Part - II
Attraction Behaviour of Predatory Nematodes Towards Prey
CHAPTER I

ATTRACTION RESPONSES OF PREDATORY NEMATODES TOWARDS PREY INDIVIDUALS BELONGING TO DIFFERENT TROPHIC GROUPS

INTRODUCTION

Several studies have been made on the predatory behaviour and predatory potential of nematodes (Bilgrami et al., 1984; Bilgrami et al., 1985c; Bilgrami, 1992; 1993; 1995b) but not much has been done to explore chemo-atraction behaviour of predatory nematodes using prey attractants and other chemicals. Some preliminary and casual studies made by earlier workers revealed aggregation of predators around an injured prey (Esser, 1963). The phenomenon, also observed by Yeates (1969) and Bilgrami et al., (1985b), was attributed to attractants dispersed by the prey nematodes. Bilgrami & Jairajpuri (1988; 1989a; 1989b) for the first time confirmed movements of two species of Diplogasterid predators viz.. Mononchoides longicaudatus and M. fortidens in response to prey attractants/repellents. Prey attractants are also chemicals similar to sex pheromones which are secreted into the environment and are required to bring predator and prey individuals together for interaction. The efficiency of prey attractants as a means of communication between two individuals depends upon their volatility and dispersal abilities to reach predators, transient changes of signal (Green, 1971) and the type of prey contents and size of prey (Bilgrami & Jairajpuri, 1989a). Every species of prey may elicit differential attraction responses of different species of predators. Such a response may be called as preferential response of predators which results due to emission of attractants, repellents or undesirable secretions by prey nematodes. Such chemicals when emitted in an environment may lead predators to exhibit meager to moderate to maximum attraction responses. Besides, the chemical composition, concentration, quality and quantity of prey secretions
also influence attraction responses of predatory nematodes as these characteristics vary between individuals and species of prey nematodes.

Since, very little is known about predator’s responses towards prey attractants and repellents in general and prey individuals belonging to different trophic groups in particular, experiments were designed here in order to firstly, enable us to identify attractive and non-attractive species of prey; secondly, to determine preferential behaviour of predatory nematodes and thirdly, to differentiate between the least, moderately less, moderately high and most attractive prey individuals and prey trophic groups. Such a classification of prey nematodes in relation to predator’s response should lead to establish effective combinations of predators and prey. This information regarding the efficacy of predatory nematodes may be used to stimulate their predatory activity in fields for nematode bio-control programs.

MATERIALS AND METHODS

To test the attraction responses of *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* towards prey nematodes belonging to different trophic groups, Petri-dish experiments were performed. All conditions remained same as described in the section entitled "Materials and Methods (General-I)" append supra. Two sets of experiments were performed. In the first, excised prey individuals (cut in two pieces) while in the second set of experiment non-excised (intact and live) prey individuals were used. For the definitions of the prey trophic groups viz., saprophagous, epidermal feeders, cortical feeders, endodermal feeders (endo-parasites), migratory semi-endodermal feeders (migratory semi-endoparasites), virus vectors and predaceous nematodes in accordance with Bilgrami (1993; 1995) and Yeates *et al.*, (1993) was followed here. The responses of *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* were tested separately towards excised and non-excised individuals of prey nematodes which are described in Table-III.
TABLE - III

LIST OF PREY NEMATODES BELONGING TO DIFFERENT PREY TROPHIC GROUPS USED AS PREY

The following species of prey nematodes belonging to different prey trophic groups were used as prey.

<table>
<thead>
<tr>
<th>Prey trophic groups</th>
<th>Species of prey</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saprophagous</td>
<td>1. <em>Chiloplacus symmetricus</em></td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>2. <em>Mesorhabditis</em> sp.</td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>3. <em>Acrobeloides</em> sp.</td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>4. <em>Tobrilus</em> sp.</td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>5. <em>Rhabditis</em> sp.</td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>6. <em>Cephalobus</em> sp.</td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>7. <em>Acrobeloides</em> sp.</td>
<td>Culture</td>
</tr>
<tr>
<td>Endodermal feeders</td>
<td>1. <em>Meloidogyne incognita</em> juv.</td>
<td>Root galls</td>
</tr>
<tr>
<td></td>
<td>2. <em>Anguina tritici</em> juv.</td>
<td>Wheat galls</td>
</tr>
<tr>
<td></td>
<td>3. <em>Heterodera</em> mothi juv.</td>
<td>Cysts</td>
</tr>
<tr>
<td>Migratory Semi endodermal feeders</td>
<td>1. <em>Hirschmanniella oryzae</em></td>
<td>Freshly Isolated</td>
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<tr>
<td></td>
<td>2. <em>Hoplolaimus indicus</em></td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td>3. <em>Helicotylenchus indicus</em></td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td>4. <em>Scutellonema</em> sp.</td>
<td>-do-</td>
</tr>
<tr>
<td>Epidermal feeders</td>
<td>1. <em>Tylenchorhynchus</em> mashhoodi</td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td>2. <em>Basiria graminiphola</em></td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td>3. <em>Aphlenchoides</em> sp.</td>
<td>-do-</td>
</tr>
<tr>
<td>Virus Vectors</td>
<td>1. <em>Xiphinema basiri</em></td>
<td>Freshly Isolated</td>
</tr>
<tr>
<td></td>
<td>2. <em>Paralongidorus citri</em></td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td>3. <em>Longidorus attenuatus</em></td>
<td>-do-</td>
</tr>
<tr>
<td></td>
<td>4. <em>Paratrichodorus</em> mirzai</td>
<td>-do-</td>
</tr>
<tr>
<td>Cortical feeders</td>
<td>1. <em>Hemicriconemoides mangiferae</em></td>
<td>Freshly Isolated</td>
</tr>
<tr>
<td></td>
<td>2. <em>Hemicycliophora dhirendri</em></td>
<td>-do-</td>
</tr>
<tr>
<td>Predators</td>
<td>1. <em>Mesodorylaimus bastiani</em></td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>2. <em>Aquatides thornei</em></td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>3. <em>Laimydorus baldus</em></td>
<td>Culture</td>
</tr>
<tr>
<td></td>
<td>4. <em>Discolaimus major</em></td>
<td>Culture</td>
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</tbody>
</table>
Forty replicates of each experiments were set. Scores, Log Scores and Mean Log Scores were obtained and plotted in the graphs. Different species of nematodes belonging to various prey trophic groups were selected so that comparative attraction profile of the four species of predators could be made and their preferences for particular prey to be determined. Figures 7-14 show the mean attraction response (MLS) of M. bastiani, A. thornei, L. baldus and D. major towards each prey trophic group. Such responses of predators were calculated by taking the mean of the total response (MLS) of prey individuals belonging to a particular trophic group. The data collected was subjected to various statistical tests which are described in "Materials and Methods (General-1)". In Table -III nematodes which were used as prey are mentioned by their species names. However, in the following text various prey nematodes are referred by their generic names only while describing results and drawing conclusions. Such an option was selected to make comparative studies at generic as well as prey trophic levels instead of species level. Such studies should definitely be more comprehensive and comparable to reach conclusions and make practical applications in stimulating field efficacy of predatory nematodes.

RESULTS

Chemo-attraction responses of M. bastiani, A. thornei, L. baldus and D. major were tested towards prey individuals belonging to different trophic groups viz., saprophagous, virus vectors, predators, epidermal feeder, endodermal feeder, migratory semi endodermal feeders and cortical feeders. All species of predators exhibited differential attraction responses towards different species of prey belonging to different trophic groups.
(A) ATTRACTION RESPONSES OF PREDATORS TOWARDS SAPROPHAGOUS NEMATODES (FIG. 7)

All nematodes belonging to saprophagous groups viz., Chiloplacus, Acrobeles, Mesorhabditis, Cephalobus, Tobrilus, Rhabditis and Acrobeloides attracted M. bastiani, A. thornei, L. baldus and D. major. Attraction responses of these predators varied from prey to prey. The excised prey individuals of all species of saprophagous nematodes elicited attraction response of predators more than the non-excised (live) prey individuals.

a) Attraction responses of M. bastiani (Fig. 7A): M. bastiani responded maximally towards excised Rhabditis (MLS = 2.21 ± 0.12; CV = 6%; p < 0.05) and Mesorhabditis (MLS = 2.18 ± 0.13; p < 0.05) with least degree of variation (CV = 6%). The distribution of M. bastiani corresponded to ranks 8, 9, 10, 12, 13, 14 and 15 and 10, 11, 12, 13, 14 and 15 respectively. The excised individuals of Acrobeles (MLS = 1.67 ± 0.36; CV = 21%) and Tobrilus (MLS = 1.72 ± 0.40; CV = 23%) were least attractive and the distribution of predator corresponded to ranks 6, 7, 8 for Acrobeles and 6, 7, 8, 9, 10, 11 for Tobrilus. Other species of saprophagous nematodes viz., Chiloplacus, Cephalobus, Acrobeloides elicited moderate responses of M. bastiani (MLS = 1.91 to 2.12) when tested as prey.

M. bastiani also showed maximum response towards non-excised individuals of Rhabditis (MLS = 2.08 ± 0.11; CV = 5%; p < 0.05) and Mesorhabditis (MLS = 2.05 ± 0.10; CV = 5%; p < 0.05). The distribution of predators corresponded to ranks 8, 9, 10, 11, 12, 13 for Rhabditis and 7, 9, 10, 11, 12, for Mesorhabditis. Non-excised Acrobeles (MLS = 1.62 ± 0.36) and Tobrilus individuals (MLS = 1.67 ± 0.36) were least attractive to these predators (p < 0.05) with high degree of variation (CV = 22%). The distribution of predators corresponded to ranks 6, 7, 8, 9 in presence of Acrobeles and Tobrilus. Chiloplacus, Cephalobus and Acrobeloides were moderately attractive to M. bastiani (MLS = 1.81 - 1.95).
b) **Attraction responses of A. thorrei (Fig. 7B):** Excised individuals of *Rhabditis* were preferred most (MLS = 2.30 ± 0.40; p < 0.05) by *A. thorrei*. The attraction of predators was most consistent (CV = 17%) and their distribution corresponded to ranks 13, 14, 15 and 16. Predators were least responsive to the attractants dispersed by *Acrobeles* (MLS = 1.64 ± 0.38; CV = 23%) and *Tobrilus* (MLS = 1.74 ± 0.38; CV = 22%). Thus, the distribution of predators corresponded to ranks 6, 9, 11 in presence of *Acrobeles* and 6, 7, 8, 9, 11 and 13 in presence of *Tobrilus*. *Chiloplacus Mesorhabditis*, *Cephalobus*, and *Acrobeloides* were moderately attractive to *A. thorrei* (MLS = 1.96 - 2.22).

Similar to excised individuals, the non-excised individuals of *Rhabditis* elicited maximum response of *A. thorrei* (MLS = 2.19 ± 0.16; CV = 7%; p < 0.05). Non-excised individuals of *Acrobeles* and *Tobrilus* were, however, least attractive to *A. thorrei* (MLS = 1.63 ± 0.37; CV = 23% and 1.72 ± 0.36; CV = 21%, respectively). Other species of saprophagous nematodes were moderately attractive to *A. thorrei* (MLS = 1.90 - 2.11). The distribution of predators corresponded to ranks 8, 11, 12, 13, 14 and 17 in presence of *Rhabditis* and 6, 7, 8 and 11 in presence of *Acrobeles* or *Tobrilus* respectively.

c) **Attraction responses of L. baldus (Fig. 7C):** Similar to *M. bastiani* and *A. thorrei*, members of *L. baldus* also responded maximum to the attractants emitted by excised *Rhabditis* (MLS = 2.31 ± 0.18; CV = 8%; p < 0.05). Excised individuals of *Acrobeles* and *Tobrilus* were found to be least attractive to *L. baldus* (MLS = 1.72 ± 0.36; CV = 21% and 1.81 ± 0.31; CV = 17%). The distribution of predators corresponded to ranks 8, 9, 10, 13, 14, 15, 17, 18 and 20 in presence of excised individuals of *Rhabditis* in presence of individuals of *Acrobeles* and *Tobrilus*, the distribution corresponded to ranks 6, 7, 8, 9, 10, 11 and 6, 7, 8 respectively. Other
species of saprophagous nematodes included in present study were found to be moderately attractive to *L. baldus*.

Non-excised individuals of *Acrobeles* and *Tohrilus* were least attractive (MLS = 1.67 ± 0.36; CV = 21% and 1.72 ± 0.37; CV = 21%) to *L. baldus*, with the distribution of predators corresponding to ranks 6, 7, 8 and 6, 7, 8, 11, respectively. Non-excised individuals of *Rhabditis* were found to be most attractive to *L. baldus* (MLS = 2.19 ± 0.15; CV = 7%; p < 0.05) with the distribution of predators corresponding to ranks 7, 10, 12, 13, 15, 16 and 17. Individuals of *Chilopacus, Mesorhabditis, Cephalobus* and *Acrobeleoides* when used as prey attracted *L. baldus* in moderate numbers.

d) **Attraction responses of *D. major* (Fig. 7D):** The response of the members of *D. major* towards the excised individuals of *Rhabditis* was maximum (MLS = 2.29 ± 0.19, CV = 8%; p < 0.05) and their distribution corresponded to ranks 7, 13, 15, 16 and 17. Other species of saprophagous nematodes when tested as prey were moderately attractive to *D. major* (MLS = 2.12 to 2.26) except *Tohrilus* and *Acrobeles*. *D. major* showed minimum chemotactic responses towards excised individuals of *Tohrilus* and *Acrobeles* (MLS = 1.91±0.36; CV=19% and 2.01±0.02; CV = 1%). The distribution of *D. major* corresponded to ranks 6, 7, 8, 13 and 7, 10, 11 in presence of *Tohrilus* and *Acrobeles* respectively. Compared to *M. bastiani, A. thornei* and *L. baldus*, *D. major* showed higher overall attraction response towards saprophagous nematodes.

*D. major* exhibited maximum attraction towards non-excised individuals of *Rhabditis* (MLS = 2.20±0.20; CV = 9%; p < 0.05), with its distribution corresponding to ranks 7, 8, 13 and 16. This was higher than that recorded in presence of non-excised *Tohrilus* (6, 7 and 13) and *Acrobeles* individuals (6, 7, 10 and 11) which elicited least chemotactic
Fig. 7: Attraction responses of predators towards excised and non-excised prey individuals belonging to saprophagous nematodes. A = *M. bastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. CS = *Chiloplacus*; ME = *Mesorhabditis*; AC = *Acrobeles*; TO = *Tobrilus*; RH = *Rhabditis*; CE = *Cephalobus*; AB = *Acrobeloides*. 
response in this predator (MLS = 1.77±0.45; CV = 25% and 1.87±0.32; CV = 17%). The attractants diffused by other species of saprophagous nematodes were moderately attractive to D. major (MLS = 1.94 to 2.12).

(B) ATTRACTION RESPONSES OF PREDATORS TOWARDS EPIDERMAL FEEDERS (FIG. 8)

Four species of predators viz., M. hastiani, A. thornei, L. baldus and D. major exhibited chemo-attraction towards all three species of epidermal feeders which were used as prey. Their attraction responses varied with the species of predators and excised or non-excised individuals of prey.

a) Attraction responses of M. bastiani (Fig. 8A): M. bastiani preferred excised individuals of Aphelenchoides and migrated most towards them (MLS = 2.20 ± 0.12; p < 0.05) with least degree of variation (CV = 6%). The distribution of M. bastiani corresponded to ranks 10, 11, 12, 13, 14 and 15. Basiria was least attractive (MLS = 2.13 ± 0.13; CV = 6%) to M. hastiani and the distribution of predators corresponded to ranks 8, 9, 10, 11, 13, 14 and 15. Excised individual of Tylenchorhynchus was moderately attractive to M. hastiani (MLS = 2.15 ± 0.17; CV = 8%).

Attraction responses of M. bastiani towards non-excised individuals of Tylenchorhynchus, Basiria and Aphelenchoides was identical (2.04± 0.09; CV = 5%) (p > 0.05). The distribution of M. bastiani corresponded to ranks 5, 6, 7, 8, 9, 10, 11, 12, 13 and 15 in the presence of non-excised individuals of Tylenchorhynchus, Basiria and Aphelenchoides.

b) Attraction responses of A. thornei (Fig. 8B): The presence of excised individuals of Aphelenchoides in Petri-dishes yielded maximum attraction of A. thornei (MLS = 2.23 ± 0.19; CV = 8%; p < 0.05). Tylenchorhynchus was least (MLS = 2.19 ± 0.20; CV = 9%) and Basiria was moderately attractive to these predators (MLS = 2.20 ± 0.13; CV = 6%). The distri-
bution of *A. thornei* corresponded to ranks 7, 8, 9, 11, 12, 13, 14, 15 and 17 and 7, 8, 13, 15, 16 and 17 in presence of excised individuals of *Aphelenchoides* and *Tylenchorhynchus* respectively.

*Basiria.* when tested live or intact attracted maximum number of *A. thornei* (MLS = 2.14 ± 0.13; CV = 6%; p < 0.05) and its distribution corresponded to ranks 10, 11, 12, and 13. The non-excised individuals of *Tylenchorhynchus* or *Aphelenchoides* were least attractive to *A. thornei* (MLS = 2.09 ± 0.13; CV = 6%). The distribution of predators corresponded to ranks 7, 8, 9, 10, 12, 13 and 14 in presence of non-excised individuals of *Tylenchorhynchus* or *Aphelenchoides*.

c) **Attraction responses of *L. baldus*** (Fig. 8C): *L. baldus* exhibited a strong chemotactic response towards excised individuals of *Basiria* (MLS = 2.30 ± 0.13; CV = 6%; p < 0.05). *L. baldus* were found to be distributed in the ranks 10, 11, 12, 13, 14, 15 and 16. This predator responded moderately to excised individuals of *Aphelenchoides* (MLS = 2.24 ± 0.14; CV = 6%). *L. baldus* was attracted least by *Tylenchorhynchus* (MLS = 2.17 ± 0.16; CV = 7%; p < 0.05) as its distribution corresponded to ranks 7, 8, 9, 10, 13, 14 and 15.

When tested towards non-excised individuals of epidermal feeders, *L. baldus* exhibited maximum response towards *Basiria* (MLS = 2.19 ± 0.15; CV = 7%). Their distribution corresponded to ranks 7, 10, 13, 14, 15 and 18. This predator was moderately responsive to attractants released by *Tylenchorhynchus* (MLS = 2.06 ± 0.11; CV = 5%). The attraction was recorded least towards *Aphelenchoides* and distribution of this predator corresponded to ranks 6, 7, 13, 14 and 15.

d) **Attraction responses of *D. major*** (Fig. 8D): Unlike other species of predators, *D. major* preferred excised individuals of *Tylenchorhynchus* and migrated maximum towards attractants released by them (MLS = 2.27 ± 0.21; CV = 9%; p < 0.05). The distribution of *D. major* corresponded
Fig. 8: Attraction responses of predators towards excised and non-excised prey individuals belonging to epidermal feeders. A = *M. bastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. TM = *Tylenchorhynchus*. BA = *Basiria*; AP = *Aphlenchoides*. 
to ranks 11, 15, 16 and 17 in presence of *Tylenchorhynchus*. *D. major* exhibited moderate degree of attraction (MLS = 2.25 ± 0.20; CV = 9%) towards excised individuals of *Aphelenchoides*. The attraction was least when this predator was tested with *Basiria* (MLS = 2.22 ± 0.17; CV = 8%; p < 0.05). The distribution of predators corresponded to ranks 11, 13, 16 or 17 in presence of *Aphelenchoides* and 11, 13, 15 and 16 in presence of *Basiria*.

The attraction of *D. major* was recorded maximum towards non-excised individuals of *Tylenchorhynchus* (MLS = 2.21 ± 0.19; CV = 9%) and least when tested towards *Basiria* (MLS = 2.07 ± 0.13; CV = 6%) (p < 0.05). The distribution of *D. major* corresponded to ranks 9, 10, 13, 14 and 17 in presence *Tylenchorhynchus* and 7, 8, 11 and 15 in presence of *Basiria*. The degree of attraction of *D. major* towards non-excised individual of *Aphelenchoides* was moderate (MLS = 2.08 ± 0.14; CV = 7%) (p < 0.05).

(C) ATTRACTION RESPONSES OF PREDATORS TOWARDS MIGRATORY SEMI ENDODERMAL FEEDERS (FIG. 9)

*M. bastiani, A. thornei, L. baldus* and *D. major* migrated more towards the attractants emitted by excised individuals of migratory semi endodermal feeders than their live or intact members. Degree of attraction varied with different species of predators used.

a) Attraction responses of *M. bastiani* (Fig. 9A): Excised individuals of *Hirschmanniella, Hoplolaimus* and *Scutellonema* elicited maximum responses of *M. bastiani* (MLS = 2.18 - 2.19; p < 0.05) with a least degree of variation (CV = 7-9%). The distribution of *M. bastiani* corresponded to ranks 7, 8, 9, 10, 13, 14, 15, 16 and 17 in presence of the above three species of prey nematodes. *M. bastiani* was least responsive to the attractants released by excised *Helicotylenchus* individuals.
The chemotactic response of *M. bastiani* towards non-excised individuals of migratory semi endodermal feeders was at par with that in presence of *Hirschmanniella* and *Scutellonema* (MIS = 2.02 - 2.05: p < 0.05). The distribution of predators corresponded to ranks 6, 7, 8, 9, 10, 11, 13, 14, 15 and 17 in presence of them. *Hoploaimus* elicited moderate attraction response of *M. bastiani* (MLS = 1.90 ± 0.32; CV = 17%) while, *Helicotylenchus* the least (MLS = 1.75 ± 0.35) and with much inconsistency (CV = 20%).

b) **Attraction responses of *A. thornei* (Fig. 9B):** The excised individuals of *Hirschmanniella* attracted predators most (MLS = 2.30 ± 0.13; p < 0.05) with least degree of variation (CV = 6%). With the excised individual of *Hirschmanniella* taken as prey, the distribution of *A. thornei* was found to correspond with the ranks 11, 12, 13, 14, 15 and 17 in Petri-dishes. *A thornei* exhibited moderate attraction in response to the attractants dispersed by excised specimen of *Scutellonema* (MLS = 2.24 ± 0.16; CV = 7%). The attraction was recorded least towards *Hoploaimus* (MLS = 2.19 ± 0.15; CV = 7%) and distribution of predators corresponded to ranks 7, 10, 11, 12, 13, 15, 16 and 17.

The non-excised individuals of *Scutellonema* yielded maximum response of *A thornei* (MLS = 2.13 ± 0.16; CV = 7%). The distribution of predators in presence of this prey corresponded to ranks 8, 9, 10, 11, 12, 13, 14, 15 and 17. *Hoploaimus* yielded moderate attraction response of *A thornei* (MLS = 1.95 ± 0.18; CV = 9%) while *Helicotylenchus* did the least (MLS = 1.79 ± 0.42; CV = 23%). In presence of non-excised *Helicotylenchus* the distribution of *A thornei* corresponded to lower ranks 4, 6, 7, 8, 9, 10, 11 and 15.

c) **Attraction responses of *L. baldus* (Fig. 9C):** The excised individuals of *Hirschmanniella* were most attractive to *L baldus* (MLS = 2.30 ± 0.13; CV = 6%) with the distribution of this predators corresponding to the ranks
10, 11, 13, 14, 15 and 17. Attractants dispersed by excised individuals of *Scutellonema* and *Hoplolaimus* attracted this predator moderately (MLS = 2.23 ± 0.14; CV = 6% and MLS = 2.16 ± 0.18; CV = 8%). with the distribution of the predator corresponding to ranks 7, 8, 9, 10, 11, 13, 14, 15, 16, and 17 in the case of both these prey species.

The non-excised individuals of *Helicotylenchus* elicited minimum responses of predators (MLS = 1.67 ± 0.36; CV = 21%). In this case the distribution of predators corresponded to ranks 6, 7 and 8. While *Hirschmanniella* elicited maximum attraction response (MLS = 2.13 ± 0.14; CV = 6%). *Hoplolaimus* and *Scutellonema* elicited moderate attraction response of *L. baldus* (MLS = 2.01 ± 0.23; CV = 11% in the case of *Hoplolaimus* and MLS = 2.10 ± 0.13; CV = 6% in the case of *Scutellonema*) (P < 0.05).

d) Attraction responses of *D. major* (Fig. 9D): The excised specimen of migratory semi endoparasites. *Hirschmanniella* were most preferred prey individuals. *D. major* responded maximally towards the attractants released by *Hirschmanniella* (MLS = 2.30 ± 0.67; CV = 29%). The excised individuals of *Helicotylenchus* yielded minimum response of this predator (MLS = 1.74 ± 0.40; CV = 23%). The distribution of *D. major* in presence of *Helicotylenchus* corresponded to lower ranks 6, 10 and 11. Other individuals belonging to migratory semi endodermal feeders viz.. *Hoplolaimus* and *Scutellonema* were moderately attractive to predators when tested in the excised state (MLS = 2.21 - 2.25).

The responses of *D. major* towards these four semi endodermal feeders were identical to its responses towards their non-excised individuals. *D. major* preferred *Hirschmanniella* most (MLS = 2.21 ± 0.14; CV = 6%; p < 0.05) and the distribution of its specimen corresponded to ranks 8, 10, 13, 14 and 17. *Helicotylenchus* when tested as non-excised prey yielded least chemotactic response of *D. major* (MLS = 1.94 ± 0.37;
Fig. 9: Attraction responses of predators towards excised and non-excised prey individuals belonging to migratory semi endodermal feeders. A = M. bastiani; B = A. thornei; C = L. baldus; D = D. major. HZ = Hirschmanniella; HI = Helicotylenchus; HO = Hoplolaimus; SC = Scutellonema.
CV 19%: p < 0.05) but Hoplolaimus and Scutellonema elicited moderate (MLS 2.14 and 2.17) attractive response of this predator. The distribution of individuals of D. major corresponded to ranks 6, 8, 10, 11, 13, 14 and 15 in presence of live Helicotylenchus.

(D) ATTRACTION RESPONSES OF PREDATORS TOWARDS ENDODERMAL FEEDERS (FIG. 10)

Compared to their live and intact individuals, the attractants dispersed by their excised second stage juveniles elicited strong chemotactic attraction responses all four species of predators. However, the degree of attraction varied with species of predators and prey.

a) Attraction responses of M. bastiani (Fig. 10A): M. bastiani preferred excised specimen of Anguina and migrated most towards them (MLS = 2.15 ± 0.38: p < 0.05) with least degree of variation (CV = 18%). The distribution of M. bastiani corresponded to ranks 6, 8, 9, 11, 15, 16 and 17. Meloidogyne juveniles were least attractive (MLS = 2.03 ± 0.23: CV = 11%) to M. bastiani and the distribution of predators corresponded to ranks 6, 9, 10, 11, 12, 13 and 14. Excised second stage juveniles of Heterodera were moderately attractive to M. bastiani (MLS = 2.12 ± 0.15: CV = 7%).

While the second stage juveniles of Anguina were most attractive (MLS = 2.01 ± 0.24; CV = 12%). Heterodera was moderately attractive (MLS = 1.95 ± 0.28; CV = 14%) and Meloidogyne juveniles least attractive (MLS = 1.91 ± 0.25; CV = 13%) to M. bastiani when these endodermal feeders were tested as live and intact (p < 0.05). The distribution of M. bastiani corresponded to ranks 6, 7, 8, 9, 10 and 11 in the presence of non-excised Anguina and Meloidogyne juveniles.
b) Attraction responses of *A. thornei* (Fig. 10B): The presence of excised second stage juveniles of *Anguina* in Petri-dishes yielded maximum attraction of *A. thornei* (MLS = 2.26 ± 0.11; CV = 5%; p < 0.05). *Meloidogyne* juveniles were least attractive (MLS = 2.17 ± 0.14; CV = 6%) whereas *Heterodera* was moderately attractive to these predators (MLS = 2.22 ± 0.14; CV = 6%). The distribution of *A. thornei* corresponded to ranks 7, 12, 13, 14, 15 and 6, 7, 13, 14, 15 in presence of excised *Anguina* and *Heterodera* juveniles respectively.

*Anguina* juveniles, when tested live and intact, attracted maximum number of *A. thornei* (MLS = 2.23 ± 0.15; CV = 7%) and the distribution of predators corresponded to ranks 7, 8, 9, 10, 13, 14, 15 and 17. The non-excised individuals of *Heterodera* were least attractive to *A. thornei* (MLS = 1.97 ± 0.19; CV = 10%, p < 0.05). The low attraction response of *A. thornei* towards non-excised *Heterodera* corresponded to lower ranks viz., 6, 7, 8, and 11. *Meloidogyne* juveniles were moderately attractive to these predators.

c) Attraction responses of *L. baldus* (Fig. 10C): *L. baldus* exhibited a strong chemotactic response towards excised individuals of *Anguina* (MLS = 2.36 ± 0.11; CV = 5%; p < 0.05). Specimens of *L. baldus* were found to be distributed in the ranks 7, 12, 13, 14 and 15. This predator responded moderately to excised juveniles of *Meloidogyne* (MLS = 2.19 ± 0.15; CV = 7%). *L. baldus* was least attracted by *Heterodera* (MLS = 2.05 ± 0.36; CV = 17%; p < 0.05) as the distribution of its specimens corresponded to ranks 6, 7, 13, 14 and 15.

When tested towards non-excised individuals of endodermal feeders, *L. baldus* exhibited maximum response towards *Anguina* (MLS = 2.15 ± 0.15; CV = 7%). Their distribution corresponded to ranks 7, 8, 9, 10, 13 and 14. This predator was moderately responsive to attractants released by *Meloidogyne* (MLS = 2.04 ± 0.10; CV = 5%). The attraction was
Fig. 10: Attraction responses of predators towards excised and non-excised prey individuals belonging to endodermal feeders. A = *M. bastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. MI = *Meloidogyne*; AT = *Anguina*; HM = *Heterodera*. 
recorded least towards *Heterodera* juveniles where distribution of this predator corresponded to ranks 6, 7, 8, 9, 11 and 13.

d) **Attraction responses of *D. major*** (Fig. 10D): Unlike other species of predators, *D. major* prefered excised individuals of *Meloidogyne* and migrated maximum towards attractants released by them (MLS = 2.21 ± 0.20; CV = 9%; p < 0.05). The distribution of *D. major* corresponded to ranks 7, 8, 15 and 16 in presence of *Meloidogyne* juveniles. *D. major* exhibited moderate degree of attraction (MLS = 2.18 ± 0.14; CV = 6%) towards excised individuals of *Anguina*. The attraction was least (MLS = 2.05 ± 0.13; CV = 6%; p < 0.05) when this predator was tested in presence of second stage juveniles of *Heterodera*. The distribution of predators in the three zones of the Petri-dishes corresponded to ranks 10, 11, 15, 16 in presence of *Meloidogyne* and to ranks 7, 8, 13 in presence of *Heterodera*.

The attraction of *D. major* was recorded maximum towards non-excised individuals of *Anguina* (MLS = 2.13 ± 0.15; CV = 7%), and least when tested towards *Heterodera* juveniles (MLS = 1.94 ± 0.37; CV = 19%). The distribution of *D. major* corresponded to ranks 7, 8, 14, 15 and 6, 11, 13 in presence of non-excised *Meloidogyne* and *Heterodera* juveniles respectively. The degree of attraction of *D. major* remained same towards non-excised juveniles of *Meloidogyne* and *Anguina* (p > 0.05).

(E) **Attraction responses of predators towards virus vectors**

(Fig. 11)

Four species of predators exhibited chemo-attraction towards all species of virus vectors viz., *Xiphinema, Paralongidorus, Longidorus* and *Paratrichodorus*. Their attraction responses varied from species to species and from individual to individual.
a) **Attraction responses of *M. bastiani* (Fig. 11A):** The excised individuals of *Paralongidorus* and *Longidorus* were most attractive to *M. bastiani* (MLS = 2.00 ± 0.22; CV = 6%; and MLS = 2.01 ± 0.13; CV = 11%; p < 0.05). The distribution of *M. bastiani* in presence of them corresponded to ranks 6, 8, 9, 10, 11, 12, 14 and 6, 7, 8, 11, 12, 13, 15, respectively. This predator responded least (MLS = 1.71 ± 0.43; CV = 25%; p < 0.05) to the attractants released by *Pararichodorus* and its distribution corresponded to ranks 4, 5, 6, 8, 9, 10, 11 and 13. *M. bastiani* exhibited moderate degree of attraction towards excised individuals of *Xiphinema* (MLS = 1.91 ± 0.25; CV = 13%).

The response of *M. bastiani* towards non-excised individuals of *Paralongidorus* was maximum (MLS = 1.94 ± 0.35; CV = 18%). It was minimum when *Pararichodorus* individuals (MLS = 1.58 ± 0.41; CV = 26%) were used as prey. The distribution of *M. bastiani* corresponded to ranks 6, 8, 9, 10, 11, 13, 15 and 4, 5, 6, 7, 9, 11 in presence of non-excised *Paralongidorus* and *Pararichodorus* individuals respectively. Non-excised individuals of both *Xiphinema* (MLS = 1.81 ± 0.32; CV = 18%) and *Longidorus* (MLS = 1.85 ± 0.36; CV = 19%) were moderately attractive to *M. bastiani*.

b) **Attraction responses of *A. thornei* (Fig. 11B):** *A. thornei* preferred excised individuals of *Paralongidorus* most and migrated maximum towards them in response to their attractants (MLS = 2.20 ± 0.22; CV = 10%; p < 0.05). The distribution of *A. thornei* corresponded to higher ranks i.e., 6, 7, 8, 9, 11, 13 and 15. Excised individuals of *Pararichodorus* elicited least chemotactic response of *A. thornei* (MLS = 1.78 ± 0.43; CV = 24%). The distribution of this predator corresponded to ranks 5, 6, 7, 8, 10, 11 and 15. The degree of attraction was moderate towards excised individuals of both *Xiphinema* (MLS = 1.99 ± 0.21; CV = 10%) and *Longidorus* (MLS = 2.10 ± 0.14; CV = 7%).
Similar to excised individuals, the non-excised individuals of Paralongidorus elicited maximum attraction response of A. thornei (MLS = 2.02 ± 0.23; CV = 11%; p < 0.05). The distribution of A. thornei corresponded to ranks 6, 7, 8, 9, 11, 12 and 13. Individuals belonging to Xiphinema and Longidorus were moderately attractive to A. thornei (MLS = 1.86 ± 0.29; CV = 15% and MLS = 1.95 ± 0.28; CV = 14%) while the specimen of Paratrichodorus were least attractive to it (MLS = 1.61 ± 0.38; CV = 24%; p < 0.05). In presence of Paratrichodorus the distribution of predators was recorded in the ranks 4, 5, 6, 7, 8, 10 and 11.

c) Attraction responses of L. baldus (Fig. 11C): L. baldus showed identical chemotactic responses towards attractants dispersed by Paralongidorus and Longidorus (MLS = 2.01 ± 0.23; CV = 11%; p > 0.05). L. baldus preferred their attractants and migrated in maximum numbers towards them. While the degree of attraction of L. baldus towards Xiphinema was moderate (MLS = 1.91 ± 0.25; CV = 13%). it was least towards Paratrichodorus (MLS = 1.72 ± 0.40; CV = 23%; p < 0.05). The predators were found to be distributed in the ranks 6, 7, 8, 9, 10, 11, 13, 14, 16, 18 and 4, 5, 6, 7, 9, 10 in presence of excised Paralongidorus and Longidorus and Paratrichodorus respectively.

Among the virus vectors studied here, non-excised individuals of Longidorus (MLS = 1.95 ± 0.18. CV = 9%) were found to be most attractive while Paratrichodorus individuals were least attractive (MLS = 1.62 ± 0.37; CV = 23%; p < 0.05). The distribution of L. baldus corresponded to ranks 6, 7, 8, 9, 10, 11 in presence of Longidorus and to ranks 5, 6, 7, 8, 11 in presence of Paratrichodorus.

d) Attraction responses of D. major (Fig. 11D): Unlike other species of predators, D. major prefered attractants released by the excised individuals
Fig. 11: Attraction responses of predators towards excised and non-excised prey individuals belonging to virus vectors. A = *M. bastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. XB = *Xiphinema*; PC = *Paralongidorus*; LA = *Longidorus*; PT = *Paratrichodorus*. 
of *Xiphinema* (MLS = 2.05 ± 0.13; CV = 6%) and *Longidorus* (MLS = 2.06 ± 0.13; CV = 6%) (p < 0.05). The distribution of *D. major* corresponded to ranks 7, 8, 10, 11, 13 and 15 in presence of their excised individuals. In their excised state, specimens of *Paralongidorus* elicited moderate response of *D. major* (MLS = 1.92 ± 0.37; CV = 19%). while *Paratrichodorus* the least (MLS = 1.86 ± 0.32; CV = 17%; p < 0.05). The distribution of *D. major* corresponded to ranks 6, 7, 8 and 11.

Similar to excised, the non-excised individuals of *Xiphinema* and *Longidorus* were most attractive to *D. major* (MLS = 1.93 ± 0.37; CV = 19% and MLS = 1.94 ± 0.38; CV = 19%. respectively) (p < 0.05). In their non-excised state, specimens of *Paralongidorus* were moderately attractive (MLS = 1.85 ± 0.31; CV = 17%) to *D. major*, while *Paratrichodorus* individuals were least attractive (MLS = 1.72 ± 0.38; CV = 22%; p < 0.05). The distribution of predators corresponded to ranks 6, 8, 10, 11, 13 in presence of *Xiphinema* and to ranks 6, 11, 15 in presence of *Longidorus*. The distribution of *D. major* for non-excised individuals of *Paratrichodorus* corresponded to ranks 6, 7 and 8.

(F) ATTRACTION RESPONSES OF PREDATORS TOWARDS CORTICAL FEEDERS
(Fig. 12)

The two species of cortical feeders viz., *Hemicriconemoides* and *Hemicycliophora* tested here elicited different attraction responses in *M. bastiani, A. thornei, L. baldus* and *D. major*. Response of a given species of predator also differed with the excised or non-excised state of the individuals of a given prey species.

a) Attraction responses of *M. bastiani* (Fig. 12A): The chemotactic responses of *M. bastiani* towards excised individuals of *Hemicriconemoides* and *Hemicycliophora* were identical (MLS = 2.02; p < 0.05). The distribution of *M. bastiani* corresponded to ranks 6, 7, 8, 9, 10, 11, 16, 17
in presence of *Hemicriconemoides* and to ranks 7, 8, 10, 11, 13 in presence of *Hemicycliophora*.

Compared to non-excised individuals of *Hemicycliophora*, the non-excised individuals of *Hemicriconemoides* were slightly more attractive to this predator (MLS = 2.01 ± 0.08; CV = 4%; p < 0.05). The distribution of *M. bastiani* corresponded to ranks 7, 8, 9 and 15 in presence of individuals of *Hemicriconemoides*.

b) **Attraction responses of A. thornei (Fig. 12B):** Compared to the excised individuals of *Hemicycliophora*, the excised individuals of *Hemicriconemoides* were found to be more attractive (MLS = 2.15 ± 0.19; CV = 9%; p < 0.05) to *A. thornei* (MLS = 2.04 ± 0.35; CV = 17%).

Like was the case with its excised individuals, the non-excised individuals of *Hemicriconemoides* were also found to be more attractive to *A. thornei* (MLS = 2.00 ± 0.32; CV = 16%; p < 0.05) than the non-excised individuals of *Hemicycliophora* (1.92 ± 0.26; CV = 13%). The distribution of *A. thornei* corresponded to ranks 6, 7, 8, 10, 11, 13, 14 and 15 and 6, 7, 8, 9 and 13 respectively.

c) **Attraction responses of L. baldus (Fig. 12C):** Similar to *M. bastiani*, *L. baldus* also showed slight difference in its chemotactic response towards excised individuals of these two species of cortical feeders (MLS = 2.01-2.02, p > 0.05). This predator was found to be distributed in the ranks 6, 7, 8, 9, 10, 11, 13, 14 and 6, 7, 8, 9, 10, 11, 14, 15 and 16 in presence of *Hemicriconemoides* and *Hemicycliophora* respectively.

Non-excised individuals of *Hemicriconemoides* attracted *L. baldus* more (MLS = 1.96 ± 0.83; CV = 42%; p < 0.05) than the non-excised individuals of *Hemicycliophora* (MLS = 1.90 ± 0.24; CV = 13%). This predator was found to be distributed in the ranks 6, 7, 8, 9, 10, 11 and
Fig. 12: Attraction responses of predators towards excised and non-excised prey individuals belonging to cortical feeders. A = M. bastiani; B = A. thornei; C = L. baldus; D = D. major. HM = Hemicriconemoides; HD = Hemicycliophora.
6, 7, 8, 10, respectively in the presence of \textit{Hemicriconemoides} and \textit{Hemicycliophora}.

d) Attraction responses of \textit{D. major} (Fig. 12D): The excised individuals of \textit{Hemicycliophora} (MLS = 2.10 ± 0.16; CV = 8\%) and \textit{Hemicriconemoides} (MLS = 2.08 ± 0.16; CV = 8\%) elicited identical attraction responses of \textit{D. major} (p > 0.05). Individuals of \textit{D. major} were recorded in the ranks 7, 13 and 14 and 8, 10, 11, 14 and 15 in presence of \textit{Hemicycliophora} and \textit{Hemicriconemoides} respectively.

Like was the case with the excised individuals of these two species regarding their attractiveness to \textit{D. major}, the non-excised individuals of \textit{Hemicycliophora} were more attractive to predators (MLS = 2.05 ± 0.13; CV = 6\%; p < 0.05) than the non-excised individuals of \textit{Hemicriconemoides} (MLS = 2.00 ± 0.02; CV = 1\%). The distribution of predators corresponded to ranks 7, 8, 11, 14 and 7, 8, 10, 11 in presence of non-excised individuals of the above two species of cortical feeders respectively.

(G) Attraction responses of predators towards predators (kept as prey) (Fig. 13)

All four species of predators studied here viz., \textit{M. bastiani}, \textit{A. thornei}, \textit{L. baldus} and \textit{D. major} attracted their own individuals most when tested as prey. Their excised individuals were more attractive to predators than the non-excised. The intra-specific response of all four species of predators was more than their inter-specific attraction responses.

a) Attraction responses of \textit{M. bastiani} (Fig. 13A): Excised individuals of \textit{Mesodorylaimus} when used as prey were more attractive to \textit{M. bastiani} than the excised individuals of \textit{Aquatides}, \textit{Laimydorus} and \textit{Discolaimus} (MLS = 2.23 ± 0.23; CV = 10\%; p < 0.05). The distribution of \textit{M. bastiani} towards excised individuals of the same species taken as prey corresponded
to ranks 8, 9, 10, 11, 14, 17, 18 and 19. Excised individuals of Discolaimus were least attractive to *M. bastiani* and in their case the distribution of predators corresponded to ranks 6, 7, 8, 9, 10, 11, 13, 14, 17 and 18. The chemotactic response of *M. bastiani* was, however, moderate towards the attractants which were diffused by Laimydorus (MLS = 2.14 ± 0.19; CV = 9%) and Aquatides (MLS = 2.11 ± 0.30; CV = 14%).

Non-excised individuals of all the four species of predators when used here as prey elicited positive attraction in *M. bastiani*. However, in its role as predator *M. bastiani* preferred as prey members of its own kind (MLS = 2.16 ± 0.31; CV =14%; p < 0.05) more than those of other three species. The distribution of predators corresponded to ranks 6, 8, 9, 10, 14, 15, 16, 17 and 18. Non-excised individuals of Discolaimus were least attractive (MLS = 1.90 ± 0.32; CV = 17%; p < 0.05) while those of Aquatides and Laimydorus were moderately attractive (MLS = 2.01-2.03).

b) Attraction responses of *A. thornei* (Fig. 13B): Individuals of *A. thornei* also exhibited maximum attraction towards the excised individuals of their own kind than towards the member of other three species. (MLS = 2.27± 0.21; CV = 9%; p < 0.05). *A. thornei* was least attracted by excised specimen of Mesodorylaimus (MLS = 2.17 ± 0.19; CV = 9%). The attraction of *A. thornei* towards Laimydorus (MLS = 2.24 ± 0.17; CV = 7%) and Discolaimus (MLS = 2.21 ± 0.18; CV = 8%) was moderate. The distribution of *A. thornei* corresponded to ranks 8, 9, 10, 11, 13, 14, 15, 16 and 17 in presence of excised individuals of Discolaimus.

Similar to its excised individuals, the non-excised individuals of Aquatides also elicited maximum attraction response of *A. thornei* (MLS = 2.11 ± 0.30; CV = 14%; p < 0.05). The distribution of *A. thornei* corresponded to ranks 6, 7, 8, 9, 10, 11, 13, 14, 17 and 18. Non-excised
specimen of both *Laimydorus* elicited moderate response of *A. thornei* 
(MLS = 2.09 ± 0.15; CV = 7%), while the non-excised individuals of 
*Mesodorylaimus* or *Discolaimus* were least attractive to it (MLS = 2.04 
± 0.34-0.35; CV = 16-17%; p < 0.05).

c) **Attraction responses of *L. baldus* (Fig. 13C):** Similar to above 
mentioned species of predators. *L. baldus* also exhibited maximum at-
traction towards excised individuals of its own kind (MLS = 2.23 ± 0.13; 
CV = 6%; p < 0.05), with its distribution corresponding to ranks 10, 11, 
13, 14, 15 and 16. Excised individuals of both *Aquatides* (MLS = 2.20±0.14; 
CV=6%) and *Discolaimus* (MLS = 2.13±0.14; CV = 7%) elicited moderate 
response of *L. baldus*, while the excised individuals of *Mesodorylaimus* 
were least attractive to it (MLS = 2.09 ± 0.12; CV = 6%; p < 0.05). 

*L. baldus* also exhibited maximum attraction towards non-excised 
individuals of its own kind. (MLS = 2.08 ± 0.11; CV = 5%; p < 0.05). 
Non-excised individuals of both *Aquatides* and *Discolaimus* elicited moderate 
response of *L. baldus* (MLS = 2.04 ± 0.24; CV = 12% and MLS = 2.02 
± 0.25; CV = 12%. respectively) while the non-excised specimen of 
*Mesodorylaimus* were least attractive to it (MLS = 1.96 ± 0.18; CV = 9%; 
p < 0.05). The distribution of *L. baldus* corresponded to ranks 6, 7, 8, 
9, 10, 11, 13 and 15 in presence of individuals of its own kind and to 
ranks 6, 7, 8, 9, 10 and 11 in presence of non-excised individuals of 
*Mesodorylaimus*.

d) **Attraction responses of *D. major* (Fig. 13D):** A strong intra-specific 
attraction response was observed when individuals of *D. major* were tested 
taking members of their own kind as prey (MLS = 2.29 ± 0.18; CV = 
8%; p < 0.05). In this case the distribution of *D. major* corresponded to 
ranks 7, 8, 14, 15 and 16. Excised specimens of *Mesodorylaimus* were 
least attractive (MLS = 2.01 ± 0.02; CV = 1%; p < 0.05) whereas, those
Fig. 13: Attraction responses of predators towards excised and non-excised prey individuals belonging to predatory nematodes. A = *M. hastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. LB = *Laimydorus*; MB = *Mesodorylaimus*; AT = *Aquatides*; DM = *Discolaimus*. 
belonging to *Laimydorus* (MLS = 2.09 ± 0.20; CV = 9%) and *Aquatides* (MLS = 2.13 ± 0.15; CV = 7%) were moderately attractive to *D. major*.

*D. major* also exhibited maximum attraction towards non-excised individuals of its own kind (MLS = 2.13 ± 0.14; CV = 6%; p < 0.05), with the distribution in this case corresponding to ranks 10, 11, 13 and 15. *D. major* was least responsive to attractants which were dispersed by non-excised specimen of *Laimydorus* (MLS = 1.86 ± 0.32; CV = 17%; p < 0.05). It was moderately responsive to the attractants diffused by non-excised members of *Mesodorylaimus* and *Aquatides* (MLS = 1.88 ± 0.33; CV = 17% and MLS = 2.02 ± 0.44; CV = 22%, respectively).

**ATTRACTION RESPONSES OF THE PREDATORS TOWARDS PREY NEMATODES BELONGING TO DIFFERENT TROPHIC GROUPS (FIG. 14)**

The pooled observations regarding various species of prey nematodes belonging to different trophic groups revealed on analysis that the attraction responses of *M. hastiani, L. baldus, D. major* and *A. thornei* varied with different trophic groups in the case of a given species of predators and with the species of predators in the case of a given trophic group. Excised and non-excised individuals of epidermal feeders when tested as prey attracted all species of predators most except *A. thornei* which was most responsive to prey individuals belonging to predatory nematodes. Endodermal feeders were second to epidermal feeders to elicit predator's responses more than the other prey trophic groups. Virus vector was the least attractive prey trophic group for *M. bastiani, A. thornei, L. baldus* and *D. major* when its individuals were tested either as excised or non-excised.

a) **Attraction responses of *M. bastiani* (Fig. 14A):** *M. bastiani* exhibited maximum attraction towards both excised (MLS = 2.16 ± 0.08; CV = 4%)
and non-excised specimens of epidermal feeders (MLS = 2.04 ± 0.01; CV = 1%) (p < 0.05). While on the other hand specimen of virus vector nematodes were least attractive to them (excised individual: MLS = 1.90±0.14; CV = 7% and non-excised individuals: 1.79±0.11; CV = 6%). Prey nematodes belonging to other trophic groups were moderately attractive to *M. bastiani*.

b) **Attraction responses of *A. thornei* (Fig. 14B):** The attractants released by both the excised as well as non-excised individuals of predatory nematodes, epidermal and endodermal feeders taken as prey attracted *A. thornei* most (excised specimen: MLS = 2.20-2.22 ± 0.04-0.05; CV = 2% and non-excised specimen: MLS = 2.07-2.10 ± 0.01-0.03; CV = 1-6%). Excised and non-excised individuals of virus vectors and migratory semi endodermal feeders elicited least attraction response of *A. thornei* (MLS = 2.01-2.03 ± 0.18-0.41; CV = 9-20% and MLS = 1.86-1.99 ± 0.16-0.18; CV = 9%, respectively). Members of other trophic groups attracted these predators in moderate numbers whether the prey specimens were excised or non-excised.

c) **Attraction responses of *L. baldus* (Fig. 14C):** The degree of attraction of *L. baldus* was maximum towards both excised (MLS = 2.23 ± 0.06: CV = 3%) as well as non-excised individuals (MLS = 2.10 ± 0.08; CV = 4%) of epidermal feeders (p < 0.05). It was recorded minimum for both excised as well as non-excised individuals of virus vectors (excised specimen: MLS = 1.91 ± 0.14; CV = 7%; non-excised specimen: MLS = 1.77 ± 0.14; CV = 8%). *L. baldus* exhibited moderate degree of attraction for both excised as well as non-excised individuals of saprophagous nematodes, predators (taken as prey), migratory semi-endodermal, endodermal and cortical feeders. The degree of attraction ranged between MLS = 2.01 - 2.20 when excised individuals of the nematodes were least and it was between MLS = 1.92 - 2.03 when their non-excised individuals were taken.
Fig. 14: Attraction responses of predators towards prey nematodes belonging to different trophic groups. A = *M. hystiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. SP = Saprophagous nematodes; EP = Epidermal feeders; SE = Migratory semi-endodermal feeders; VV = Virus vectors; PR = Predators; EN = Endodermal feeders; CF = Cortical feeders.
d) **Attraction responses of D. major (Fig. 14D):** Unlike other three species of predators studied here, *D. major* was most responsive to the attractants diffused by excised individuals of epidermal feeders ($\text{MLS} = 2.24 \pm 0.02; \text{CV} = 1\%$) and saprophagous or endodermal feeders ($\text{MLS} = 2.14 \pm 0.13; \text{CV} = 6\%$). The attraction of *D. major* was moderate but significant towards excised ($\text{MLS} = 2.09 - 2.14$) and non-excised ($\text{MLS} = 1.97$ to $2.11$) individuals of saprophagous nematodes, predators (taken as prey), migratory semi endodermal feeders, endodermal feeders and cortical feeders. Individuals belonging to virus vector nematodes when tested as prey elicited least response of *D. major* in either of the two conditions (excised or non-excised).

**DISCUSSION**

Contrary to the earlier hypothesis that predatory nematodes are unable to respond to prey secretions and that their predation depends upon chance encounters with prey nematodes, Esser (1963); Wyss & Grootaert (1977); Bilgrami *et al.* (1985c); Shafqat *et al.* (1987) demonstrated that *Lafronema vulvapapillatum, Aquatides thornei* and *Dorylaimus stagnalis* responded positively, attracted towards excised prey individuals and aggregated at feeding sites around prey individuals which were either injured or captured by another member of same species of predator. Their observations have led to speculate the occurrence of chemo-attraction in predatory nematodes similar to plant parasitic nematodes where such a phenomenon is of common occurrence. Chemo-attraction in predatory nematodes could play a significant role in establishing predator-prey encounters thus stimulating their rate of predation. Similarly, the diplogasterid predators *viz.*, *Mononchoides longicaudatus* and *M. fortidens* perceived prey attractants and responded positively and significantly towards live and excised prey individuals belonging to saprophagous nematodes, ecto and endo-parasitic nematodes and bacteria (Bilgrami & Jairajpuri, 1988). The mechanisms
of pre-feeding (aggregation of predators during feeding) and post-feeding aggregation (aggregation of predators after completing feeding) of diplogasterid predators (Bilgrami & Jairajpuri, 1989a) and those belonging to Dipelenteron colobocercus (Yeates, 1969); Aquatides thornei (Bilgrami et al., 1985c) and Dorylaimus stagnalis (Shafqat et al., 1987) at feeding sites around a prey nematode which was either injured or captured by another member of the same predator suggest more than a casual role of chemo-attraction in establishing predator-prey encounters and determining rate of predation by different species of predators in addition to chance contacts which predators make with their prey individuals.

Present observations on the attraction of M. bastiani, A. thornei, L. baldus and D. major towards excised and non-excised prey individuals belonging to different trophic groups also revealed their positive and significant chemotactic responses towards prey individuals belonging to different prey trophic categories in response to the attractants/repellents dispersed by them in the environment. As already mentioned above under the heading of attraction responses of the predatory nematodes towards prey nematodes belonging to different trophy groups, the attraction responses of the four species of predators varied with different trophic groups in case of a given species of predator and with the species of predators in the case of given trophic groups. The differential responses of predators towards different prey nematodes suggest their preferential behaviour. Various types of prey nematodes, the chemical composition, concentration, quality and quantity of prey secretions may be attributed to differential attractive responses of different species of predators which were used during present observations. Such characteristics show interspecific as well as intraspecific variations (Doncaster & Seymour, 1973; Bilgrami & Jairajpuri, 1988; Jairajpuri & Bilgrami, 1990a). The chemical composition of prey individuals may be determined by a number of physio-chemical
factors, more specially the ageing and starvation of prey individuals (Cooper & Van Gundy, 1970; Reversat, 1981a; 1981b) and food and feeding habits of predators and prey (Bilgrami et al., 1986a; Bilgrami, 1990b; Jairajpuri & Bilgrami, 1990a).

Differences in the degree of attraction of *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* both when used in the role of a predator as well as when put as prey animals may have been due to specific differences in minimum response threshold of predators in their formal role, and differences in minimum perceptible attraction gradient in their later role. It may also have resulted due to the differences in their inert behaviour as well as minimum perceptible attraction gradient formed by prey attractants and minimum response threshold of predators. It is possible to make considerable deductions here about the properties of the attractants and the behaviour of the nematodes in a particular environment if basic assumptions on both the diffusion of prey attractants, minimum perceptible attraction gradient, sensory sensitivity of predatory nematodes and minimum response threshold are accepted. The actual and effective concentration of attractants required to develop minimum perceptible attraction gradient in an environment will therefore depend upon the rate of emission, rate of diffusion and loss of active components of prey attractants. In an unrestricted environment the attraction gradient continue to extend until the loss of chemical component equals to the rate of emission (Green, 1971). The dependence of predator’s sensory sensitivity or minimum response threshold level on minimum perceptible attraction gradient may be explained here by comparing *M. longicaudatus* and *M. fortidens* (Bilgrami & Jairajpuri, 1988) and *Allodorylaimus americanus* and *Discolaimus silvicolus* (Khan et al., 1995a) with the present species of dorylaim (*M. bastiani*, *L. baldus* and *D. major*) and nygolaim (*A. thornei*) predators which are used as predators during present studies.
Nematodes which were used as prey required only 4 h to develop minimum perceptible attraction gradient which was perceived by *M. longicaudatus* and *M. fortidens* at their minimum response threshold (Bilgrami & Jairajpuri, 1988). The same, however, is not the case with the dorylaim and nygolaim predators used for present studies. An extended incubation period of 16 h was required by prey nematodes belonging to different trophic groups to develop minimum perceptible attraction gradient which could be perceptible to *M. basiiani*, *A. thornei*, *L. baldus* and *D. major* at their minimum response threshold level. The minimum perceptible attraction gradient for prey and minimum response threshold levels of predators showed both intraspecific as well as interspecific variations (Bilgrami et al., 1985a; 1985b). Present studies revealed that various prey species required different periods of incubation to develop minimum perceptible attraction gradient and likewise the different species of predators had their respective levels of minimum response threshold to react. Thus, predators having low minimum response threshold level may react more quickly even to sensory signals of weaker intensity in comparison to those predators whose minimum response threshold level is high. Predators with high minimum response threshold level require concentrated attractant chemicals to develop concentrated minimum perceptible attraction gradient in the medium before they would respond. It may therefore, be concluded that *M. basiiani*, *A. thornei*, *L. baldus* and *D. major* posses elevated minimum response threshold level, requiring high concentration of minimum perceptible attraction gradient in the medium. On the other hand, diplogasterid predators had low minimum response threshold level and thus could sense attraction gradient within four hours of incubation at minimum perceptible attraction gradient. Such a response could not be recorded in case of *A. thornei* and *Dorylaimus stagnalis* (Bilgrami et al., 1985c; Shafqat et al., 1987) as prey nematodes failed to develop minimum perceptible attraction gradient up to required minimum response threshold level of
these predators since prey individuals were incubated for four and twenty four hours respectively. Thus, period of prey incubation appears to play certain role in the development of minimum perceptible attraction gradient which may vary with the species of predators as well as prey. The above predators, however, aggregated around an injured prey at feeding sites in response to attractants dispersed by them.

Some species of prey nematodes also secrete repellents which may be undesirable for predators. Esser (1963) and Bilgrami & Jairajpuri (1988) suggested that species of Helicotylenchus secrete some toxic secretions which make them resistant to predators. The fact that the two species of diplogasterid predators viz., M. fortidens and M. longicaudatus were attracted less towards Helicotylenchus, Longidorus and Xiphinema suggest that these prey nematodes might have released secretions which were either repellents or unfavourable to predators leading them to exhibit meager to moderate responses. The same appears to be the case with present studies on M. bastiani, A. thornei, L. baldus and D. major. These species of predators also exhibited least attractive responses towards excised as well as non-excised individuals of Helicotylenchus but showed mild to moderate attractive responses when Acrobeles, Xiphinema and Paratrichodorus were used as prey. The low rate of predation by many species of predators on Helicotylenchus also indicates that this species of prey has some repellent chemicals in its body secretions which provide chemical resistance to them against predation (Bilgrami et al., 1986a; Bilgrami, 1992; 1993; 1995b) and produced repulsiveness during act of predation and feeding (Bilgrami et al., 1984; 1985c; Bilgrami & Jairajpuri, 1988; Khan et al., 1991; 1994; 1995a,b). This phenomenon was also supported by difference in the attraction of all the four species of predators studied here in the sense that when excised and non-excised individuals of Helicotylenchus were used as prey than the excised individuals of the prey nematodes elicited pred-
ator's responses less than their non-excised individuals. Such attraction responses were, however, in sharp contrast to those shown by these predators towards other prey species of nematodes in whose case excised individuals were found to be more attractive than their non-excised members. The maximum attraction of predators towards members of the genera *Mesorhabditis, Aphelenchoides, Hirschmanniella, Anguina, Paralongidorus, Hemicriconemoides* as well as towards the members of these four species of predators when used as prey in their respective trophic groups suggest that all these types of prey nematodes emitted favourable secretions for predators which acted as attractants. In contrast to this, however, *Tohrilus, Basiria, Heterodera* and *Hemicycliophora* elicited moderate attraction responses of predators.

When mean responses of predators towards different trophic groups were analyzed it was found that epidermal feeders were most preferred trophic group for all species of predators both in their excised or as well as non-excised state. *A. thornei* presented an exception as it responded maximum to members of all the four species of predators when they were put as prey. Among all the trophic groups, the endodermal feeders were second only to the epidermal feeders in eliciting maximum predator's responses under similar conditions. Both in their excised as well as non-excised state the virus vector nematodes were least attractive prey trophic group for *M. bastiani, A. thornei, L. baldus* and *D. major*. The other prey trophic groups *viz.*, migratory semi endodermal feeders, cortical feeders, saprophagous nematodes and predatory nematodes (taken as prey) were moderately attractive to predators. Various prey trophic groups may therefore be arranged in descending order of their attractiveness to these four species of predators as described in Table IV & V.
### TABLE - IV

ATTRACTIVENESS OF PREY TROPHIC GROUPS TO VARIOUS SPECIES OF PREDATORS WHEN EXCISED INDIVIDUALS WERE USED AS PREY

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<tr>
<th>Predators</th>
<th>Prey Trophic Groups</th>
<th>Mean Log Score</th>
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<td><em>D. major</em></td>
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Figures in parenthesis show Mean Log Score values of trophic groups.

EP = Epidermal feeders  
EN = Endodermal feeders  
SA = Saprophagous nematodes  
PR = Predatory nematodes  
SE = Migratory semi endodermal feeders  
CF = Cortical feeders  
VV = Virus vectors
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<tr>
<th>Predators</th>
<th>Prey Trophic Groups</th>
<th>Mean Log Score</th>
</tr>
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<td><em>L. baldus</em></td>
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<td><em>D. major</em></td>
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EP = Epidermal feeders
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SA = Saprophagous nematodes
PR = Predatory nematodes
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CF = Cortical feeders
VV = Virus vectors
CHAPTER 2

EFFECT OF BIOTIC AND ABIOTIC FACTORS ON THE
ATTRACTION OF PREDATORY NEMATODES
TOWARDS PREY

INTRODUCTION

Similar to other behavioural activities the chemo-attraction behaviour of predatory nematodes is also influenced by various biotic and abiotic factors. It is all the more so because these tiny organisms live within the soil where they are subjected to various environmental changes that occur within their ecosystem. Effects of various edaphic and environmental factors are well known on their rate of predation (Bilgrami et al., 1983; Jairajpuri & Bilgrami, 1990; Bilgrami, 1998a); feeding (Bilgrami & Jairajpuri, 1990); and development (Grootaert & Maertens, 1976; Shafqat et al., 1991) etc. But such influences on the chemo-attraction behaviour of predatory nematodes are still not properly understood. Those studies which have been made so far in this field are neither sufficient nor exhaustive enough to justify the role of various biotic, abiotic and environmental factors on predator's migration towards prey secretions. Bilgrami & Jairajpuri (1988) were the first to study the effects of some factors including temperature, starvation etc., on the attraction behaviour of predators belonging to two species of diplogasterid nematodes, namely, *Mononchoides longicaudatus* and *M. fortidens*. Bilgrami & Jairajpuri (1989c) found that variation in thicknesses of agar as well as concentration of agar governed chemo-attraction behaviour of these two species of predators. It is presumed that similar to their influence on other behavioural parameters of predatory nematodes, various parameters like physical (Bilgrami et al., 1985a; Hatz & Dickson, 1992; Anand et al., 1996); chemical (Ward, 1978; Bilgrami et al., 1986; Dusenbery, 1987; Khlibsuwan et al., 1992; Anderson et al., 1997b); edaphic (Griffiths et al., 1995; Anand et al., 1996; Anderson et al., 1997a; Crawford et al., 1993; Young et al., 1994); biological (Croll &
Sukhdoo, 1981; Bilgrami et al., 1985a; 1985c; Bilgrami et al., 1986b) and agronomical parameters (Jairajpuri & Bilgrami, 1990; Bilgrami, 1998b) also influence the chemo-attraction behaviour of these animals.

The work presented in this chapter is an effort to study the effect of some important biotic (prey incubation, starvation of predators, prey density) and abiotic factors (temperature, agar thicknesses, agar concentrations and distance of predators from prey) on the attraction behaviour of Mesodorylaimus bastiani, Aquatides thornei, Laimydorus baldus and Discolaimus baldus using adult individuals of Hirschmanniella and second stage juveniles of Meloidogyne as prey. It is indeed true that there are several factors other than those included in the present study which also need thorough investigations, but time limit and various other constraints did not allow their analysis.

MATERIALS AND METHODS

To determine the effects of various biotic and abiotic factors like prey density, period of prey incubation, different temperatures, starvation period of predators, agar concentrations, agar thicknesses and distance of predators from the source of attraction (prey) on the attraction responses of M. bastiani, A. thornei, L. baldus and D. major, the live and adult individuals of Hirschmanniella and second stage juveniles of Meloidogyne were used as prey. For various experiments the specimens of predators were obtained from their culture which was maintained in the laboratory. The prey nematodes viz., adults of Hirschmanniella and second stage juveniles of Meloidogyne were isolated fresh for each experiment from the soil collected from paddy fields and culture pots respectively using Baermann’s Funnel and Decantation Techniques as described in the section of “Materials and Methods (General-I)” of this thesis. The influence of various factors on the attraction behaviour of four species of predators
was studied by performing Petri-dish experiments as described earlier. All experimental conditions remained same for every experiment as mentioned while describing Petri-dish experiments except those which are described here under various biotic and abiotic factors. All experiments were replicated 40 times, means were taken and plotted in the graphs. All recorded data on the attraction of predatory nematodes towards their prey was put to statistical analysis using statistical methods as described above under “Materials and Methods (General-I)”.

(A) Effect of prey density on the attraction of predators towards prey:
To observe the effect of prey density (prey number) on the attraction of M. bastiani, A. thornei, L. baldus and D. major 25, 50, 75, 100, 125, 150, 175, 200, 225 and 250 individuals belonging to Hirschmanniella and Meloidogyne were inoculated as prey in the straw pipe of separate sets of Petri-dishes. They were incubated prior to the inoculation of predators. Observations were made on the distribution of predators and Scores. Log scores and Mean Log Scores were calculated. All predators were tested separately.

(B) Effect of period of prey incubation on the attraction of predators towards prey: Prey nematodes belonging to Hirschmanniella and Meloidogyne were separately incubated for 4, 8, 12, 16, 20 and 24 h by placing them in the straw pipe of separate Petri-dishes to allow dispersion of prey attractants and to develop perceptible attraction gradient in the agar medium. The predators, M. bastiani, A. thornei, L. baldus and D. major were released at various places of reference circle after incubating prey nematodes for the above periods and their distribution was recorded after the desired period. The four species of predators were tested in separate sets of Petri-dishes.
(C) Effect of different temperatures on the attraction of predators towards prey: To determine the effect of different temperatures on the attraction of *M. bastiani, A. thornei, L. baldus* and *D. major*, individuals belonging to *Hirschmanniella* and *Meloidogyne* were inoculated in straw pipe and incubated as prey at 5, 10, 15, 20, 25, 30, 35 and 40 °C. The predators were released at different places of the reference circle and Petri-dishes containing prey and predators were again placed at same temperatures where they were kept earlier. Observations on the distribution of predators were made when required and converted to Scores, Log scores and Mean Log Scores. Each species of predator was tested separately towards each species of prey.

(D) Effect of period of starvation of predator on the attraction of predators towards prey: To find out the effect of starvation on the attraction of *M. bastiani, A. thornei, L. baldus* and *D. major* the predators were starved for 0 (fresh), 2, 4, 6, 8, 10 and 12 days by keeping them in cavity blocks containing water without any prey nematode or bacteria. Predators were transferred to fresh water each day. Day 0 refers to fresh predators (well fed). Each group of starving predator was tested separately towards each species of prey i.e., *Hirschmanniella* and *Meloidogyne* which were previously incubated in the straw pipes of separate sets of Petri-dishes.

(E) Effect of agar concentration on the attraction of predators towards prey: To observe the effect of agar concentrations on the attraction of *M. bastiani, A. thornei, L. baldus* and *D. major* desired number of individuals belonging to *Hirschmanniella* and *Meloidogyne* were incubated as prey in separate sets of Petri-dishes containing 1%, 2%, 3%, 4%, 5%, and 6% water agar. Separate experiments were made to determine the attraction profile of each species of predator in different concentration of water agar.
(F) **Effect of agar thicknesses on the attraction of predators towards prey:** To observe the effect of different thicknesses of water agar on the attraction of *M. bastiani, A. thornei, L. baldus* and *D. major* desired number of *Hirschmanniella* and *Meloidogyne* individuals were released in straw pipe of separate Petri-dishes containing 2, 4, 6, 8, 10 and 12 mm thick agar layers for incubation. Attraction of each species of predator was tested towards both species of prey by releasing them in Petri-dishes containing agar layers of the above mentioned thicknesses previously incubated with 25 individuals of prey. Observations were made when required and the distribution of predators was recorded and converted to Scores, Log scores and Mean Log Scores.

(G) **Effect of distance of prey on the attraction of predators towards prey:** The effect of distance of prey (prey attractants) i.e., source of attraction on the degree of attraction of *M. bastiani, A. thornei, L. baldus* and *D. major* was studied in 7 cm diameter Petri-dishes containing 1% water agar. The dishes were marked at the bottom by straight lines (Fig. 15) into seven zones and numbered serially as 1, 2, 3, 4, 5, 6, and 7 (Bilgrami *et. al.*, 1985). A plastic straw pipe with one end sealed with a piece of nylon sieve of 400 mesh was placed vertically in zone 1 so that the sealed end of the pipe remained inside the agar. Twenty five individuals belonging to *Hirschmanniella* were released in the straw pipe as prey and the whole set was left for incubation for 16h. Taking separate Petri-dish for each one of the four species of predators, twenty five specimens of a given species of predators were released at different points in zone 2 of separate Petri-dishes. Similarly, same number of predators were released in the zones 3, 4, 5, 6 and 7 of separate sets of Petri-dishes and observations were made after 6 h. All experiment were replicate five times.
Fig. 15: Experimental design to test the influence of distance of prey on the attraction of predatory nematodes.
RESULTS

All biotic and abiotic factors viz., prey density, period of prey incubation, starvation of predators, temperatures, agar thicknesses, agar concentrations and distance of prey (prey attractants) governed attraction responses of *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* towards *Hirschmanniella* and second stage juveniles of *Meloidogyne*.

(A) EFFECT OF PREY DENSITY ON THE ATTRACTION OF PREDATORS TOWARDS PREY (FIG. 16)

The degree of attraction of *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* was influenced by different population densities of prey individuals belonging to *Hirschmanniella* and *Meloidogyne*.

**a) Effect of prey density on *M. bastiani* (Fig. 16A):** There was a high degree of positive correlation between the attraction of *M. bastiani* and the number of *Hirschmanniella* (r = 0.76; PE(r) = 0.073; t = 4.20; p < 0.05) or *Meloidogyne* individuals (r = 0.87; PE(r) = 0.04; t = 6.35; p < 0.05) used as prey. The degree of attraction of *M. bastiani* towards both species of prey increased significantly with the increase in the number of prey up to a population of 175 prey individuals. Predators exhibited lesser degree of attraction when tested towards a population of more than 175 prey individuals belonging either to adult *Hirschmanniella* or *Meloidogyne* juveniles. *M. bastiani* was least responsive towards a population of 25 *Meloidogyne* (MLS = 1.95 ± 0.18; CV = 9%) or *Hirschmanniella* individuals (MLS = 2.12; ± 0.13; CV = 7%) (p < 0.05). The degree of attraction was recorded maximum towards a population of 175 *Meloidogyne* (MLS = 2.24; ± 0.15; CV = 6%)(p < 0.05). *Hirschmanniella* specimens (MLS = 2.31; ± 0.18; CV = 8%(p < 0.05). Individuals of *Hirschmanniella* were more attractive to the predator than were *Meloidogyne* specimens.
b) Effect of prey density on *A. thornei* (Fig. 16B): A positive and significant correlation was recorded between the degree of attraction and the number of *Meloidogyne* \((r = 0.81; \text{PE}(r) = 0.06; t = 4.97; p < 0.05)\) or *Hirschmanniella* \((r = 0.95; \text{PE}(r) = 0.02; t = 10.95; p < 0.05)\) individuals used as prey. The chemotactic responses of *A. thornei* increased with the increase in the number of *Meloidogyne* juveniles up to a population containing 175 individuals. In contrast, in presence of *Hirschmanniella*, attraction increased consistently up to a population of 225 prey individuals. Attraction responses of *A. thornei* towards the two species of prey declined thereafter. A population of 25 individuals belonging to *Meloidogyne* (MLS = 1.96 ± 0.18; CV = 9%) or *Hirschmanniella* (MLS = 2.04 ± 0.24; CV = 11%) was least attractive \((p < 0.05)\) while 175 individuals of *Meloidogyne* (MLS = 2.19 ± 0.19; CV = 9%) and 225 *Hirschmanniella* (MLS = 2.30 ± 0.13; CV = 6%) extracted maximum attraction response of these predators \((p < 0.05)\). *A. thornei* was more responsive to *Hirschmanniella* at various population densities in comparison to the second stage juveniles of *Meloidogyne*.

c) Effect of prey density on *L. baldus* (Fig. 16C): Similar to *M. bastiani* and *A. thornei*, these predators also preferred *Hirschmanniella* at various population densities more than the second stage juveniles of *Meloidogyne*. There was positive and significant correlation between the attraction of *L. baldus* and number of prey incubated when *Hirschmanniella* \((r = 0.88; \text{PE}(r) = 0.07; t = 4.81; p < 0.05)\) or *Meloidogyne* juveniles \((r = 0.90; \text{PE}(r) = 0.03; t = 7.43; p < 0.05)\) were tested as prey. Predators responded minimum towards a population consisting either of 25 individuals of *Hirschmanniella* (MLS = 2.01 ± 0.24; CV = 12%) or *Meloidogyne* (MLS = 1.94 ± 0.35; CV = 18%). Attraction was maximum when 225 individuals of *Hirschmanniella* (MLS = 2.31 ± 0.13; CV = 6%) or 250 individuals of *Meloidogyne* (MLS = 2.23 ± 0.13; CV = 6%) were used as prey.
Fig. 16: Effect of prey density on attraction responses of predators towards prey nematodes. A = *M. bistantii*; B = *A. thorneii*; C = *L. baldus*; D = *D. major*. 
d) **Effect of prey density on D. major (Fig. 16D):** These predators also exhibited attraction profile similar to other species of predators when individuals of *Hirschmanniella* and *Meloidogyne* were tested as prey in various population concentrations. There was a positive and significant correlation between the degree of attraction and prey population of *Hirschmanniella* \( r = 0.98; \text{PE}(r) = 0.006; t = 17.73; p < 0.05 \) and *Meloidogyne* \( r = 0.97; \text{PE}(r) = 0.01; t = 14.36; p < 0.05 \). Attraction increased significantly as the number of prey individual increased from 25 to 250. *Hirschmanniella* was more attractive to *D. major* when tested at various population densities in comparison to the second stage juveniles of *Meloidogyne*. The former species of prey attracted maximum response of these predators when tested in a population of 250 prey individuals \( \text{MLS} = 2.43 \pm 0.13; \text{CV} = 5\% \) whereas the later did so when tested in a population of 225 prey individuals \( \text{MLS} = 2.33 \pm 0.20; \text{CV} = 8\% \).

**B)** **EFFECT OF PERIOD OF PREY INCUBATION ON THE ATTRACTION OF PREDATORS TOWARDS PREY (FIG. 17)**

Different periods of prey incubation had curvilinear relationship with the attraction of *M. bastiani, A. thornei, L. baldus* and *D. major* when *Hirschmanniella* and second stage juveniles of *Meloidogyne* were used as prey. The individual responses, however, varied between different species of predators.

a) **Effect of prey incubation on M. bastiani (Fig. 17A):** A 16h incubation of *Hirschmanniella* and *Meloidogyne* juveniles yielded maximum attraction of *M. bastiani* \( \text{MLS} = 2.02 \pm 0.24; \text{CV} = 12\% \) and \( 2.00 \pm 0.24; \text{CV} = 12\% \) respectively. Shorter (4h) and longer (24h) periods of prey incubation extracted minimum degree of attraction from *M. bastiani* \( \text{MLS} = 1.39-1.92 \) when *Hirschmanniella* or *Meloidogyne* nematodes were used as prey. There was a positive correlation between the attraction and period
of prey incubation (Hirschmanniella: $r = 0.60; \text{PE}(r) = 0.11; t = 2.73$
and Meloidogyne: $r = 0.62; \text{PE}(r) = 0.10; t = 2.84; p < 0.05$). M. bastiani
was more responsive to Hirschmanniella than to Meloidogyne juveniles
at various periods of prey incubation.

b) Effect of prey incubation on A. thornei (Fig. 17B): Prey nematodes
viz., Hirschmanniella and Meloidogyne elicited least responses of A. thornei
when incubated for 4h (MLS = 1.39 ± 0.38; CV = 27% and MLS = 1.43
± 0.35; CV = 24%) and 24h (MLS = 1.43 ± 0.35; CV = 24% and MLS
= 1.39 ± 0.32; CV = 23%; $p < 0.05$ respectively). Predators were most
responsive to prey attractants when Meloidogyne (MLS = 2.06 ± 0.12; CV
= 6%) or Hirschmanniella (MLS = 2.12 ± 0.14; CV = 7%) were incubated
for 16h. There was a positive and significant correlation between the
attraction and period of prey incubation (Hirschmanniella: $r = 0.65; \text{PE}(r)
= 0.10; t = 3.07$ and Meloidogyne: $r = 0.71; \text{PE}(r) = 0.87; t = 3.01; p
< 0.05$).

c) Effect of prey incubation on L. baldus (Fig. 17C): Trends similar
to M. bastiani and A. thornei were observed in case of L. baldus when
individuals of Hirschmanniella and Meloidogyne were used as prey. This
predator was more responsive to the attractants dispersed by Hirschmanniella.
Prey nematodes, Hirschmanniella (MLS = 2.04 ± 0.10; CV = 5%) or
Meloidogyne juveniles (MLS = 2.01 ± 0.23; CV = 11%) when incubated
for 16h attracted maximum predators and attraction was the least when
the two species of prey were incubated for 4h (MLS = 1.43-1.46) and 24
h (MLS = 1.39-1.46) respectively ($p < 0.05$). The increase in attraction
responses of predators towards prey nematodes which were incubated from
4 to 16h was significant ($p < 0.05$) and its relationship with the period
of incubation was positive in case of Hirschmanniella ($r = 0.58; \text{PE}(r)
= 0.10; t = 2.56$) and Meloidogyne ($r = 0.62; \text{PE}(r) = 0.10; t = 2.84$).
Fig. 17: Effect of time of prey incubation on attraction responses of predators towards prey nematodes. A = M. hastiani; B = A. thornei; C = L. baldus; D = D. major.
d) Effect of prey incubation on *D. major* (Fig. 17D): Incubation periods of 12 and 16h were most favourable as predators responded maximum towards *Meloidogyne* (MLS = 2.10-2.12; CV = 7%) and *Hirschmanniella* (MLS = 2.20 - 2.21; CV = 6-9%). Short (4h) (MLS = 1.66 ± 0.56; CV = 34%) or long periods (24h) of prey incubation of *Meloidogyne* (MLS = 1.65 ± 0.57; CV = 34%) yielded meager attractive responses of *D. major*. Similar to other predators, *D. major* also responded more towards *Hirschmanniella* than towards *Meloidogyne*. The increase in attraction from 4 to 16 h was significant (p < 0.05) and the relationship was recorded positive (r = 0.77; PE(r) = 0.07; t = 4.34) and (r = 0.78; PE(r) = 0.06; t = 4.48 p < 0.05).

(C) **EFFECT OF DIFFERENT TEMPERATURES ON THE ATTRACTION OF PREDATORS TOWARDS PREY** (FIG. 18)

Attraction of four species of predators was influenced by the change in temperature regime from 5 to 40 °C. All predators were more responsive towards attractants diffused by the prey nematodes, *Hirschmanniella* and *Meloidogyne* when tested at various temperatures.

a) Effect of different temperatures on *M. bastiani*: (Fig. 18A) There was a curvilinear relationship between the degree of attraction of *M. bastiani* and various temperatures with a positive and significant correlation when either *Hirschmanniella* (r = 0.79; PE(r) = 0.06; t = 4.63; p < 0.05) or *Meloidogyne* individuals (r = 0.74; PE(r) = 0.7; t = 3.96; p < 0.05) were used as prey. Maximum attraction towards both *Hirschmanniella* and *Meloidogyne* was recorded at 30°C (MLS = 2.04 ± 0.09; CV = 5% and MLS = 1.95 ± 0.18; CV = 9%, respectively; p < 0.05). Temperatures both more than 30°C as well as less than it suppressed predator’s responses with the degree of attraction at 25°C and 35°C being only slightly less than that recorded at 30°C. Attractants diffused by both species of prey...
nematodes were least attractive when predators were tested at 5°C (MLS = 1.37 ± 0.40; CV = 29% and MLS = 1.39 ± 0.38; CV = 27%, respectively).

b) Effect of different temperatures on *A. thornei* (Fig. 18B): Attractants emitted by adult *Hirschmanniella* were most attractive to *A. thornei* when experiments were performed at 30°C (MLS = 2.11 ± 0.13; CV = 6%) and *Meloidogyne* when tested at 35°C (MLS = 2.01 ± 0.23; CV = 11%) (*p* < 0.05). The attraction was the least when tested at 5°C (MLS = 1.41 ± 0.37; CV = 26% and MLS = 1.51 ± 0.41; CV = 27%). The chemotactic responses of predators increased significantly up to 30°C but decreased thereafter from MLS = 2.05 to MLS = 1.77 (*p* < 0.05). The coefficient of correlation between the degree of attraction and temperature was found to be positive and significant when individuals of *Hirschmanniella* (*r* = 0.80; PE(*r*) = 0.06; *t* = 4.8) or *Meloidogyne* (*r* = 0.75; PE(*r*) = 0.07; *t* = 4.01) were used as prey (*p* < 0.05).

c) Effect of different temperatures on *L. baldus* (Fig. 18C): These predators also exhibited their attraction profile similar to *M. bastiani* and *A. thornei* responding maximally towards the attractants dispersed by the individuals of *Hirschmanniella* (MLS = 2.15 ± 0.15; CV = 7%) or *Meloidogyne* (MLS = 2.04 ± 0.09; CV = 4%) at 30°C. In both cases the coefficients of correlation between the attraction and temperature were found to be positive and significant (*r* = 0.73; PE(*r*) = 0.08; *t* = 3.62 and *r* = 0.65; PE(*r*) = 0.10; *t* = 3.07) (*p* < 0.05). At 5°C *L. baldus* was least responsive to the attractants which were emitted either by *Hirschmanniella* (MLS = 1.35 ± 0.35; CV = 26%) or *Meloidogyne* juveniles (MLS = 1.34 ± 0.38; CV = 28%) (*p* < 0.05).

d) Effect of different temperatures on *D. major* (Fig 18D): Unlike the other three species of predators, *D. major* exhibited maximum attraction when this predators was tested at 35°C with prey individuals belonging
Fig. 18: Effect of temperatures on attraction responses of predators towards prey nematodes. A = *M. hastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*.
to *Hirschmanniella* (MLS = 2.24 ± 0.21; CV = 9%) and *Meloidogyne* (MLS = 2.12 ± 0.15; CV = 7%). The degree of attraction depended upon temperature and significant positive relationship was recorded in case of both the prey nematodes (r = 0.87; PE(r) = 0.04; t = 6.35; p < 0.05). There was a significant increase in the attraction of *D. major* from MLS = 1.41 to 2.24 towards *Hirschmanniella* and from MLS = 1.35 to 2.12 towards *Meloidogyne* individuals when observations were made at temperatures ranging between 5 to 35°C. The chemotactic response of predators declined at 40°C. Chemo-attraction was suppressed significantly at 5°C (MLS = 1.35 ± 0.38; CV = 28%) in case of *Meloidogyne* and (MLS = 1.41 ± 0.33; CV = 23%) in case of *Hirschmanniella*.

### (D) EFFECT OF PERIOD OF STARVATION OF PREDATORS ON THEIR ATTRACTION TOWARDS PREY (FIG. 19)

Four species of predators, *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* when starved for varying periods exhibited differential responses towards *Hirschmanniella* and *Meloidogyne* juveniles. All groups of starving predators were more responsive to the attractants diffused by *Hirschmanniella*.

**a) Effect of starvation on *M. bastiani* (Fig. 19A):** A positive correlation was recorded between the attraction of *M. bastiani* and period of starvation of predators when *Hirschmanniella* (r = 0.99; PE(r) = 0.001; t = 25.27) or *Meloidogyne* individuals (r = 0.76; PE(r) = 0.07; t = 3.20) (p < 0.05) were used as prey. Attraction of these predators increased with the increase in the period of starvation significantly from 0 (fresh and well fed predators) to 10 days in response to attractants dispersed by either the individuals of *Hirschmanniella* (MLS = 2.06 - 2.22) or *Meloidogyne* (MLS = 1.95 - 2.13). Ten days starved predators exhibited maximum attraction responses towards prey attractants. In contrast, fresh and well fed indi-
individuals of *M. hastiani* were least responsive to attractants dispersed by either of the two species of prey.

**b) Effect of starvation on *A. thornei* (Fig. 19B):** The degree of attraction of *A. thornei* increased significantly with the increase in period of starvation from 0 (fresh) to 10 days of food deprivation when prey individuals belonging to *Hirschmanniella* (MLS = 2.08 - 2.25) or *Meloidogyne* (MLS = 2.04 - 2.20) were used as prey (p < 0.05). *Hirschmanniella* and *Meloidogyne* individuals which were least attractive to fresh and well fed predators (MLS = 2.04 and 2.08) elicited maximum responses of 10 days starved predators (p < 0.05). Attraction of *A. thornei* towards both species of prey depended positively and significantly upon their duration of starvation i.e., food deprivation (*r* = 0.98; PE(*r*) = 0.006; *t* = 17.73; *p* < 0.05).

**c) Effect of starvation on *L. baldus* (Fig. 19C):** Similar to *M. bastiani* and *A. thornei*, a high degree of correlation was recorded between the degree of attraction of *L. baldus* towards both *Hirschmanniella* (*r* = 0.98; PE(*r*) = 0.006; *t* = 17.73) and *Meloidogyne* (*r* = 0.96; PE(*r*) = 0.001; *t* = 12.34) (p < 0.05) over different periods of starvation of predators. There was a significant increase in predator’s responses towards prey attractants as starvation increased from 0 (MLS = 2.04 ± 0.33; CV = 16%) to 10 days (MLS = 2.30 ± 0.04; CV = 2%) and from 0 (MLS = 2.01 ± 0.24; CV = 12%) to 10 days (MLS = 2.20 ± 0.13; CV = 6%) respectively in case of *Hirschmanniella* and *Meloidogyne* (p < 0.05). Predators exhibited minimum degree of attraction when their fresh (well fed) individuals were tested either with the specimens of *Hirschmanniella* (MLS = 2.04 ± 0.33; CV = 16%) or *Meloidogyne* (MLS = 2.01 ± 0.24; CV = 12%) as prey. Predators showed maximum attraction (p < 0.05) when their 10 days starved specimen were tested towards *Meloidogyne* and *Hirschmanniella* (MLS = 2.20 ± 0.13; CV = 6% and MLS = 2.30 ± 0.04; CV = 2%, respectively).
Fig. 19: Effect of starvation of predators on attraction responses of predators towards prey nematodes. A = M. bastiani; B = A. thornei; C = L. baldus; D = D. major.
d) Effect of starvation on *D. major* (Fig. 19D): There was a positive and significant correlation between the chemo-attraction responses of *D. major* and period of starvation when individuals of *Hirschmanniella* (*r* = 0.97; PE(r) = 0.10; *t* = 14.36) or *Meloidogyne* (*r* = 0.98; PE(r) 0.006; *t* = 17.73) were tested as prey. Attraction of predators increased significantly with the increase in the period of starvation from 0 to 10 days (*p* < 0.05). The increase in the degree of attraction of *D. major* with the increase in period of their food deprivation was recorded significant in presence of *Hirschmanniella* (MLS = 2.20 ± 0.20; CV = 9% to MLS = 2.36 ± 0.08; CV = 3%) as well as *Meloidogyne* individuals (MLS = 2.11±0.14; CV = 7% to MLS = 2.32±0.19; CV = 9%). The fresh or well fed predators were least responsive in comparison to 10 day starved predators which exhibited maximum attraction response to the attractants dispersed by *Hirschmanniella* (MLS = 2.36 ± 0.08; CV = 3%) or *Meloidogyne* (MLS = 2.32 ± 0.20; CV = 9%).

(E) EFFECT OF AGAR CONCENTRATIONS ON THE ATTRACTION OF PREDATORS TOWARDS PREY (FIG. 20)

Similar to other factors, agar concentrations also governed chemo-tactic responses of the four species of predators. Attraction responses of predators varied at different concentrations of agar. However, it was noticed in all concentration of agar that all species of predators responded more towards adult individuals of *Hirschmanniella* than towards second stage juveniles of *Meloidogyne*.

a) Effect of agar concentrations on *M. bastiani* (Fig. 20A): Agar concentrations ranging between 1 - 2% were most favourable as predators exhibited maximum responses towards *Hirschmanniella* (MLS = 2.01 ± 0.22; CV = 11%) and *Meloidogyne* (MLS = 1.95 0.18; CV = 9% and MLS = 1.90 ± 0.32; CV = 17%) at these concentrations. The degree of
attraction decreased as agar concentration increased. *M. bastiani* was least responsive to the attractants released by *Hirschmanniella* (*MLS = 1.30 ± 0.21; CV = 16%*) or *Meloidogyne* (*MLS = 1.28 ± 0.30; CV = 23%*) when tested at 6% agar concentration. The relationship between the degree of attraction and agar concentration was negative and significant (*r* = -0.95; *PE*(*r*) = 0.02; *t* = 10.95 and *r* = -0.98; *PE*(*r*) = 0.006; *t* = 17.73) when individuals either of *Hirschmanniella* or *Meloidogyne* were used as prey.

**b) Effect of agar concentrations on A. thornei** (Fig. 20B): The two parameters viz., predator's responses to prey attractants and agar concentrations were negatively but significantly correlated when predators were tested towards *Hirschmanniella* (*r* = -0.96; *PE*(*r*) = 0.01; *t* = 12.34) or *Meloidogyne* (*r* = -0.98; *PE*(*r*) = 0.006; *t* = 17.73). Concentrations between 1-2% agar favoured predators most as they were most responsive to the attractants dispersed by both *Hirschmanniella* (*MLS = 2.12 ± 0.14; CV = 7% and MLS = 2.08 ± 0.13; CV = 6%) as well as *Meloidogyne* (*MLS = 2.01 ± 0.12; CV = 6% and MLS = 2.00 ± 0.32; CV = 16%). The ability of predators to perceive prey attractants declined with the increase in the concentration of agar. Agar concentration of 6% was most unfavourable as predators failed to respond to prey secretions (*MLS = 1.35 ± 0.34; CV = 25% and MLS = 1.30 ± 0.29; CV = 22%) released by *Hirschmanniella* and *Meloidogyne* respectively.

**c) Effect of agar concentrations on L. baldus** (Fig. 20C): There was a high degree of a negative correlation between attraction and agar concentrations as attraction responses of predators declined significantly towards both *Hirschmanniella* (*r* = -0.87; *PE*(*r*) = 0.04; *t* = 6.35) as well as *Meloidogyne* (*r* = -0.97; *PE*(*r*) 0.01; *t* = 14.36) when concentrations of agar was raised from 1 to 6%. A concentration of 1% agar yielded maximum attraction of *L. baldus* towards *Hirschmanniella* (*MLS = 2.02*
Fig. 20: Effect of agar concentrations on attraction responses of predators towards prey nematodes. A = M. hastiani, B = A. thornei; C = L. baldus, D = D. major.
The chemotactic response of predators was recorded least when *Hirschmanniella* (MLS = 1.33 ± 0.36; CV = 26%) or *Meloidogyne* (MLS = 1.28 ± 0.34; CV = 24%) were tested as prey at a concentration of 6% water agar.

d) **Effect of agar concentrations on *D. major* (Fig. 20D):** The ability of *D. major* to perceive attractants dispersed by prey individuals was inhibited most at higher agar concentrations. Predators exhibited least attraction towards *Hirschmanniella* (MLS = 1.41 ± 0.34; CV = 24%) and *Meloidogyne* individuals (MLS = 1.33 ± 0.41; CV = 31%) at 6% agar concentration. The attraction of predators was recorded maximum towards both *Hirschmanniella* (MLS = 2.20 ± 0.19; CV = 9%) as well as *Meloidogyne* (MLS = 2.10 ± 0.16; CV = 8%) at 1% concentration of water agar. Similar to other species of predators the degree of attraction declined gradually from 1% to 6% and the relationship between the two parameters was found to be negative and significant when either of these two species of nematodes was used as prey (*r* = - 0.98; PE(*r*) = 0.006; *t* = 17.73).

(F) **EFFECT OF VARIOUS THICKNESSES OF AGAR ON THE ATTRACTION OF PREDATORS TOWARDS PREY** (Fig. 21)

Agar layers of varying thicknesses influenced the degree of attraction of *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* towards attractants released by prey individuals belonging to *Hirschmanniella* and *Meloidogyne*. Adult specimens of *Hirschmanniella* were more attractive to predators in comparison to *Meloidogyne* juveniles when tested at different thicknesses of water-agar.

a) **Effect of various thicknesses of agar on *M. bastiani* (Fig.21A):** The degree of attraction of *M. bastiani* towards the prey decreased with the increase in the thickness of agar layer from 2 mm to 12 mm when
individuals of *Hirschmanniella* (MLS = 2.04 to 1.81; r = -0.99; PE(r) = 0.003; t = 25.27) or *Meloidogyne* (MLS = 1.97 to 1.73; r = -0.99; PE(r) = 0.003; t = 25.27) were used as prey. *M. bastiani* responded maximum towards *Hirschmanniella* (MLS = 2.04 ± 0.09; CV = 4%) as well as *Meloidogyne* (MLS = 1.97 ± 0.20; CV = 10%) when tested in a 2 mm thick agar layer. The responses of predators were minimum in presence of any one of the above two species of prey when studies were made in 12 mm thick layer of water agar (MLS = 1.81 ± 0.31; CV = 17% and 1.73 ± 0.41; CV = 24%, respectively) (p < 0.05).

b) Effect of various thicknesses of agar on *A. thornei* (Fig. 21B): There was a negative but significant correlation between the attraction of predators and increasing thicknesses of agar layers when *Hirschmanniella* (r = -0.96; PE(r) = 0.01; t = 12.34) or *Meloidogyne* individuals (r = -0.99; PE(r) = 0.003; t = 25.27) (p < 0.05) were used as prey. The degree of attraction of *A. thornei* was maximum in a 2 mm thick agar layer towards attractants diffused by both *Hirschmanniella* (MLS = 2.09 ± 0.12; CV = 6%) as well as *Meloidogyne* (MLS = 2.04 ± 0.24; CV = 12%). However, 12 mm thick agar layer was most unfavourable to predators as their degree of attraction declined significantly in presence of both *Hirschmanniella* (MLS = 1.79 ± 0.42; CV = 23%) as well as *Meloidogyne* (MLS = 1.78 ± 0.43; CV = 24%).

c) Effect of various thicknesses of agar on *L. baldus* (Fig. 21C): A significantly high degree of negative correlation was noted between responses of predators towards attractants diffused either by *Hirschmanniella* (r = -0.97; PE(r) = 0.01; t = 14.36) or *Meloidogyne* (r = -0.98; PE(r) = 0.006; t = 17.73) and increasing thicknesses of agar (p < 0.05). A 2 mm thick layer favoured predators most as their attraction was maximum towards both *Hirschmanniella* (MLS = 2.06 ± 0.11; CV = 5%) as well as *Meloidogyne*
Fig. 21: Effect of agar thicknesses on attraction responses of predators towards prey nematodes. A = *M. bastiani*; B = *A. thornei*; C = *L. baldus*; D = *D. major*. 

- For **A. thornei**: $y = -0.05x + 1.60$, $r = -0.97$, $p < 0.05$.
- For **L. baldus**: $y = -0.05x + 1.59$, $r = -0.99$, $p < 0.05$.
- For **D. major**: $y = -0.05x + 1.60$, $r = -0.96$, $p < 0.05$. 

In each graph, the data points are plotted with their corresponding linear regression lines.
(MLS = 2.00 ± 0.32; CV = 16%). The degree of attraction of predators declined gradually at agar layers more than 2 mm thick. *Hirschmanniella* (MLS = 1.71 ± 0.35; CV = 20%) or *Meloidogyne* individuals (MLS = 1.56±0.41; CV = 26%) could elicit meager responses of these predators when tested at 12 mm thick agar layer (p < 0.05).

d) **Effect of various thicknesses of agar on *D. major* (Fig. 21D):** There was gradual decrease in the degree of attraction of *D. major* when *Hirschmanniella* (MLS = 2.21 to 1.67) or *Meloidogyne* (MLS = 2.10 to 1.59) were used as prey in 2 to 12mm thick agar layers. Maximum attraction was recorded in 2 mm thick agar layers in response to attractants dispersed by prey individuals belonging to *Hirschmanniella* (MLS = 2.21 ± 0.19; CV = 9%) or *Meloidogyne* (MLS = 2.10 ± 0.15; CV = 7%) while minimum attraction was recorded in a 12 mm thick layer of agar (MLS = 1.67 ± 0.51; CV = 30% and MLS = 1.59 ± 0.51; CV = 32%, respectively) (p < 0.05). The attraction was recorded to be significant but negative in relation to agar thicknesses in case of both species of prey nematodes (r = - 0.97; PE(r) = 0.01; t = 14.36 and r = - 0.99; PE(r) = 0.003; t = 25.27, respectively) (P < 0.05).

(G) **EFFECT OF DISTANCE OF PREDATORS FROM THE SOURCE OF ATTRACTION (PREY)** (FIG. 22-23)

Increase in the distance of four species of predators viz., *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* from the source of attraction i.e., prey nematodes, affected their movements towards adult *Hirschmanniella*. Number of predators in sectors 1, 2 and 3 decreased gradually but significantly as the distance of inoculation of predators from prey nematodes increased (p < 0.05).

All species of predators exhibited maximum response to prey attractants when inoculated 1 or 2 cm away from the source of attraction.
Fig. 22: Effect of distance of inoculation of predators from prey on their attraction responses. A-F = *M. bastiani*: G-L = *A. thorei*. ↓ - Point of inoculation of predators.
Fig. 23: Effect of distance of inoculation of predators from prey on their attraction responses. A-F = *L. baldus*; G-L = *D. major*.↓ - Point of inoculation of predators.
i.e., sector 2 and 3. The attraction responses of dorylaim and nygolaim predators were moderate when tested from other zones of the Petri-dishes except sector 7 i.e., 6 cm away from prey nematodes which yielded least chemotactic response. *A. thornei* (Fig. 22G-L) and *D. major* (Fig. 23G-L) were more responsive to prey attractants from different zones of Petri-dishes as compared to *M. bastiani* (Fig. 22A-F) or *L. baldus* (Fig. 23A-F).

**DISCUSSION**

The attractiveness of prey nematodes to different species of predators is more likely to be affected by the environment. The organisms such as nematodes which grow in soil may be more sensitive to various soil conditions. Each species of predator may have specific conditions and requirements for various biotic and abiotic factors for their growth and normal behaviour. So, it is a difficult job to generalize such conditions which favour predator's normal behavioural responses to prey kairomones or allomones. *In vitro* studies on the effects of such factors on chemotraction of predatory nematodes may produce similar results under natural conditions and may help in determining those conditions which are favourable for their migration towards different species of prey nematodes. Adverse or favourable influences of many factors like activity of prey, type of prey, type of body cuticle, temperature, starvation, seasonal fluctuations, soil types, soil pH and agrochemicals (Bilgrami, 1990b; Bilgrami *et al.*, 1983; Bilgrami & Jairajpuri, 1989c, 1990; Yeates, 1969; Jairajpuri & Bilgrami, 1990; Khan *et al.*, 1991; Kulshreshtha *et al.*, 1993) are better understood regarding predation by different species of predators. But not much was previously studied regarding their influence on chemotraction behaviour of predators. Present studies suggest that chemotraction activities of predatory nematodes also depend upon various biotic and abiotic factors as is indicated by their regression analysis and coefficients of correlation.
During present studies *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* exhibited differential attraction responses towards both *Hirschmanniella* as well as *Meloidogyne*. However, all predators were attracted more towards the former species of prey. Such differences in predator's responses may be attributed, firstly to the differences in their inert behaviour, secondly to their preferences for a particular prey species and thirdly to the chemical composition, concentration, quantity and quality of prey secretions/attractants as these characteristics vary from species to species and individuals to individuals (Bilgrami, 1990b; Bilgrami, 1992; 1993; 1995b).

Formation of minimum perceptible attraction gradient in agar and around predators is an important attribute which may influence attraction of predators. There are various factors like temperature, period of starvation of predators, period of prey incubation, agar thicknesses, distance of predator's inoculation, speed of dispersion of attractants, period of observation, prey density etc., which govern minimum response threshold of predators and formation of minimum perceptible attraction gradient (which a predator can perceive followed by the exhibit of its responses).

*Mononchoides longicaudatus* and *M. fortidens* required eight hour incubation of prey attractants to develop minimum perceptible attraction gradient (Bilgrami & Jairajpuri. 1988), whereas *Allodorylaimus americanus* and *Discolaimus silvicolus* did so after a 12h incubation (Khan *et al.*, 1995a). *Aquatides thornei* failed to produce any response even after 8h of prey incubation (Bilgrami *et al.*, 1985c). During present observations *Hirschmanniella* and *Meloidogyne* required 12 to 16h incubation to develop minimum perceptible attraction gradient and to elicit minimum response threshold of the predators. This disparity may be attributed to the formation of minimum perceptible attraction gradient by prey secre-
tions as well as minimum response threshold of the predators. Such characteristics may show intraspecific as well as interspecific variations. In some, the intensity of these characteristics may be high while in others it may be low. Individuals with low perception threshold level could perceive attractants early from long distances while those having high threshold levels could take longer time to perceive stimuli even from short distances. *M. hastiani, A. thornei, L. baldus* and *D. major* which required 12-16h prey incubation during present study appeared to have high threshold level to perceive minimum perceptible attraction gradient which could have been developed by predators even much earlier. *M. fortidens* and *M. longicaudatus* had low perception threshold level and thus could sense relatively weaker stimuli developed during 8h of incubation of prey attractants (Bilgrami & Jairajpuri, 1988). Thus, period of prey incubation appears to play certain role in the development of minimum perceptible attraction gradient which may vary between species of prey nematodes belonging to different trophic groups.

The abundance of prey and hunger level of predators are another potential factors which influence food requirements of predatory nematodes (Bilgrami & Jairajpuri, 1988; Shafqat et al., 1987). These factors may also be taken into account to understand their effects on prey searching and attraction behaviour of predatory nematodes. During present observations when prey nematodes were plentiful attractants had greater positive impact on the attraction profile of *M. hastiani, A. thornei, L. baldus* and *D. major* than when prey individuals were scarce. This is perhaps due to lower mean concentration of attractants at low, and higher mean concentration of attractants at high prey density and increased biomass. Attractants with higher mean concentration may be able to disperse in wider area and develop minimum perceptible attraction gradient quickly which would remain effective for longer duration.
The starving predator could sense even weaker stimuli due to decrease in minimum response threshold (Doncaster & Seymour, 1973; Bilgrami & Jairajpuri, 1988). A phenomenon which could be substantiated with increased predation by starving dorylaim (Shafqat et al., 1987), nygolaim (Bilgrami et al., 1985c); actinolaim (Khan et al., 1995b) and diplogasterid predators (Bilgrami & Jairajpuri, 1990). *Hirschmanniella*, however, did not exhibit same phenomenon and Bilgrami et al. (1985b) attributed it to increased minimum response threshold of nematodes due to their increased level of hunger. The stimulated responses of starving *M. bastiani*, *A. thornei*, *L. baldus* and *D. major* to prey secretions during present observations may therefore be attributed to decreased level of minimum response threshold in predatory nematodes due to the increase in the period of their starvation. On the other hand differences in the attraction of predators which were used for present studies at different thicknesses of agar may also be attributed to the same phenomenon. Various thicknesses of agar layers might have affected the dispersion of prey attractants and by obstructing the formation of minimum perceptible attraction gradient particularly in more than 4 mm thick agar layers.

The attraction of *Hirschmanniella* towards cabbage roots (Bilgrami et al., 1985b) and *M. fortidens* and *M. longicaudatus* towards prey (Bilgrami & Jairajpuri, 1988) decreased with the increase in their distance of inoculation from the source of attraction. This phenomenon which was also observed during present studies could be related to the rate of dispersion of prey attractants and time taken by them to develop minimum perceptible attraction gradient. It appears therefore, that stimuli of stronger intensity only could develop minimum perceptible attraction gradient to elicit minimum response threshold of predators over long distances but those with weaker intensity attracted predators from short distances only.
In nematodes temperature produces certain interesting changes more specially with respect to their activity and movement. There are usually two types of effects that can be produced by temperature on nematodes. One is on the sensory behavioural responses mediated through the sensory receptors and the other is the thermodynamic effect resulting from the changes that occur in the rate of metabolic processes of nematodes (Jairajpuri & Bilgrami, 1990). Wallace (1963) concluded that majority of nematodes became inactive between 5 to 15°C and 30 to 40°C and optimum temperature lies between 20 and 30°C. These may vary between different individuals and species of predatory nematodes under different environmental conditions. Azmi & Jairajpuri (1977a) also found temperatures between 25 to 30°C to be optimum for the nematodes they had tested. Bilgrami et al. (1983) and Grootaert & Maertens (1976) found temperatures affecting activity of predatory nematodes. A temperature range of 20-25°C was preferred by rice-root nematode *H. oryzae* to exhibit maximum attraction towards cabbage seedlings (Bilgrami et al., 1985a). In case of *M. longicaudatus* and *M. fortidens* a significant correlation was recorded between their predation and temperatures (Bilgrami & Jairajpuri, 1990a) and attraction and temperature (Bilgrami & Jairajpuri, 1988). The optimum temperatures for these predators were recorded to be between 25 to 30°C. Since, chemotraction is a sensory phenomenon which may also be influenced by the changes in temperature. the decreased attraction of *M. hastiani, A. thornei, L. baldus* and *D. major* at temperatures less than 25°C and more than 35°C may be attributed firstly, to their inhibited activity (Bilgrami, 1993) and secondly, to slow rate of dispersion of prey attractants (required to develop minimum perceptible attraction gradient in the surroundings) due to unfavourable temperature regim.

The movement and locomotion are necessary for feeding and mating activities. In experimental studies agar concentrations govern activities
of nematodes (Wallace, 1969; Azmi & Jairajpuri, 1977b). Bilgrami et al., (1983) attributed low rate of predation by Mononchus aquaticus to inhibited activity of predators and prey due to increase in agar concentrations. Shafqat et al., (1987) while evaluating the predatory abilities of D. stagnalis also reached to a similar conclusion and found lower concentrations of agar more favourable for predation. A highly significant correlation was found between the degree of attraction of M. longicaudatus and M. fortidens towards prey attractants and agar concentrations (Bilgrami & Jairajpuri, 1989b). During present study attraction responses of M. bastiani, A. thornei, L. baldus and D. major also decreased with the increase in agar concentration. Thus, the inhibited activity of predators resulting due to the resistance generated by concentrated agar surface and lack off moisture, might be the reason of decreased attraction of these four species of predators when tested at concentrations higher than 2% water agar (Wallace, 1969; Azmi & Jairajpuri, 1977b; Bilgrami et al., 1983).