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Predator Ants of the Date Palm Termite *Microcerotermes diversus* Silvestri and Effects of ant Morphometric Characteristics on ant Functional Response

Masoud Latifian[1, *], Behzad Habibpour[2], Brad Kard[3]

[1]Date Palm and Tropical Fruit Research Center, Horticulture Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Ahvaz, Iran

[2]Department of Plant Protection, College of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran

[3]Department of Entomology and Plant Pathology, Oklahoma State University, Stillwater, USA

Email address:
masoud_latifian@yahoo.com (M. Latifian)

[*]Corresponding author

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Abstract: Scouting for formicidae presence in *Microcerotermes diversus* galleries was conducted from March to September 2014 in 10 date palm trees located in the Omaltomire region of Khuzestan Province, Iran. Measurements and morphological observations were made of 20 ant workers. For the *in vitro* predation test, *M. diversus* nymphs (n = 10 per replicate) were placed in a petri dish. Then, live freshly field-collected worker of ants were added. After 24 h, the number termite nymphs that were fully or partially devoured was determined. Five ants, including *Plagiolepis pallescens*, *Polyrhachis lacteipennis*, *Pheidole teneriffana*, *Crematogaster antaris*, and *Monomorium destructor* were predators of termites in date palm orchards. *P. lacteipennis* and *P. teneriffana*, and *P. pallescens*, *C. antaris*, and *M. destructor*, showed Type II and Type III functional responses, respectively. The highest predation efficiency, and the lowest handing time coupled with the highest attack rate by predators was recorded for *P. lacteipennis* and *P. teneriffana*, and *C. antaris* and *M. destructor*, respectively. Predator ant characteristics measured include: HL-Head length; HW-head width; SL-scape length; EL-eye length; PW-pronotal width; WL-thorax length; GL-gaster length; TL-total length; FL-femur length. HL, HW, SL, EL and FL showed positive effects on the functional response parameters. Results showed that termite defense capabilities declined with increasing of ant predation efficiency.

Keywords: Ant Morphology, Date palm, Predatory Ants, Termites

1. Introduction

Termites are major pests of date palms (*Phoenix dactylifera*) in Khuzestan Province and surrounding areas. Termites cause considerable damage along the Karon River in Southwest of Iran. *Microcerotermes diversus* is the dominant species in this region [1]. Abiotic and biotic factors including climate, soil type, garden management practices, and natural enemies are among the most influential factors affecting termite populations [2, 3].

Ants (Hymenoptera) are the largest group of predators of termites worldwide [4]. They both share the same habitats and are abundant in terms of biomass and density [5]. Ants and termites have engaged in predator-prey evolutionary relationships during 100 million years of coexistence, with ants developing several predatory tactics and termites responding with several defensive strategies [4, 6, 7].

Some Harrier ants, including *Dorylines* and *Ponerines*, can also quickly destroy a nest of termites [8]. *Dorylines* cause high mortality in *Macrotermes* populations. *Megaponera* ants exhibit discovery capabilities of terrestrial escape channels of *Macrotermes subhylinus*. *Ponerines* can embattle thousands of termites in a large nest within a day [9]. Some kinds of ants have the ability to hunt several different termite groups. For example, Brazilian ants can feed on termites from the genera *Cornitermes*, *Syntermes*, and *Coptotermes* [10]. Studies on predatory behavior of ants on termites have been conducted similarly for other arthropod predators [11].

One of the important factors that affected hunting success was ratio of predator body size to prey. Arthropod predators often hunt prey smaller than themselves. The ratio of predator-to-prey body length can vary from 100 to 0.3, and in some cases such as Military ants is ~0.1 [12, 13]. Predator-prey interactions are inherently size-dependent. Measurements of body sizes of interacting predators and prey are essential to understanding their feeding relationships, and are increasingly important for food-web studies [14].

In this study the efficiency of predator ants on the dominant termite pest of date palm, *M. diversus*, was evaluated by comparing ant functional responses. The effects of their morphometric characteristics were analyzed and evaluated relative to their predation ability.

2. Methods

2.1. Study Site

Investigations were conducted from March through September 2014 on the 'Date Palm and Tropical Fruits Research Center' located in the Omaltomire region of Khuzestan Province, southwest Iran. Ten date palm trees were evaluated during a period of high air temperatures. Study site geographic coordinates are 48°34' east longitude and 31°14' north latitude.

2.2. Sampling

Ant collections were conducted by scouting for ant presence in *M. diversus* galleries in selected date palm trees. Foraging ants were collected from date palm stems using a porter during low river tide. Collections of ant nests and foragers in galleries were accomplished during high tide by utilizing a boat. The date palm orchards flood during high tides because they are near tidal areas of the Persian Gulf. Due to the low slope of the riverbed, changing the flow of water from the sea to land is a matter of a few meters in the surface. This happens twice a day

2.3. Identification

Ants were kept in 75% alcohol. External features were examined to identify to species. In addition, confirmation of ant identifications was conducted by the Zoology Museum of Iranian Plant Protection Research Institute [15-18].

2.4. Morphometrics

Measurements and morphological observations were made of 20 workers from each ant species. For predator ant descriptions, several morphological measurements of different worker characteristics were determined: HL-Head length; HW-head width; SL-scape length; EL-eye length; PW-pronotal width; WL-thorax length; GL-gaster length; TL-total length; FL-femur length [19, 20].

2.5. Statistics

To compare measurements and index means among ant populations, analysis of variance (ANOVA) was conducted. Post-hoc comparisons were performed using Bonferroni means comparisons for worker morphometrics.

2.6. In Vitro Predation

Groups of *M. diversus* workers (n = 2, 4, 8, 12, or 32 per replicate) were contained in a petri dish. One active, freshly field-collected adult of each ant species was then added to each petri dish. For controls, an ant worker, or a late instar *M. diversus* but without the ant predator, were similarly prepared. For each group or control petri dish, the experiment was replicated four times (four petri dishes) and conducted under ambient room conditions (25±2°C; 60±5% RH). After 24 h, the number of *M. diversus* that were fully or partially devoured was determined for each petri dish.

2.7. Response Calculations

The components related to the functional response were calculated using SAS software and the Juliano method for hypothesis testing (Juliano 1993). The type of functional response was selected by logistic regression models. The relationship between the surviving number of worker termite prey (N_e) related to their initial number (N_t) was simulated. Hypothesis testing included functional response parameters estimations and comparison of different models. Nonlinear least squares regression was used for this purpose. These techniques were applied to the untransformed data [21]. Holling disc equation (Equation 1) was used for this purpose. Random searching was calculated using Equations 1 and 2 [22].

Equation 1: $$N_e = \frac{a'TN_tP_t}{1 + a'T_hN_t}$$

Equation 2: $$N_e = N_t[1 - \exp(\frac{-a'TP_t}{1 + a'T_hN_t})]$$

Equation 3: $$N_e = \frac{dTP_tN_t + bTP_tN^2{}_t}{1 + CN_t + dT_hN_t + bT_hN^2{}_t}$$

In Equations 1, 2 and 3, parameters described as N_e equal the number of termites that were exposed to ants, and N_t is the number of termites that were attacked by ants. P_t is the number of ants in the test at time *t*, with an instantaneous power search or attack constant or search efficiency, *T* is total time available to ants, N_t is the number of termites in the test at time t, and T_h is the handling time [21, 22].

Here, *b*, *C* and *d* are constants in Equation 3. The estimated parameters (a'; T_h; T/T_h) were compared for different numbers of predator ants for assessing predator efficiency. a' is the ratio of termites that different predator ants are faced with per unit of available search time. T_h means all the actions occurring during predatory time, with the exception non-submission, pursuit, cleaning, self-assembly, and relaxation times. T/T_h also was the highest attack rate [21].

2.8. Analysis of Morphometric Characteristics and Functional Response Parameters

Correlation analysis was conducted between morphometic characters and functional response parameters, including HL, HW, SL, EL, PW, WL, GL, TL, and FL as independent factors, and the functional response parameters including a', T_h, and T/T_h as dependent factors. Correlation analysis evaluated the strength of a relationship between two groups of numerical measurements studied in this research. Positive correlation exists if one variable increases simultaneously with the other. Negative correlation exists if one variable decreases while the other increases. Pearson's coefficient is the measurement of correlation and ranges (depending on the correlation) between +1 and -1; +1 indicate the strongest positive correlation possible, -1 indicates the strongest negative correlation possible. Therefore the closer the coefficient to either of these numbers the stronger the correlation of the data it represents.

3. Results

3.1. Predator Ants

Five ant species from two subfamilies, five tribes, and five genera were identified (Table 1).

Table 1. *Predator ants of M. diversus.*

Subfamily	Tribe	Species
Formicinae	Plagiolepidini	*Plagiolepis pallescens* Forel
	Camponotini	*Polyrhachis lacteipennis* Smith
Myrmicinae	Attini	*Pheidole teneriffana* Forel
	Crematogastrini	*Crematogaster antaris* Forel
	Solenopsidini	*Monomorium destructor* Jerdon

3.2. Morphometrics

Measurements for five worker predator ants (Table 2).

Table 2. *Average worker measurements of predator ants[1].*

Ant species	mean ±SE, mm				
	HL	HW	SL	EL	PW
P. pallescens	1.91±0.21a	1.62±0.32a	2.13±0.33a	0.48±0.06a	0.72±0.04a
P. lacteipennis	0.82±0.09b	0.74±0.05bc	0.92±0.05bc	0.21±0.02b	0.32±0.02b
P. teneriffana	0.43±0.03c	0.35±0.03c	0.41±0.07c	0.11±0.01c	0.14±0.01c
C. antaris	0.95±0.08ab	0.83±0.04b	1.12±0.25b	0.25±0.03b	0.33±0.02b
M. destructor	0.24±0.02d	0.21±0.02cd	0.34±0.06c	0.07±0.02c	0.74±0.05a

	mean ±SE, mm			
	WL	GL	TL	FL
P. pallescens	3.81±0.41ab	2.76±0.31a	8.92±0.71a	3.02±0.41a
P. lacteipennis	1.94±0.22cd	1.42±0.19b	4.53±0.38c	1.51±0.23bc
P. teneriffana	0.92±0.07d	0.65±0.07c	2.11±0.29d	0.71±0.12c
C. antaris	2.32±0.51c	1.67±0.12b	5.47±0.63bc	1.78±0.37bc
M. destructor	4.13±0.43a	2.98±0.61a	9.61±1.02a	3.17±0.49a

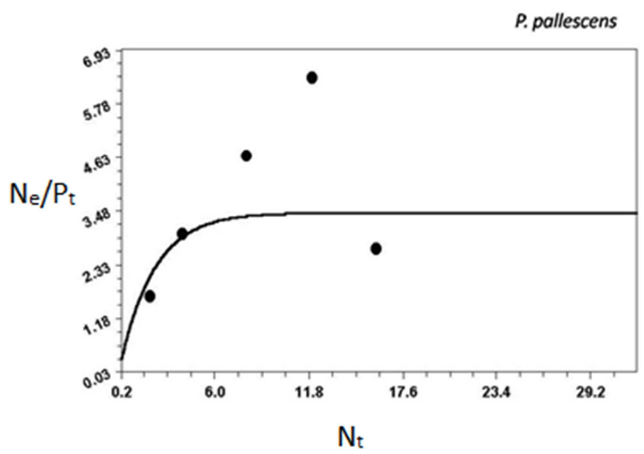
[1]Down columns, means followed by the same letter are not significantly different.
Means are not compared across rows

3.3. Functional Responses

The mean number of date palm termites consumed by each predator ant species increased significantly as the number of *M. diversus* workers increased. The functional response curves obtained (Figure 1) show variation of predator ant consumption at different termite densities.

If ant density is constant then they can regulate termite density only if they have a type III functional response because this is the only type of functional response for which prey mortality can increase with increasing prey density. However, regulating effect of ant is limited to the interval of termite density where mortality increases. If ant density exceeds the upper limit of this interval, then mortality due to predation starts declining, and predation will cause a positive feed-back. As a result, the number of prey will get out of control. They will grow in numbers until some other factors (diseases of food shortage) will stop their reproduction. This phenomenon is known as escape from natural enemies [23].

The functional response parameters including searching-predator efficiency (a'), handling time (T_h) and maximum attack rate (T/T_h) were calculated for each predator ant species (Table 3).



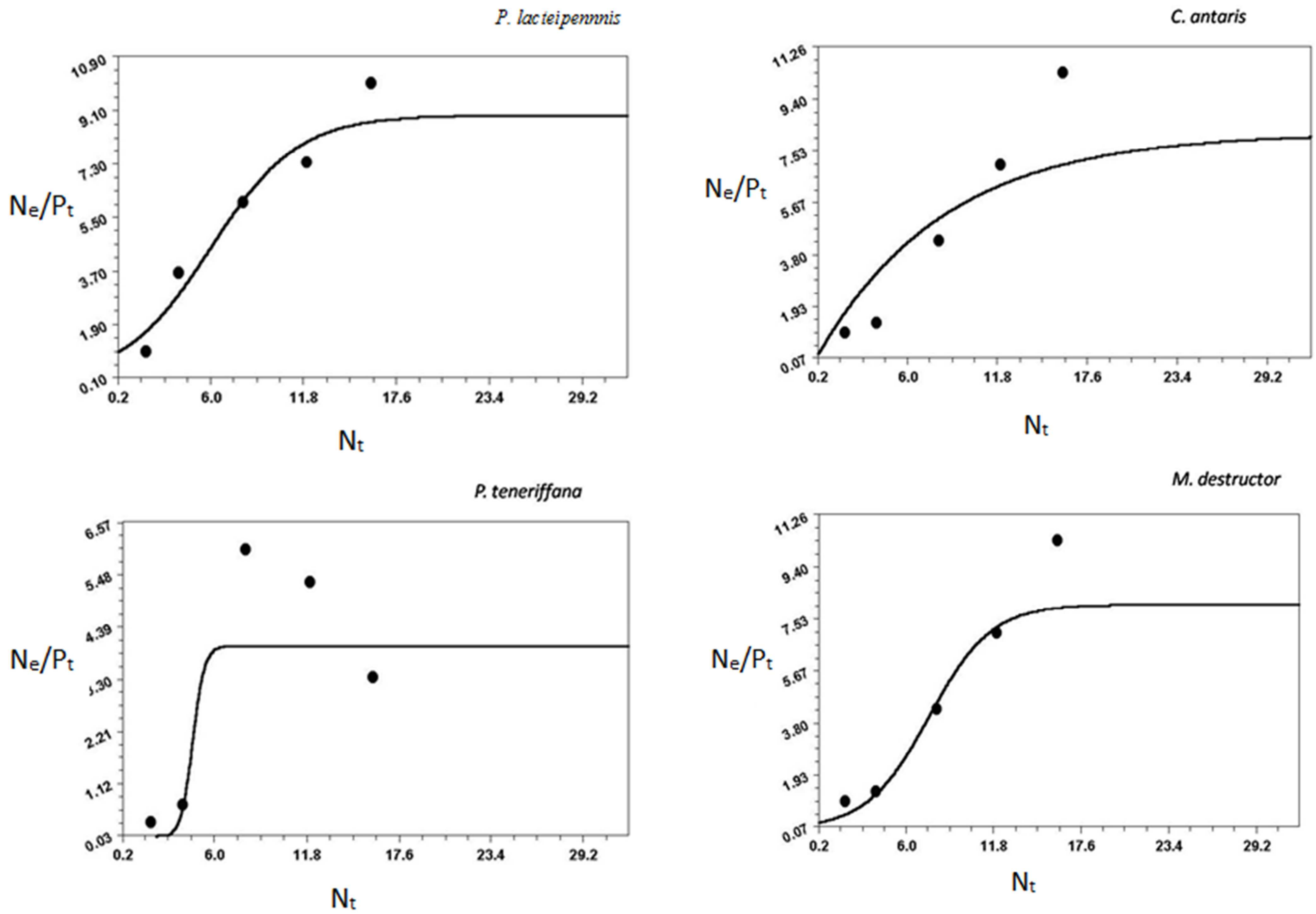


Figure 1. *Functional response of the predator ant to the density of M. diversus workers[1].*

[1]N_t = number of termites in petri dish at time t, 24 hours
N_e = number of surviving termites
P_t = number of ants in petri dish at time t

Table 3. *Functional response parameters for different species of predatory ants[1].*

Ant species	Functional[1] response type	Determination coefficient (R^2)	Predator efficiency (a')	Handling time (T_h)	Attack rate (T/T_h)
P. pallescens	Type III	0.98	1.112	0.202	15.24
P. lacteipennis	Type II	0.97	1.367	0.065	46.11
P. teneriffana	Type II	0.66	0.358	0.068	60.58
C. antaris	Type III	0.82	0.884	0.235	16.74
M. destructor	Type III	0.61	0.932	0.041	105.97

Type II: increased termite density reduces probability of encountering a predator ant
Type III: predator – prey interactions relatively stable

The functional response of *P. lacteipennis* and *P. teneriffana* are Type II. Therefore, the probability of encountering predators for each individual worker termite was reduced permanently by increasing termite worker densities. *P. pallescens*, *C. antaris*, and *M. destructor* had functional response Type III. Type III indicates stabilizing interactions between predator and prey. The highest and lowest predator efficiencies were shown by *P. lacteipennis* and *P. teneriffana*, respectively. The minimum handling time was estimated for *P. lacteipennis*, *P. teneriffana*, and *M. destructor* with the maximum handling times attributed to *P. pallescens* and *C. antaris* The highest and lowest attack rates are shown by *M. destructor* respectively. According to ~~the~~ overall results, *M. destructor* is the strongest predatory ant against *M. diversus*. It has the median predator efficiency, but lowest handling time and the highest attack rate compared with the other four predatory ants.

3.4. Effects of Morphometric Characteristic on the Functional Responses

Effects of the morphometric characteristics of predatory ants on different behavioral response parameters are shown in Figure 2.

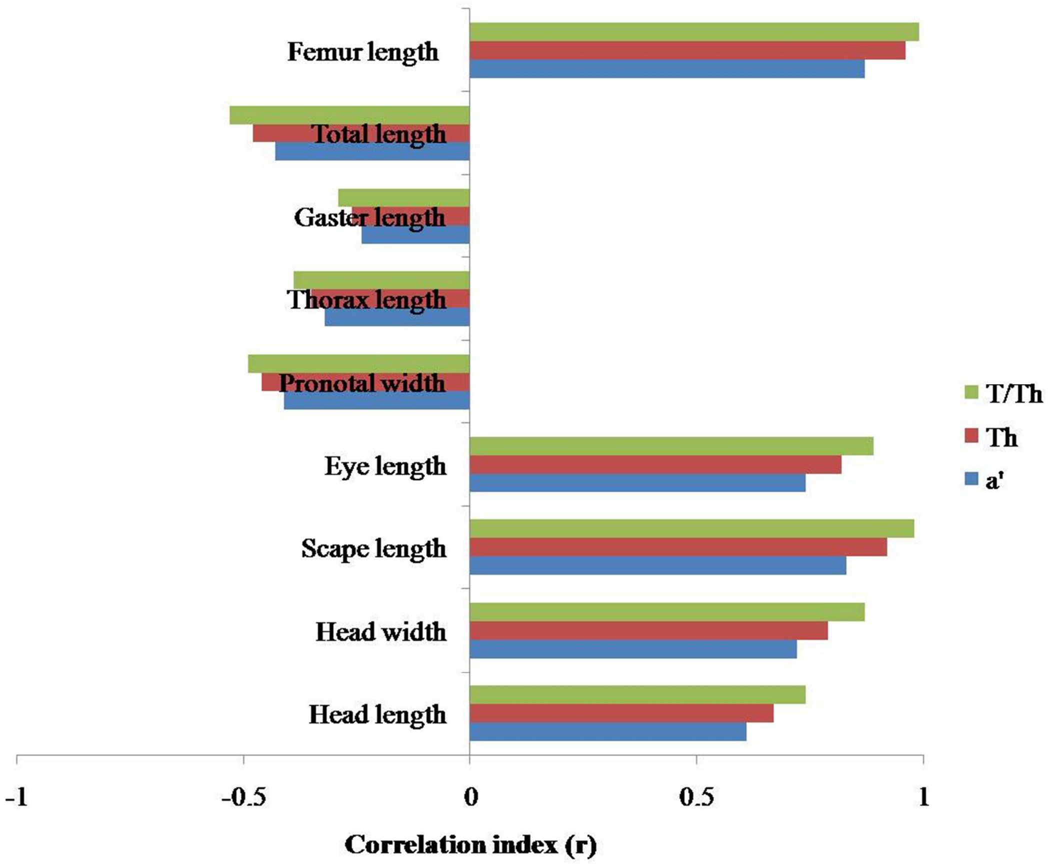


Figure 2. *Collerogram of relationships between morphometic characteristics and functional response parameters of predatory ants.*

In correlation analysis, we estimate a sample correlation coefficient, more specifically the Pearson Product Moment correlation coefficient. The sample correlation coefficient, denoted r, ranges between -1 and +1 and quantifies the direction and strength of the linear association between the two variables. The correlation between two variables can be positive (i.e., higher levels of one variable are associated with higher levels of the other) or negative (i.e., higher levels of one variable are associated with lower levels of the other). The sign of the correlation coefficient indicates the direction of the association. The magnitude of the correlation coefficient indicates the strength of the association.

Morphometric characteristics that are positively correlated with beneficial behavioral response parameters have increased effects on predation efficiency. Characteristics with negatively correlated values have reductive effects on predation ability. Among the positive effects characteristics, FL increased the mobility of ants and therefore enhanced their ability to pursue worker termites. Two characteristics including EL and SL have positive effects on detecting suitable prey. The width and length of the head capsule also have positive effects on behavioral response parameters because they can increase the killing ability of predatory ants. Characteristics such as TL, GL, WL, and PW had negative effects on behavioral responses because they reduced ant mobility. However, these effects were not significant.

4. Discussion

Ants are a primary enemy of termites and may affect some termite densities in natural settings. The degree of predation depends on the population of the ant colony compared with termite density and accessibility, and the availability of other food sources for ants [24]. Termites defend their colony from predatory ant attack. The primary physical defense in many termite species is nest construction, which provides shelter and limits access, guarded by a specialized soldier caste using one or a combination of methods: cutting mandibles, abdominal dehiscence, or chemical secretions [25, 26].

With different ant species, predator size is positively correlated with average size of the prey. However, correlations depend on the method and type of hunting [27]. For example, predator ants of subfamilies Myrmeciinae and Ponerinae often choose prey smaller than themselves. Results of this study showed that *P. teneriffana*, *C. antaris and M. destructor* consumed date palm termites smaller than themselves. Another group of predatory ants such as Formicinae have self-defense, therefore this group can hunt a wider range of prey sizes than the first group [28]. *P. lacteipennis* and *P. teneriffana* showed similar predator efficiency in this study. Other studies have shown that some species of the subfamily Dolichoderine can hunt prey individuals up to 15 times larger than themselves [29].

Results of this study show a positive relationship between increasing predator efficiency and some characteristics of body size. Increased some characteristics of body size enhances the ability of predatory ants to hunt date palm termites Predatory ants have the ability to consume *M. diversus* as soft-bodied termite have little ability to defend themselves. Predation efficiency improved with increasing some part of ant body size including eye length, scape length, head width and Head length.

Ants must move at a speed that can be sustained for long periods in a manner that is energetically efficient [30]. In terms of energy economy, an increase in the size of all body parts may not have equal effects in increasing the predator efficiency. Characteristics such as eye, femur, and head size positively correlated with predation efficiency.

5. Conclusion

Ant body size is important in terms of the size of prey consumed [31]. Predator body size has a complex relationship with prey size, and it affects ecological characteristics including distribution capacity, competitive ability, and the risk of natural enemies [32, 33]. Several species of ants are active in date palm gardens. Although a study on the role of predatory ants has not yet been conducted on population fluctuation of date palm termites in field conditions, overall, predatory ants appear to have an important role in mortality and natural control of date palm termites.

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