Nematol. medit. (1995), 23: 81-88

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NUMERICAL ANALYSIS OF THE PREDATORY RELATIONS BETWEEN *MESODORYLAIMUS BASTIANI* (NEMATODA: DORYLAIMIDA) AND DIFFERENT PREY TROPHIC CATEGORIES

by
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Summary. Numerical analysis of relations between the predator *Mesodorylaimus bastiani* and prey nematodes belonging to five trophic groups viz., bacteriophagous, endoparasitic, ectoparasitic-epidermal feeders, ectoparasitic-cortical feeders and predaceous nematodes was made. Predators were most successful on endo-parasitic nematodes. Predaceous nematodes as prey exhibited high degree of resistance against predation by *M. bastiani.* Only 11% attacks resulted in wounding out of 31% encounters that resulted in attacks. Physical characteristics viz., thick body cuticle, body annulations, thick longitudinal cuticular folds are hypothesised as the cause of 100% resistance of *Hoplolaimus indicus*, *Hemicriconemoides mangiferae*, *Hemicycliophora dhirenderi* and *Dorylaimus stagnalis. Mononchoides fortidens*, *M. longicaudatus* and *Mylonchulus minor* also appeared to have resisted predation by their cuticular characteristics and behavioural patterns. Low strike rate of *M. bastiani* and less feeding after wounding on *Helicotylenchus indicus* has been attributed to repulsive/unattractive prey secretions (chemical resistance). Feeding time required to consume an individual depended upon the size of the prey, maximum being on *Paralongidorus citri* and minimum on *Cephalobus* sp. The body cuticle, cuticle texture, quality, quantity and chemical composition of prey contents also influenced feeding by predators on different prey.

Studies have been made on predation by different groups of nematodes (Esser, 1963; 1987; Bilgrami, 1990) but, with the exception of Bilgrami and Jairajpuri (1989), ways of quantifying predation have not been identified. Bilgrami and Jairajpuri (1989) proposed mathematical models to measure and quantify the strike rate of the predators *Mononchoides longicaudatus* and *M. fortidens* and the degree of resistance and susceptibility of different prey nematodes. Earlier observations by Grootaert *et al.* (1977) on *Butlerius* sp. and later by Small and Grootaert (1983) on *Mononchus aquaticus*, *Labronema vulvapapillatum* and *Butlerius degrisse* provided some significant information in this regard. However, there is still a need to analyse predatory relations of nematodes with different prey trophic categories. In the present work a numerical analysis of the relationship between predation by a dorylaimid predator, *Mesodorylaimus bastiani* (Thorne *et* Swanger) Andrassy and nematode belonging to different prey trophic categories has been made. These studies may be helpful in establishing predator-prey relationships of *M. bastiani.* The most effective and suitable combinations of predator and prey could be the most efficient predator (in terms of highest strike rate) and most susceptible prey (i.e., most vulnerable to predation).

Materials and methods

Mesodorylaimus bastiani was collected from the Victoria Gate, Aligarh Muslim University, Aligarh, and cultured on bacteriophagous nematodes in Petri-dishes containing 1% water-agar at 28 ± 2 °C (Bilgrami and Jairajpuri, 1988). Prey nematodes belonging to five trophic categories were selected for analysis of predation (Table I) as described by Bilgrami (1993). The encounters (i.e., lip contact of predators with the prey at right angles) between predators and prey were observed in Petri-dishes containing 1% water agar, using a stereoscopic binocular microscope. For fifty such encounters fresh combinations of predator and prey individuals were used (Bilgrami, 1993). To reduce the effect of satiation and prey habituation, a prey nematode was placed in front of the head of 4-6 days starved but active predator with the help of a fine needle without touching (disturbing) the predator in any manner.

Such observations were recorded where the predators behaved as normally as could be ensured. The strike rate (SR) of *M. Bastiani* and the degree of resistance (PR) and suceptibility (PS) of different prey were determined and analysed by the methods of Bilgrami and Jairajpuri (1989).

$$(SR\%) = \frac{EA}{E} \times 100; \quad (PR\%) = \frac{EA - AW}{EA} \times 100;$$

$$PS(\%) = 100 - PR$$

where, E = Total number of encounters made by the predators, Ea = Total number of encounters resulting in attack; AW = Total number of attacks resulting in wounding. Feeding after wounding the prey (FW %) was determined by the total number of prey individuals wounded (AW) by the predators. Prey individuals left unconsumed (PL%) by the predators were also determined. Feeding time (FT), i.e. the time taken by a single predator to consume an individual prey, was recorded.

The untransformed results were analysed to obtain coefficient of correlation (r), standard deviation (SD), standard error (SE) and coefficient of variation (CV).

Results

There was no correlation between encounters resulting in attacks and attacks resulting in wounding by *M. bastiani* on bacteriophagous nematodes but feeding after wounding depended upon attacks resulting in wounding ($r = 0.98$, $SE = \pm 0.006$, $p < 0.05$) (p = degree of significance of relationship, "r"). Also there was no correlation between encounters resulting in attacks and attacks resulting in wounding on endoparasitic nematodes, cortical feeders and predaceous nematodes when they were used as prey. Similarly the relationship between attacks resulting in wounding and feeding after wounding was insignificant when endoparasitic nematodes, cortical feeders and predators were used as prey for *M. bastiani.* A significant correlation was observed between encounters resulting in attacks and attacks resulting in wounding ($r = 0.88$; $SE = \pm 0.05$; $p < 0.05$) and attacks resulting in wounding and feeding after wounding ($r = 0.90$; $SE = \pm 0.04$; $p < 0.05$) when epidermal feeders were used as prey.

The strike rate of the predator and the resistance and susceptibility of the five prey trophic categories are shown in Table II.

Meloidogyne incognita (Kofoid *et* White) Chitw. was the most susceptible prey (PS = 87%). Predators fed maximally (FW = 89%) on it. *Anguina tritici* (Steinbuch) Filipjev received most attacks (SR = 84%) with PR = 17%. Maximum number of individuals of *A. tritici* were left unconsumed (PL = 13%) by the predators. The minimum feeding time (FT) was recorded on *M. incognita* (FT = 33 min) and maximum on *A. tritici* (FT = 36 min).

M. bastiani preyed most successfuly on *Xiphinema insigne* Loos (SR = 72%). It wounded maximum number of individuals and fed most frequently upon them but with *Longidorus* sp. most individuals were unconsumed (PL = 32%). The cortical feeders were comparatively less resistant to predation (PR = 18-19%) except *Paratrichodorus* sp. (PR = 36%) and *Longidorus*

TABLE I - *Classification of plant parasitic nematodes used as prey and their hosts.*

Prey trophic categories (PTC)	Prey species	Authority	Source of collection
Saprophagus nematodes	*Panagrellus redivivus*, *Chiloplacus symmetricus*, *Cephalobus* sp. *Acrobeloides* sp. *Rhabditis* sp. *Acrobelus* sp.	(Linn) Goodey (Thorne) Thorne	Laboratory culture
Migratory juveniles (sedentary endo-parasites)	*Meloidogyne incognita*	(Kofoid *et* White) Chitw.	Tomato
	Heterodera mothi	Khan *et* Hussain	Motha grass
	Anguina tritici	(Steinbuch) Filipjev	Wheat galls
Epidermal feeders (ecto-parasites)	*Helicotylenchus indicus*	Siddiqi	Rose bed
	Hoplolaimus indicus	Sher	Palm
	Tylenchorhynchus mashhoodi	Siddiqi *et* Basir	Paddy
	Hirschmanniella oryzae	(Breda de Haan) Luc *et* Goodey	Paddy
	Basiria sp.		Paddy
	Hemicycliophora dhirenderi	Hussain *et* Khan	Rose bed
	Hemicriconemoides mangiferae	Siddiqi	Rose bed
	Scutellonema sp.		Grass
	Aphelenchoides sp.		Paddy
Cortical feeders (ecto-parasites)	*Xiphinema americanum*	Cobb	Hedge
	X. insigne	Loos	Mulbery
	Paratrichodorus sp.		Mulbery
	Paralongidorus citri	(Siddiqi) Siddiqi, Hooper *et* Khan	Citrus
	Longidorus sp.		Mulbery
Predaceous nematodes	*Mononchus aquaticus*	Coetzee	
	Mylonchulus minor	(Cobb) Andrassy	Laboratory culture
	Dorylaimus stagnalis	Dujardin	
	Aporcelaimellus nivalis	(Altherr) Heyns	
	Mesodorylaimus bastiani	(Butschlii) Andrassy	
	Aquatides thornei	(Schneider) Ahmad *et* Jairajpuri	
	Mononchoides fortidens	(Schuurmans Stekhoven) Taylor *et* Hechler	
	Mononchoides longicaudatus	(Khera) Andrassy	

TABLE II - *Strike rate of the predator,* Mesodorylaimus bastiani *and resistance and susceptibility of different prey trophic categories.*

Prey species	No. of encounters	Attacks		Wounding			Feeding	
		Encounters resulted into attack	Strike rate of predators	Attacks resulted into wounding	Prey resistance	Feeding after wounding	Prey left unconsumed	Duration of feeding
	E	EA (%)	SR (%)	AW (%)	PR (%)	FW (%)	(PL (%)	(FTm)
Endoparasitic Nematodes								
Meloidogyne incognita	50	40	80	88	13	89	10	33
Heterodera mothi	50	42	84	86	14	86	10	34
Anguina tritici	50	42	84	83	17	86	13	36
Ectoparasitic: Cortical Feeders								
Xiphinema americanum	50	32	64	81	19	85	27	67
Xiphinema insigne	50	36	72	81	19	93	22	61
Longidorus sp.	50	35	70	71	29	88	32	89
Paralongidorus citri	50	34	68	82	18	86	25	102
Paratrichodorus sp.	50	33	66	64	36	86	22	40
Ectoparasitic: Epidermal Feeders								
Tylenchorhynchus mashhoodi	50	32	64	78	19	80	20	41
Hirschmanniella oryzae	50	36	72	78	22	88	20	53
Hoplolaimus indicus	50	28	56	0	100	0	0	–
Helicotylenchus indicus	50	24	48	75	25	33	100	Few min.
Scutellonema sp.	50	31	62	0	100	0	0	–
Hemicriconemoides mangiferae	50	21	42	0	100	0	0	–
Hemicycliophora dherendri	50	24	48	0	100	0	0	–
Aphelenchoides sp.	50	33	66	79	21	89	22	45
Basiria sp.	50	30	60	60	40	72	23	35
Saprophagous nematodes								
Panagrellus redivivus	50	35	70	65	34	87	10	41
Cephalobus sp.	50	34	68	71	29	83	15	33
Acrobeloides sp.	50	28	56	61	32	95	0	57
Rhabditis sp.	50	31	62	16	84	80	0	39
Acrobelus sp.	50	30	60	33	67	80	13	51
Chiloplacus symmetricus	50	24	48	75	25	89	13	36
Predaceous Nematodes								
Mononchus aquaticus	50	23	46	13	87	67	0	43
Mylonchulus minor	50	83	16	0	100	0	0	–
Dorylaimus stagnalis	50	11	22	0	100	0	0	–
Aporcelaimellus nivalis	50	16	32	21	81	100	0	70

TABLE II - *(continuation)*

Prey species	No. of encounters E	Attacks: Encounters resulted into attack EA (%)	Attacks: Strike rate of predators SR (%)	Wounding: Attacks resulted into wounding AW (%)	Wounding: Prey resistance PR (%)	Wounding: Feeding after wounding FW (%)	Feeding: Prey left unconsumed (PL (%)	Feeding: Duration of feeding (FTm)
Mesodorylaimus bastiani	50	17	34	24	76	100	25	46
Aquatides thornei	50	23	46	26	74	100	0	47
Mononchoides longicaudatus	50	12	24	0	100	0	0	–
Mononchoides fortidens	50	14	28	0	100	0	0	–

* Predator fed upon only one individual of prey; E = Total numbers of encounters made between predators and prey; EA = Encounters resulting in attacks; SR = Strike rate of predators; AW = Attacks resulting in wounding; PR = Prey resistance; PS = Prey susceptibility; FW = Feeding after wounding prey; PL = Prey left unconsumed; FT = Feeding time.

sp. (PR = 29%). *M. bastiani* took an average of 102 min to consume an individual of *Paralongidorus citri* (Siddiqi) Siddiqi, Hooper *et* Khan but required less time to consume an individual of *Paratrichodorus* sp. (FT = 40 min).

Hoplolaimus indicus Sher, *Hemicriconemoides mangiferae* Siddiqi, *Hemicycliophora dhirenderi* Hussain *et* Khan and *Scutellonema* sp., were totally resistant (PR = 100%). Interactions with *Hirschmanniella oryzae* (Breda de Haan) Luc *et* Goodey yielded maximum SR = 72%. Most individuals of *Tylenchorhynchus mashhoodi* Siddiqi *et* Basir, *H. oryzae* and *Aphelenchoides* sp. were wounded (FW = 78-79%). Although, 75% of attacks on *Helicotylenchus indicus* Siddiqi resulted in wounding, predators continued feeding only upon 33% of individuals. All wounded specimens were left unconsumed (PL = 100%). Maximum feeding (FW = 88-89%) was recorded on *H. oryzae* and *Aphelenchoides* sp. *Mesodorylaimus bastiani* required 53 min to consume an individual of *H. oryzae* and 35 min to consume an individual of *Basiria* sp.

Panagrellus redivivus (Linn) Goodey was attacked most (SR = 70%) by *M. bastiani*. The attacks on *Cephalobus* sp. and *Chiloplacus symmetricus* (Thorne) Thorne resulted in maximum wounding as the two nematodes were highly susceptible to predation (PS = 71-75%). *Rhabditis* sp. was the most resistant species (PR = 84%). Predators fed maximally upon *C. symmetricus* (FW = 89%) and *Acrobeloides* sp., (FW = 95%) and left 10-15% individuals of *P. redivivus*, *Cephalobus* sp., *Acrobeloides* sp. and *C. symmetricus* unconsumed but none of *Rhabditis* and *Acrobeloides* sp. Minimum FT = 33 min was required to consume totally *Cephalobus* sp., and maximum FT = 57 min for *Acrobeloides* sp.

Mylonchulus minor (Cobb) Andrassy, *Dorylaimus stagnalis* Dujardin, *Mononchoides fortidens* (Schuurmans Stekkoven) Taylor *et* Hechler and *M. longicaudatus* were totally resistant to predation by *M. bastiani* (PR = 100%). The rate of wounding of *A. nivalis*, *M. bastiani* and *A. thornei* was low (AW = 21-26%) but that of feeding was maximal (FW = 100%). *M. bastiani* left 25% of their own members unconsumed but none of others. It required 70 min to consume *A. nivalis* and 43 min to consume *M. aquaticus* totally.

TABLE III - *Numerical analysis of relationships between* Mesodorylaimus bastiani *and different prey trophic categories.*

Prey Trophic catagories	SR	AW	PR	FW	PL	FT
	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD
Saprophagous	61 ± 8.1 (13)	54 ± 23.5 (43)	45 ± 24.0 (54)	86 ± 5.9 (7)	9 ± 6.8 (75)	43 ± 9.2 (22)
Endoparasitic	83 ± 2.3 (3)	85 ± 2.5 (3)	15 ± 2.1 (47)	85 ± 2.1 (2)	11 ± 1.7 (16)	34 ± 1.5 (4)
Ectoparasitic: cortical feeders	68 ± 3.2 (5)	76 ± 7.0 (11)	24 ± 8.0 (33)	88 ± 3.2 (4)	26 ± 4.2 (16)	72 ± 24.2 (34)
Ectoparasitic: Epidermal feeder	58 ± 9.8 (17)	41 ± 39.4 (96)	59 ± 39.7 (69)	40 ± 39.10 (99)	21 ± 20.7 (99)	44 ± 7.5 (17)
Predaceous	31 ± 10.8 (35)	11 ± 2.4 (21)	84 ± 15.9 (19)	46 ± 45.2 (98)	3 ± 2.8 (93)	52 ± 13.9 (27)

SR = Strike rate of Predators; AW = Attacks resulting in wounding; PR = Prey resistance; FW = Feeding after wounding prey; PL = Prey left unconsumed; FT = Feeding time; M = Mean; SD = Standard Deviation. All figures are nearest to whole numbers. Figures in parantheses are the CV (Coefficient of Variation values in percent).

From the analysis of relationships between *M. bastiani* and different prey trophic categories (Table III) we can make the following assumptions:

– maximum encounters resulted in attacks with endoparasites (SR = M ± SD 83% ± 2.3; CV = 3%; $p < 0.05$); most encounters failed to provoke predators to attack other species of predators (prey) (SR = M ± SD 31% ± 10.8; CV = 35%; $p < 0.05$);

– the endoparasitic nematodes were most susceptible as they were wounded in large numbers (AW = M ± SD 85% ± 2.5; CV = 3%; $p < 0.05$); the predaceous group was most resistant to wounding (AW = M ± SD 11% ± 2.4; CV = 21%; $p < 0.05$);

– when used as prey predaceous nematodes formed the most resistant trophic group (PR = M ± SD 84 ± 15.9; CV = 19%; $p < 0.05$); endoparasitic nematodes showed high degree of susceptibility to predation (PR = M ± SD 15% ± 2.1; CV = 47%; $p < 0.05$);

– maximum variation in feeding after wounding occurred on epidermal feeders (CV = 99%) and the least with endo-parasitic nematodes (CV = 2%); cortical feeders were fed upon most by *M. bastiani* (FW = M ± SD 88% ± 3.2; CV = 4%; $p < 0.05$); the epidermal feeders were not prefered by the predators as only 40% ± 39.1 of wounded individuals were consumed;

– *M. bastiani* left most cortical feeders unconsumed (PL = M ± SD 26 ± 4.2; CV = 16%) but consumed more individuals of predaceous species (PL = M ± SD 3 ± 2.8; CV = 99%);

– *M. bastiani* took a maximum of 72 ± 24.2 min to consume an individual of cortical feeders whereas the predators required 34 ± 1.5 min to consume completely an endo-parasitic nematode.

Discussion

M. bastiani is predaceous on nematodes belonging to different trophic categories similar to *Aporcelaimellus nivalis* (Bilgrami, 1993). Its relationship with individual prey species varied.

The characterization of prey trophic categories has revealed that migratory juveniles of sedentary endo-parasites were most vulnerable to predation as they appeared to lack anti-predation characteristics (Esser, 1963; Grootaert *et al.*, 1977; Small and Grootaert, 1983; Bilgrami and Jairajpuri, 1989; Khan *et al.*, 1991). Bacterial feeders which have a soft body and smooth cuticle are highly susceptible to wounding despite their activity. The ecto-parasitic nematodes (cortical and epidermal feeders) and predaceous nematodes possess physical and behavioural characteristics which resist predation better than other prey trophic categories. The reason why cortical feeders were more susceptible to predation could be their inactivity, large body size and inability to take evasive action (body undulations, escape response) when attacked. *Aporcelaimellus nivalis* also exhibited an identical relationship with different prey trophic categories (Bilgrami, 1993). However, *A. nivalis* has a higher strike rate, a high degree of prey wounding and takes less time to consume prey than *M. bastiani*. The prey trophic categories were also more resistant to predation by *M. bastiani* than *A. nivalis*.

The absence of predation on *Hoplolaimus indicus*, *Scutellonema* sp., *H. mangiferae*, *H. dhirendri*, *Acrobelus* sp., *M. minor*, *M. fortidens*, *M. longicaudatus* and *D. stagnalis* is attributed to physical characteristics e.g., thick cuticle, body annulations and thick cuticular folds (Esser, 1963; Small and Grootaert, 1983; Bilgrami and Jairajpuri, 1989, 1990). The bacteriophagous (*Rhabditis* sp., and *C. symmetricus*) and predatory nematodes, (*M. fortidens*, *M. longicaudatus* and *M. minor*) avoid predation because of behavioural characteristics (Bilgrami *et. al.*, 1983; 1985a; Bilgrami and Jairajpuri, 1989).

Dorylaim predators repulsed from feeding and regurgitate the contents of *Helicotylenchus* sp. (Esser, 1963; Grootaert *et. al.*, 1977; Small, 1987; Shafqat *et al.*, 1987; Bilgrami and Jairajpuri, 1989; 1990). *M. bastiani* also showed similar behaviour when wounded *Helicotylenchus indicus* and initiated feeding. The duration of feeding depended upon the size of prey, prey volume and the chemical composition of the prey contents (Bilgrami *et al.*, 1985b). Positive correlations between attacks resulting in wounding and feeding after wounding by *M. bastiani* suggest that feeding is always dependent upon wounding and once the prey is wounded it lose its resistance. Similar correlations were also observed by Bilgrami (1993) with *A. nivalis* using same prey trophic categories.

Acknowledgements. The author is grateful to the Department of Science and Technology, New Delhi for providing financial assistance to carry out this work.

Literature cited

BILGRAMI A. L., 1990. *Predaceous dorylaims*, pp. 143-148. In Nematode Bio-control: Aspects and Prospects (M. S. Jairajpuri, M. M. Alam and I. Ahmad eds.) CBS publishers & Distributors Pvt. Ltd. New Delhi.

BILGRAMI A. L., 1993. Analysis of the predation by *Aporcelaimellus nivalis* on prey nematodes from different prey trophic categories. *Nematologica*, *39*: 356-365.

BILGRAMI A. L., AHAMD I. and JAIRAJPURI M. S., 1983. Some factors influencing predation by *Mononchus aquaticus*. *Rev. Nematol.*, *6*: 325-326.

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

BILGRAMI A. L., AHMAD I. and JAIRAJPURI M. S., 1985b. Factors influencing attraction of adult *Hirschmanniella oryzae* towards cabbage seedlings. *Rev. Nematol.*, *8*: 67-75.

BILGRAMI A. L. and JAIRAJPURI M. S., 1988. Attraction of *Mononchoides longicaudatus* and *M. fortidens* (Nematoda: Diplogasterida) towards prey and factors influencing attraction. *Rev. Nematol.*, *11*: 195-202.

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

BILGRAMI A. L. and JAIRAJPURI M. S., 1990. Predation by *Mononchoides fortidens* and *M. longicaudatus* (Nematoda: Diplogasterida). *Nematologica*, *35*: 475-488.

ESSER R. P., 1963. Nematode interactions in plates of non-sterile water-agar. *Proc. Soil Crop Sci. Soc. Fla.*, *23*: 121-138.

ESSER R. P., 1987. Biological control of nematodes by nematodes I. Dorylaims (Nematoda: Dorylaimida). Nematology Circular, 4, pp. 4.

GROOTAERT P., JAQUES A. and SMALL R. W., 1977. Prey selection in *Butlerius* sp. (Rhabditida: Diplogasteridae). *Meded. Facult. Landb. Rijksuniv. Gent*, *42*: 1559-1563.

KHAN Z., BILGRAMI A. L. and JAIRAJPURI M. S., 1991. Observations on the predation ability of *Aporcelaimellus nivalis* (Altherr, 1952) Heyns, 1966 (Nematoda: Dorylaimida). *Nematologica*: *37*: 333-342.

SHAFQAT S., BILGRAMI A. L. and JAIRAJPURI M. S., 1987. Evaluation of the predation ability of *Dorylaimus stagnalis* Dujardin, 1845 (Nematoda: Dorylaimida). *Rev. Nematol.*, *10*: 455-461.

SMALL R. W., 1987. A review of the prey nematodes. *Pedobiologia*, *30*: 179-206.

SMALL R. W. and GROOTAERT G., 1983. Observations on the predation abilities of some soil dwelling predatory nematodes. *Nematologica*: *29*: 109-118.

Accepted for publication on 3 January 1995.