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Host Affinity of Nematode Species of the Genus *Aphelenchoides*

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Abstract: ***Aphelenchoides are commonly known as foliar nematodes. Information on host diversity and host taxonomic affiliation revealed that out of 23 nematode species11were monophagous, and of these 70% species preferred dicotyledons. All the monophagous species had GAI value of 1.000. Polyphagous species were species specific. However, generalized picture revealed that 69.71, 14.86 and 15.43% plant species were accepted as host from dicotyledons, monocotyledons and others (non-angiosperms), respectively. A. cibolensis was exclusively feeding on non-angiosperms (ferns, junipers, pines). A fragariae showed greater affiliation to dicot-herbaceae and indicated 3 possible evolutionary lineages which contributed host taxonomic affinity in the range of 70 to 86%.***

Keywords: *Aphelenchoides*:, Nematodes, Host Range, Host Taxonomic Affinity

1. Introduction

Plant parasitic nematodes of the genus *Aphelenchoides* (Tylenchida: Aphelenchoididae) are commonly known as foliar nematodes. Almost all foliar nematodes feed as ecto-or endoparasites on above ground plant parts and some species may cause economic losses in both mono and dicotyledonous plants (Rybarczyk-Mydtowska *et al*, 2012). However, *A. subtenuis* has shown to feed on roots of narcissus (Mor and Spiegel, 1993). Many species of *Aphelenchoides* feed on fungi (Hunt, 1993). Fungi feeding species are common in soil and generally appear to have short stylets (< 8 um) than plant feeding species (Wikipedia, 2016). Thorsteinson (1960) believed that many insect species prefer host plants from certain taxonomic groups. Similar observations were made in insects by Rathore and Lal (1998) and Rathore and Tiwari (2014) in pod borer, *Maruca vitrata* and whitefly, *Bemisia tabaci,* respectively. In case of nematodes also, taxonomic affiliations and evolutionary lineages were observed in *Meloidogyne incognita* (Rathore and Ali, 2014), in 62 species of *Heterodera*

(Rathore and Tiwari, 2015a), 33 species of *Helicotylenchus* (Rathore and Tiwari, 2015 b), 68 species of *Meloidogyne* (Rathore and Tiwari, 2016a) and 28 species of *Paratylenchus* (Rathore and Tiwari, 2016b). An attempt was, therefore, made to understand the host preference of 23 species of *Aphelenchoides* as they are different from other parasitic nematodes in their seriousness and attraction towards plants.

2. Materials and Methods

Host plants of *Aphelenchoides* species were downloaded from Nemaplex (2015) and were aligned with the families and orders following taxonomic classification of Hutchinson (1973). Hutchinson divided angiosperms in subphylum dicotyledons and monocotyledons. Both subphyla were further partitioned into divisions. Dicotyledons is comprised of lignosae (fundamentally woody plants) and herbaceae (fundamentally herbaceous plants), and monocotyledons divided into calyciferae (calyx bearers-with distinct calyx and corolla), corolliferae (calyx and corolla are more or less similar) and glumiflorae (perianth is much more reduced or represented by lodicules). Host plants other than angiosperms were listed as others. *Aphelenchoides* species were designated as mono, oligo and polyphagous by following the definitions of Barnays and Chapman (1994) where monophagous feeds on plants of a single genus, while oligophagous utilizes plants of different genera in a single plant family; polyphagous consumes plants from different plant families. Rathore and Tiwari (2015) developed two indices, i.e., Specific Affiliation Index (SAI) and General Affiliation Index (GAI) for comparison within and between species, respectively. We employed GAI which is as follows:

$$GAI = THs + 2/G+F+O$$

Where, THs=Total number of host plants of a given nematode species, G=No. of host genera, F= No. of host families, and O= No. of host orders. Value of 2 was used as a correction factor. GAI value equal or greater than 1 indicated greater affiliation (mostly monophagy) and less than 1 showed lower affiliation (oligophagy and polyphagy). Sometimes polyphagous species greater association for certain groups also showed GAI value >1.

3. Results and Discussion

Observations based on all the species reported herein, 11 showed monophagy. Out of these 7 nematode species viz., *A. arachis* (Fabaceae), *A. citri, A. goodeyi, A. rutgersi, A. sphaerocephalus* (Rutaceae*), A. hamatus* (Rosaceae*), A. parietinus* (Malvaceae) preferred hosts from lignosae and one *A. solani* (Solanaceae) from herbaceae only. Three nematode species viz., *A. heterophallus, A. nechaleos* and *A. paranechaleos* reported family Poaceae in monocotyledons. This shows that more than 70% monophagous species preferred dicotyledons. All the monophagous species had GAI value of 1.000 (Table 1). Among the polyphagous, the preference was species specific and number of host species ranged from 2 to 389 for different nematode species (Table 1). However, a generalized view revealed that 69.71, 14.86 and 15.43 % plant species were accepted as a host from

dicotyledons, monocotyledons and others, respectively (Table 2), and more than 50% plant species were from dicot-herbaceae alone. Monocotyledons shared less number of host species which had contribution of corolliferae (11.77%) and glumiflorae (2.81%). It is amazing to observe that 15.43% host species were other than angiosperms (non-angiosperms) and *A. cibolensis* has been reported to feed only on ferns, junipers and pines (Table 1). Prominent polyphagous species like *A. besseyi, A. fragariae* and *A. ritzemabosi* also possessed these non-angiosperms in their list of host plants.

Aphelenchoides dominated by fungivorous species are mostly considered harmless. But *A. besseyi, A. fragariae, A. ritzemabosi* and *A. subtenuiis* are serious plant parasites. Molecular study revealed that genus is not monophyletic and *A. besseyi* and *A. ritzemabosi* cluster together and they are phylogenetically isolated from *A. fragariae* and *A. subtenuis* and most other fungivorous species (Ryabarczyk-Mydtowska et al , 2012).

Morphological and molecular characterization of morphologically similar population extracted from rice and forage grass seeds revealed two dichotomous groups with Group-rice and Group-forage populations genetically similar to *A. besseyi* and *A. fugiensis,* respectively (de Jesus et al, 2016).

Among the four plant parasitic species *A. besseyi* has similar number of host species in both dicot and monocotyledons with marginally greater preference to dicots. *A. fragariae* and *A. ritzemabosi* showed much greater affinity to dicots over monocots, whereas *A. subtenuis* alleniated preference to monocots (Table 1). Host affinities do not follow the molecular clustering in these nematode species. GAI also varied greatly and the values were 0.679, 1.362, 1.005 and 1.040 for *A. besseyi, A. fragariae, A. ritzemabosi* and *A. subtenuis*, respectively indicating that last three species in spite of being polyphagous had high affinity to their host clusters/groups.

A. fragariae showed maximum number of plant species in its host range and were found in all taxonomic divisions of angiosperms and others (non-angiosperms). In lignosae, host species spread out to 17 families (15 orders) and in herbaceae 29 families (20 orders) and contributed 233 host species. In monocotyledons host plants belonging to corolliferae were to the tune of 10.80%, whereas calyciferae and glumiflorae combination gave less than 1.50%. This species also feeds on large number of host plants from non-angiosperms.

No evolutionary pattern could be traced for host plants in lignosae. However, in herbaceae three prominent lineages were observed.
1. Ranales—Saxifragales—Solanales—Personales
2. Ranales—Saxifragales—Campanales—Asterales
3. Ranales—Geraniales—Polemonales—Boraginales—Lamiales

On the basis of number of host species in herbaceae, the above lineages contributed 44.20, 45.86 and 38.67%, respectively in that order. Contribution of different lineages based on total number of host species (389) was 20.50, 21.37 and 18.00% for 1, 2 and 3, respectively and combined for all the three lineages was 59.87%. In monocotyledons host plants evolved from Liliales stock were preferred.

Gymnosperms are comprised of trees and shrubs usually evergreen, needle like or fern like foliage but very ancient phylum of plants. More than 25% of such plants (ferns, juniper, pines) or almost 1/4th of the total host species of *A. fragariae*. It is amazing to report such a strong affinity to these non-angiosperms plants. In angiosperms, Paeoniaceae and Ranunculaceae are primitive in the order Ranales in herbaceae group and contributed 34 host species. Orders Ranales in herbaceae and Magnoliales in lignosae divisions of dicotyledons are said to be evolved parallely from gymnosperms (Hutchinson, 1973).

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Table 1. Host taxonomic affinity with different species of Aphelenchoides

Sl. No.	*Ahelenchoides species*	*Plant taxonomic groups*	*No. of Plants*	*GAI*	*Status*
1.	*A. arachidis*	**DL**-Fabaceae (1) (*Arachis hypogaea*)	1	1.000	Mono
2.	*A.aligarhiensis*	**DL**-Cucurbitaceae (1), Rutaceae (1); DH-Brassicaceae (1)	3	0.556	Poly
3.	*A. besseyi*	**DL**-Fabaceae (2), Hydrangeaceae (1),Rosaceae (3); **DH**-Aste ceae (9), Balsaminaceae (1), Lamiaceae (1), Scrophulariaceae (1), Solanaceae (1); **MCor**-Agavaceae (1), Amaryllidaceae (1),Iridaceae (1), Orchidaceae (1); **MGlu**-Cyperaceae(1),Poaceae (9); **Others**-Polypodiaceae (1)	34	0.679	Poly
4.	*A. bicaudatus*	**DL**-Fabaceae (1), Rosaceae (1); **MCor**-Liliaceae (1), Orchidaceae (1); **MGlu**-Poaceae (2)	6	0.500	Poly
5.	*A. blastophthorus*	**DL**-Begoniaceae (1), Violaceae (1); **DH**-Boraginaceae (1)Dipsacaceae (3), Ranunculaceae (2); **MCor**-Amaryllidaceae (1), Iridaceae (1), Liliaceae (1)	11	0.481	Poly
6.	*A. cibolensis*	**Others**-Cupressaceae (2)(*Juniperus deppeana, J. monosperma)*, Pinaceae (1) (Pinus edulis)	3	0.833	Poly
7.	*A. citri*	**DL**-Rutaceae (1), (*Citrus x limonia*)	1	1.000	Mono
8.	*A. coffeae*	**DL**-Geraniaceae (1**); MCor**-Orchidaceae (1)	2	0.667	Poly
9.	*A. fragariae*	**DL**-Begoniaceae (6), Cactaceae (1), Caprifoliaceae (4), Cistaceae (1), Diapensiaceae (1), Dipterocarpaceae (8) Fabaceae (1), Hydrangeaceae (2), Loganiaceae (2), Moraceae (11), Myrsinaceae (2), Oleaceae (1), Rosaceae (6),Rubiaceae(3),Ulmaceae(1),Verbenaceae (7),Violaceae (3); **DH**-Acanthaceae (4), Amaran-thaceae (1), Apiaceae (5), Aristolochiaceae (2),, Asteraceae (25),Balsaminaceae (1), Boraginaceae (5), Brassicaceae (2), Caryophyll ceae(2), Crassulaceae (2), Dipsacaceae (6), Geraniaceae (3), Gesne- riaceae (7), Halogidaceae (1), Hydrophyllaceae (1), Lamiaceae (24), Lobeliaceae (1), Onagraceae (1), Oxalidaceae (1), Paeoniaceae (6), Piperaceae (1), Plumbaginaceae (2), Polemoniaceae (1), Polygona-ceae (2), Primulaceae (14), Ranunculaceae (28), Saxifragaceae (21),Scrophulariceae (10), Solanaceae (2); **MCaly**- Commelinaceae (2);MCor-Amaryllidaceae (4), Araceae (3), Iridaceae (3), Liliaceae (24), Orchidaceae (8); **MGlu**-Cyperaceae (2), Poaceae (1); Others-Adiantaceae (1), Aspleniaceae (1), Athyriaceae (4), Dennstaedtiaceae (1) , Dryopteridaceae (2), Osmundaceae (2), Pinaceae(1), Pteridaceae (4), Polypodiaceae (78), Schizaeaceae (6), Thelypteridaceae (1)	389	1.362	Poly
10.	*A. goodeyi*	**DL**-Rutaceae (1) (*Citrus sp.*)	1	1.000	Mono
11.	*A. hamatus*	**DL**-Rosaceae (1) (*Fragaria x ananassa*)	1	1.000	Mono
12.	*A. heterophallus*	**MGlu**-Poaceae (1) (*Saccharum officinarum)*	1	1.000	Mono
13.	*A. hunti*	**DH**-Convolvulaceae (1), Solanaceae (1**); MCor**-Alstroemeriaceae (1), Liliaceae (1)	4	0.545	Poly
14.	*A. limberi*	**DL**-Ulmaceae (1); **DH**-Asteraceae (1)	2	0.667	Poly
15.	*A. nechaleos*	**MGlu**-Poaceae (1) (*Oryza sativa*)	1	1.000	Mono
16.	*A. ormerodis*	**DH**-Crassulaceae (1), Saxifragaceae (1), Plumbaginaceae (1)	3	0.625	Poly
17.	*A. paranechaleos)*	**MGlu**-Poaceae (1) (*Oryza sativa)*	1	1.000	Mono
18.	*A. parietinus*	**DL**-Malvaceae (1) (*Gossypium sp.)*	1	1.000	Mono
19.	*A. ritzemabosi*	**DL**-Begoniaceae (1), Bignoniaceae (2), Carpifoliaceae (2), Fabaceae (5), Loganiaceae (2), Myrsinaceae (1), Oleaceae (1), Rosaceae (7),Rubiaceae (1), Salicaceae (1), Urticaceae (3), Verbenaceae (1), Vitaceae (1); **DH**-Apiaceae (2) , Asteraceae (66), Balsaminaceae (1), Berberidaceae (1), Boraginaceae (1), Brassicaceae (5), Campanulac (2), Caryophyllaceae (3), Chenopodiaceae (1), Convolvulaceae (1), Crassulaceae (1), Dipsacaceae (5), Gesneriaceae (4), Lamiaceae (14), Polemoniaceae (5), Onagraceae (1), Paeoniaceae (1), Papaveraceae (3), Piperaceae (4), Plantaginaceae (1), Plumbaginaceae (3),Polygonaceae (1), Primulaceae (2), Ranunculaceae (13), Saxifragaceae (7),Scrophulariaceae (12), Solanaceae (5), Valerianaceae (1); MCor- Amaryllidaceae (1), Araceae (1), Iridaceae (1), Liliaceae (7); **MGlu**-Poaceae (1); **Others**-Blechnaceae (1), Dryopteridaceae (1), Poly-podiaceae (2)	209	1.005	Poly
20.	*A. rutgersi*	**DL**-Rutaceae (1) (*Citrus sp.)*	1	1.000	Mono
21.	*A. solani*	**DH**-Solanaceae (1) (*Solanum tuberosum*)	1	1.000	Mono

22.	*Aphelenchoides sp.*	**DL**-Begoniaceae (1), Moraceae (3), Myrsinaceae (2); **DH**-Balsami- naceae (1), Convolvulaceae (1), Crassulaceae (1), Polygonaceae (1), Ranunculaceae (1); **MCor**-Liliaceae (1)**; MGlu**-Poaceae (1); Others-Polypodiaceae (1)	14	0.485	Poly
23.	*A. sphaerocephalus*	**DL**-Rutaceae (1) (*Evodia roxburghiana*)	1	1.000	Mono
24.	*A. subtenuis*	**DL**-Fabaceae (1); DH-Paeoniaceae (1),Polemoniaceae (1); **MCor**- Amaryllidaceae (8), Iridaceae (7), Liliaceae (4)	22	1.040	Poly

DL-Dicotyledons-lignosae; **DH**-Dicotyledons-herbaceae; **MCaly**-Monocotyledons-calyciferae; *MCor*-Monocotyledons-corolliferae; **MGlu**-Monocotyledons-glumiflorae: **Others**-host –plants other than angiosperms; **Mono**-monophagous, **Poly**-polyphagous

Table 2: Host-taxonomic affinity across Aphelenchoides species

Host-plant parameters	Dicotyledons		Monocotyledons			Others	Total
	Lignosae	Herbaceae	Caly	Cor	Glu		
Species	115(16.13)	382(53.58)	2(0.28)	84(11.77)	20(2.81)	110(15.43)	713
Genera	70(17.99)	215(55.27)	2(0.51)	46(11.83)	19(4.88)	37(9.51)	389
Families	51(27.42)	81(43.55)	2(0.54)	25(13.44)	10(5.38)	18(9.68)	186
Orders	48(30.57)	64(40.76)	2(0.640	25(15.92)	10(6.37)	9(5.73)	157
Total	284(19.65)	742(51.35)	6(0.42)	180(12.46)	59(4.08)	174(12.04)	1445

Figures on parentheses are % values ; Caly – Calyciferae; Cor- Corolliferae; Glu- Glumiflorae ; others – host plant other than angiosperm.