FUDMA Journal of Agriculture and Agricultural Technology
ISSN: 2504-9496
Vol. 4 No. 2, December 2018: Pp 131-139

PLANT-PARASITIC NEMATODES ASSOCIATED WITH SUGARCANE (*SACCHARUM*SPP. L.) IN SOME SELECTED LOCATIONS IN ZARIA LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

*[1]Abdulsalam, S., [1]Alhassan, F., and [2]Chindo, P. S.,
[1] Samaru College of Agriculture, Division of Agricultural Colleges, Ahmadu Bello University Zaria
[2]Faculty of Agriculture, Department of Crop Protection Ahmadu Bello University Zaria
*Corresponding author's e-mail: sulsalam@yahoo.com
+2348065376105

Abstract

A field survey of sugarcane plantation in Zaria Local Government Area of Kaduna State was conducted to identify the diverse nematodes species associated with the crop and to determine their prominence value and frequency of occurrence on the field. A total of Nineteen (19) genera of plant-parasitic nematodes were found in association with the roots and rhizosphere of the sugarcane plants. *Scutellonema* spp. and *Rotylenchus* spp. were the most frequently occurring (60%) in all the soil samples. *Ditylenchus* spp. was not identified from the soil samples. The most prominent nematode encountered in the soil was *Scutellonema* spp. (20449.4), followed by *Rotylenchus* spp. (13452.2) and *Helicotylenchus* spp. (5889), respectively. In root samples, *Heterodera* spp. and *Tylenchus* spp. had the highest absolute frequency of occurrence (27%). *Aphelenchoides* spp. was the most prominent (2302.5) plant-parasitic nematode encountered in the root, followed by *Ditylenchus* spp. (1964.4) and *Heterodera* spp.(1893.5), respectively. Other plant-parasitic nematodes genera were identified at varying absolute frequencies and prominence values. Therefore, there is need for nematode control for improved yield.

Keywords: Sugarcane, Absolute frequency, Prominence value.

Introduction

Sugarcane (*Saccharum* spp. L.) is an important food crop of the tropics and subtropics. The main product which is sugar is used universally as sweeteners, blender and as preservatives. It has also become an essential part in many diets, and almost indispensable in the food manufacturing and pharmaceutical industries (Girei and Giroh, 2012). In Nigeria, sugarcane is an important cash crop earning small-scale farmers approximately US$ 50 million annually (Kaduna State Agricultural Development Project (KADP), 2013; National Sugarcane Development Council (NSDC), 2013). However, over the last decade there has been a steady decline of cane yields, falling from 18.90tonne per hectare in 2010 to 3.31tonne per hectare in 2013 (KADP, 2013; FAO, 2013). Probable causes for this reduction in productivity include the widespread use of low quality sugarcane varieties, technical know-how, poor agricultural and land management practices, and pests and diseases. Among pests and diseases plant-parasitic nematodes have been reported to cause significant yield loss in sugarcane production (Government of Kenya (Gok), 2010; Nzioki and Chirchir, 2010; Afolami, *et al*., 2014).

Nematode diversity on sugarcane is greater than most other cultivated crops, with more than 310 species and 48 genera of endo and ectoparasitic nematodes reported from the root and rhizosphere of the plant (Adesiyan *et al*., 1990; Cadet and Spaull, 2005). *Meloidogyne*, and *Pratylenchus* are the two species of plant-parasitic nematodes most frequently reported as highly pathogenic to sugarcane worldwide (Spaull and Cadet, 1991; Michel *et al*., 2005).Afolami *et al*. (2014) also reported *Meloidogyne incognita*, *Heterodera sacchari* and *Pratylenchus* spp. as nematodes associated with yield reduction of sugarcane in Bacita, Nigeria. He noted that damage due to the feeding activities of these nematodes on sugarcane resulted in, stunted plants with fewer mature tillers which appear to be wilting and plant with very patchy appearance. The sugarcane roots also become stunted, pitted and clubbed, thus, leading to a great reduction in the quality and quantity of the harvested sugarcane. Odihinrin (1977) however reported total crop failure on the sugarcane fields due to damage by plant-parasitic nematodes.

The association of sugarcane to plant-parasitic nematodes has also been reported in the South-western parts of Nigeria (Afolami *et al*., 2014), but little or no work has been done on the diversity of nematodes species associated with this crop in Zaria Local Government Area of Kaduna State. It becomes imperative that research be conducted on the distribution and identification of the plant-parasitic nematodes associated with this important crop so as to be able to formulate some management measures that will reduce losses. It is in line with the above that this work was conceived.

Materials and methods

Survey of sugarcane fields

Survey of sugarcane fields was conducted in Zaria Local Government Area (LGA) of Kaduna State between April and June, 2017. Soil and root samples of sugarcane were collected from three selected farms. Ten samples each of sugarcane roots and soil per farm was collected in a systematic zigzag pattern at different corners of the field and at the centre to obtain a representative sample (Coryne *et al*., 2007). A total of thirty soil and root samples were taken in the Local Government Area. The whole plants were gently dug out using a hoe to a depth of 30 cm taking care not to damage the fine roots. About 1 kg rhizosphere soil was taken after uprooting the plant. Approximately 10 kg of soil per farm was obtained by compositing 10 samples (soil and root) from locations within an area of 0.5 ha of each field. The roots together with soil samples were put in a polyethylene bag, sealed and labeled accordingly before transported in a cool box to the Nematology Laboratory, Department of Crop Protection, Ahmadu Bello University, Zaria and stored at 4 ^{0}C in the cold room before nematodes were extracted and identified within one week of collection.

Extraction of nematodes from the soil

Sieving and decanting method combined with Baerman's tray method was used for nematode extraction from the soil as described by Coyne *et al*., (2007).Each soil sample was first mixed thoroughly. Pebbles, gravels and other heavy particles were removed. 500cm^3 of soil was measured into a plastic bucket containing two to three liters of water. On soaking, the soil lumps were broken with the fingers; the suspension properly stirred and allowed to settle for one minute. This suspension was poured into another bucket through a coarse sieve. More water was added to the residue in the first bucket and the process was repeated after which the remainder in the first bucket was discarded and washed.

The nematodes suspension with fine soil particles were passed through fine sieves of 0.045mm and 0.075mm in diameter. These sieves were placed on top of each other with the one of 0.075mm in diameter on the top. With this arrangement, nematode that pass through the 0.075mm sieve will be collected by the second sieve. The suspension in the second bucket was poured into the sieves and the sieves shaken to quicken the drainage of water. Finally, the content of the two sieves were then washed into beakers, using water contained in a wash bottle. The suspension was gently poured in a sieve lined with two ply tissue paper placed in an extraction dish. Tap water was poured carefully into the dish in which the sieve is resting. The set up was then poured separately into beakers and left for 24 hours for the nematodes to settle at the bottom.

Extraction of nematodes from the root

Nematode juveniles were extracted from infested roots of eggplant, using Maceration technique (Coyne *et al*., 2007). The roots were washed with gentle flowing tap water to get rid of adhering soil and then chopped with a pair of scissors into pieces of 1 – 2 cm length. These pieces of each sample were weighed using electric weighing balance and 2 g of roots were removed and placed separately in an electric blender with water to cover the blades. Roots were blended for 5 seconds bursts. The suspension of roots and water were poured into a beaker, rinsing out the blender container of all debris, using water contained in a wash bottle. The suspension of roots and water were treated as in above.

To count the nematodes from soil and root samples, the suspension of nematodes were transferred into a measuring cylinder and made to 100 ml with tap water. Air was bubbled into the cylinder using an aquarium pump to keep it agitated and homogenized. 10 ml aliquot of the bubbled suspension were pippeted into Doncaster's counting dish and the nematode populations were counted under a dissecting stereoscopic microscope with under stage lighting at 10 × 4 magnification. Nematodes identification chart described by (Mai and Mullin, 1996) was used in identifying the different species of parasitic nematodes.
The population densities of nematodes species in the samples collected were analyzed using Absolute Frequency and Prominence Value (Norton, 1989):

$$AF = 100\,\frac{g}{n}$$

Where:
AF = absolute frequency;
g = number of samples containing a genus;
n = total number of samples collected.

$$PV = d\sqrt{AF}$$

Where:
PV = prominence value;
d = nematode density;

Results

Nematodes types identified

Nineteen general belonging to fourteen families in three orders, Tylenchida, Dorylaimida and Triplochida were found associated with sugarcane in Zaria Local Government Area (LGA) of Kaduna State (Table I). The genera were; *Aphelenchoides*, *Aphelenchus*, *Criconemella*, *Ditylenchus*, *Helicotylenchus*, *Heterodera*, *Hoplolaimus*, *Longidorus*, *Meloidogyne*, *Paratylenchus*, *Pratylenchus*, *Rotylenchus*, *Rotylenchulus*, *Scutellonema*, *Trichodorus*, *Tylenchorhynchus*, *Tylenchulus*, *Tylenchus* and *Xiphinema*. However, eleven of the genera were present in the roots,

namely: *Aphelenchoides*, *Aphelenchus*, *Ditylenchus*, *Helicotylenchus*, *Heterodera*, *Hoplolaimus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchus*, *Scutellonema* and *Tylenchus*. (Table I). Ten of the genera were present in both sugarcane roots and soils, namely; *Aphelenchus*, *Aphelenchoides*, *Heterodera*, *Hoplolaimus*, *Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchus*, *Scutellonema* and *Tylenchus*. *Ditylenchus* was only extracted from the roots.

Table I: Plant-parasitic nematodes genera isolated from soils and roots of sugarcane in Zaria local government area of Kaduna State.

Order	Sub-order	Family	Genus	
			Soil	Root
Tylenchida	Aphelenchina	Aphelenchidae	*Aphelenchus*	*Aphelenchus*
		Aphelenchoididae	*Aphelenchoides*	*Aphelenchoides*
	Tylenchina	Anguinidae	–	*Ditylenchus*
		Belonolaimidae	*Tylenchorhynchus*	–
		Criconematidae	*Criconemella*	–
		Heteroderidae	*Heterodera*	*Heterodera*
		Hoplolaimidae	*Hoplolaimus*	*Hoplolaimus*
			Helicotylenchus	*Helicotylenchus*
			Rotylenchulus	
			Rotylenchus	*Rotylenchus*
			Scutellonema	*Scutellonema*
		Meloidogynidae	*Meloidogyne*	*Meloidogyne*
		Paratylenchidae	*Paratylenchus*	–
		Pratylenchidae	*Pratylenchus*	*Pratylenchus*
		Tylenchulidae	*Tylenchulus*	–
		Tylenchidae	*Tylenchus*	*Tylenchus*
Dorylaimida	Dorylaimina	Longidoridae	*Longidorus*	–
			Xiphinema	–
Triplonchida	Diphtherophorina	Trichodoridae	*Trichodorus*	–

– = Absence of nematodes

–

Seventy nine percent (78%) of the nematode genera identified belonged to the order Tylenchida, while 16% belonged to the order Dolylaimida and Triplonchida. Family Hoplolaimidae had the highest representative with five genera out of the nineteen. Family Tylenchulidae represented one genus of nematodes which are not considered to be of major economic importance in crop production. Occurrence of most of these plant-parasitic nematode genera cut across various locations in Zaria LGA.

Absolute frequency of occurrence (A/F) of nematodes

Plant-parasitic nematodes were detected in nearly every sample but at varying absolute frequencies of occurrence. *Rotylenchus* spp. and *Scutellonema* spp. were present in all locations at high frequencies (Table II). *Paratylenchus* spp. occurred in moderate frequencies in all the three locations. *Helicotylenchus* spp. and *Hoplolaimus* spp. occurred in all the locations while *Tylenchus* spp. and *Xiphinema* spp. occurred in 60% of the locations all at low frequencies. *Aphelenchoides* spp., *Rotylenchulus* spp., *Heterodera* spp. and *Meloidogyne* spp. were present in only one location (Ungwan Alkali Gangare, Ungwan Fatika and Ungwan Fanwanki) at very low frequencies while the rest were present in nearly all the other locations (Table II).

Although plant-parasitic nematodes occurred across all sampled locations, sugarcane roots from UngwanFatikahad the highest (10) genera of plant-parasitic nematodes occurrence followed by UngwanFanwaki (8) and Ungwan Alkali Gangare (5) (Table III) while Ungwan Fatika and Ungwan Fanwak recorded the highest (15) occurrence of soil nematodes and Ungwan Alkali Gangare recorded the least number (9) of genera (Table II).

Rotylenchus spp. and *Scutellonema* spp. were present with an absolute frequency (A/F) of 60% in the soil. These nematodes occurred in high frequency in nearly all sampled areas. However, Ugwan Alkali Gangare exhibited slightly lower frequency. Nearly 40% of the nematode genera isolated from soil samples (eight genera out of nineteen) had a low absolute frequency (17 - 33%). These were; *Helicotylenchus* spp. (33%), *Hoplolaimus* spp. (33%), *Tylenchus*spp. (30%), *Xiphinema* spp. (27), *Criconemella* spp. (23%), *Trichodorus* spp. (23%) and *Tylenchorhynchus*spp. (20%) (Table II).

Table II: Absolute frequency of plant-parasitic nematode genera in soil samples of sugarcane in Zaria local government area of Kaduna State

Nematode genera	Absolute frequency (%) of nematodes (100 cm^3 of Soil)			
	Ungwan Fatika (n=10)	Ungwan Fanwanki (n=10)	Ungwan Alkali Gangare(n=10)	All locations (n=30)
Aphelenchoides	0	0	20	7
Aphelenchus	10	10	20	13
Criconemella	40	20	10	23
Ditylenchus	0	0	0	0
Helicotylenchus	40	40	20	33
Heterodera	0	10	0	3
Hoplolaimus	60	20	20	33
Longidorus	10	30	0	13
Meloidogyne	0	10	0	3
Paratylenchus	60	30	40	43
Pratylenchus	20	30	0	17
Rotylenchulus	40	0	0	13
Rotylenchus	70	70	40	60
Scutellonema	80	70	30	60
Trichodorus	40	30	0	23
Tylenchorhynchus	40	20	0	20
Tylenchulus	20	10	0	10
Tylenchus	40	0	50	30
Xiphinema	40	40	0	27

n = number of samples, 0 = absence of nematodes

Aphelenchus spp., *Longidorus* spp., *Rotylenchulus* spp., *Tylenchulus* spp., and *Aphenchoides* spp. were present in the soil at very low absolute frequency of 13%, 13%, 13%, 10% and 7% respectively. The remaining two genera (*Meloidogyne* spp. and *Heterodera* spp.) were recovered in less than 5% (i.e. 3%) absolute frequency in the soil.

Hundred percent of the total root samples collected had *Heterodera* spp. This genus was present in sugarcane roots at a low frequency (27%) in 100%

of the locations. However, it was found in moderate frequency in Ungwan Fatika (Table III). *Tylenchus* spp., *Aphelenchoides* spp., *Ditylenchus* spp.,*Pratylenchus* spp., *Hoplolaimus* spp. and *Meloidogyne* spp. were present in sugarcane roots at low frequencies of 27%, 23%, 23%, 17%, 13% and 10% respectively. *Rotylenchus* spp., *Scutellonema* spp., *Aphelenchus* spp. and *Helicotylenchus* spp. have the lowest absolute frequencies (7%, 7%, 3% and 3%) of the nematodes population in the root of sugarcane obtained in all the locations (Table 3.3).

Table III: Absolute frequency of plant-parasitic nematode genera in Sugarcane Roots from Zaria Local Government Area of Kaduna State

Nematode genera	Absolute frequency (%) of nematodes (10 g of Roots)			
	Ungwan Fatika (n=10)	Ungwan Fanwanki (n=10)	Ungwan Alkali Gangare(n=10)	All locations (n=30)
Aphelenchoides	40	10	20	23
Aphelenchus	0	10	0	3
Ditylenchus	30	20	10	23
Helicotylenchus	10	0	0	3
Heterodera	40	20	20	27
Hoplolaimus	20	20	0	13
Meloidogyne	10	20	0	10
Pratylenchus	30	10	10	17
Rotylenchus	20	0	0	7
Scutellonema	10	0	10	7
Tylenchus	30	50	0	27

n = number of samples, 0 = absence of nematodes

Prominence value

Table IV shows prominence values of various plant-parasitic nematodes encountered in the soil in sugarcane fields in Zaria Local Government Area of Kaduna State. *Scutellonema* spp. was the most prominent nematode found in the soil (20449.4) followed by *Rotylenchus* spp. (13452.2) and *Helicotylenchus*spp (5889.0), respectively. *Meloidogyne* spp., *Heterodera* spp. and *Aphelenchoides* spp. were the least (60.9, 158.2 and 241.0) encountered genera.

Table IV: Prominence value of plant-parasitic nematode genera in soil samples of sugarcane in Zaria local government area of Kaduna State

Nematode genera	Prominence value of nematodes (100 cm^3 of soil)			
	Ungwan Fatika (n=10)	Ungwan Fanwanki (n=10)	Ungwan Alkali Gangare(n=10)	All Locations (n=30)
Aphelenchoides	6830.5	0	1252.2	241.0
Aphelenchus	632.5	948.7	2593.8	1314.5
Criconemella	3162.3	894.4	316.2	1288.1
Ditylenchus	0	0	0	0
Helicotylenchus	10498.8	5439.1	2415.0	5889.0
Heterodera	0	822.2	0	158.2
Hoplolaimus	14020.2	1878.3	1788.9	5061.4
Longidorus	632.5	3286.3	0	973.7
Meloidogyne	0	316.2	0	60.9
Paratylenchus	9450.1	1917.0	4427.2	4981.0
Pratylenchus	2146.6	2190.9	0	1197.5
Rotylenchulus	4427.2	0	0	852.0
Rotylenchus	25350.8	9203.3	6830.5	13452.2
Scutellonema	45794.7	15310.9	5312.9	20449.4
Trichodorus	3794.7	3505.4	0	1996.6
Tylenchorhynchus	0	1788.9	0	2206.3
Tylenchulus	1788.9	316.2	0	527.0
Tylenchus	5692.1	0	4949.7	2921.2
Xiphinema	5692.1	5059.6	0	2926.3

n = number of samples, 0 = absence of nematodes

In the case of the roots, *Aphelenchoides* spp. was the most prominent (2302.5) plant-parasitic nematode, followed by *Ditylenchus* spp. (1964.4) and *Heterodera* spp. (1893.5), respectively (Table V). *Helicotylenhus* spp. (60.9), *Aphelenchus* spp. (121.7) and *Meloidogyne* spp. (316.2) were the least prominent encountered genera.

Table V: Prominence value of plant-parasitic nematode genera in sugarcane roots from Zaria local government area of Kaduna State

Nematode genera	Prominence value based on nematode/ 10 g of root			
	Ungwan Fatika (n=10)	Ungwan Fanwanki (n=10)	Ungwan Alkali Gangare(n=10)	All Locations (n=30)
Aphelenchoides	4933.2	316.2	2459.7	2302.5
Aphelenchus	0.0	632.5	0.0	121.7
Ditylenchus	3943.6	1643.2	632.5	1964.4
Helicotylenchus	316.2	0.0	0.0	60.9
Heterodera	4427.2	894.4	0.0	1893.5
Hoplolaimus	2146.6	894.4	894.4	827.7
Meloidogyne	316.2	894.4	0.0	316.2
Pratylenchus	4929.5	316.2	316.2	1496.9
Rotylenchus	2236.1	0.0	0.0	430.3
Scutellonema	1264.9	0.0	316.2	430.3
Tylenchus	2190.9	4454.8	0.0	1773.0

n = number of samples, 0 = absence of nematodes

Disscussion

This study has shown that nineteen (19) genera of plant-parasitic nematodes (PPNs) were found associated with sugarcane fields in Zaria Local Government Area of Kaduna State. This result was different from the findings of Afolami *et al*. (2014) that 12 genera of plant-parasitic nematodes associated with sugarcane in Bacita, Kwara State of Nigeria. Patrick and Mireille, (1992) also reported 13 genera of plant-parasitic nematodes associated with sugarcane in Ivory Coast. Similarly, Shireesha and Vanita Das (2014) reported the presence of 8 genera of plant-parasitic nematodes associated with sugarcane in India. These differences can be as a result of the climatic conditions (temperature, sunshine, humidity, soil-physical chemical properties and varietal differences) which act both on the development of the nematodes and sugarcane (Afolami *et al*., 2014). Climatic conditions especially high temperature and sunshine during the dry season helps to kill many soil borne pests and pathogens including plant-parasitic nematodes (Elmore *et al*., 1997).

Scutellonema spp. and *Rotylenchus* spp. were found to be the most predominant plant-parasitic nematodes associated with sugarcane by virtue of its population encountered in soils in the three locations. This agrees with earlier reports that plant-parasitic nematodes (*Scutellonema* spp. and *Rotylenchus* spp.) are known to be associated with sugarcane in Ivory Coast and India (Patrick and Mireille, 1992; Shireesha and Vanita Das 2014).

Paratylenchus spp. was the second most populous nematode in all locations in terms of frequency of occurrence in the rhizosphere soil but does not attract so much importance when compared to*Heteroderasacharri*.The cyst nematode, *Heterodera* genera outnumbered *Rotylenchus*, *Scutellonema*, *Helicotylenchus* and *Hoplolaimus* in terms of prominence in the roots. This is due to the fact that *H. sacharri*is a sedentary endoparasite.

The high population of *Heterodera*observed in the root was also evident in some of the cysts presence on the roots of the sugarcane sampled from the locations of the Local Government areas. Afolami

(2014) and Cadet and Spaull (2003) reported *Heterodera*, *Meloidogyne* and *Pratylenchus* as nematodes associated with yield reduction in Nigeria and other parts of the world. Patrick and Mireille (1992) working in Ivory Coast and Burkina Faso, reported that *Heterodera* and *Pratylenchus* were among the widespread and devastating nematodes species on sugarcane. Irrigation which is a regular practice on the sugarcane plantation could have also contributed to the widespread distribution of *Heterodera*. Odihinrin (1977) reported those *Heterodera* cysts are easily carried in the irrigation canals by flood waters as a means of dissemination.

Xiphinema spp., *Longidorus* spp. and *Trichodorus* spp. were recovered from soil but was devoid of *Ditylenchus* spp. The presence of these virus vectors were clear indications that there may be possible association with virus diseases sometimes found on sugarcane e.g. sugarcane mosaic virus, sugarcane streak mosaic virus and sugarcane yellow leaf virus (Wada *et al*., 2017). Even though nematodes can cause diseases to plant by themselves, virus transmitting nematodes can become part of an etiological complex, resulting in a combine pathogenic potential that sometimes appears to be far greater than the sum of the damage either of the pathogens can produce individually (Ramgareeb *et al*., 2010; Mishra *et al*., 2010). The present study is in agreement with earlier findings of Afolami *et al*. (2014) who reported that species of *Trichodorus*, *Longidorus*, *Xiphinema*, and *Paratrichodorus* were associated with sugarcane.

The study also reveals the presence of important ecto and endo parasitic nematodes such as *Criconemella* spp., *Helicotylenchus* spp., *Rotylenchulus* spp., *Hoplolaimus* spp., *Tylenchus* spp., *Tylenchorhynchus* spp. and *Ditylenchus* spp. which have been frequently associated with yield reduction in sugarcane production worldwide (Schenck and Holtzman, 1990; Crow, 2004). These nematodes pests were also encountered in populations that could be detrimental to plant health and good yield which according to Afolami (2000) is the ultimate goal of farmers. Reports from other parts of the world (Spaull and Cadet, 1991; Blair *et al*., 1999; Bond *et al*., 2000) have indicated these nematode species as important pests of sugarcane causing plant debilitation and poor growth.

The prominence values of *Meloidogyne* spp., *Aphelenchus* spp., *Longidorus* spp. and *Aphelenchoides* spp. recovered were very low. This suggests that these nematodes might not be economically important on sugarcane and may have also resulted from interspecific competition (Afolami, 2000).

Nematode distribution and abundance varied from field to field, suggesting that the relative occurrence and abundance is determined by several factors within the environment such as cropping system, type of soil, plant age, cultural practices, soil moisture, temperature etc (Wei *et al*., 2012; Afolami *et al*., 2014).

Conclusion

The study therefore, has clearly showed that sugarcane in the three locations in Zaria Local Government area harbored plant-parasitic nematodes. Some of the nematodes are in their abundance; (*Rotylenchus* spp., *Scutellonema* spp., *Paratylenchus* spp., *Helicotylenchus* spp. and *Hoplolaimus* spp.) while the population of others is negligible (*Aphelenchus* spp., *Aphelenchoides* spp. and *Tylenchulus* spp.) and seemingly does not pose any threat to the plant.

Recommendations

There is need to educate local farmers on the large diversity of plant-parasitic nematodes associated with sugarcane and their damage potentials by creating awareness programmes. Screening seed plants and regular plant quarantine services should be employed prior to the introduction of new varieties to sugarcane farmers and also, effective nematode management strategies should be considered in order to improve yield in sugarcane fields in Zaria LGA of Kaduna State.

References

Adesiyan, S.O., Caveness, F.E., Adeniji, M.O. and Fawole, B. (1990). Nematode Pest of Tropical Crops. Heinemann Educational Books (Nigeria) Plc.

Afolami, S.O. (2000). Suggestion for the improvement of current methods of studying and reporting resistance to root-knot nematodes.*International Journal of Nematology*, 10(1), 94-100.

Afolami, S., Solomon, S. and Daramola, F. (2014). Biodiversity of plant-parasitic nematodes of sugarcane in Bacita, Nigeria.*Journal of Entomology and Nematology*, 6(6), 71-79.

Blair, B.L., Stirling, G.R. and Whittle, P. J. L. (1999). Distribution of pest nematode on sugarcane in South Queensland and relationship to soil texture, cultivar, crop age and region.*Australian Journal of Experimental Agriculture*, 39, 43 – 49.

Bond, J. P., McGawley, E. C. and Hoy, J. H. (2000).Distribution of plant-parasitic nematodes on sugarcane in Louisiana and efficiency of nematicides.*Supplementary Journal of Nematology*, 32, 493 – 501.

Cadet, P. and Spaull, V. W. (2003).Effect of nematodes on the sustained production of sugarcane in South Africa. Field Crops Research, 83, 91–100.

Cadet, P. and Spaull, V. W. (2005). Nematode parasites of sugarcane. In Luc M, Sikora RA, Bridge J (Eds.). Plant-parasitic nematodes in subtropical and tropical agriculture.(2nd edn.). (pp 645-674). CABI Publishing, Cambridge.

Coyne, D. L, Nicol, J. M. and Claudius-Cole, B. (2007).*Practical Plant Nematology*: A Field and Laboratory Guide, IITA, Ibadan, Nigeria. 82pp.

Crow, W. T. (2004). Plant-parasitic nematodes on sugarcane in Florida.Florida Cooperative Extension Services Institute of Food and Agricultural Sciences, University of Florida.Pp. 1 – 2.

Doncaster, C. C. (1962). A counting dish for nematodes.*Nematologica* 7, 334-336.

Elmore, C.L., Stapleton, J. J., Bell, C.E. and DeVay, J.E. (1997). Soil Solarization: A non pesticidal method for controlling diseases, nematodes and weeds. *Oakland:University ofCalifornia Agricultural Natural Resource Publication*, 21377.

FAOSTAT (2013). Food and Agriculture Organization of the United Nationshttp://faostat.fao.org/site/567/default.aspx#ancor

Girei, A.A. and Giroh, D.Y. (2012).Analysis of the Factors Affecting Sugarcane (*Saccharumofficinarum*) Production under the Out-growers Scheme in Numan Local Government Area Adamawa State.*Journal of Education and Practice*, 3 (8), 195 – 200.

Government of Kenya (2010). Kenya Sugar Industry Strategic Plan for 2010–2014. Government of Kenya Press.

Kaduna State Agricultural Development Project (KADP), (2013). Agricultural Production Survey.

Mai, W. F. and Mullin, P. G. (1996).Plant-parasitic nematodes.Cornell University Press.

Michel, L. U. C., Sikora, R. A. and Bridge, J. (2005).Plant-parasitic nematodes in subtropical and tropical agriculture.2nd Edition. Pp. 493 - 520.

Mishra, S., Singh, D.,Tiwari, A. K.,Lal, M.and Rao, G. P. (2010). Elimination of Sugarcane mosaic virus and Sugarcane streak mosaic virus by tissue culture. *Sugarcane International*, 28, 119–122.

.

National Sugar Development Council (2013). *Policy Report*. www.ngnatsugarpolicy.org

Norton, D.C. (1989).Abiotic factors and plant-parasitic nematode communities.*Journal of Nematology*, 21, 299-307.

Nzioki, H.S. and Chirchir, A.K. (2010). Yield loss assessment due to nematodes associated with sugarcane in Kenya. Proceedings 12th KARI Biennial Science Conference (pp. 707-714). KARI Conference Hall, KARI Head Quarters Building, Nairobi, 8th – 12th November, 2010.

Odihinrin, R.A. (1977). Irrigation water as a means for the dissemination of the sugarcane cyst nematode *Heteroderasacchari* at Bacita sugar estate. Occasional publication. *Nigeria Society for Plant Protection*, 2, 58.

Patrick, Q. and Mireille, F. (1991). Plant-parasitic nematodes associated with sugarcane in the Ivory Coast. *Fundamental and Applied Nematology*, 15 (5), 473-478.

Ramgareeb, S., Snyman, S.J., Van Antwerpen, T. and Rutherford, R.S. (2010). Elimination of virus and rapid propagation of disease free sugarcane (*Saccharum* spp. cultivar NCO 376) using apical meristem culture. *Plant Cell Tissue Org*, 100,175–181.

Schenck, S. and Holtzman, O.V. (1990).Evaluation of potential problems in a changing agricultural system.Nematode Control in Hawaiian Crops.*Plant Diseases*, 74: 837 - 843.

Shireesha, R. and Vanita Das, V. (2014).Studies of plant-parasitic nematodes in sugarcane plants in Nizamabad district (Telangana), India.*The International Journal of Science and Technology* 2(13), 198 - 201.

Spaull, V.W. and Cadet, P. (1991).Nematode parasites of sugarcane. In: plant-parasitic Nematodes in Subtropical and Tropical Agriculture. Sikora, M. L. V. C. and Bridge, R. A. J. Eds, pp.461-491.Wallingford, UK CAB International.

Wada, A.C., Abo-Elwafa, A., Salaudeen, M.T., Bello, L.Y. and Kwon-Ndung, E.H. (2017).Sugarcane production problems in Nigeria and some Northern Africa Coutries .*Direct Research Journal of Agriculture and Food Science*, 5(3), 141 - 160.

Wei, C.Z., Zhengi, H.F., Li Q., Lu X. T., Yu, Q., Haiyang, Z., Quansheng, C., Nianpeng, H., Paul, K., Wenju, L. and Xinguo, H. (2012). Nitrogen addition regulates soil nematode community composition through ammonium suppression. PLOS ONE 7, 243384