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IDENTIFICATION SCHEME FOR *HETERODERA* SPECIES IN INDIA

BY

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A compendium of all the cyst forming species recorded from India has been given. Identification keys based on larvae, cysts alone, hosts alone as also taking all the parameters together have been formulated for the six tested species as well as for all the other species recorded from the country. A proposal has been put forward to modify Mulvey's groups with addition of Group VI and re-definitions of Groups IV and V. *Heterodera chaubattia* is being considered as species inquirende because of inadequate description and non-availability of types.

Morphological characters separating different species of *Heterodera* have been considered quite constant by Franklin (1971). According to her, if the contents of even a single cyst, which is in good condition, are examined, it may be possible to reach to conclusion about the specific identity. She has also suggested that in some cases where host range is limited, the host plant may be diagnostic. While morphological characters, by and large, are dependable and could be used with proper understanding and caution in the identification of a species, in many cases it becomes difficult because of inadequate descriptions as well as lack of perception of various morphological features of the juveniles, females and cysts. This is particularly true of the species described prior to 1970. The value of cone tops was stressed by Oostenbrink and den Ouden (1954) with the host plant specialization as an additional support in the identification of the species. Most of the described species are on the basis of limited population studies and often more than one species have been described from one host plant, differing from each other in range of measurements or other "minor characters". During the last decade some comprehensive studies have been made on the cyst forming nematodes which have been of great value in the understanding of the group as a whole (Mulvey, 1972; Stone, 1977). Despite the fact that 17 species of the cyst forming nematodes have been recorded from this country, with some of them associated with economically important crop plants, no effort has been made, so far, to study them from the point of view of defining morphological features which will aid in the identification of the species. Often cysts are encountered in soil and a definite association with a particular crop is not possible, as has been the case with the

3 species (*H. carotae*, *H. chaubattia* and *H. galeopsidis*) recorded from the country. Similarly, larvae are quite commonly encountered in many soil collections and in the absence of any definite crop association, specific identification is not attempted. Taking these facts into consideration, the morphological values of six species (*H. cajani*, *H. graminis*, *H. mothi*, *H. oryzicola*, *H. sorghi*, and *H. zeae*) which were investigated earlier and subjected to discriminant function analysis, were taken into cosideration in devising keys for identification.

A proposal is also being made for modification of Mulvey's group V with an addition of a new group named here as group VI with a view to clarify some of the inconsistencies present therein.

An upto-date list and status of the cyst-forming nematodes recorded from the country is given in Tables I and II. The distribution map of all the species is in Figure 1.

IDENTIFICATION KEY OF CYST NEMATODE SPECIES IN INDIA BASED ON CYST AND CONE TOP STRUCTURES

1. Cyst round, without posterior protuberance..... *Globodera rostochiensis* and *G. pallida*

   Cyst lemon to spherical shaped with posterior protuberance.....2

2. Cyst lemon shaped, bifenestrate.....*Heterodera avenae*

   Cyst basically lemon shaped, circumfenestrate.....*H. cacti* (*Cactodera* ?)

   Cyst lemon to spherical shaped, ambifenestrate.....3

3. Underbridge well developed.....4

   Underbridge weak and slender.....9

   Underbridge absent, cyst spherical.....*H. carotae*

4. Underbridge 100-155 μm in length, bullate.....5

   Underbridge 40-100 μm in length, bullate.....6

   Underbridge 60-112 μm in length, abullate.....8

5. Underbridge with finger like projections, vulval slit length 50-52 μm..... *H. sacchari*

   Underbridge without finger like projections, vulval slit length 28-51 μm..... *H. sorghi*

6. Underbridge short (averaging 49 μm), rod shaped, cross bullae present..... *H. zeae*

   Underbridge moderate in length (averaging 65 μm), cross bullae absent..... *H. cajani*

   Underbridge length 80-100 μm.....7

7. Depth of underbridge 33-38 μm .....*H. trifolii*

   Depth of underbridge 37-40 μm.....*H. galeopsidis*

8. Vulval knobs present, underbridge depth 15-35 μm.....*H. graminis*

   Vulval knobs absent, underbridge depth 52-60 μm.....*H. delvii*

9. Cyst slender, L/W ratio about 2.....10

   Cyst lemon shaped, L/W ratio about 1.3.....*H. oryzicola*

10. Cone tops without bullae or vulval denticles (verrucae).....*H. cyperi*

    Vulval denticles (verrucae) present, bullae may be present or absent..... *H. mothi*

IDENTIFICATION KEY OF CYST NEMATODE SPECIES IN INDIA BASED ON CHARACTERS OF SECOND STAGE LARVAE, CYSTS AND CONE TOP STRUCTURES

1. Juveniles with 3 lateral incisures.....2

   Juveniles with 4 lateral incisures.....7

2 Underbridge well developed, 60-112 μm in length, abullate.....3

   Underbridge well developed 100-155 μm in length, bullate.....4

   Underbridge weak, slender or absent.....5

3. Larval stylet length 18-20 μm, underbridge depth 52-60 μm.....*H. delvii*

   Larval stylet length 19-24 μm, underbridge depth 15-35 μm.....*H. graminis*

4. Underbridge with finger like projections; vulval slit 50-52 μm long..... *H. sacchari*

   Underbridge without finger like projections; vulval slit 22-51 μm long..... *H. sorghi*

5. Cyst slender, L/W ratio about 2.....6

   Cyst lemon shaped, L/W ratio about 1.3.....*H. oryzicola*

   Cyst spherical, underbridge absent.....*H. carotae*

6. Underbridge short (averaging 49 μm), rod shaped, cross bullae present..... *H. zeae*

   Underbridge moderate in length (averaging 65 μm), cross bullae absent..... *H. cajani*

   Underbridge length 80-100 μm.....7

7. Depth of underbridge 33-38 μm .....*H. trifolii*

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   Cyst spherical, underbridge absent.....*H. carotae*

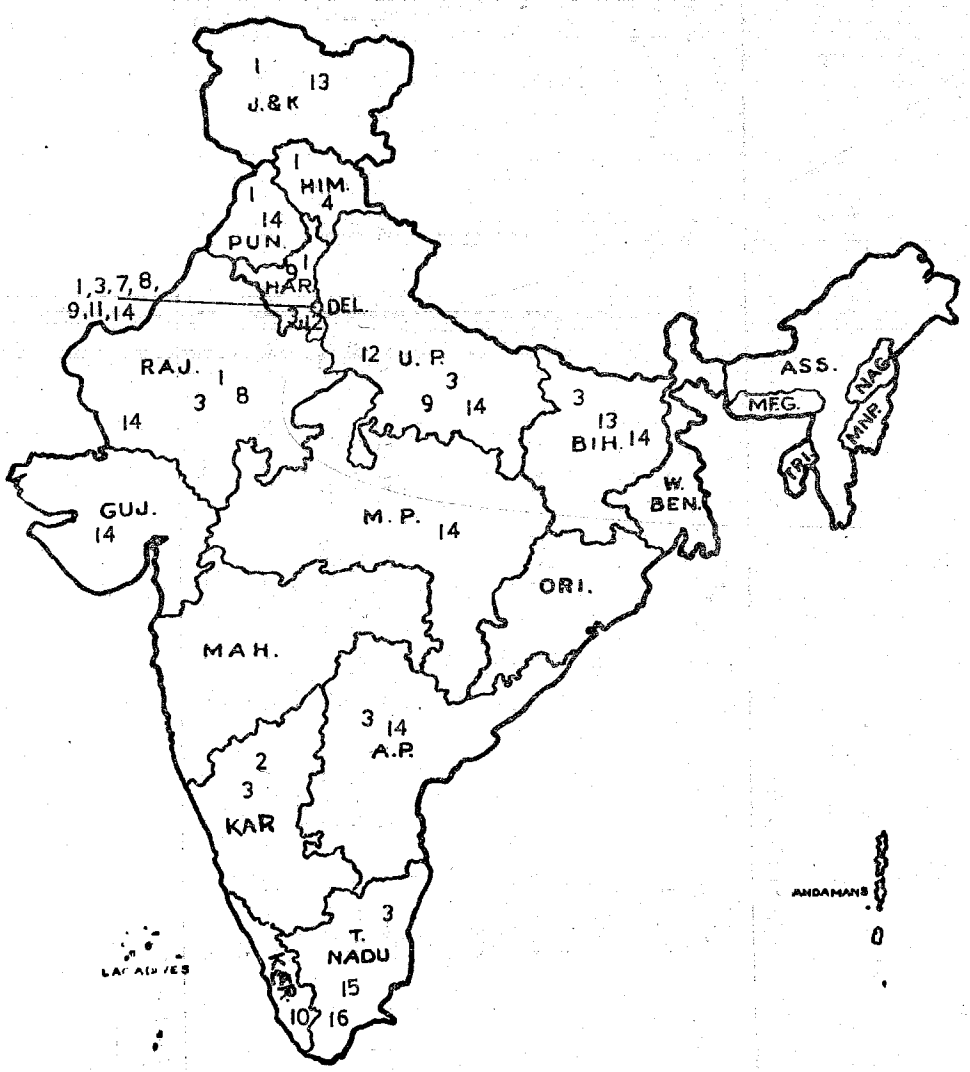
6. Cone tops with vulval denticles, bullae present or absent.....*H. mothi*
   Vulval denticles absent; bullae absent.....*H. cyperi*
7. Cyst lemon shaped, bifenestrate.....*H. avenae*
   Cyst basically lemon shaped, circumfenestrate.....*H. cacti* (=*Cactodera cacti*)
   Cyst lemon to spherical shaped, ambifenestrate.....8
8. Underbridge short (average 49 μm), rod shaped, cross bullae present..... *H. zeae*
   Underbridge moderate in length (average 65 μm), cross bullae absent..... *H. cajani*
   Uuderbridge 80-100 μm long.....9
9. Larval stylet length 25-30 μm.....*H. trifolii*
   Larval stylet length 22-24 μm.....*H. galeopsidis*

HOST DIFFERENTIAL SCHEME FOR HETERODERA SPECIES IDENTIFICATION

1. Graminacious plants (+).....2
   Graminacious plants (−).....*H. cajani*
2. *Eleusine coracana* (+).....3
   Eleusine coracana (−).....4
3. *Cyperus rotundus* (+), *Secale cereale* (—), *Oryza sativa* (−).....*H. sorghi*
   C. rotundus (−), *S. cereale* (+), *O. sativa* (+).....*H. zeae*
4. *Triticum* species (+).....*H. avenae*
   Triticum species (−).....5
5. *Cynodon dactylon* (+), *O. sativa* (−).....*H. graminis*
   O. sativa (+), C. *dactylon* (—).....*H. oryzicola*
   Cyperus rotundus (+).....*H. mothi*

+=Host —=Non host

The above scheme is based on the investigated host range tests. For the other recorded species (*cacti, carotae, cyperi, galeopsidis, sacchari* and *trifolii*) only



1—*H. avenae;* 2—*H. cacti;* 3—*H. cajani;* 4—*H. carotae;* 5—*H. cyperi;* 6—*H. delvii;* 7—*H. galeopsidis;* 8—*H. graminis;* 9—*H. mothi;* 10—*H. oryzicola;* 11—*H. sacchari;* 12—*H. sorghi;* 13—*H. trifolii;* 14—*H. zeae;* 15—*Globodera pallida;* 16—*G. rostochiensis*

TABLE I

Range of measurements of Heterodera *species in India (Second stage larvae)*

Species	Body length (BL)	Body width	Stylet length (Sty. L)	Ant. end to Exc. pore	Ant. end to junction	Ant. end to oeso. gland	Tail length (TL)	Hyaline tail length	Ant. end to median bulb (AE-MB)	Lateral lines
H. avenae	491—614		25—29				51—73	34—52		4
H. cacti	364—630		22—25				34—52	14—21		4
H. cajani	345—515	15—20	22—27	72—113	85—124	111—158	31—52	14—30	57—77	4
H. carotae	420—454		23—24				48—53	30		4
H. cyperi	414—465		19—21				56—63	18—31		3
H. delvii	466—520		18—20				49—60	29—36		3
H. galeopsides	396—522		22—24					33		4
H. graminis	320—444	14—23	19—24	75—109	71—113	110—172	41—68	23—37	45—70	3
H. mothi	350—503	14—20	16—19	74— 94	85—120	123—174	54—85	27—45	44—68	3
H. oryzicola	370—486	15—22	17—22	75—107	84—122	120—185	46—75	22—41	54—71	3
H. sacchari	420—530	17—19	21—24					20—30		3
H. sorghi	400—525	16—20	20—23	72—119	76—134	122—185	42—60	24—38	54—74	3
H. trifoli	430—547	18—21	25—30				56—70	33—41	76—86	4
H. zeae	360—440	14—23	19—25	68—114	98—142	129—187	31—56	15—31	55—78	4

Measurements in μm

Species	a	b	b'	c	c'	Hyaline	BL/	Stylet knob	Host	Reference

Species	a	b	b'	c	c'	Hyaline TL/Sty. L	BL/ AE-MB	Stylet knob shape	Host	Reference
H. avenae	22.6—28.7	4.2—7.7		7.6—12.0				Ant. directed	Wheat & Barley	Vasudeva (1958)
H. cacti	15—21	2.1—2.8		7.8—10.7				-do-	*Echinopsis*	Kumar (1964)
H. cajani	18.3—28.9	3.2—5.3	2.5—3.7	7.8—12.3	2.7—6.1	0.5—1.3	5.2—7.2	-do-	Pigeon pea	Koshy (1967)
H. carotae									Soil	Swarup *et al.* (1964)
H. cyperi	24.3—26.0	2.7—3.0		7.0— 7.8				Roundish	*Cynodon dactylon*	Kumar (1980)
H. delvii	18—31	4.3—5.3	3.0—3.6	8—10				Ant. directed	*Eleusine coracana*	Jairajpuri *et al.* (1979)
H. galeopsides						1.5			Soil	Swarup *et al.* (1964)
H. graminis	16—27	2.3—4.6	2.2—3.4	5.3—10 0	3.4—5.8	1.0—1.7	5.3—8.3	-do-	*C. dactylon*	
H. mothi	21.8—32.1	2.7—5.2	2.5—3.8	5.1— 8.1	4.8—9.9	1.6—2.9	6.2—9.4	Roundish	*Cyperus rotundus*	Khan & Husain (1965)
H. oryzicola	19.0—29.7	3.3—4.7	2.3—3.5	5.3— 9.2	3.9—9.0	1.1—2.2	5.6—7.5	-do-	*Oryza sativa*	Rao & Jaya-prakash (1978)
H. sacchari	24—28	2.3—3.6		8.3— 9.5				Ant. directed	*Saccharum spontaneum*	Swarup *et al.* (1964)
H. sorghi	20—28	3.8—6.2	2.5—3.9	7.5— 9.9	3.1—5.9	1.0—1.9	5.7—8.8	-do-	*Sorghum vulgare*	Jain *et al.* (1982)
H. trifolii								-do-	Soil	Sen (1963)
H. zeae	17.2—28.2	2.7—6.5	2.1—4.2	7.0—13.0	2.4—6.0	0.7—1.4	5.1—6.8	-do-	*Zea mays*	Koshy *et al.* (1971)

H. chaubattia is considered as species inquirende

TABLE II

Range of measurements of Heterodera *species in India (Cysts and cone top structures)*

Species	Cyst length (µm)	Cyst width (µm)	Cyst (L/W)	Vulval slit length	Fenestral length	Fenestral width	Underbridge length	Underbridge width	Vulval bridge	Basin	Bullae	Fenestral shape	Anus	Underbridge depth
H. avenae	470—1010	370—730	1.1—1.9	10—13	43—44	21—23	—	—	6— 8		+	Bifenestrate		
H. cacti	430— 750	400—600	1.1—1.4	15—28	20—40	18—30	—				±	Circum.	Distinct	
H. cajani	350— 690	175—500	1.0—2.5	35—53	30—51	25—41	52— 88	12—27	4—10	5—11	+	Ambi.		16—32
H. carotae	340— 520	340—450		45—50	34—40	38—40	—	—			—	Ambi.		
H. cyperi	410— 742	229—382		30—35	27—35	20—28	40— 60	10—12			—	Ambi.	Distinct	
H. delvii	520— 618	280—430		36—45	40—56	36—45	96—112	30—39			—	Ambi.	Distinct	52—60
H. galeopsidis	450—1000	420—700		40—52	41—46	31—38	80—100	15—25			+	Ambi.		37—40
H. graminis	350— 927	297—701	1.1—1.6	35—50	32—72	25—48	60—107	18—40	5—10	6—12	—	Ambi.		15—35
H. mothi	430— 810	210—480	1.5—2.4	29—45	26—50	20—40	53— 85	7—21	4— 7	5—13	±	Ambi.	Distinct	14—28
H. oryzicola	410— 620	220—290	1.0—1.8	29—40	20—45	20—45	50—94	10—24	5— 7	10—24	±	Ambi.	Distinct	13—24
H. sacchari	380—1030	280—830	1.0—2.2	50—52	45—55	35—45	100—150	50—70			+	Ambi.		22—28
H. sorghi	470— 990	350—600	1.2—1.9	28—51	32—65	27—56	100—150	28—52	4— 9	6—17	+	Ambi.		24—54
H. trifolii	400— 980	350—670		39—52	40—58	30—52	80—100	20—28			+	Ambi.		33—38
H. zeae	310— 700	190—600	1.1—1.8	30—58	38—60	16—45	40— 61	8—17	4—10	5—15	+	Ambi.		10—26

Measurements in um

the hosts on which they have been recorded can be taken into consideration for a fit in the key but cannot be negatived on plants which have not been tested. *H. chaubattia* is being considered as species inquirende.

Proposal for modification of Mulvey's classification groups

Mulvey (1972) categorised the cyst nematode species under five groups on the basis of cyst shape and cone top structures. The group demarcation criteria are based on cyst shape (Groups I and II), fenestral shape (Groups II and III), vulval slit length (Groups III and IV) and absence or presence of bullae and underbridge (Groups IV and V). The validity of the groups is mainly on the consistency of these characters within a group and thus are useful. However, characters like bullae and underbridge (particularly bullae) have been observed to be quite variable, even within a species. The use of these as key characters, particularly in IV and V groups, has led to confusion, e.g., the definition of group IV is "bullae present in all species and are small to large; underbridge is generally well developed", but the key to the species of Group IV includes "bullae few or none on peripheral wall of the cone" which is in contradiction to the definition of Gronp IV. Similarly, in Group V "bullae rarely present, underbridge either absent or slender", a long and strongly developed underbridge is taken as key character to distinguish *H. graminis* from *H. cyperi* and *H. cardiolata* which also contradicts the very basis of the group.

Number, shape, size and position of bullae have been found to be inconsistent, particularly in some species like *H. mothi* and *H. oryzicola* where bullae are recorded from few (in some cases none) to many in number whereas in *H. avenae*, *H. cajani* and *H. zeae*, bullae are always found to be consistently present. In some species, the taxonomic use of bullae as character is limited and need to be used with caution. However, in order to facilitate the identification scheme a new group (Group VI) is proposed.

Group VI (Definition) : Cyst with posterior protuberance, lemon to spherical shaped, vulval slit long, underbridge well developed, bullae absent, ambifenestaate.

KEY TO GROUPS
(Group IV onwards)

1. Underbridge generally well developed, bullae present in all species, small to large	Group IV
Underbridge either absent or slender, bullae rarely present	Group V
Underbridge well developed, bullae absent	Group VI

KEY TO SPECIES OF GROUP VI—NEW GROUP

1. Underbridge more than 115 μm, with well developed furcations.....*H. graminophila*
   Underbridge less than 115 μm, with less strongly developed furcations.....2
2. Cyst basically spherical, wavy striae strongly developed.....*H. canadensis*
   Cyst basically lemon shaped, wavy striae moderately developed.....*H. graminis*

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