67
October	I	46.67	43.33	26.67
	II	20.00	16.67	40.00
November	I	33.33	3.33	33.33
	II	23.33	20.00	36.67
December	I	43.33	16.67	13.33
	II	20.00	6.67	43.33
January-17	I	0.00	16.67	23.33
	II	0.00	23.33	13.33
February	I	3.33	3.33	6.67
	II	6.67	13.33	0.00
March	I	16.67	0.00	0.00
	II	10.00	0.00	3.33
April	I	13.33	36.67	3.33
	II	33.33	20.00	0.00
May	I	26.67	36.67	20.00
	II	40.00	43.33	3.33
June	I	13.33	16.67	43.33
	II	20.00	13.33	0.00
July	I	26.67	36.67	33.33
	II	13.33	6.67	26.67

Table 2: Incidence of termites on baits in agro-ecosystem during different months of 2017-2018.

Months	Fortnight	Bait damage (%)		
		Agro-ecosystem		
		Maize	Sunflower	Finger millet
August 2017	I	26.67	20.00	13.33
	II	30.00	36.67	30.00
September	I	46.67	26.67	36.67
	II	56.67	26.67	43.33
October	I	36.67	36.67	30.00
	II	23.33	23.33	43.33
November	I	20.00	0.00	23.33
	II	0.00	16.67	26.67
December	I	3.33	0.00	30.00
	II	6.67	3.33	33.33
January 2018	I	0.00	0.00	10.00
	II	3.33	13.33	0.00
February	I	3.33	0.00	0.00
	II	10.00	16.67	6.67
March	I	30.00	23.33	6.67
	II	13.33	36.67	26.67
April	I	16.67	26.67	13.33
	II	33.33	26.67	10.00
May	I	46.67	13.33	26.67
	II	36.67	36.67	23.33
June	I	10.00	0.00	43.33
	II	6.67	3.33	36.67
July	I	36.67	26.67	26.67
	II	20.00	36.67	26.67

Table 3: Correlation between termite incidence and abiotic factors in different cropping system during 2016-18

Particular	Max. temperature	Min. temperature	Max. RH	Min. RH	Sunshine hours	Total rain fall	Min. soil temperature	Max. soil temperature	*In situ* soil moisture	*In situ* soil temperature
Termite incidence to baits in maize plot	+0.155	+0.425**	-0.014	+0.095	-0.261	+0.708**	+0.253	-0.091	+0.699**	-0.049
Termite incidence to baits in sunflower plot	+0.282	+0.351*	+0.038	-0.083	-0.130	+0.549**	+0.290*	+0.037	+0.472**	+0.103
Termite incidence to baits in finger millet plot	-0.396**	-0.014	+0.290*	+0.411**	-0.360*	0.142	-0.304*	-0.378**	0.252	-0.299*

Note: ** Significant at $p \leq 0.01$ level Max- Maximum, Min- Minimum
* Significant at $p \leq 0.05$ level RH-Relative humidity

Table 4: Regression equation between termite incidence and abiotic factors in different cropping system during 2016-18

Particular	Regression equation	R^2 Value
Termite incidence to bait in maize plot	$Y= 11.34+1.51X_1-0.64X_2-1.09X_3+0.37X_4-1.11X_5+0.14X_6+0.13X_7-0.58X_8+1.21X_9+1.80X_{10}$	0.676
Termite incidence to bait in sunflower plot	$Y= -181.90+6.25X_1-3.09X_2+0.80X_3+0.15X_4-1.69X_5+0.12X_6-0.46X_7-0.59X_8+0.76X_9+0.78X_{10}$	0.493
Termite incidence to bait in finger millet plot	$Y= 139.44+0.26X_1+0.59X_2-0.65X_3+0.34X_4-1.42X_5-0.02X_6-3.23X_7+0.25X_8+0.60X_9-0.82X_{10}$	0.262

Note:
a= Constant
X_1 =Maximum temperature
X_2 = Minimum temperature
X_3 = Maximum relative humidity
X_4 = Minimum relative humidity
X_5 = Sunshine hours
X_6 = Total rainfall
X_7 = Minimum soil temperature
X_8 = Maximum soil temperature
X_9 = *In situ* soil moisture
X_{10} = *In situ* soil temperature

Table 5: Stepwise regression analysis showing the significant abiotic factors against termite incidence in different cropping system during 2016-18

Crop	Variable	Multiple regression coefficient	Standard error	't' Value	'F' Value	R^2 Value
Maize	X_6= Total Rainfall	0.134	0.038	3.56**	26.33	0.642
	X_9 =*In situ* soil moisture	1.401	0.373	3.75**		
	X_3 = Maximum relative humidity	-0.810	0.320	-2.53		
Regression equation, $Y= 72.18+0.134X_6+1.401X_9-0.810X_3$						
Sunflower	X_6= Total Rainfall	0.15	0.03	4.71**	14.02	0.384
	X_1= Maximum temperature	1.69	0.69	2.45*		
Regression equation, $Y= - 37.63+0.15\ X_6+1.69X_1$						
Finger millet	X_4 = Minimum relative humidity	0.69	0.22	3.05*	9.32	0.169
Regression equation, $Y= -12.84+0.69X_5$						

Note: ** Significant at $p \leq 0.01$ level
* Significant at $p \leq 0.05$ level

Conclusion

From the field experiment it was evident that termites activity varied among the field crops. Abiotic factors were the major factors in determining the intensity of the termites foraging and extent of damage.

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