Sudan University of Science and Technology

College of Graduate Studies

Studies on Plant Parasitic Nematodes on Banana in Sennar and Kassala States

دراسات على النيماتودا المتطفلة على نبات الموز فى ولايتى سنار وكسلا

A thesis submitted in to the Sudan University of Science and Technology in Fulfillment of the requirement for M.Sc. (Agric) in crop protection (Plant Pathology)

By

Duria Abdelsalam Eltahir Elshakh

Supervisor: Dr. Ibrahim Saeed Mohammed

2014

بسم الله الرحمن الرحيم

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2014

Dedication

To the soul of my father

Lovely mother

Intimate husband

Brothers and sisters

To all those who search of knowledge

ACKNOWLEDGMENT

Thanks and praise to the Beneficent and Merciful God who provided me with health, strength and patience to have this drop from the renewable flood of knowledge.

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LIST OF CONTENTS

CHAPTER TWO

LITERATURE REVIEW

LIST OF TABLES

LIST OF PLATES

Studies on Plant Parasitic Nematodes on Banana in Sennar and Kassala States

Abstract

The burrowing nematode (*Radopholus similis*) causes a lot of damage the world over, and is capable of destroying major banana plantations as well as citruses, Plant yield losses as high as 50% have been observed under heavy nematode infestation. The objective of this study is to obtain baseline information on plant parasitic nematodes associated with banana farms in Sennar and Kassala areas and the damage of banana nematode *Radopholus Similis.*

A survey was conducted at two main banana growing states, Sennar and Kassala. Samples of plant roots and soil from the rhizosphere zone were collected randomly from 25 and 10 farms randomly selected from Sennar and Kassala States respectively, representing the type of varieties grown, irrigation system, soil type, machinery used, source of new planting (suckers), cropping system and crop rotation. Nematode extraction was undertaken using the Baermann-funnel technique.The results showed that nematode densities was

higher in Kassala than in Sennar State.The most prevailing nematode species identified associated with plant rhizosphere in the two states were, *Pratylenchus Spp*., *Helicotylenchus Sp., Rotylenchus sp., Scutellonema Sp.,Xiphinema Sp., Longidorus Sp*., *Tylenchus Sp., Radopholus Sp*. and *Hoplolaimus Sp*. However, the nematode species, *Radopholus similis* was predominantly isolated from roots as well as rhizosphere regions of banana in the two States.

دراسات على النيماتودا المتطفلة على نبات الموز فى ولايتى سنار وكسلا

ملخص الاطروحة

من المتعارف أن النيماتودا الحافرة burrowing nematode (*Radopholus similis*) تسبب الكثير من الضرر على مستوى العالم ولها المقدرة على تدمير محاصيل الموز الرئيسية. وقد تلاحظ ان نسبة الفاقد من المحصول قد تصل الى اكثر من 50% فى حالة الاصابة الشديدة. الهدف من هذه الدراسة هو الحصول على معلومات اساسية فيما يتعلق بالنيماتودا المتطفلة على محصول الموز بمناطق كسلا وسنارومعرفة الضرر الذى تسببه النيماتودا المتطفلة على الموز ، أجرى المسح بولايتي سنار وكسلا وهما الولايتين الرئيسيتين من حيث زراعة الموز فى السودان. أخذت عينات التربة والجذور عشوائيا من 10،25 مزارع أختيرت عشوائيا من ولايتى سنار وكسلا على التوالى؛ مع الأخذ فى الاعتبار الأصناف المزروعة، نظام الرى، نوع التربة، الآليات المستخدمة، مصدر الخلف التى تستخدم فى الزراعة، نظام الزراعة والدورة الزراعية . أستخدم "قمع بيرمان" لاسخلاص النيماتودا الحية . أظهرت النتائج أن كثافة النيماتودا أعلى فى ولاية كسلا عنها فى ولاية سنار. أكثر الأنواع السائدة من النيماتودا المتطفلة والتى تم عزلها من التربة والتعرف عليها بالولايتين هي :

Pratylenchus Spp., *Helicotylenchus Sp., Rotylenchus sp., Scutellonema Sp.,Xiphinema Sp., Longidorus Sp*., *Tylenchus Sp., Radopholus Sp*. and *Hoplolaimus Sp*.

على أي حال، فإن النوع (*Radopholus similis*) قد تم عزله بالدرجة الأولى من جذور الموز بكلتا الولايتين.

CHAPTER ONE

INTRODUCTION

Plant parasitic nematodes are recognized as important pests of bananas in most regions of the world. Annual crop losses caused by plant-parasitic nematodes are estimated at 8.8 – 14.6% of total crop production and 100 – 157 billion $ worldwide (Sasser & Freckman, 1987; Koenning *et al*., 1999; Abad *et al*., 2008; Nicol *et al*, 2011).

Banana (*Musa spp*) is a popular and widely consumed tropical fruit that provides carbohydrates, proteins, vitamins and minerals to more than 400 million people world wide (INIBAP, 1987).

Banana is the fourth most important food product within the least developed countries, being the staple food for some 400 million people (CTB, 2011).

Of all the fruits, banana holds first place by production volume and is amongst the five most consumed fruits on the planet (FAO, 2011).

Banana is a perennial crop that is grown on the same site for many years. This practice provides conditions for nematode survival and population increase. Roots damaged by nematodes are inefficient in water and nutrient uptake.

The consequences of this damage are a reduced rate of plant growth, lengthening of the vegetative cycle, suppression of bunch weights, and a reduction in the productive life of the farm (McSorley and Parrado, 1986; Bridge, 1988; Fogain and Gowen, 1997; Araya *et. al*., 1999). Top-heavy banana plants may fall over (topple) at fruiting or during strong winds due to the loss of anchoring roots (Gowen, 1995; Whitehead, 1998).

In Rwanda, where banana is an important food and cash crop, two nematode species, *P. goodeyi* and *Meloidogyne spp.*, have been reported to cause significant damage to root system of banana (Okech *et. al*., 2002; Gaidashova *et. al*., 2004).

Nematode management has so far been through rotation, replanting and mulching as well as nematicide application (Gowen, 1993).

Severe nematode damage to banana crops has also been reported in Southeast Asia and all other South Pacific Islands, including the neighboring independent nation of Samoa (Siddiqi, 1973; Bridge, 1988; Davide, 1 995).

Where nematode attack cannot be prevented by using clean planting material in nematode-free soil and growing the plants under strict quarantine conditions, nematode management in bananas is mainly based on crop rotation and chemical control (Gowen and Quénéhervé 1990). However, in those areas where bananas are grown continuously, crop rotation cannot be practised, while at the same time, the price of chemical nematicides is often costive for small farmers. It is also important to note that most nematicides are extremely toxic for the environment.

Although naturally occurring nematode resistance and tolerance

has long been exploited for many agricultural crops (De Waele 1996), this method of nematode management has so far been neglected in bananas. This is despite the evidence, that nematode resistance and tolerance sources are present in the *Musa* gene pool (Pinochet 1996).

1.1. Nematodes of banana

Many nematode species have been reported to be associated with banana and plantain production (Chabrier and Quénéhervé, 2003; Fogain and Gowen, 1997). However, the most economically important species destroy the primary roots, disrupting the anchorage system and resulting in toppling of the plants. These include the burrowing nematode, *Radopholus similis*, the lesion nematode, *Pratylenchus coffeae* and the spiral nematode, *Helicotylenchus multicintus* (Gowen *et al*., 2005).

Some sedentary endoparasites such as root-knot nematode, *Meloidogyne spp*. (Fargette, 1987) and the reniform nematode, *Rotylenchulus reniformis* (Edmunds, 1971) also parasitize plantains.

Radopholus similis (Cobb), with the name "nematodo barrenador" in Spanish and burrowing nematode or "Fiji banana-root nematode" in English, is one of the ten most important phytohelminths in the tropics (Haegeman *et al.*, 2010). Known in the past by many names (Luc, 1987), it parasitizes more than 250 species of plants (Haegeman *et al.*, 2010), and because of geographic expansion, especially in the second half of the twentieth century, has become a major pathogen in banana (*Musa sp*.), causing the so-called "blackhead banana disease", "banana toppling disease" or "pourriture vermiculaire du bananier." Similarly, it devastated the cultivation of black pepper on an Indonesian island in the early 1930s (MacGowan, 1982; Ramana and Eapen, 2000; Thorne, 1961) and currently has a high position in the ranking of important pathogens of ornamental plants such as *Anthurium spp*., *Calathea spp*. and *Dracaena spp.* (Uchida *et al.*, 2003).

Radopholus similis

1.2. Classification scheme by Luc (1987) Elbadri (2000)

Phylum: Nematoda

Class: Secernentea

Order: Tylenchida

Sub-order: Tylenchina

Super-family: Tylenchoidea

Family: Pratylenchidae

Sub-family: Pratylenchinae

Genus: Radopholus

Species: *R. similis*

1.3. Life cycle and biology

Radopholus similis is migratory and generally amphimictic endoparasite fulfills its life cycle in 20 to 25 days at 24 to 32°C (Gowen and Quénéhervé, 1990; Haegeman *et al.*, 2010) and has abundant genes for reproduction, development, parasitism and survival (Haegeman *et al.*, 2010).

In bananas, penetration occurs mostly near the root tips, but nematodes can invade along the entire length of the root. Females and all juvenile stages are infective although males, morphologically degenerate (without stylet), are probably not parasitic. After entering the roots of banana, the nematodes occupy an intercellular position in the cortical parenchyma where they feed on the cytoplasm of nearby cells, causing cavities which then coalesce to appear as tunnels. Invasion of the stele is never observed, even in heavily infected roots. The presence of lignified and suberized layers in endodermal cells of endodermal layers limits invasion of the vascular bundle by *R. similis*. Phenolic compounds play a significant role in the host plant's defence response to the nematode. High levels of lignin, flavanoids, dopamine, cafeic esters and ferulic acids were associated with low levels of penetration in resistant cultivars (Valette *et al*., 1998b). Except for the first juvenile stage (L1) and the male, the other states are infective, especially in the female (Gowen and Quénéhervé, 1990; Quénéhervé, 2009). The infective states penetrate the deep layers of the root with little effect on the central cylinder, empty the contents of the cortex parenchyma cells that develop into cavities and tunnels, and at the same time, the necrotic tissues acquire a reddish and finally blackish tone (Gowen and Quénéhervé, 1990).

It is within infected tissues that females lay their eggs, with an average of four to five eggs per day for 2 weeks. The complete life cycle from egg to egg spans 20-25 days at a temperature range of 24-32°C, the eggs hatch after 8-10 days and the juvenile stages are completed in 10-13 days (Gowen and Quénéhervé, 1990; Loos, 1962).

In absence or reduced densities of competitors such as *Helicotylenchus multicinctus*, high populations of *R. similis* colonize the entire set of banana roots. The presence of competitors reduces the density of *R. similis* in the soil and roots and restricts it to the areas close to the rhizome (Queneherve, 1990).

1.4. Geographic distribution

R.similis is wide spread in most banana-growing regions of the world and present in glasshouses in temperate areas (Orton Williams and Siddiqi, 1973; O'Bannon, 1977).

Burrowing nematode is native to Australasia, but is found worldwide in tropical and subtropical regions of Africa, Asia, Australia, North and South America, and many island regions. The widespread range of this nematode is due to its dissemination with propagative plant material, especially infected banana corms (O'Bannon 1977, Gowen *et. al*. 2005).

Table (1) Distribution of *R. similis* (Anonymous, 1986; Eppo, 1979, 1988, 1992, 1997; Whitehead, 1998; Elbadri, 2000).

Region	Country

Africa	Burundi, Cameroun, Central African Republic, Congo, Ivory Coast, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Madagascar, Mauritius, Malawi, Mozambique, Nigeria, Reunion, Senegal, Seychelles, Somalia, Sudan, South Africa, Tanzania, Zambia, Zimbabwe and Uganda.
Asia	Brunei, Japan, India, Malaysia, Pakistan, Oman, Thailand, Sri Lanka, and Yemen.
Australia	
Central America & Caribbean Islands	Barbados, Belize, Costa Rica, Cuba, Dominica, Dominican Republic, El salvador, Guadeloupe, Guatemala, Jamaica, Martinique, Mexico, Panama, Puerto Rico, St. Kitts, St. Lucia, St. Vincent, and Grenadines, Trinidad and Tobago, and Union States Virgin Islands.
Europe	England, France, Germany, Netherlands, Belgium, Denmark, Italy, Portugal.
North America	Canada, USA.

Pacific Islands	Fiji, Indonesia, New Zealand, Philippines.
South America	Brazil, Colombia, French Guyana, Ecuador, Guyana, Peru, Suriname and Venezuela.

1.5. Damage

Nematode infestation results in root damage of plants, reduced water and nutrient uptake with severe infestation leading to stunted growth and reduced yields and toppling (Speijer and De Waele, 1997).

Radopholus similis attack root and corm tissues causing damage that can reduce bunch size, shorten the life of production, prolong the vegetative cycle and cause banana plants to topple (McSorley and Parado, 1986; Bridge, 1988; Chabrier and Quénéhervé, 2003). Additional indicators are the root weight of the bunch and the number of hands (Araya and De Waele, 2004).

Macroscopically, several dark red lesions appear on the outer part of the root, penetrating throughout the cortex but not into the stele; adjacent lesions may coalesce and the cortical root tissue atrophies and later turns black. In heavy infestations the lesion girdles the roots.

Nematodes migrate from infected roots into the corm causing black lesions which may then spread around the corm. Roots emerging become infected as they grow out of the corm. Uprooting occurs commonly in wind storms or if heavy rains loosen the soil (Gowen and Quénéhervé, 1990).

1.6. Economic importance

The burrowing nematode *Radopholus similis* is among the most destructive pests of banana (Sarah *et al*., 1996). Plant yield losses as high as 50% have been observed under heavy nematode infestation (Speijer *et al*., 1999; Speijer and Kajumba, 2000).

Radopholus spp., are migratory, and endophyto parasitic nematodes that are prevalent in many tropical and subtropical regions throughout the world (Loof, 1991). They damage a wide range of plants by extensively wounding cortical tissues as they feed in roots. *Radopholus spp.* are considered to be among the 10 most damaging plant-parasitic nematodes world-wide (Sasser and Freckman, 1987).

Radopholus similis is a worldwide problem in banana growing regions causing yield losses of 30-50% in Costa Rica and Panama, 40% in Africa, and 30-60% in India (Davide, 1995). Severe nematode damage to banana crops has also been reported in Southeast Asia and all other South Pacific Islands, including the neighboring independent nation of Samoa (Siddiqi, 1973; Bridge, 1988; Davide, 1 995).

The lack of new land free from the burrowing nematode in banana producing countries has prevented the exclusion of the nematode from new banana plantations and has caused the persistence of nematode problems, which result in crop losses ranging 30-80% (Gowen *et al*. 2005).

In Florida, the citrus race of the burrowing nematode causes spreading decline symptoms only in the deep and coarse sandy soil of the Ridge in central Florida, where yield losses range 40-80% (Duncan, 2005).

Yield suppression caused by this nematode on banana and citrus ranges 5-100% and are influenced by many factors, such as soil type and climate (Gowen and Queneherve, 1990; O' Bannon and Esser, 1985). Severe losses are reported on black pepper (Koshy and Bridge, 1990).

1.7. Nematode in the Sudan

Since serious nematological investigations started in 1960,when Decker and Elamin conducted a survey in Fung area followed by a research program in the Gezira Research Station (GRS) Yassin, (1970).

Irrigation schemes such as, Gezira, Rahad, New Halfa and the white and the Blue Nile schemes. These irrigated schemes work through furrow irrigation system. Many field crops are cultivated such as, groundnuts, sorghum, wheat and sugarcane as well as vegetables mainly tomato, onion and medicinal and aromatic plants (Hassan *et al*., 1983, Elbadri, 1991).

Due to intensified cropping system, plant parasitic nematodes become increasingly important as direct crop pests (Yassin *et al*., 1970; Elbadri, 1991).

In spite of losses caused by nematodes, their damage is often confused with other soil factors e.g. soil nutritional imbalances (Decker *et al*., 1984, Elbadri, 1991).

Later studies on plant parasitic nematodes delt with the most economically important species such as, the root-knot nematodes (*Meloidogyne javanica* and *M. incognita*) in vegetables and the field crops, Root-lesion nematodes (*Pratylenchus sudanensis*) it was found to be highly pathogenic to cotton, cv. Barakat under laboratory conditions at the Gezira Research Station (GRS) (Yassin, 1973). *Pratylenchus sudanensis* resulted in accentuated wilt of Barakat cotton plants when coupled with the vascular wilt fungus, *Fusarium oxysporum f. sp*. v*asinectum,* in greenhouse tests at the GRS (Yassin, 1974a). The Dagger nematodes the most important of

these is *Xiphinema basiri*, it was isolated from around the roots of diseased citrus and mango trees. (Yassin, 1974c). The majority of other species were associated with the roots of orchard trees. An exception was *X. simillimum*, Loof and Yassin, 1970, which was associated with the roots of cotton plants, Needle nematodes in the genus *Longidorus,* are closely related to dagger nematodes. Ecologically, however, they are different from dagger nematodes in that they often occur in association with the roots of field crops, e.g. cotton, mint, Jew's mallow (Decker *et al.,* 1979). The damage they can inflict on the roots is also very similar to that resulting from dagger nematode attack (Yassin, 1974c).

Other species of plant parasitic nematodes reported at that time included the lance nematodes (*Hoplolaimus sp.*) in fruit trees and field crops, the stunt nematodes (*Tylenchorhynchus sp*.) and the helical nematodes (*Helicotylenchus* spp.) in sugarcane and onion plants (Yassin, 1972, 1973, 1974a, 1974b, 1974c, 1975 and1986; Yassin and Zeidan, 1982, Elbadri *et al*., 1997, 2003, 2009a and 2009b).

Morphology and systematic of 34 species belonging to seventeen genera occurring in central Sudan are comprehensively studied by (Yassin *et al*., 1970). Moreover, Loof and Yassin (1970) described three new species of nematodes, namely *Xiphinema simillimum, Paratrophurus labiates* and *Pratylenchus sudanensis*. Elamin and Siddigi (1970) reported 28 species belonging to 21genera.

In 1970 three species were described by Fortuner and Siddiqi namely *Aphelenchoides siddiqi, Helicotylenchus byname* and *Concephalus.* Decker *et al*., (1975) described *Pratylenchus sudanensis. Paratrophurus kenanae* described by Decker and Elamin (1978). 46 different plant parasitic nematodes were described by Abdalla (2000); six of them were identified for first time. These include: *Helicotylenchus babekeri H. abuharazai, Pratylenchus yassini, P. elamini, Aphelenchoides ltayebi* and *Aphelenchus declarer.* Zeidan (1990) thus concluded that the total number of nematodes known from the Sudan increased from 80 to 130 species.

Recently Elbadri *et al*., (2009a, 2010) has described *Helicotylenchus zeidani, Tylenchorhynchus elamini,* and *T. sudanensis* from sugarcane. Zeidan (1990) studied free living nematodes Central, Eastern, and Western parts of the Sudan from vegetables, field `crops, fruit trees and ornamentals. He reported 12 free living nematodes, three of them were identified anew species namely: *Rhadolaimus ritae*, *Monhystera unkiubernaculum* and *Eumanhystera sudanensis.* However, more recently Elbadri *et al*., (2008) described *Mylencholus sudanensis*, *M. yassini*, *M. abulelhassani* and *Achromadora sudanensis* as a new species from sugarcane.

The objective of this study is to obtain baseline information on plant parasitic nematodes associated with banana farms in Sennar areas and Kassala and the damage of banana nematode *Radopholus Similis.*

CHAPTER TWO

LITERATURE REVIEW

2.1. Banana

Musa species are native to tropical South and Southeast Asia, and are likely to have been first domesticated in Papua New Guinea. (Tracing antiquity of banana cultivation in Papua New Guinea, Nelson, Ploetz and Kepler 2006).

Bananas (*Musa spp*.) are among the most important food crops in the world (Sharrock and Frison, 1999). In 2013 bananas were fourth among the main world food crops (After rice, wheat and maize) in financial value. (Holmes Bob, 2013).

2.2. **Nutritive value of Banana**

Banana is a popular and widely consumed tropical fruit that provides carbohydrates, proteins, vitamins and minerals to more than 400 million people world wide (INIBAP, 1987). The fruits have beneficial nutritional properties. They are a good source of vitamin C, B6 and A. Bananas have a high content of carbohydrates and fiber, while they are low in protein levels and fat they are rich in potassium. (UNCTAD, 2009). In Ghana which is an agrarian economy driven by agricultural productivity and production, Bananas and plantains constitute about 13% of horticultural Agricultural Gross Domestic product (NARP, 1994). Bananas and plantains are among the cheapest foods to produce in Ghana. They are also important sources of rural income (Ortiz and Vuylsteke, 1996). Among staple foods, plantains have the second highest calorie to price ratio after cassava. On the average, plantain supplies 9.5% of the total caloric intake among the Ghanaian population (FAO, 2001).

Based on the 2010 statistic from FAO, banana is grown in more than 150 countries of an area about 4 771 944 hectares.

Bananas are the world's best-selling fruits, followed by apples

and oranges with annual sales of approximately US 2.5 billion (Ploetz, 2001; Denis, 2009). In 2010 the estimated world production was 102,114,819 Metric Tons (source FAOSTAT, 2011), which corresponds to about 15 kg per person (in 2010 the world had about 6.9 billion persons). Being a tropical and perennial plant that can be harvested all year round the crop grows best under warm conditions, roughly the area between latitudes 30°N and 30°S (Morton, 1987).

2.3. Production and export of bananas and plantains by country (FAO 2011).

Table 2: Banana Production

Country	Millions of tonnes	Percentage of world total
India	29.7	20%
Uganda	11.1	8%
China	10.7	7%
Philippines	9.2	6%
Ecuador	8.0	6%
Brazil	7.3	5%
Indonesia	6.1	4%
Colombia	5.1	4%
Cameroon	4.8	3%
Tanzania	3.9	3%
All other countries	49.6	34%
Total world	**145.4**	100%

Table 3: Banana Exports

Country	Millions of tonnes	Percentage of world total
Ecuador	5.2	29%
Costa Rica	1.8	10%
Colombia	1.8	10%
Philippines	1.6	9%
Guatemala	1.5	8%
All other countries	6.0	34%
Total world	**17.9**	100%

Statistics on the production and export of bananas and plantains are available from the Food and Agriculture Organization. Some countries produce statistics which distinguish between bananas and plantains, but three of the top four producers (India, China and the Philippines) do not, so comparisons can only be made using the total for bananas and plantains combined. The 2011 statistics (Table 2) show that India led the world in banana production, producing around 20% of the worldwide crop of 145 million metric tonnes. Uganda was the next largest producer with around 8% of the worldwide crop. Its national data does distinguish between bananas and plantains, and shows that the latter made up over 95% of production. Ten countries produced around two thirds of the total world production. (FAO 2011). The statistics for the export of bananas and plantains show a rather different picture (Table 3). Total world exports at around 18 million metric tonnes amounted to only 12% of total world production; two thirds of the exports were generated by only five countries. The top three producing countries do not appear in this table, and two countries, Costa Rica and Guatemala, do not appear in the table of top producers. Only the Philippines have a consistent position in both tables. Exports were dominated by Ecuador, with 29% of the world total. Statistics for Ecuador distinguish between bananas and plantains; 93% of its exports were classified as bananas. (FAO 2011).

These figures are an approximation because the bulk of world banana production (85 %) comes from relatively small plots or Back yard gardens, where statistics are lacking.

In many developing countries, the bulk of banana production is self consumed or locally traded, thereby playing a crucial role in food security (FAO, 2002).

70 million people in West and Central Africa are estimated to

derive more than one quarter of their food energy requirements from banana plantains, making them one of the most important sources of food energy in African lowland humid forest zone (Rony, 1990).

In Sudan, banana fruits are very popular and widely consumed due to their lower prices as compared with other fruit crops. The crop is grown in many parts of the country, including Khartoum and Kassala States as well as along the banks of the Blue Nile. Sennar, in Central Sudan, is one of the most important areas of banana production for local consumption and export. The total area cultivated to banana is estimated to 68,500 feddan, producing about 822,000 tons annually (Statistics, Department of Horticulture, Ministry of Agriculture, 2013).

Mixed cropping system in Kassala state

The Burrowing nematode, *Radopholus similis* was first described by Nathan A. Cobb in necrotic tissue of the roots of *Musa sp* in 1891, burrowing nematode is one of the most important root pathogens attacking bananas (O'Bannon, 1977).

The widespread range of this nematode is due to its dissemination with propagative plant material, especially infected banana corms (O'Bannon 1977, Gowen *et. al.* 2005). Unlike most other plant parasitic nematodes, the influence of soil texture on burrowing nematode population levels varies with the host (Chabrier *et. al.* 2010).

Radopholus similis infection on citrus is favored by coarse sandy soil that is poor in organic matter, but is hindered by fine textured soils rich in organic matter. (O'Bannon 1977).

2.4. Morphology

The burrowing nematode is an amphimictic species characterized by accentuated sexual dimorphism. Males of this species have a poorly developed stylet, a distinct elevated lip region set off by a distinct constriction and a coarsely crenate bursa enveloping 2/3 of the tail. *R. similis* females have well developed esophagus and stylet [18 (16-21) µm long], spherical spermatheca containing rod like sperms and an elongateconoid tail with a narrow rounded or indented terminus

(Esser, *et al*., 1984; Orton Williams and Siddiqi, 1973; Elbadri, 2000; Elbadri *et. al.*, 1999, 1999a).

2.5. *Radopholus similis* hosts

A revision of *Radopholus similis* hosts includes 365 plants (Holdeman, 1986).

Table (4) Host range of *R. similis* (Elbadri, 2000).

Herbaceous crops	Banana,*Musa acuminate* Colla; *M. balbisiana* Colla (Musaceae); Abaca (Manila hemp), *Musa textilis* Nee. Sugarcane; *Saccharum officinarum;* L. (Graminae); Ginger, *Zingiber officinale* Rose. (Zingiberaceae); Pepper; *Piper nigrum* L. (Piperaceae); Edible canna, Canna edulis Ker-Gawl; (Cannaceae).
Tree crops Tree crops	Citrus; *Citrus spp* (Rutaceae; Aurantoideae, Citrinae) Avocado; *Persea Americana* Mill. (Lauraceae); Coffee; *Coffea Arabica* (Rubiaceae); Tea; *Camellia sinensis* (L) Kuntz. (Theaceae);Common biriba; *Rollinia deliciosa* Safford (Annonaceae); Japanese Persimmon, *Diospyros Kaki* L.F. (Ebenaceae); Loguat, *Eriobotrya japonica*

	(Thunb.) Lindl. (Rosaceae); Guava, *Psidium guava.* (Myrtaceae).
Palms	Polar palm; neantheballa Palm; *Chamaedorea elegans* Mart. (Palmae); Coconut Palm; *Cocos mucifera* L. (Palmae); Betelnut palm, areca palm; *Areca catechu* L.; Date palm; *Phoenix dactylifera* L.
Indoor decorative plants	Anthurium; *Anthurium andraeanum* Linden and other species (Araceae); Calathea, *Calathea spp*. (Marantaceae); Philodendron, *Philodendron spp*. (Araceae).

2.6. *R. similis* races

DuCharme & Birchfield (1956) recognized 2 physiological races of *R. similis*: one race parasitizes banana and many other hosts but not citrus, the other parasitizes both banana and citrus. Burrowing nematodes cause spreading decline of citrus in Florida only. Although no significant morphological differences were detected between the two races, the citrus race has been raised to sibling species rank and designated as *R. citrophilus* (Huettel *et. al*., 1984) on the basis of putative biochemical, physiological, and karyotypic differences. However, recent investigations based on provenances from several parts of the world suggest that citrus parasitism appears to be associated with limited changes in the burrowing nematode genome and do not support assignment of sibling species status with respect to citrus parasitism (Kaplan & Oppermann, 1997). Citrus and non-citrus parasitic burrowing nematodes are not reproductively isolated. There is a considerable genetic variability within the species, and so a species status for *R. citrophilus* is not considered justified (Kaplan *et. al*., 1997; Valette *et al*., 1998; Elbabri *et. al*., 1999). *R. citrophilus* was recently correctly considered as a junior synonym of *R. similis* by (Valette *et. al*., 1998; Elbadri *et. al*, 1998, 1999, 1999a,). Consequently there is no possibility to distinguish races of *R. similis* attacking citrus and those not attacking citrus.

2.7. Control measures of plant parasitic nematodes

2.7.1. Biological control of *R. similis* by nematophagous fungi

Nematode destroying fungi are natural enemies of plant parasitic nematodes (Nordbring-Hertz *et al*., 2002). Some of these use adhesive conidia, branches, knobs and mycelia to parasitize nematodes by means of adhesive layer covering part or all of device surfaces (Yang *et al*., 2007). Other fungi immobilize or kill nematodes by releasing toxins. This group of fungi has recently drawn much attention because of their potential as biological control agents of nematodes that are parasitic on plants and animals (Jansson and Porsson, 2000, Sanyal 2000, Masoomeh, *et al*., 2004).

2.7.1.1. Endophytes

A promising option currently under investigation for nematode management in banana is the use of antagonistic, endophytic Micro organisms (Sikora *et al*., 2003; Dubois *et al*., 2004; Gold and Dubois, 2005; Athman, 2006; Athman *et al.*, 2006; Dubois *et al*., 2006). Endophytes are micro-organisms that spend part or all of their life cycle residing benignly inside host plant tissues (Wilson,1995). Many endophytes form mutualistic relationships with their host plants, from which they obtain nutrients and in turn confer protection against biotic and abiotic stresses to the plant (Schulz and Boyle, 2005). In banana, naturally occurring endophytic *Fusarium oxysporum* isolates antagonized *R. similis* in vitro through the production of nematode-antagonistic metabolites (Elbadri, 1991; Dubois *et al*., 2004; Athman *et al*., 2006). Inoculation of some of these isolates into tissue culture plants resulted in improved plant growth and reduced nematode densities and damage (Dubois *et al*., 2004; Athman, 2006).

2.7.1.2. *Paecilomyces lilacinus*

Paecilomyces lilacinus strain 251 is a commercially available fungal pathogen of nematode eggs. In addition, this fungus also can parasitize females of sedentary nematodes and their reproductive structures (Elbadri, 1991; Holland *et al*.1999; Siddiqui *et al*. 2000; Khan *et al.* 2006a). The use of *P. lilacinus* Strain 251 to control *R. similis* (Mendoza *et al.*2004, 2007; Khan *et al*. 2006b) has been studied.

2.7.1.3. Mycorrhizal fungi

Inoculation of plantain tissue culture plants with the arbuscular mycorrhizal fungi (AMF) during the weaning phase significantly improved plant growth and reduced *R. similis* populations compared to non mycorrhized plants (Elsen *et al*., 2003).

2.7.1.4. Formulated biocontrol agents

Several microbial pathogens have been developed into commercial formulation against nematodes. These include the bacteria *Pasteuria penetrans* (Formerly known as *Bacillus penetrans*), *Bacillus thuringiensis* (available in insecticidal formulations) and *Burkholderia cepacia*. Nematicidal fungi include *Trichoderma harzianum*, *Paecilomyces lilacinus*, *Hirsutella rhossiliensis*, *Hirsutella minnesotensis, Verticillum chlamydosporum* and *Arthrobotrys dactyloides*, another fungus, *Myrothecium verrucaria*, found to be highly effective in the control of nematodes (Anon, 1997b) and is available in a commercial formulation (Ditera™). Offers a combination of several mycorrhizal fungal spores in a nematode control product called prosper- (Nema™). Stain microbial products offers the bacterium *Burkholderia cepacia* in a product called (Deny™) and Blue Circle™ Rincon – Vitova offers a product called

Activate™ whose active ingredient is the bacterium *Bacillus chitinosporus* (Quarles, 2005).

2.7.2. Cultural control

The most important measure to control nematodes in banana stands is the use of healthy planting material (Sarah, 2000). Using pest and disease free material reduces the spread of nematodes to new fields (Speijer *et al*., 1995). Clean planting material can be obtained in several ways. Corm paring, which involves removal of nematode infested roots and corm tissue, can reduce initial infestation (Speijer *et al*., 1995, Gold *et al*., 1998). Hot water treatment of corm pared suckers by dipping in hot water at a temperature of 53 °C for 20 min (Speijer *et al*., 1995, Gold *et al*., 1998). Rides the plants of nematodes, leading to crop yield improvements of about 30% in the first crop cycle (Speijer *et al*., 1999a).

2.7.2.1. Crop rotation and cover crops

Crop rotation to a non host crop is often adequate by itself to prevent nematode populations from reaching economically damaging levels. However, it is necessary to positively identify the species of nematodes in order to know their hosts or non hosts plants (Wang, *et al*., 2004). A general rule of thumb is to rotate to crops that are not related to each other. For example, a pumpkin/bell pepper rotation might be more effective, also the rotation from a broad leaf to a grass is even better.

Asparagus, corn, onions, garlic, small grains Cahaba white vetch, and nova vetch are good rotation crops for reducing root knot nematode populations. (Yepsen, 1984, Peet, 1996, Wang, *et al*., 2004), such rotations will not only help prevent nematode populations from reaching economic levels, but will also help to control plant diseases and insect pests management.

2.7.2.2. Influence of fertilizers

Nematodes can be controlled through the application of fertilizers. Calcium Cyanamid in particular proved to have a nematicidal activity as fertilizers which affect both the nematode and the host plants. Sometimes it suppresses pathogenic capability of nematodes but often may only improve the growth of the plant and lessen the pathogenicity of nematodes without killing it (Decker, *et al*., 1984).

2.7.2.3. The time of planting/harvesting may be utilized to exploit differential environmental effects on nematode populations versus crop growth and maturity. For example, early planting of crops such as wheat, barley, rye, chickpea and potato has restricted associated nematode damage in some instances (Brown, 1987; Duncan, 1991; Trivedi and Barker, 1986).

2.7.2.4. Bare fallowing

Some nematodes decline rapidly under bare fallowing. Some success using such method was accepted as control of root – lesion nematode.*Pratylenchus penetrans*, *Rotylenchulus reneformis* and burrowing nematodes, *Radopholus similis* may obtain when the soil were left free or fallow (Whitehead, 1997).

After 1 year of fallow, a duration that is sufficient to considerably reduce the abundance of root-feeding nematodes (Chabrier *et al*., 2010).

2.7.2.5. Green manures and trap cropping

The number of some important nematodes pests in the soil has been greatly decreased by growing resistant, green manure crops or for short period susceptible crops, both of which attract and trap the nematodes in their roots (Whitehead, 1997).

Some plants produce allelochemical that function as a nematode toxic compounds, such as polythienyls, glucosinolates, cyanogenic glycosides, alkaloids, lipids, terpenoids, steroids, trirerpenoids andphenolics, suchplants include: castor bean, chrysanthemum, partiridge pea, velvet bean, sesame, jack bean, crotalaria, Sudan grass, indigo, tephrosia. These toxic compound are exuded during the growing season or released during green manure decomposition (Chitwood, 2002, Wang *et al*., 2002). Some researchers found that, control of root-lesion nematodeon potato could be achieved through forage pearl millet(Canadian Hybrid 101) and marigold (Crakerjack) as a rotation crops with potatoes which resulted in a fewer root lesion nematodes and increased potato yields in contrast to rotation with rye (Ball-Coelho, *et al*., 2003).

After evaluating nine types of organic manure, Pattison *et al.* (2011) determined that residues of those vegetables that are

high in N and C such as the banana and some grasses are highly recommended to decrease the *R. similis* population, similarly McIntyre *et al.* (1999) observed that the mulch with waste banana or corn mitigated the impact of this parasite. Although each type of organic manure has its own impact on the density of nematodes, this practice has physical, biological and chemical benefits (Tabarant *et al*., 2011). They decrease soil temperature and often the rate of reproduction of the nematode (Araya and De Waele, 2005), increase soil porosity, absorption capacity and replacement of water, root biomass, increase the concentration of C, K and Mg in the planted crop, especially in poor soils (McIntyre *et al.*, 1999) and the biological mineralization of nitrogen (Tabarant *et al.*, 2011). They stimulate antagonists (Pattison *et al.*, 2011) and by improving the health status of the roots, the production of offspring and increase the longevity of the cultivation (Coyne *et al.*, 2005).

2.7.2.6. Inter- and intra-cropping

Inter- and intra-cropping is a widely used practice in several countries. Various types of mixed cropping and asynchronous temporal planting may limit nematode damage as outlined by Raymundo (1985). Definitive data on these practices are rather limited.

2.7.3. Use of resistant varieties

Planting resistant varieties, either singly or in mixtures, is also an option, especially for smallholder farmers who cannot afford crop rotations or fallows. Strong resistance to *R. similis* has been identified in Pisang jari buaya clones of *Musa spp*. AA group, (Pinochet and Rowe, (1979), the banana cultivars

Yangambi KM5 (AAA), Gross Michel (AAA), (Table 5) Fogain and Gowen, (1997), Sarah *et al*., (1997) and Kunnan (A B) Collingborn *et al*., (2000). Studies to investigate the resistance mechanisms in Yangambi KM5, revealed greater amounts of preformed phenolic compounds (Valette *et al*., 1998), Elbadri (2009), while Kunnan cultivars are found to possess high amounts of condensed tannins (Collignborn *et al*., 2000). Resistance may offer along-term intervention against nematodes for resource poor farmers in Africa.

However, resistance to nematodes has not been identified for cooking banana cultivars. Banana improvement by means of conventional plant breeding, has proved to be extremely difficult due to the genetic complexity of the crop and the long period required to evaluate crossings for resistance to different nematode collections (Stover and Buddenhagen, 1986, Tripathi, 2003). In addition, most of banana varieties are triploid genotypes that are almost or fully sterile, which further complicates the situation.

Table (5): Banana cultivars used in green house experiments (Speijer and Dewaele, 1997).

Cultivar	Genome	ITC Code	Host status
Pisangjari Buaya	AA	ITC-0312	Immune resistant to *R. similis*
Yangambi KM5	AAA	ITC-1123	High resistant to *R. similis*
Gross Michel	AAA	ITC-1122	Moderately resistant to *R. similis*
Grand nain	AAA	ITC-0180	Susceptible to all nematodes

2.7.4. Vertical resistance

This type of resistance in plants to pathogens, including nematodes, theoretically falls under the strategy of reducing initial inoculum level (Vanderplank, 1963). This situation clearly is true for resistant cultivars that function in large part as trap crops.

2.7.5. Physical Control

2.7.5.1. Flooding

The control of nematodes by flooding has been advocated in certain locations (Gowen and Quénéhervé, 1990). Flooding of the soil for 7-9 months kills nematodes by reducing the amount of oxygen available for respiration and increasing concentration of naturally occurring substances such as organic acids, methan and hydrogen sulfide – that are toxic to nematodes (Mac Guidwin, 1993).

2.7.5.2. **Heat solarization**

The technique of increasing soil temperatures by solarization can be of value in controlling nematodes (FAO, 1991; Gaur and Perry, 1991b). All nematodes in soil can be killed by steaming or electrically or heating it. As moist, well drained soil usually contains at least 10% water raising its temperature to 50 - 55 °C to kill the nematodes in expensive. In warm climates, nematodes in top soil out of doors and in glass houses are killed by solarization for 4-8 weeks double layers poly ethylene.

2.7.6. Control of nematodes by herbal extracts

The use of herbal extracts against plant parasitic nematodes studied by many authors, Coxa *et al*., (2006), Mennan and Pandy and Kalra (2005), and Elbadri *et al*., (2008).

Five essential oil and 15 herbal extracts were evaluated to control *Bursaphelenchus xylophillus* in laboratory, from clove plant (*Syzgium aromaticum),* mustard (*Brassica integrefolia*), thyme (*Thymus vulgaris*) and (*Pelargonium inguinas*) were found to be highly promising and gave excellent control of the

nematode all the time of exposure, (Elbadri *et al*., 2008). Several plants have been identified to have nematicidal properties either in their seeds, fruits, leaves, barks, roots or in their exudates (Table). These include the caster plant (*Ricinus spp*), *Stylosanthes gracilis, Chromoleana odormatum,* the neem tree (*Azardirachta indica)* raspberry canes, water hyacians (*Eichorina crassipes)* and sunhemp (*Crotolarea ochrolenca)* (Egunjiobi, 1982).

Table (6): Directory of least toxic pest control products (Quarles, William, 2005, Elbadri and Yassin, 2010).

Botanical nematicides	Producers or distributors
Nemastop (Organic extracts	Soils technology crop poulenger U

with/fatty acids)	S A
Dragonfire (Sesame oil)	poulenger U S A
Ontrol (Sesame meal)	Natural organic products
Nemagard (Ground up sesame plant)	Monsoon, peaceful valley
Neem cake	Soils technology crop
Armorex (Sesame oil, garlic, rosemary eugenol, white pepper)	

2.7.7. Chemical control

Nematicides available on the world markets (Sasser, 1989) may be classified as fumigants and non-fumigants, and considerable research is focusing on the development of novel compounds. The properties that are responsible for soil fumigants being excellent nematicides may result in their being placed under regulatory review (Bird, 1987).

Fumigation was used successfully against stem nematode in seed of different crops, *Ditylenchus dipsaci* and white tip nematode *Aphelenchoids besseyi*. Dipping of potato tubers in fenamiphos or ethoprophos freed them of the false root-knot nematode, *Nacobbus* *aberrans*. Dipping banana corms in the nematicidal liquids or coating them with clay nematicide slurry

protects them from early attack by burrowing nematode *Radopholus similis* and spiral nematode *Helicotylenchus multicintus* (Whitehead, 1997).

In general, seed dressing decrease nematode damage but most of the nematicides are very toxic to vertebrates and to their hazard during handling (Whitehead, 1997).

Currently available soil fumigants can greatly decrease the numbers of soil plant parasitic nematodes. Soil fumigants work best in moist soil. Injecting large amounts of fumigants into soil can kill nearly all the virus vector nematodes, so preventing transmission of those viruses for several years. Very small amount of soil fumigant applied to the seed furrows at sowing have controlled cereal cyst nematode *Heterodera avenae*, and row fumigant with small amount of 1, 3 dichloropropene have also some success against beet cyst nematodes (Whitehead, 1997).

The control of root- knot nematodes *M. javanica*, *M. arenaria* and *M. thamasi* were recorded in Egypt can be achieved by using nematicides like Nemacur, Vydate, Furidan (Carbofuran), and Temik (Amin, 1997).

Chemicals are expensive and rather hazardous to use under our existing peasant farming especially in food crops (Elbadri, 2004).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Samples collection

The study was conducted in the Gezira Research station (Plant Pathology Section).

Soil and roots samples were collected from infected soil and roots around banana plantation on banana farms in Sennar and kassala states. The depth of sampling was 10-15 cm since the most of nematodes are found in this range. The soil and roots samples were put in polyethylene bags and labeled, and then transferred carefully to the laboratory for nematode extraction.

3.2. Washing and extraction of nematodes

The Baermann-funnel technique was used for extraction of the nematode (Yassin, 1967).

Before washing all the soil samples were homogenized several times. 100 gm of soil was moisted by adding 200 ml of water in a 1000 ml beaker and 600 ml of water was added later. The soil sample was thoroughly mixed and left for half an hour. Using tap water, moistened soil mixture was passed through a sieve 125 mm to separate large soil granules and other soil debris.

Soil surface was filtrated several times to ensure maximum collection of nematodes. The supernatant was decanted in 38 mm sieve and carefully washed with tap water to get rid of mud to ensure clean nematodes. The residue containing living nematodes was collected in 100 ml beaker and poured into 5 inches diameter funnel containing water, the funnel was covered with a muslin and/or double play fitted into the stem of the funnel with a clip at its end. Then living nematodes were swimed and passed freely downwards.

After 24 hours the nematodes were accumulated in the stem of the funnel and collected in a test tube and labeled.

3.3. Estimation of the living nematodes

Living nematodes in the test tube were extracted from 100 gm of soil as mentioned before and were transferred in the counting dish using microscope. Then the nematode genera were counted.

3.4. Extraction and estimation of the nematodes from the roots

When the roots were removed from the soil, they were washed in running tap water, and dried with tissue paper.

The roots were cut in 0.5-1 cm pieces, a 10 g was been taken from it and put in 100 ml of distilled water in kitchen blender and macerated 1 time for 15 seconds. The macerated suspension was collected in 100 ml beaker and poured into 5 inches diameter funnel containing water, the funnel was covered with a muslin and/or double play Kleenex (to trap the left debris). 15 cm rubber tubing was fitted into the stem of the funnel with a clip at its end. Then living nematodes were swimed and passed freely downwards. After 24 hours the nematodes were accumulated in the stem of the funnel and collected in a test tube and labeled, then counted using binocular.

3.5. Measurement of root necrosis

Five functional primary roots were selected randomly, at least 10 cm long. The five roots were cut length rise, score at one half of each of the five roots by measuring the % of root length necrosis. The longitudinally per root half can be 20 %, giving a maximum root necrosis of 100 % for the vive halves together. The necrosis of individual roots were recorded (RN1 to RN5) and the total root necrosis of the sample was calculated (Total RN).

The data recorded were arranged and analyzed statistically using computer packages (MSTAT).

3.6. Nematode fixation

Nematode populations were extracted from soil and roots were killed by adding 4% formaldehyde and heated in a flame.

Seinhorst's rapid method (Seinhorst, 1959 as modified by De Grisse, 1969) was used. Nematodes were transferred to solution 1(99 parts formalin 4% plus 1 part pure glycerin) in a staining block and placed uncovered in a desiccator that contained 95% ethanol. The desiccator was left overnight in an incubator adjusted at 37 °C. Next day, some of the solution in the block was removed, then 3-4 drops of solution 2 (ethanol 95 parts plus glycerin 5 parts) were added to the dish 3-4 times every two hours, during which the staining block was partially covered to allow slow evaporation. Finally 3-4 drops of solution 3 (ethanol 50 parts plus glycerin50 parts) were added and the block was left overnight at 37 °C.

Measurement of root necrosis

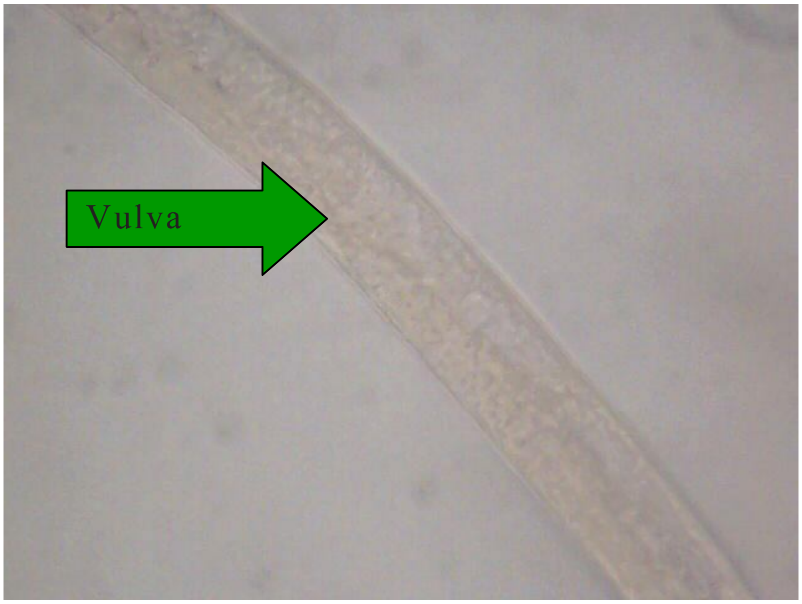
Root knot (*Meloidogyne Spp*.)

3.7. Mounting

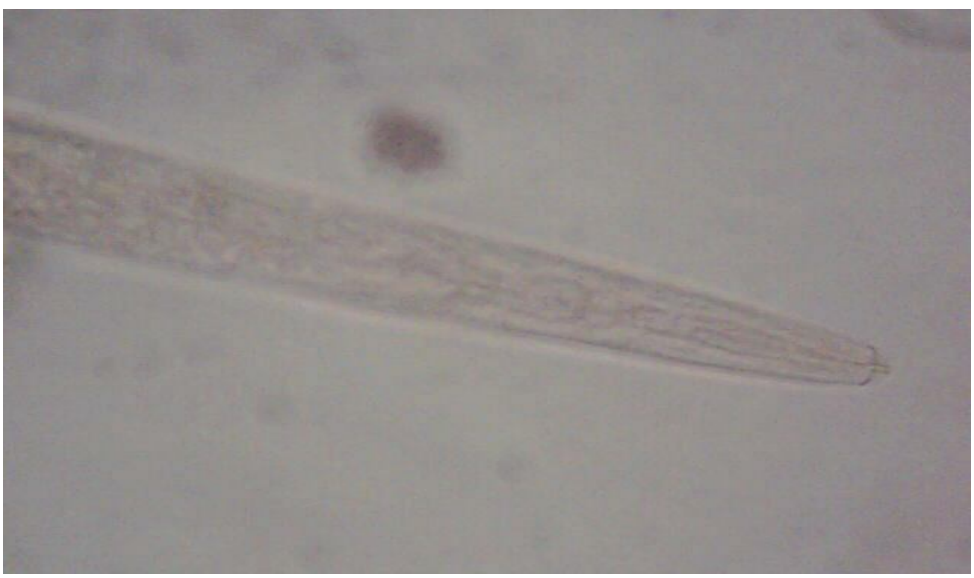
Permanent slides were prepared according to cobb (1918).A cover slip was placed on an aluminum frame, and a paraffin ring was made on with heated copper tube and paraffin. A drop of glycerin was placed at the center of the paraffin ring. Six to eight adults were transferred to the drop and covered with a second cover slip. The whole was gently heated on a plate till the paraffin ring melted and then allowed to cool down again. Nematodes in each slide were studied by light microscope.

3.8. Measurements and drawings

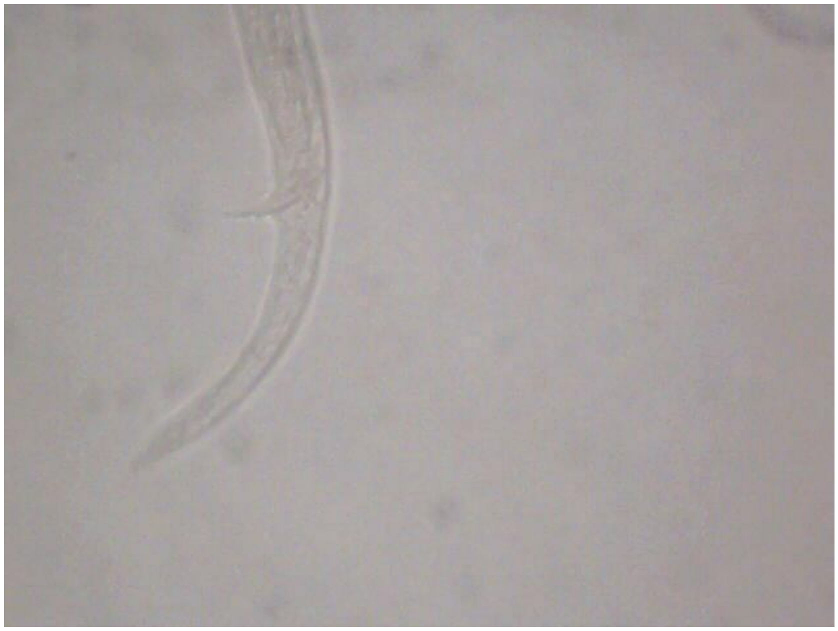
To identify nematodes, measurements were taken using drawing tube and measurements light microscope with the highest magnification. The ratios or symbols used are according to Geraert (1968), Hooper (1985), and Geraert & Raski (1987).



Radopholus similis Female with vulva near mid body



Radopholus similis Female head region



Radopholus similis Male Tail

CHAPTER FOUR

RESULTS

4.1. Survey of plant Parasitic Nematodes Associated with Banana in Sennar during June 2011 and Kassala State during 9-12 October 2011.

4.1.1. Sennar State

Table (7) Frequency distribution and percentage for farmers according to the type of soil.

Type of soil	Frequency Distribution	Percent
Loamy	21	84
Sandy	0	0
Clay	4	16
Sandy clay	0	0
Total	25	100

Table (8) Frequency distribution and percentage for farmers according to the presence of crop cycle.

Crop cycle	Frequency Distribution	percent
Yes	0	0
No	25	100
Total	25	100

Table (9) Frequency distribution and percentage for farmers according to the irrigation method.

Irrigation method	Frequency Distribution	Percent
Single plot	0	0
The plots opening on each other	25	100
TOTAL	25	100

Table (10) Frequency distribution and percentage for farmers according to the suckers treatment before cultivation.

suckers treatment	Frequency Distribution	Percent
Hot water	0	0
No treatment	25	100
Total	25	100

Table (11) Frequency distribution and percentage for farmers according to cleaning the agricultural equipment before using.

cleaning the agricultural equipment before using	Frequency Distribution	Percent
Yes	6	24
No	19	76
Total	25	100

Table (12) Frequency distribution and percentage for farmers according to use mixed cropping system.

use mixed cropping system	Frequency Distribution	Percent
Yes	11	44
No	14	56
Total	25	100

4.1.2. Kassala State

Table (13) Frequency distribution and percentage for farmers according to the type of soil.

Type of soil	Frequency Distribution	Percent
Loamy	0	100
Sandy	10	0
Clay	0	0
Sandy clay	0	0
Total	10	100

It is worth to mention that the soil type in Kassala is lighter than that of Sennar state.

Table (14) Frequency distribution and percentage for farmers according to the presence of crop cycle.

crop cycle	Frequency Distribution	percent
Yes	0	0
No	10	100
Total	10	100

It is observed that all the farmers not follow crop cycle.

Table (15) Frequency distribution and percentage for farmers according to the irrigation method.

Irrigation method	Frequency Distribution	Percent
Single plot	0	0
The plots opening on each other	10	100
Total	10	100

Table (16) Frequency distribution and percentage for farmers according to the suckers treatment before cultivation.

suckers treatment	Frequency Distribution	Percent
Hot water	0	0
No treatment	10	10
Total	10	100

Table (17) Frequency distribution and percentage for farmers according to cleaning the agricultural equipment before using.

cleaning the agricultural equipment before using	Frequency Distribution	Percent
Yes	0	0
No	10	100
Total	10	100

We observed that all the farmers on Kassla state 100% not cleaning the equipment against 24% on Sennar state.

Table (18) Frequency distribution and percentage for farmers according to use mixed cropping system.

use mixed cropping system	Frequency Distribution	Percent
Yes	10	100
No	0	0
Total	10	100

It is observed that the mixed cropping system adopted in Kassala state is behind the increased number of nematodes as shown in table (18).

Table (19) Distribution and population of various plant parasitic nematodes in the banana plant *Musa spp.* In 25 Banana farm on Sennar state from soil.

Nematode genera	Localities and nematodes population per kg soil									
	Algenaina	Abo gayli	Grisli	Alaazaza	Um binain	Alsabonab i	Abo naama	Galgani	Um sonut	Algazaier
Pr.	+	+	+	+	+	-	-	+	+	+
Ra.	+	+	+	+	+	+	+	+	+	+
He.	+	+	+	+	+	+	+	+	+	+
Rot.	+	-	-	-	-	-	-	-	-	-
Sc.	+	-	+	-	-	-	-	-	-	-
X.	+	+	+	+	+	+	+	+	+	+
L.	+	+	+	+	+	+	+	+	+	+
Hop.	-	-	-	-	-	-	-	-	-	-
Ty.	+	+	+	+	+	+	+	+	+	+
Fl	-	-	-	-	-	-	-	-	-	-
Total	535	635	2830	367	612	206	460	382	312	610

Pr = Pratylenchus, Ra = Radopholus, He = Helicotylenchus, Rot. = Rotylenchus, Sc. = Scutellonema, X = Xiphinema, L. = Longidorus, Hop. Hoplolaimus, Ty = Tylenchothynchus, F = Free Living nematodes.

+ = 1-10 nematodes; ++ = 11-20 nematodes; +++ = 20-50 nematodes

Table (20) Roots damage assessment by Score the % of 5 roots cortex showing necrosis in Sennar state.

Locality	Algenaina	Abo gayli	Grisli	Alaazaza	Um binain	Alsabonabi	Abo naama	Galgani	Um sonut	Algazaier
Root necrosis%	15%	3.6%	2.6%	3%	15%	16.2%	10%	3.7%	19%	10.3%

Table (21) Population of various plant parasitic nematodes in the banana plant *Musa spp.* In 25 Banana farm on Sennar state from roots.

Nematode genera	Localities and nematodes population per 10 g roots									
	Algenaina	Abo gayli	Grisli	Alaazaza	Um binain	Alsabonabi	Abo naama	Galgani	Um sonut	Algazaier
Pr.	+	+	+	+	-	+	+	-	+	+
Ra.	+	+	+	+	+	+	+	+	+	+
He.	-	-	-	-	+	+	-	-	-	-
Rot.	-	-	-	-	-	-	-	-	-	-
Sc.	+	+	+	+	-	-	+	-	-	+
X.	-	-	-	-	+	-	-	-	-	-
L.	-	-	-	-	+	-	-	-	-	-
Hop.	-	-	-	-	-	-	-	-	-	-
Ty.	+	+	+	+	+	+	+	+	+	+
F	-	-	-	-	-	-	-	-	-	-
Total	93	299	98	77	261	71	11	61	76	62

Pr = Pratylenchus, Ra = Radopholus, He = Helicotylenchus, Rot. = Rotylenchus, Sc. = Scutellonema, X = Xiphinema, L. = Longidorus, Hop. Hoplolaimus, Ty = Tylenchothynchus, F = Free Living nematodes.
+ = 1-10 nematodes; ++ = 11-20 nematodes; +++ = 20-50 nematodes.

Table (22) Distribution and population of various plant parasitic nematodes in the ba

10 Banana farms in Kassala state from soil.

Nematode genera	Localities and nematodes population per k g so	
	South alsawagi	Wad sharefai
Pr.	+	+
Ra.	+	+
He.	+	+
Rot.	-	-
Sc.	+	-
X.	+	+
L.	-	+
Hop.	+	-
Ty.	+	-
F	-	-
Total	10122	6000

Pr = Pratylenchus, Ra = Radopholus, He = Helicotylenchus, Rot. = Rotylenchus, Sc. = Sc

Xiphinema, L. = Longidorus, Hop. Hoplolaimus, Ty = Tylenchothynchus, F = Free Living

+ = 1-10 nematodes; ++ = 11-20 nematodes; +++ = 20-50 nematodes.

Table (23) Roots damage assessment by Score the % of 5 roots cortex showing ne
state.

Locality	South alsawagi	Wad sharefai	
Root necrosis%	48%	23%	

Table (24) Population of various plant parasitic nematodes in the banana plant
Banana farm on Kassala state from roots.

Nematode genera	Localities and nematodes population per 10 g roo		
	South alsawagi	Wad sharefai	
Pr.	+	+	
Ra.	+	+	
He.	+		
Rot.	-	-	
Sc.	-	-	
X.	+	-	
L.	+	-	
Hop.	-	-	
Ty.	+	-	
F	-	-	
Total	380	282	

Pr = Pratylenchus, Ra = Radopholus, He = Helicotylenchus, Rot. = Rotylenchus, Sc. = Sc
Xiphinema, L. = Longidorus, Hop. Hoplolaimus, Ty = Tylenchothynchus, F = Free Living
+ = 1-10 nematodes; ++ = 11-20 nematodes; +++ = 20-50 nematodes.

Table (25) List of abbreviations used in morphometrics.

Abbreviation	Character
L	Total body length
m.b.w	Maximum body width
a	Total body length/ Maximum body width
Oes. length	Oesophagus length
b	Total body length/ distance from anterior end to junction of Oesophagus and intestine.
Oes. gl. l.	Oesophagus gland length
b′	Total body length/ distance from anterior end to posterior end of Oesophageal glands
C	Total body length/ tail length
b.w.a	Body width at anus
c′	Tail length/ body width at anus
v	Distance from head end to vulva/ body length x 100
v′	Distance from head end to vulva/ distance from head end to anus x 100
DGO	Dorsal Oesophageal gland orifice
Ex. pore	Execretory pore
G1	Anterior ovary length
G2	Posterior ovary length
Spic. length	Spicule length
Gub. length	Gubernaculum length

4.6. Table (26) Morphometrics in (um) of females from *Radopholus similis* populations.

Character	Populations									
L	718	687	812	706	562	625	631	593	687	750
m.b.w	23	20	23	22	20	22	23	22	23	26
a	31.2	34.3	35.3	32	28.1	28.4	27.4	26.9	29.8	28.8
Oes.length	85	88	84	91	71	74	74	84	81	88
b	8.4	7.8	9.6	7.7	7.9	8.4	8.5	7	8.4	8.5
Oes.gl.l	143	146	165	145	139	152	153	129	147	172
b´	5	4.7	4.9	4.8	4	4.1	4.1	4.5	4.6	4.3
Tail length	69	56	69	66	63	63	68	57	66	69
C	10.4	12.2	11.7	10.6	8.9	9.9	9.2	10.4	10.4	10.8
b.w.a	16	16.8	20	18	14	16	16	15	18	18
C´	4.3	3.3	3.4	3.6	4.5	3.9	4.2	3.8	3.6	3.8
Head-vulva	362	381	450	387	343	356	337	387	368	450
v	50.4	55.4	55.4	54.8	61	56	53.4	65.2	53.5	60
Head-anus	649	631	743	640	499	562	563	536	621	681
v´	55.7	60.3	60.5	60.4	68.7	63.3	59.8	72.2	59.2	66
Stylet length	22	22	22	18	18	17.6	19	17	20	21
DGO	5	5	4.4	4	4	4.8	4	4.2	4.2	5
E.x Pore	88	93	88	95	76	78	79	86	86	92
G1	125	189	223	200	158	171	169	201	192	222
G2	122	175	205	188	151	162	161	187	186	205
Head-height	2.6	3	5	4.9	3	4	4.5	3	4.2	5
Head-width	8.6	8	9	9	8	10	9	8	9.5	10.5

Table (26) (contd.)

Character	Populations								
L	562	618	668	725	623	656	580	710	698	630
m.b.w	20	23	23	22	22	24	22	24	24	23
a	28.1	26.8	29	32.9	28.3	27.3	26.3	29.5	29	27.3
Oes.length	81	74	82	88	82	84.1	82.8	94.6	81.1	78.7
b	6.9	8.3	8.1	8.2	7.7	7.8	7	7.5	8.6	8
Oes.gl.l	144	147	155	161.1	141.5	152.5	141.4	147	155.1	143.1
b´	3.9	4.2	4.3	4.5	4.4	4.3	4.1	4.8	4.5	4
Tail length	68	63	74	78	75.9	80	71	82.5	77	63
C	8.2	9.8	9	9.2	8.2	8.2	8.1	8.6	9	10
b.w.a	16	15	15	17	18	18.1	17.7	16	16.4	16
C´	4.2	4,2	4.9	4.5	4.2	4.4	4	5.1	4.6	3.9
Head-vulva	375	325	393	418	312	332	300	360	362	340
v	66	52	58.8	57.6	50	50.6	51.7	50.7	51.8	53.9
Head-anus	506	555	594	647	547.1	576	509	627.5	621	567
v´	74.1	58.5	66.1	64.6	57	57.6	58.9	57.3	58.2	59.9
Stylet length	16	18	18	20	21	17	17	18	17.2	19
DGO	3	5	5	4	4.4	4.3	3.5	3.9	4	4.9
E.x Pore	88	82	84	91	88	87	85	98	86	85
G1	164	175	160	172	194	202	173	193	218	191
G2	155	157	153	165	172	185	151	178	211	176
Head-height	4	4	4	4	5	3	4.3	3.6	5	3
Head-width	9	10	10	9	10	9	9.4	9	10	9

4.7. Table (27) Morphometrics in (um) of males from *Radopholus similis* populatio

character	Populations							
L	625	546	587	510	608	490	594	575
m.b.w.	19	16.5	19	17	16	15	16.9	18.3
a	32.8	33	30.8	30	38	32.6	35.1	31.4
Oes.length	78	68	80	71	74	68	77	74
b	8	8	7.3	7.1	8.2	7.2	7.7	7.7
Oes.gl.l.	111	103	109	113	107	97	112	98
b´	5.6	5.3	5.3	4.5	5.6	5	5.3	5.8
tail length	72	70	66	60	79	62	73	68
C	8.6	7.8	8.8	8.5	7.6	7.9	8.1	8.4
b.w.a	14	12	13	12.3	14	11	14	13
c´	5.4	5.8	5	4.8	5.6	5.6	5.2	5.2
Ex. Pore	87	72	85	73	82	71	86	82
Testis length	214	200	185	188	201	180	211	194
Spic.length	19	18	20	18	21	16	21	19
Gub.length	11	9.5	10.4	9.7	10.8	9	10.8	10.5
Stylet length	13	12	12	12.4	14	11.8	12.8	13
Head-height	5	5.8	6	4	5	5	6.3	5.8
Head-width	7	6	8.2	8	8.4	7	8.3	8

Table (27) (contd.)

character	Populations								
L	520	618	541	530	640	634	560	518	5
m.b.w.	15	18	16	16	20	19	18	17	1
a	34.6	34.3	33.8	33	32	33.3	31	30.4	3
Oes.length	66	82	82	72	80	78	70	74	
b	7.8	7.5	6.5	7.3	8	8.1	7.9	7	7
Oes.gl.l.	105	113	96	102	110	108	116	103.6	9
b´	4.9	5.4	5.6	5.1	5.8	5.8	4.8	5	
tail length	65	69	70	64	85	76	69.1	68	7
C	8	8.9	7.7	8.2	7.5	8.3	8.1	7.6	
b.w.a	12	13	13	14	15.4	13.8	13.4	13.2	
c´	5.4	5.3	5.3	4.5	5.5	5.5	5.1	5.1	5
Ex. Pore	75	76	80	82	87	86	79	82	
Testis length	208	204	218	209	206	210	199	202	
Spic.length	19	18	20	19.4	18	20	19	17	
Gub.length	10	11	11	9	9	10	10.5	10	
Stylet length	12.6	13	11	14	13	12	12.8	14	1
Head-height	5.6	6	5	6	5	6	6	6	
Head-width	7.8	7	7	7	7	8	7.8	8	

Table (27) (contd.)

character	Populations								
L	602	504	600	584	514	622	598	610	502	506
m.b.w.	18.2	15.7	18.7	17	16	19	17.8	18.4	16	15.8
a	33	32	32	34	32.1	32.7	33.5	33.1	31.3	32
Oes.length	75.2	74.1	78	81	74	79	76	74.3	73.8	71
b	8	6.8	7.6	7.2	6.9	7.8	7.8	8.2	6.8	7.1
Oes.gl.l.	111	95	109	101	102.8	113	115	124	104	99
b´	5.4	5.3	5.5	5.7	5	5.5	5.2	4.9	4.8	5.1
tail length	81	78	72.2	73	64	74	69.5	80	62.7	63
C	7.4	6.4	8.3	8	8	8.4	8.6	7.6	8	8
b.w.a	13.5	15.6	11	12	12.8	12.7	14.1	13	12	12.6
c´	6	5	6	6	5	5.8	4.9	6.1	5.2	5
Ex. Pore	83	84	85	89	84	82	86	90	80	79
Testis length	218	190	200	196	198	204	201	204	196	194
Spic.length	18	16	20	17	18	17	20	19	18	19
Gub.length	11.5	9	10	9.6	10.5	10	11	9	10	9
Stylet length	11	12	11	11	13	12	14	13.6	14	11
Head-height	5	6	5	6	5	6	6	6	5	6
Head-width	7	7	8	8	7	7	8	7	7	8

Tables 26, 27 represent the morphometrics of all 50 *R. similis* populations (20 females, 30 males). All measurements are given in micrometer. Values of measurements and ratios in the tables are presented as mean ± SD (ranges minimum and maximum are between brackets).

Measurements are an average for 20 females and 30 males from each population.

CHAPTER FIVE

DISCUSSION

5.1. SURVEY

A survey of 35 banana farmers in Kassala and Sennar state indicated that there is an increased number of nematode in Kassala state compared with that of Sennar area this could be resulted to the soil type on Kassala state is lighter (Table 13 Kassala survey) than that of sennar (Table 7 Sennar survey), as reported by (Chabrier *et al*. 2010) that *Radopholus similis* infection on citrus is favored by coarse sandy soil that is poor in organic matter, but is hindered by fine textured soils rich in organic matter.

The mixed cropping system adopted in Kassala area which is one of the locations covered by the survey seems to be behind the increased number of nematodes shown in (Table18) and help in generation of new races. DuCharme and Birchfield (1956) recognized 2 physiological races of *R. similis*: one race.

parasitizes banana and many other hosts but not citrus, the other parasitizes both banana and citrus.

Continuous cultivation of land without resting period or adoption of fallow system seems to be one of the factors behind development of nematode population. Fallow is a simple tactic for reducing nematode populations through starvation, as suggested by Tyler in 1933. Also (Chabrier and Que´ne´herve´, 2003). Reported that the land is cleared of nematodes by a fallow period.

The irrigation method which is used in banana plants opening on each other (Table 9 in Sennar and Table 15 in Kassala state) that allow the nematodes transfer from plant to other with the water and this may help of nematodes distribution. Also the unclean equipments may be behind the increased number of nematodes as shown on (Table 17) all the farmers on Kassla state 100% not cleaning the equipments before entered it to the farm against 24% on Sennar state.

5.2. Estimation of the living nematodes

The results showed that the nematodes density was higher in Kassala State than Sennar State.

The most prevailing nematodes species identified associated with plant rhizosphere in the two states were, *Pratylenchus Spp*., *Helicotylenchus spp*., *Rotylenchus spp*., *Scutellonema Spp*., *Xiphinema spp*., *Longidorus Sp*., *Tylenchus Spp*. and *Hoplolaimus Spp*.

However, the nematode species, *Radopholus similis* was predominantly isolated from roots of banana in the two States.

5.3. Estimation of the nematodes from the roots

The results showed that the nematodes density on roots was higher in Kassala State than Sennar State. Damage thresholds are difficult to apply to bananas because of the numerous factors affecting nematode populations on a perennial crop (Gowen, 1995). Reported thresholds vary from 1,000 burrowing nematodes per 100 g of roots in W.Africa, to 20,000 per 100 g of roots in Costa Rica (Gowen and Queneherve, 1990). Taking this disparity into consideration, Gowen and Queneherve (1990) proposed that crop losses will occur at nematode population densities greater than 2,000 per 100 g of roots. This level was surpassed on all banana farms in American Samoa. Considering the amount of root damage that was associated with these populations.

5.4. Measurement of root necrosis

The migratory feeding behavior of this nematode in the root tissues caused the formation of lesions, which may enlarge and coalesce, resulting in the large necrotic areas and this accounts for the high percent root necrosis observed.

Severity of root damage will be estimated as the total percentage of necrotic root cortex for the five root lengths should be considered for evaluation based on a system of five classes (Bridge and Gowen, 1993; Moens *et al.*, 2001): 0 = no necrotic roots and undamaged, 1 = less than 25% of roots with necrosis, slight damage, 2 = 26 to 50% of roots with necrosis, moderate damage, 3 = 51 to 75% of roots with necrosis, severe damage 4 = more than 75% of roots with necrosis, very severe damage.

Damage score usually has a strong relationship with crop yield losses (Coyne *et al.*, 2007). Severely damaged roots normally topple-over at the expense of yield, while undamaged root systems have the capacity to support fruit bearing plants till harvest.

In this study Root necrosis ratings for all nematode species averaged 10.8% (2.6-19%) in Sennar state which was evaluated in class 1, compare with 29.3% (17-48%) in Kassla state evaluated in class 2.

5.5. Classical Morphology

1- Females

The morphometrics data we obtained were within the ranges reported by Elbadri (2000).

The longest female was found in population Kassla state (average length = 662 um). (Table 26).

Head measurements were almost identical in all populations, ranging from (9.2 × 3.9).

The stylet length (average length = 18.8 um). The DGO was situated near the stylet base in all the populations (the average = 4.3 um).

The excretory pore opened ventrally (the average = 86.7). The vulva opening was in average found at 55.4 % of the body length. Ovaries extended anteriorly and posteriorly with a single row of oocytes; the length of the posterior ovary was slightly shorter than the anterior one. Tail shape pointed to tapering with smooth terminus. (Length average = 68.9 um).

From these data the *Radopholus* genera found:-

Kassala and Sennar states were assumed to the *R. similis*.

2- Males

Generally males were more slender and shorter than the females (Elbadri, 2000). The average length (567.6 um), (Table 27), lip regions were rounded, set off with weak cephalic sclerotization. The stylet was reduced, stylet knobs were absent. The average spicule length (18.4 um), (Table 27). The gubernaculum was stout, protruding slightly from the cloaca and was almost half as long as spicule. Male gonads were usually outstretched with variable length (Table 27). Male genital tracts were filled with rod-like sperm.

In general the male tail end was more slender than the female tail end and pointed to tapering with smooth terminus. The average length = 70.6 um.

In conclusion the study showed that the nematodes density was higher in Kassala State than Sennar State.

The soil type, irrigation method, mixed cropping system; unclean equipment and continuous cultivation of land without resting period or adoption of fallow system are the most factors influence on banana nematode spread.

The most prevailing nematodes species identified associated with plant rhizosphere in the two states were, *Pratylenchus Spp*., *Helicotylenchus spp*., *Rotylenchus spp*., *Scutellonema Spp*., *Xiphinema spp*., *Longidorus Spp*., *Tylenchus Spp*. and *Hoplolaimus Spp*.

However, the nematode species, *Radopholus similis* was predominantly isolated from roots of banana in the two States.

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APPENDICES

Kassala State

Table (1) Frequency distribution and percentage for farmers according to their age

Age	Frequency Distribution	Percent
25-45	3	30
46-65	4	40
66-85	3	30
Total	10	100

Table (2) Frequency distribution and percentage for farmers according to their education levels

Education level illiterate	Frequency Distribution	Percent
Kalwa	1	10
Basic	1	10
Intermediate	1	10
Secondary	6	40
University	0	0
Total	10	100

Table (3) Frequency distribution and percentage for farmers according to their experience in agriculture

Experience years	Frequency Distribution	Percent
1-15	0	0
16-30	4	40
31-45	3	30
46-60	3	30
Total	10	100

Table (4) Frequency distribution and percentage for farmers according to years of experience in banana production

Experience years	Frequency Distribution	Percent
1-15	1	10
16-30	6	60
31-45	1	10
46-60	2	20
Total	10	100

Table (5) Frequency distribution and percentage for farmers according to their farm area

Farm area	Frequency Distribution	Percent
1-15	9	90
16-30	0	0
31-45	0	0
46-60	1	10
Total	10	100

Table (6) Frequency distribution and percentage for farmers according to the area of the cultivated banana

Banana area	Frequency Distribution	Percent
1-5	10	100
6-10	0	0
11-15	0	0
16-20	0	0
Total	10	100

Table (7) Frequency distribution and percentage for farmers according to the years of banana cultivation on the soil.

Years number of banana cultivation	Frequency Distribution	Percent
1-20	4	40
21-40	4	40
41-60	1	10
61-80	1	10
Total	10	100

Table (8) Frequency distribution and percentage for farmers according to banana cultivation continuity

Duration	Frequency Distribution	percent
Continuous	6	60
Not Continuous	4	40
Total	10	100

Table (9) Frequency distribution and percentage for farmers according to the presence of crops before banana cultivation

Crop before banana	Frequency Distribution	percent
Yes	10	100
No	0	0
Total	10	100

Table (10) Frequency distribution and percentage for farmers according to the banana cultivation immediately after the previous crop

banana cultivation immediately after the	Frequency Distribution	percent
Yes	5	50
NO	5	50
Total	10	100

Table (11) Frequency distribution and percentage for farmers according to the plant age

Age of plant	Frequency Distribution	Percent
1-5	10	100
6-10	0	0
Total	10	100

Table (12) Frequency distribution and percentage for farmers according to the number of picking per year

Number of picking	Frequency Distribution	Percent
10	3	30
11	1	10
12	6	60
Total	10	100

Table (13) Frequency distribution and percentage for farmers according to the number of the hands on the bunches

Hands number	Frequency Distribution	Percent
>10	6	60
10	1	10
>10	3	30
Total	10	100

Table (14) Frequency distribution and percentage for farmers according to the finger size

Finger size	Frequency Distribution	Percent
Big	0	0
Small	10	100
Median	0	0
Total	10	100

Table (15) Frequency distribution and percentage for farmers according to the production relationship in the farm

Relationship type	Frequency Distribution	Percent
Own farm	8	80
Renter	2	20
Share	0	0
Governmental	0	0
Total	10	100

Table (16) Frequency distribution and percentage for farmers according to the banana Varieties in the farm

Cultivated Varieties	Frequency Distribution	Percent
Local	1	10
Imported	9	90
Total	10	100

Table (17) Frequency distribution and percentage for farmers according to the suckers source

Suckers source	Frequency Distribution	Percent
From the farm	4	40
From other farmer	6	60
Others	0	0
Total	10	100

Table (18) Frequency distribution and percentage for farmers according to the things witch the farmer must take care from it when they want to choose the cultivars

the things witch the farmer must take care from it	Frequency Distribution	Percent
Good and healthy	1	10
Young	9	90
Others	0	0
Total	10	100

Table (19) Frequency distribution and percentage for farmers according to the type of the suckers

type of the suckers	Frequency Distribution	Percent
Sword	3	30
Butts	7	70
Total	10	100

Table (20) Frequency distribution and percentage for farmers according to the spaces between the plants

The spaces between the plants	Frequency Distribution	Percent
2×3	0	0
3×3	2	20
4×4	8	80
Total	10	100

Table (21) Frequency distribution and percentage for farmers according to the suckers number beside the mother plant

suckers number	Frequency Distribution	Percent
3-4	10	100
5-10	0	0
<10	0	0
Total	10	100

Table (22) Frequency distribution and percentage for farmers according to the method of weed control

Weed control	Frequency Distribution	Percent
Manual	3	30
Use herbicides	0	0
Manual+ herbicides	5	50
No control	2	20
Total	10	100

Table (23) Frequency distribution and percentage for farmers according to the type of the fertilizer

Fertilizer type	Frequency Distribution	Percent
Urea	3	30
Phosphorus	7	70
Animal residue	0	0
Bird residue	0	0
Not use fertilizer	0	0
Total	10	100

Table (24) Frequency distribution and percentage for farmers according to amount of the applied fertilizer

Mount of fertilizer per feddan	Frequency Distribution	Percent
1-2	0	0
<2	10	100
Not applied fertilizer	0	0
Total	10	100

Table (25) Frequency distribution and percentage for farmers according to the time of applied fertilizer

applied fertilizer time	Frequency Distribution	Percent
Summer	0	0
Winter	10	100
Total	10	100

Table (26) Frequency distribution and percentage for farmers according to the dieses symptoms

Symptoms	Frequency Distribution	Percent
Yellowish	2	20
Stunted	8	80
Wilting	0	0
Toppling over	0	0
Roots swelling	0	0
Others	0	0
Total	10	100

Table (27) Frequency distribution and percentage for farmers according to covering banana bunches, propping the bearing plant and cutting the terminal male bud

Covering the bunches, propping the plant and debuding	Frequency Distribution	Percent
Yes	1	10
No	9	90
Total	10	100

Table (28) Frequency distribution and percentage for farmers according to if they receive any information about banana production

information about banana production	Frequency Distribution	Percent
Yes	10	100
No	0	-
Total	10	100

Table (29) Frequency distribution and percentage for farmers according to if they had agricultural equipment

Do you had agricultural equipment	Frequency Distribution	Percent
Yes	1	10
No	9	90
Total	10	100

Sennar State

Table (1) Frequency distribution and percentage for farmers according to their age

Age	Frequency Distribution	Percent
25-45	15	60
46-65	9	36
66-85	1	4
Total	25	100

Table (2) Frequency distribution and percentage for farmers according to their education levels

Education level illiterate	Frequency Distribution	Percent
	1	4.0
Kalwa	2	8.0
Basic	4	16.0
Intermediate	5	20.0
Secondary	9	36.0
University	4	16.0
Total	25	100

Table (3) Frequency distribution and percentage for farmers according to their experience in agriculture

Experience years	Frequency Distribution	Percent
1-15	10	40.0
16-30	7	28.0
31-45	6	24.0
46-60	2	8.0
Total	25	100

Table (4) Frequency distribution and percentage for farmers according to years of experience in banana production

Experience years	Frequency Distribution	Percent
1-15	16	64.0
16-30	6	24.0
31-45	3	12.0
46-60	0	2
Total	25	100

Table (5) Frequency distribution and percentage for farmers according to their farm area

Farm area	Frequency Distribution	Percent
1-15	22	88.0
16-30	3	12.0
31-45	0	0
Total	25	100

Table (6) Frequency distribution and percentage for farmers according to the area of the cultivated banana

Banana area	Frequency Distribution	Percent
1-5	19	76.0
6-10	4	16.0
11-15	1	4.0
16-20	1	4.0
Total	25	100

Table (7) Frequency distribution and percentage for farmers according to the years of banana cultivation on the soil

Years number of banana cultivation	Frequency Distribution	Percent
1-20	22	88
21-40	3	12
41-60	0	0
61-80	0	0
Total	25	100

Table (8) Frequency distribution and percentage for farmers according to banana cultivation continuity

Duration	Frequency Distribution	percent
Continuous	17	68
Not Continuous	8	32
Total	25	100

Table (9) Frequency distribution and percentage for farmers according to the presence of crops before banana cultivation

Crop before banana	Frequency Distribution	percent
Yes	5	20
No	20	80
TOTAL	25	100

Table (10) Frequency distribution and percentage for farmers according to the banana cultivation immediately after the previous crop

Banana cultivation immediately after the previous crop	Frequency Distribution	percent
Yes	5	20
NO	20	80
TOTAL	25	100

Table (11) Frequency distribution and percentage for farmers according to the plant age

Age of plant	Frequency Distribution	Percent
1-5	25	100
6-10	0	0
TOTAL	25	100

Table (12) Frequency distribution and percentage for farmers according to the number of picking per year

Number of picking	Frequency Distribution	Percent
10	9	36
11	5	20
12	11	44
TOTAL	25	100

Table (13) Frequency distribution and percentage for farmers according to the number of the hands on the bunches

Hands number	Frequency Distribution	Percent
>10	8	32
10	9	36
>10	8	32
TOTAL	25	100

Table (14) Frequency distribution and percentage for farmers according to the finger size

finger size	Frequency Distribution	Percent
Big	11	44
Small	0	0
Median	14	56
TOTAL	25	100

Table (15) Frequency distribution and percentage for farmers according to the production relationship in the farm

Relationship type	Frequency Distribution	Percent
Own farm	17	68
Renter	6	24
Share	2	8
Governmental	0	0
TOTAL	25	100

Table (16) Frequency distribution and percentage for farmers according to the banana Varieties in the farm

Cultivated Varieties	Frequency Distribution	Percent
Local	22	88
Imported	3	12
TOTAL	25	100

Table (17) Frequency distribution and percentage for farmers according to the suckers source.

Suckers source	Frequency Distribution	Percent
From the farm	4	16
From other farmer	20	80
Others	1	4
TOTAL	25	100

Table (18) Frequency distribution and percentage for farmers according to the things witch the farmer must take care from it when they want to choose the cultivars

the things witch the farmer must take care from it	Frequency Distribution	Percent
Good and healthy	9	36
Young	6	24
Others	10	40
Total	25	100

Table (19) Frequency distribution and percentage for farmers according to the type of the suckers

type of the suckers	Frequency Distribution	Percent
Sword	21	84
Butts	4	16
Total	25	100

Table (20) Frequency distribution and percentage for farmers according to the spaces between the plants

The spaces between the plants	Frequency Distribution	Percent
2×3	6	24
3×3	16	64
4×4	3	12
Total	25	100

Table (21) Frequency distribution and percentage for farmers according to the suckers number beside the mother plant

suckers number	Frequency Distribution	Percent
3-4	6	24
5-10	9	36
<10	10	40
Total	25	100

Table (22) Frequency distribution and percentage for farmers according to the method of weeds control

Weeds control	Frequency Distribution	Percent
Manual	25	100
Use herbicides	0	0
Manual+ herbicides	0	0
No control	0	0
Total	25	100

Table (23) Frequency distribution and percentage for farmers according to the type of the fertilizer

Fertilizer type	Frequency Distribution	Percent
Urea	5	20
Phosphorus	-	-
Animal residue	1	4
Bird residue	16	64
Not use fertilizer	3	12
Total	25	100

Table (24) Frequency distribution and percentage for farmers according to amount of the applied fertilizer

Mount of fertilizer per feddans	Frequency Distribution	Percent
1-2	8	32
<2	14	56
Not applied fertilizer	3	12
Total	25	100

Table (25) Frequency distribution and percentage for farmers according to the time of applied fertilizer

applied fertilizer time	Frequency Distribution	Percent
Summer	0	0
Winter	25	100
Total	25	100

Table (26) Frequency distribution and percentage for farmers according to the dieses symptoms

Symptoms	Frequency Distribution	Percent
Yellowish	5	20
Stunted	3	12
Wilting	0	0
Toppling over	4	16
Roots Swelling	0	0
Others	13	52
Total	25	100

Table (27) Frequency distribution and percentage for farmers according to covering banana bunches, propping the bearing plant and cutting the terminal male bud

Covering the bunches, propping the plant and debuding	Frequency Distribution	Percent
Yes	8	32
No	17	68
Total	25	100

Table (28) Frequency distribution and percentage for farmers according to if they receive any information about banana production.

Information received about banana production	Frequency Distribution	Percent
Yes	10	40
No	15	60
Total	25	100

Table (29) Frequency distribution and percentage for farmers according to if they had agricultural equipment.

Do you had agricultural equipment	Frequency Distribution	Percent
Yes	24	96
No	1	4
Total	25	100