Interaction between *Pratylenchus sefaensis*, *Meloidogyne javanica* and *Rotylenchulus reniformis* in sole and mixed crops of maize and cowpea

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Summary

The interaction between *Pratylenchus sefaensis* Fortuner, *Meloidogyne javanica* (Treub) Chitwood, and *Rotylenchulus reniformis* Linford & Oliveira on cowpea and maize grown sole and in association was studied in a split-plot experiment having nematodes in the main, and cropping in the subplots. Under sole crops of maize and cowpea, respectively, *P. sefaensis* and *M. javanica* were three and two times as numerous as those under the crop mixtures; *R. reniformis* was nine times more abundant under cowpea than under maize sole crop. In all cases, mixed cultures significantly reduced soil numbers of *P. sefaensis* relative to maize monoculture, and *M. javanica* and *R. reniformis* relative to cowpea sole crop with consequent benefits to both crops. Within cowpea roots, both *P. sefaensis* and *R. reniformis* were less in plants under mixed cultures, although *R. reniformis* inside maize roots increased under the system. The nematodes in concomitance inhibited one another significantly, especially where the three occurred together. *M. javanica* inhibited *P. sefaensis* penetration into the roots of cowpea and maize more than did *M. javanica* occurring together with *R. reniformis*. *P. sefaensis* enhanced the entry of *R. reniformis* into cowpea and maize roots. Least yields of maize and cowpeas were harvested where *P. sefaensis* and *M. javanica* respectively occurred alone. But the shoots, roots and plant heights of maize were reduced in treatments receiving *P. sefaensis* alone or in combination with *M. javanica* and/or *R. reniformis*. Similar reductions [illegible]

populations of these nematodes. Cropping systems constitute a key determinant in the predominance of a nematode species in a

In West Africa, species of *Pratylenchus, Meloidogyne* and *Rotylenchulus* often naturally occur together on common host plants, especially cowpea, *Vigna unguiculata* (L) Walp (Caveness, 1965 *b*, 1973; Olowe, 1981). *P. brachyurus* Godfrey, *M. javanica* (Treub) Chitwood and *R. reniformis* Lindord & Oliveira are individually known to cause significant economic losses on maize, *Zea mays* L. (Caveness, 1965; Olowe, 1969; Egunjobi, 1974) and cowpea (Caveness, 1973; Ogunfowora, 1976), both of which are normally grown in association in traditional mixed cultures.

Scanty information exists on the interaction of these nematodes in agricultural lands (Taha & Kassab, 1978 *a, b*), although the interaction between other nematode species have been studied (Johnson & Nusbaum, 1970; Gray & Bird, 1972; Turner & Chapman, 1972; Thomas & Clark, 1983 *a, b*).

The ecology of nematodes on crops in mixed cultures is still poorly understood (Egunjobi, 1984), despite the current belief that multiple/mixed crop cultures may possess pest management properties (Perrin, 1977). Recent evidence shows that mixed cropping systems may reduce insect pests by up to 50-90 % under certain conditions. Nwosu (1981) also indicated that resource efficiency is higher for mixtures than for sole crops.

This study sought to understand how mixed cropping systems may affect the population dynamics of *P. sefaensis, M. javanica,* and *R. reniformis* in soil and within the roots of maize and cowpea when occurring singly and together. It also attempted to relate these populations to the yield of the crops.

Materials and methods

The investigations were carried out in 0.26 m^3 microplots in an open field at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (lat. 7° 30′ N, long. 3° 54′ E). The soil was of the Apomu series, composed of 68 % sand, 17 % silt, 5 % clay, with a pH of 6.5. The plots had supported one crop of cassava (*Manihot esculenta* Crantz) during the previous year, and herboured about ten *Rotylenchulus reniformis*/100 ml of soil. *Pratylenchus brachyurus* were occasionally encountered in negligible numbers

iii) Cowpea cv. Ife BPC grown in association with maize cv. Farz 27 (MzC^1).

iv) Cowpea cv. Ife Brown grown in association with maize cv. Farz 27 (MzC^2).

v) Sole crop of maize, cv. Farz 27 (Mz).

Seeds were sown three per hole and four holes per microplot on April 1, 1983, spaced 30 cm. apart, and thinned to one per hole one week after planting.

Nematode treatments (main treatments)

Seven days after planting, and in appropriate plots, each plant was inoculated with 2 000 *P. sefaensis* and 2 000 *M. javanica,* separately or together as necessary, in addition to the natural soil populations (10/100 ml) of *R. reniformis.* This results in the following seven nematode treatments :

1) *R. reniformis* alone (R).
2) *R. reniformis* + *P. sefaensis* (R + P).
3) *R. reniformis* + *M. javanica* (R + M).
4) *M. javanica* alone (M).
5) *P. sefaensis* alone (P).
6) *M. javanica* + *P. sefaensis* (M + P).
7) *M. javanica* + *P. sefaensis* + *R. reniformis* (M + P + R).

Viable eggs plus larvae of *M. javanica* used for the inoculation were extracted by the method of Hussey and Barker (1973) from roots of previously infested pawpaw (*Carica papaya* L.) trees. They were inoculated with a pipette in 10 ml water around each seedling roots. *P. sefaensis* was inoculated on finely chopped 2 g infested maize roots.

Crop culture

The plants were watered daily during the dry season until stable rains persisted. At planting, fertilizer (NPK 15 : 15 : 15) was appliet at 100 kg/ha. Each treatment was replicated thrice. The experiment was terminated fourteen weeks after planting (15-7-83).

Nematode and crop yield assessment

Soil and root nematode populations were assessed at [illegible] weekly for nine weeks, commencing seven days after planting. Grain yields were harvested at maturity from cowpea, ten weeks, and from maize, fourteen weeks after planting. Fresh shoot and root weights were taken for both maize and cowpeas. Pod weights, seed numbers per pod and pod numbers per plant were also recorded in respect of cowpeas. All data were subjected to combined analysis of variance, and the means were compared by Fisher's LSD and Duncan's multiple range tests.

Results

Nematode populations as influenced by the cropping systems

When compared under the cropping systems, *P. sefaensis* populations were significantly highest in soil under maize sole crops and least in soil under cowpea monocrops (Fig. 1). On the contrary, *M. javanica* and *R. reniformis* were most abundant in soil under cowpea monocultures, and least under maize (Fig. 1).

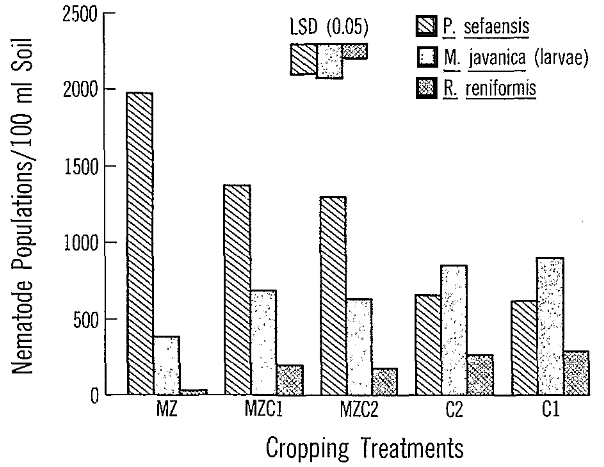

Fig. 1. Populations of *Pratylenchus sefaensis, Meloidogyne javanica* and *Rotylenchulus reniformis* under maize/cowpea sole and mixed cultures.

Mixed cultures reduced significantly soil populations of *P. sefaensis* relative to maize monocultures; and the populations of *M. javanica* and *R. reniformis* relative to cowpea monocultures (Fig. 1). *R. reniformis* populations were highest and least in soil under monocultures of cowpea and maize respectively. Within cowpea roots, *P. sefaensis* as well as *R. reniformis* were significantly reduced by the mixed cultures (Figs 2 & 8). Cowpea cv. Ife Brown maintained significantly higher populations of *M. javanica* than the cultivar Ife BPC. Both *M. javanica* and *R. reniformis* were significantly more numerous within the roots of maize grown in association with the cowpeas than in roots of maize in sole crop (Fig. 3). But populations of *P. sefaensis* within maize roots

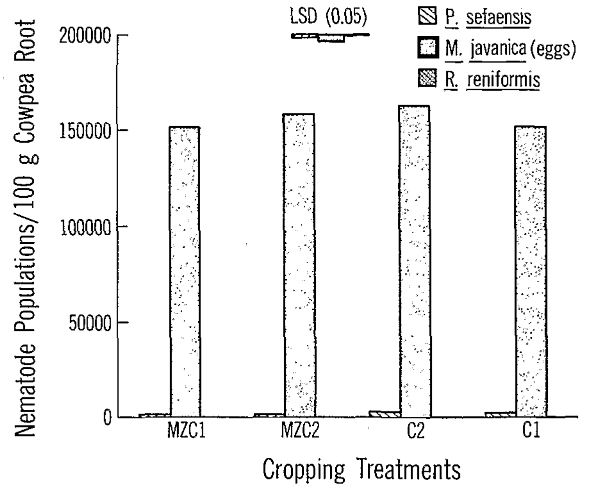

Fig. 2. Populations of *Pratylenchus sefaensis, Meloidogyne javanica* and *Rotylenchulus reniformis* within cowpea roots as influenced by maize/cowpea sole and mixed cultures.

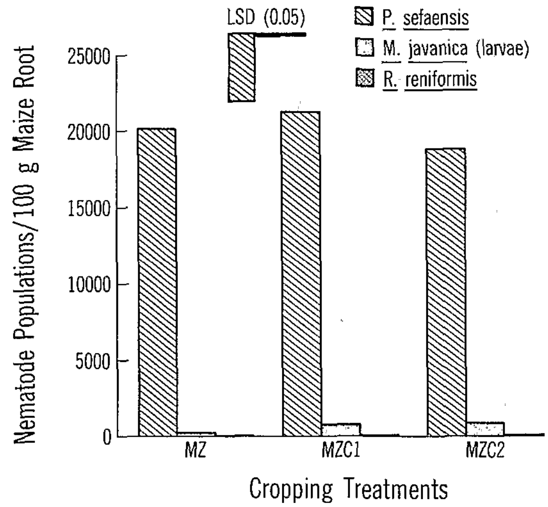

Fig. 3. Populations of *Pratylenchus sefaensis, Meloidogyne javanica* and *Rotylenchulus reniformis* within maize roots as affected by maize/cowpea sole and mixed cultures.

were not significantly affected by the mixed cultures (Fig. 3).

Nematode-nematode interaction as it affects the component species

Pratylenchus sefaensis

Generally, *P. sefaensis* was most abundant in soil wherever it occurred alone, and minimal where the three nematodes occurred together (Fig. 4). This pattern was consistent for most cropping systems although differed in the maize monoculture where *P. sefaensis* population

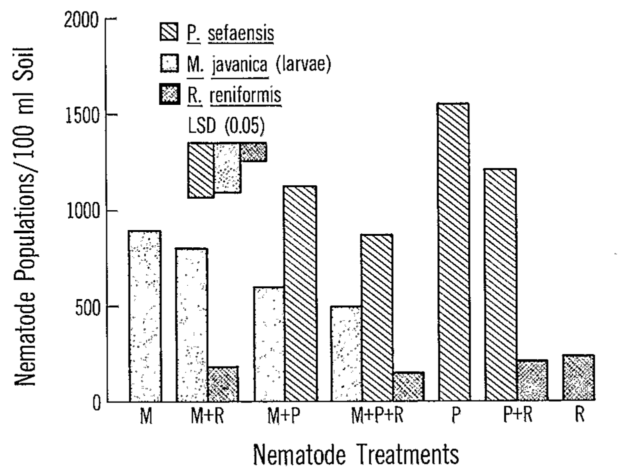

Fig. 4. Effects of the interaction between *Pratylenchus sefaensis*, *Meloidogyne javanica* and *Rotylenchulus reniformis* on population levels of the component species in the soil.

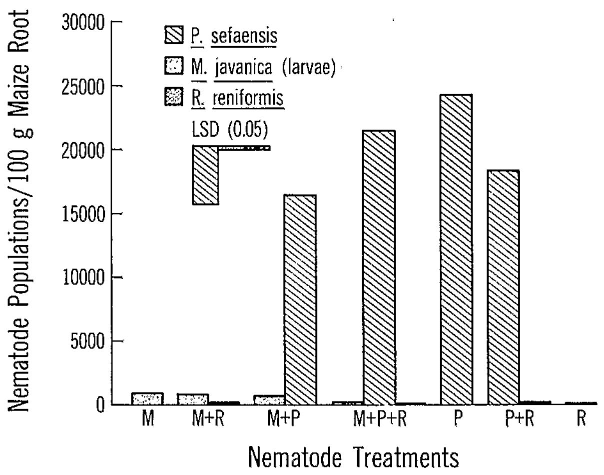

Fig. 6. Effects of the interaction of *Pratylenchus sefaensis*, *Meloidogyne javanica* and *Rotylenchulus reniformis* on populations of the component species within maize roots.

was highest in presence of *M. javanica*. That numbers of *P. sefaensis* inside both maize and cowpea roots were highest when occurring alone and lowest, when in concomitance with *M. javanica* (Figs 5 & 6) was also consistent for all cropping systems.

Meloidogyne javanica

Both in the soil and within maize and cowpea roots,

all cropping systems except in roots of maize in sole stand where *M. javanica* was significantly highest in presence of *P. sefaensis* (Fig. 10).

Rotylenchulus reniformis

R. reniformis, when occurring alone in the soil, was on the average 1 3/4 times as numerous as when the three nematode species occurred together (Fig. 4). But within maize roots, highest and lowest populations occurred

The cropping systems also affected the pattern of interaction in the soil. Under both cowpea and maize sole crops, *R. reniformis* numbers were lowest where the three nematodes co-existed, and highest usually where it occurred alone. However, in the mixed cultures, lowest populations were on the contrary, recovered where the nematode occurred alone, and the highest where the three occurred in concomitance (Fig. 8).

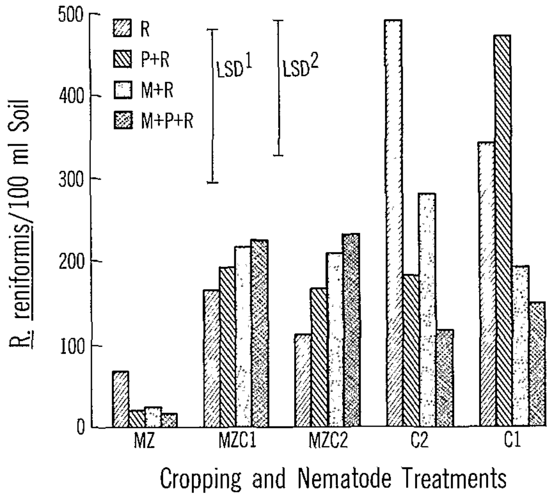

Fig. 8. Soil populations of *R. reniformis* under selected cropping and nematode treatments.

it received only *P. sefaensis*. Indeed, yield was lower in all treatments receiving *P. sefaensis* than those without.

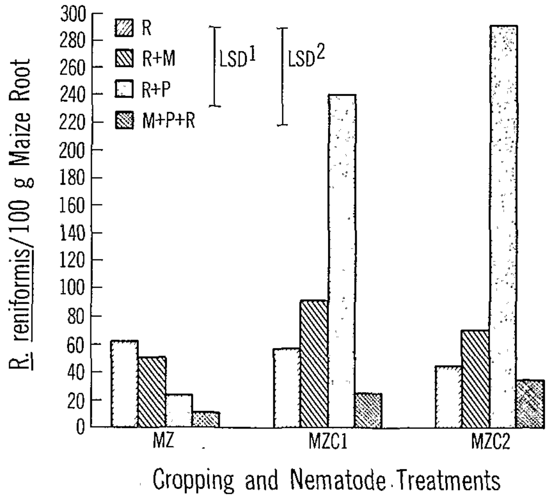

Fig. 9. Maize root populations of *R. reniformis* under selected cropping and nematode treatments.

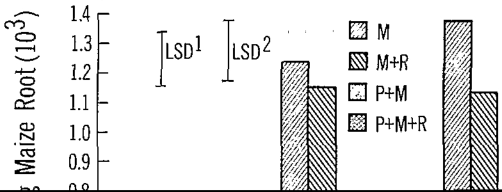

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Table 1

Cowpea yield in relation to nematode treatments

	Yield parameters						
Nematodes	*Grain yield (g/plant)*	*Root wt. (g/plant)*	*Shoot wt. (g/plant)*	*Pod (no/plant)*	*Seed (no/pod)*	*Pod (wt/plant)*	*Plant height (cm)*
P + R	15.8[(1), (a)]	65[e]	184[a]	11.3[a]	14.3[a]	17.5[a]	135[b]
R	14.9[a, b]	68[c]	190[a]	11.3[a]	14.1[a, b]	17.0[a]	157[a]
P	14.3[b]	67[c]	197[a]	10.5[b]	13.8[b]	16.0[b]	130[c]
M + R	6.6[c]	95[c]	151[b, c]	4.8[d]	11.2[c]	7.9[c]	104[d]
M + P	6.4[c]	104[b]	163[b]	5.8[c]	10.8[c]	7.7[c]	100[e]
M + P + R	6.1[c]	90[d]	141[c]	4.8[d]	10.3[d]	7.1[c]	98[f]
M	4.6[d]	122[a]	147[b, c]	4.4[d]	10.2[d]	5.3[d]	88[f]
LDS (5 %)	0.87	4.90	18.01	0.61	0.38	0.89	1.86

(1) Means of twelve replicates each.
(a) Figures followed by the same letters are not statistically significantly different from one another (Duncan's test).

Table 2

Maize yield in relation to nematode treatments

	Yield parameters			
Nematodes	*Grain yield (g/plant)*	*Root wt. (g/plant)*	*Shoot wt. (g/plant)*	*Plant height (cm)*
M	95[(1), (a)]	122[a]	377[a]	184[c]
R	94[a]	118[a]	367[a]	195[a]
M + R	93[a]	126[a]	408[a]	187[b]
P + R	82[b]	83[b]	290[d]	163[f]
M + P	76[b]	103[b]	337[c]	177[d]
P + M + R	76[b]	76[c]	286[d]	173[f]
P	63[c]	65[d]	284[d]	160[g]
LSD (5 %)	8.45	7.52	25.0	1.48

(1) Means of twelve replicates each.
(a) Figures followed by the same letters are not statistically significantly different from one another (Duncan's test).

Discussion and conclusions

Cropping systems and nematode numbers

In the soil, nematode populations were selectively and significantly affected by maize and/or cowpea crops. The predominance of *P. sefaensis* on one hand and *M. javanica* and *R. reniformis* on the other hand, in maize and cowpea soils, respectively, is a strong indicator of their host preferences. *Pratylenchus* spp. have long been associated with maize (Dickerson, Darling & Griffin, 1964; Olowe, 1969; Tarte, 1971; Olthof & Potter, 1972; Caveness, 1973; Norton & Nyvall, 1982); whereas *M. javanica* and *R. reniformis* are more important parasites of cowpeas (Sellshop, 1961; Caveness, 1965 *a, b,* 1973; Ogunfowora, 1981; Olowe, 1981). Our results confirm these earlier findings.

Whereas populations of *P. sefaensis* within cowpea roots were significantly influenced by the cropping treatments, those within maize roots were unaffected. Egunjobi (1984) made a similar observation in respect of *P. brachyurus* and maize cv. NSl associated with three grain legumes including cowpea. However, the entry of *M. javanica* and *R. reniformis* into maize roots was significantly enhanced by the presence of cowpea in the

Table 3

Cowpea yield patterns under mixed and monocultures of maize and/or cowpea

[redacted]

Crops	*Grain yield (g/plant)*	*Pod (g/plant)*	*Seed (no/pod)*	*Pod (no/plant)*	*Shoot wt. (g/plant)*	*Root wt. (g/plant)*	*Plant height (cm)*
C^2	$10.1^{(1),(a)}$	11.4^{a}	12.4^{a}	8.0^{a}	185^{b}	$88^{a,b}$	120.0^{a}
MzC^2	$9.9^{a,b}$	11.3^{a}	12.0^{a}	7.7^{a}	196^{a}	93^{a}	135.0^{a}
Mzc^1	$9.7^{a,b}$	11.0^{a}	12.1^{a}	7.6^{a}	149^{c}	$86^{b,c}$	110.0^{c}
C^1	9.5^{b}	11.1^{a}	12.0^{a}	7.5^{a}	141^{c}	82^{c}	100.0^{d}
LSD (5 %)	0.48	0.48	0.48	0.48	2.09	8.50	8.71

(1) Means of 21 replicates each.
(a) Figures followed by the same letters are not statistically different from one another (Duncan's test).

Table 4

Maize yield patterns as influenced by mixed and monocultures of maize and/or cowpeas

Crops	*Yield parameters*			
	Grain yield (g/plant)	*Shoot wt. (g/plant)*	*Root wt. (g/plant)*	*Plant height (cm)*
Mzc^1	$88^{(1),(a)}$	341^{a}	104^{a}	179^{a}
MzC^2	82^{b}	339^{a}	100^{a}	180^{a}
Mz	79^{b}	327^{b}	94^{b}	171^{b}
LSD (5 %)	5.24	9.84	4.93	2.46

(1) Means of 21 replicates each.
(a) Figures followed by the same letters are not statistically significantly different from one another (Duncan's test).

crop infestation by these nematode pests. What the cropping system does to a nematode pest, and whether the crop benefits or losses from the association is relative to the crop components and the principal nematode [redacted]

NEMATODE-NEMATODE INTERACTION AND POPULATIONS OF THE COMPONENT NEMATODE SPP

Generally, each component nematode species was inhibited by the presence of the others, especially in the soil where the more the species present, the more was the inhibition. This also was true of *M. javanica* within cowpea roots. These results confirm many earlier ones and suggest that activities of a nematode species are inhibited by the presence of other nematode species (Estores & Chen, 1971; Gray & Bird, 1972; Turner & Chapman, 1972; Singh, 1976; Taha & Kassab, 1978). The nature of inhibition, however, varies with species composition and the nematode environment. For example *P. sefaenis* within both maize and cowpea roots was more significantly inhibited by *M. javanica* than by the three species together. So also, *R. reniformis* differed from the others in that it was most numerous, within maize and cowpea roots where it occurred with *P. sefaensis,* and least where the three occurred together. *Meloidogyne* spp. reproduction was more affected than that of *Pratylenchus* where *Meloidogyne* and *Pratylenchus* spp. occur together. Turner & Chapman, 1972; Gray & Bird, 1972; Van Gundy & Kirkpatrick, 1975). Thomas and Clark (1983*a*) found that large populations of *M. incognita* inoculated into a field naturally infested [redacted] initial nematode numbers. Johnson and Nusbaum (1970) claimed that the mechanism of *M. incognita, M. hapla,* and *P. brachyurus* associative interaction was indirect, involving individual host-nematode responses.

Our pre-experimental nematode count however confirmed Clark's (1983*b*) claim that *Meloidogyne* spp. has lower survival rate than *R. reniformis* : in pre-experimental soil samples taken during the dry adverse season (March 1983) soil populations of *R. reniformis/M. javanica* was in the ratio 20 : 1. Final populations under their favoured cowpea crop showed a reproductive potential ratio of 100 : 1 for *M. javanica/R. reniformis.*

Reductions in populations of *P. sefaensis* in the roots of cowpea grown with maize was perhaps due to a diversionary effect whereby maize, being a better host of the nematode than the cowpea, attracted more *P. sefaensis* than did the cowpea. Trenbath (1976) proposed such a diversionary action in explaining a similar situation in Australia.

Nematode interactions, cropping systems and the yield of maize and cowpeas

An improvement of 10-11 % in maize grain yield associated with the mixed cropping systems is negatively correlated with a 31 % reduction in *P. sefaensis* popu-

distances of 130 cm that separated our experimental microplots.

With respect to maize yields in mixed cultures, Agboola and Fayemi (1971), and Andrews (1972*a*, 1972*b*) reported reductions in yield where cereals were intercropped with grain legumes. But, interplanting maize with cowpea had no effect on maize yield, according to a study by the Nigerian Federal Department of Agriculture (Anon., 1953). Naugju (1973) explained a mixed-culture induced yield increase in maize in terms of greater utilization of environmental resources and lower incidence of diseases. Egunjobi (1984) agreed with the latter in relation to increased maize yield in maize-cowpea mixed cultures on *P. brachyurus* infested field.

Yield patterns when related to nematode community structure and population patterns of specific nematode species tend to indicate the host preferences of the component nematode species in concomitance. Whereas significant reductions in cowpea yields were, for example, associated with *M. javanica,* especially when occurring in monospecific communities, the crop suffered no such losses associable with *P. sefaensis* or *R. reniformis* either singly or in concomitance. On the contrary, maize declines were associated with the presence of *P. sefaensis* alone or in combination with the other nemareductions. *Meloidogyne* spp. is less often associated with maize yield declines. It became evident only recently that these species could cause as much as 8 % to 14 % yield loss in maize in Central America and Tropical Africa respectively (Sasser, 1979). Similar to our observations, and contrary to Saka's (1981), Hemeng (1981) found no galls on maize roots in Ghana, although reduced productivity was evident at very high inoculum rate of 90 egg masses per plant.

Where *R. reniformis* occurred alone, no reductions in maize nor cowpea were evident when yields were compared with those from plots treated with the other nematodes. Although maize is a poor host of *R. reniformis* (Caveness, 1967), it is known to cause significant reductions in cowpea yields (Gupta & Yadav, 1980), a reduction which, understandably cannot be apparent under our particular situation where comparisons are made with more competitive nematodes like *M. javanica*. However, our results indicate that *R. reniformis*, an apparently insignificant parasite of maize, could become pathogenic to maize when associated with *Pratylenchus* spp.

Although *M. javanica* and *R. reniformis* co-exist usually on cowpea, *R. reniformis* appears to be a weaker pathogen than *M. javanica*. Thomas and Clark (1983*a*) made similar observations and explained that higher reproductive capability and a destructive self-limiting effect of *M. incognita* may constitute a major weapon in the inhibition of *R. reniformis* by *M. incognita*. In this study, reproductive potential $\left(\frac{pf-pi}{pi}\right)$ of *M. javanica* was 100 times better than that of *R. reniformis*. Our results, however, disagree with Johnson (1969) and Thomas and Clark (1983) who reported a linear correlation between increases in numbers of nematode species and decreasing yield, indicating that variations are to be expected with differences in the environmental factors, host plants, and the nematode species involved.

Conclusions

Evidence from this study indicate that host crop plays a key role in the determination of which nematode species predominates in a given field and time. It is also feasible that cropping maize together with cowpeas may prove an effective weapon in the management of some nematode pests with specific advantages for maize crop in particular.

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