



Asian Journal of Crop Science

ISSN 1994-7879

science
alert
<http://www.scialert.net>

ANSI*net*
an open access publisher
<http://ansinet.com>

Studies on the Occurrence and Distribution of Plant-Parasitic Nematodes in Some Pineapple-Producing States in Nigeria

¹F.Y. Daramola, ²S.O. Afolami, ³A.A. Idowu and ³E.I. Nwanguma

¹Department of Crop Science, Landmark University, P.M.B. 1001, Omu-Aran, Nigeria

²Department of Crop Protection, Federal University of Agriculture, Abeokuta, Nigeria

³National Horticultural Research Institute, Ibadan, Nigeria

Corresponding Author: F.Y. Daramola, Department of Crop Science, Landmark University, P.M.B. 1001, Omu-Aran, Nigeria

ABSTRACT

Nematode pests of pineapple have not been widely studied in Nigeria compared to other countries. This study investigated the geographical distribution of nematodes associated with pineapple in three pineapple-producing states in Nigeria. A total of 78 farms were sampled from Oyo, Ogun and Osun States using the Agricultural Development Project in each state as a pilot to locate representative farmlands in the States. The modified Baermann Extraction Tray method of Whitehead and Hemming was used for the extraction of vermiform nematodes from soil. Eighteen species of plant-parasitic nematodes (PPN) were found associated with pineapple from the fields surveyed as follows: *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Pratylenchus brachyurus*, *Tylenchus* sp., *Helicotylenchus dihystra*, *Scutellonema brachyurum*, *Hoplolaimus pararobustus*, *Criconemoides limitaneum*, *Paratylenchus minutus*, *Gracilaria* sp., *Hemicriconemoides* sp., *Hemicycliophora* sp., *Aphelenchus* sp., *Aphelenchoides* sp., *Tylenchorhynchus* sp., *Paratrophurus* sp., *Dolichoderus* sp. and *Xiphinema nigeriense*. The most prominent plant-parasitic nematodes found in association with pineapple on all the fields were *P. brachyurus*, *H. dihystra*, *S. brachyurum*, *R. reniformis* and *M. incognita* occurring at frequency ratings of 88, 80, 71, 56 and 44%, respectively. The study indicated a widespread distribution of plant-parasitic nematodes of pineapple in Southwestern Nigeria.

Key words: Plant-parasitic nematodes, pineapple, survey, population density, frequency rating, geographical distribution, Nigeria

INTRODUCTION

Pineapple is a luscious tropical fruit. It is an important fruit in Nigeria and has great potential for canning and export in addition to its diverse socio-economic uses (Babatola, 1985). Ripe pineapple fruits can be eaten fresh as dessert, in salads or they can be processed into sauces, concentrates, marmalades or canned juice (Purseglove, 1972). The pineapple juice is useful as a diuretic which can be taken as an antidote against seasickness, as a worm expellant and also to expedite labour in pregnant women. The flesh of young unripe fruits can be used for the treatment of venereal diseases and can also be deliberately ingested to induce menstrual bleeding or achieve abortion (Morton, 1987). The stems and leaves of pineapple are also sources of fibre, which can be

processed into paper and also into 'pina cloths'. The pineapple crown can be used for animal feeds while the entire plant can be potted and used as an indoor ornament (Purseglove, 1972; Morton, 1987; Leal and Eckenbrugge, 1996).

Fresh pineapple fruit is a good source of vitamins A, B1, B6 and C, copper, manganese and dietary fibre (Morton, 1987). It also contains the proteolytic enzyme bromelain, which has valuable biological properties such as interfering with the growth of malignant cells, inhibiting platelet aggregation, fibrinolytic and anti-inflammatory actions (Gailhofer *et al.*, 1998; Mynott *et al.*, 1999; Hale *et al.*, 2005). The increase in awareness of the health and nutritional benefits derivable from fruits has led to a boost in the demand for fruits which have popular dietary supplements and desert in Nigeria. Consequently, this has caused a resultant greater market demand for pineapple amidst other fruit (Babatola, 1985).

Nigeria on the global scene has the largest land area for pineapple production, yet ranked the eighth largest pineapple-producing country (Asopa, 2003). Pineapple is grown mainly in the south and western parts of the country (Ucheagwu, 1985) and the contribution to the global pineapple production is about 910,000 metric tonnes (FAOSTAT, 2010). Nigeria only contributes a small share (6%) of the world pineapple despite having the largest land area for production, thus reflecting a low yield in pineapple production in the country (Mark, 2006).

Plant-parasitic nematodes have consistently been implicated as one of the major causes of economic loss to horticultural and field crops all over the world (Stirling and Pattison, 2008). In pineapple fields, damage by plant parasitic nematodes pose a major limitation to pineapple production and often results in significant losses (Rohrbach and Apt, 1986). The Hawaii pineapple industry, the world's largest, suffered a great decline and has been shrinking since the 1950s as a result of damage by plant parasitic nematodes. The number of people growing pineapple in the state also fell from 47 in 1970-15 in 2002, (reducing acreage from 61,000 to 19,000) (USDA, 2003).

In Nigeria, attacks by populations *Meloidogyne incognita*, *Pratylenchus* sp., *Helicotylenchus multicinctus* and *Scutellonema clathricaudatum* have been identified as major causes of poor yield and reduced sucker production in pineapple (Babatola, 1985). Caveness (1965) found some plant-parasitic nematodes in association with the roots of pineapple plants from the North, East, West and mid-West regions of the country. The plant-parasitic nematodes he reported include; *Dolichodorus nigeriensis*, *Helicotylenchus* sp., *H. dihystra*, *Hemicylichophora* spp., *H. oostenbrinki*, *Hoplolaimus pararobustus*, *P. brachyurus*, *S. clathricaudatum*, *Scutellonema* sp., *Tylenchorhynchus* spp., *Xiphinema ebriense* and *Xiphinema nigeriense*. There is however, no recent report in literature on the distribution of plant-parasitic nematodes and an estimate of yield losses due to their infestation on pineapple fields in Nigeria. This present study aimed at providing an update on plant-parasitic nematodes associated with pineapple in the grower's fields in three southern states that produce the crop in Nigeria.

MATERIALS AND METHODS

A survey was carried out to determine the types, frequency and distribution of plant-parasitic nematodes associated with pineapple in south-west Nigeria. The pineapple-producing states surveyed were Oyo, Ogun and Osun States. Pineapple farms were purposively selected from each state using the Agricultural Development Project (ADP) structure as a guide to locate representative pineapple fields in each state. The criteria for selection of the farms to sample were

based on accessibility, availability of farmer or escort and the willingness of the farmer to allow sample collection from his farm. A total of 78 farms were sampled from the three states.

Soil samples for the survey were collected from the rhizosphere of the pineapple plants with the aid of a soil auger to a depth of about 15 cm and within a 25 cm radius from the base of the pineapple plants. Thirty soil core samples per hectare were randomly taken from each of the pineapple fields and bulked together to form a composite sample, which gave a representation of the nematode situation on the particular field.

The Extraction Tray method of Whitehead and Hemming (1965) was used for the extraction of vermiform nematodes. Two hundred grams of each of the composite samples were placed in the upper sieve of a modified Baermann Extraction tray which is made up of a double ply facial tissue sandwiched between a pair of plastic sieves and placed in a bowl of water with about 500 mL of water in it. This was allowed to remain undisturbed for 48 h, after which the sieves were gently lifted off. The resulting nematode suspension in the bowl were poured into a 500 mL Nalgene wash bottles and left undisturbed for 5 h.

The nematode suspension was concentrated to about 20-25 mL by removing excess water (supernatant) using the settling-siphon method (Caveness, 1975). The different genera and nematode species recovered were identified under a compound microscope using the Pictorial key to genera of plant-parasitic nematodes by Mai and Lyon (1960). Counting of identified nematode species was done under a stereoscopic microscope using Doncaster (1962) counting dish.

RESULTS

Occurrence and geographical distribution of plant-parasitic nematodes: Eighteen species of plant-parasitic nematodes were identified and recorded in association with pineapple from Oyo and Osun and Ogun States of Nigeria (Table 1). The plant-parasitic nematodes recovered from soil

Table 1: Occurrence and geographical distribution of plant-parasitic nematodes of pineapple in three southern states of Nigeria

Nematode	States		
	Oyo	Ogun	Osun
<i>Meloidogyne incognita</i>	x	x	x
<i>Tylenchus</i> sp.	x	x	x
<i>Pratylenchus brachyurus</i>	x	x	x
<i>Paratylenchus minutus</i>	x	x	x
<i>Helicotylenchus dihystera</i>	x	x	x
<i>Scutellonema brachyurum</i>	x	x	x
<i>Hoplolaimus pararobustus</i>	x	-	x
<i>Rotylenchulus reniformis</i>	x	x	x
<i>Gracilaria</i> sp.	-	x	-
<i>Criconemoides limitaneum</i>	x	x	x
<i>Hemicycliophora</i> sp.	x	x	x
<i>Aphelenchus</i> sp.	x	x	x
<i>Aphelenchoides</i> sp.	x	x	x
<i>Paratrophurus</i> sp.	x	x	x
<i>Hemicriconemoides</i> sp.	x	-	-
<i>Tylenchorhynchus</i> sp.	x	x	x
<i>Dolichodorus</i> sp.	-	-	x
<i>Xiphinema nigeriense</i>	x	x	x

x: Present, -: Absent

in the pineapple fields include; *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Pratylenchus brachyurus*, *Tylenchus* sp., *Helicotylenchus dihystera*, *Scutellonema brachyurum*, *Hoplolaimus pararobustus*, *Criconemoides limitaneum*, *Paratylenchus minutus*, *Gracilaria* sp., *Hemicriconemoides* sp., *Hemicycliophora* sp., *Aphelenchus* sp. *Aphelenchoides* sp., *Tylenchorhynchus* sp. *Paratrophurus* sp. *Dolichodorus* sp. and *Xiphinema nigeriense*. There is a widespread occurrence and distribution of these nematode species on pineapple fields in the three states surveyed. However, *Gracilaria* sp., was only recorded in Ogun State, *Hemicriconemoides* sp. in Oyo state, *Dolichodorus* sp. was recorded on pineapple-cocoa intercrop in Osun state, while *Hoplolaimus* sp. were frequently encountered in pineapple fields in Oyo and Osun states.

Frequency of occurrence of plant-parasitic nematodes: *Tylenchus* sp., was the most ubiquitous having been found in large populations and occurring in all the farms at a frequency rating of 100% in all the states surveyed. *P. brachyurus*, *Aphelenchus* sp., *H. dihystera* and *S. brachyurum* were numerous and commonly encountered in the soil, occurring at a frequency rating of 88, 82, 80 and 71% percent, respectively (Table 2). The result also shows a widespread occurrence of *R. reniformis* and *M. incognita*, which were found occurring in large populations in the soil samples at 56 and 44% frequency ratings respectively. The least frequently encountered nematode species in all the all the states however, are *Dolichodorus*, *Hemicriconemoides* and *Paratrophurus* species which were found occurring at frequency ratings of 1.8, 2.7 and 5.4%, respectively.

The prominent plant-parasitic nematodes found on pineapple in Oyo state were *Tylenchus* sp., *Pratylenchus brachyurus*, *Helicotylenchus dihystera*, *Aphelenchus* sp., *Scutellonema brachyurum*, *Rotylenchulus reniformis* and *Meloidogyne incognita* (Fig. 1). *Tylenchus* sp. was the most ubiquitous with 100% frequency rating in all soil samples. *P. brachyurus* and *H. dihystera*,

Table 2: Frequency of occurrence of plant-parasitic nematodes associated with pineapple in southwestern Nigeria

Nematodes	Frequency of occurrence (%)
<i>Tylenchus</i> sp.	100.00
<i>Pratylenchus brachyurus</i>	88.29
<i>Aphelenchus</i> sp.	81.98
<i>Helicotylenchus dihystera</i>	80.18
<i>Scutellonema brachyurum</i>	71.17
<i>Rotylenchulus reniformis</i>	55.86
<i>Meloidogyne incognita</i>	44.14
<i>Hoplolaimus pararobustus</i>	21.62
<i>Criconemoides limitaneum</i>	20.72
<i>Paratylenchus minutus</i>	18.02
<i>Hemicycliophora</i> sp.	14.41
<i>Aphelenchoides</i> sp.	12.61
<i>Gracilaria</i> sp.	12.61
<i>Xiphinema nigeriense</i>	11.71
<i>Tylenchorhynchus</i> sp.	6.31
<i>Paratrophurus</i> sp.	5.41
<i>Hemicriconemoides</i> sp.	2.70
<i>Dolichodorus</i> sp.	1.80

*Frequency of occurrence is expressed as a percentage of the total number of samples examined ($n/N \times 100$), Where n = No. of time a nematode occurs, N = the sample size, Sample size (N) = 78

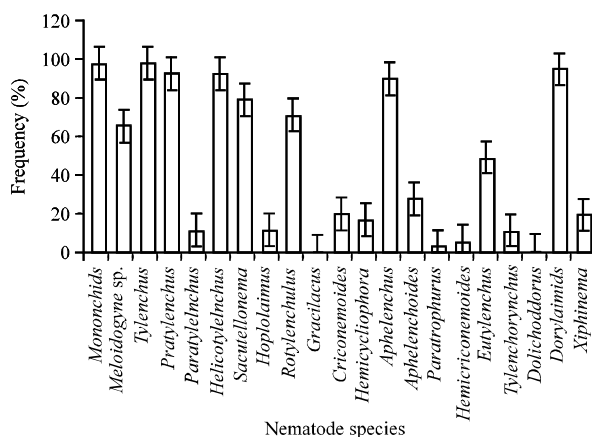


Fig. 1: Frequency rating of nematodes found in association with pineapple in Oyo state during a field survey in 2009

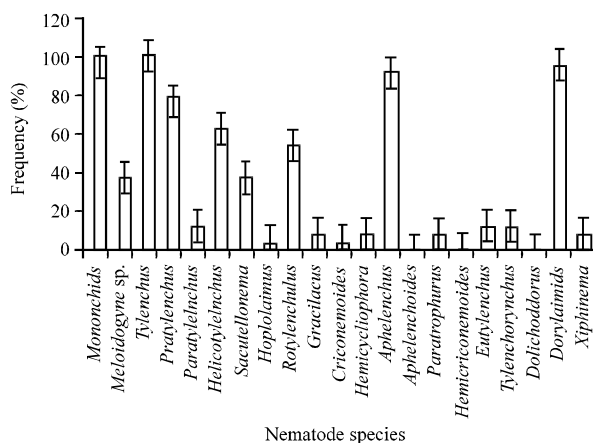


Fig. 2: Frequency rating of nematodes found in association with pineapple in Ogun state during a field survey in 2009

both occurred at a frequency rating of 94%, of the soils examined while *Aphelenchus* sp., *S. brachyurum*, *R. reniformis* and *M. incognita* were found occurring at 92, 81, 72 and 67%, respectively. There was no record of *Gracilaria* sp. and *Dolichodoros* sp. from soil samples from the state, however low populations of *Criconemoides limitaneum* and *Hemicycliophora* sp. were recorded at frequency ratings of 19 and 17%, respectively (Fig. 1).

In Ogun state, the prominent plant-parasitic nematodes are *Tylenchus* sp., *Aphelenchus* sp., *P. brachyurus*, *H. dihystra*, *R. reniformis* and *M. incognita* (Fig. 2). They occurred at frequency ratings of 100, 91 and 79, 63, 54 and 38%, respectively. Low populations of *Gracilaria* sp., *Criconemoides limitaneum* and *Hemicycliophora* sp., were recorded at frequency ratings of 8, 8 and 4%, respectively. In Osun state however, larger populations and diversity of plant-parasitic nematodes were recorded from the pineapple fields. *Tylenchus* sp. and *H. dihystra* were the most frequently encountered in the soil samples examined and both had frequency ratings of 100% each. *S. brachyurum*, *P. brachyurus*, *R. reniformis* and *M. incognita* were also common and abundant

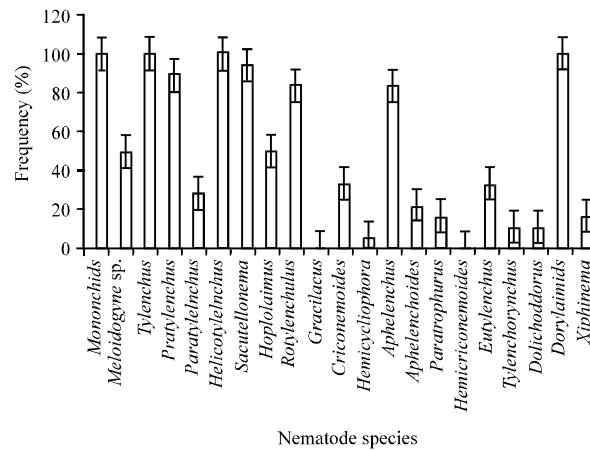


Fig. 3: Frequency rating of nematodes found in association with pineapple in Osun Nigeria during a field survey in 2009

Table 3: Population density of nematode species associated with pineapple in Oyo state, Nigeria

Nematode species	Nematode population (/200 mL soil)	Population (%)
<i>Mononchida</i>	11661	46.0
<i>Meloidogyne incognita</i>	819	3.2
<i>Tylenchus</i> sp.	6495	25.6
<i>Pratylenchus brachyurus</i>	350	1.4
<i>Paratylenchus minutus</i>	18	0.1
<i>Helicotylenchus dihystra</i>	1670	6.6
<i>Scutellonema brachyurum</i>	561	2.2
<i>Hoplolaimus pararobustus</i>	48	0.2
<i>Rotylenchulus reniformis</i>	755	3.0
<i>Criconemoides limitaneum</i>	96	0.4
<i>Hemicycliophora</i> sp.	99	0.4
<i>Aphelenchus</i> sp.	619	2.4
<i>Aphelenchoides</i> sp.	86	0.3
<i>Paratrophurus</i> sp.	52	0.2
<i>Hemicriconemoides</i> sp.	5	0.02
<i>Eutylenchus</i> sp.	103	0.4
<i>Tylenchorhynchus</i> sp.	12	0.05
<i>Xiphinema nigeriense</i>	47	0.2
<i>Dorylaimida</i>	1865	7.4
Total	25361	

Sample size (N) = 36

in the pineapple soils, occurring at frequency ratings of 94, 89, 83 and 50%, respectively. There was no record of *Gracilaria* sp., in pineapple fields in Osun State, however low populations of *C. limitaneum* and *Hemicycliophora* sp. were recorded occurring at frequency ratings of 33 and 6%, respectively. *Paratylenchus minutus* and *Dolichodorus* sp. were also found occurring in low populations from pineapple fields in the state (Fig. 3).

Population density of nematode species associated with pineapple: The population densities of the individual nematode species associated with pineapple in the three states surveyed are illustrated in Table 3-5. In Oyo state, high populations of *Tylenchus* sp., *H. dihystra*,

Table 4: Population density of nematode species associated with pineapple in Ogun state, Nigeria

Nematode species	Population (/200 mL soil)	Population (%)
<i>Mononchida</i>	10093	69.8
<i>Meloidogyne incognita</i>	145	1.0
<i>Tylenchus</i> sp.	1467	10.1
<i>Pratylenchus brachyurus</i>	128	1.0
<i>Paratylenchus minutus</i>	21	0.2
<i>Helicotylenchus dihystra</i>	162	1.1
<i>Scutellonema brachyurus</i>	106	0.7
<i>Hoplolaimus pararobustus</i>	2	0.01
<i>Rotylenchulus reniformis</i>	863	6.0
<i>Gracilaria</i> sp.	13	0.1
<i>Criconemoides</i> sp.	2	0.01
<i>Hemicycliophora</i> sp.	2	0.01
<i>Aphelenchus</i> sp.	423	2.9
<i>Paratrophurus</i> sp.	3	0.02
<i>Eutylenchus</i> sp.	13	0.1
<i>Tylenchorhynchus</i> sp.	15	0.1
<i>Xiphinema nigeriense</i>	4	0.02
<i>Dorylaimida</i>	1009	7.0
Total	14471	

Sample size (N) = 24

Table 5: Population density of nematode species associated with pineapple in Osun state, Nigeria

Nematode species	Population (/200 mL soil)	Population (%)
<i>Mononchida</i>	9327	59.2
<i>Meloidogyne incognita</i>	155	1.0
<i>Tylenchus</i> sp.	2496	15.9
<i>Pratylenchus brachyurus</i>	298	1.9
<i>Paratylenchus minutus</i>	146	0.9
<i>Helicotylenchus dihystra</i>	505	3.2
<i>Scutellonema brachyurum</i>	375	2.4
<i>Hoplolaimus pararobustus</i>	73	0.5
<i>Rotylenchulus reniformis</i>	797	5.1
<i>Criconemoides limitaneum</i>	59	0.4
<i>Hemicycliophora</i> sp.	2	0.01
<i>Aphelenchus</i> sp.	209	1.3
<i>Aphelenchoides</i> sp.	22	0.1
<i>Paratrophurus</i> sp.	22	0.1
<i>Eutylenchus</i> sp.	21	0.1
<i>Tylenchorhynchus</i> sp.	5	0.03
<i>Dolichodorus</i> sp.	4	0.03
<i>Xiphinema nigeriense</i>	14	0.1
<i>Dorylaimida</i>	1219	7.7
Total	15749	

Sample size (N) =18

M. incognita, *R. reniformis* and *Aphelenchoides* sp. were recorded on pineapple fields while *Hemicriconemoides*, *Paratrophurus* and *Tylenchus* species were recorded in very low populations (Table 3). Ogun state also recorded high populations of *Tylenchus* sp. *R. reniformis*,

Aphelenchoides sp. and *M. incognita* while low populations of *Hoplolaimus*, *Criconemoides* and *Hemicycliophora* species were recorded in the State (Table 4). In Osun state however, *Tylenchus* sp. *R. reniformis*, *Scutellonema* sp. *H. dihystra* and *P. brachyurus* were found in high populations while *Tylenchorhynchus*, *Dolichodorus* and *Hemicycliophora* species were the nematode species occurring in low populations in the pineapple fields from the State (Table 5).

DISCUSSION

This study provides an update on the findings of Caveness (1965). The result of this study also shows that *Meloidogyne* sp. *Pratylenchus brachyurus* and *Rotylenchulus reniformis* which have been implicated world-wide as important nematode pests of pineapple are common and abundant in pineapple fields in Nigeria. The spiral nematodes (*Helicotylenchus* sp.) found in large numbers in the pineapple soils, as indicated by the result of these investigation, has also been reported to be important in pineapples (Babatola, 1985; Rohrbach and Apt, 1986; Ko and Schmitt, 1993).

Tylenchus spp. and *Aphelenchus* spp. were found occurring in large numbers and at frequency ratings of 100% in all the soil samples examined from the pineapple fields surveyed. The abundance of these nematode species in soil has been variously reported but their importance in agricultural fields is yet to be established (Bafokuzara, 1996). These nematode species have also been found to exhibit mycophagy in soil (Magnusson, 1986) therefore their relative abundance in the soil could not have been as a result of their direct feeding relationship with the pineapple roots but could probably be correlated to the composition of mycoflora in these soils as indicated by Walter (1987). Adding to the parasitic load in the soil are *S. brachyurum*, *Hoplolaimus pararobustus*, *C. limitaneum*, *Hemicriconemoides* sp., *Hemicycliophora* sp., *Tylenchorhynchus* sp., *Paratrophurus* sp. and *Xiphinema nigeriense*. Most of these nematodes are of limited or unknown pathogenicity (Sipes *et al.*, 2005). However the presence of these several nematode species in pineapple could form an additional pressure of parasitism and their occurrence in large populations pose a threat to pineapple production.

Dolichodorus sp. was observed on pineapple fields intercropped with *Theobroma cacao* in some fields in Osun State and this probably reflects the effect of cropping systems on nematode diversity in the soil. The presence of cacao which is as an alternate or a more suitable host for the nematode specie, as indicated by Lewis and Golden (1980) could have been responsible for the association of *Dolichodorus* sp. with pineapple in the fields.

Report on the association of *Paratylenchus* and *Gracilaria* species with pineapple and their damage has not previously been reported from Nigeria fields. *Paratylenchus* sp. however, been reported as major nematode pest of economic importance of pineapple in Malaysia and has been reported in exceedingly high number in pineapple fields in Hawaii (Hassan *et al.*, 2006).

The widespread distribution of plant-parasitic nematodes that have been known to cause plant debility and poor yields in Nigeria is disturbing and could be a factor in the low production of pineapple recorded in the country. The insidious nature of damage caused by plant-parasitic nematodes make their damaging potential to be underestimated and often mistaken for damage caused by other plant pathogens. In most cases farmers are not aware or adequately informed and equipped to combat these menace to crops. It is therefore imperative that awareness be created for farmers on the damaging effects of plant-parasitic nematodes on fruit crops.

CONCLUSION

The study shows that *Meloidogyne incognita*, *Pratylenchus brachyurus* and *Rotylenchulus reniformis*, which have been implicated worldwide as important nematode pests of

pineapple with other plant-parasitic nematodes that had not been previously reported are common and abundant in the pineapple fields in south-western Nigeria. The widespread distribution of these plant-parasitic nematodes that have been known to cause plant debility and poor yields in Nigeria is disturbing and could be a factor responsible for the low yields recorded in pineapple production from the country.

Farmers are therefore encouraged to plant certified suckers and not source their planting materials from nematode-infested fields. They should embrace good and sustainable cultural practices that could promote good yield, effectively manage and reduce the spread of plant-parasitic nematodes.

ACKNOWLEDGMENT

This research has been supported by research grant from the National Horticultural Research Institute, Idi-Isin, Ibadan, Nigeria.

REFERENCES

- Asopa, V.N., 2003. Competitiveness in pineapple canning industry. Proceedings of the Hawaii International Conference on Business, June 18-21, 2003, Honolulu, Hawaii USA, pp: 1-3.
- Babatola, J.O., 1985. Diseases and pests of fruits and their control in Nigeria. Proceedings of the National Workshop on Fruit Production in Nigeria, March 14-16, 1985, Ibadan, pp: 120-131.
- Bafokuzara, N.D., 1996. Incidence of different nematodes on vegetable and fruit crops and preliminary assessment of yield loss due to *Meloidogyne* species in Uganda. *Nematol. Brasileira*, 20: 32-43.
- Caveness, F.E., 1965. End of tour progress report on the nematology project. Ministry of Agriculture and Natural Resources Western Region, Nigeria and the United States of America Agency for International Development. USAID/NIGERIA, pp: 47.
- Caveness, F.E., 1975. A simple siphon method for separating nematodes from excess water. *Nematropica*, 5: 30-32.
- Doncaster, C.C., 1962. A counting dish for nematodes. *Nematologica*, 7: 334-337.
- FAOSTAT, 2010. Pineapple production statistics. [http://faostat.fao.org/site/567/Desktop Default.aspx?PageID=567#ancor](http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor)
- Gailhofer, G., M. Wilders-Truschnig, J. Smolle and M. Ludvan, 1988. Asthma caused by bromelain: An occupational allergy. *Clin. Exp. Allergy*, 18: 445-450.
- Hale, L.P., P.K. Greer, C.T. Trinh and M.R. Gottfried, 2005. Treatment with oral bromelain decreases colonic inflammation in the IL-10 deficient murine model of inflammatory bowel disease. *Clin. Immunol.*, 116: 135-142.
- Hassan, N.M., A.B. Ismail and M. Zulkifli, 2006. Nematode infestation on commercial pineapple cultivation on infested Peatland. Horticultural Research Center, MARDI. Malaysia.
- Ko, M.P. and D.P. Schmitt, 1993. Pineapple inter-cycle cover crops to reduce plant-parasitic nematode population. *Acta. Hortic.*, 334: 373-382.
- Leal, F. and G.C. Eckenbrugge, 1996. *Fruits Breeding*. John Wiley and Sons, New York, pp: 565-606.
- Lewis, S.A. and A.M. Golden, 1980. Description and SEM observations of *Dolichodorus marylandicus* n. sp. With a key to species of *Dolichodorus*. *J. Nematol.*, 13: 128-135.
- Magnusson, M.L., 1986. Root diffusates and plant parasitic nematodes. *Vaxtskyddsnotiser*, 50: 168-170.

- Mai, W.F. and H.H. Lyon, 1960. Pictorial Key to Genera of Plant Parasitic Nematodes. Art Craft, Ithaca, New York, Pages: 153.
- Mark, M.R., 2006. Pineapple (*Ananas comosus*). Mark's Fruit Crops, <http://fruit-crops.com/pinapple/>
- Morton, J., 1987. Pineapple. In: Fruits of Warm Climates, Morton, J.F. (Ed.). J.F. Morton, Miami, FL., USA., pp: 18-28.
- Mynott, T.L., A. Ladhams, P. Scarmato and C.R. Engwerda, 1999. Bromelain, from pineapple stems, proteolytically blocks activation of extracellular regulated kinase-2 in T cells. *J. Immunol.*, 163: 2568-2575.
- Purseglove, J.W., 1972. Tropical Crops: Monocotyledons. Longman, London, pp: 75-91.
- Rohrbach, K.G. and W.J. Apt, 1986. Nematode and disease problems of pineapple. *Plant Dis.*, 70: 81-87.
- Sipes, B.S., E.P. Caswell, J. Chen Sarah and W.J. Apt, 2005. Nematodes Parasites of Pineapple. In: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture, Luc, M., R.A. Sikora and J. Bridge (Eds.). 2nd Edn., CAB International, Wallingford, UK., pp: 709-731.
- Stirling, G.R. and A.B. Pattison, 2008. Beyond chemical dependency for managing plant parasitic nematodes. Examples from banana, pineapple and vegetable industries of tropical and subtropical Australia. *Aust. Plant Pathol.*, 37: 254-267.
- USDA, 2003. Fruit and tree nuts outlook. Bigger Citrus Crop Forecast for 2003/04, <http://usda01.library.cornell.edu/usda/ers/FTS//2000s/2003/FTS-11-21-2003.pdf>
- Ucheagwu, A.C., 1985. Pineapple production in Nigeria. Processings of National Food Production Workshops, 1985, FACU, pp: 71-76.
- Walter, D.E., 1987. Trophic behaviour of (mycophagous) microathropods. *Ecology*, 68: 226-229.
- Whitehead, A.G. and J.R. Hemming, 1965. A comparison of some quantitative methods of extracting small vermiform nematodes from soil. *Ann. Applied Biol.*, 55: 25-38.