SURVEY OF PLANT-PARASITIC NEMATODES ASSOCIATED WITH CASSAVA IN OSUN STATE, NIGERIA

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ABSTRACT

A survey was conducted to determine the types, frequency and population of plant parasitic nematodes associated with cassava (Manihot spp.) in three agro-ecological regions of Osun state, of Nigeria. The state was divided into three agricultural zones which included; Iwo, Oshogbo and Ife/Ijesha. The survey was conducted in October 2010 and November 2012. In each zone, 20 cassava based farm were randomly selected for sampling. In each farm, 30 plants were randomly sampled. Soil samples were collected around the roots of each plant using a soil auger and plant parasitic nematodes were extracted from the soil samples. Identification of plant parasitic nematodes to the generic level was carried out. Five genera of plant parasitic nematodes were encountered in soil samples collected from the three zones including Meloidogyne spp., Pratylenchus spp., Helicotylenchus spp., Scutellonema spp., and Paratylenchus spp. Apart from Paratylenchus spp. these nematodes have been implicated worldwide as important nematode pests of cassava. Meloidogyne spp. was the most frequently occurring species in the state followed by Pratylenchus, Helicotylenchus and Scutellonema spp. The least occurring species was Paratylenchus. These plant-parasitic nematodes could constitute a problem to cassava production in Osun State.

INTRODUCTION

Cassava (Manihot esculenta Crantz) is a major staple crop and one of the major sources of food energy for more than 200 million people in the tropics (Hahn et al., 1980). This crop plays a vital role in the food security of the rural economy because of its capacity to yield under marginal soil conditions and its tolerance to drought (IITA, 2004). It is the most widely cultivated crop in the tropics; predominantly grown by smallholder farmers and dependent on seasonal rainfall (IITA, 2004). Rural and urban communities use cassava mainly as food in both fresh and processed forms. In recent years, cassava has been increasingly used as raw material in the manufacture of various industrial products such as starch and flour (Nasser and Oritz, 2010). With increased prospects of starch

from cassava as a source of ethanol for biofuels, its cultivation is transforming from subsistence to a more commercially-oriented farming enterprise (Nasser and Oritz, 2010). Among the cassava-growing regions of the world, Africa accounts for more than 50% of the global cassava production of 233.8 million metric tonnes (Batiano et al., 2007). Nigeria is the largest producer of cassava in the world and its production is currently put at about 33.8 million tonnes/year (FAO, 2003).

However, the production of cassava is extremely low particularly in Africa where the yield in tonnes per hectare is 19% below the world average and 35% below the yields in South America. Pests and diseases have been identified as main causes of yield reduction in cassava production (Hahn et al., 1989; IITA, 2004; Banito, 2003; Fermont, 2009). Major diseases affecting cassava in Africa include Cassava mosaic disease (CMD), Cassava bacterial blight (CBB), Cassava anthracnose disease and nematode diseases (Coyne, 1994; Hillocks and Wydra, 2002). Many nematode species have been reported to be associated with cassava, but only few are known to cause economic damage to the crop. Meloidogyne incognita, M. javanica and Pratylenchus spp. have been reported to cause serious damage on cassava (Coyne, 1994). Losses of up to 98% have been recorded under heavy infestation by Meloidogyne spp. (Coyne, 1994). A wide range of plant-parasitic nematodes have been reported to be associated with cassava across Africa including Benin, Burundi, Cameroun, Cote d'voire, Ghana, Kenya, Malawi, Mozambique, Niger, Nigeria, Tanzania, Togo, Uganda, Zambia and Zimbabwe (Bridge et al., 2005). Some of these nematodes are Rotylenchus reniformis, M. incognita, M. javanica, Pratylenchus brachyurus, Scutelonema clathricaudatum, S. magniphasmum, S. paralabiatum, S. unum, H. erythrinae and H. dihystera (Caveness, 1967; Bridge et al., 1991; Ray et al., 1992; Coyne et al., 2003; Bridge et al., 2005). Although the list of nematodes is extensive, the majority of the nematode species appear however, of limited importance with little evidence of significant effect on the crop (Bridge et al., 2005). This might be partly due to the fact that, the damage they cause regularly goes unnoticed because of the naturally knoblly and rough texture of the roots, which can disguise the nematode damage (Talwana et al., 1997).

Plant parasitic nematodes associated with cassava in Osun state, particularly in Ife/Ijesha, Oshogbo and Iwo have not been reported. This study was therefore conducted to provide baseline data on nematodes associated with cassava in Osun state of Nigeria.

Descriptions of the Agricultural Zones (Iwo, Oshogbo and Ife / Ijesha) of Osun state based on its Agro-ecological and Cultural Characteristics

Iwo zone (forest / savanna transition)

This zone is characterized by derived savanna vegetation with rainfall averaging 1,100 mm per annum. The soils of the area are mainly derived from undifferentiated basement complex rocks with pebble beds and to a lesser extent coarse granite parent material. The topography is mainly undulating plains, dissected plains and patches of nearly level to gently undulating plains. Farmlands may be acquired by inheritance, purchase, leasing etc. Typically, farm size ranges between 0.5-2 ha; Farmers do have multiple farm plots (Salimonu, 2008). Arable crops cultivated include maize, cassava, okra, soybean and chili pepper.

Oshogbo zone (Savannah zone)

This zone is located at the northern part of the state and it is characterized by savanna vegetation. The topography is mainly gently undulating plains with undulating dissected plains. Annual rainfall is about 800 mm per

annum. Average farm size is between 0.5 and 1.5 ha, and farmlands are typically inherited. They may also be purchased outright or leased, payment being cash or a share of the farm produce. The soils of the area are derived mainly from quartzite and basement complex rocks. The main crops cultivated are maize, cassava, okra, soybean and cowpea (Salami and Sangoyomi, 2013).

Ife/Ijesha (Forest zone)

This zone is characterized by forest vegetation. It's a humid tropic with distinct dry and wet seasons of about four and eight months respectively (Ande and Senjobi, 2010; Amujoyegbe and Alabi, 2012). Annual rainfall and mean air temperature is about 1300 mm per annum and 13°C respectively. This zone is specifically underlain by coarse / medium grained granite gneisses (Boesse and Ocan, 1988). This terrain is unique being below a rock hill. Hence hill creep soils are expected to dominate the area especially on the upper slope position (Ande and Senjobi, 2010). The main crops cultivated are cacao, oil palm, yams, cassava, and maize. Although cassava is grown in this zone, but it is relatively less important (Sangoyomi and Salami, 2013).

MATERIALS AND METHODS

Soil Sampling and Laboratory Analysis

A survey was carried out to determine the types, frequency and distribution of plant-parasitic nematodes associated with cassava in three zones of Osun State Nigeria. Cassava farms were purposively selected from each zone using the Agricultural Development Project (ADP) structure as a guide to locate representative cassava fields in each zone (Daramola et al., 2012). 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 or her farm (Daramola et al., 2012). A total of 60 farms were sampled from the three zones. In this study Osun state was divided into three agricultural zones based on its agro-ecological and cultural characteristics namely; Iwo, Oshogbo and Ife/Ijesha. Cassava is grown at subsistence and large scales in all three zones.

Cassava plants were sampled in the month of October in 2010 and 2012. In each zone, 20 cassava based cropping system farms were randomly selected. In each farm, 30 plants were randomly selected and soil samples were collected from around the roots of each plant using a soil auger along the four cardinal directions at the base of each plant (depth 0-30 cm; diameter 1.9 cm). Samples from each farm were pooled and sealed in plastic bags (Radiant Packaging, Nigeria) and protected from the sun (Ricka and Barker, 1992). The samples were properly labeled and taken to laboratory for analysis. Plant-parasitic nematodes were extracted from the soil using the method described by Whitehead and Hemming (1965). Each composite soil samples was mixed thoroughly and plant-parasitic nematodes were extracted from 200 ml sub-sample. The set up was left undisturbed for 24 hours before decanting the suspension into a beaker. Twenty extraction trays were set up per sample. Plant-parasitic nematodes extracted from each suspension were killed by adding an equal volume of hot water to the nematode suspension. The suspension was thoroughly mixed using a magnetic stirrer and 5 ml aliquot was drawn from each suspension into a Doncaster (1962) counting dish for identification and quantification of the extracted nematodes. Temporary mounts of nematodes were prepared prior to nematode identification. Identification of plant-parasitic nematodes to the generic level was done using the Lucid-key of Bell (2004).

Statistical Analysis

Mean values, standard deviation of means were calculated using Statistical Packages for

social Sciences (SPSS) (2010). The percentage nematode population was determined using the formula (n / N) x 100, where n = number of time a nematode occurs in all the samples, while N = total population of all the nematodes extracted in all the samples.

RESULTS

Five genera of plant parasitic nematodes were identified in soil samples collected from the three zones. The plant-parasitic nematodes were Meloidogyne spp., Pratylenchus spp., Helicotylenchus spp., Scutellonema spp., and Paratylenchus spp. (Table 1). Table 2. Shows the frequency of occurrence of plant-parasitic nematodes associated with cassava in Osun state Nigeria (2010). Meloidogyne spp. was the most frequently occurring species in the soil (91.7%) followed by Pratylenchus spp. with a frequency rating of 77.3% while Helicotylenchus spp. and Scutellonema spp. had a frequency rating of 57.8% and 24.8% respectively.

Table 1. Occurrence and geographical distribution of plant parasitic nematodes of cassava in three zones of Osun State, Nigeria

	Zones		
Nematode spp.	Oshogbo	Ife /Ijesha	Iwo
Meloidogyne	x	x	x
Helicotylenchus	x	x	x
Paratylenchus	x	x	x
Pratylenchus	x	x	x
Scutellonema	x	x	x

x = present

Table 2. Frequency of occurrence of plant-parasitic nematodes associated with cassava in Osun State, Nigeria (2010).

Nematode spp.	Frequency of occurrence	Frequency (%)
Meloidogyne	55.0	91.7
Helicotylenchus	34.7	57.8
Paratylenchus	9.7	16.2
Pratylenchus	46.4	77.3
Scutellonema	14.9	24.8

Frequency of occurrence is expressed as a percentage of the total number of samples examined (n/Nx100), Where n =numberof time a nematode occurs, N = the sample size, Sample size (N) = 60.

Paratylenchus spp. had the lowest frequency rating (16.2%). The results of the 2012 sampling followed a similar trend (Table 3). Meloidogyne spp. had the highest nematode population of 1100/200 ml soil. This was followed by Pratylenchus spp., Helicotylenchus spp., Scutellonema spp. and Paratylenchus spp. with 927/200 ml soil, 694/200 ml soil, 298 / 200 ml soil and 194/200 ml soil respectively (Table 4). The result of 2012 sampling followed the same trend (Table 5).

Table 3. Frequency of occurrence of plant-parasitic nematodes associated with cassava in Osun State, Nigeria (2012).

Nematode spp.	Frequency of occurrence	Frequency (%)
Meloidogyne	60	100
Helicotylenchus	44.5	74.2
Paratylenchus	11.8	19.7
Pratylenchus	55.1	91.8
Scutellonema	25.6	42.7

Frequency of occurrence is expressed as a percentage of the total number of samples examined (n/Nx100), Where n = numberof time a nematode occurs, N = the sample size, Sample size (N) = 60.

Table 4. Soil population (number / 200 ml soil) of plant-parasitic nematodes around the roots of cassava inOshogbo zone (2010).

Nematode spp.	Nematode Population / 200 ml soil	Population (%)
Meloidogyne	1100	34
Helicotylenchus	694	22
Paratylenchus	194	6
Pratylenchus	927	29
Scutellonema	298	9
	3213	

Sample size (N) = 20

Table 5. Soil population (number / 200 ml soil) of plant-parasitic nematodes around the roots of cassava inOshogbo zone (2012).

Nematode spp.	Nematode Population / 200 ml soil	Population (%)
Meloidogyne	1520	36
Helicotylenchus	889	21
Paratylenchus	236	6
Pratylenchus	1101	26
Scutellonema	512	12
	4258	

Sample size (N) = 20.

Table 6 shows the soil population (number/200 ml soil) of plant-parasitic nematodes around the roots of cassava in Ife/Ijesha zone (2010).

Table 6. Soil population (number / 200 ml soil) of plant-parasiticnematodes around the roots of cassava inIfe / Ijesha zone (2010).

Nematode spp.	Nematode Population / 200 ml soil	Population (%)
Meloidogyne	981	34
Helicotylenchus	230	8.1
Paratylenchus	640	22
Pratylenchus	702	25
Scutellonema	306	11
	2859	

Sample size (N) = 20

Meloidogyne spp., had the highest nematode population of 981/200 ml soil. This was followed by Pratylenchus spp. with a nematode population of 702/200 ml soil, while Paratylenchus spp. had a nematode population of 640/200 ml soil. Scutelonema spp. had a nematode population of 306 / 200 ml soil. The lowest nematode population of 230/200 ml soil were observed in Helicotylenchus spp. The result of 2012 sampling followed the same trend, except that Paratylenchus spp. had the least nematode population of 54/200 ml soil (Table 7). Table 8 shows the soil population of plant-parasitic nematodes around the roots of cassava in Iwo zone (2010).

Table 7. Soil population (number / 200 ml soil) of plant parasitic nematodes around the roots of cassava inIfe / Ijesha zone (2012).

Nematode spp.	Nematode Population / 200 ml soil	Population (%
Meloidogyne	996	42
Helicotylenchus	524	22
Paratylenchus	54	2
Pratylenchus	615	26
Scutellonema	209	9
	2398	

Sample size (N) = 20

Table 8. Soil population (number / 200 ml soil) of plant-parasitic nematodes around the roots of cassava inIwo zone (2010).

Nematode spp.	Nematode Population / 200 ml soil	Population (%)
Meloidogyne	1091	31
Helicotylenchus	767	22
Paratylenchus	558	16
Pratylenchus	891	25
Scutellonema	269	8
	3576	

Sample size (N) = 20.

The result shows that, Meloidogyne spp. had a the highest nematode population of 1091/200 ml soil, followed by Pratylenchus spp. with a soil population of 891/200 ml soil. Helicotylenchus spp. and Paratylenchus spp. had a nematode population of 767/200 ml soil and 558/200 ml soil respectively, while Scutelonema spp. had the least population of 269/200 ml soil. In 2012, Paratylenchus spp. had the lowest nematode population of 154 ml/soil, while Meloidogyne spp. had the highest nematode population of 1262 / 200 ml soil (Table 9).

Table 9. Soil population (number / 200 ml soil) of plant-parasitic nematodes around the roots of cassava inIwo zone (2012).

Nematode spp.	Nematode Population / 200 ml soil	Population (%)
Meloidogyne	1262	35
Helicotylenchus	806	23
Paratylenchus	154	4
Pratylenchus	920	26
Scutellonema	425	12
	3567	

Sample size (N) = 20.

DISCUSSION

The results of this study show that Meloidogyne sp. Pratylenchus spp., Scutelonema spp. and Helicotylenchus spp. which have been implicated worldwide as important nematode pests of cassava are common in cassava fields in Osun state, Nigeria. Paratylenchus spp. which has not been implicated in cassava roots was also encountered in the three zones around the roots of cassava. This result confirms those of McSorley et al. (1983) who reported Pratylenchus brachyurus, Rotylenchus reniformis, Helicotylenchus spp., Scutelonema spp. and Meloidogyne spp. as the major plant-parasitic nematodes associated with cassava in United State of America. M. incognita and M. javanica are the most widely reported and economically important in the world (McSorley et al., 1983). Also Coyne and Namaganda (1994) identified Meloidogyne spp. as the most important nematode species limiting cassava production in Uganda. They observed root knot nematode galling damage to cassava roots on 94% of 88 fields examined. Out of the damaged crops 17% were severely galled (Bridge et al., 2005). However their findings are at variance with those of Van Den Over et al. (1997) who reported that in four cassava variety trials conducted in Mozambique, large numbers of root knot nematodes were found on several cultivars during 1995 sampling, but no distorted roots were observed. They further noted that root knot nematode densities in excess of 100 J2 / g of root were observed in only 7 % of thirty cassava root samples from smallholder's farm formally grown to cotton under irrigation. In Nampula province, were cassava had been grown only for one or two

years after the war, no serious root knot nematode infestation was detected in the 27 samples from smallholder's farm.

However heavy root-knot nematode infestations were observed in cowpea, pigeon pea and tomatoes planted as mixed crops with cassava. They also reported that low number of lesion nematodes was found in 44% of the samples collected from the two districts. DeGuiran (1965) reported that P. brachyurus is the most common plant-parasitic nematode occurring on cassava in Togo, with population density up to 400/g of root. He further stated that the nematode was attributed to contributing to a gradual yield decline over several years of production. Under screenhouse conditions, an eightfold population increase in P. brachyurus density was observed after three months on cassava cv. IAC-105.66 in Brazil (Charchar and Huang, 1981). In Kenya severe damage to small number of cassava germplasm lines (1%) was observed in a breeder's selection trials (Coyne et al., 2004). In a related study Makumbi-Kidza et al. (2007) reported that M. incognita significantly reduced the number of storage roots formed on cassava plants inoculated at 14, 40, 70, and 88 days after planting and the total weight of storage-roots in plants inoculated at 1, 14, 40, 70, and 88 days after planting in comparison to uninoculated plants. Root-knot nematodes induce gall formation on feeder roots and sometimes on tubers. A reduction of plant height by as 52 % and storage root loss of 87% have been reported by earlier worker (Caveness, 1965).

The study shows that Meloidogyne spp., Pratylenchus spp. Helicotylenchus spp. and Scutellonema spp., which have been implicated worldwide as important nematode pests of cassava are common in the cassava fields in Osun state Nigeria. However Paratylenchus have not been reported in cassava fields elsewhere. Though the population of plant-parasitic nematodes associated with cassava in the state is of limited importance but the intensification of cassava production in the state may increase their population. Farmers should therefore use resistant cultivars and appropriate farm practices that will not favour their build up.

REFERENCES

Amujoyegbe, J.B and Alabi, O.S. 2012. Cropping system analysis of two agro ecological zones of Southwestern Nigeria. J. Agri. Ext. and Rural Dev., 4, 396-401.

Ande, O.T and Senjobi, B. 2010. Lithologic discontinuity and pedogenetic characterization on an aberrant toposequence associated with a rock hill in South Western Nigeria. International Journal of the Physical Sciences 5, 596-604.

Banito, A. 2003. Integrated control of cassava bacterial blight in West Africa in relation to ecozones, host plant resistance and cultural practices. PhD thesis, University of Hannover, pp. 148.

Bationo, A., Kihara, J., Vanlauwe, B., Waswa, B., Kimetu, J. 2007. Soil organic carbon dynamics, functions and management in West African agro-ecosystems. Agri syst. 94: 13-25.

Bell, M. 2004. Plant-parasitic nematodes: Lucid key to 30 Genera of plant-parasitic nematodes. http://www.lucidcentral.com/keys/nematodes.

Boesse, J.M., Ocan, O.O. 1988. Geology and Evolution of the Ife-Ilesa Schist Belt, S.W. Nigeria. Proceedings of Benin – Nigeria Geotraverse International Meeting on Proterozic Geology and Tectonic of High Grade Terrains. Nov. 28th to 30th, Obafemi Awolowo University, Ile – Ife, Nigeria. pp. 200 – 225.

Bridge, J., Coyne, L. and Charles, K.L. 2005. Nematode parasites of tropical root and

tuber crops. In: Luc M., Sikora, R.A. and Bridge, J. (Eds). Plant parasitic nematodes in subtropical and tropical agriculture. Second edition CABI publishing pp: 221-252.

Bridge, J., Otim- Nape, G.W. and Namanganda, J.M. 1991. The root-knot nematode Meloidogyne incognita causing damage to cassava in Uganda, Afro Asian j. Nematol. 1: 116-117.

Caveness, F.E. 1965. A survey of plant parasitic nematodes in Nigeria. USDA, Shelter, California, pp. 276

Caveness, F.E. 1967. 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.

Charchar, J.M. and Huang, C. S. 1981. Circulo de hospedeiras de Pratylenchus brachyurus. 3. Plantas diversas Brasileira, fitopatal. 6:469-473.

Coyne D.L. 1994. Nematode pests of cassava. Africa crop Sci J., 2: 335-339.

Coyne, D.L. and Namanganda, I.M. 1994. Root-knot nematodes Meloidogyne spp. Incidence on cassava in two areas of Uganda. Roots, 1: 12-13.

Coyne, D.L. Talwana, L.A.H. and Malsen, N.R. 2003. Plant-parasitic nematodes associated with root and tuber crops in Uganda. International J. Nematol., 10: 153-158.

Coyne, L. 2004. Nematodes: Pre and post pests of roots and tuber crops. A brief overview. In: Akoroda, M.O. and Ekanayake, I.J. (eds) Proceedings of the international symposium for root and tuber crops. 12-16 November 2001, Ibadan pp. 522-526.

Daramola, F.Y., Afolami, S.O., Idowu, A.A. and Nwaguma, E.I. 2012. Studies on the occurrence and distribution of plant-parasitic nemstodes in some pineapple producing states in Nigeria. Asian J. Crop Sci., 5: 190-199.

DeGuiran, G. 1965. Nematodes associes au manioc dansle su du Togo. In: Comptes renduesdes travaus du congres de la protection culture tropicales, Marsailles, pp. 677-680.

Doncaster, C.C., 1962. A counting dish for nematodes. Nematologica, 7: 334-337.

FAO. 2003. FAOSTAT, FAO statistical database Agriculture. Food and Agricultural Organization.

Fermont, A.M. 2009. Cassava and soil fertility in intensifying smallholder farming systems of East Africa. Published doctoral dissertation. Wageningen University and Research Centre, Wageningen. pp 123.

Hahn, S.K., Terry, E.R. and Leuschner, K. 1980. Breeding cassava for resistance to cassava mosaic disease, Euphytica 29:673-683.

Hahn, S.K., Soba, J.C.G. and Ikotun, T. 1989. Resistance breeding in root and tuber crops at the international institute of tropical agriculture (IITA) Ibadan Nigeria, Crop Prot., 8:147-168.

Hillocks, R.J., Wydra, K. 2002. Bacterial, fungal and nematode diseases. In: Hillocks RJ, Thresh JM, Bellotti, A.C. (eds) Cassava: biology, production and utilization, CABI, pp. 261-280.

International Institute of Tropical Agriculture (IITA). 2004. Preemptive management of the virulent cassava mosaic disease through an integrated cassava development approach for enhanced rural sector economy in the south-south and south-east zones of Nigeria. IITA, Ibadan, Nigeria. pp. 79.

Makumbi-Kidza, N.N., Speijer, P. R. and Sikora, R.A. 2007. Effects of Meloidogyne incognita on growth and storage root formation of cassava (Manihot esculenta). J. Nematol. 32: 475-477.

McSorley, R., Ohair, S.K and Parrado, J.L 1983. Nematodes of cassava Manihot

esculenta Crantz. Nematropica, 13:261-287.

Nassar, N. and Ortiz, R. 2010. Breeding cassava to feed the poor, pp. 78-84. In: scientific American http://www.scientificamerican.com/article.cfm?id=breeding-cassava).

Ray, S Sahoo, N.K. and Mohanti, K. 1992. Plant parasitic nematodes associated with yam in Orissa. J. Root crops, 18: 70-72.

Ricka, D.A., Barker, K.R. 1992. Nematode assays and advisory services. In: Nematology in the southern region of the United States R. D. Riggs (Eds) South cooperative service bulletin 276 Arkansas agric. exp. Fayetteville, Arkansas. pp. 8-20.

Salami, B. T. and Sangoyomi, T. E. 2013. Soil fertility status of cassava fields in south western Nigeria. American J. Experim. Agr. 3: 152-164.

Salimonu, K.K. 2008. Access to fertilizer subsidy among food crop farmers in Osun State, Nigeria. International J. Agr. Econ. & Rural Dev., 1: 1-8.

SPSS, 2010. Windows 16.0. SPSS Inc., Chicago, IL, USA.

Talwana, L.A.H., Speijer, E. Adipala and Malson, N.R (1997) Early screening of cassava for resistance to root-knot nematodes. Nematropica, 27:19-25.

Van Den Over, R, Esther Van Den, B and Jorge, A.C. 1997. Plant parasitic nematodes associated with crops grown by smallholders in Mozambique. Fundam. Appl. Nemal. 21: 645-654.

Whitehead, A.G. and Hemming, J.R. 1965. A comparison of some quantitative methods extracting small vermiform nematodes from soil. Ann. Appl. Biol., 55: 25-38.

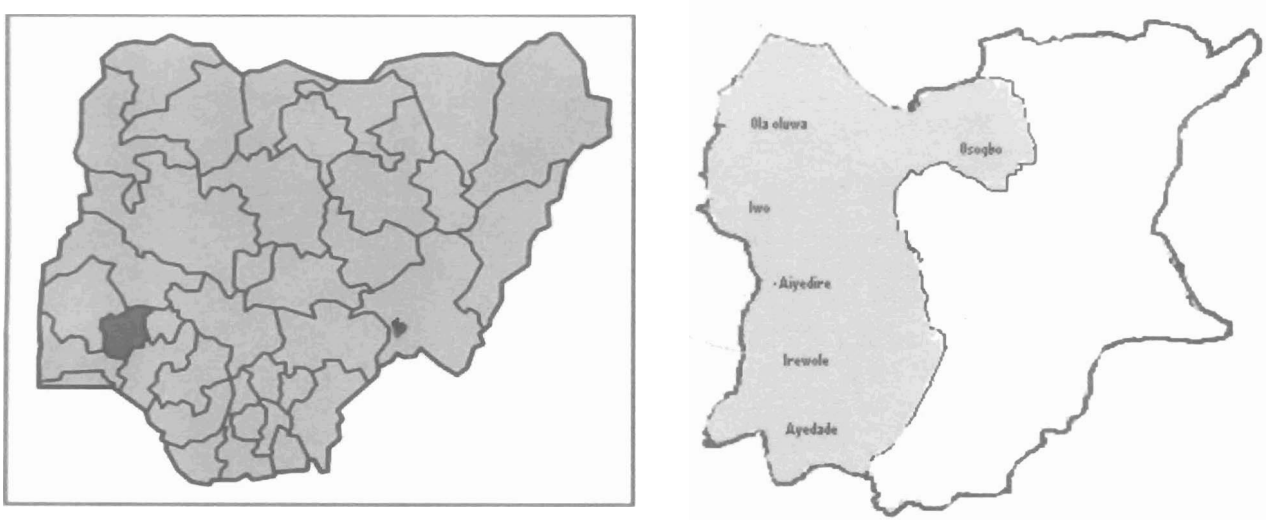

Fig. 1. Map of Osun State, Nigeria with study area shaded. Inset is a map of Nigeria with Osun state highlighted. Source: Salami and Sangoyomi, 2013.