THE INFLUENCE OF CLIMATIC FEATURES ON DISTRIBUTION AND INFECTION OF ROOT- KNOT NEMATODES, *MELOIDOGYNE* SPP, IN COWPEA GROWING AREAS IN NIGERIA.

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Abstract

The effect of climatic features on distribution and infection of root knot nematodes was investigated in 248 cowpea growing areas in 31 states and the Federal Capital Territory of Nigeria. The studies revealed pronounced incidence of *Meloidogyne javanica* (65.5%) at high altitude of 500-2000 m, high mean annual maximum temperature of 32-40 °C, low mean annual minimum temperature of 11-18 °C, low mean annual precipitation of 0.1-1530 mm and in hot Sudan savannah vegetation of six months or less of wet and dry season, prevailing in the core North (North east and North west) of the Northern region. In contrast, *M. incognita* (83.1%) was overwhelmingly dominant at low attitude of 15-650 m, mean annual maximum temperature of 24-27 °C, mean annual minimum temperature of 21-23 °C, mean annual precipitation of 1170-4700 mm and in warm humid forest vegetation of 8 months or more of wet season and 4 months or less of dry season, operating in the southern region (Southeast, Southwest and Southsouth). The two species (*M. incognita*) (44.2%) and *M. javanica* (51.7%) were, however, common at intermediate altitude of 305-1859 m, moderate mean annual maximum temperature of 29-32 °C, moderate mean annual minimum temperature of 18-21 °C, moderate mean annual precipitation of 800-2000 mm and in moderate Guinea savannah vegetation of 7 months of wet season and 5 months of dry season, prevailing in the Middle belt (North central). The distribution of *M. arenaria* though sparse (4.1%), followed that of *M. incognita* in relation to altitude, temperature, precipitation and vegetation. In overall distribution, *M. incognita* (51.8%) was more widespread than *M. javanica* (44.1%). The occurrence of pure population of *M incognita* (31.9%) and *M. javanica* (37.1%) was encountered. *Meloidogyne arenaria* was never found as a pure population or as a mixture with *M. javanica* but with *M. incognita* (2.0%) or with *M. incognita* and *M. javanica together* (4.0%). The mean galling infection by the two species was significantly more severe in the humid forest southern region (11-50% of the root system galled) than in the dry Sudan savannah Core North (1-30% of the root system galled). Generally, *Meloidogyne incognita* caused more severe mean galling infection (11-30% of the root system galled) than *M. javanica* (1-10% of the root system galled). The polarized ecological distribution and infection of the *M. incognita* and *M. javanica* in, the present studies show the climatic preference of the nematodes, and gives a guide in targeting a workable control strategy.

Keywords: Climatic features, cowpea, distribution, infection, root-knot nematodes.

1. Introduction

The cowpea, *Vigna unguiculata* (L.) Walp., is a draught tolerant grain legume (Hall and Patel, 1987) well adapted to semi-arid region, and can grow in almost every ecological zone including space station (Ohlers and Mitchel, 1995). The world annual dry grain production of the crop is estimated at 3.7 million tonnes on an area of 9.8 million hectares with an average world grain yield of 0.378 tonnes/ha (FAO, 2004) and Nigeria produces 2.2 million tonnes annually on 5 million hectares of land at an average gain yield of 0.440 tonnes/ha (FAO, 2004) with the core North (Northeast and Northwest) accounting for the largest production (84%) (FOS, 1998).

The crop is an important grain legume human food (Bittenbender, 1992), animal feed (Norman et al., 1982), medicinal herbs (Duke, 1990), agricultural/ horticultural crop and as a source of revenue earning (Bitten-bender *et al.*, 1984).

The Cowpea crop is attacked by numerous plant parasitic nematodes (Caveness and Ogunfowora, 1985). However, the root knot nematodes, especially *M. incognita*, *M. javanica*, *M. kikuyensis* and *M.*

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hapla, are of major economic constraint to cowpea production (Sasser, 1979; Roberts *et al.*, 1996), and are reported to cause a grain yield loss between 5 and 69%(Krishnappa, 1985; Luc *et al.*, 1990) or of 43% grain loss singly or in combination in West Africa (Sasser, 1979) with *M. incognita* causing the greatest grain yield loss followed by *M. javanica* and *M. arenaria* (Toler *et al.*, 1963). Though root-knot nematodes are pathogenic on cowpea, the distribution and infection of the nematodes are influenced by climatic factors of altitude, temperature, and rainfall. *Meloidogyne javanica* is variously reported to be of wide distribution in high and *Meloidogyne incognita* in low altitudes (Abu-Gbabieh, 1979; Stephen, 1979; Idowu, 1981; Taylor *et al.*, 1982). *Meloidogyne arenaria* showed similar distribution for the same range of altitudes as *Meloidogyne incognita* (Taylor *et al.*, 1982).

However, at intermediate altitude with moderate rainfall, the two species (*M. incognita* and *M. javanica*) manifested about the same distribution as both species were common (Whitehead, 1969).

Considering temperature effect, *Meloidogyne javanica* was reported to be pronounced at a temperature as low as 12-21 °C and as high as up to 36 °C than *M. incognita* (Taylor *et al.*, 1982; Noe & Sikora, 1990) which could hardly survive at low temperature of about 15 °C and high temperature of about 33 °C (Sasser *et al.*,1983). *Meloidogyne javanica* also manifested a higher optimum temperature requirement of 4-5% than *M. incognita* (Ibrahim, 1985). The temperature requirement of *M. arenaria* for cold or warm conditions overlaps that of *M. incognita* (Taylor *et al.*, 1982).

Rainfall intensity and pattern are reported to be associated with distribution of root knot nematodes (Caveness and Badra, 1980; Taylor *et al.*,1982) *Meloidogyne javanica* was more dominant at dry condition than *M. incognita* and *M. arenaria* as it could thrive well under dry condition of up to 12 months and with precipitation as low as 2 mm (Idowu, 1981; Taylor *et al.*,1982). The moisture requirement of *M. arenaria* blends with that of *M. incognita* as the species flourished (68-70%) in wet conditions of up to 1500 mm as *M. incognita* (Sasser *et al.*,1983) but rarely (5%) survives a precipitation of 10 mm and dry condition of 11 to 12 months (Taylor *et al.*,1982). However, mixture of the three species, but commonly of *M. incognita* and *M. javanica*, thrived when the rainfall just exceeded 500 mm and well distributed over the year (Whitehead, 1969; Taylor *et al.*,1982).

In Nigeria, three species of root knot nematodes, *M. incognita*, *M. javanica* and *M. arenaria* occurred with the prevalence of *M. javanica* in the hot Northern savannah region (Wilson, 1962) and *M. incognita* in the warm Southern humid forest region (Caveness, 1967a). These nematodes, singly or in combination have been implicated in grain yield loss of cowpea of up to 94% (Caveness, 1973; Ogunforwora 1976; Olowe, 1981; Fademi and Fawole, 1992).

Inspite of root knot nematodes as disease causal agents limiting the production of cowpea, little work has been done on elucidating the effect of climatic influence in regulating the prevalence and infection of these root knot nematodes on cowpea as a single crop. In order to target an effective control strategy, it is desirable to investigate the relative importance and distribution of the root knot nematodes as potential production constraint on cowpea, and the precise role of climatic features. Therefore, the present study sought to determine the distribution and infection of the root knot nematodes in both the savannah Northern and humid forest Southern regions of Nigeria as influenced by altitude, temperature, rainfall and vegetation.

2. Materials and Methods

(a) Soil and root sample collection

The incidence and infection of root knot nematode in relation to climatic features were evaluated in 248 cowpea farms in 31 states and the Federal Capital Territory, covering both the Northern and the Southern regions of Nigeria (Fig. 1.). Soil and root samples between 20 and 30 were collected in a systematic zigzag (Z) manner across each farm field depending on the size of the field. The soil samples were collected around the root at 10-15 cm soil depth with a hand trowel. The roots were carefully uprooted with a spade fork, and rated for the proportion of the root system galled (Elimiligy, 1968; Kinlock, 1990): 1 = 0 (no infection), 2 = 1-10% of the root system galled (slight infection), 3 = 11-30% (moderate infection), 4 = 31-50% (heavy infection), 5 = 51-75% (severe infection) and 6 = 76-100% (very severe infection). The top plants were then cut off, leaving the root system. The soil samples from each farm were pooled together, mixed thoroughly, and a sub-sample of about 1.5 kilogram was taken into a polythene bag. The roots were similarly pooled together, tied with a piece of twine, and added to the corresponding soil samples. The soils with the root samples were then taken to the laboratory and kept in refrigerators at 5 °C, while awaiting processing for species identification and analysis.

(b) Root knot nematode identification

In the laboratory, galls were cut off from infected roots from each farm, the galls were mixed thoroughly, and fifty galls were randomly taken and placed in Petri-dishes. Adult root knot nematode females were teased out of the root galls from each of the cowpea farms, and transferred into a single Petri-dish. A minimum of 30 mature adult females were randomly taken and processed for perienal pattern mount (10 patterns per slide) (Taylor and Netscher, 1974) for species identification (Eisenback *et al.*,1981).

(c) Bioassay

To determine whether root knot nematodes were present in farms that showed no galling infection at the time of sampling, about 1 Kg of soil from soil collection from each of the cowpea farms (40) showing no root galling infection (15.8%) were potted into 12.5 cm plastic pots and sown to a known susceptible cowpea cultivar Acc. 73001. The cultures were maintained in the greenhouse to allow for development of the adult females and galling infection of the roots. The infected and galled roots were then uprooted as needed as from 60 days after planting. The matured adult females were randomly teased out from the galls and processed for root knot nematode identification as described above.

(d) Climatic features

Information on the climatic features in the sample areas were collected from the agricultural stations in localities and states where samples were collected.

(e) Statistical Analysis

The data on root galling infection were subjected to ANOVA analysis to determine statistical significance in galling infection. The means were separated by Fisher's LSD test at P = 0.05. Associations among the various physicochemical features were correlated using Pearson correlation coefficient.

3. Results

(a) Altitude and distribution

The occurrence of *M. incognita*, *M. javanica* and *M. arenaria* showed relationship with altitude. *Melodiogyne incognita* occurred predominately (83.1%) at low altitude of 15-650 m, prevailing in the South (Southeast, Southwest and South-south) while *M. javanica* was predominant (65.5%) at high altitude of 500-2000 m of the hot core North (northeast and northwest (Table 1, Fig 1). At the intermediate altitude of 305-1859 m of the Middle belt, the two species tended to be common at about the same abundance of 44.2% for *M. incognita* and 51 9% for *M. javanica* (Table 1).

(b) Temperature

Temperature affected the distribution of the nematodes differentially with *M. javanica* showing preference for higher and lower temperature than *M. incognita* (Table 1, Fig. 1). *Meloidogyne javanica* was more abundant (65.5%) at higher (hot) temperature of 32-40 °C of the core North than *M. incognita* (31.3%) which showed more abundance (83.1%) than *M. javanica* (12.8%) at lower warm temperature of 24-27 °C of the South. In the same vein, *Meloidogyne javanica* was more pronounced at low temperature of 11-18 °C in the core North than *M. incognita*, which was more concentrated at higher low temperature of 21-23 °C of the South. At the Middle belt of intermediate moderate high temperature of 29-32 °C, intermediate moderate low temperature of 18-21 °C, the abundance of the two species (*M. incognita*, 44.2%; *M. javanica*, 51.9%) assumed almost equal distribution.

(c) Precipitation and distribution

Rainfall intensity influenced the prevalence of the root knot nematodes (Table 1, Fig. 1). *Meloidogyne incognita* thrived abundantly (83.1%) at high precipitation of 1170-4700 mm, prevailing in South, while *M. javanica* flourished dominantly (65.5%) at low precipitation of 0.1-1530 mm of the core North of the North. On the other- hand, both species showed balanced abundance of about equal magnitude at intermediate precipitation of 800-2000 mm of the Middle belt.

(d) Vegetation and distribution

Vegetation affected the prevalence of the two species with *Meloidogyne incognita* abounding in the humid forest of the South and *M. javanica* in the Sudan savannah of the core North. The two species leveled up to about the same abundance in the Guinea savannah of the Middle belt (Table 1, Fig. 1).

(e) Climatic features and infection

Galling infection was significantly severe (11-50% of the root system galled) in the humid forest region of low altitude (15-650 m), warm temperature (24-27 °C) and high rainfall (1170-470 mm) prevailing in the South, where *M. incognita* was dominant (83.1%) but significantly mild (1-30% of the root system galled) in the hot Sudan savannah region of high altitude (500-2000 m), high (32-40 °C) and low (11-18 °C) temperature operating in core North where *M. javanica* was pronounced (65.5%). Overall, *Meloidogyne incognita* caused more severe mean galling infection (11-30% of the root system galled) and larger galls than *M. javanica* (1-10% of the root system galled) (Table 2).

4. Discussion

(a) Ecological distribution

The occurrence of *M. incognita*, *M. javanica* and *M. arenaria* with the prevalence of *M. javanica* in the dry Sudan savannah of the core North (North east and North west) and that of *M. incognita* in the wet humid forest South confirms previous findings (Wilson, 1962: Caveness, 1967a), and shows the differential ecological and climatic adaptation of the two species. This coupled with the commonness of the two species in the intermediate and climatically moderate and balanced Guinea savannah of Middle belt gives an insight into which species to target for control measures in the different ecological regions.

(b) Altitude and distribution

The prevalence of *M. javanica* at high altitude of up to 2000 m in the North is consonant with similar distribution studies by other workers who reported the dominance of *M. javanica* at high altitudes in

Nigeria (Idowu, 1981) and other highlands (Stephan, 1979). This may account for the ability of the species to withstand extreme cold temperature as high altitude entails coldness.

The abundance of *M. incognita* at low altitude of 15-650 m in the South collaborates similar report of concentration of *M. incognita* at low altitude below 900 m in Nigeria (Idowu, 1981) or at other low/ coastal lands (Abu-Gharbieh, 1979; Stephan, 1979). The sharp differential distribution of the two species in high and low altitudes may suggest that *M. javanica* is indigenous to high altitude and *M. incognita* to low altitude. The flourishing of the two species at intermediate altitude of 305-1829 m of the Middle belt supports the finding of Whitehead (1969) that *M. incognita* and *M. javanica* were common at intermediate altitude.

(c) Temperature and distribution

The preponderance of *M. javanica* at high temperature of 32-40 °C and low temperature of 11-18 °C in contrast to *M. incognita* which was pronounced at lower temperatures of 24-27 °C and low temperatures of 21-23 °C essentially suggests that *M. javanica* is more tolerant to high and low temperatures than *M. incognita*, and might account for its ability to thrive better under the dry conditions in the core North. In a similar distribution studies, *M. javanica* has been shown to be more tolerant to lower temperature of 12-15 °C and higher temperature of 36 °C (Taylor *et al.*, 1982; Sassser, *et al.*, 1983). Ibrahim (1985) in Jordan also reported that *M. javanica* showed an optimal temperature requirement of 4-5 °C higher than that of *M. incognita*. The species (*M. javanica*) was also reported to survive and thrive best at 27-30 °C and *M. incognita* at lower temperature of 24-25 °C (Taylor et al., 1982). The same nematode (*Meloidogyne javanica*) was also shown to reproduce well at 31 °C (Trudgill, 1995) while *M. incognita* reproduced optimally at a lower temperature of 25 °C (Ploeg and Maris, 1999) with a temperature of 35.4 °C inhibiting its reproduction (Ploeg and Maris, 1999). The low prevalence of *M. incognita* at low temperature supports similar findings by other workers. The species has also been found to be less tolerant to cold condition as about 3% of the nematode migrated through a distance of 20 cm and infected tomato roots in 10 days at low temperature of 14 °C, (Roberts *et al.*,1981), and at 16.3 °C, the species took 63 days to complete its life cycle with development becoming inhibited at 16, 12 or 8 °C (Ploeg and Maris, 1999).

The commonness of the two species at moderate low temperature of 18-21 °C and high temperature of 29-32 °C is in agreement with observation and Elmiligy (1971) that survival of nematodes is often best at moderate temperatures.

The wide range of temperature difference between the savannah core North(32-40 °C) and the humid forest South (24-27 °C) coupled with the differential temperature preference of *M. javanica* for high temperature and that of *M. incognita* for low temperature suggests the need to breed for temperature stable resistant cowpea cultivars. Resistance in crop cultivars is known to break down progressively with rise in temperature (Roberts *et al.*,1998), and even reversed by high temperature (Dropkin, 1969).

(d) Precipitation and distribution

The prominence of *M. incognita* (83.1%) at higher precipitation of 1170-4700 mm of the South and that of *M. javanica* (65.5%) at low precipitation of 0.1-1530 mm of the core North of North shows that *M. javanica* is better adapted to low moisture and dry condition than *M. incognita*. This agrees with similar finding that *M. javanica* thrived favourably under dry condition of even up to 12 months and precipitation of as low as 2 mm (Taylor *et al.*,1982), and that *M. incognita* could hardly survive under dry condition of over 4 months and precipitation of up to 500 mm and below (Taylor *et al.*,1982).

The commonness of the two species at moderate precipitation of 800-2000 mm in the Middle-belt may suggest that the rainfall intensity and pattern enhance seemingly favourable condition for multiplication of the two species and for balanced inter-specific competition. Rainfall provides the soil with moisture which is critical for nematode activity, host availability and survival during wet or dry season. Apart from governing the life process of nematodes, moisture also constitutes an important medium for migration as nematodes live in a film of water.

(e) Climatic features and infection

The more severe galling infection of the nematodes in the humid forest South than in the Sudan savannah core North may be largely attributed to the cropping regime and climatic conditions. The humid forest vegetation in the South provides 8 months of rain (precipitation, 1170-4700 mm), enabling two annual cropping seasons of early March to July and late season of August to November. This will allow for long growth of the cowpea and other host crops (Caveness, 1967b) on which the nematodes will feed and multiply rapidly during the season. The weeds (Odihirn and Adesida, 1975; Ogbujji, 1978) and grasses (Adeniji and Cheda, 1971) and the long maturity cereal component in the cowpea mixed cropping encountered in the sampled areas will collectively act as reservoir hosts to ensure continued propagation and infection of the nematodes during short dry intercrop period between seasons (Egunjobi, 1985; 1992).

The low altitude (15-6500 m) of the humid South, which ensures low water table, the favourable cool temperature of 24-27 °C (Taylor *et al.*,1982; Udo and Mamman, 1993), the facilitated moist and warm soil that drains rapidly, thereby enhancing rapid oxygen aeration (Schmidt and Norton, 1972; Norton, 1978) will further promote the continuation of multiplication and infection of the two species on cowpea.

However, the dominance and severe infection of *M. incognita* over *M. javanica* in the humid South may be related to the favourable cropping and climatic factors in addition to better suitability of the host crop, cowpea (Toler et al.,1963), favourable warm temperature which falls within the optimum temperature (25 °C) of *M. incognita* (Taylor *et al.*,1982; Trudgill, 1995) and the stronger virulence of *M. incognita* over *M. javanica* (Eisenback and Griffin, 1978). *Meloidogyne javanica* is reported to be less adapted to the climatic conditions of low altitude, cool temperature and heavy rainfall, prevailing in the humid forest South (Taylor *et al.*, 1982). However, the dominance of *M. javanica* over *M. incognita* in the dry Sudan may be attributed to better tolerance of the nematode to high (32-40 °C) and low (11-18 °C) temperature, low precipitation of 0.1-1530 mm (Sasser *et al.*, 1993; Udo and Mamman, 1993; Trudgill, 1995), prevailing in the region. *Meloidogyne incognita* is reported to poorly accommodate these climatic conditions (Taylor *et al.*,1982). Ibrahim (1985) also showed that *M. javanica* manifested higher optimum temperature of 4-5 °C over *M. incognita*.The commonness of the two species in the Guinea savannah vegetation of the Middle belt may be a function of the peculiarity of climatic condition of the vegetation in the region, which is intermediate between the two extremes of the Sudan savannah of the core North and the humid forest of the South. The vegetation of the Middle belt provides 7 months of rain which is a month more than that of the Sudan savannah vegetation of the core North and a month less than that of the humid forest vegetation of the South. The altitude (305-1829 m) and the temperature (29-32 °C) are also moderate and intermediate. Thus, the vegetation is a blend, tempering and buffering the extreme vegetation of core North and that of the South. This, therefore, may create a conducive environment for balanced interspecific competition and multiplication of the two species, though to a lesser extent with *M. incognita* (Table 1) which is less adapted to their climatic conditions (Taylor *et al.*,1982).

The similarity of distribution of *M. arenaria* within the same altitude, temperature, precipitation and vegetation spectrum as that for *M. incognita* suggests that the species has the same range of requirement as *M. incognita*.

The polarized ecological distribution and infection of the *M. incognita* and *M. javanica* in the present studies show the climatic preference of the three species and give a guide in targeting a workable control strategy.

5. Conclusion

Climatic features of altitude, temperature, precipitation, rainfall pattern and vegetation affected *Meloidogyne incognita* and *M. javanica* differentially. *Meloidogyne incognita* showed preference for low altitude, cool temperature, high precipitation, intense rainfall and humid forest ecology while, in contrast, *M. javanica* thrived best at high altitude, high and low temperature, low precipitation, sparse rainfall and Sudan savannah ecology: But at moderate climatic conditions, operating in the Middle belt (North central), the two species exhibited about equal abundance.

The present finding gives an insight into which species to target for control in the different ecology, and also advocates breeding for temperature resistant cowpea cultivars to be able to withstand the differential temperature in the different ecologies of dry and hot Sudan savannah of the core North and wet and cool humid forest of the South.

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Table 1: Distribution of root knot nematodes *(Meloidogyne spp)* in relation to climatic features in cowpea growing areas in Nigeria.

		Number of Root knot Nematode			Climatic features				
Region	Locality (Cowpea Farms) (No)	*M.incognita*	*M. javanica.*	*M. arenaria*	Mean annual precipitation (mm)	Mean annual min. temp. (°C)	Mean annual max. temp. (°C)	Altitude (m)	Vegetation/ Rainfall pattern
North									
North east (NE)	44	20(30.3)	44(66.7)	2(3.0)	0.1-1300	11-12	33-40	600-2000	Sudan savannah. Wet season, 6 months or less Dry season, 6 months or less
North west (NW)	40	20(32.3)	40(64.5)	2(3.2)	100 0-15 30	11-18	32-40	500-1000	
Total NE/NW (Core North)	84	40(31.3)	84(65.5)	4(3..1)	0.1-1530	11-18	32-40	500-2000	
Middle belt (North Central)	68	53(44.2)	62(51.9)	5(14.2)	800.0-200	18-21	29-32	305-1829	Guinea savannah Wet season, 7 months. Dry season, 5 months
Total (North)	152	93(37.5)	146(58.9)	9(3.6)	0.1-2000	11-18	32-40	305-2000	
South									
South east	7	7(87.5)	1(12.5)	-	1800-2000	21-23	24-27	100-200	Rain/swamp forest Wet season 8 Months or more Dry season, 4 months or less
South west	69	69(19.2)	13(15.3)	3(3.5)	1170-2540	21-23	24-27	15-650	
South south	20	20(83.3)	1(4.2)	3(12.5)	2000-4700	21-23	24-27	30-305	
Total (South)	96	96(83.1)	15(12.8)	6(5.1)	1170-4700	21-23	24-27	15-650	
Total (South & North)	248	189(51.8)	16(44.1)	15(4.1)	0.1-4700	11-23	24-40	15-2000	

Figures in parentheses indicate percentage incidence

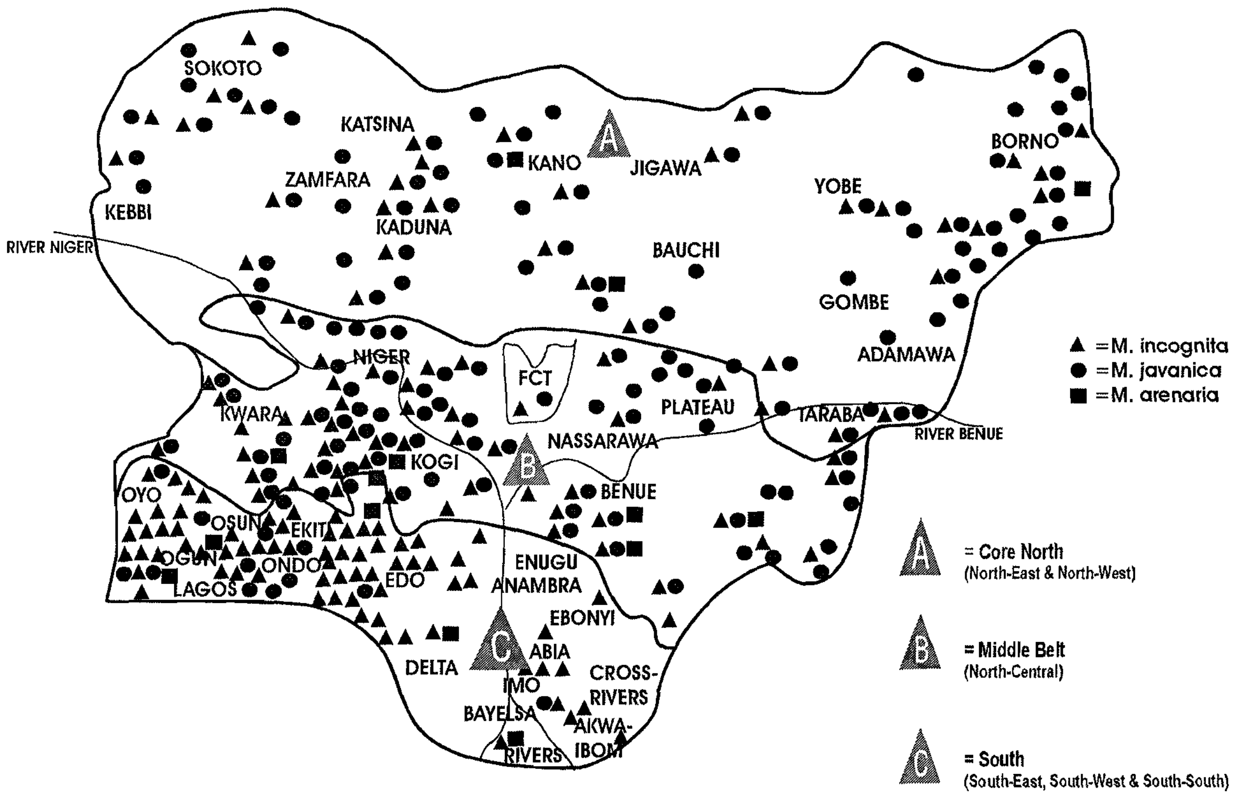

Fig: 1 Distribution of *Meloidogyne incognita, M. javanica and M. arenaria* in cowpea growing areas in Nigeria

Table 2: Overall root knot nematode (*Meloidogyne incognita, M. javanica and M.arenaria*) galling infection on cowpea in relation to ecological regions in cowpea growing areas in Nigeria.

Region	Locality Cowpea farms (No)	Vegetation	Mean galling index	Galling severity
North				
North west	44	Sudan savannah	2..4a	Slight infection
North east	40		2.5a	Moderate infection
Middle-belt (North central)	68	Guinea savannah	2.6 a	Moderate infection
South				
South- south	7		2.7 a	Moderate infection
South west	69	Humid forest	3.1ab	Moderate infection
South east	70		3.7b	Heavy infection

Root galling index: 1=0 (No galling infection on root system), 2 = 1-10% of the root system Galled (Slight infection), 3 = 11- 30% (Moderate infection), 4 = 31- 50% (Heavy infection) 5 = 51- 75% (Severe infection) and 6 = 76-100% (Very severe infection)

Means flanked by the same letter(s) in the same column are not significantly different at P=0.05 according to LSD test.