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Effect of Crop Rotation on *Meloidogyne* spp. and *Pratylenchus* spp. Populations in Strawberry Fields in Taiwan

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Abstract: Changes in population levels of *Meloidogyne hapla*, *M. incognita*, *Pratylenchus coffeae*, and *P. penetrans* were studied in 12 strawberry fields in the Dahu region of Taiwan. Ten potential rotation crops and two cultural practices were evaluated for their effect on nematode populations and influence on strawberry yield. Rotation with rice or taro and the cultural practice of flooding and bare fallowing for four months were found to reduce nematode soil populations to two or fewer nematodes per 100 ml soil. Average strawberry yields increased between 2.4% to 6.3% following taro compared to the bare fallow treatment. Corn suppressed *M. incognita* and *M. hapla* populations and resulted in an increased in strawberry yield compared to bare fallow. Other phytopathogens also present in these fields limited taro as the rotation choice for nematode management. Results of this research and economic analysis of the input requirements for various rotation crops, corn and bare fallow were recommended as the most appropriate rotation strategies for nematode management in strawberry in this region.

Key words: bitter gourd, *Capsicum annuum*, *Colocasia esculena*, corn, fallow, *Glycine max*, *Hibiscus esculentus*, India sesbania, lana vetch, *Lycopersicon esculentum*, *Meloidogyne hapla*, *Meloidogyne incognita*, *Momordica charantia*, Okra, *Oryza sativa*, pepper, *Pratylenchus coffeae*, *Pratylenchus penetrans*, rice, rotation, *Sesbania sesban*, soybean, strawberry yield, taro, *Vicia sativa*, *Zea mays*.

Continuous cropping of susceptible crops in local farming systems in Taiwan leads to the accumulation of pests. Strawberry, *Fragaria chiloensis* (Duchesne), is the major crop in the Dahu region of Taiwan, where it is grown mostly on "pick-your-own fruit" farms. This practice reduces labor inputs for harvesting and generates approximately US$13,000/ha profit. Because strawberries are offered directly in the field, growers are seeking alternatives to chemical pesticides to manage pests and pathogens out of concern for human health and the potential contamination of ground water (Lee, 1993).

The most widely planted strawberry cultivar in Taiwan is Toyoka, which was introduced from Japan in 1985 (Lee, 1993). In a 2002 survey, strawberries were found to be most intensively planted in Miaoli County at altitudes of 50 to 1,100 m, where 364 ha out of a total of 418 ha in Taiwan were grown (Anonymous, 2002). Strawberry is grown from late September until April or early May the following year. During the summer, many crops are grown in rotation with strawberry (Lee, 1993).

A large number of nematode species affect strawberry growth (Mass, 1984). Phytoparasitic nematodes reported from Taiwan include *Pratylenchus penetrans* and *P. coffeae*, and both were associated with a root decline disease in strawberry plantings. Infected plants were stunted, had reduced runner plant production, and had shorter and more erect petioles. *Pratylenchus penetrans* is considered the most important of the four species of root lesion nematodes in strawberry plantings, and no strawberry cultivars are known to have resistance to *P. penetrans*. The cultivar Toyoka is susceptible to both lesion nematodes and root-knot nematodes (Tsay, 1996).

Crop rotation is among the oldest and most important methods for managing nematodes in annual crops, but development of crop rotation programs is often constrained by specialized cropping practices, equipment requirements, local climate, and the market value of the crops (Thomason and Caswell, 1987). In an optimum crop rotation system, the preceding crop prevents damage to the following crop by suppressing the target nematode population without increasing other species of nematodes that may be parasitic to the future crop (Johnson, 1985).

After harvesting strawberries in the Dahu area, approximately four months are available to grow another crop in the rotation, and usually high-value summer vegetables are grown. A preliminary survey of strawberry fields indicated that *Meloidogyne hapla, M. incognita, P. coffeae* and *P. penetrans* were the predominant nematodes present. Bitter gourd was a popular rotation crop in the early 1990s, but it is highly susceptible to root-knot nematodes, and rotation with this crop caused root-knot nematode populations to increase and damage strawberry crops. The objectives of this study were to evaluate different cultural practices and 10 rotation crops as potential nematode management tactics in the Dahu region strawberry production system.

Materials and Methods

The strawberry production area in the Dahu region of Taiwan is located at 120°45' E and 24°25' N, with an altitude ranging from 50 to 700 m. Based on a preliminary survey, four farms, each containing one dominant plant-parasitic nematode (*M. hapla, M. incognita, P. coffeae* or *P. penetrans*), were chosen for this study. Each farm was approximately 2 ha in area and was divided into five blocks for experimentation (Table 1). Farms MI and PC practiced bare fallowing in the summer sea-

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TABLE 1. Location, altitude, cropping history of experimental farm sites and dominant nematode species present in the experimental field sites.

Location	Block	Experiment	Year of test	Dominant nematode	Altitude
Farm MH	1	Prominence value[a]	1991–2003	*Meloidogyne hapla*	500–700
	2	10 crops rotation[b]	1999–2000		
	3	5 crops rotation[c]	2000–2001		
	4	5 crops rotation	2001–2002		
	5	5 crops rotation	2002–2003		
Farm MI	1	Prominence value	1991–2003	*Meloidogyne incognita*	50–150
	2	10 crops rotation	1999–2000		
	3	5 crops rotation	2000–2001		
	4	5 crops rotation	2001–2002		
	5	5 crops rotation	2002–2003		
Farm PC	1	Prominence value	1991–2003	*Pratylenchus coffeae*	50–150
	2	10 crops rotation	1999–2000		
	3	5 crops rotation	2000–2001		
	4	5 crops rotation	2001–2002		
	5	5 crops rotation	2002–2003		
Farm PP	1	Prominence value	1991–2003	*Pratylenchus penetrans*	500–700
	2	10 crops rotation	1999–2000		
	3	5 crops rotation	2000–2001		
	4	5 crops rotation	2001–2002		
	5	5 crops rotation	2002–2003		

[a] The samples taken to obtain prominence values were from block 1 in this farm.
[b] Ten different crops and two cultural practices were conducted in block 2 in this farm.
[c] Five different crops are bare fallowing were conducted in block 3 in this farm.

son, and farms MH and PP grew strawberry continuously.

Monitoring nematode soil populations: The four plant-parasitic nematodes were monitored in each farm from 1991 to 2003. Samples (300 g soil/sample) were collected 3 mon (January) after strawberry planting time by removing the plant top and digging up the plants with the soil around the rhizosphere. A 100 g combination of soil and roots was taken; nematodes in the soil were isolated using a modified Baermann funnel technique (Dropkin, 1980), and only plant-parasitic nematodes that could be identified to species were counted. Root-knot nematodes on the roots were identified to species by examining perineal pattern. Between 30 and 35 samples were taken from each farm, and the data pooled. Since density and frequency provide different information about populations, we combined the two into the Prominence value. Prominence values of these four nematodes were calculated using the following formula (Norton, 1978):

Absolute frequency = (Numbers of samples containing a species/Numbers of samples collected) x 100

$$\text{Absolute Density} = \frac{\text{A mean of a species in the samples}}{\text{Unit of soil and roots (100 g)}}$$

Prominence value = Absolute density x (Absolute frequency)$^{1/2}$

To determine the frequencies of all plant-parasitic nematodes present in the Dahu area in 2000, a total of 126 samples collected in that year were pooled to generate relative frequency indices based on the following formula (Lin and Tsay, 1984):

$$\text{Relative frequency} = \frac{\text{Absolute frequency of a species}}{\text{Sum of absolute frequency of all species}} \times 100$$

Evaluation of crop rotation and other cultural practices: In 1999, a preliminary evaluation of potential rotation crops was made on block 2 of each farm. The 0.4 ha block was divided into 12 plots approximately 330 m^2 for 10 different rotation crops, bare fallow, and flooding treatments. Four samples were taken from each plot to obtain P_i before rotation and P_f when the rotation crops were taken out of the fields. For each crop, there was one plot available on each of the four farms. Nematode counts were based on the average of 4 samples/plot.

Bare fallow and flooding were considered as the control treatments. The 10 rotation crops were: rice (*Oryza sativa* L.) Taichung 65, obtained from Agricultural Research Institute, Wufeng, Taiwan; edible soybean (*Glycine max* (L.) Merr.) Kaohsiung #1, obtained from Kaohsiung District Agricultural Research and Extension Station, Pingtung, Taiwan; taro (*Colocasia esculena* (L.) Schott.), a local variety; sweet corn (*Zea mays* L. var. *rugosa* Bonaf.) cv. Honey Jean No. 2; tomato (*Lycopersicon esculentum* L.) cv. Farmers 301; okra (*Hibiscus esculentus* L.) cv. Lucky five; pepper (*Capsicum annuum* L.) cv. Sunny star; and bitter gourd (*Momordica charantia* L.) cv. Moon shine (all from Know-You Company, Kaohsiung, Taiwan). India sesbania (*Sesbania sesban* L.) Merr. and lana vetch (*Vicia sativa* L.) were obtained from Changhwa County, Taiwan. Rotation crops were planted 7 to 10 d after the previous strawberry crop was harvested and removed at the end of August. The rice crop required 1-mon flooding; soil barriers 15-cm wide and 30-cm high were built around the block to maintain the water level. The other crops were planted according to standard agronomic practices for the area.

Strawberry (var. *ananassa* Duch.) cultivar Toyoka tissue-cultured seedlings were obtained from the Taichung District Agricultural Research and Extension Station, Taichung, Taiwan. Strawberries were planted in the 70-cm-wide and 30-cm-high beds in late September and covered with silver PV plastic tarp to control weeds. Peters professional water soluble fertilizer (The Scotts Company, Ohio, USA; N-P-K: 20–20–20) was applied at the rate of 2,000 kg/ha before planting. Two applications of 10% fenpropathrin powder (Sumitomo Co., Taipei, Taiwan) were applied to kill mites at 21 and 31 d after strawberry planting. To obtain yield of strawberry after the crop rotation, ripe berries were collected 120 to 130 d after planting (January), when the first round of berries were mature. Fruits on 24 randomly selected plants in a block were picked and weighed, and the plants were dug up for root galling or necrosis index evaluation. Galling index and necrosis index ranged from 0 to 4, based on percentage of roots galled or lesion area on the roots: 0 = 0 %, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%.

From 2000 to 2003, only five crops and bare fallow were repeated in blocks 3, 4 and 5. The five crops were chosen because they were already used in nearby farms for their economic value or for having potential to lower the population of plant-parasitic nematodes. In Farms MH and PP, corn, rice, taro, tomato and lana vetch were used as rotation crops. In Farms MI and PC, tomato and lana vetch were substituted by bitter gourd and India sesbania.

Results

Meloidogyne hapla had the largest change in prominence value over the 12-year period from 1,235 initially to 423. Values for the other three species also declined, *M. incognita* from 726 to 625, *P. penetrans* from 409 to 340 and *P. coffeae* from 26 to 6. The four nematodes persisted in the strawberry monoculture system (Fig. 1). *Meloidogyne incognita* had the highest relative frequency of the four species; in 2000 it was 28.57%, followed by *P. penetrans* at 20.14%, *M. hapla* at 16.62%, and *P. coffeae* at 16.36%.

Four minor nematodes, listed from higher to lower frequency, were also detected during the surveys: *Paratylenchus curvitatus, Tylenchorhynchus martini, Hemicriconemoides* sp. and *Hoplolaimus* sp. The frequency of these nematodes showed no obvious differences from year to year. The sum of the relative frequency of the four major nematodes was 81.72%. Among the major nematode species, *P. coffeae* had the lowest relative frequency of 16.39%, though this was much higher than

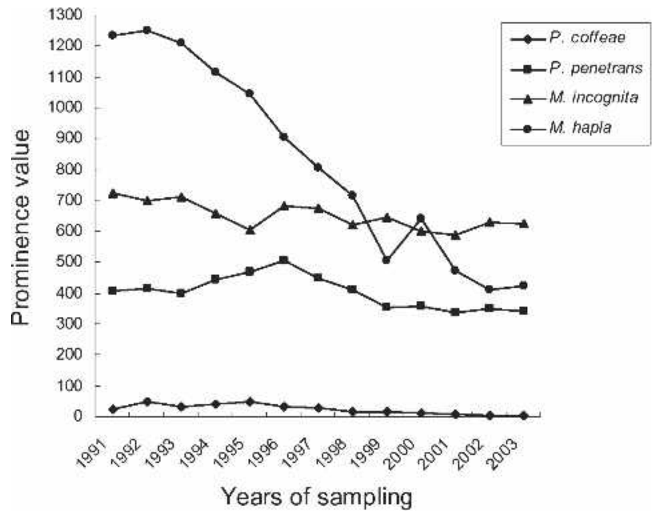

Fig. 1. Prominence values of *Meloidogyne incognita*, *M. hapla*, *Pratylenchus coffeae* and *P. penetrans* from block 1 of four strawberry farms in the Dahu area of Taiwan.

5.85% frequency of *P. curvitatus*, the most frequent of the minor nematodes in 2000. The four minor nematodes were found to be restricted to the same locations over the survey years, with *P. curvitatus* mostly on Farms MH and PP and the other three nematodes on Farms MI and PC.

Flooding and bare fallow treatments lowered soil populations of the four major nematodes. All 10 rotation crops grown in 1999 lowered the number of *M. hapla*, with Rf ratios < 1. Corn, rice and taro lowered the population density of *M. incognita*, whereas soybean, tomato, okra and bitter gourd were good hosts for this nematode and increased its soil population densities (Table 2).

Rice, taro and tomato were resistant to both species of root-lesion nematode, with R ratios < 1 in each combination. India sesbania also lowered the population of *P. coffeae*. Strawberry yield and root galling index in plots of Farm MI previously rotated with corn, rice and taro were not different ($P > 0.05$) compared to the fallow treatment (Table 3A). In plots of Farm MH, rotation with corn, rice and lana vetch resulted in a galling index of zero on strawberry, and strawberry yields were the same as those following the fallow treatment (Table 3B). On Farm PP, after rotations with rice and taro, the strawberry had the lowest necrosis index. Rotations with corn and tomato did not eliminate nematode populations in the soil, but resulted in similar strawberry yields to those following bare fallow. Rotation with lana vetch increased *P. penetrans* populations and lowered the strawberry yield ($P < 0.05$) (Table 4A). On Farm PC, rotation with rice resulted in a strawberry necrosis index of zero and yields the same as after bare fallow. Rotation with corn resulted in lower ($P < 0.05$) strawberry yields compared to the fallow treatment. Bitter gourd increased *P. coffeae* populations in the soil, and two out of three experiments had lower ($P < 0.05$)

TABLE 2. The number of nematodes per 100 cm^3 soil and the R ratio after crop rotation, flooding and fallowing practices conducted in block 2 of farms MH, MI, PC, and PP in 1999.

	Meloidogyne incognita			*Meloidogyne hapla*			*Pratylenchus penetrans*			*Pratylenchus coffeae*		
	no./100 cm^3 soil			no./100 cm^3 soil			no./100 cm^3 soil			no./100 cm^3 soil		
Treatment	Apr. 27	Aug. 30	Pf/Pi	Apr. 27	Aug. 30	Pf/Pi	Apr. 27	Aug. 30	Pf/Pi	Apr. 27	Aug. 30	Pf/Pi
Corn	20a[a]	1c	0.1	11a	0b	0	12a	15b	1.25	19a	76ab	4
Rice	18a	0d	0	8a	0b	0	14a	0d	0	19a	0d	0
Soybean	16a	325a	20.3	6a	4a	0.6	12a	40ab	3.3	20a	27b	1.4
Taro	20a	2c	0.1	8a	0b	0	15a	0d	0	22a	2c	0.1
Tomato	19a	414a	21.8	8a	3a	0.4	15a	2c	0.1	20a	1c	0.1
Okra	20a	480a	24	10a	9a	0.9	12a	17b	1.4	18a	15b	0.8
Bitter gourd	18a	457a	25.4	9a	8a	0.9	12a	22b	1.8	16a	20b	1.3
Pepper	18a	295ab	16.4	9a	4a	0.4	11a	24b	2.2	19a	19b	1
India sesbania	20a	320a	16	10a	3a	0.3	14a	15b	1.1	20a	18b	0.9
Lana vetch	19a	45b	2.4	8a	0b	0	15a	109a	7.3	20a	120a	6
Flooding	19a	0d	0	9a	0b	0	14a	0d	0	21a	0d	0
Fallow	20a	1c	0.1	10a	0b	0	12a	0d	0	20a	0d	0

[a] Data are the means of 10 replicates. Means in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

strawberry yields compared to bare fallow. Rotation with taro and India sesbania resulted in moderate levels of root lesion on strawberry, and strawberry yields were not different ($P < 0.05$) from the fallow treatment except in 2001 (Table 4B).

Discussion

Crop rotation practices have been questioned in recent years due to the increasing occurrence of fields containing two or more species of plant-parasitic nematodes (Fortnum et al., 2001). As the species complexity of major nematode pathogens increases in a particular field, the ability to design effective rotations becomes more difficult (Thomason and Caswell, 1987). Data of prominence values (Fig. 1) and the relative frequencies (the highest was 28.57%) indicated the population number as well as the dominance of a plant-parasitic nematode was stable over the years in one farm. It is critical to evaluate rotation crops for suppression of not only the primary target nematode, but also for their effects on populations of other nematode pests (McSorley and Dickson, 1995). Here, we provide the first report of managing multiple plant-parasitic nematodes in a local farming system in Taiwan.

TABLE 3A. The galling index and fruit yield of strawberry after crop rotation and bare fallowing treatments in the *Meloidogyne incognita*-infested field site on Farm MI.

Rotation crop	Galling index[a]			Fruit yield[b] (g/plant)		
Year	2001	2002	2003	2001	2002	2003
Corn	0.2a[c]	0.2a	0.1a	160b	155c	163c
Rice	0.0a	0.0a	0.0a	152b	149c	150b
Bitter gourd	3.8b	4.0b	4.0b	75a	42a	51a
Taro	0.1a	0.0a	0.0a	150b	150c	155b
India sesbania	3.5b	3.7b	3.5b	80a	63b	55a
Fallow	0.0a	0.0a	0.0a	146b	146c	148b

Several crops had been used for the conventional rotation schedule, e.g., rice was rotated with strawberry in the low-altitude areas, and our results showed that this practice reduced both root-knot nematodes species to undetectable levels (Tables 3,4). In addition, the yields of the subsequent strawberry crop were similar to those following bare fallow treatment. However, rice is no longer a favorable choice of rotation in recent years due to its low economic value (US$2,742/ha; Anonymous, 2002). Some green manure crops, such as India sesbania, also have been a preferred choice because of a fast growth rate, whereas others, such as lana vetch, are restricted by climatic requirements and only planted in the high-altitude areas. However, India sesbania increased populations of *M. incognita* in our field experiments. The survey data indicated that *M. incognita* had the highest relative frequency and was the most prevalent species in this local farming system. Therefore, India sesbania should not be considered in the rotation schedule. Lana vetch lowered *M. hapla*

TABLE 3B. The galling index and fruit yield of strawberry after crop rotation and bare fallowing treatments in the *Meloidogyne hapla*-infested field site on Farm MH.

Rotation crop	Galling index			Fruit yield (g/plant)		
Year	2001	2002	2003	2001	2002	2003
Corn	0.0a	0.0a	0.0a	155b	150b	157b
Rice	0.0a	0.0a	0.0a	150b	145b	150b
Tomato	2.3b	2.5b	2.4c	73a	68a	73a
Pepper	1.8b	1.8b	1.6b	69a	71a	75a
Lana vetch	0.0a	0.0a	0.0a	151b	142b	146b
Fallowing	0.0a	0.0a	0.0a	150b	140b	145b

[a]Galling index ranged from 0 to 4 and was based on percentage of roots galled; 0 = 0%, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%.

[b]Fruit weights were obtained by randomly sampling one row of the block, taking all the mature strawberries from the plants and dividing by the number of plants in the row.

[c]Means in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

TABLE 4A. The necrosis index and fruit yields of strawberry after crop rotation and bare fallowing treatments in the *Pratylenchus penetrans*-infested field site on farm PP.

Rotation crop	Necrosis index[a]			Fruit yield[b] (g/plant)		
Year	2001	2002	2003	2001	2002	2003
Corn	1.8c[c]	1.6bc	1.2c	110ab	102b	100b
Rice	0.0a	0.0a	0.0a	145b	93ab	99b
Taro	0.1a	0.0a	0.0a	149b	115b	95b
Tomato	0.9b	0.6b	0.2b	132ab	100b	95b
Lana vetch	2.5c	2.7c	2.5d	93a	72a	50a
Fallow	0.0a	0.0a	0.0a	150b	110b	92b

populations, and the following strawberry yield was better than the bare fallow treatment. In fields where *M. hapla* is the key nematode pest, lana vetch would be a suitable rotation choice; however, continuously rotating with this plant is not recommended, because it is a good host for the root-lesion nematodes common in this production area.

Strawberries used to be planted continuously to produce runners for seedlings in high-altitude areas. This explained the high prominence values of *M. hapla* and *P. penetrans* found on Farms MH and PP. The irrigation in these fields depended on ground water, and the year 1999 was a very dry year. Strawberry growth in Farm MH was generally poor that year, and it also effected a large change of prominence value of *M. hapla*. Tissue-culture seedlings are now available and fields in the high-altitude areas are free for rotation. Farmers have used rotation with bitter gourd and other winter vegetables because the earlier harvest time (late August) meant a better market price. However, our results showed that the current bitter gourd-strawberry rotation resulted in high *M. incognita* population densities and poor growth of strawberry. Based on these concerns, some of the high economic value crops which were suitable for the climate in this area, such as edible soybean, tomato, okra and pepper, as well as bitter gourd, were evaluated in this study. The data on bitter gourd showed it was an

TABLE 4B. The necrosis index and fruit yields of strawberries after crop rotation and bare fallowing treatments in the *Pratylenchus coffeae*-infested field site on farm PC.

Rotation crop	Necrosis index			Fruit yield (g/plant)		
Year	2001	2002	2003	2001	2002	2003
Corn	2.3c	2.2c	1.9c	88a	85a	90a
Rice	0.0a	0.0a	0.0a	150b	146b	134b
Bitter gourd	0.2a	1.2bc	1.5c	142bc	80a	82a
Taro	0.7b	0.3a	0.5b	140c	140b	148b
India sesbania	3.3d	0.9b	0.7b	85a	120ab	130b
Fallow	0.0a	0.0a	0.0a	152b	125ab	129b

[a]Necrosis index ranged from 0 to 4 and was based on percentage of lesion area on the roots; 0 = 0%, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%.
[b]Fruit weights were obtained by randomly sampling one row of the block, taking all the mature strawberries from the plants and dividing by the number of plants in the row.
[c]Means in the same column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

excellent host for *M. incognita* and the *Pratylenchus* spp. Strawberry yields in the *M. incognita*-infested fields following bitter gourd were reduced by 48.6% (2001) to 71.2% (2002), compared to the bare fallow treatment. Similarly, soybean and okra were also good hosts for *M. incognita*, and these crops are not suitable for rotation in this local farming system. Tomato was further evaluated in 2001 to 2003 in this study. Although populations of both *M. hapla* and *P. penetrans* were suppressed following rotation with tomato (Table 2), the average strawberry yields of three years were reduced 51% by *M. hapla* and 5.9% by *P. penetrans*, when compared to the average strawberry yield following the bare fallow treatment. Rotation with pepper also lowered population densities of *M. hapl*a, but the strawberry yield following pepper was reduced by up to 54% (2001) compared to the bare fallow treatment.

Disease complexes usually involve pests from different categories. In a previous study, rotation crops effectively lowered the population of *M. incognita* on eggplant, but later the plants exhibited root-tip and stubby-root damage typical of *Belonolaimus* spp. or *Paratrichodorus* spp. (McSorley and Dickson, 1995). Other research also indicated that a disease complex with *P. penetrans* and *Rhizoctonia fragariae* is damaging to strawberry. The efficacy of crop rotation as a general management tactic is unproven since specific rotation crops have not been evaluated sufficiently for both nematodes and fungi (LaMondia, 1999). These examples illustrate the risks of using rotation crops effective against a single key pest. Rotation with taro reduced the populations of the four key nematodes to two or less nematodes per 100 cm^3 soil. The average yields of strawberry after bare fallow increased 2.4% and 6.3% when *P. penetrans* and *P. coffeae* were present, respectively. Plant pathogens other than nematodes were also found in the Dahu area causing diseases such as anthracnose, bacterial wilt, and Phytophthora blight. Taro as well as strawberry was very susceptible to Phytophthora blight, and the incidence of Phytophthora blight on strawberries following taro was high.

Corn would be a good choice for rotation in this local farming system because it is not a host for these fungal and bacterial pathogens and also has high economic value (US$3,902/ha, Anonymous, 2000) compared to the rice rotation. Corn lowered populations of the two *Meloidogyne* species, and strawberry yields were also increased following corn. However, corn was a host for both root-lesion nematodes; the average strawberry yields following corn were reduced 34.7% and 8.4%, respectively, when *P. coffeae* or *P. penetrans* were present.

There is no single rotation, rootstock, or nematicide that can control all nematode pest problems, and strategies of nematode control must remain as flexible as the agricultural systems in which they operate (McKenry, 1987). In the Dahu local farming system in

Taiwan where *M. incognita*, *M. hapla*, *P. coffeae* and *P. penetrans* are dominant plant-parasitic nematodes, our results indicate that rotation with corn or bare fallow are suitable management options depending on the key pest nematode present in a strawberry field, resulting in reduced nematode populations in soil and increased revenue for the growers.

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