AN INTEGRATED APPROACH FOR THE MANAGEMENT OF POTATO CYST NEMATODES, *GLOBODERA ROSTOCHIENSIS* AND *G. PALLIDA* IN INDIA

K. Devrajan, N. Seenivasan, N. Selvaraj and G. Rajendran

Horticultural Research Station, Vijayanagaram, Udhagamandalam - 643 001 (T.N.), India

Summary. Field studies were conducted to investigate the effect of a plant growth promoting rhizobacterium, *Pseudomonas fluorescens*, neem cake, mustard intercrop and carbofuran 3 G, in different combinations, on potato cyst nematodes, *Globodera rostochiensis* and *G. pallida,* and yield of two potato cultivars *viz.,* Kufri Jyoti and Kufri Giriraj. Higher tuber yields and lower nematode densities, in terms of number of females/2.5 cm root and number of eggs/g soil, were recorded for the cultivar Kufri Giriraj. In both of the cultivars, an application of *P. fluorescens* + neem cake + mustard intercrop + carbofuran 3 G increased the yield and reduced the potato cyst nematode population the most, followed by the application of *P. fluorescens* + neem cake + mustard intercrop, which was almost equally effective.

The potato cyst nematodes, *Globodera rostochiensis* (Woll.) and *G. pallida* Stone, are the major constraint for potato cultivation in the Nilgiri hills of Tamil Nadu State, India, causing up to 80 per cent loss of yield (Krishna Prasad, 1992). Soil treatment with nematicides has been an established practice in India for the control of cyst-forming nematodes of the genus *Globodera*, though it is very expensive for the farming community. Since a decade ago, nematode management strategies have moved towards partial or complete avoidance of chemicals due to groundwater contamination and other environmental hazards. In the wake of acceptance of eco-friendly approaches, potato cyst nematode management tactics have come to depend on the use of organic amendments (Kantharaju and Reddy, 2001), antagonistic plants (Franco *et al.*, 1999) and biocontrol agents (Mani *et al.*, 1998). Therefore, the effects of different management practices to control potato cyst nematodes on two different potato cultivars were explored.

MATERIALS AND METHODS

Two field experiments, in two different seasons, were conducted in a loamy soil of pH 5.5 infested with a mixed population of *Globodera rostochiensis* and *G. pallida*, at the Research Farm of the Horticultural Research Station (Tamil Nadu Agricultural University), Udhagamandalam, India during 2001-2002. The experiment was laid out in a split plot design with three replications in 3 m x 4 m plots on a bench terrace. The potato (*Solanum tuberosum* L.) cultivars Kufri Jyoti and Kufri Giriraj were the main plot treatments. The nematode management practices listed in Tables I and II constituted the sub-plot treatments. The talc-based commercial formulations of *Pseudomonas fluorescens* Migula, containing 15×10^8 colony forming units/g, were obtained from Tamil Nadu Agricultural University, Coimbatore, India. *Pseudomonas fluorescens*, neem cake and carbofuran were applied to the soil and mixed thoroughly into it before planting. Ridges and furrows were formed with a spacing of 45 cm between ridges and potato tubers of each cultivar were planted at 20 cm intervals along the ridges. Each plot comprised 13 ridges with 15 plants in each row. Mustard was sown between the rows of potato as an intercrop at the rate of 10 g of seed/plot and the plants were uprooted 45 days after planting. All normal agronomic practices were followed. Soil samples of 100 g were taken at random from 5 places in each plot after harvest. These samples were pooled and cysts extracted from a sub-sample of 100 g using the flask method (Southey, 1986). Egg population densities were then estimated by crushing 25 cysts collected at random from each plot and counting the eggs and expressing the results as numbers/g soil (Brown, 1969). The initial population of potato cyst nematodes averaged 60 eggs/g soil. The numbers of females/2.5 cm root, after harvest, were assessed by staining root samples with acid fuschin-lactophenol. The bacterium *P. fluorescens* was re-isolated from the soil of inoculated plots by the serial dilution plate technique (Rodriguez-Kabana, 1967) and grown on King's B medium (King *et al.,* 1954). Tuber yield was recorded after harvest and benefit-cost ratios for each treatment were worked out. The data from the two experiments were pooled and analyzed statistically.

RESULTS

The results revealed significant differences in the number of females/2.5 cm root, number of eggs/g soil and yield between the cultivars Kufri Giriraj and Kufri

Jyoti (Table I). Kufri Giriraj had the smaller mean number of females (5.4), whereas Kufri Jyoti had a mean of 6.6/2.5 cm root. Among the treatments, *P. fluorescens* + neem cake + mustard intercrop + carbofuran allowed the least nematode infestation (2.3 females/2.5 cm root), which was on a par with *P. fluorescens* + neem cake + mustard intercrop (2.7 females/2.5 cm root). When the effects of individual treatment components are considered, carbofuran gave the maximum reduction (70% over control), followed by neem cake (45%), *P. fluorescens* (44%) and mustard intercrop (43%). In two-component combinations, *P. fluorescens* + neem cake performed well by causing 67% decrease of females/2.5 cm root over the control. Between the cultivars, Kufri Giriraj had the smaller mean number of eggs/g soil post-harvest (31.7), while Kufri Jyoti had 40.7 eggs/g soil. When the treatments with two or more components are considered, *P. fluorescens* + neem cake + mustard intercrop + carbofuran had the lowest egg population (36.2 eggs/g soil), followed by the treatment *P. fluorescens* + neem cake + mustard intercrop (39.8 eggs/g soil), which was on a par.

A mean tuber yield of 21.4 mt/ha was recorded for Kufri Giriraj, whereas Kufri Jyoti yielded a mean of only 14.5 mt/ha (Table I). Among the different treatments, *P. fluorescens* + neem cake + mustard intercrop + carbofuran, produced the greatest yield (24.9 mt/ha, meaned over both cultivars), which was on a par with *P. fluorescens* + neem cake + mustard intercrop. Differences were observed in the yield performance of the two cultivars with Kufri Giriraj performing better than Kufri Jyoti. Kufri Giriraj produced 29.3 mt/ha of tuber yield in plots treated with *P. fluorescens* + neem cake + mustard intercrop + carbofuran and 28.7 mt/ha of tubers in plots treated with *P. fluorescens* + neem cake + mustard intercrop. In Kufri Jyoti, treating with *P. fluorescens* + neem cake + mustard intercrop + carbofuran gave a maximum yield of 20.5 mt/ha, similar to that obtained with *P. fluorescens* + neem cake + mustard intercrop (19.5 mt/ha).

The bacterium, *P. fluorescens* was re-isolated from all of the inoculated plots and more colony forming units from the initial inoculum were isolated when the bacterium was combined with neem cake (Table II).

The economic analysis revealed that, with the cv. Kufri Giriraj, the treatment with *P. fluorescens* + neem cake + mustard intercrop gave the highest benefit–cost

Table I. Effect of different management practices on *Globodera rostochiensis* and *G. pallida* and tuber yield (pooled means of 2 experiments).

Treatment	Number of females/2.5 cm root			Number of eggs/g soil at harvest			Yield mt/ha		
	Kufri Jyoti	Kufri Giriraj	Mean	Kufri Jyoti	Kufri Giriraj	Mean	Kufri Jyoti	Kufri Giriraj	Mean
P. fluorescens at the rate of 2.5 kg/ha	8.5	6.5	7.5	126.3	93.7	110.0	11.2	16.9	14.1
Neem cake at the rate of 1 t/ha	8.6	6.2	7.4	113.0	105.0	109.0	11.9	17.7	14.8
Mustard intercrop	9.1	6.0	7.6	135.7	88.0	111.8	10.3	15.1	12.7
P. fluorescens + neem cake	4.4	4.3	4.4	59.0	79.7	69.3	17.4	25.1	21.3
P. fluorescens + mustard intercrop	6.1	4.9	5.5	76.0	63.3	69.7	14.5	21.5	18.0
Neem cake + mustard intercrop	5.5	4.6	5.0	80.0	63.7	71.8	15.1	22.5	18.8
P. fluorescens + neem cake + mustard intercrop	3.0	2.4	2.7	45.7	34.0	39.8	19.5	28.7	24.4
P. fluorescens + neem cake + mustard intercrop + Carbofuran	2.7	2.0	2.3	40.7	31.7	36.2	20.5	29.3	24.9
Carbofuran 3 G at the rate of 1 kg a.i./ha	3.7	4.3	4.0	83.3	40.3	61.8	16.1	24.1	20.9
Untreated control	14.6	12.2	13.4	178.0	150.3	164.2	8.5	12.6	10.6
Mean	6.6	5.4		93.8	75.0		14.5	21.4	
	SED	CD at 5%		SED	CD at 5%		SED	CD at 5%	
Variety (V)	0.19	0.40		0.16	0.50		0.11	0.47	
Treatment (T)	0.15	0.30		2.18	4.43		0.25	0.54	
V at T	0.22	0.54		2.92	5.96		0.37	0.83	
T at V	0.21	0.43		3.09	6.26		0.48	0.16	

Table II. Re-isolation of *Pseudomonas fluorescens* from the plots at the end of the experiment and economics of each treatment for the potato cultivars Kufri Jyoti and Kufri Giriraj.

Treatment	Re-isolation of *P. fluorescens*		Benefit-cost ratio	
	cv. Kufri Jyoti	cv. Kufri Giriraj	cv. Kufri Jyoti	cv. Kufri Giriraj
P. fluorescens at the rate of 2.5 kg/ha	+	+	1.7	2.5
Neem cake at the rate of 1 t/ha	-	-	1.6	1.9
Mustard intercrop	-	-	1.5	1.8
P. fluorescens + neem cake	++	++	2.3	2.7
P. fluorescens + mustard intercrop	+	+	2.1	2.3
Neem cake + mustard intercrop	-	-	1.9	2.9
P. fluorescens + neem cake + mustard intercrop	++	++	2.5	3.0
P. fluorescens + neem cake + mustard intercrop + Carbofuran	++	++	2.5	2.9
Carbofuran 3 G at the rate of 1 kg a.i./ha	-	-	2.3	2.8
Untreated control	-	-	1.3	1.5

+ : < 15 x 10^8 colony forming units/g soil; ++ : > 15 x 10^8 colony forming units/g soil; - : not found

ratio of 3.0 followed by the *P. fluorescens* + neem cake + mustard intercrop + carbofuran treatment. With the cv. Kufri Jyoti, application of *P. fluorescens* + neem cake + mustard intercrop + carbofuran and *P. fluorescens* + neem cake + mustard intercrop gave similar benefit-cost ratios of 2.5 (Table II).

DISCUSSION

The experimental results indicated that integration of *P. fluorescens*, neem cake and mustard intercrop reduced populations of potato cyst nematodes and increased tuber yields. The addition of carbofuran did not significantly increase yield and nematode control. The explanations for these results might lie in the antagonistic activity of *P. fluorescens* (Santhi and Sivakumar, 1995; Cronin *et al.*, 1997), the nematicidal activity of neem cake (Alam *et al.*, 1979) and the toxic principles in mustard root exudates (Haque and Gaur, 1988) towards potato cyst nematodes. The reasons for improvement in nematode control in such an integrated approach can only be surmised as the hatched juveniles would be immobilized or killed by the nematicidal principles of neem cake and the mustard intercrop. The development and reproduction potential of some of the juveniles that managed to penetrate the potato roots might have been affected by the colonization of *P. fluorescens,* as suggested by Santhi and Sivakumar (1995). Cronin *et al.* (1997) reported that the antibiotic, 2-4 diacetyl phloroglucinol, produced by *P. fluorescens* was inhibitory to *G. rostochiensis*. The re-isolation of the bacterium from the treated plots showed that *P. fluorescens* can survive in acid organic soils. The higher bacterial activity in neem treated plots might be explained by the decomposition of neem cake releasing residual organic matter into the soil, so increasing bacterial activity and persistence. In spite of the greater increase in yield after treatment with *P. fluorescens* + neem cake + mustard intercrop + carbofuran, the application of *P. fluorescens* + neem cake + mustard intercrop proved to be more economical, having the same benefit-cost ratio for both the potato cultivars. Hence, it could be concluded that integration of *P. fluorescens,* neem cake and a mustard intercrop is an economical and effective management practice for the control of potato cyst nematodes.

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