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DEVELOPMENT OF *HETERODERA AVENAE* BIOTYPE HA 31 ON RESISTANT BARLEY AND OAT CULTIVARS

by
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Summary. Development of *Heterodera avenae* biotype Ha 31 was compared on the resistant cultivars barley C 164 and oat Kent and on the susceptible cultivar wheat C 306. Juveniles (J_2) penetrated each of the cultivars but significantly fewer penetrated the roots of oat. Further development ceased in oat and J_2 disintegrated except for the few which were able to develop into normal males. Development in barley roots was normal, but the majority of adult females remained small-sized and failed to extrude from the roots and thus were unable to copulate and reproduce; sex ratio was affected in favour of males. Oat cultivars HFO 114, Kent, OS 6 and OS 7 commonly grown in Haryana state of India were resistant to biotype Ha 31 of *H. avenae*.

Barley (*Hordeum vulgare* L.) cv. C 164 is resistant to the Mahendragarh, Haryana (India) population of *Heterodera avenae* Woll. biotype Ha 31 and is recommended for cultivation in the State where the nematode is known to be present (Anon., 1977). However, nothing is known about the mechanism of resistance in this cultivar except for the observation that it significantly changes the sex ratio of *H. avenae* to 1:119 in favour of males (Bhatti *et al.*, 1976). The present studies were initially planned to study the mechanism of change in this sex ratio. Later, oat (*Avena sativa* L.) cv. Kent was included as our preliminary observations revealed that four recommended cultivars of oat for Haryana State, India, viz., HFO 114, Kent, OS 6, OS 7 (all hexaploid, n = 42) are highly resistant to the Mahendragarh population of *H. avenae*.

Materials and methods

Seeds of the four oat cultivars were sown in November 1991 and 1992 in 15 cm diam. earthen pots containing steam sterilized soil. After germination, one plant per pot was maintained. Seven days after germination, groups of four pots each were inoculated with ten cysts (cyst contents = 415 eggs and J_2/cyst) of *H. avenae*. One hundred and twenty days after inoculation the soil was processed through a 60 mesh sieve and the number of cysts (root + soil) were counted. The cultivars were categorised according to a scale as indicated in Table I.

Seedlings of barley cv. C 164, oat cv. Kent and wheat (*Triticum aestivum* L.) cv. C 306 (susceptible check), inoculated with five cysts per pot (cyst contents = 421 eggs and J_2/cyst) isolated from the infested soil of the Mahendragarh district were used to study development of the nematode. Plants were uprooted at weekly interval for the first 35 days after inoculation and at 9-10 days interval thereafter. Roots of uprooted plants were stained in 0.1% acid fuchsin lactophenol and observations on the developmental stages were made by mounting the nematodes dissected out of roots in lactophenol. Thirtyfive days after inoculation soil of

TABLE I - *Reaction of common oat cultivars of Haryana to* Heterodera avenae *biotype Ha 31.*

Cultivar	Origin	Avg. number of cysts formed/pot	Reaction*
Oat			
HFO-114	Selection from line 37/14	0.25	R
Kent	Introduction	0.00	R
OS 6	HFO-10xHFO-55P_2-2	0.10	R
OS 7	HFO-10xHFO-55P_2-3	0.30	R
Wheat (check)			
WH 147	(E48TOxC303)x(S339xVI8)	85.00	S

* R = resistant (0-4 cysts/plant); MR = moderately resistant (4.1-9 cysts/plant); S = susceptible (more than 9 cysts/plant).

each pot was also processed through a 100 mesh sieve to recover white females/cysts and then through a 300 mesh with final extraction in a modified Baermann funnel to extract the males in each pot. Males collected were killed and fixed in hot 4% formalin and processed to anhydrous glycerine by the slow method. Measurements, where indicated, were made with an ocular micrometer. Each treatment was replicated three times and selected data were analysed by computing the critical difference (C.D.) at 5%. The experimetn was conducted in the greenhouse of the Department of Nematology, CCS Haryana Agricultural University, Hisar during the months of December, 1993 to March, 1994 when minimum temperature ranged from 0.8 to 3.2 °C and the maximum from 26.3 to 38.2 °C.

Results and discussion

All four of the commonly grown oat cutivars in Haryana were found to be highly resistant to the tested *H. avenae* population (Table I).

Developmental studies (Table II) revealed that J_2 penetration of the roots occurred in oat cv. Kent, barley cv. C 164 and wheat cv. C 306 conforming to general trend reported in resistant cultivars. However, fewer nematodes penetrated the roots of oat cv. Kent compared with barley C 164 and wheat C 306. This may be due to differences in the root size of these cultivars although fewer nematodes in barley roots than oat and wheat have been reported by several workers (Spaull and Hague, 1978; Price and Hague, 1981; Cook and Mizen, 1991).

Further development of *H. avenae* differed in the three crop cultivars tested. In oat cv. Kent, penetration continued up to 37 days after which few J_2 left the roots. Infected roots showed little or no swelling, no branching of roots at the infection sites or adhering soil particles; also no prominent syncytium was apparent. Development was inhibited beyond J_2 and the majority of nematodes that had penetrated the roots died and disintegrated. Only a few J_2, destined to become males, were able to develop further and reached adulthood which supports Cotten's (1967) hypothesis that male development is retarded less in resistant genotypes. All such males were normal (with one testis) and there was no evidence of sex reversal or intersex production as reported for several species of *Meloidogyne* and *H. zeae* (Bajaj *et al.*, 1986; Cook, 1991). The differential development of males as shown in Table II affected the sex ratio in roots, soil and in total.

TABLE II - *Development of* H. avenae *biotype 31 on susceptible wheat, cv. C 306, and resistant barley, cv. C 164 and oat, cv. Kent.*

Days after inoculation	Host	% Developmental stages in roots							Soil	
		Total population	J_2	J_3 undifer-entiated	J_3/J_4 ♀	J_3 ♂	A ♀	J_4/A ♂	♀	♂
14	Wheat	68.0	100	0	0	0	0	0	0	0
	Oat	21.3	100	0	0	0	0	0	0	0
	Barley	48.3	100	0	0	0	0	0	0	0
21	Wheat	72.5	100	0	0	0	0	0	0	0
	Oat	22.3	100	0	0	0	0	0	0	0
	Barley	110.0	100	0	0	0	0	0	0	0
28	Wheat	168.0	0	50	40.7	9.3	0	0	0	0
	Oat	76.3	100	0	0	0	0	0	0	0
	Barley	160.3	21.3	68.4	2.6	7.9	0	0	0	0
37	Wheat	129.3	0	35.7	21.4	35.7	0	7.1	0	0
	Oat	100.6	100	0	0	0	0	0	0	0
	Barley	134.3	0	21.9	21.8	3.7	0	18.75	0	0
46	Wheat	104.0	0	0	55.5	5.3	0	39.2	0	0
	Oat	60.0	96.7	0	0	3.3	0	0	0	0
	Barley	105.3	0	7.4	22.2	14.8	0	55.5	0	0
53	Wheat	94	0	4.4	62.6	4.4	0	28.6	4.7	11.0
	Oat*	39.3	96.6	3.4	0	0	0	0	–	0.67
	Barley	206.6	0	3.1	40.3	0	0	56.0	0	13.0
65	Wheat	65.3	0	0	32.6	0	28.5	38.8	11.3	81.3
	Oat*	17.3	84.6	0	0	0	0	15.4	0	0.33
	Barley	38.7	0	0	33.3	0	22.2	44.4	0	34.0
77	Wheat	22	0	0	0	0	0	0	25.5	42.0
	Oat*	0	0	0	0	0	0	0	0	5.0
	Barley	51.7	0	0	12.0	0	48.5	39.5	2	20.0
89	Wheat	0	0	0	0	0	0	0	38.5	3.0
	Oat*	0	0	0	0	0	0	0	0	1.0
	Barley	32	0	0	0	0	62.5	37.5	2	4.5
105	Wheat	0	0	0	0	0	0	0	30	0
	Oat*	0	0	0	0	0	0	0	0	0
	Barley	4	0	0	0	0	100	0	2.5	0

C.D. at 5% for total root population 21 and 28 days after inoculation = 41.3 and 72.3, respectively.

NOTE: i) moulting specimens included in next stage; ii) *No. of developmental stages do not reflect real number as many of them degenerate at J_2; iii) All the males are normal.

Compared with oat cv. Kent emigration of J_2 started earlier, i.e. from 28 days onwards, in wheat C 306 and barley C 164. Infected root portions of both wheat and barley were distinctly swollen/galled, bore lateral branches and had soil particles adhering. Further development and sex ratio was almost at par in the two cereals up to 46 days (ignoring 28th day after inoculation when the sex of a large proportion of J_2/J_3 could not be ascertained). Rate of further nematode development also remained similar in wheat and barley (Table II).

Males produced started leaving the roots 53 days after inoculation and could be collected from the soil. These males were not very long-lived as only a few were encountered at 77 days after inoculation. As with those formed on oat cv. Kent roots, all the males were normal in having one testis only.

There was also little difference in the rate and number of female juveniles that developed to become adults in wheat C 306 and barley C 164. This partly agrees with the observations of Gokte and Swarup (1984) on barley cv. Rajkiran and Ratna. Nevertheless, J_4 females produced on barley C 164 were distinctly smaller (142.2 (82-185) µm) than those produced on wheat C 306 (202.1 (143-311) µm). Adult females developed in barley C 164, remained inside the roots and failed to rupture the root cortex and protrude from the roots due to their small size (Table III). Such females naturally could not copulate and lay viable egs. The inability of females to rupture the cortex has also been as a reason for the resistance of maize to *H. avenae* (Johnson and Fushtey, 1966). The small size of females was also ultimately reflected in egg content (48 eggs per cyst on barley vs. 435 eggs per cyst on wheat C 306) of the cysts recovered from the soil. The inability of females to protrude from roots, together with the short life span of the males accounts for the change in sex ratio in roots, soil and in totality as compared to susceptible wheat C 306. Thus the sex ratio will vary with time and therefore, the time of observation should be mentioned when presenting results of sex ratios. Sex ratio as reported by Bhatti *et al.* (1976) was perhaps based on the data recorded from soil during the mid-season of the crop when most of the females were inside the roots of resistant barley cultivars, C 164, BP 263 and BP 264.

The above results indicate that different mechanisms of resistance operate in oat cv. Kent and barley cv. C 164; With oat cv. Kent, expression of resistance is earlier and development is arrested at J_2 except for a few which develop into males. Cook and Mizen (1991) reported that *H. avenae* resistant oat cultivars affected the establishment, rate of development

TABLE III - *Width of cysts and white females of* H. avenae *biotype 31 formed on susceptible wheat C 306 and resistant barley C 164.*

Crop	Cyst* from soil (µm)	White female** from root (µm)
Wheat C 306	536.1 (401-591)	356.8 (254-409)
Barley C 164	314.2 (155-467)	213.3 (183-254)
t	7.319	3.39
df	20	9
p at 0.5%	3.15	3.69

* 105 and ** 77 days after inoculation, respectively.

within roots and also the proportion of established nematodes that become females. Nevertheless, contrary to our results with oat cv. Kent, some development occurred in all the resistant cultivars (Welson, Silva, Buck 212 and Avon) that they tested. These differences in the expression of resistance in oat indicate that more than one gene, operating at different times of development, may account for resistance in oats. Unfortunately, the genetics of resistance in oats is not fully known (Cook and York, 1982). In barley C 164 development of nematode, formation of syncytium and its maintenance is apparently normal. Similar results have also been recorded for other barley resistant cultivars (Rajkiran, Ratna) and the resistance as expressed on the basis of suppression of nematode reproduction (determined by number of egg laying females) results from the inability of young females to grow further and protrude out of the roots. Since syncytium is maintained throughout the nematode development such resistant barley cultivars are as vulnerable to nematode damage as are susceptible ones and not much differences in yield can be expected in the first year. However, due to the reduction of inoculum in the field (cyst population and their egg contents), crops of resistant or susceptible cultivars are likely to suffer less in the following years.

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