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Management of the root-knot nematode (*Meloidogyne incognita*) in carrots by intercropping

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The management of root-knot nematode (*Meloidogyne incognita*) in carrot was studied over a three-year period in St. Vincent. Onion (*Allium cepa*), chive (*Allium schoenoprassum*), corn (Zea mais) and eddoe (*Colocasia esculenta* var. *antiquorum*) were found effective in reducing root-knot nematode population densities in the soil. Cropping systems were then designed and tested for their effectiveness in reducing nematode population densities and galling damage in carrot (*Daucus carota*). Cabbage-carrot, chive-carrot and onion-carrot were found to be the most effective. Cabbage-carrot and chive-carrot significantly reduced unmarketable yields and root damage in carrots as compared to carrot monoculture. Root gall index was positively correlated with unmarketable yields. Economic analysis showed that the two intercropping systems were more efficient in the use of land, labour and capital resources than carrot monoculture, and that the overall farm income is greatly increased by intercropping carrot with cabbage or chive.

Keywords: Carrot; *Meloidogyne incognita*; Intercropping; Chive; Cabbage

Introduction

Crop rotation has long been identified as an efficient means of controlling several important nematode pests (Hutton et al., 1982; Netscher, 1985). More recently, intercropping or multiple cropping as a means of managing nematode pests has attracted the attention of researchers world-wide, (Adams et al., 1971; Perrin, 1977). Trembath (1976) produced the first evidence from Australia that nematodes and diseases may be impeded when both hosts and non-hosts are grown in mixtures. Several other workers (Brodie & Murphy, 1975; Mc Donald, 1985b) have shown that multiple cropping harbours significantly fewer nematodes than monocultures. This has been attributed to a differential susceptibility to pests, pathogens and nematodes (Altieri, 1983). Work has included studies in the tropics to identify those systems which most effectively control plant nematodes, including the root-knot nematode (Egunjobi, 1985; Rhodes, 1985).

Carrot production in St. Vincent has been on the decline since 1976. Losses during the period 1976-1978 were estimated to be between 55% and 60% (Barker & Henderson, 1985), which reduced annual revenue by over EC$ 500,000 (Sing,1979). This resulted in a significant reduction in foreign exchange earnings, and at the regional level, disrupted production of a major carrot producer and led to increased importation of carrots from extra-regional sources. This decline in

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production was attributed to the root-knot nematode (RKN) (*Meloidogyne incognita* (Kofoid & White, Chitwood), and to the fungal pathogen *Sclerotium rolfsii*. Singh (1982) subsequently confirmed *M. incognita* as the major contributor to the decline in carrot yield and quality in St. Vincent. This paper presents results of a 3-year study, using a systems approach, to manage the root-knot nematode in carrots in St. Vincent including an economic analysis of the carrot intercropping systems investigated.

Materials and methods

Studies were conducted on farms in the Leeward and Windward districts of St. Vincent over 3 years, using a farming systems methodology developed by CARDI (CARDI, 1983). The objective of the first year's experiment was to identify crops which reduce *M. incognita* populations in the soil. Two farms were selected in Rosehall, North Leeward, a major carrot producing region. The two farms had a similar history of heavy RKN infestations, and were in the same agro-ecological zone. The soils were both Belmont gravelly, sandy loams (Typic Hapludolls, loamy, skeletal, mixed) (Ahmad, 1981).

Six crops; Onion (*Allium cepa* L. cv. Texas Yellow Grano), chive (*Allium schoenoprassum* L.), corn (*Zea mays* L.), eddoe (*Colocasia esculenta* (L.)Schott cv. *antiquorum*), bean (*Phaseolus vulgaris* L. cv. Kentucky Wonder), and carrot (*Daucus carota* L., cv. Danvers Half Long) were planted in individual plots 3m x 6m with 0.5m pathways separating each plot. There were four rows per plot. The six treatments were arranged as randomized complete blocks (RCBs) with three replicates per farm.

In the second year, the objective was to test the influence of four cropping systems, including pure stands of carrot on the suppression of the RKN populations. On the same two farms, three intercrop systems; onion-carrot, chive-carrot and cabbage-carrot, were established on plots 5.5m x 3.0m. There were four ridges per plot. In the intercropped plots, each ridge had two rows of carrot, and one row of the intercrop. In the purestand plots, there were three rows of carrots per ridge. Cabbage seedlings were planted 45 cm apart. Chive setts, onion and carrot were sown to give an intra-row spacing of 15 cm, after the onions and carrots were thinned. The four treatments were replicated four times in a RCB design on each farm.

Five farms were used in the third year. Four were in the North Leeward district and the other at Biabou, Windward. All five farms were plagued with RKN damage in carrots. The soil at Biabou was a Greggs loam and clay loam (Typic Dystrandept, Ahmad 1981). Two selected intercropping systems, cabbage-carrot and chive-carrot were tested and compared with purestand carrot. Plot size was 6m x 5m with 60cm separating each plot. There were five ridges per plot. The cabbage and chive intercrops were planted two weeks before seeding the carrots. Planting was completed between November 1985 and mid-January, 1986. Crop management included fertilizing, manual weed control and insect pest control, as required (Mc Donald, 1985a). The procedures for nematode sampling and processing (Mc Donald (1985a) and extraction (Gowen and Edmunds, 1973) were the same in all experiments.

Analyses of variance were performed on transformed [$Y = \log_{10}(x+1)$] pre-plant density counts. Population density counts after four months of crop growth were adjusted for the pre-plant counts, using co-variance analysis. Standard procedures for analysis of variance were used. Correlation co-efficients between un-marketable carrot yields and mean root gall indices and between marketable carrot yields and mean root gall indices were calculated. The economics of the intercropping systems was analysed and compared with carrot monoculture using partial budgeting.

Table 1 Mean soil populations of *M. incognita* juveniles, after four month's growth of six selected crops in 1984[1)]

Farm	Crops											
	Onion		Chive		Corn		Eddoe		Beans		Carrots	
	Preplant	4Mo[2)]	Preplant	4Mo	Preplant	4Mo	Preplant	4Mo	Preplant	4Mo	Preplant	4Mo
1	67	27	10	3	40	22	40	25	30	72	47	125
2	60	12	50	30	30	27	17	7	73	140	33	142
Means	64	20	30	17	35	25	29	16	52	106	40	184
L.S.D.(P=0.05) = ±0.9												

1) Data were transformed ($\log_{10}[x+1]$) for analysis of variance and calculating LSD values. Population density counts were based on means of three replicates per farm. Soil sample size = 200 cm^3.
2) 4Mo = sampling after 4 months of crop growth

Table 2 Effects of four cropping systems on mean soil population densities of *M. incognita* juveniles, per 200cm^3 of soil in 1985[1)]

Cropping system	Nematode counts		
	Preplant	Postplant[2)] (Unadjusted)	Postplant[2)] (Adjusted for preplant count)
Onion-Carrot	125	60	69
Cabbage-Carrot	149	104	109
Chive-Carrot	208	129	115
Carrot (purestand)	188	445	417
C.V.(%)	9.5	9.62	8.74
L.S.D (P = 0.05)	N.S	0.22	0.20

1) See notes for Table 1 regarding statistical treatment. Means based on 4 replications/farm with 4 observations
2) Post-plant count after 4 months' growth of crops.

Results

In 1984 and 1985 there were significant differences (P = 0.05) among means of post-plant population densities of *M. incognita* with highest levels in carrot and bean (Table 1). The differences among mean post-plant population counts adjusted for initial counts were also highly significant (P = 0.01) (Table 2). In 1985, yields of marketable carrots under the four cropping systems were not significantly different, but reductions in the root gall index (RGI) under the intercrops were significant (Table 3). In 1986, there were no significant differences among cropping systems in marketable carrot yield, but treatment differences were significant for unmarketable yield (Table 4). Unmarketable yields for the chive-carrot, cabbage-carrot and sole-carrot systems were respectively, 19.2%, 21.8% and 22.3% of the total carrot yield

Table 3 Effect of four cropping systems on marketable yield and root galling of carrot at four farms in 1985

Cropping System	Yield of Carrots (t/ha)	Root Gall Index[1)]
Onion-Carrot	6.73	1.9a[2)]
Cabbage-Carrot	5.52	1.9a
Chive-Carrot	8.87	1.3a
Carrot (alone)	7.09	3.1b
C.V. (%)	36.5	30.1

1) Mean root gall index based on: 0 = no root infected; 1 = few small galls; 2 = many small galls; 3 = a few large galls; 4 = root with many large galls; 5 = root with knotted growth.
2) Means followed by a common letter are not significantly different (at P = 0.05) as determined by Duncan's Multiple Range Test.

Table 4 Effect of cropping systems on yields and root galling of carrot. Mean of five farms in 1986 (after Mc Donald, 1986).

Cropping system	Yield of carrots (t/ha)			Root Gall Index[1)]
	Total	Marketable	Unmarketable	
Cabbage-Carrot	11.58	9.05	2.53	2.1
Chive-Carrot	11.58	9.35	2.23	1.8
Carrot (purestand)	14.05	10.91	3.14	2.8
C.V. (%)	21.1	25.4	26.1	

1) Mean root gall index as for Table 3.

Significant positive correlations were observed between the mean RGI and unmarketable yield (r = 0.59*) but RGI was not significantly correlated with marketable yield. The RGI ranged from 1.7 to 2.8 among the five farms.

The mean costs and returns per hectare in cabbage-carrot, chive-carrot and purestand carrot systems are presented in Table 5. The returns to land, risk and management per unit labour and capital were compared. The highest returns to these two factors were EC$23,447 per ha from the cabbage-carrot treatment, followed by EC$13,342 per ha for the chive-carrot treatment. Purestand carrots gave the lowest returns with $9,350 per ha. Although there was a 33% reduction in the carrot population in the two intercrop systems compared to purestand carrots, the reduction in the income derived from carrots in the cabbage-carrot and chive-carrot systems was only (18% and 13%, respectively. A comparison of costs and returns from the intercrops themselves is presented in Table 6.

The intercropping systems of cabbage-carrot and chive-carrot provided higher returns per unit of all resources than purestand carrot. Thus, the intercropping systems are more efficient utilizers of these resources. Edje (1970) also showed that mixed cropping is more efficient than monocropping in terms of total productivity per unit area of land and utilization in the ecosystem. The analysis also shows that the benefits from the intercrops more than covered the cost of establishing and maintaining them in the system and that the overall farm income is increased by intercropping carrot with cabbage or chive.

Table 5 Mean costs and returns per hectare in three carrot cropping systems in 1986

	Cropping system		
	Cabbage/ Carrot	Chives/ Carrot	Purestand Carrot
Gross returns[1)]			
Carrot	19,800	21,120	24,200
Cabbage	19,717	-	-
Chives	-	8,469	-
Total returns	39,517	29,589	24,200
Materials costs	891	858	776
Returns to land, labour, risk and management	38,626	28,731	23,424
Labour costs	15,179	15,389	14,074
Returns to land, etc.			
Land ($/ha)	23,447	13,342	9,350
Labour ($/hr)	3.7	2.1	1.6
Capital ($/$)	26.3	15.6	12.0

1) Farm gate prices (EC$ per Kg) for carrot, cabbage and chive were respectively: $1.76, $3.30 and $1.65.

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Table 6 Costs and returns from intercrops in carrot-intercrop systems

	Intercrop	
	Cabbage	Chive
Costs[1)]	4,613	4,794
Returns		
Gross	19,717	8,469
Net	15,104	3,675
% Returns to costs	327	77

1) 1/3 of the cost of fertilizer, fertilizer application, and weeding is borne by the intercrop in addition to costs solely attributed to the intercrop.

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