

## DOES SOIL SURFACE TEMPERATURE INFLUENCE THE DAILY AND SEASONAL FORAGING ACTIVITY PATTERNS OF *TRICHOMYRMEX SCABRICEPS* ANT COLONIES?

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**ABSTRACT :** Insects are known to show changes in their foraging behaviour with respect to environmental conditions, such as light, temperature and humidity. However, very few studies have focused on the influence of temperature on the daily and seasonal activity patterns of ant species. While, the colonies of *Trichomyrmex scabriceps* ants are reported to occur in many parts of India, particularly in the arid and semi-arid regions, its foraging ecology is still unknown. The present study is aimed at investigating the influence of soil temperature on the foraging activity patterns of *T. scabriceps* colonies. The soil surface temperature and concomitantly the daily foraging activities, in terms of the number of ant foragers exiting and returning to the active, main nests of *T. scabriceps* was recorded regularly, at hourly intervals (from 6:00h to 19:00h), during three different seasons, summer, winter and rainy, in three managed ecosystems. The results of the field observations revealed that the number of foragers leaving the nest was always higher before mid-day (the peak foraging period) while the number of returning foragers was higher during the post-noon period. Although *T. scabriceps* colonies preferred the warmer parts of the day, for active diurnal and unimodal foraging, their activity was limited by the maximum ( $42^{\circ}\text{C}\pm 2^{\circ}\text{C}$ ) and the minimum ( $18^{\circ}\text{C}\pm 2^{\circ}\text{C}$ ) critical temperatures of the soil. The study showed that the soil surface temperature not only influenced the onset and the decline of their foraging activities but also affected the peak foraging period. Seasonal changes in temperature, from summer to rainy and winter months, exerted an adaptive effect on the activity patterns, in the form of a two hour forward shift in the onset of the daily activity, in correspondence to the decreasing trend in the soil temperature. Thus, both the daily and the seasonal activity patterns of *T. scabriceps* colonies are apparently fine-tuned to changes in the soil surface temperature.

**Key words :** Peak foraging period, daily foraging, diurnal foraging, critical mean soil temperature.

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### INTRODUCTION

Ants occupy distinct temporal niches by maintaining specific daily and seasonal activity patterns in order to avoid their natural enemies, reduce competition, and to use the food resources efficiently (Agarwal and Rastogi, 2009; Retana *et al*, 2015; Ekka *et al*, 2020). They demonstrate appropriate behavioural strategies in response to crucial environmental factors such as light, temperature and humidity (Cerda *et al*, 1998; Narendra *et al*, 2010). Depending on the species and their habitat preferences, ants respond to temporal changes in temperature in diverse ways, such as by switching from diurnal to nocturnal activity patterns (Fellers, 1989; Heatwole and Muir, 1989), continuous to bimodal patterns (Greenaway, 1981; Heatwole and Harrington, 1989; Heatwole and Muir, 1991) or even by aestivating

during specific seasons (Talbot, 1943; Brieese and Macauley, 1980). Although, ants experience daily and seasonal temperature fluctuations while foraging, only a few studies have addressed their thermal tolerance response in the context of their foraging activities (Heatwole and Harrington, 1989).

In the present study, we have examined the effect of soil surface temperature on the daily foraging activities of the ground-nesting *Trichomyrmex scabriceps* Mayr ant colonies, during three seasons, to find whether changes in the soil temperature regulate the foraging activity patterns of the ant colonies. *Trichomyrmex scabriceps* is one of the least studied ant species, although it is commonly found in many parts of India, particularly in the arid and semi-arid areas (Bharti *et al*, 2016). Till date, not a single study has focused on the foraging activity

patterns of this ant species. Hence, we hypothesized that if temperature has a regulatory effect on the foraging schedules of *T. scabriceps* workers, it would be expected that: (1) the onset and decline of their daily foraging activity patterns would be affected by changes in the soil surface temperature, (2) there would be a fine-tuning of the foraging activities of the ant workers exiting the nest to forage as well as of those returning to the nest after foraging to match with the preferred temperature range, and (3) the temperature range of the foraging activities under natural field conditions would correspond to the tolerance limits imposed by the natural seasonal changes.

## MATERIALS AND METHODS

### Study sites

Field studies were conducted during summer, winter and rainy seasons, from June 2019 to 2020, in three managed ecosystems, including the Botanical garden, Horticulture farm, and the Agriculture farm. Preliminary field observations showed the presence of many nests of *T. scabriceps*, particularly in the compact soil of the unpaved paths in each study site. All the sites were located within the campus of Banaras Hindu University, Uttar Pradesh (25°18' N, 83°03' E), 129 m above sea level, in India. Mature and active main nests (n=15 per site) of *T. scabriceps* were marked in each site and the daily foraging patterns were recorded for each nest during summer (April–June), rainy (July–September) and winter (December–February) seasons.

### Soil surface temperature and the daily foraging activity patterns of *T. scabriceps* colonies

Daily foraging patterns of *T. scabriceps* colonies were monitored by recording the number of foragers leaving each nest and those returning back to the nest (time period per observation = 30 min.), at hourly intervals (from 6:00h to 19:00h). Observations were taken for 5 consecutive days for each nest (Shukla *et al.*, 2018). Soil-surface temperature was recorded (to a precision of  $\pm 0.1^\circ\text{C}$ ) by a platinum resistance thermometer, which was used to record the temperature of the top 2 mm soil of bare, un-vegetated ground in each site.

### Statistical analysis

Both the temperature and foraging activities data were subjected to one-way ANOVA (analysis of variance), using SPSS 25.0, followed by Tukey's HSD *post hoc* test to analyze the variations in the foraging activities during the different seasons. The results were expressed as mean  $\pm$  SEM (standard error of the mean), where  $P < 0.05$  was considered as statistically significant.

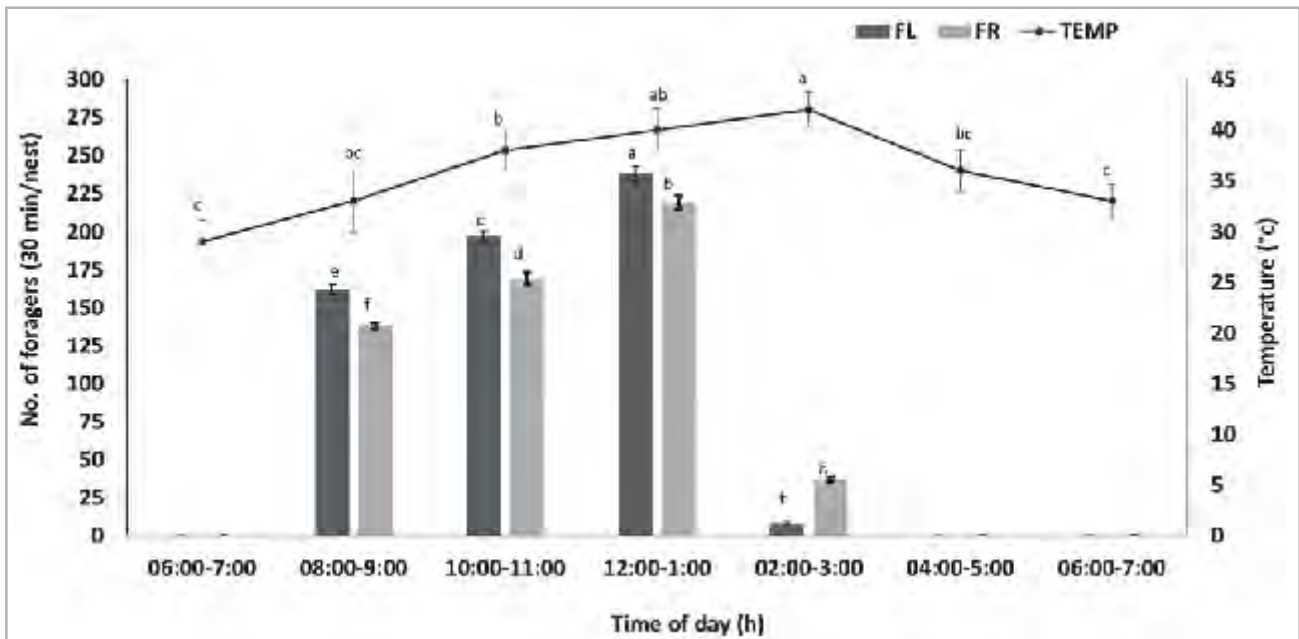
## RESULTS AND DISCUSSION

The results of the present study revealed that the daily foraging activities of *T. scabriceps* ant colonies during all the three seasons were regulated by the changes in the soil surface temperature. The ground temperature apparently plays a key role in influencing the number of foragers of *T. scabriceps* colonies which leave the nest to forage and the number of foragers that return to the nest. The fine-tuning effect of temperature in modulating the colony activities was most clearly evident from the seasonal changes in the onset and decline in the daily activities of the ant foragers.

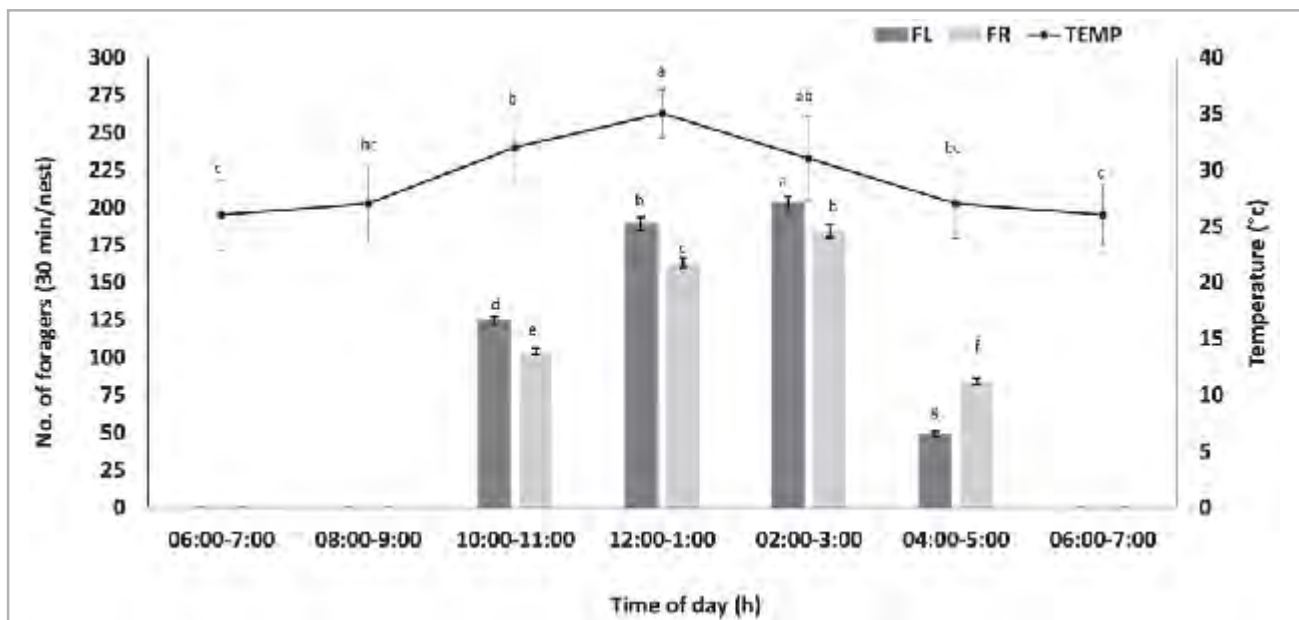
This is the first report highlighting the effect of soil temperature on the diurnal foraging patterns of *T. scabriceps* colonies. The foraging activities of *T. scabriceps*, commonly reported to inhabit arid areas, showed a unimodal pattern and a general preference for foraging during the afternoon time period. This is in contrast to the foraging activity patterns of some ant species, such as *Diacamma* sp. and *Myrmecaria* sp. from India, which either exhibit a greatly reduced activity during noon (as in the case of *Diacamma* sp.) or a gradual decline in the number of foragers exiting a nest after mid-day (Rastogi *et al.*, 1997).

However, the daily onset of foraging in *T. scabriceps* colonies occurred exclusively during the morning time period. The foraging activities shifted from 8:00 h in summer to 10:00 h, *i.e.*, to later hours of the day, during the rainy and the winter seasons. The ambient soil temperature for the onset of foraging activity varied seasonally, from  $30^\circ\text{C} \pm 2^\circ\text{C}$  during the summer and rainy seasons to  $25^\circ\text{C} \pm 2^\circ\text{C}$  during the winter months, indicating that the foragers preferred the warmer time periods for searching and retrieving their food. This in turn had significant influence on the peak foraging hours and caused a two-hour shift in the peak activity from 12:00h–13:00h in the summer months to 14:00h–15:00h during the rainy and winter seasons.

During the summer months the outward-bound foragers ( $162.46 \pm 3.33$ ) exited the nest to search for food at earlier hours (at 8:00h) when the number of returning foragers was considerably less ( $188.71 \pm 3.14$ ). It is noteworthy that although *T. scabriceps* colonies apparently prefer the warmer parts of the day for their foraging activities, the upper threshold falls in the range of  $40^\circ\text{C}$  to  $42^\circ\text{C}$ , since the number of foragers exiting the nest declined steeply at  $41^\circ\text{C} \pm 2^\circ\text{C}$ , while only a few ( $22.24 \pm 3.42$ ) straggling returning foragers were recorded to enter the nest during this high temperature period. Our results have provided support for previous findings



**Fig. 1 :** Daily foraging activity pattern of *Trichomyrmex scabriceps* workers (indicated in bars) quantified by the mean number of foragers leaving (FL) and returning (FR) to the main nest ( $n=45$ ) (during a 30 min time period per nest; recorded at hourly intervals) with reference to the soil temperature (indicated by the unbroken line; mean $\pm$  SE) during the summer season (April-June, 2021). Analysis of variance (One-way ANOVA) followed by Tukey's HSD *post hoc* test showed significantly higher activity between 12:00h-13:00h, and higher soil surface temperature at  $38\pm 2^{\circ}\text{C}$ . Different letters on error bars indicate significant differences ( $p<0.05$ ).

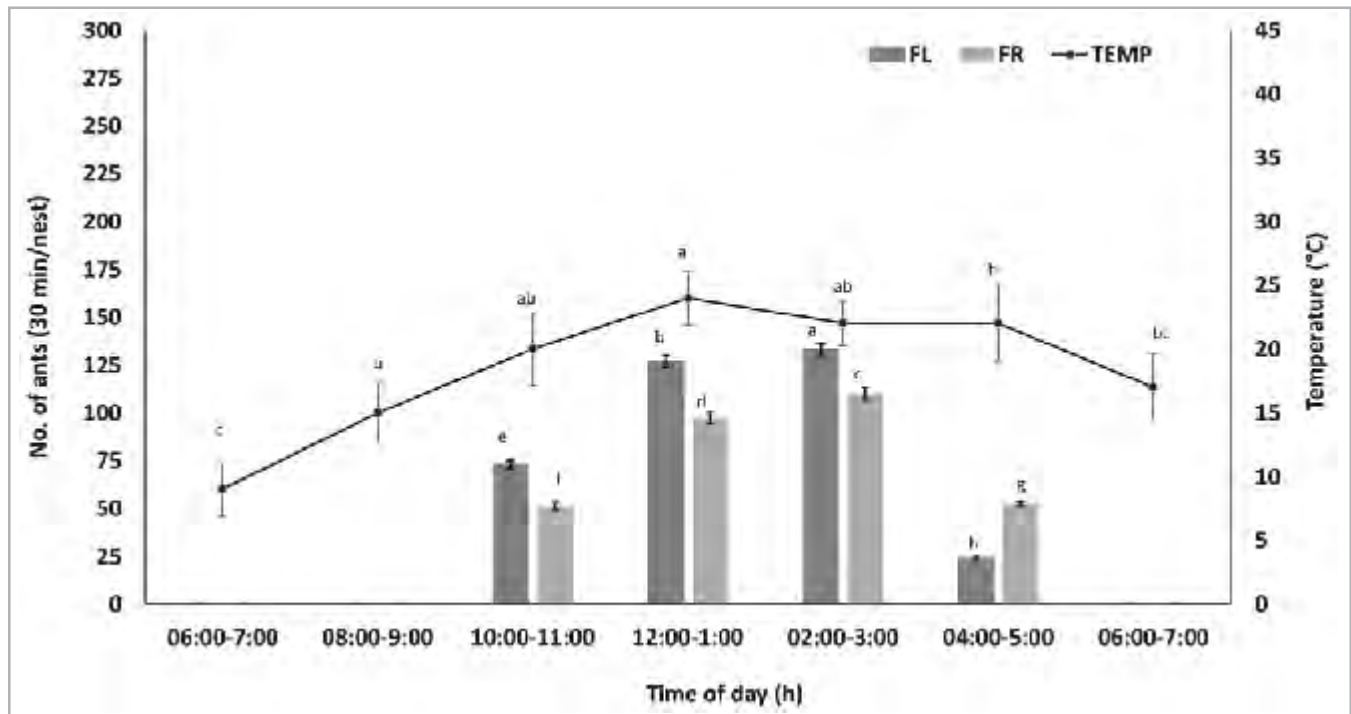


**Fig. 2 :** Daily foraging activity pattern of *Trichomyrmex scabriceps* workers (indicated in bars) quantified by the mean number of foragers leaving (FL) and returning (FR) to the main nest ( $n=45$ ) (during a 30 min time period per nest; recorded at hourly intervals) with reference to the soil temperature (indicated by the unbroken line; mean $\pm$  SE) during the rainy season (July-Sept., 2021). Analysis of variance (One-way ANOVA) followed by Tukey's HSD *post hoc* test showed significantly higher activity between 14:00h-15:00h, and higher soil surface temperature at  $32\pm 2^{\circ}\text{C}$ . Different letters on error bars indicate significant differences ( $p<0.05$ ).

(Hölldobler and Wilson, 1990), which reported that most of the ant species forage at soil surface temperatures between  $10^{\circ}\text{C}$  and  $45^{\circ}\text{C}$ . For instance, workers of *Rhytidoponera convexa* and *Solenopsis invicta* forage at temperatures of  $13^{\circ}\text{C}$ – $31^{\circ}\text{C}$  and  $15^{\circ}\text{C}$ – $43^{\circ}\text{C}$ , respectively (Briese and Macauley, 1980; Porter and

Tschinkel, 1987).

Further, during the rainy and winter seasons the number of *T. scabriceps* foragers exited the nest at 10:00 h, and the foraging activity was maintained till 15:00h-16:00 h. It is interesting to note that the mean number of foragers recorded leaving a nest was always significantly



**Fig. 3 :** Daily foraging activity pattern of *Trichomyrmex scabriceps* workers quantified by the mean number of foragers leaving (FL) and returning (FR) to the main nest ( $n=45$ ) (during a 30 min time period per nest; recorded at hourly intervals) with reference to the soil temperature (indicated by the unbroken line; mean  $\pm$  SE) during the winter season (Dec.-Feb., 2021). Analysis of variance (One-way ANOVA) followed by Tukey's HSD *post hoc* test showed significantly higher activity between 14:00h-15:00h, and higher soil temperature at  $25 \pm 2^\circ\text{C}$ . Different letters on error bars indicate significant differences ( $p < 0.05$ ).

higher than the mean number of returning foragers till the occurrence of the peak foraging activity. In direct contrast, during the later (*i.e.*, in the post-noon period) foraging hours the mean number of foragers returning to the nest increased significantly (Figs. 2 and 3).

It is clearly evident from the study that workers usually avoided exiting their nests at temperatures over  $35^\circ\text{C}$ , delaying the time of forager exit or ceasing outbound activity when the temperature reached  $38^\circ\text{C} \pm 2^\circ\text{C}$  (Figs. 1-3). Also, the foraging activity of *T. scabriceps* colonies ceased when the critical minimum soil temperature was  $\leq 20 \pm 2^\circ\text{C}$  (Fig. 3). Again, the results also show that the workers ceased their foraging activities completely when the critical maximum soil temperature was  $\geq 42^\circ\text{C} \pm 2^\circ\text{C}$  (Fig. 1). Thus, the preferred foraging range of *T. scabriceps* colonies lies between  $20^\circ\text{C}$  and  $42^\circ\text{C}$ , indicating that temperatures beyond  $42^\circ\text{C}$  may have adverse effect on the foraging ants.

Our study demonstrates that the soil surface temperature has important influence in regulating the foraging activities of *T. scabriceps* colonies. Ant species belonging to the genus *Trichomyrmex* earlier known as *Monomorium* (Radchenko *et al.*, 1997) often make ground trails (Rastogi *et al.*, 1997). Since the foragers of this species characteristically move on the bare ground, along a well-marked trail, their legs are in direct contact

with the soil surface (pers. obs.) Consequently, avoidance of foraging activities during high thermal conditions is a sound adaptive strategy of the foragers. Moreover, it is well-known that the exposure to high thermal conditions decreases the metabolic rates of worker ants of many species (Andrew *et al.*, 2013) and effects the pheromone trails in *Tapinoma nigerrimum* ants (Oudenhove *et al.*, 2011). Our results also confirm other studies which suggest that although several biotic and abiotic factors are of importance, temperature is the most significant predictor of the foraging activities of many ant species including those of tropical and subtropical regions, such as the fire ant, and the leaf cutting ants (Porter and Tschinkel, 1987; Ruano *et al.*, 2000; Vogt *et al.*, 2003; Tizón *et al.*, 2014).

To conclude, this study highlights the fact that soil surface temperatures may serve as an important adaptive factor for the *T. scabriceps* foragers to have critical minimum and maximum temperatures for foraging. This species which is common to arid regions has evolved a strategy to forage during warmer parts of the day but responds to and avoids the very low ( $< 20^\circ\text{C}$ ) and very high ( $> 42^\circ\text{C}$ ), which would plausibly have detrimental effects on the physiology of the ant workers.

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