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Predatory behaviour of a nematode feeding mite *Tyrophagus putrescentiae* (Sarcoptiformes : Acaridae)

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Summary – Observations on *Tyrophagus putrescentiae* revealed that these mites are predaceous on many species of plant and soil nematodes belonging to three prey trophic categories viz., saprophagous, plant parasitic and predaceous nematodes. Mites preferred second-stage juveniles of plant parasitic nematodes but predaceous nematodes resisted predation comparatively better than others. Physical and behavioural characteristics have been attributed to the cause of resistance. Predation by *T. putrescentiae* is density dependent which required essentially a contact between the chelecerae and the body of prey. Chelecerae are the main killing and feeding organs. Legs are used to hold the prey during attack and feeding. An injured prey, if escaped, attracted other mites which aggregated at feeding site. The aggregation of mites at feeding site often resulted in struggle amongst them in order to snatch the prey and feed. Factors like temperature, agar concentrations, agar thicknesses and test arena governed predation by *T. putrescentiae*. The mites turned coprophagous (feeding on their own excreta) in the absence of prey. No cannibalistic behaviour was observed in *T. putrescentiae* either in the presence or absence of prey nematodes.

Résumé – ***Comportement prédateur de l'acarien nématophage*** **Tyrophagus putrescentiae** ***(Sarcoptiformes : Acaridae)*** – Les observations effectuées sur *Tyrophagus putrescentiae* montrent que cet acarien agit comme prédateur de nombreuses espèces de nématodes phytoparasites ou libres appartenant à trois types trophiques : saprophages, phyto-parasites, prédateurs. L'acarien préfère les juvéniles de deuxième stade des nématodes endoparasites tandis que les espèces prédatrices lui résistent mieux que celles des autres groupes. Des caractéristiques physiques et comportementales sont mises en relation avec cette résistance. La prédation par *T. putrescentiae* dépend de la densité des proies car requérant nécessairement un contact entre les chélicères de l'acarien et le corps de la proie. Ces chélicères constituent les principaux organes permettant de tuer et d'ingérer des proies. Les pattes sont utilisées pendant l'attaque et l'exécution de la proie. Une proie blessée et ayant échappé à l'agresseur attire d'autres acariens qui se concentrent au niveau des blessures. Une telle aggrégation conduit à une lutte entre les individus afin d'attraper et d'ingérer la proie. Les facteurs gouvernant la prédation sont la température, la concentration en agar et son épaisseur ainsi que la surface disponible. En l'absence de proie, les acariens deviennent coprophages, ingérant leurs propres excreta. Aucun cannibalisme n'a été observé, tant en présence qu'en l'absence de proie.

Keys-words : *Tyrophagus putrescentiae,* mites, predator, behaviour.

The feeding by mites on nematodes was first reported by Linford and Oliviera (1938). Since then, the work on mites and their possible influence on soil nematode populations remained very limited. Murphy and Doncaster (1957) reported injury of *Heterodera* cysts by a mite. The most definite association between mites and nematodes came from the work of Rodriguez *et al.* (1972) who cultured *Macrocheles muscaedomesticae* on *Rhabditis* sp., and found it to prefer house fly eggs over nematodes. Its proto- and deutero-nymphs under same conditions, however, preferred nematodes. Rockett and Woodring (1965) found an oribited mite *Pergalumna* sp. feeding on *Pelodera lambdiense* and *Tylenchorhynchus martini* in large numbers. Muraoka and Ishibishi (1976) identified 41 species of mites that could feed on *Cephalobus* sp. The saccate adult females of *Heterodera glycines* and *Meloidogyne incognita* were not devoured by the mites but their juveniles were consumed (Muraoka & Ishibishi, 1976). Imbriani and Mankau (1983) observed voracious feeding by a neostigmatid mite *Lasioseius sculpatus* on *Aphelenchus avenae* and *Cephalobus* sp. In culture, increased population of mite resulted in a significant decline of *Aphelenchus avenae* (Imbriani & Mankau, 1983) and predatory and saprophagous nematodes (Bilgrami & Tahseen, 1992). In the present work observations were made on the predatory behaviour of a nematode feeding mite *Tyrophagus putrescentiae* using plant and soil nematodes as prey.

Materials and methods

Tyrophagus putrescentiae was cultured in Petri-dishes containing 1 % water agar using *Rhabditis* and *Cephalobus* spp., as prey. A small amount of infant milk powder (Lactogen) was spread over the surface of agar to encourage bacteria to grow. Bacteria served as food for the prey nematodes.

Observations on predation by *T. putrescentiae* were made in small cavity blocks containing 1 % water agar

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using *Hirschmanniella oryzae* and second stage juveniles of *Meloidogyne incognita* as prey separately. Fifty individuals each of two species of prey were subjected to predation by five adult mites. The number of prey killed or injured was counted after 24 h. All experiments were made at 28 ± 2 °C and replicated five times. The conditions remained the same for all the experiments unless mentioned otherwise.

PREY CATCHING AND FEEDING MECHANISMS

Prey catching and feeding mechanisms were studied in culture dishes and special observation chambers as designed by Bilgrami and Tahseen (1992). A plastic ring 1 cm high and 2 cm in diameter, glued to a coverslip at one end, was fixed in the middle of the metallic slide. The chamber, thus formed, was filled with 1 % water-agar. The mites and prey nematodes were then inoculated. The ring was sealed with another coverslip to prevent air drying and escape of mites. Predation was observed on *H. oryze* and *M. incognita.* Observations were made at more than 100 × magnifications.

RATE OF PREDATION BY *T. PUTRESCENTIAE* ON DIFFERENT SPECIES OF PREY NEMATODES

The rate of predation by *T. putrescentiae* was observed on prey species belonging to three different prey trophic categories viz., saprophagous : *Rhabditis, Cephalobus, Acrobeloides, Acrobeles, Mesorhabditis, Tobrilus* spp. and *Chiloplacus symmetricus;* plant parasitic : *M. ingognita, Anguina tritici, Heterodera mothi, Hirschmanniella oryzae, Tylenchorhynchus mashhoodi, Hoplolaimus indicus, Helicotylenchus indicus, Basiria* sp., *Hemicriconemoides mangiferae : Hemicycliophora dhirendri, Aphelenchoides, Xiphinema basiri, Paralongidorus citri, Longidorus* and *Paratrichodorus* spp.; predaceous : *Mononchus aquaticus, Mylonchulus dentatus, Dorylaimus stagnalis, Aquatides thornei, Mononchoides longicaudatus, M. fortidens* and *Aporcelaimellus nivelis.*

PREDATORY PROFILE

Rate of predation was determined over a period of 10 days. Each day after observation mites were transferred to another cavity block containing fresh agar and the same number of prey nematodes.

EFFECT OF PREY DENSITY

Effect of prey density on the rate of predation was observed by placing the mites with 50, 100, 150, 200, 250, 300, 350, 400, 450 and 500 individuals of *M. incognita* and *H. oryzae.*

EFFECT OF STARVATION OF MITES

To determine the effect of starvation (deprivation of food) of *T. putrescentiae* O (fresh), 2, 4, 6, 8, 10, 12 and 14 days starved mites were released with prey nematodes. Each group of starving mites was tested separately.

EFFECT OF TEMPERATURE

Effect of temperature on the rate of predation was determined by releasing mites with prey nematodes at temperatures ranging from 5 to 40 °C (with an interval of 5 °C).

EFFECT OF AGAR CONCENTRATION

To observe the effect of agar concentrations on predation, the mites were placed with prey nematodes in cavity blocks containing 1, 2, 3, 4, 5, and 6 % water agar.

EFFECT OF AGAR THICKNESS

Prey nematodes were subjected to predation by the mites in cavity blocks containing 2, 4, 6, 8, 10, 12 and 14 mm thick agar layers to observe the effect of agar thicknesses on the rate of predation.

EFFECT OF TEST AREA

To determine the effect of surface area on the rate of predation by mites 4 mm thick agar blocks of 0.5, 1, 1.5, 2, 2.5 and 3 cm radius were taken in cavity blocks. The area of each block was calculated by $\pi r^r \times$ thickness of the agar.

Results

T. putrescentiae is predaceous, and feeds on nematodes and other micro-organisms in culture dishes. During routine observations, the culture of many saprophagous *(Rhabditis, Cephalobus, Acrobeloides, Acrobeles, Mesorhabditis, Tobrilus* spp., *Panagrellus redivivus* and *C. symmetricus)* and predaceous nematodes *(M. aquaticus, M. dentatus, D. stagnalis, A. thornei, M. longicaudatus, M. fortidens, M. bastiani, D. silvicolus* and *A. nivelis)* were found heavily contaminated with *T. putrescentiae. T. putrescentiae* fed voraciously, restricted their multiplication and reproduction. As a result of extensive predation, the population of nematodes declined significantly. In some cases even a whole population perished.

Predation depended upon chance encounters with prey individuals. *T. putrescentiae* could hold its prey by its pulp (used to identify prey organisms and other objects) and legs as soon as prey came in contact. The legs are used for holding and wounding prey. Chelecerae is the main killing and feeding organ, used for grasping, crushing and shredding prey into pieces. The ingestion of prey contents was intermittent (2-3 feeding bouts at a time; 22-26 feeding bouts/minute) with short periods of resting activity at regular intervals. Feeding time depended upon the type of prey. Mites took longer to consume large prey than small. Physical characteristics which provide resistance to prey nematodes against predation governed attacks by the mites, puncturing of cuticle and time of feeding. No cannibalistic tendency was observed in *T. putrescentiae.*

If an injured prey escaped, it attracted other mites, which aggregated around it to feed. During feeding a struggle to be the first to hold of prey and to feed was

observed. Mites pulled the prey in opposite directions in order to snatch it and the prey was torn into two or more pieces, one going to each mite.

The mites also consumed their own faecal matter while moving randomly, mainly in the absence of prey nematodes. The nymphal stages of mites fed on dead, injured or inactive prey individuals.

RATE OF PREDATION BY *T. PUTRESCENTIAE* ON DIFFERENT SPECIES OF PREY NEMATODES

Migratory juveniles of sedentary endo-parasites were the most susceptible to predation and were most preferred by the mites. Predatory nematodes avoided predation comparatively well when used as prey against *T. putrescentiae*. They were preferred least by the mites.

Saprophagus nematodes (Table 1, A)

Maximum predation occurred on *Acrobeloides* sp. (MSD 38 ± 1.2) with a low degree of variation. *Acrobeles* sp. was least preferred (MSD 29 ± 1.3) ($p < 0.05$).

Plant parasitic nematodes (Table 1, B)

The juveniles of *A. tritici, M. incognita,* and *H. mothi* were killed most by the mites. *T. mashhoodi, Hoplolaimus indicus, Helicotylenchus indicus, H. mangiferae* and *H. dhirendri* resisted predation better than other species of plant parasitic nematodes. Predation occurred on 32-82 % population of these prey. The rest of the nematodes of this trophic group were killed in moderate numbers ($p < 0.05$).

Predaceous nematodes (Table 1, C)

Different species of predatory nematodes exhibited resistance against predation. 24-48 % of the population of predaceous nematodes was preyed upon by the mites. The maximum predation was on *M. aquaticus* (MSD 24 ± 2.5, CV = 10 %) and *A. thornei* (MSD 24 ± 2.5, CV = 23 %) and minimum on *D. stagnalis* (MSD 12 ± 2.5, CV = 21 %) ($p < 0.05$).

PREDATORY PROFILE (Fig. 1 A).

T. putrescentiae killed the same number of prey individuals each day over a period of ten days ($p > 0.05$). More individuals of *M. incognita* were killed than *H. oryzae.*

PREY DENSITY (Fig. 1 B)

The rate of killing *M. incognita* and *H. oryzae* by *T. putrescentiae* increased with the increase in prey density ($p < 0.05$). Maximum predation occurred in a population of 500 prey individuals and minimum in 50 ($p < 0.05$).

EFFECT OF STARVATION OF MITES (Fig. 2 A)

Rate of predation by *T. putrescentiae* increased with the increase in the period of starvation. Number of prey killed by 14 day starved mites was significantly more than the fresh (0 day) ($p < 0.05$).

Table 1. *Rate of predation by* Tyrophagus putrescentiae *on different species of nematodes belonging to different trophic groups.*

Prey species	Mean killing	Percent killing	CV (%)
A : SAPROPHAGOUS			
Rhabditis sp.	33 ± 3.1 (30-37)	66	9
C. symmetricus	35 ± 1.6 (33-37)	70	5
Acrobeloides sp.	38 ± 1.2 (37-40)	76	3
Acrobeles sp.	29 ± 1.3 (27-31)	58	5
Mesorhabditis sp.	37 ± 1.5 (35-39)	74	4
Tobrilus	30 ± 2.5 (28-34)	60	8
B : PLANT PARASITIC			
Meloidogyne incognita	39 ± 4.1 (34-44)	78	11
Anguina tritici	41 ± 2.0 (37-44)	82	5
Heterodera mothi	40 ± 2.9 (36-44)	80	3
Hirschmanniella oryzae	31 ± 3.0 (28-36)	62	10
Tylenchorhynchus mashhoodi	27 ± 1.5 (25-29)	54	5
Hoplolaimus indicus	21 ± 1.1 (19-22)	42	5
Helicotylenchus indicus	20 ± 1.6 (18-22)	40	8
Basiria sp.	30 ± 3.5 (27-36)	60	12
Hemicriconemoides mangiferae	16 ± 2.9 (12-20)	32	6
Hemicycliophora dhirendri	18 ± 1.2 (17-20)	36	7
Aphelenchoides sp.	29 ± 2.3 (27-33)	58	8
Xiphinema basiri	28 ± 1.9 (26-31)	59	7
Paralongidorus citri	20 ± 4.6 (16-28)	40	23
Longidorus sp.	22 ± 5.0 (14-28)	44	23
Paratrichodorus sp.	24 ± 6.4 (18-32)	48	27
C : PREDACEOUS			
Mononchus aquaticus	24 ± 2.5 (20-26)	48	10
Mylonchulus dentatus	22 ± 3.2 (18-26)	44	14
Dorylaimus stagnalis	12 ± 2.5 (9-15)	24	21
Aquatides thornei	24 ± 5.5 (15-28)	48	23
Mononchoides longicaudatus	21 ± 5.1 (14-28)	42	25
Mononchoides fortidens	19 ± 2.1 (17-22)	38	11
Aporcelaimellus nivalis	21 ± 2.2 (18-24)	42	11

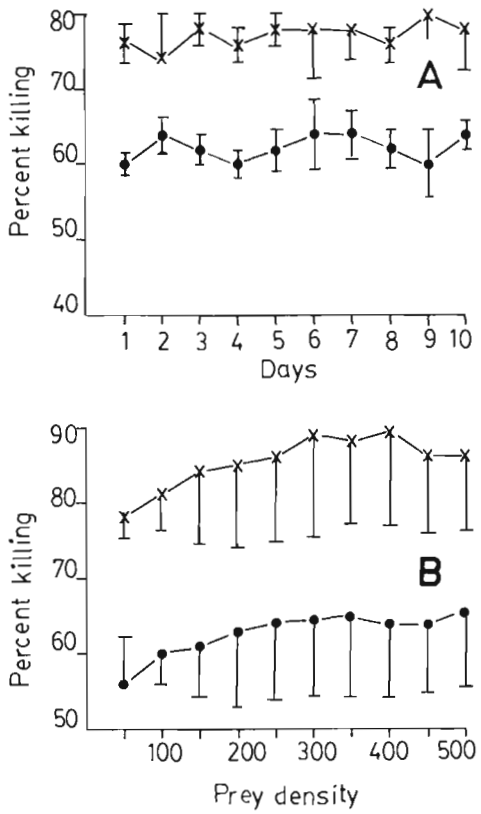

Fig. 1. *A : Predatory profile of* Tyrophagus putrescentiae *over a period of 10 days; B : Effect of prey density on the rate of predation by* Tyrophagus putrescentiae (X = Meloidogyne incognita, *J2;* ● : Hirschmanniella oryzae).

EFFECT OF TEMPERATURE (Fig. 2 B)

Temperature also governed predation by *T. putrescentiae*. Rate of killing *M. incognita* and *H. oryzae* increased significantly up to 25 °C ($p < 0.05$) but remained constant thereafter ($p > 0.05$).

EFFECT OF AGAR CONCENTRATIONS (Fig. 2 C)

Rate of predation was directly proportional to agar concentrations. Maximum killing was recorded at higher concentrations (5-6 %) ($p < 0.05$). Low concentrations (1-2 %) yielded minimum predation by *T. putrescentiae*.

EFFECT OF AGAR THICKNESSES (Fig. 2 D)

Predation decreased with the increase in agar thickness. Agar layers more than 6 mm did not favour predation. Mites killed maximum number of prey in 2-6 mm thick agar layers ($p < 0.05$).

EFFECT OF TEST AREA (Fig. 3)

Surface area affected predation greatly by *T. putrescentiae*. Predator-prey encounters in small test areas (0.31 cm^3 to 1.3 cm^3) yielded maximum predation whereas in large areas (2.8 to 1.3 cm^3) predation declined sharply ($p < 0.05$).

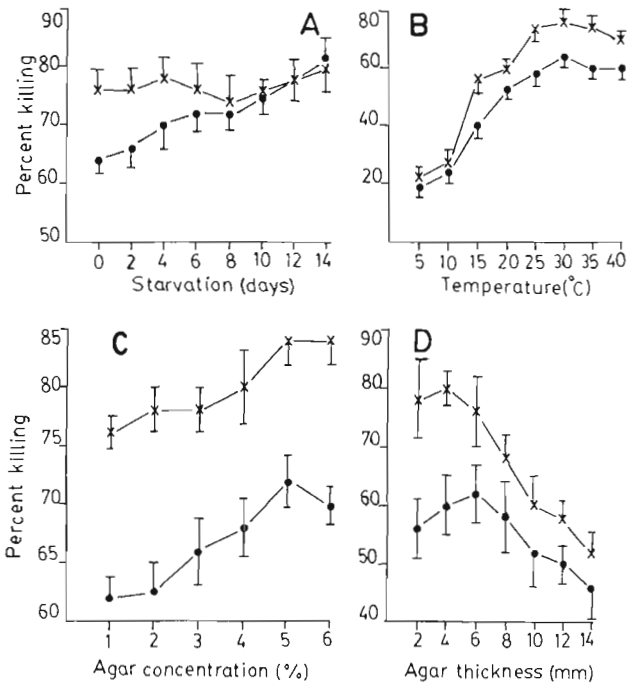

Fig. 2. *Effect of various factors on the rate of predation by* Tyrophagus putrescentiae. *A : Starvation; B : Temperature; C : Agar concentratum; D : Agar thickness* (X = Meloidogyne incognita, *J2;* ● = Hirschmanniella oryzae).

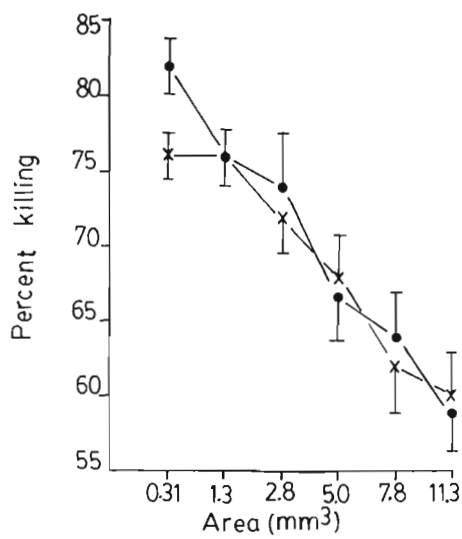

Fig. 3. *Effect of test area on the rate of predation by* Tyrophagus putrescentiae (X = Meloidogyne incognita, *J2;* ● = Hirschmanniella oryzae).

Discussion

Observations on *T. putrescentiae* suggest that these mites are predaceous in nature and feed voraciously on plant and soil nematodes belonging to different trophic groups. *T. putrescentiae* possess greater predatory potentials mainly because of their ability to kill a variety of nematodes in large numbers in culture and experimental dishes (Bilgrami & Tahseen, 1992). Rockett and Woodring (1966) also observed voracious feeding by an oribated mite *Pergalumna* sp. on *Pelodera lambdiense* and *Tylenchorhynchus martini.*

Probing before attacking prey is a common phenomenon in predatory nematodes (Bilgrami *et al.* 1985; Bilgrami, 1990 *a*; Bilgrami & Jairajpuri, 1990) but *T. putrescentiae* did not show any such mechanism. Predation by the mites depended upon physical contacts with the prey nematode. Contact of prey with the chelecerae of the mites was necessary to initiate an attack. An injured prey, however, attracted other mites which aggregated around it and fed together. This suggests that the mites are able to perceive prey secretions and respond positively towards them, similarly to predatory nematodes which move in response to prey secretions, aggregate around prey and feed (Bilgrami, 1990 *b*).

The reason why the second stages of *M. incognita, H. mothi* and *A. tritici* killed more than other plant parasitic and predatory nematodes, could be attributed to physical, chemical and behavioural characteristics which provide resistance against predation (Bilgrami & Jairajpuri, 1989, Bilgrami, 1992). Such anti-predation characteristics are generally absent in endo-parasitic nematodes.

Increased predation by *T. putrescentiae* with increasing number of *H. oryzae* and *M. incognita* suggest density-dependent predation, as is the case with many predaceous nematodes (Bilgrami *et al.* 1984; 1985; Bilgrami & Jairajpuri, 1990). This increase in predation may be attributed to improved chance of contacts between prey and predators. During the present observations increased predation by the mites with the increase in the period of starvation may be due to the apititic conditions which are governed by the duration of starvation. Differential rate of predation by *T. putrescentiae* at different temperatures and agar concentrations may be attributed to the activity of mites and prey nematodes (Bilgrami *et al.,* 1983). More predation in a small test area suggests that small surface area provided mites more nematodes per unit area to attack than the large ones. Thus more encounters between prey nematodes and mites occurred which resulted in increased predation by the mites. The rate of decline in predation by *T. putrescentiae* in thick agar layers is probably because of the migration of prey nematodes into the agar. The thickness of agar provided prey nematodes more area to avoid predation as the mites could not penetrate agar. *T. putrescentiae* is coprophagous which feeds on its own faecal matter generally when prey nematodes are absent (Bilgrami & Tahseen, 1992). This kind of behaviour suggests that mites undergo starvation in the absence of food (prey). No cannibalisitic tendency was observed in mites.

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References

BILGRAMI, A. L. (1990 *a*). Diplogasterid predators; *In :* Jairajpuri, M. S., Alam & Ahmad, I. (Eds). *Nematode Bio-control : aspects and prospects* CBS publishers & Distributors Pvt. Ltd New Delhi : 135-142.

BILGRAMI, A. L. (1990 *b*). Predaceous dorylaims : *In :* Jairajpuri, M. S., Alam & Ahmad, I. (Eds). *Nematode bio-control : aspects and prospects.* CBS publishers & Distributors Pvt. Ltd. New Delhi : 143-148.

BILGRAMI, A. L. (1992). Resistance and susceptibility of prey nematodes to predation and strike rate of the predators *Mononchus aquaticus, Dorylaimus stagnalis* and *Aquatides thornei. Fundam. appl. Nematol.,* 15 : 265-270.

BILGRAMI, A. L., AHMAD, I. & JAIRAJPURI, M. S. (1983). Some factors influencing predation by *Mononchus aquaticus. Revue Nématol.,* 6 : 325-326.

BILGRAMI, A. L., AHMAD, I. & JAIRAJPURI, M. S. (1984). Observations on the predatory behaviour of *Mononchus aquaticus. Nematol. medit.,* 12 : 41-45.

BILGRAMI, A. L., AHMAD, I. & JAIRAJPURI, M. S. (1985). Predatory behaviour of *Aquatides thornei* (Nygolaimina : Nematoda). *Nematologica* (1984), 30 : 457-462.

BILGRAMI, A. L. & TAHSEEN, Q. (1992). A nematode feeding mite, *Tyrophagus putrescentiae* (Sarcoptiformis : Acaridae). *Fundam. appl. Nematol., 15 :* 477-478.

BILGRAMI, A. L. & JAIRAJPURI, M. S. (1989). Resistance of prey to predation and strike rate of the predators *Mononchoides longicaudatus* and *M. fortidens* (Nematoda : Diplogasterida). *Revue Nématol.* 12 : 45-49.

BILGRAMI, A. L. & JAIRAJPURI, M. S. (1990). Predatory abilities of *Mononchoides longicaudatus* and *M. fortidens* (Nematoda : Diplogasterida) and factors influencing predation. *Nematologica,* 35 : 475-488.

IMBRIANI, J. I. & MANKAU, R. (1983). Studies on *Lasioseius sculpatus,* a neostigmatid mite predaceous on nematodes. *J. Nematol.,* 15 : 523-528.

LINFORD, M. B. & OLIVIERA, J. M. (1938). Potential agent of biological control of plant parasitic nematodes. *Phytopathology,* 28 : 14.

MURAOKA, M. & ISHIBISHI, N. (1976). Nematode feeding mites and their feeding behaviour. *Appl. Ent. Zool.,* 11 : 1-7.

MURPHY, P. W. & DONCASTER, C. C. (1957). A culture method for soil microfauna and its application to the study of nematode predation. *Nematologica,* 2 : 202-214.

ROCKETT, C. L. & WOODRING, J. P. (1966). Biological investigation on a new species of ceratozetes and of *Pergalumna. Acarologia,* 8 : 14-18.

RODRIGUEZ, T. G., WADE, C. F. & WELLS, C. N. (1962). Nematodes as natural food for *Macrocheles muscaedomesticae* (Acarina : Macrochelidae) a predator of the house fly egg. *Ann. ent. Soc. Am.,* 55 : 507-511.