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The effect of potato trap crops and fallow on decline of *Globodera rostochiensis*

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SUMMARY

The effects of 1 to 6 wk growth of resistant and susceptible potato cultivars on *Globodera rostochiensis* population decline were studied in pot and microplot experiments. In pot experiments, potato plants were hand pulled or killed with glyphosate herbicide at weekly intervals for 4 or 6 wk after shoot emergence. In microplot experiments, potato plants were killed with glyphosate herbicide weekly for 4 wk after shoot emergence. After 4 wk the number of viable eggs had declined more in pots where potato plants were grown (66–87%) than in pots of fallow soil (35%). Although decline in numbers of viable eggs under resistant and susceptible cultivars did not differ significantly, there was a trend towards greater decline under resistant plants. Duration of plant growth was positively correlated with decline in viable eggs when plants were killed with glyphosate but not when they were hand pulled. However, in microplot experiments using glyphosate, decline in viable eggs after 1 wk of potato plant growth (55%) was not different from that after 4 wk (57%). Numbers of viable eggs in fallow soil declined less 5 cm deep (34%) than 15 cm deep (50%). All of the viable eggs contained in cysts on the soil surface died within 5 months, probably due to high temperature.

INTRODUCTION

Potato root diffusates from both resistant and susceptible potato cultivars stimulate juveniles of the potato cyst nematode *Globodera rostochiensis* (Wollenweber) Behrens Race 1 (Ro1 or R1A) to hatch and emerge from cysts (Jones, 1966). This phenomenon has been exploited by using potatoes as a trap crop to reduce nematode numbers in soil (Mugniery & Balandras, 1984; Brodie, 1982; Whitehead, 1977). Duration of potato plant growth is positively correlated with decrease in nematode numbers for up to 6 wk after planting (Whitehead, 1977), but most juvenile invasion occurs within the first 3 wk (Brodie, 1982). The timing of destruction or removal of susceptible cultivars of potatoes grown as trap crops is critical, to ensure that nematode numbers do not increase. Resistant cutivars are as effective as susceptible cultivars in inducing hatch of juveniles (Brodie, 1982), and the timing of their destruction or removal when used as trap crops would be much less critical because they allow little or no reproduction. Populations of *G. rostochiensis* decline more rapidly from high than from low densities on both resistant and susceptible cultivars (LaMondia, 1984; Seinhorst, 1984). It is not known how this positive correlation between density and population decrease would affect the control achieved by trap cropping at different nematode densities.

Decline in numbers of viable encysted juveniles under non-host crops or fallow appears to be density independent. The rate of decline is generally 30–40% (Cooper, 1954; Huijsman, 1961; Storey, 1984), with some reports of up to 60% reduction in the first year after a potato crop; however 25% of the initial population can still remain after 4 yr (Cole & Howard, 1962).

The experiments reported here were performed to determine 1) the relationship between population decline and duration of potato plant growth, 2) the effect of soil type and initial population density on population decline rate, and 3) the rate of decline in numbers of encysted juveniles at different depths in fallow soil.

MATERIALS AND METHODS

Pot experiments were performed in a greenhouse (22–28°C) using clay pots of 7·6 cm diam. The pots were filled with a soil mixture consisting of 1 part sand:1 part recycled compost. Thirty cysts of *Globodera rostochiensis* of known viable egg contents were thoroughly mixed with the soil in each pot. The pots were planted with the resistant cultivar Hudson, the susceptible cultivar Katahdin, or left fallow. After the desired duration of growth, the plants were either hand pulled or killed with 2% glyphosate herbicide. At the end of the experiments, cysts were extracted from all pots by Fenwick can and their viable contents were determined.

Microplot experiments were performed in fibreglass microplots (0·9 m diam. and 1·2 m deep) containing soil naturally infested with *G. rostochiensis*. Of 100 microplots, 40 contained silt loam soil, 30 contained clay soil, and 30 contained organic (muck) soil. Before the experiment, soil in each plot was completely mixed to a depth of at least 20 cm and ten 50 ml soil samples were taken and bulked. A USDA cyst extractor (a modified Fenwick can; Spears, 1968), was used to process a 250 ml subsample from each plot. The cysts were separated from debris in the extract using acetone in a modification of a technique developed by Brodie, Blow, Brace & King (1976) and the numbers of viable juveniles per ml of soil determined. Three tubers of the resistant cultivar Hudson were planted in each microplot; 10:20:20 (N:P:K) compound fertiliser was applied at a rate equivalent to 168 kg/ha. Potato plants were killed with glyphosate 1, 2, 3 or 4 wk after shoot emergence. At the end of the experiment the soil was mixed, sampled, and processed as before to determine the number of viable juveniles per ml of soil. Microplots were grouped into three classes based on initial population density to test the effect of density on population decline. Initial nematode densities in the silt loam plots ranged from 8·0 to 186·0 eggs per ml of soil with a mean of 57·8. Plots were grouped in classes of 0–30, 30–60 and greater than 60 eggs per ml of soil with 13 microplots per class. Initial densities in the organic soil plots ranged from 3·8 to 45·1 eggs per ml of soil, with a mean of 16·1. The mean initial density in the clay soil was 25·6 eggs per ml of soil, with a range of 5·2 to 65·2 eggs per ml. Plots were grouped into classes of 0–10, 10–20 and greater than 20 eggs per ml of soil for the organic soil and 0–20, 20–30 and greater than 30 eggs per ml of soil for the clay soil. There were 10 plots per class for each of these two soil types.

To measure the rate of decline of population density under bare fallow at different soil depths, 40 batches of 50 newly produced cysts were enclosed in 1·5 cm square nylon bags and buried 5 and 15 cm deep or placed on the surface of clay loam soil during June, 1982. To reduce variation, these cysts were of uniform size and age (produced in 1982, sieved to 0·25–0·35 mm). Initial numbers of viable juveniles per cyst were determined by crushing five batches of 50 cysts each and counting the juveniles released. At intervals after the bags were buried, two bags from each depth were removed and five batches of 20 cysts each were crushed to determine viable juveniles/cyst. The plots in which bags were buried were kept free of plant growth by repeated applications of glyphosate herbicide.

Table 1. *The effect of duration of resistant potato plant growth and method of plant destruction on the decline in numbers of viable eggs/cyst of* Globodera rostochiensis

Time after plant emergence (wk)	Method of plant destruction	Viable eggs/cyst	% decline
0	Hand pulled	38 ab†	75
1	Hand pulled	22 ab	85
2	Hand pulled	11 a	92
3	Hand pulled	46 bc	68
4	Hand pulled	20 ab	87
0	Herbicide*	105 d	29
1	Herbicide	52 bc	65
2	Herbicide	36 ab	76
3	Herbicide	33 ab	78
4	Herbicide	52 abc	66
Control (fallow)‡		96 d	35

* 2% glyphosate.
† Numbers followed by same letters are not significantly different ($P = 0{\cdot}01$) (AOV: Duncan's MRT).
‡ Fallowed for 5 wk with herbicide applied to soil surface after 1 wk.

RESULTS

In the first pot experiments, decline in *Globodera rostochiensis* population density was significantly greater in pots where the resistant cultivar Hudson was grown than it was in fallow soil (Table 1). Approximately 90% of inoculum cysts were recovered from soil in pots. The method of plant destruction significantly influenced population decline only when plants were destroyed at shoot emergence; on this sampling occasion population decline was significantly greater in pots where plants were hand pulled than in pots where they were killed with glyphosate. Although method of destroying plants 1 wk or more after shoot emergence did not significantly influence population decline, there was a tendency for decline to be greater when plants were hand pulled.

In the second pot experiment, cultivar status (resistant or susceptible) had no significant influence on population decline up to 6 wk after emergence (Table 2). However, duration of potato plant growth significantly influenced population decline, which was greater when plants had grown 3 wk or longer after shoot emergence before being killed with glyphosate. Population decline under plants that had grown less than 3 wk was not different from that in fallow soil.

In the microplot experiments, initial population density, soil type and duration of potato plant growth did not significantly affect population decline of *G. rostochiensis* (Table 3).

In the study on the effect of time and depth below soil surface on numbers of viable juveniles/cyst in fallow soil, there were significant reductions in viable juveniles/cyst of approximately 15 and 30% per year for 5 and 15 cm deep, respectively (Table 4). Population reduction 15 cm deep was significantly greater than that at 5 cm deep. Encysted juveniles in bags on the soil surface were all killed within 5 months.

DISCUSSION

The greater reduction in *Globodera rostochiensis* population achieved in the greenhouse pot experiment when plants were hand pulled at emergence rather than killed with glyphosate is probably due to production of root diffusate by roots left in the soil. The amount of *G. rostochiensis* population reduction achieved when plants were killed with glyphosate appears to be related to how quickly the herbicide acts on the plant. Under greenhouse conditions,

Table 2. *The effect of duration of susceptible or resistant potato plant growth on the decline in numbers of viable eggs/cyst of* Globodera rostochiensis

Time after plant emergence (wk)	Resistant cultivar	Susceptible cultivar	Fallow (control)
	Mean viable eggs/cyst*		
1	159 a	121 a	192 a
2	134 a	128 a	226 a
3	79 b	69 b	204 a
4	47 b	94 b	213 a
5	64 b	87 b	202 a
6	53 b	82 b	168 a

* Means followed by the same letter are not significantly different ($P = 0{\cdot}01$) (AOV: Duncan's MRT).
Initial viable eggs/cyst = 210·0 eggs/cyst.

Table 3. *The effect of soil type and duration of plant growth on* Globodera rostochiensis *population decline*

Soil type	Duration of plant growth (wk) 1	2	3	4	Mean
	% population decline*				
Silt loam	56·8	61·1	60·0	54·6	58·1
Muck (organic)	46·9	50·9	51·7	62·2	52·9
Clay	62·4	51·8	53·2	54·7	55·5
Mean	55·4	54·6	55·0	57·2	

* Average of three density classes: no significant effect of density (AOV).

plants showed symptoms of herbicide damage 24 h after applications and were completely dead within 3 days. Under microplot conditions, plants did not die until 21–28 days after herbicide application, probably due to the cool wet conditions that prevailed. Our data suggest that a potato plant that grows at least 3 wk exerts maximum influence on hatching of *G. rostochiensis* eggs and subsequent population decline. This agrees with previous research which showed that most of the juveniles that emerge from eggs and invade potato roots do so within 3 wk (Brodie, 1982).

In microplots, neither soil type nor duration of plant growth significantly affected *G. rostochiensis* population reduction under the resistant cultivar Hudson; approximately 50–60% population reduction was achieved in all three soils regardless of duration of plant growth. The systemic herbicide glyphosate was applied to potato shoots 1, 2, 3 or 4 wk after emergence, but several weeks were required for death of the entire plant. Roots may have continued to

Table 4. *Rate of population decline of* Globodera rostochiensis *at different depths in fallow soil*

Months after inoculation†	Depth (cm) 0*	5	15
	% population decline		
5	100	7·4	14·6
10	100	13·1	39·8
12		8·4	29·9
17		29·1	61·0
22		34·2	50·6

* 0 cm = cysts on the soil surface.
† Cysts buried in June.
AOV: Significant effect of depth and time on decline in fallow soil.

stimulate hatch for a period of time after herbicide application, resulting in similar population reductions after 1–4 wk of plant growth before herbicide application.

Decline of *G. rostochiensis* in fallow soil was 15–30% per year, significantly less than population reduction caused by growing resistant cultivars for 1–4 wk. The different rates of population reduction under resistant potato cultivars and fallow are especially significant in terms of time requirements for population decline. Spears, Mai & Betz (1956) reported that a 9-yr fallow was required to reduce the percent of cysts with viable contents in a field from 17% to 0%. We have demonstrated that growing resistant potato cultivars can effect the same population change in only 2 yr (unpublished).

Encysted juveniles placed on the soil surface in June were all killed within 5 months. Their death was not due to hatch, and the appearance of the dead juveniles in eggs was similar to that of juveniles killed by high temperature (LaMondia & Brodie, 1984). When placed at different depths in soil, nematode populations declined more rapidly at a depth of 15 cm than a depth of 5 cm as a result of hatching and subsequent death rather than death within eggs. Whitehead (1977) found that cysts may be fairly uniformly distributed to 40 cm deep. These results indicate that to estimate *G. rostochiensis* population reduction under fallow reliably, soil samples should be representative of the entire soil profile.

Whitehead (1977) also found that trap cropping for 6 wk reduced *G. rostochiensis* numbers in soil by 65%, compared to only 20% decline under bare fallow, but concluded that "trap cropping is an unattractive method of controlling potato cyst-nematodes'. The reason cited was the importance of timing potato plant destruction. Destroying plants too early (4 wk) did not hatch juveniles whereas destroying a susceptible trap crop too late (8 wk) resulted in nematode reproduction and population increase. The risk associated with the timing of trap crop removal can be eliminated through the use of potato cultivars resistant to *G. rostochiensis*.

In the absence of chemical management tactics, resistant potato cultivars are the most effective means of nematode control (Brodie, 1976). After an infested field has been identified, the probability of spreading potato cyst-nematodes from that field is greatest during the first year of resistant potato production. Initially reducing *G. rostochiensis* population numbers by means of trap cropping with a resistant potato cultivar would substantially reduce the probability of spread from an infested field.

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