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INVESTIGATIONS ON *HETERODERA AVENAE* IN ITALY[1]

by
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The cereal cyst nematode *Heterodera avenae* Woll. has been reported to cause severe yield losses of wheat (*Triticum* spp.), barley (*Hordeum vulgare* L.) and oats (*Avena sativa* L.) in Europe (Mezzetti, 1953; Dixon, 1969; Stone, 1968; Andersson, 1982), Australia (Meagher and Brown, 1974; Meagher, 1982; Brown, 1984) and elsewhere, thus stimulating research on the biology and control of the nematode.

Heterodera avenae has been shown to complete only one generation in a growing season of the host plant (Kerry and Hague, 1974). However, hatching behaviour of populations from different climatic conditions may greatly differ. In Canada (Fushtey and Johnson, 1966), a substantial hatch occurred only when cysts were kept at 7°C for 8 weeks, but populations of the nematode from Australia (Banyer and Fisher, 1971), and Italy (Greco, 1981) did not require cold pretreatment to hatch. In France, Rivoal (1982) found that populations of the nematode from the north mostly hatched in spring, while populations from the south hatched in winter. The reproduction of the nematode may be greatly affected by soil fungi parasitizing females and eggs, thus preventing increases of the nematode populations despite continuous cropping with cereals (Gair *et al.*, 1969; Kerry *et al.*, 1982a, 1982b).

The extent of damage caused by *H. avenae* may vary from field to field.

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A decrease of damage to cereals when sowing these crops continuously on the same land infested with *H. avenae* was reported by Collingwood (cited in Kerry *et al.*, 1982a). Meagher and Brown (1974) reported a negative correlation between nematode density and wheat yield with a tolerance limit of 0.3 eggs per g soil. There is no information on yield losses caused by the nematode to wheat in Italy. Therefore investigations were undertaken on the relation between population densities of *H. avenae* and yield of hard wheat (*Triticum durum* Desf.) and the survival of the nematode in the absence of a host.

Materials and Methods

In September 1984 cysts were extracted, using a large can (Caswell *et al.*, 1985) from a field at Gravina di Puglia (province of Bari), in which wheat had been severely damaged by *H. avenae* in the previous growing season. Cysts and debris were dried in the shade and mixed with 40 kg of steam sterilized soil. Cysts were extracted from 10 subsamples of 10 g each of this mixture and crushed to estimate the egg content. Appropriate amounts of the mixture were then thoroughly and separately mixed with the soil in microplots to give a range of population densities of 0.0, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, and 64 eggs/g of soil. Bottomless concrete tubes of 30×30×50 cm, were sunk into the soil up to 5 cm from their top and used as microplots at Bari. Each was filled with 36 dm^3 of soil (sand 49.2%; silt 15.8%; clay 35%; O.M. 2.4%) from a field in which no cereals had been grown during the last 5 years. The microplots were arranged in a random block with seven replicates at each population level. To each microplot 15 g of N-P (7-20) were applied and 2 g of hard wheat cv. Appulo were sown per microplot on 13 December 1984. During the experiment nitrogen fertilizer (5 g/microplot) was applied in mid February and at the end of March 1985. At harvest straw and grain yield of each microplot were recorded.

A soil sample, composed of 24 cores, was collected from each microplot using a 2.5 cm wide, 30 cm long auger. Cysts were extracted with the Fenwick can from a 200 g dried subsample, separated from debris by the Seinhorst's (1974) ethanol method and crushed according to Bijloo's modified method (Seinhorst and Den Ouden, 1966) to estimate the egg content.

Microplots were sampled again in December to measure the nematode population densities before sowing the next crop. Fertilizer was applied, the plots were dug and cv. Appulo sown on 5 December. Because nematode reproduction varied in 1985 the numbers of microplots per inoculum level were different in 1986 and were larger at 0-0.5 egg/g soil (Tabel I). Nitrogen fertilizer was applied in February and March. The crop was maintained free of weeds and irrigated only when there was little rainfall. Soil temperature at 20 cm depth was recorded during the experiment.

To ascertain the decline of *H. avenae* in the absence of a host, nematode density was determined in 1.5 kg soil samples from each of four microplots harvested in June 1985. Samples were collected monthly between 22 August and 7 July 1986, with the exception of April and June 1986. Also at each sampling date a hatching test was started with cysts from the soil samples. Batches of 100 cysts per sample were incubated (Greco *et al.*, 1982a) for four weeks at 20°C in tap water; water was renewed weekly. Emerging juveniles were counted and at the end of the hatching test cysts were crushed, their egg content determined and hatching percentages calculated.

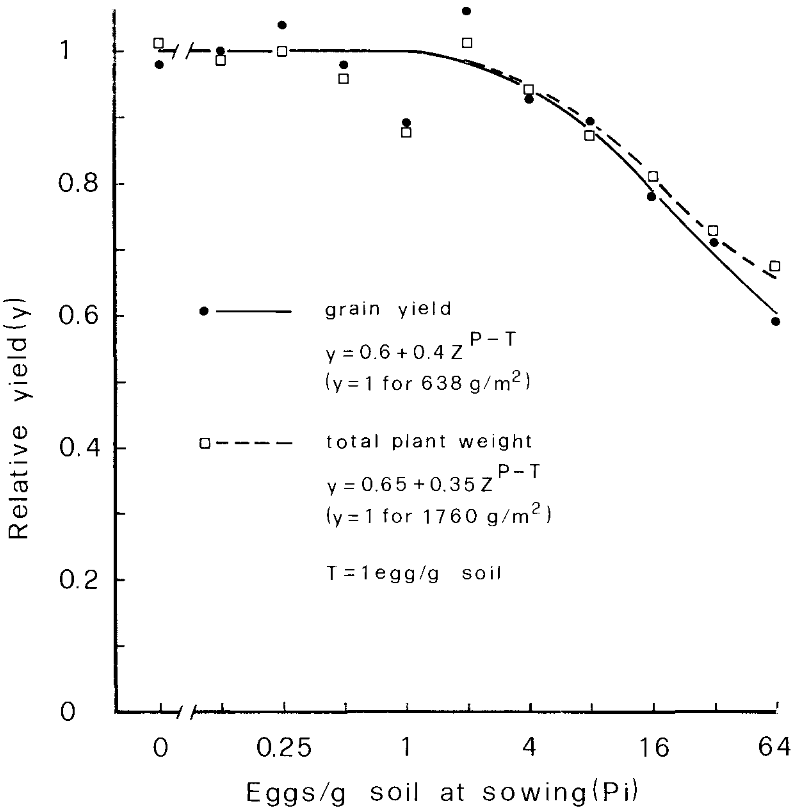

Fig. 1 - Relationship between population densities of *Heterodera avenae* and yield of hard wheat in 1985.

Results

In early January 1985, soil temperature at 20 cm depth was exceptionally low for the area (1 °C), compared with the average winter temperature (8-10°C), but the air temperature rose to 36°C on April 10, which might have adversely affected the nematode. Symptoms of nematode attack (yellowing and stunting) were evident in February and March 1985, but rarely evident thereafter. Data of grain yields in 1985 fitted to the equation $y = m + (1\text{-}m)z^{P \cdot T}$ proposed by Seinhorst (1986), with a tolerance limit (T) of 1 egg/g soil (Fig. 1) and minimum yields (m) of 0.60 and 0.65 for grain yield and above ground parts of the plants, respectively. In 1986 yields varied but there were no significant differences in yields between small and large nematode densities (Table I).

Table I - *Effect of population densities of* Heterodera avenae *on the yield of hard wheat grown in microplots in 1986.*

Egg/g soil at sowing	Number of microplots	Yield (g/microplot)	
		Grain + Straw	Grain
0 - 0.5	37	173.4	67.2
0.5 - 1	4	165.5	61.1
1 - 2	6	173.7	69.1
2 - 4	3	161.0	63.2
4 - 6	3	161.7	60.8
6 - 8	1	113.0	37.0
8 - 10	3	180.3	70.7
10 - 12	2	150.5	59.7
12 - 14	7	143.6	56.8
16 - 18	2	196.5	77.5
18 - 20	1	136.0	57.5
20 - 22	3	119.7	44.5
22 - 24	2	127.0	46.5
24 - 26	3	163.7	66.5
26 - 28	1	239.0	99.0
30 - 32	2	208.5	82.5
32 - 34	1	180.0	67.5
40 - 42	1	166.0	65.0

The relationship between nematode population density before sowing (*Pi*) and after harvest (*Pf*) is adequately fitted by the equation $Pf = axy({}^{e}logq)^{-1}(1 - q^{Pi}) + (1 - x)Pi + sx(1 - y)Pi$ (Seinhorst, 1970), especially for the first year of the investigation (Fig. 2). In the second year, final populations of *H. avenae* were smaller and more variable. However by fitting the equation to the data, maximum reproduction rates (*Pf*/*Pi*) of 5.6 and 3.4, at the lowest initial density, were derived for 1985 and 1986, respectively. The equilibrium density was estimated to be 40 eggs/g soil in 1985 and 36 eggs/g soil in 1986. In the absence of the host the population of *H. avenae* at harvest was 26% and 12% of that at sowing in 1985 and 1986, respectively.

The population of the cereal cyst nematode seems to have remained rather constant during the summer. However, a sharp and continuous

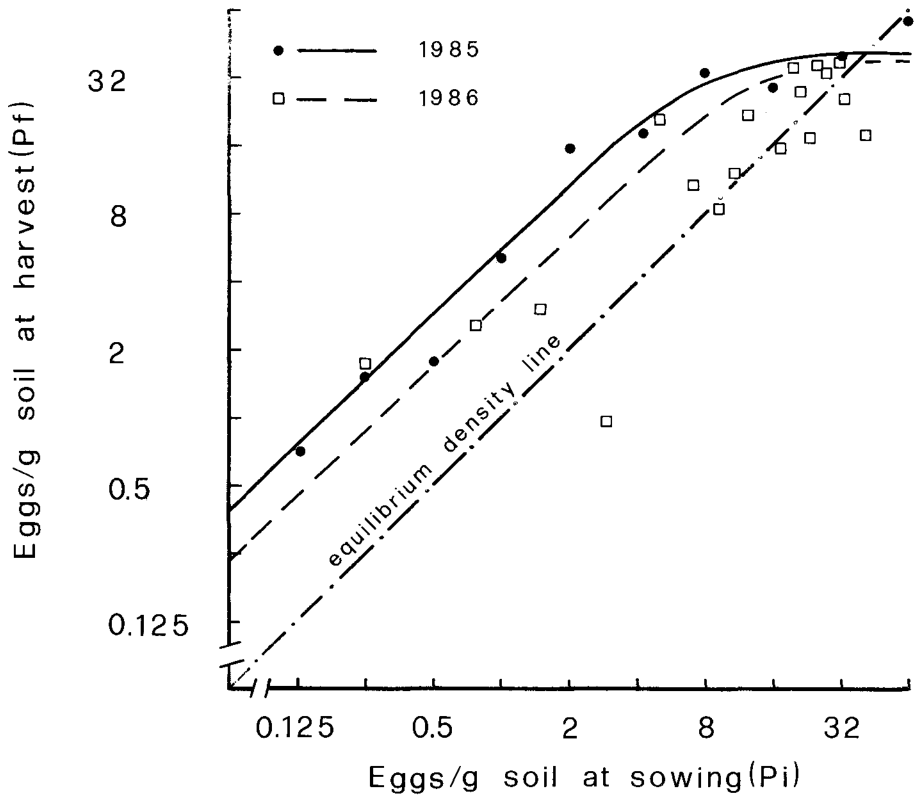

Fig. 2 - Relationship between initial (*Pi*) and final (*Pf*) population densities of *Heterodera avenae* in 1985 and 1986.

decline of the egg population of the nematode started in late October (Fig. 3) after the first rain occurred and the soil temperature dropped to 15°C. The nematode soil population density by mid December was 50% and that in early March 8% of that in August.

Hatching of eggs in the laboratory tests was greatly affected by soil conditions at the time the cysts were collected. Less than 1% of the eggs hatched from cysts collected in August and September 1985 when the soil temperature at 20 cm depth was 22-30°C and the average soil moisture content 7%. By mid October rains occurred, the soil temperature dropped to 15°C, and cysts collected on 21 October gave 9.8% hatch after 4 weeks of incubation. Thereafter the percent hatch up to early March was 50%, except in February when only 33% of the eggs hatched (Fig. 4). Few juveniles emerged from cysts collected later, following a rise in soil temperature and reduction of soil moisture content. Most of the juveniles emerged from cysts collected from October to March, during the first week of incubation.

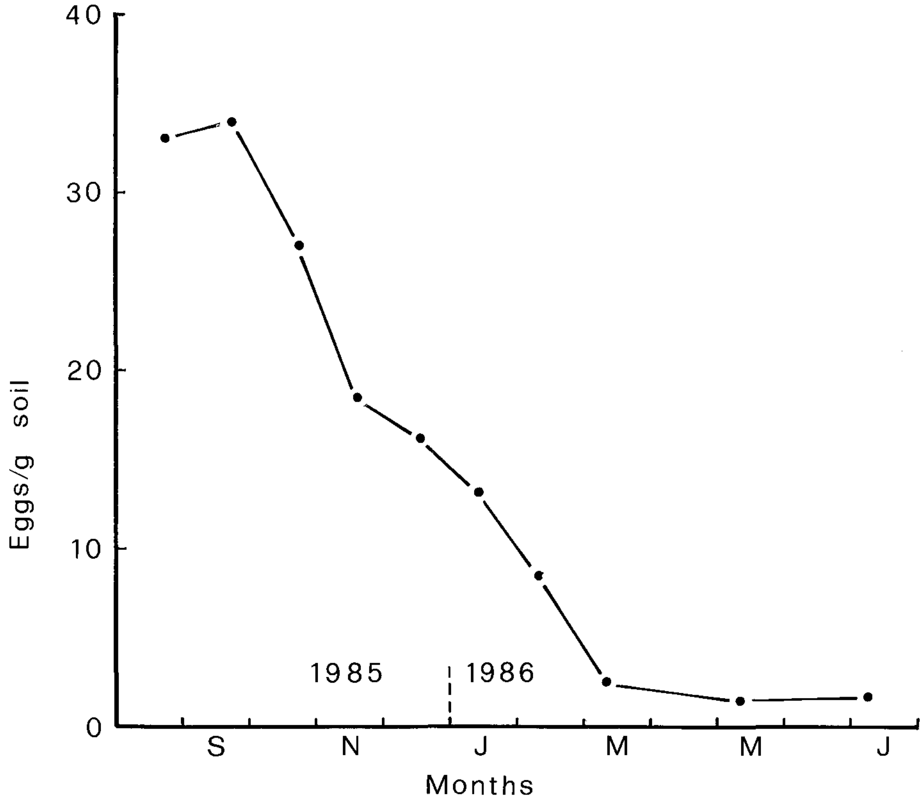

Fig. 3 - Decline of *Heterodera avenae* population in the absence of host from August 1985 until July 1986.

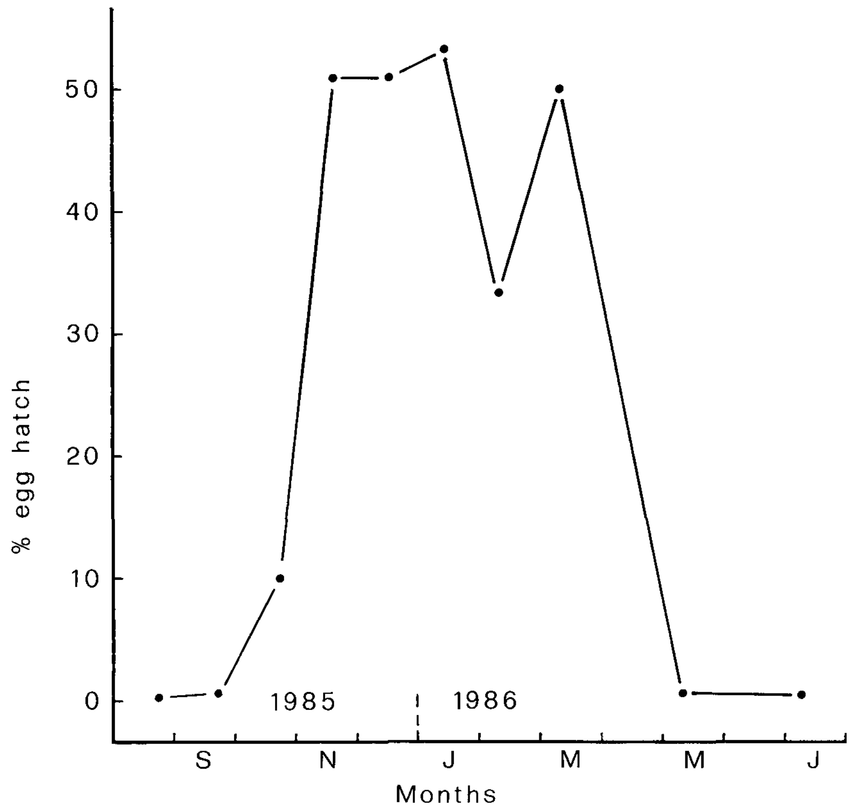

Fig. 4 - Hatching of eggs in cysts of *Heterodera avenae* collected monthly from August 1985 until July 1986 and incubated in tap water for four weeks at 20°C.

Discussion and Conclusions

The tolerance limit of hard wheat to *H. avenae* obtained in 1985 is the same as that reported for oats (Andersen, 1961 cited in Andersson, 1982) but higher than 0.3/g soil reported for wheat (Meagher and Brown, 1974). Resowing wheat in the same microplots did not result in clear symptoms of nematode attack nor in consistent differences in yield between microplots with small and large nematode soil population densities at sowing. However, data of yield obtained in 1986 were hard to explain.

The rate of reproduction of *H. avenae* in 1985 was much less than that of other cyst forming nematodes in the same area (Greco and Brandonisio, 1980; Greco *et al.*, 1981; Greco *et al.*, 1982b). However, Andersson (1982) stated that reproduction rates of *H. avenae* are very often < 10 compared to the maximum of 5.6 and 3.4 estimated in our experiments in 1985 and 1986, respectively (Fig. 2). Low population changes have also been reported in Australia (Meagher and Brown, 1974).

Greco (1981) found that some juveniles emerged from newly formed cysts of *H. avenae* and that no cool pretreatment was necessary for a substantial hatch to occur. The hatching study undertaken in 1985 clearly showed that reduction in soil moisture content and increase in soil temperature, usually occurring in summer, induce egg dormancy since < 1% of the eggs hatched throughout September. Moreover, not particularly low temperatures were required to stimulate hatching, and many juveniles emerged from cysts following rainfall and the drop of the soil temperature to 15°C. Autumn and winter hatch of the eggs is responsible for the strong decline of the nematode soil population in the same period. Therefore sowing cereals as late as possible may avoid damage caused by the nematode.

In southern Italy cereals are continuously or intensively cultivated on the same land in many areas. Nevertheless even though *H. avenae* was found in 37% of fields which had patches of stunted cereals (Inserra *et al.*, 1978), samples taken at the time of sowing of wheat revealed that soil populations of the nematode rarely exceeded the tolerance limit for the crop (Greco, unpublished).

We think that the soil type, which very often contains more than 35% of clay, and environmental conditions in southern Italy are responsible for maintaining the nematode populations at very low levels and therefore for the apparent absence of damage. Without crop rotation there is only a 50% reduction in population density between harvest and sowing of the next crop and only some 25% between very earliest and latest sowing date. However, growing a non host crop every two-three years would largely eliminate any danger of crop loss.

SUMMARY

Microplots (30x30x50 cm) were inoculated at Bari with 0, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32 and 64 eggs of *Heterodera avenae* Woll./g soil and sown with hard wheat in 1984 and again in 1985, to investigate the relationship between population density of the nematode and yield of wheat. Some of the microplots were used in 1985-1986 to investigate the decline of *H. avenae* populations and the hatching of the nematode throughout the year, under southern Italian climatic conditions. The nematode affected the yield in 1985 when a tolerance limit of wheat to the cereal cyst nematode of 1 egg/g soil and minimum relative yield of 0.60 and 0.65 for weight of grain and above ground parts of the plant were estimated. Apparently no

damage was caused by the nematode in 1986. Maximum reproduction rates of *H. avenae* of 5.6 and 3.4 and equilibrium densities of 40 and 36 eggs/g soil were obtained in 1985 and 1986, respectively. In the absence of a host, populations did not decline during summer but then by about 40% between September and November and by about 90% between September and March. Almost no eggs hatched in late spring and in summer, but about 50% of the eggs hatched from the second half of October through to March.

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