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CONTROL OF *HETERODERA CICERI* BY CROP ROTATION

by
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Summary. A field experiment in Syria in 1986-1991 tested the efficacy of six four-year crop rotations for the control of *Heterodera ciceri* on chickpea and grasspea. Crop sequences included cultivation of non-host crops (barley and wheat) for 0, 1, 2 or 3 consecutive years. The soil populations of the nematode remained at high levels in plots planted with host crops every year or every other year (max 63 eggs/g soil), but declined to 43-63% and 12-16% when non-host crops were cultivated for 1 or 2-3 consecutive years, respectively. The nematode reproduction rate decreased as the soil population of the nematode increased and was 17 at 2 eggs/g soil and 3 at 14 eggs/g soil. Biological and grain yields of grasspea increased 1.1 and 2.6 times, respectively, when no host plant was cultivated for 2 consecutive years. Chickpea was destroyed by frost in March 1990; hence it was resown in the next season. The chickpea seed yields increased by 2.1, 4.5 and 7.9 times in plots in which non-host crops had been cultivated for 1, 2 or 3 consecutive years, respectively.

Chickpea (*Cicer arietinum* L.) is an important pulse crop in Syria and several pests and diseases cause yield reduction. Among them the chickpea cyst nematode, *Heterodera ciceri* Vovlas, Greco *et* Di Vito, has been reported to cause severe damage to chickpea and lentil (*Lens culinaris* Medic.) in the north of the country (Greco *et al.*, 1984; Vovlas *et al.*, 1985). Although nematicides and soil solarization may provide satisfactory control of *H. ciceri* (Di Vito *et al.*, 1991) they are not economically feasible in the marginal lands where chickpea is mostly cultivated. No chickpea cultivar resistant to the nematode is available so far but like other cyst forming nematodes it has a rather narrow host range, *H. ciceri* reproducing well only on chickpea, lentil, pea (*Pisum sativum* L.) and grasspea (*Lathyrus sativus* L.) (Greco *et al.*, 1986). This suggests suitable crop rotations could be used to control the nematode. A field trial in Syria in 1986-1991 tested the effect of six crop sequences on the dynamics of *H. ciceri* and on the yield of chickpea and grasspea.

Materials and methods

The trial was undertaken in a field that had been cultivated with lentil the previous year and infested with *H. ciceri* (13 eggs/g soil) at the main station (Tel Hadya, Aleppo, Syria) of the International Center for Agricultural Research in the Dry Areas (ICARDA) in 1986. After harvest of the previous season crop 50 kg P_2O_5/ha were applied and the field rotovated before sowing new crop. The trial consisted of 30 plots of 60 m^2 (10 x 6 m) each, to accomodate six four-year crop rotations with five replications in a randomized complete-block design.

The six four-year crop sequences are listed in Table I. There were 13 rows of chickpea in each plot spaced 45 cm apart, and 20 of grasspea and lentil spaced 30 cm apart per plot. Cereals, lentil and grasspea were sown in mid November and winter chickpea in mid December. All crops were rainfed and grown following the agronomic practices recommended for the area. Weeding was done by hand twice in every growing season. Harvest was done in May for grasspea and lentil and June for chickpea, barley (*Hordeum vulgare* L.) and wheat (*Triticum durum* Desf.). Biological and grain yields were determined for each crop. Harvest index was also calculated. Symptoms of nematode attack (yellowing and growth reduction) were scored on a 1-9 scale, on 30 April 1991.

A 2 kg soil sample, composed of 40 cores 1.5 cm in diameter and 30 cm deep, was collected from each plot before sowing and after harvest every year. Each sample was air dried and 200 g soil were processed by the Fenwick can to extract the nematode cysts. These were separated from soil debris by the alcohol floatation method (Seinhorst, 1974), in which ethanol was substituted by a 1.25 sp.g. magnesium sulphate solution. The cysts were counted and then crushed to determine their egg content (Seinhorst and Den Ouden, 1966).

Results and discussion

Environmental conditions were suitable for nematode development and plant growth during the first three years of the trial. An exceptional frost occurred in mid March of the fourth year (1990) when the air temperature dropped to -7 to -8.5 °C during three consecutive nights, completely killing chickpea, but with grasspea recovering. Although some nematode reproduction occurred in the chickpea

TABLE I - *Crop sequences for the control of chickpea cyst nematode,* Heterodera ciceri

Rotation (1)	Crop sequences (2)				
	1986/87	1987/88	1988/89	1989/90	1990/91
L - C - L - C	Lentil +	Chickpea +	Lentil +	Chickpea +	Chickpea +
W - C - W - C	Wheat*	Chickpea +	Wheat*	Chickpea +	Chickpea +
C - W - B - C	Chickpea +	Wheat*	Barley*	Chickpea +	Chickpea +
W - B - W - C	Wheat*	Barley*	Wheat*	Chickpea +	Chickpea +
La - C - L - La	Lathyrus +	Chickpea +	Lentil +	Lathyrus +	Chickpea +
La - W - B - La	Lathyrus +	Wheat*	Barley*	Lathyrus +	Chickpea +

(1) L = Lentil (cv. ILL 4401); C = Chickpea (cv. Ghab 1 except in 1990/91 when it was cv. Ghab 3); W = Wheat (cv. Sham 1); B = Barley (cv. Arabi Abyad); La = Lathyrus (cv. Acc. no. 439).
(2) + = Host; * = Non host.

TABLE II - *Effect of six crop rotations on plant visual damage score and yield of chickpea during the 1990-91 cropping season in a field infested with* Heterodera ciceri *in Syria*

Crop rotation*	Visual score (1-9)**	Biological yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
L - C - L - C	5.0	507.6	22.4	485.8	4.60
W - C - W - C	4.8	616.8	46.6	570.2	6.92
C - W - B - C	3.4	914.0	101.4	812.6	11.82
W - B - W - C	2.0	723.0	177.4	545.6	20.42
La - C - L - La	8.2	389.2	4.6	384.6	0.91
La - W - B - La	5.8	641.8	52.4	589.4	5.16
LSD (P = 0.05)	1.8	363.2	109.6	289.1	11.25

* L = Lentil; C = Chickpea; W = Wheat; B = Barley; La = Lathyrus.
** 1 = free from damage; and 9 = severe damages.

plots, all the plots were resown in mid December, 1990 and harvested the following June.

The soil population of the nematode declined by 57 - 37% after one year of cultivation with non-host crops (Fig. 1) and by 84 - 88% when host crops were absent for 2 or 3 consecutive years. However, after cultivation of chickpea, grasspea and lentil the nematode population increased sharply and remained at a high level in plots planted to these crops every year or every other year. Maximum nematode density was 63 eggs/g soil, at which level the yield of chickpea would be zero (Greco *et al.*, 1988). In November 1989, before sowing chickpea, the nematode population in the plots that had been planted to non-host crops for 2 or 3 consecutive years was 2.5 - 3.7 eggs/g soil, which is significantly (P = 0.01) less than in the other crop sequences (Fig. 1). In July, 1991 after growing chickpea in all plots the nematode soil population, although variable, was very high (54 - 78 eggs/g soil) in plots planted to grasspea the previous year and in those in which chickpea and lentil had been cultivated every year or every other year and lower but still high (21 - 31 eggs/g soil) in the rotation when a host crop was grown in a 3 and 4 year cycle. The reproduction rate of the nematode was related to the nematode population density before planting the host crops; it was 17 at 2 eggs/g soil and only 3 at 14 eggs/g soil.

The annual decline of *H. ciceri* in this experiment is similar to that observed with pea cyst nematode, *H. goettingiana* Liebscher, in the Mediterranean region (Di Vito and Greco, 1986) and to many other cyst forming nematodes.

The visual damage score of chickpea in 1991 was high in the plots planted to host plants every year (5 - 8.2), but decreased as increased the number of years with a non-host, and was only 2 in the four year crop rotation.

Although biological yield of grasspea in 1989-90 did not differ between plots planted continuously to host crops

(La - C - L - La) or every 3 years (La - W - B - La) but grain yield in the latter rotation was 2.6 times that of the first crop sequence.

No yield of chickpea was obtained during the 1989-90 season because of frost damage and thus the effect of crop rotation for the control of *H. ciceri* cannot be assessed. However, Greco *et al.* (1988), derived curves relating soil densities of the nematode to yield of chickpea and lentil. Based on these findings and on the soil population of *H. ciceri* occurring in the plots at sowing in the fourth year, the expected yield loss of chickpea would have been about 60% in the plots planted continuously or every other year with a host crop and only 5% when a 3 or 4 year crop rotation was used. Cultivation of chickpea again in the 1990-91 season showed that biological yield in the 2, 3, and 4 year term rotation was 1.2, 1.8 and 1.4 times that obtained when a host crop was grown every year (Table II). The yield levels were low because of low rainfall (293 mm as against a long term of 324 mm).

The harvest index increased as the time gap between host crops increased (Table II) indicating a better grain yield performance of chickpea plants when nematode population densities are low. In heavily infested soils, chickpea plants may not show symptoms of nematode attack at a early stage of development, but may greatly suffer from nematode attack later, thus leading to poor flowering and yield.

Seinhorst (1965; 1986) demonstrated that the relation between nematode density at sowing and yield of the host plant is described by equation $y = m + (1 - m)\, z^{P-T}$ where y = relative yield, the ratio between the yield at P and that at $P \leqslant T$; P = the nematode population at sowing (here expressed as eggs/g soil); T = tolerance limit, the nematode soil population below which no yield loss occur; m = the minimum relative yield = y at very high P; and z a costant with z^{-T} = 1.05. Although chickpea yields in June 1991 in plots with similar nematode densities before sowing were rather variable, fitting the above model to chickpea yield data (Fig. 2) gave a tolerance limit for the crop to the nematode of 0.9 egg/g soil, close to that of 1 egg/g soil reported earlier (Greco *et al.*, 1988) and thus confirming the high pathogenicity of *H. ciceri* to chickpea.

In conclusion, this investigation has demonstrated that crop rotation can be used to reduce soil population densities of *H. ciceri* to non-damaging levels for host plants such as chickpea and grasspea, which are common in Syria. However, the suggested rotation would limit the cultivation of host crops to every 3 - 4 years. Cultivation of the hosts continuously or every other year will result in high nematode soil population densities and severe yield loss.

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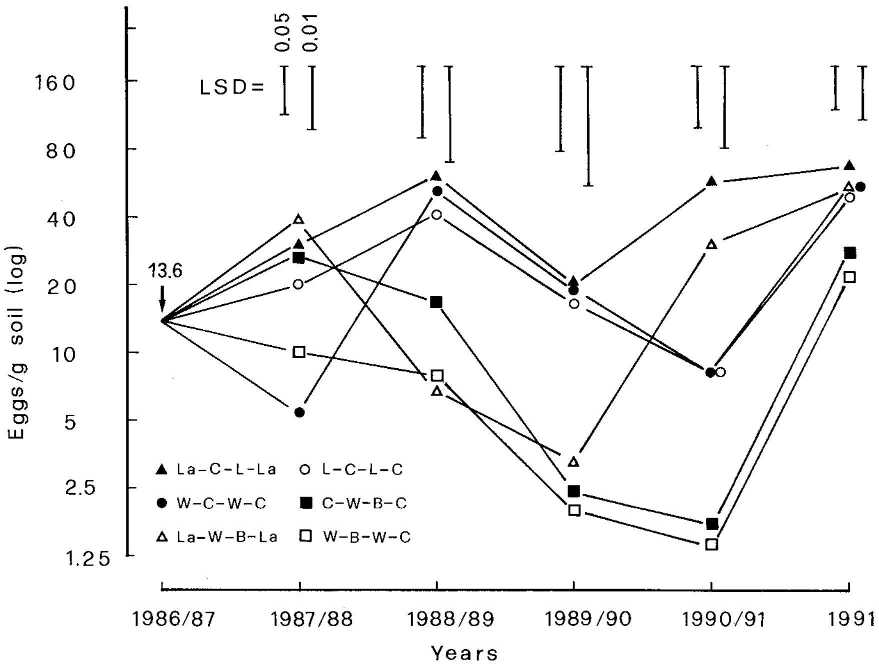

Fig. 1 - Effect of six crop sequences on population dynamics of *Heterodera ciceri* in Syria, in 1986-1991.

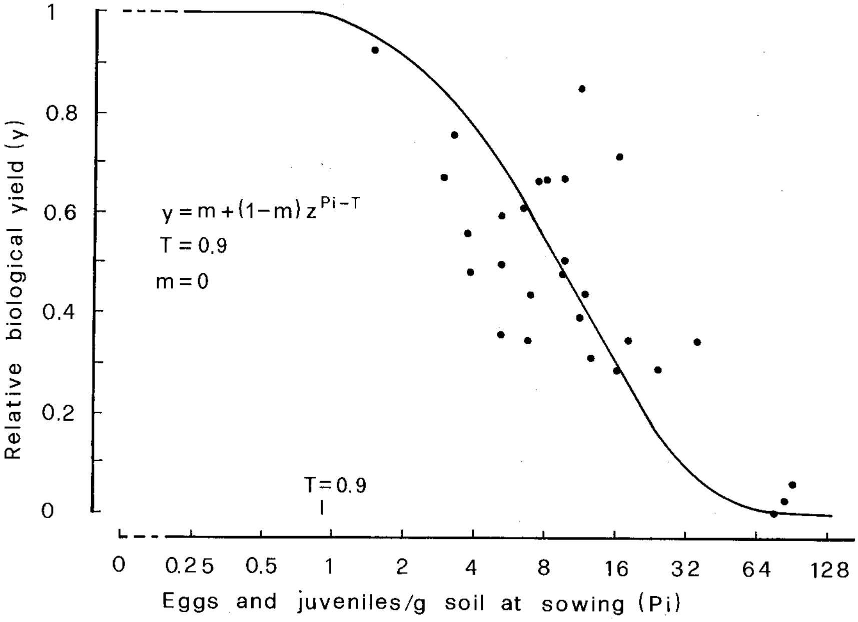

Fig. 2 - Relationship between initial population densities of *Heterodera ciceri* (*Pi*) at sowing (December 1990) and relative biological yield (*y*) of chickpea at harvest (June 1991) in Syria. Each point is the value of a single plot.

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