A SURVEY OF NEMATODE GENERA IN THE RHIZOSPHERE OF FRUIT TREES IN AHMADU BELLO UNIVERSITY RESIDENTIAL AREAS IN SAMARU, ZARIA.

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL,
AHMADU BELLO UNIVERSITY ZARIA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER SCIENCE IN BCOIOGY

FACULTY OF SCIENCE
DEPARTMENT OF BIOLOGICAL SCIENCES
AHMADU BELLO UNIVERSITY
ZARIA - NIGERIA

OCTOBER, 1990

DEDICATION

Dedicated to my husband

and

Children, Aniekan, Iniobong and Uduak.

DECLARATION

I hereby declare that this thesis is a record of my own research. It has not been presented by me or anyone else in any previous application for a higher degree.

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CERTIFICATION

This thesis entitled "A Survey of nematode genera in the rhizosphere of fruit trees in Ahmadu Bello University Residential areas in Samaru, Zaria," by Yetunde Temitope Thomas meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENT

I wish to thank, Prof. C. Vajime, Head, Department of Biological Sciences, Ahmadu Bello University, Zaria, for providing the facilities for this work, and acting as my supervisor following the departure of Dr. Z. Hussain.

I am immensely grateful to Dr. F.A. Khan, Mrs Ogunlela, Mr. Ansah and Mrs. Iyortsuun for their assistance.

The patience shown by Bro. E. Adeleke and staff of DP Services in typing the thesis is duly acknowledged.

ABSTRACT

Soil samples around some fruit trees in samaru residential areas of Ahmadu Bello University were taken and analysed to find the nematodes present in them.

With the aid of a modified Baerman's funnel and decantation methods, nematode fauna were extracted and analysed. A total of about 17 genera of plant parasitic, freeliving and algal feeders forms of nematodes were found present. They included plant parasitic forms Rotylenchus spp., Tylenchus spp., Tylenchorynchus spp., Hoplolaimus spp., Helicotylenchus spp., Hejucriconemoides spp., Ditylenchus spp., Telotylenchus spp., ScuteUonema spp. and Longidorus spp., the parasites of other nematodes, Mnonchus spp. and Discolaimus spp., saprophagous forms such as Diplogasteroidea spp., Drylaimus spp., Acrobeles spp., Dorylaimellus spp., and the algal feeder, Eudorylaimus spp.

Helicotylenchus spp. were the most widely distributed, occurring in relatively large populations at all sample sites and around all fruit tree species sampled.

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CHAPTER ONE

I N T R O D U C T I O N

1.1 A Survey

Nematodes or roundworms inhabit all types of environments infesting both plants and animals, or sometimes just living in association with the plants, e.g. freeliving forms like members of the superfamily Rhabiditoidea Travasses, 1930. Hardly is any plant free from infestation by nematodes. Plants parasitic forms include Meloidogyne spp Goeldi, 1887, Hoplolaimus spp; Daday, 1905 and a host of others. All other organisms including man and his domesticated animals are not exempted from the effect of these organisms as various forms of nematodes cause great damage to man, e.g. Drancuculus medinensis and Ascaris lumbricoides.

In fact, nematodes parasitic on animals were recorded in Egypt as early as 1553 - 1550 BC (Thorne, 1961). It is believed that the "fiery serpents" which attacked the Israelites as recorded in Numbers 21:6 - 9 were actually Guinea worms. Aristotle (384 - 322 BC) mentioned animal parasitic nematodes as if they were well known at that time. Linnaeus (1758) recorded several genera under the group vermis in his "Systema Natura." These large nematodes though easily seen were not extensively studied until the 19th century when microscopes became available.

The existence of plant parasitic nematodes was not known until the middle of the 18th century when the wheat gall nematode, Anguina tritici (Steinbuch, 1799) Chitwood, 1935, was first recorded by Needham 1743. Over one hundred years elapsed before other significant contributions were made by Kuhn, who

discovered the stem bulb nematode in 1857. Schachtii (1859) also suggested that a failure of sugar beet is caused by a nematode Heterodera schatii. Since then many nematologists have recorded the presence of parasitic nematodes in virtually all crops. In fact, virtually every cubic centimetre of soil has been found to be inhabited by nematodes. They are found in abundance in the upper rhizosphere and could be found down to about 20 feet below the surface of the soil.

Plant parasitic nematodes include Meloidogyne spp. Goeldi, 1887, Syn. Caconema a Cobb, 1924 usually found infesting almost every type of field crop in the tropical, subtropical and Mediterranean countries. Many other plant parasitic forms exist around, and on various host roots. The worms could be found on any part of the plant, from the root (e.g. Meloidogyne spp.) to the seed (e.g. Anguina tritici). The small size of these plant and soil forms made them escape detection for a long time.

1.2 Habitat and habits

Cobb (1915) concluded that nematodes inhabit virtually any place on earth where any living thing might survive. These include soils, deserts, bottom of lakes, rivers, hot springs or even the polar regions where temperatures are constantly below freezing point. Chitwood (1877) noted that the nematodes foreshadow the arthropods by their large numbers. Filipjev (1931) reported that 4,601 different species had been named and described. Of these, 2,205 species are known parasites of vertebrates, 231 species are parasites of invertebrates, about 1,175 species are found inhabiting marine waters, and 990 species

are found in fresh water, soil or other habitats. However species feeding on plants were not separated from species living in the soil.

1.3 Nematode Classification

Chitwood (1933) established two major classes which he called phasmida and Aphasmida based on the pesence or absence of phasmids, usually found in the cephalic region of some nematodes like Acrobeles spp; Von Linstow, 1877. Dougherty (1958) observed that Phasmida and Aphasmida were pre-empted by a name assigned to a group of insects in the order Orthoptera, and he thus proposed a new name Secernentea V. Linstow, 1958 for the nematodes with phasmids. Chitwood (1958) later amended and validated Adenophorea V. Linstow, 1958 for nematodes without phasmid (Aphasmida). The presence or absence of phasmids continues to be one of the chief morphological characters used in identification of nematodes (Thorne, 1961). Phasmids are absent in Tylenchus, Bastian, 1865., Ditylenchus, Filipjev, 1936, Anguina Scopoli, 1777 and other related genera. In these genera, phasmids even when present are beyond powers of resolution (Thorne, 1961).

The location of the amphid apertures is the anatomical feature used to separate Secernentea from Adenophora. In Secernentea, amphids are always located on the anterior lip-bases, e.g. in Tylenchoidea Chitwood and Chitwood, 1937, and Aphlenchoidea Thorne, 1949, while in Adenophorea the apertures are at the base of the lip region as in Dorylaimoidea, de Man 1876, or well behind the lips as in Plectoidea Chitwood, 1937, and Tripyloidea Chitwood, 1937.

The spears of all Tylenchs have ventral oblique aperture while in Dorylaimus Dujardin, 1845 the aperture is dorsal invariably. This characteristic helps in determining whether a spear bearing specimen belongs to Secernentea or Adenophora. Chambers, Thorne (1961) as well as Mai et al (1964) made very good illustrations of nematodes which aid in their identification.

Goodey (1963) recorded that plant and soil nematodes have representatives in the orders Tylenchida Thorne, 1949, Rhabditida Sch. stec., 1950, Menhysterida de Coninck, 1933, Enoplida Chitwood, 1933, Dorylaimida Pearse, 1942, and Trichosyringida Ward, 1917. Nematodes with protrusible stylet are in the order Tylenchida which includes most of the plant parasitic forms. Others belong to the group of Dorylaimida which include the known vectors of viruses. Some stages in the life cycle of Trichosyringida also have mouth stylet, but these are parasitic on arthropods or vertebrates. Many of the most commonly occurying microphagus forms are present in the order Rhabditida Hooper, 1969.

1.4 Morphology of Plant Parasitic and Soil Nematodes.

Plant parasitic and freeliving soil nematodes are elongate, slender and translucent organisms with lengths ranging from 0.3mm to 5.0mm (Taylor, 1971). Majority of the forms are less than 2.0mm in length with cylindrical bodies. Some forms are fusiform, e.g. Meloidogyne spp. Goeldi, 1889, while others are pear, lemon, reniform or irregularly saccate in shape. Anteriorly in some forms the body may taper, but many remain

almost cylindrical in the lip region, e.g. Mononchus species Bastian, 1865. The posterior end of the body may vary in form from bluntly rounded terminus of Hoplolaimus corantalus Daday, 1905, to the elongate filiform tail of Prismatolaimus stenuis de Man, 1880.

The body width varies and may be less than 1% of the body length of the nematode as in Ecphyadophora de Man, 1921, or as much as 1.5% of the body length as in Criconema Hofmamer and Menzel, 1914. It is important to note that the forms among nematodes aree so variarble that probably not one statement about them can be made that does not have exceptions.

1.5 General Body Divisions

The nematode body is not divided into definite parts but there are certain subdivisions to which common names have been given for convenience. The anterior end bears the head which contains the mouth and pharynx and bears cephalic papillae or setae. The neck is the portion between the head and the base of the oesophagus as in figure 1, while the tail extentds from the anus to the terminus of the animal. Longitudinally the body is divided into four regions namely: dorsal, right and left lateral, and ventral regions. For purposes of orientation, the ventral region is determined by the fact that the bodies of majority of the species are naturally bent ventrally to some degree. In cases where the body is straight, the anal opening is present even in the larval stages. Mature females possess a vulva placed ventrally and located around the middle of the body in some forms like Tylenchorhynchus, Cobb 1913, Syn. Bitylenchus, Filipjev

1934, far back near the anus as in Criconema, Hofmanner and Menzel 1914, and forward toward the base of the Oesophagus, like in Tylencholaimellus Cobb, 1915, and Syn. Pharetrolaimellus, de Man 1921. The excretory pore when present is located ventrally between the nerve and the base of oesophagus, with rare exceptions like Tylenchulus, Cobb, 1913.

1.6 Plant Parasitic Nematodes

Most plant parasitic nematodes found in association with roots are too small to be seen with the naked eye (with a few exceptions), but they are found only within or protruding from roots (rhizosphere) and are either ecto- or endo-parasites. Their average length is about 1mm. Species like Trichodorus christei Allen, 1957, are found to be shorter than average with adults growing to only about 0.7mm in length, i.e. about the size of some rootlets where they feed. The sting nematodes, Belonolaimus longicaudatus Syn Rau, 1958, Belonolaimus gracilis Steiner, 1949, are longer than average, having a length of about 2mm.

Sexes are separate as in all nematodes with the males slightly smaller in most cases than the females. The most obvious difference in sex occurs at the posterior end where the presence of spicules and other copulatory organs, often including a bursa, may cause the tail of the male to differ sharply in shape and appearance from that of the female. In some plant parasitic nematode species, males and females are not alike in shape and size. For example, in the root knot nematode or Meloidogyne species the female is much fatter than the male. In

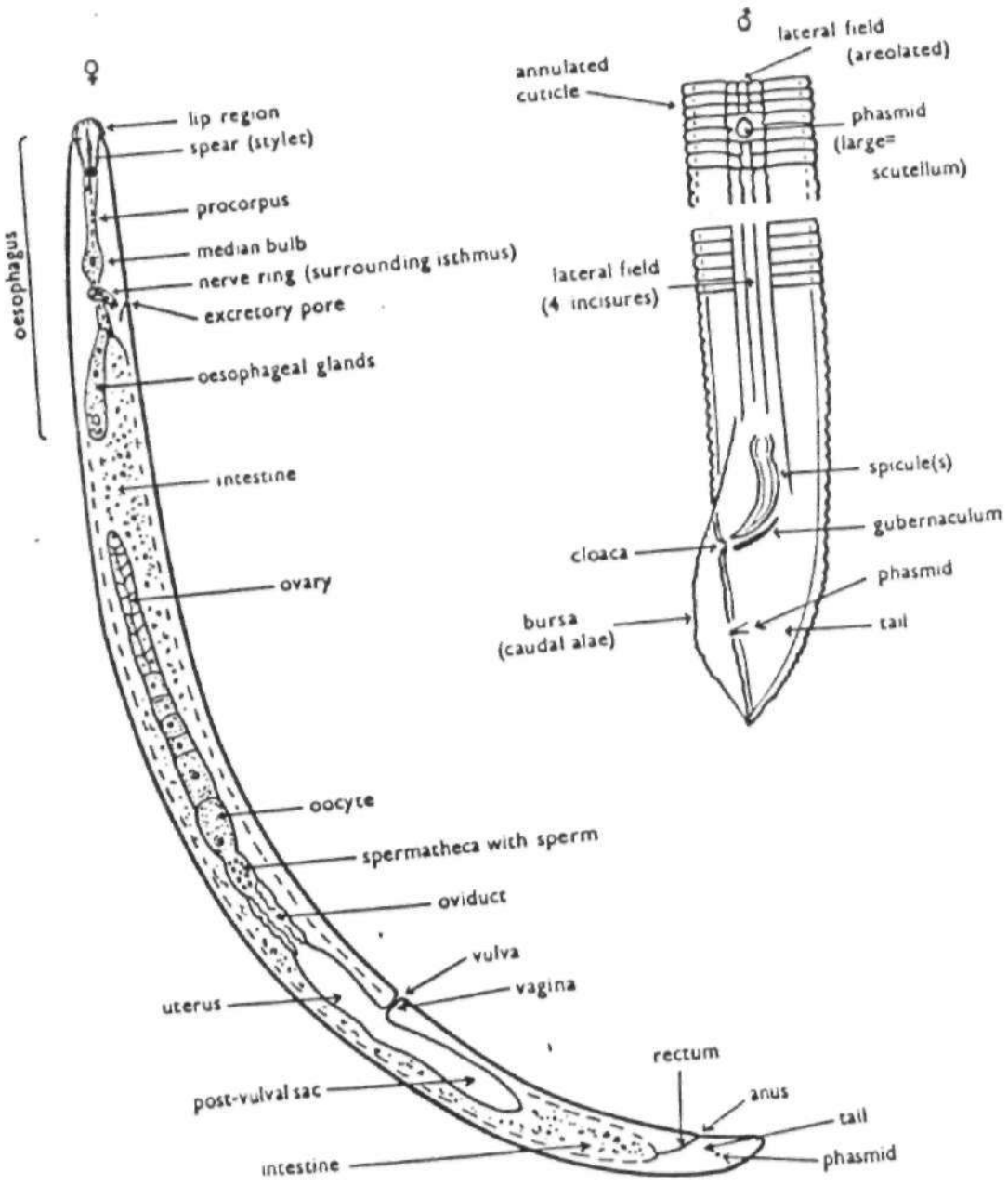


FIGURE 1: TYLENCHID NEMATODE SHOWING PRINCIPAL SRTUCTURES.

the citrus nematode, Tylenchulus semipenetrans Cobb, 1913, and the reniform nematode Rotylenchulus reniformis Linford and Oliveira, 1940, Syn. Spirotylenchus Lordello and Cesnik, 1958, Leiperotylenchus Das, 1960, the females once established within the tissue of the plant remain there after losing their slender form as they develoip and become lemon-shaped, pear-shaped or sometimes almost spherical. The males on the other hand remain cell-shaped.

Most plant parasitic nematodes feed on plant tissues around the rhisosphere of the plant with means of a minute hypodermic needle like stylet. Some forms feed on buds, stems and leaves of plants, while others feed on structures like roots below the ground (Christie, 1959).

1.7 Feeding and Damage to Plants

Nematodes guided by their amphids locate and approach a plant root following a gradient of root excretions, and with the help of their papillae they bring their head to a feeding position. The stylet is then used to puncture a cell and to inject the oesophageal gland secretions which liquify a portion of the cell contents. The liquid is then sucked into the stylet and passed into the intestine by the oesophagus. Nematodes mode of feeding results in different types of damages in the plants.

A typical example is in the damage to roots, where, for example, shortening of roots reduces the accessibility of the plant to water and food. Damage to feeder roots also prevents normal assimilation of water and plant food. Other types of damage result from the effect of digestive enzymes (which are

sometimes toxic) secreted into the cells. These enzymes kill the cells as in the case of migratory parasites like Anguina tritici. Neighbouring cells may be unaffected. Some nematodes produce substances which result in growth effects extending beyond the cells actually punctured. An example is provided by root galls or plants infested by Meloidogyne species. Similar giantcells also form in roots parasitised by Heterodera species Schmidt, 1871, Syn . Heterobolbus Railliet, 1896, (Heterodera) Skarbilovich, 1959, (Globodera) Skarbilovich, 1959, where galls are less conspicuous. Still, other species like Nacobbus Thorne and Allen, 1944 also form distinct galls which could be mistaken for root knot galls.

Nematode injury to plant roots in the field is almost invariably complicated by the immediate invasion of affected tissue by bacteria and fungi. The site of injury is initially small and marked with discoloured spots. This is followed by fungal and bacterial invasion of the dead tissue resulting in general rotting or galling of roots, and sometimes stimulating formation of lateral roots about the injury. Crosse and Pitcher (1952) demonstrated that cauliflower disease of strawberry plants which occurs in England and in the continent of Europe is caused by a bud nematode of the genus Aphlenchoides Fischer, 1894, Syn. (Pathoaphelenchus) Cobb, 1927 (Schistonchus) Cobb, 1927 in combination with Corynebacterium fascicins Tilford Dowson. It was found that neither the nematode nor the bacterium acting alone could cause the disease.

Other injuries resulting from nematode infestation of various plant parts include:

(i) Crinkled or distorted stems and foliage, for example that caused by Anguina tritici larvae in wheat seed (Christie, 1959).

(ii) Seed gall formation on grasses and cereals by Anguina species (Christie, 1959).

(iii) necrosis and discolouration, as in the red ring disease of coconut palms caused by Aphelenchoides cocophilus Fischer, 1894, and Ditylenchus dispaci (the stem nematode) Filipjev and Sch. Stek, 1941;

(iv) leaf galls produced by Anguina balsamophila Filipjev, 1936 and many other types of damages.

Sometimes damage to plant might not be due to only one nematode type. In Sanford, Florida, celery was found to be injured by the simultaneous action of sting nematodes Belonolaimus Steiner, 1949, owl nematodes Dolichodorus heterocephalis Cobb, 1914, stubby root nematodes Trichodorus spp, Cobb, 1913, and occassionally root knot nematodes Meloidogyne species (Christie, 1959). Another problem created by nematodes is the formation of cysts, for example, by Heterodera species which makes their control very difficult. The genus Heterodera Schmidt, 1871 has also been reported to infest a variety of hosts, and thus creating more problems in control.

The various types of damage to plants by nematodes are known to be of economic importance in various parts of the world. For example, Heterodera Schachtii Schmidt, 1871, syn. Tylenchus schachtii (Schmidt, 1871) Oerley, 1880, Heterobolbus schachtii (Schmidt, 1871) Railliet, 1896, Heterodera (H) Schachtii Schmidt, 1871 (Skarbilovich, 1959), H. Schachtii minor O. Schmidt, 1930,

Heterodera rostochiensis of potato; Heterodera goettinguana of pea, Meloidogyne species are known to infest a variety of plants in the United States of America, England and even in Nigeria. It is, however, important to note that many plant nematodes can persist in soil without a host for months or even years, and hence their presence around plant roots does not necessarily mean that they are attacking the particular plant. They may be surviving from a preceeding crop or from weeds. Nevertheless, some nematodes are definitely deleterous to plant growth and the disease complexes they cause are worthy of note.

1.8 Nematode Problem

1.8.1 General

Nematode problems associated with agricultural crops until recently used to go unnoticed, partly because the nematodes parasitic on plants are very small, and partly because generally other problems like poor soil conditions like lack of fertility or soil exhaustion were blamed for poor yields. The losses due to plant parasitic nematodes became apparent when nematicides became cheaply available. Scientists could perform experiments using nematicide treated farms and farms not treated, and thus comparing yields (Taylor, 1961). Even with this progress in the field of nematology, accurate information on the extent of crop losses caused by plant parasitic nematodes is still sometimes difficult to obtain in developed and developing countries. However, some information on the extent of damages is obtainable from the literature. For instance, Taylor (1967) was able to quantify losses due to nematodes infestation when he compared

yields in a large number of fumigated and non-fumigated plots in the temperate zone of the United States of America. He showed crop reduction of about 37 per cent in nematode infested soils. The most severe nematology problems occur when good host crops are grown too frequently for too long on the same land (Chitwood, 1966).

1.8.2 Nematode Problem in Nigeria

Nigeria unfortunately grows good host crops too fequently for too long on the same land. In addition, the higher temperatures and longer growing seasons in Nigeria favour the production of more generations of nematodes, and thus a higher nematode population and crop damage. Generally, there are more susceptible crops per year in warmer areas, where there is a high population build up. It has also been observed that some of the more damaging species such as Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949, occur in warmer areas and so, do more severe disease complexes (Mai, 1971). Unfortunately, Nigeria, as well as most developing nations have very good natural soil temperatures, plant types and farming methods that encourage high increases in nematode populations all year round. Yet these countries must depend on these perennial crops and on crops grown without rotation to feed their ever increasing population.

Nematode problem in Nigeria, as in most developing countries, is further complicated by poor communications and lack of travel personnel to study the problems and advise farmers adequately. Furthermore, quarantine regulations are often

lacking and even where stipulated, ways of enforcing them are not ensured. Crop growing practices also keep changing and one finds that crops that were hitherto grown mainly in the south, such as fruit trees, are now grown freely in the north. Prevention or reduction of crop losses due to plant parasitic nematodes is one important way of increasing yields. The first step towards achieving this goal is surveying the nematode situation in the country (Nigeria), and determining the species present, their distribution and the damage caused to various crops.

This study therefore constitutes a step towards increasing our wealth of information on the nematodes of importance in agriculture in the Zaria area. Much of the work done so far in this area has been on the Meloidogyne species and Scutellonema species Andrassy, 1958 which compete favourably with man for most of his food products worldwide. Our study is therefore aimed at identifying nematode species or genera occurring in the rhizosphere of fruit trees in some residential areas in Ahmadu Bello University, Zaria, Samaru. It is hoped that the study will provide useful information on the nematode fauna of the soils in these areas and help to determine which of these, if any, affect the yield of fruit trees in the area of study.

CHAPTER TWO

LITERATURE SURVEY

2.1 History of Nematology

Nematology as named by Cobb, 1859, is the study of thread worms, roundworms or eel-worms. Aristotle, 384 - 323 BC first referred to a number of animal parasitic nematodes. Other records date back to between 1550 and 1553 BC., for example, of Ascaris lumbricoides recorded in Egypt. The "fiery serpents" mentioned in the Bible are thought to be Dracunculus medinensis. Borcellus (1646) described the first free living forms, the "vinegar" eel worm, Turbatrix accti. Linnaeus (1768) recorded several genera of animal nematodes under the group vermis in his famous publication "Systema Natura." Early records of nematode parasites were from animals because the species parasitic on animals are usually larger and easier to see with the naked eyes.

2.1.1 Plant Parasitic and Soil Nematodes

Earliest reference to plant parasitic nematodes dates back to William Shakespear, when in 1594 he narrated in Act IV Scene II of his play, "Loves Labour Lost" that "sowed cockle reap'd no corn." Much later in 1743 Needham solved the riddle when he found that the "cockle" (from crushed shrunken and blackened wheat grains examined under a microscope) contained thousands of threadlike small nematode larvae of the wheat gall nematode, Anguina tritici (Steinbuch, 1799) Chitwood, 1935. The second stage larva of this nematode is found to infect seeds and remain

viable for up to thirty years for further infection. Linneaus (1768), Scopoli (1777), Steinbuch (1799) and others recorded Anguina tritici attacking many other cereals. Berkeley (1885) further observed gall formation due to the infection of root knot nematode, Meloidogyne spp. in cucumber plants grown in green houses. Kuhn (1857) described Ditylenchus dispsaci (Kuhn, 1857) Filipjev, 1936 from malformed floral heads of teasel, Dispsacus fullonuml.

In the middle of the 19th century in Germany, sugar beet nematode, Heterodera schachtii became a serious threat to the production of sugar. This was mainly because there was intensive production without adequate crop rotation, thus creating ideal conditions for the development of pests (Thorne, 1961). Schachi (1859) observed a serious disease caused by a nematode later identified by Schmidt in 1871 as Heterodera schactii which for years inflicted losses in many fields in Germany. Strubell (1888) provided a detailed morphological study of the species. The Sugar beet nematode Heterodera schactii has now been redesignated as Globodera schachtii Skarbibvich, 1959 and found to be a major problem in the non-productive fields of sugar beet throughout Europe. Investigations on the control of the sugar beet nematode dominated the nematological scene in Europe from 1870 to 1910. Kuhn (1874) and co-workers such as Liebscher, Molz, Muller, Chatin and others were outstanding leaders in the studies of the sugar beet nematode. These workers examined the host plants, life history, habitats, distribution, etiology and methods of control of Globodera schachtii.

Probably the first soil fumigation for nematode control was

done by Kuhn in 1871 when he applied carbon disulphide to sugar beet nematode infested fields. He and his associates tried various methods of control such as 'trap crops' or 'Frangpflanzen', planting rape and other rapidly growing host in an attempt to induce the larval nematodes to hatch from the eggs and emerge from the brown cysts. Then by careful timing, the plants were removed and destroyed before the life cycle of the nematode could be completed. They were not very successful with this method of control so crop rotation was tried instead. Crop rotation proved to be the most effective and economical method of control and the principal methods of Kuhn et al (1871) are currently in use throughout the sugar beet industry of Europe and America.

As workers became more conscious about the activities of nematodes, other important plant parasites were described. Berkeley (1855) described 'Vibrios' from galls on the roots of cucumber in England. Greef (1872) found Anguillula radicicola or Ditylenchus radicicola producing galls on roots of Poa annua and other grasses. The first mention of root knot nematodes was by Cornu in 1879. He described Anguillula marioni or Meloidogyne marioni (Cornu, 1879) Chitwood, 1949 the causal agent of galls on roots of Onobrychis sativa. Geoldi (1887) published a description of Meloidogyne exigua which produced galls on the roots of coffee in Brazil.

Freeliving nematodes were described by Borellus in 1656, the first being the vinegar eel worm (earlier referred to as Turbatrix accti Peters, 1927). Other freeliving forms have been extracted from fresh and salt water by Muller (1786), Bory

(1824), Dujardin (1845), Carter (1959), Eberth (1863) and others. They gave the first descriptions of the gross anatomy of these freeliving nematodes. Bastian (1865) presented the first comprehensive paper on freeling nematodes. He was able to describe 100 new species belonging to 300 genera of which 23 were new. His studies were restricted to certain areas in England.

The beginning of the science of Phytonematology was marked by Bastian's (1865) monograph published on Anguillulidae. He reviewed for the first time the possibilities of intensive collection of soil and plant tissues as well as fresh and salt water in order to extract nematodes. Butschli (1873) provided the first detailed descriptions on the morphology of freeliving nematodes and identified many important characteristic features which are currently in use for the differentiation of various genera and species of nematodes. de Man produced an excellent well illustrated paper in 1876, and in 1884 he further produced his important taxonomic monograph in which he gave a formula with which nematodes are identified.

de Man's monograph illustrated clearly that when certain portions of the body of nematodes are measured, some proportions could be calculated and used in identification of nematodes. These proportions were designated as follows:

$$\text{Alpha} = \frac{\text{Body length}}{\text{greatest body width}}$$

$$\text{Beta} = \frac{\text{Body length}}{\text{distance from head end to posterior end of oesophageal glands.}}$$

$$\text{gamma} = \frac{\text{Body length}}{\text{distance from tail end to cloacal opening.}}$$

These proportions have been modified, but still used by taxonomists in the identification of nematodes.

Orley (1880) described 202 species representing 27 genera of freeling and plant parasitic nematodes. The work included a bibliography which became a valuable source of reference for subsequent publications by workers, and provided brief descriptions and numerous illustrations of fair quality. Micoletzky (1915) working on soil and fresh water nematodes, provided extensive keys to species and discussions on various groups fround in different habitats. The author tried to condense the taxonomy rather than expand it and produced an impossible conglomeration of trinomial nomenclature which was unacceptable to other workers. Micoletzky (1925), however, provided a description of sporozoan parasites of nematodes. An important literature on "Nematodes that are of importance in agriculture" was produced by Filipjev in 1934. The text, which was later produced under the new title of "A manual of Agricultural Helminthology," in 1941 provided "a most comprehensive compendium of nematological informaition," and is especially valuable as a referene source on the taxonomic studies of plant parasitic freeliving, as well as insect parasitic nematodes.

Numerous studies on soil and fresh water nematodes were carried out between 1910 and 1940 by various researchers. These studies led to the discovery of new species and occassionally new genera. For instance, Schneider (1939) made an especially

notable compilation of species in his "Freilebende and pflanzenparasitische Nematoden." Goodey (1923) described many species of plant and soil nematodes and in 1933 published "Plant Parasitic Nematodes and the diseases they cause." Goodey's emphasis was on the role of plant parasitic nematodes in agriculture with reference to the symptoms they show, as well as some illustrative drawings of the species of nematodes involved. Later, Goodey (1951) published the text entitled "Soil and fresh Water nematodes," which included information on the taxonomic studies of nematodes. A revised edition of this literature by Goodey (1963) is still considered as one of the reference resources for the identification of nematodes.

2.2 Control of Nematodes

Soil fumigation originated in France in the early 1860's when entomologists applied carbon disulphide for the control of Phyloxera on grapes. Kuhn (1871) first applied carbon disulphide for the control of the sugar beet nematode, but the results were not very encouraging.

Nematicidal qualities of cholopicrin were discovered in 1919 by Mathew working in England. Johnson and Godfrey (1932) showed that using chloropicrin on a large scale in plots in Hawaii led to the destruction of 99 to 100 per cent of the nematodes. Commercial fumigation ceased for several years until Carter (1943) reported that dichloropropene-dichloropropane (D.D.) mixture was a promising new soil fumigant, when applied at the rate of 250 pounds per acre. The discovery of D.D. marked the beginning of the present day soil fumigation industry. Early

demonstrations were so successful that within five years many thousands of acres had been treated and soil fumigation had been accepted as a successful and profitable practice.

Preliminary experiments with ethylene dibromide (ED) were performed in 1944 by Kagy and Youngson, as well as Christie (Thorne, 1961). Christie (1959) reported favourable results from his experiments with ethylene dibromide (ED). Ed was shown to be effective against nematodes (except cyst forming types), and also gave remarkable results in the control of wire worms.

Limitations on the efficiency of soil fumigation were soon discovered. Light and sandy loam soils with a moisture holding capacity of 20 per cent or less are known to respond readily resulting in excellent crops following fumigation. However, heavy clay loams and muck require two or three times the amount of fumigant, and generally less excellent crops follow fumigation. Loose peat soils are known to give little or no response even to excessive applications. Other principal methods of control available include crop rotation, cultural methods and using of resistant crops. However, each of these is found to have its limitations and sometimes more than one method has to be used to obtain good results (Thorne, 1961).

2.3 Economic Imprtance of Plant Parasitic Nematodes.

The effects of plant parasitic nematode on the reduction of yields in many crops have been reported by various workers over the years (Liu, et al, 1971; Ritter, 1972; Kyrov, 1972a; Kyrov, 1972b; Lordello, 1974; Adamova, 1975). For instance, Braithwate (1974) reported that plant parasitic nematodes are

associated with all the economically important crops of Monterrant in West Indies and suggested that nematodes contribute to the poor crop yields on the island. In Nigeria, Egunjobi (1974) reported a 28.5 per cent reduction in the yield of maize crop in Western Nigeria in the year 1970 as a result of about a 55 per cent increase in the population of Pratylenchus branchyrus in maize roots. Adamova (1975) also reported a decrease in yield of luerne of about 50 per cent in south Monrovia as a result of a severe attack of Ditylenchus dispsaci Kuhn, 1857, Fillipjev, 1936. A reduction of about 40 per cent in germination was also observed by Liu, et al,(1971) in poorly drained areas. Losses due to root knot nematode in Southern Europe and the Meditteranean have been estimated to be up to 50 per cent of the gross production of vegetables and 20 per cent of fruit plants (Ritter, 1971).

Attempts have been made by some workers to quantify losses in monetary terms. Thus, Pratylenchus vulnus Allen and Jensen, 1951 was reported to have caused losses of up to half a million dollars on wallnuts production in California (Lownshbery and Thomason (1959). The total annual losses due to plant parasitic nematode attack in that state alone, have been reported to be over 90 million dollars (Allen and Maggenti, 1959). In the United States of America as a whole estimated annual losses in cultivated crops due to plant nematodes infestation range from 250 to 500 million dollars (Hutchison et al,1961, Cains, 1955). Similarly, estimates in England and Wales in 1949 showed that the annual losses in potatoes caused by Globodera rostochiensis Woflenweber, 1923, was up to 200,000 tonnes, representing about

two million pounds (Scutley and Samuel, 1954). Of course, further increase in monetary losses could be due to use of nematicides which are very expensive.

Apart from reduction in yields, nematodes also interfere with the metabolic activites of plants. Most of the nematodes found below the ground feed on small non-suberized roots. This results in the damage of the root system. Some nematodes like Trichodorus spp. Cobb, 1913 and Tylenchorhynchus claytoni Steiner, 1937, can inhibit root growth without producing any recognisable symptoms (Christie, 1952, Graham, 1954). In many cases, the roots appear to be short, stubby and malformed due to infestation by Belonolaimus gracilis Steiner, Syn B. longicaudatus Rau, 1958, and Dolichodorus heterocephalus Cobb, 1914 on celery. Rhadopholus similis (Cobb, 1893) Thorne, 1949, causes almost identical symptoms in citrus and banana roots, producing lesions which girdle the roots and weaken their anchoring power (Tarjan et al, 1952, Feder and Ford, 1957; Loos, 1959; Loos and Loos, 1960; Blake, 1961). Root feeding also impairs the uptake of water and mineral resources (Mai, 1971; Alam et al, 1975). It has also been observed that nitrate reductase activity of carrot was appreciably lowered in plants infested by Meloidogyne hapla Chitwood, 1949 when compared with those uninfested (Alam et al, 1975).

2.4 Root Proliferation

In some plants, parasitic nematode activities do not produce decay or easily detectable lesions, but instead such plants respond to nematode attack by increase in root growth. An

example is the attack of the Heterodera spp. on some hosts. This nematode has a wide range of hosts such as oats, attacked by H. avenae Wollenweber, 1924 (Scarbilovich, 1959); potato, attacked by Globodera rostochiensis; sugar beet by Heterodera Schactitii Edward, 1935; Chitwood, 1951, Sarary, 1960. The formation of numerous small roots often renders the plant susceptible to wilting and uprooting. The ability of the plant to absorb nutrient is also impaired (Alam and Saxena, 1975). Other observable physical symptoms include destruction of the epidermis, softening of the collenchyma and parenchyma cells, as well as maceration, formation of cavities and hyper-trophic growth. Fissured and broken xylem, formation of giant cells in the steler region and complete lignification of tracheids are often observed due to infestation by nematodes.

2.5 Gall Formation

Characteristic galls form on roots of some host plants when certain nematode species infest them. The size, number and shape of these galls may, however, vary for different species and different host plants. The galls are sometimes seen as small slight swellings only after six hours of innoculation. Distinct galls are formed after 24 hours and are usually confined to the root tip (Jamal, 1976). Ogbuji (1976) observed that giant cells development was mainly in the steler region, occurring only in rare cases ine the cortex. Zknovev (1975) observed that giant cells are formed as a result of secretion by the female Meloidogyne spp.

The giant cells interfere with the physiological and

metabolic functions of the plant. Bird (1974) observed the reduction in the photosynthetic rate of the plant due to the infestation of root-knot nematodes (Meloidogyne spp.). He suggested that the nematodes influence the physiology of the plant by interfering with the synthesis and translocation of growth hormones produced in the root. Wallace (1974) observed that other factors affecting photosynthesis adversely were a consequence of nematode infestation.

2.6 Association of Nematodes with other organisms

Disease complexes which occur as a result of nematode infestation also complicate the nematode problem. These complexes are formed in association with other organisms. Thus, relatively weak fungal and bacterial root pathogens, which gain entry into the roots cause tremendous damage (Mai, 1971). Nematode attacks are known to sometimes lower resistance to some diseases, such as the vascular wilt disease caused by fungi and bacteria. Plants with roots damaged by parasitic nematodes are frequently more susceptible to nutrient deficiencies, cold and drought injuries.

Species which produce large lesions in plant roots allow other organisms to enter the plants. This is followed by a succession of secondary invaders which aggravate the initial nematode damage and even assume a dominant role in the subsequent root-rot (Pemi, 1958; Mountain and Patrick, 1959). Associations between nematodes and other organisms occur by chance, but a closer relationship exists between a nematode and fungal, bacterial or viral species. Thus, the nematode may provide a means of entry into the host plant, or there may be some

synergistic effect, or even some evidence of obligate relationship (Wallace, 1963).

2.6.1 Nematode-fungus association

Atkinson (1889) observed that cotton crops are damaged more because of the multiple infections of root-knot nematode and Fusarium wilts. Following this observation, nematode-fungal complexes have received much attention especially as they affect plants like tobacco, tomato, cowpea, carnation, alfalfa, garden pea and a host of others. Holderman and Graham (1952) reported that varieties of cotton resistant to Fusarium wilt succumbed to wilt only when the string nematode Belonolaimus gracilis was present in the soil. Similarly, Meloidogyne spp. may also show such effects. Fusarium wilt in cotton was shown to increase when the plants were attacked by nematodes (Smith, 1951).

Root-rot disease is known to be more severe when plants are inoculated with a combination of fungi and nematode, compared to cases of infection by fungi alone (Saeed et al, 1972; Garcia and Mitchell, 1975; Terenti'eva et al, 1976; Edward, 1976). Jacobson (1974) reported that M.hapla increased the severity of attack and decreased the incubation period for Verticillium wilt in potatoes. Sumner and Johnson (1972) and Anwar and Khan (1973) observed a synergistic relationship between the nematodes and fungi with the host plant. Smith (1954) reported that in addition to providing openings into the root system of the host for fungi, Meloidogyne spp. also increased the susceptibility of the host in the latter stages of development. Black-Shark disease of tobacco was found to be increased by nematode attack.

Sasser et al (1955) showed that where Phytopthera parasitica variety and nicotiana and Meloidogyne spp. were inoculated together, the black shark symptoms developed earlier, and were more severe than in soil inoculated with fungus alone. Thus, it was suggested that the nematode altered the host cell biochemically thereby providing a more congenial substratum for the fungus. Holdeman (1956) showed that wilt symptoms in tobacco caused by Fusarium oxysporum variety and nicotinae were more in the presence of Tylenchorhynchus claytoni Steiner, 1937 in the soil. However, the fungus was not dependent on the nematode for the invasion of the host. Jenkins and Cavsen (1957) induced Fusarium wilt resistant tomato variety 'Chesapeak' only when root knot nematode was present along with fungal inoculum. When M. hapla was combined with fungus, only about 60 per cent wilting of the plant was recorded, while M. Incognita acrita promoted wilting of up to 100 per cent in the plants, suggesting that the two nematode species affeced the plants in different ways.

2.6.2 Nematode-virus association

That nematodes might transmit viruses to the plants they infest has been and remains a subject of interest to many nematologists for quite some time. Virologists were aware that some soil borne organisms were probably acting as vectors in such viral diseases as Scottish raspberry curl and beet ring spot (Cadman, 1956; Harrison, 1957). Allen (1948) tested the possibility for figgren disease of lettuce, but failed to prove his hypothesis because he chose a virus not transmitted by nematodes in his experiments. Hewett et al. (1958) were the

first to show that nematodes could act as vectors of soil borne viruses. They demonstrated Xiphinema index as a vector of the grapevine fan leaf virus. Since then many other viruses which are transmitted by plant parasitic nematodes have been identified.

For instance Harrison and Cadman (1959) reported that Arabis mosaic virus was closely associated with the presence of Xiphinema spp. and suggested that the nematode was a possible vector. Grapevine fan leaf virus has also been reported in Nigeria, with Xiphinema italiae Meyl, 1953 suspected to be the possible vector. Breece and Hart (1959) showed that healthy peach seedlings developed yellow bud mosaic virus in the presence of Xiphinema americanum Cobb, 1913. No symptoms occurred in the absence of the nematodes, and so it was concluded that X. americanum is the vector of this virus. Brunt (1973) identified twelve viruses known to cause necrosis in the narcissus plant in Britain. Five of these were found to be transmitted by nematodes. The stubby root nematode Trichodorus sp. Cobb, 1913; Paratrichodorus sp. and the nematode Longidorus sp. (Micoletzky, 1922) Thorne and Swanger, 1936, Syn. Dorylaimus (Longidorus) Micoletzky, 1922, probably spread the tobacco rattle virus. Bustilla (1972) observed that cowpea chlorotic mottle virus in soybean was increased by 50 to 73% in plants infested with Rotylenchus reniformis. Hansen et al (1974) investigated the ecology and transmission of the cherry rasp leaf virus CRLV in Western America and observed that Xiphinema americanium was the predominant organism resposible for transmission in the fields. The population of about 10 nematodes per 100cm^2 soil was enough

to infect boits experimentally. Cowpea mosaic virus has been reported in western Nigeria to be transmitted by Xiphinema basiri. Harrison and Cooper (1974) found that roots and leaves of field resistant cultivars can be infested with TRV only by manual inoculation but rarely by nematode vectors. Goswami et al (1976) reported that the interaction between Meloidogyne incognita and the tobacco mosaic virus weakened considerably tomato plants in glass house experiments, and resulted in reduced uptake and translocation of calcium and magnesium. Generally, about eighteen nematode species are known to transmit eleven serologically distinct NEPO and NETU viruses. These are readily transmitted by mechanical inoculation. NEPO viruses which are polyhedral in shape cause ring spot type symptoms and have vectors belonging to two closely related genera in the super family Dorylaimoidea spp. de Man, 1876, Xiphinema spp. and Longidorus spp. NETO viruses which are rod shaped are transmitted by Trichodorus spp. Cobb, 1913, and Paratrichodorus spp. in the super family Diphtherophoroidea. Various experiments examining crops and soils suggest that the spread of each antigenic variant of these viruses depends on the presence of a specific nematode (Wallace, 1963).

2.6.3 Nematode - bacterium association

Wilting also results when plants are plagued with nematode and bacterial disease complexes. As early as 1901 it was shown that tomatoes grown in the presence of nematodes are infected by bacteria like Pseudomonas solanacearum. In the absence of nematodes no wilt occurred. Meloidogyne hapla and

Helicotylenchus manus Steiner, 1945 were found to promote these bacterial associations. In wheat, the ear-cockle and Tundu diseases do not appear when they are inoculated with Anguina tritici alone (Gupta and Swarup, 1972; Midha and Swarup, 1974). The ear-cockle only manifests in the presence of Corynebacterium tricti. Gupta and Swarup, 1972 observed that when larvae were surface sterilized with 0.1 per cent mercuric chloride and inoculated alone, the only symptoms noticed were ear-cockles without the yellow ear-rot. Barker et al (1972) showed that the greatest inhibition of nodules development occurred when the bacterium Rhizobium Japanicum and Race I of Heterodera glycine were inoculated simultaneously. A fourteen-day delay in introducing H. glycine Chinohe, 1952 resulted in only slight to moderate inhibition of nodulation.

Symptoms of bacterial wilt caused by Pseudomonas solanacearum in tobacco was also increased by the root knot nematode Meloidogyne incognita acrita (Lucas et al, 1955). Thus to obtain maximum benefit from wilt resistant varieties, it was suggested that the root knot nematode should be controlled. In the spiket-light disease of wheat, the nematode Anguina tritici merely acts as a vector for the bacterial spores that adhere to the body surface of the nematode. The most striking interaction was observed in strawberry in which each organism produces its own symptom separately, but together they produce a third symptom. First, a mechanical injury is caused by bacterial infection. Foliage disorder in strawberry involving Aphelenchoides ritzemabos Schwatz, 1911; Steiner, 1933, and the coryne bacterium Fascians provide a good example of nematode bacterial complex.

The disease fails to appear if the nematode and bacteria are inoculated separtely into the plant (Crosse and Pitcher, 1952).

2.7 Nematode problems of Citrus

Plant parasitic nematodes of citrus plants escaped notice for a long time because they do not directly feed on the citrus fruit but on the roots of the trees. In this way, they interfere with the ability of these trees to produce fruits. Other factors masking nematode activity on citrus include nutritional disorders, diseases caused by viruses, fungi, insect pests, and other physical problems relating to soil flooding and drought. Neal (1889) reported for the first time in Florida, U.S.A., the association of the nematode Heterodera radicola with citrus roots. Tylenchulus semipenetrans Cobb, 1913 was discovered associated with citrus in California and Florida. Thomas (1913) working in the same region tried to find ways of preventing the spread of this nematode to new locations, though its importance to citrus agriculture was not immediately appreciated.

The number of species of plant nematodes of citrus has since been increasing steadily. Until 1900, there was only one report of root knot nematode on citrus. Between 1900 and 1949, 8 more citrus nematode species had been identified (Ducharme, 1969) and by the decade ending 1959, about 28 species had been identified. In 1960 about 152 more species were reported. By 1969 about 189 species with 39 genera of citrus nematodes had been reported in many parts of the world. Of these, 8 genera and 11 species have been proved to be parasites; 6 genera and 6 species pathogenic, while 2 genera and 2 species have been shown to be important

economically. The pathogenic species include Tylenchulus semipenetrans (Cobb, 1914; Radophelus similis Suit and Ducharme, 1953; Belonolaimus gracilis and Trichodorus Christei Standifer et al, 1960; Pratylenchus brachyurus Brooks and Perry, 1967; Hemicycliophora arenaria Van Gundy and Rackham, 1961). The genera and species of economic importance include T. semipenetrans (Baines et al, 1959) and R. Similis (Suit and Ducharme, 1953).

The tendency of nematologists to find more species of nematodes among citrus roots has been indicated by the increasing numbers of papers concerning these nematodes that have appeared. Before 1900 only one paper of importance containing information about a plant nematode of citrus was published (Neal, 1889), but since 1950 the rate of publication has increased and more than 150 papers are now published per decade. Most papers published deal with T. semipenetrans and R. similis. It is hoped that more intensive studies will be made and papers published to further describe both the identified and other unidentified species.

2.7.1 Disease recognition and Crop losses

Measuring citrus losses due to nematode disease is dependent on the recognition of the fact that their effects are generally masked by other disorders or problems, like diseases by viruses, or even the physical nature of the soil as earlier noted. However, the nature of the root damage has been studied and described for T. semipenetrans (Schneider and Baines, 1964), R. similis, (Ducharme, 1959) and H. areneria (Van Gundy and Rackham, 1961). The extent of loss in fruit production due to R. similis

has been estimated to be between 40 to 60 per cent for sweet oranges; 60 - 80 per cent for grape fruit (Suit and Ducharme, 1953). Losses incurred from damage by T. semipenetrans are just as serious as those incurred by R. similis, except that this is not as great on the individual tree as in the former case. However, T. semipenetrans has been proved to have a worldwide distribution and is the most important nematode pathogen of citrus, causing losses of great magnitude. Specific decrease in fruit production attributable to any one or more of all the nematodes associated with citrus is however difficult to recognise or measure.

2.8 Nematode Problems of Bananas

The burrowing nematode, Radopholus similis was first observed in 1893 in diseased banana plants on the island of Figi (Roman, 1986). An attempt to solve wilt problems led to the replacement of the Fusarium wilt-susceptible Gros Michel banana with the wilt resistant Cavendish cultivars between 1950 to 1970. The latter was found to be more susceptible to R. similis. Bananas infested by this nematode are often characterized by leaf chlorosis, dwarfing, thin pseudostem, small bunches and premature lodging of the plants. Dark red lesions are also known to appear on the cortical or outer part of the root as a result of infection by the nematode. Panama disease, caused by the fungus Fusarium oxysporum f. sp. cubensis, is often aggravated by the simultaneous presence of the burrowing nematode. In fact the fungi are unable to invade healthy tissue unless there are wounds caused by nematodes, other organisms, or other wounds caused by

machines. The incidence of panama disease may be enhanced by a factor of about 2 when the two pathogens coexist. The susceptibility of bananas to infection by the burrowing nematode appears to vary with different regions in which they are produced. For example, in Central America, bananas are known to be capable of withstanding relatively high population densities of the nematode of up to 10,000 nematodes/100gram; of roots, and still crop reasonably well. In Ivory Coast in Africa, however, for population densities just above 1,000 nematodes/100 grammes of roots, the plants show disease symptoms (Roman, 1986).

Worldwide estimates of banana crop losses due to infestation by the burrowing nematodes are difficult to obtain. However, yield losses of as much as 12.5 - 18 tons/hectare have been reported (Roman, 1986). Reductions of 50% in fruit yields and increases of up to 60% in premature ripening within a period of 3 to 4 years after planting have also been recorded in Mexico. Yields in non-treated banana plots were reduced by about 25metric tons/hectare in Puerto Rico (Roman, 1986).

Lesion nematodes, particularly, Pratylenchus coffeae brasiliensis Lordello, 1956, have also been known to attack bananas. The symptoms caused by P. coffeae are very similar to those of the burrowing nematode. However, the expression of symptoms in bananas is less definitive than in plantains, and bananas are usually not considered as host for this nematode. Estimated losses on bananas as a result of infestation by P. coffeae are also difficult to obtain, since the nematode is usually detected with other nematodes, such as the burrowing nematode.

The most prominent root-knot nematode species that attack bananas are Meloidogyne incognita, M. arenaria and M. javanica. Cobb (1893) reported one of the first associations of a root-knot species with bananas. In Egypt, stunted banana plants with small leaves were found to be associated with the root-knot nematode. In Puerto Rico, bananas in greenhouse experiments were found to be infested with M. incognita, and were stunted, chlorotic and the roots heavily galled (Roman, 1986). Generally, bananas grown in the field are not known to show these symptoms, but galls may be formed on the roots of plants grown in fields which had previously been cultivated with sugar cane. Losses on bananas due to root-knot nematodes have not yet been reported. In fact bananas with heavily galled roots have been known to give maximum yields (Roman, 1986).

Spiral nematodes, particularly Helicotylenchus multicintus (Cobb, 1893) Goodey, 1940, Golden 1956, have been shown to be associated with bananas since the last century (Cobb, 1893). The nematode H. multicintus is known to cause superficial lesions on the root surface. The most reliable data on banana losses due to the infestation of spiral nematodes, have been obtained in the Jordan valley in Israel, where the spiral nematodes occur in the absence of R. similis and P. coffeae. Losses as high as 5.9 kg/bunch of bananas have been reported in nematicide trials in the area (Roman, 1986).

The first record of the attack of the reniform nematode, Rotylenchulus reniformis Linford and Oliveira, 1940, on bananas was by Ayala and Roman in 1963 in the Carribbean (Roman, 1986). The reniform nematodes are known to feed on the secondary and

tertiary roots of bananas. Necrotic lesions are also produced in the area of the roots around the female head. R. reniformis is not thought to be a major factor in yield reduction in banana fields.

2.9 Nematodes associated with fruit trees in Northern Nigeria

Studies on plant parasitic nematodes associated with various fruit trees grown in the northern part of Nigeria are not yet adequately extensive. For example, data on annual losses due to attack on fruit trees by nematodes in northern Nigeria do not appear to be available. However, a few studies on nematodes associated with various fruit trees have been reported. Wilson (1962) reported the infestation of pineapples, pawpaw, strawberry and banana by Meloidogyne incognita and M. javanica in Northern Nigeria. However, Caveness (1967) working in the same region observed a number of ectoparastitic nematodes from the rhizosphere of various fruit trees, but did not report any incidence of the root-knot nematode, Meloidogyne spp. Bridge (1972) working on plant nematodes of irrigated crops in northern States of Nigeria observed the association of Helicotylenchus spp, Meloidogyne spp; Scutellonema spp., Trichodorus spp and Tylenchorynchus spp. with rough lemon; Helicotylenchus spp; Hemicriconemoides spp; Meloidogyne sp and Scutellonema spp., on strawberry; Meloidogyne sp. and Helicotylenchus sp. on passion fruit. Khan (1984) working on root-knot infection of some fruit trees on certain Zaria sites also observed the presence of Meloidogyne javanica (Trueb, 1885) Cobb, 1890 and M. incognita (Kofoid and White, 1919) Chitwood, 1949. Bos (1978) and Yisa

(1985) found similar nematode species associated with some fruit trees on some sites in Zaria. Emechebe (1980) reported the association of various plant parasitic nematodes with roots of pawpaw, citrus spp, banana and plantain in the savanna and semi-arid zones of Nigeria, but did not observe any nematode infestation of guava and mango trees. Babatola (1981), on the other hand, reported severe infestation of coconut, mango, banana, plantain, oranges, pineapple and guava in Kano, Nigeria.

It is obvious from the above that information on the nematode fauna associated with fruit trees in Northern Nigeria (and possibly Nigeria) is still inadequate. Sometimes, different results have been obtained from experiments carried out within the same region, by different workers. Most of the reported studies did not present details of the measurements used in identifying the nematodes. The present study has been undertaken in an effort to increase the available information on the nematode fauna in a section of Samaru-Zaria, Nigeria.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Area of Survey

The survey was restricted to certain fruit trees in some residential areas of the main campus of Ahmadu Bello University, in Samaru, Zaria. The areas sampled were Areas A, BZ, E and F, as well as the College of Agriculture, Samaru. Sampled areas are indicated in figure 2. Samples were taken from private gardens in the residential areas and from the orchard in the Samaru College of Agriculture.

3.2 Collection of Samples

Soil and root samples were collected around roots of various fruit trees with the aid of a hand trowel. The fruit trees from which samples were taken include: Psidium guajava L, Musa cavendish, Citrus sinensis/citrus limon, Carica papaya, Citrus limon, Citrus paradisi/Citrus limon and Citrus reticulata. About one hundred samples were collected.

At each sample site, soil and root samples were taken from a depth of about 25 - 30cm at three different points, about 1 - 2m away from the base of the tree. The three samples were then thoroughly mixed and sealed up in a polyethylene bag (to keep them moist). The samples were then stored in a refrigerator at about $5^{o}C$ until processed. Care was taken to ensure that the soil samples were properly labelled, indicating site of collection and the name of plant or fruit tree around which the sample was obtained. Most collections were done during the dry

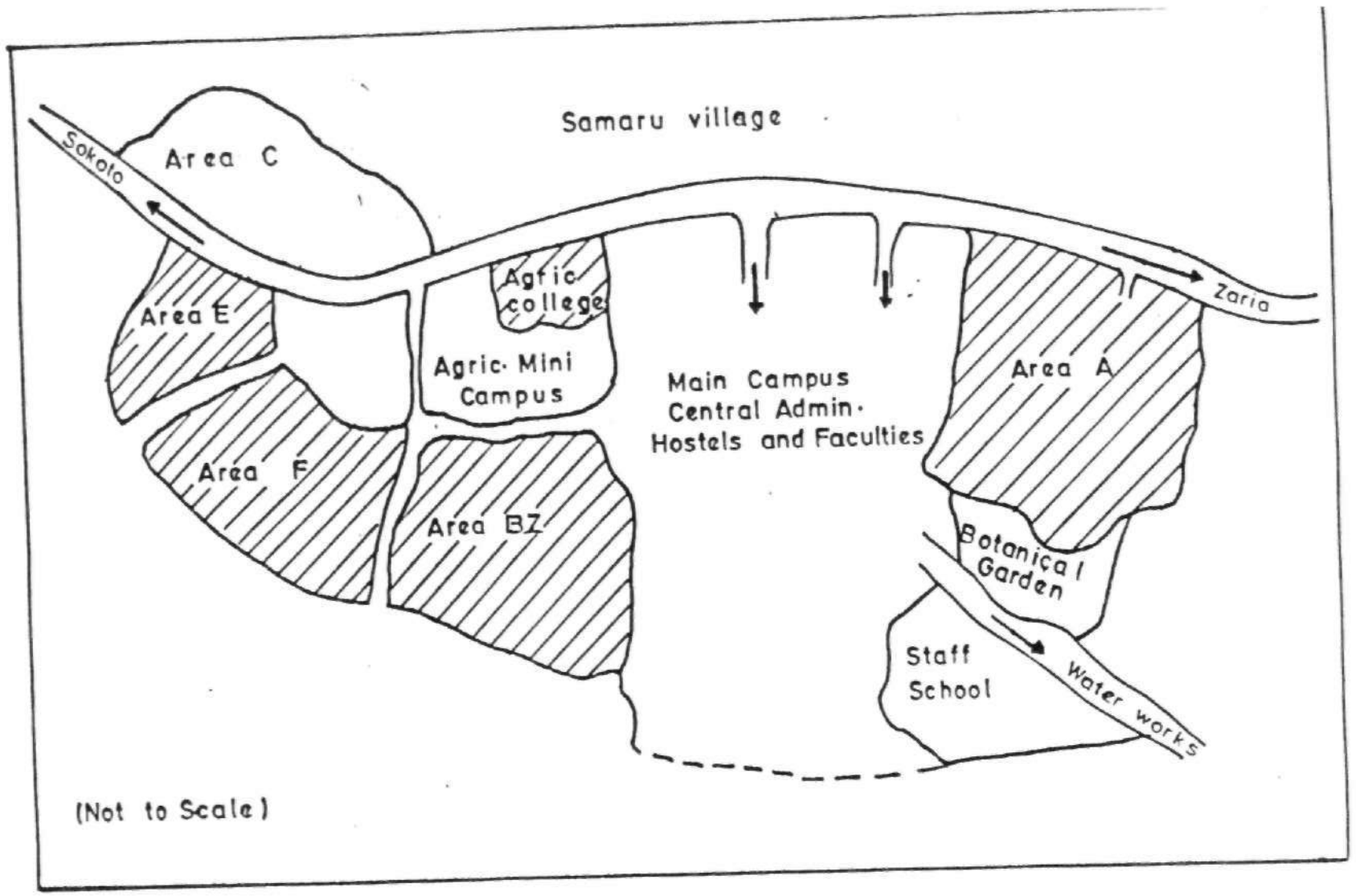


Figure 2: A MAP SHOWING AREAS (▨) SAMPLED
(Adapted from Ahmadu Bello University master plan, Samaru campus, 1980 - 1985).

season between the months of January and March. Each sample was processed soon after collection.

3.3 Processing of Samples for nematodes

Processing of the samples consists of separating the nematodes from the soil or plant material in order to identify or count them. The samples were processed by combining Baermann funnel and Cobb's (1918) sifting and gravity method.

About one kilogramme of soil (along with small roots) was taken in each case from the polyethylene bag and put into a bucket into which plenty of water was added to loosen the soil and to separate the adhering soil from the small roots. The liquid suspension was then passed several times gently through a sieve with a mesh size of 250 microns. Nematodes along with the debris collected on the mesh of the sieve were then transferred into a beaker using a little water to rinse the sieve. The content of beaker was then transferred into a small sieve lined with tissue paper (used as nematode paper) and placed in a glass funnel.

The glass funnel containing the small sieve was clamped to a stand and a rubber tube with a clip was attached to the end of the funnel stem to prevent the nematodes from escaping. The funnel with its contents was left to stand for 24 hours. After about 24 hours, the clip was released to allow almost clear water containing the nematodes, (which by now were expected to have moved down the funnel) to be collected in a beaker. The content of the beaker was then passed through the sieve (250 microns) again, in order to remove any remaining debris. The clear

mixture was collected in a beaker.

Some of the clear mixture was poured into a petri dish and viewed under a dissecting microscope to verify that some nematodes have been collected. The collected nematodes were killed in hot water quickly, (to avoid twisting), fixed in F.A. 4:10 (i.e. formalin/acetic acid mixture in the ratio of 4:10) and stored in a specimen bottle. All the 100 samples collected for this study were processed and stored as described above.

3.4 Preparation of permanent mounts

The killed and fixed nematodes were transferred with the aid of fine needles into a little water in a cavity block. The contents of the cavity block were then warmed on a heater at 40^{o}C. A drop of lactophenol was added to clear the internal structures of the nematodes. After clearing in lactophenol, the nematodes were picked with the aid of fine needles and mounted in glycerine on clean microscope slides. Care was taken to ensure that nematodes were put into the middle of the drop of glycerine and not at the edges. Some pieces of glass wool were dropped into the glycerine to prevent air bubbles from forming and also to prevent crushing of nematodes. Coverslips were carefully placed on the mount, sealed with nail varnish, labelled and the mount stored for identification of the namatodes.

3.5 Identification

With the aid of a stereoscopic microscope and a high power compound microscope of good optical quality, the nematode's body length L, oesophageal length c or c', the distance from the anterior end to the vulva v, the length of the tail from the

posterior end, the greatest width and other relevant measurements were made. The camera lucida and a stage micrometer were used in drawing a scale and calibrating the microscope. The lengths of the structures were converted to milimetres and recorded. From the measurements and with the aid of the modified de Man's formula, an attempt was made to identify the nematodes after due comparisons with originally described species.

3.5.1 de Man's formula (de Man, 1884)

L = Total body length in mm or microns.

$$a = \frac{\text{Length of nematode}}{\text{greatest body width usually taken in vulva region.}}$$

$$b = \frac{\text{Length of nematode}}{\text{length of oesophagus from anterior end}}$$

(This is valid in species where there is no overlap between the oesophageal gland and intestinal gland).

$$c = \frac{\text{Length of nematode}}{\text{length of tail, (anus to tail tip)}}$$

$$d = \frac{\text{Length of tail}}{\text{Width at anal region}}$$

v = distance of vulva from anterior end expressed as a percentage of the total body length.

Modifications which have been made to the de Man's formula are as follows:

(i) In cases where the oesophageal gland does not overlap with the intestinal gland, then;

$$b' = \frac{\text{Body length}}{\text{length of oesophagus up to the lobe of free oesophageal glands.}}$$

$$c' = \frac{\text{length of nematode}}{\text{Width of body and anal region}}$$

(ii) O = Distance between the spear knobs and the orifice of the dorsal oesophageal gland opening, expressed as the percentage of the length of the spear.

(iii) When V^1 is expressed it indicates (V_{30}^{5-10}) showing that there are two gonads and measurements are 5 and 10 from the gonads respectively.

(iv) In the males T represents the distance from the cloaca to the tip of the testes expressed as a percentage of the total body length.

V^1 = the distance from the vulva to the posterior end.

Photographs of the various menatode specimens were also taken and compared with standard drawings from the literature.

CHAPTER FOUR

RESULTS

4.1 Introduction

The soil samples collected and processed were found to contain 17 genera of soil and plant parasitic nematodes from the various locations.

Of the 17 genera of nematodes found, only Ditylenchus spp. Filipjev, 1934, Longidorus spp. (Micoletzky, 1922) Thorne and Swanger, 1936, Scutellonema spp. Andrassy, 1958, Hoplolaimus spp. Daday, 1905, Tylenchorynchus spp. Cobb, 1913a, Helicotylenchus spp Steiner, 1949, Telotylenchus spp. Siddiq, 1960 Tylenchus spp. Bastian, 1865, Rotylenchus spp. Filipjev., 1936, and Hemicriconemoides spp. Chitwood and Birchfield, 1957 are known parasites on plants. Other forms like Mononchus spp. Cobb, 1918, and Discolaimus spp. Cobb, 1913, are known to be parasitic on other plant and soil nematodes, while saprophagous forms found include Dorylaimus Thorne, 1939, Diplogasteroidea spp. de Man, 1912, Dorylaimellus spp. Cobb, 1913 and Acrobeles spp. Von Linstow, 1871 and alga feeders Eudorylaimus spp. Andrassy, 1959.

Most nematodes obtained were juveniles (larvae). Thus complete measurements for total identification could not be taken as developments of some structures like reproductive structures were incomplete. 'n', the total number of nematodes measured for each species was expectedly low and in some cases only mature females or males were found. In most cases mature males were not found.

TABLE I

Occurrence of various nematode genera in the rhizophere of certain fruit trees in Area A locality

Nematode genera	Plant Species and approximate nematode population round them					
	Psidium quajava L	Citrus sinensis L. Osb/Citrus Limon L.Burma	Citrus paradisi macf/Citrus Limon L. Burma	Citrus recticulata	Carica papaya	Musa spp
Ditylencus spp.	+	+	+	+	+	+
Tylenchus spp.	-	-	-	-	-	-
Scutellonoma spp.	-	-	-	-	+	+
Longidorus spp.	+	+	+	+	+	+
Tylenchorynchus spp.	-	-	-	-	-	-
Telotylenchus spp.	-	-	-	-	-	-
Hoplolaimus spp.	-	-	-	-	-	-
Rotylenchus spp.	-	-	-	-	-	-
Helicotylenchus spp.	+++	+++	+++	+++	+++	+++
Hemicriconemoides spp.	-	-	+	-	-	-
Diplogasteroides spp.	++	++	-	-	-	-
Acrobeles spp.	+	+	-	-	-	-
Dorylaimus spp.	-	-	-	-	-	-
Eudorylaimus spp.	++	++	++	-	++	++
Discolaimus spp.	-	++	-	-	-	-
Dorylaimellus spp.	++	-	++	++	++	-
Mononchus spp.	+++	+++	+++	+++	+++	+++

Keys:-

+++ = Nematode population of about 1,000 and above per kg of soil.

++ = Nematode population of about 500 - 800 per kg of soil.

+ = Nematode population of about 100 - 500 per kg of soil.

- = Nematode not found.

TABLE II

Occurrence of various nematode genera in the rhizophere of certain fruit trees in Area BZ locality

Nematode genera	Plant Species and approximate nematode population round them					
	Psidium guajava L	Citrus sinensis L. Osb/Citrus Limon L. Burma	Citrus paradisi macf/Citrus Limon L. Burma	Citrus recticulata	Carica papaya	Musa spp
Pitylencus spp.	-	-	-	-	-	-
Tylenchus spp.	-	-	-	-	-	-
Brutellonema spp.	-	-	-	-	-	-
Longidorus spp.	+	+	+	+	+	+
Tylenchorynchus spp.	-	-	-	-	-	-
Telotylenchus spp.	-	-	-	-	-	-
Hoplolaimus spp.	-	-	-	-	-	-
Rotylenchus spp.	-	-	-	-	-	-
Helicotylenchus spp.	+++	+++	+++	+++	+++	+++
Hemiriconemoides spp.	-	-	-	-	-	-
Diplogasteroides spp.	-	-	-	-	-	-
Aurebeles spp.	-	-	-	-	-	-
Dorylaimus spp.	-	-	-	-	-	-
Eudorylaimus spp.	++	++	++	-	++	++
Discolaimus spp.	-	++	++	-	++	-
Dorylaimellus spp.	++	-	++	++	++	-
Mononchus spp.	+++	++	+++	+++	++	+++

TABLE III

occurrence of various nematode genera in the rhizophere of certain fruit trees in Area E locality

Nematode genera	Plant Species and approximate nematode population round them					
	Psidium guajava L	Citrus sinensis L. Osb/Citrus Limon L. Burma	Citrus paradisi macf/Citrus Limon L. Burma	Citrus recticulata	Carica papaya	Musa spp
Ditylenchus spp.	-	-	-	-	-	+
Tylenchus spp.	-	-	-	-	-	-
Scutellonema spp.	-	-	-	-	-	-
Longidorus spp.	+	+	+	+	+	+
Tylenchorynchus spp.	-	-	-	-	-	-
Telotylenchus spp.	-	-	-	-	-	-
Hoplolaimus spp.	-	-	-	-	-	-
Rotylenchus spp.	++	-	-	-	++	-
Helicotylenchus spp.	+++	+++	+++	+++	+++	+++
Hemicriconemoides spp.	-	-	-	-	-	-
Diplogasteroides spp.	-	-	-	-	-	-
Acrobeles spp.	-	-	-	-	-	-
Dorylaimus spp.	-	++	-	-	++	-
Eudorylaimus spp.	++	++	++	++	++	++
Discolaimus spp.	-	++	-	-	-	-
Dorylaimellus spp.	++	-	++	++	++	-
Mononchus spp.	+++	+++	+++	+++	+++	+++

TABLE IV

occurrence of various nematode genera in the rhizophere of certain fruit trees in Area F locality

Nematode genera	Plant Species and approximate nematode population round them					
	Peidium guajava L	Citrus sinensis L. Osb/Citrus Limon L. Burma	Citrus paradisi macf/Citrus Limon L. Burma	Citrus recticulata	Carica papaya	Musa spp
Ditylencus spp.	-	-	-	-	-	-
Tylenchus spp.	-	-	-	-	-	-
Scutellonema spp.	-	-	-	-	-	-
Longidorus spp.	+	+	+	+	+	+
Tylenchorynchus spp.	-	-	-	-	-	-
Telotylenchus spp.	-	-	-	-	-	-
Hoplolaimus spp.	-	-	-	-	-	-
Rotylenchus spp.	-	-	-	-	-	-
Helicotylenchus spp.	+++	+++	+++	+++	+++	+++
Hemicriconemoides spp.	-	-	-	-	-	-
Diplogasteroides spp.	-	-	-	-	-	-
Acrobeles spp.	-	-	-	-	-	-
Dorylaimus spp.	-	-	-	-	-	-
Eudorylaimus spp.	++	+	++	-	++	++
Discolaimus spp.	-	-	-	-	-	-
Dorylaimellus spp.	++	-	++	++	++	-
Mononchus spp.	+++	+++	+++	+++	+++	+++

TABLE V

Occurrence of various nematode genera in the rhizosphere of certain fruit trees in Samaru College of Agriculture

Nematode genera	Plant Species and approximate nematode population round them					
	Psidium guajava L.	Citrus sinensis L. Osb/Citrus Limon L. Burma	Citrus paradisi macf/Citrus Limon L. Burma	Citrus recticulata	Carica papaya	Musa spp
Ditylenchus spp.	-	-	-	-	-	-
Tylenchus spp.	-	-	-	-	-	-
Criconema spp.	-	-	-	-	-	-
Longidorus spp.	-	-	-	-	-	-
Tylenchorynchus spp.	++	++	-	-	-	-
Telotylenchus spp.	-	-	-	-	-	-
Monhystera spp.	-	-	-	-	-	-
Rotylenchus spp.	-	-	-	-	-	-
Helicotylenchus spp.	+++	+++	+++	+++	+++	+++
Hemicriconemoides spp.	-	-	-	-	-	-
Dolichodorus spp.	++	++	-	-	-	-
Aphelenchus spp.	-	-	-	-	-	-
Tylenchus spp.	-	-	-	-	-	-
Filenchus spp.	++	++	++	-	++	++
Discolaimus spp.	-	-	-	-	-	-
Tylenchulus spp.	-	-	-	-	-	-
Meloidogyne spp.	+++	+++	+++	+++	+++	+++

4.2 Hoplolaimus spp. Daday, 1905

Description:

Lip region caplike, offset, divided into minute blocks by longitudinal and lateral striations, phasmids large and scutellum like, stylet with well developed forward pointing knobs. When relaxed with gentle heat individuals assume a straight or slightly arcuate position.

Measurements

Females ♀ n = 2

L = 1.65 - 1.68 a = 31.13 -33.60

b = 4.0 - 7.25 c = 42 - 65.4 V = 55 - 58

Probably Hoplolaimus pararobustus (after Sher, 1961).

Systematic positon: Tylenchida Tylenchoidea: Hoplolaimida: Hoplolaiminae: Hoplolaimus

Habitat: The nematode was found only around roots of Carica papaya in Area E of the Main campus, Ahmadu Bello University residential area.

4.3 Tylenchoryhnchus spp. Cobb, 1913

Description:

The stunt nematodes have non-overlapping oesophagus and conical tail, as well as a stylet with distinct basal knobs. When relaxed, they assume a wide C-shape. Head slightly offset, skeleton fairly well developed. Phasmids conspicuous and found about the middle of the tail. Median vulva with 2 ovaries opposed and outstretched. The females have tail slightly tapering, terminus bluntly rounded not acute.

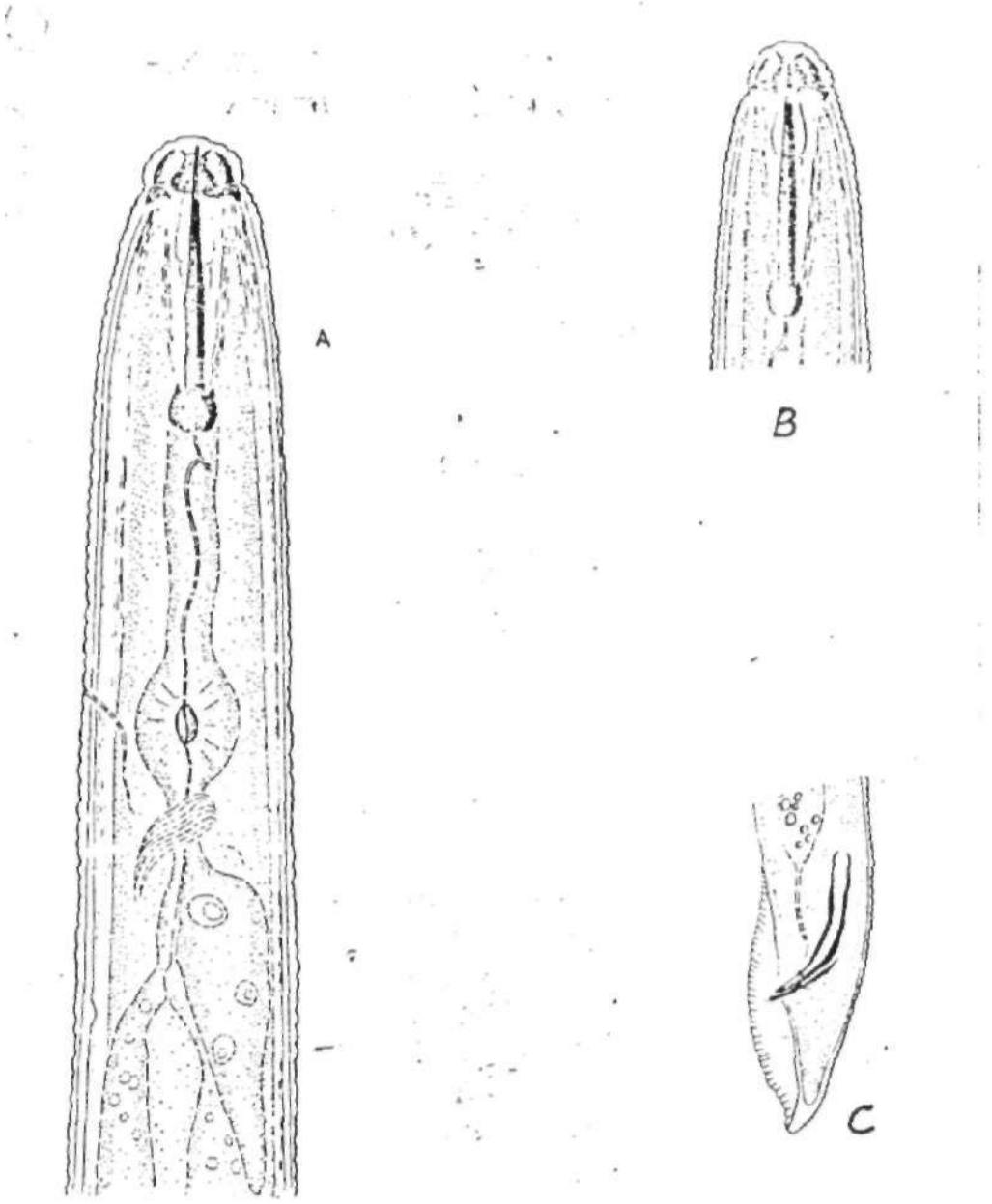


FIGURE 3: HOPLOLAIMUS SPP. (DADAY, 1905) (A) ANTERIOR PART OF FEMALE (B) HEAD OF MALE (C) MALE TAIL (AFTER HEYNS, 1971).

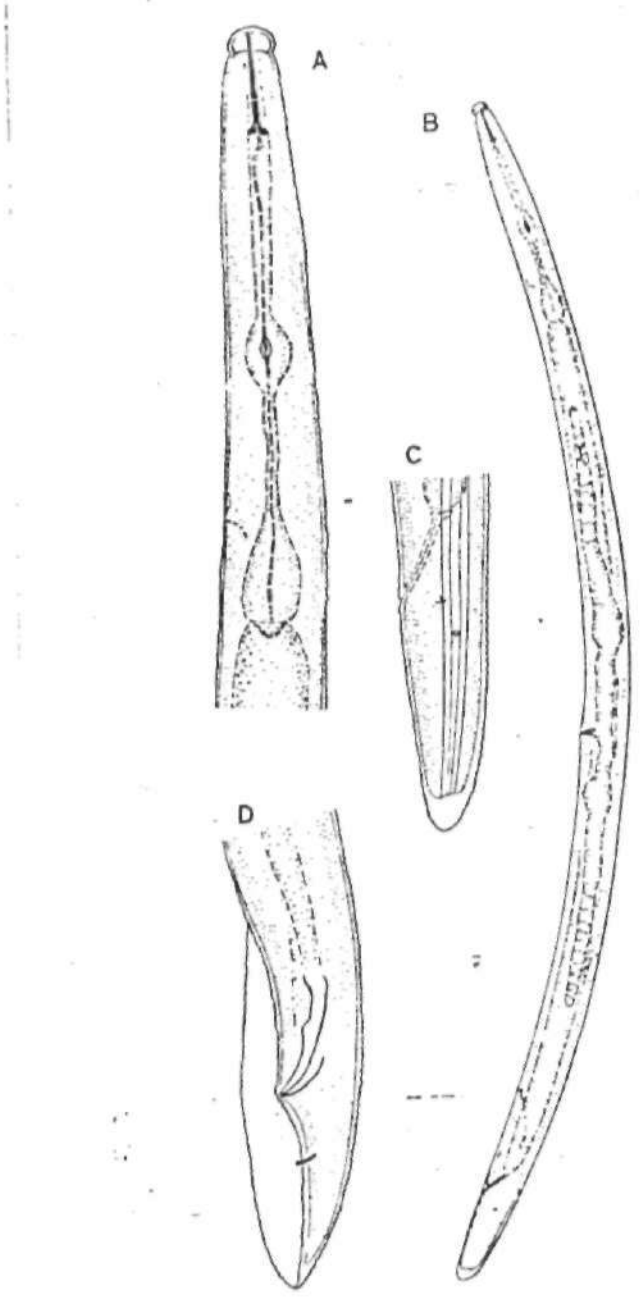


FIGURE 4: TYLENCHORHYNCHUS SPP. (COBB, 1913). (A) ANTERIOR PART (B) FEMALE (C) FEMALE TAIL (D) MALE TAIL (AFTER COBB, 1913).

Measurements

3 ♀ L = 1.16 - 1.31mm, a = 32 - 46.

b = 6 - 7, c = 33 - 46, v = 27 - 56.5

Probably Tylenchoryhnchus maximus Allen, 1955 (After Goodey, 1963).

Habitat: Found only in association with guajava in College of Agriculture, Samaru, Zaria.

Systematic position: Tylenchida; Tylenchoidea, Dolichoridae, Tylenchorhynchinae; Tylenchorhynchus Cobb, 1913.

4.4 Helicotylenchus spp. Steiner, 1949

Lip region not offset from the rest of the body and no longitudinal striation present. Position of orifice of dorsal oesophageal gland about one-quarter spear length from spear base. Oesophageal gland overlaps the intestine mostly ventrally but dorsally and laterally also. Lateral fields have four incisures.

Two amphidelphic functional ovaries. Female tail usually more curved dorsally; terminus hemispherical to elongated ventrally. Phasmids near anus. When relaxed with gentle heat nematode assumed spiral form (Sher, 1961).

Measurements

2 ♀ L = 0.69 - 0.96mm, a = 35 -48, b = 3.3 - 5.3,

c = 35 - 48, v = 56.5 - 57.2

1 ♂ L = 0.60mm, a = 30, b = 7.5, c = 20

Probably Helicotylenchus erythorinae Zimmermann, 1904.

Habitat: Found in abundance around all fruit trees from which samples were taken.

Systematic position: Tylenchida; Hoplolaimidae;

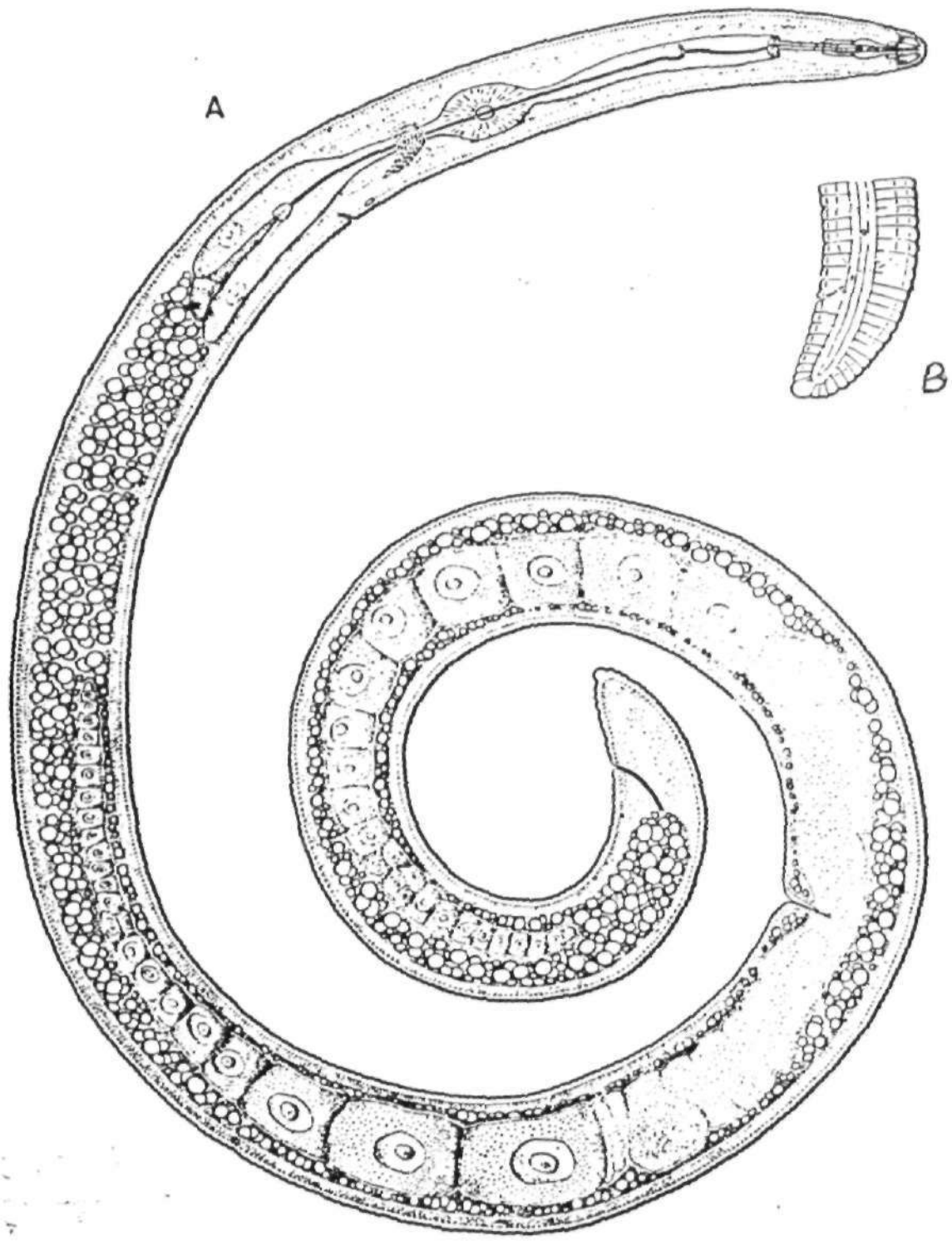


FIGURE 5: HELICOTYLENCHUS SPP. (STEINER, 1949). (A) FEMALE (B) FEMALE SURFACE VIEW OF POSTERIOR END. (AFTER SHER, 1961 COURTESY OF NEMATOLOGICA).

Hoplolaiminae; Helicotylenchus spp Steiner, 1945.

4.5 Hemicriconemoides spp. Chitwood and Birchfield, 1957

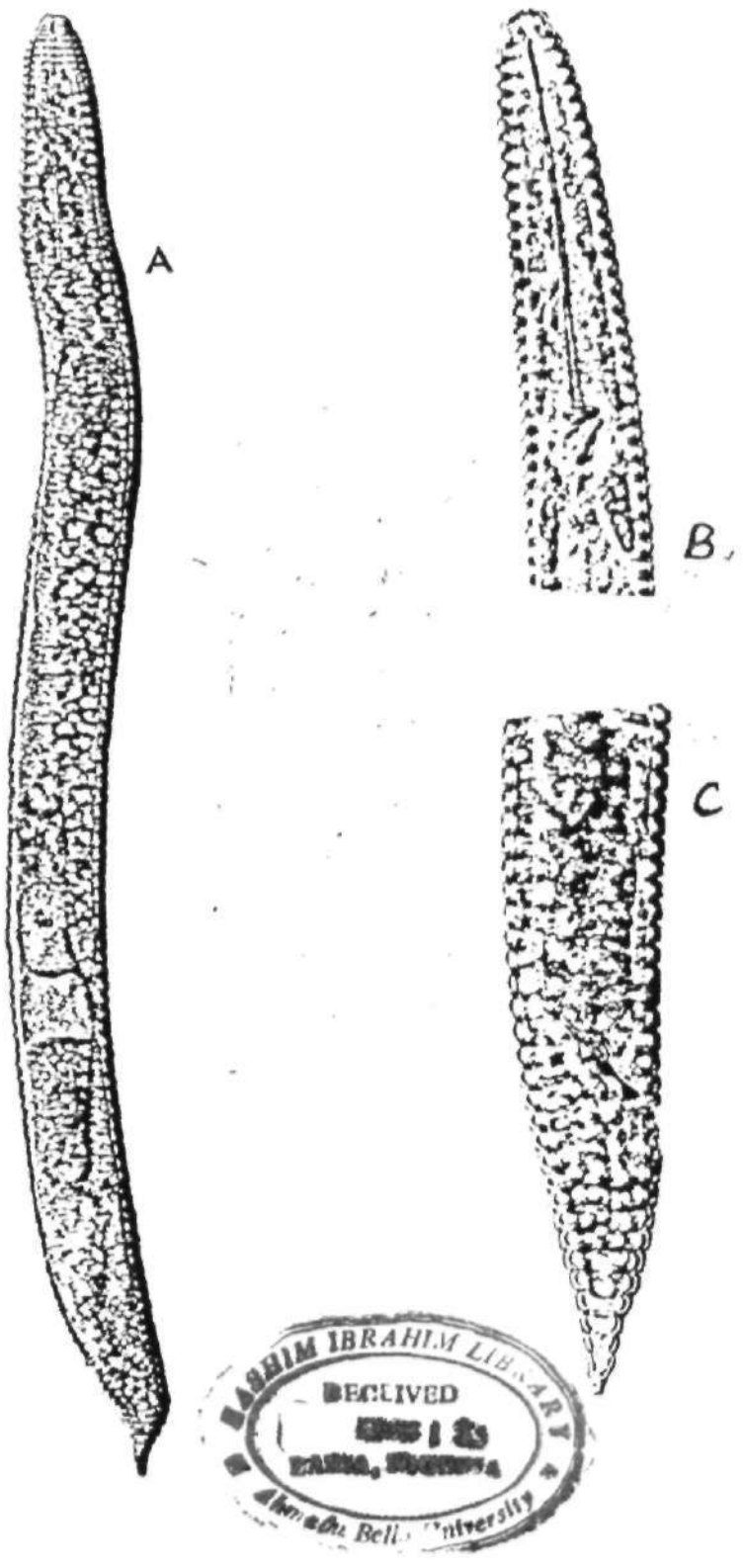
Description

Criconematinae; Body plump enclosed with two cuticles; spear knobs anchor-shaped with prominent forward-directed processes, not rounded but not sloping backward. Female body elongate-cylindrical enclosed in a cuticular sheath which is attached to the body at the head, vulva, and sometimes at the tail. Annules of sheath and body similar, coarse, smoothly rounded, not retrose, less than 150 in number. Head is flat and not offset with 2 annules, variable in shape. Vulva with lateral cuticular membranes. Ovary prodelphic outstretched, a spermatheca present.

Males with lateral fields with 4 incisures. Spicules elongate slender, slightly ventrally arcuate. Gubernaculum simple, trough-like. Bursa when present narrow with crenate margins almost enveloping the tail (Siddiqi and Goodey, 1963 and Dasgupta, Raski and Van Gundy, 1969).

Systematic Position: Tylenchida; Criconematidea; Criconematinae; Hemicronemoides Chitwood and Birchfield, 1957.

Habitat: Found only in association with Citrus paradisi macf./Citrus limon L. Burma at only one sample site (Area A).



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FIGURE 6: HEMICRICONEMOIDES SPP. (CHITWOOD AND BIRCHFIELD, 1957) (A) MATURE FEMALE (B) ANTERIOR PORTION OF FEMALE (C) POSTERIOR PORTION OF FEMALE OR TAIL (AFTER MAI AND LYON, 1975)

4.6 Acrobeles spp. Von Linstow, 1877.

Description:

Acrobelinae. Labial probolae deeply furcate and elaborately fringed. Cephalic probolae thin forwardly pointing, acute, fringed. Tails of both sexes acute. Lateral fields with crenate edges and no other incisures. Cuticle with rather coarse transverse striations. Head slightly offset by constriction and rather wider than body immediately behind. Amphid opening oval and fairly conspicuous at base of lateral cephalic probolae. Anterior part of oesophagus practically cylindrical, tapering slightly to short isthmus. *Nerve ring crossing isthmus.*

Female tail at first conical then narrowing to a fingerlike process. Vulva small and pore-like with rounded thickening *(Goodey, 1963).*

Measurements:

2 ♀ L = 1.08 - 1.40mm, a = 21.6 - 46.7,

b = 3.7 - 5.6, c = 2.7 - 9.5 v = 44.3 - 59

Probably Acrobeles maximus von Linstow, 1877 (after Goodey, 1963).

Systematic Position: Rhabditida; Rhabditoidea; Cephalobidae; Acrobeles Von Linstow, 1877.

Habitat: Found around Citrus sinensis/Citrus limon at only one sample site (Area A).

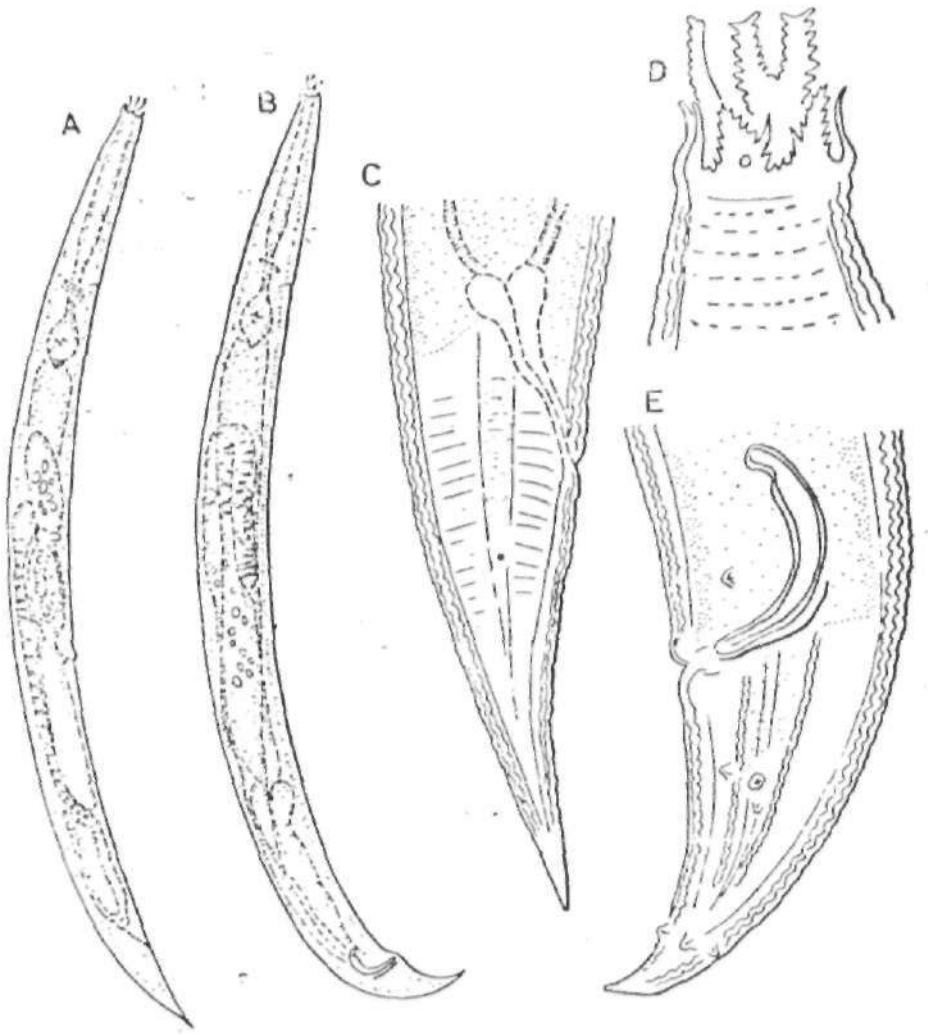


FIGURE 7: ACROBELES SPP. (STEINER, 1929) (A) FEMALE (B) MALE (C) FEMALE TAIL (D) HEAD (E) MALE TAIL. (AFTER HEYNS, 1971)

4.7 Rotylenchus spp.Filipjev 1936.

Description:

Lip region with or without annulation or striation. Oesophageal glands overlap intestine primarily dorsally and laterally. Phasmid small in posterior part of the body. Female terminus hemispherical, slightly more convex dorsally, sometimes with small rounded ventral projection.

Measurements

5 ♀ L = 1.5 - 1.8mm, a = 29 - 32,

b = 6.9 - 7.2, c = 90 - 125, v = 55 - 60%

Probably Rotylenchus uniformis (after Goodey, 1963).

Systematic Position: Tylenchida; Tylenchoidea; Hoplolaimidae; Hoplaiminae Rotylenchus Filipjev, 1936.

Habitat: Found around roots of guava (Psidium guajava) and pawpaw (Carica papaya).

4.8 Tylenchus: spp.Bastian, 1865.

Description:

Tylenchinae. Tails elongate-conoid to filiform. Lip region straited. Vulva well behind middle of body. Anterior ovary outstretched. Posterior uterine branch short, rudimentary. Bursa short adanal. Developing Oocytes and spermatocytes largely arranged in single file. Cuticle straited, lateral fields marked by incisures. No sclerotized cephalic framework present. Spear well developed and strong basal knobs.

Measurements

3 ♀ L = 0.50 - 0.70mm, a = 18 - 25,

b = 5.5, c = 2.5 - 3.5, v = 69 - 86.

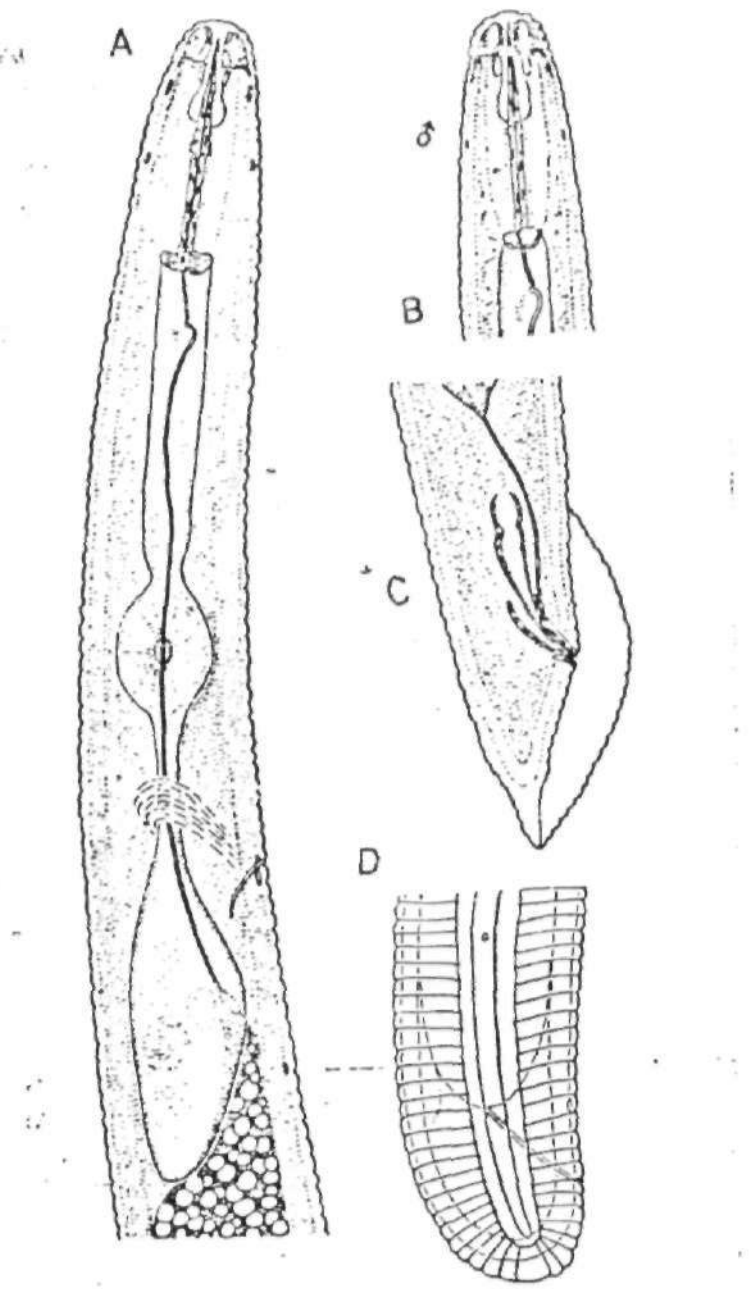


FIGURE 8: ROTYLENCHUS SPP. (FILIPJEV, 1936). (A) ANTERIOR PART OF FEMALE (B) HEAD OF MALE (C) TAIL OF MALE (D) TAIL OF FEMALE. (AFTER SHER, 1965).

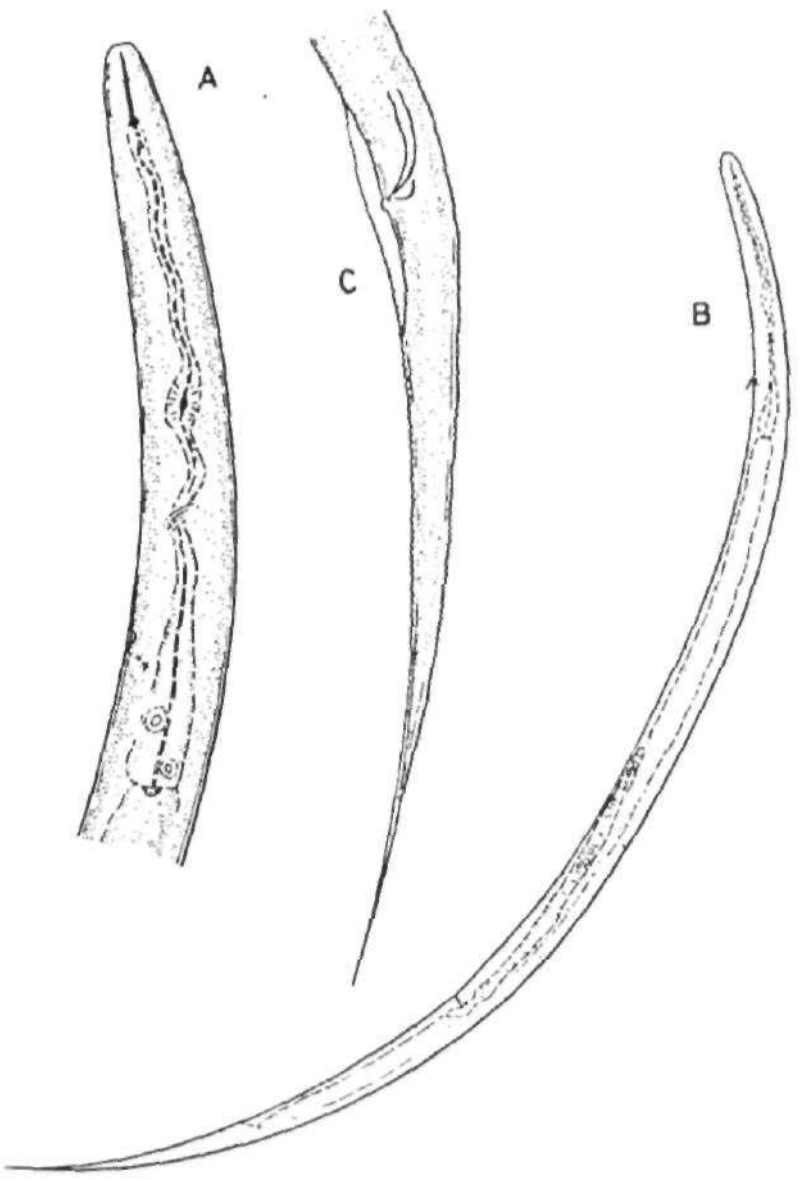


FIGURE 9: TYLENCHUS SPP. (BASTIAN, 1865). (A) ANTERIOR PART (B) FEMALE (C) MALE TAIL (AFTER HEYNS, 1971).

probably Tylenchus filiformes Butschli, 1873,(After Goodey, 1963).

Systematic Position: Tylenchida; Tylenchidae; Tylenchoinea, Tylenchidae, Tylenchinae; Tylenchus Bastian, 1865.

Habitat: Found around banana roots at one locality (Area E).

4.9 Dorylaimus spp. Dujardin, 1845

Description:

They are large species, over 1mm and up to 7mm long; cuticle thick with clear lateral pores. Head narrower than body. Not, or only slightly offset; Lips moderately developed bearing an inner circlet of six papillae and an outer of 10. Spear well developed; 'guiding ring' appearing double, the fixed anterior ring placed more than a head width from the anterior end of body. Ovary paired reflexed more than half way to vulva. Tail convex-conoid to subdigitate terminus. Tail more convex on dorsal side (Goodey, 1963).

Measurements

2 ♀ L = 1.1 - 1.2 a = 2.16 - 3; b = 0.3 - 0.35,

c = 2.7 - 3 v = 0.54 - 0.6

Probably Dorylaimus monohystea de Man, 1880 (after Goodey, 1963).

Habitat: Found around guava (Psidium guajava), Citrus sinensis/Citrus limon and Carica papaya at almost all sample areas except College of Agriculture, Samaru.

Systematic Position: Dorylamida; Dorylaimina; Dorylaimidae; Dorylaiminae spp.

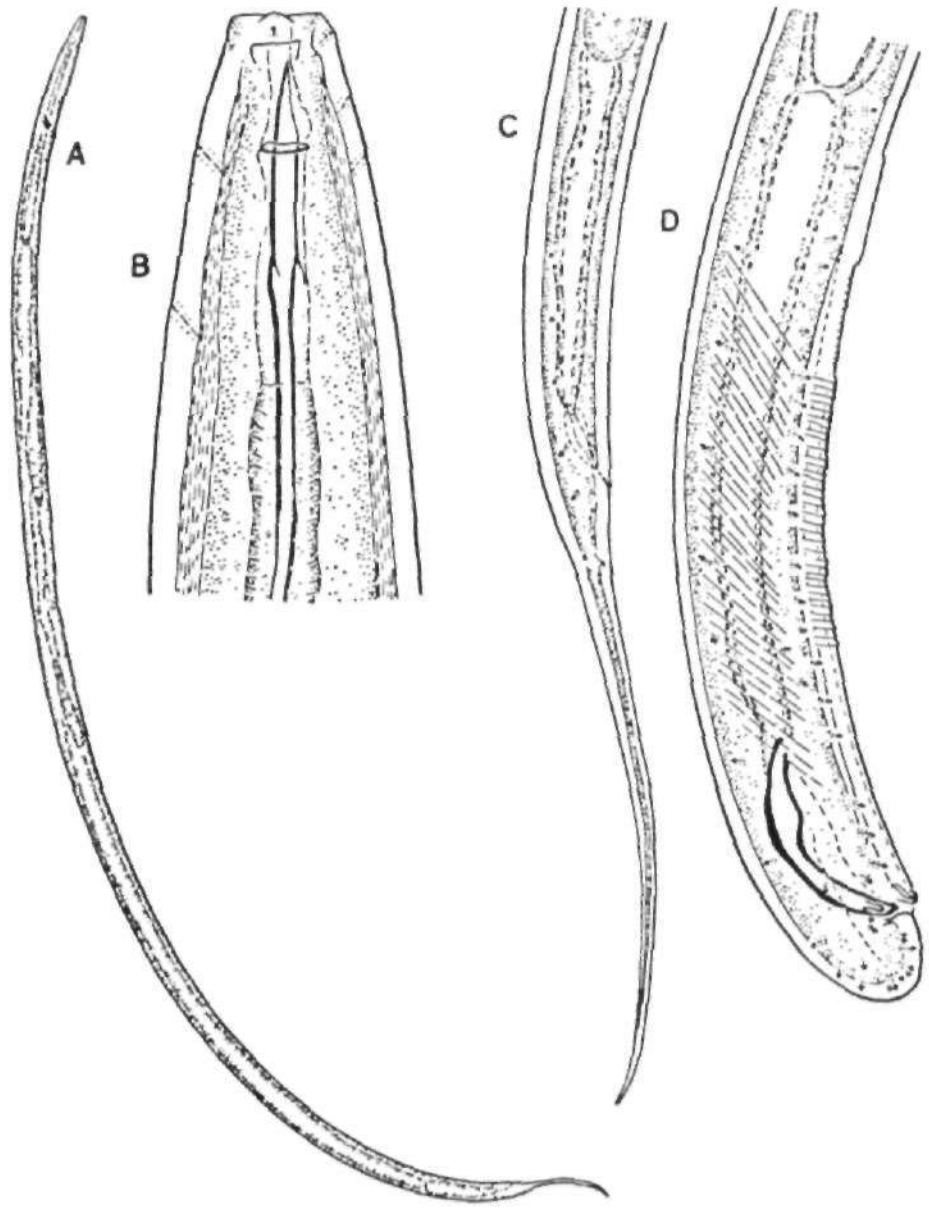


FIGURE 10: DORYLAIMUS SPP. (DUJARDIN, 1845). (A) FEMALE (B) HEAD (C) FEMALE TAIL (D) MALE TAIL (AFTER HEYNS 1971).

4.10 Eudorylaimus spp.Andrassy, 1959

Description:

Characterized by similar tails in both males and females, short conical and broadly rounded. Cuticle smooth. Head wider than body immediately behind it. Spear well developed with guiding ring appearing single. Fixed anterior ring less than one head width from the anterior end of the body. Amphids broad shield shaped with slit like apertures located close to base of lateral lips. Vulva transverse. Gonads paired, reflexed more than half way to vulva. Hind part of male without submedian papillae (Goodey, 1963).

Measurements:

1♂ L = 1.13mm, a = 28, b = 51, c = 8.0

♀ immature.

Probably Eudorylaimus carteri (Bastian, 1865) Andrassy, 1959 (After Goodey, 1963).

Systematic Position: Dorylaimida; Dorylaimina, Dorylaimoidea; Dorylaiminae; Eudorylaimus spp.

Habitat: Found around Carica papaya, Musa spp., Citrus spp and Psidium guajava. The nematode was found fairly evenly distributed at essentially all sample sites at the various locations.

4.11 Telotylenchus spp. Siddiqi 1960

Description:

Head slightly offset, skeleton fairly well developed. Phasmids conspicuous and found about the middle. Median vulva with two ovaries opposed and outstretched. Glandular part of

oesophagus overlaps the intestine for about two body widths.

Measurements:

1 ♀ L = 0.56mm, a = 16.5, b = 1.6, c = 11.2, v = 60.7

Probably Telotylenchus indicus (after Goodey, 1963).

Systematic Position Tylenchida, Tylenchoidea, Tylenchidae, Telotylenchinae Telotylenchus (Hooper, 1969)

Habitat: Found occuming around guava (Psidium guajava) and Musa spp.

4.12 Discolaimus spp.Cobb, 1913

Description

Presence of disc-like lip region expanded much more widely than the head constriction. Lateral chords with a series of glandular organs each with a duct extending through the cuticle and forming a single lateral row of pores on either side.

Amphid apertures practically invisible beneath projecting lips. Anterior ring of guiding sheat relatively high in pharynx.

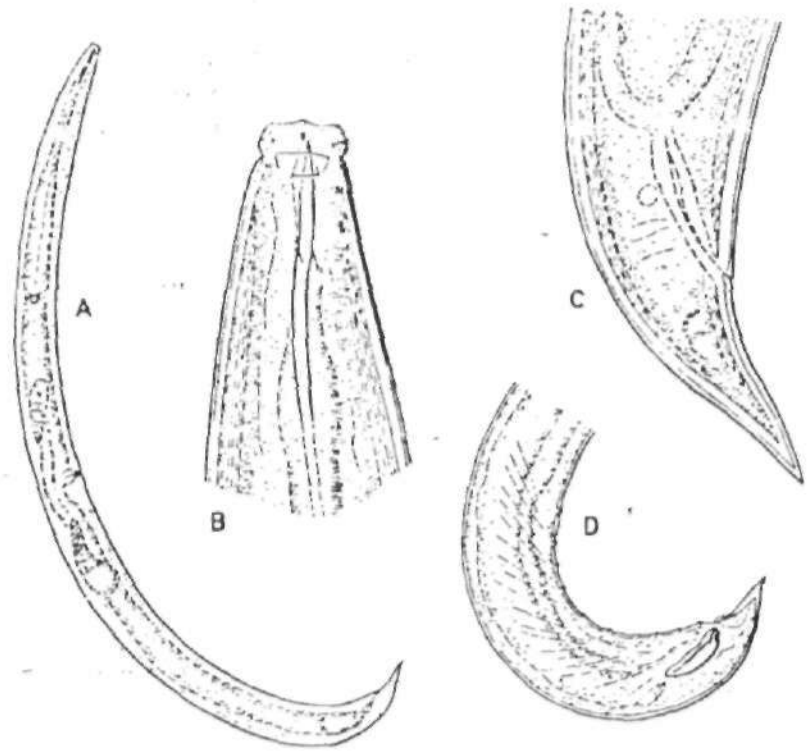


FIGURE 11: EUDORYLAIMUS SPP. (ANDRASSY, 1959). (A) FEMALE (B) HEAD (C) FEMALE TAIL (D) MALE TAIL (AFTER HEYNS 1971)

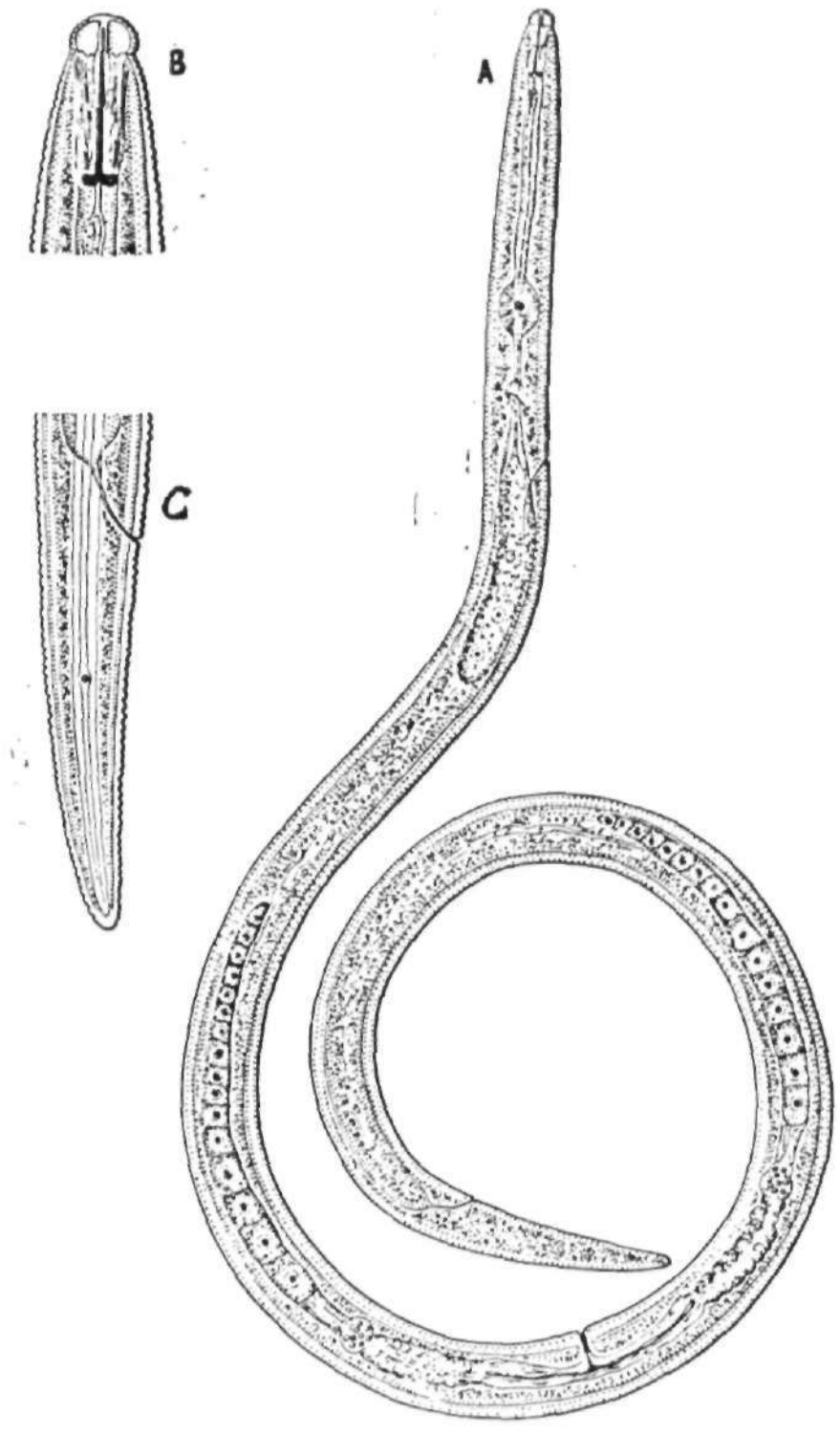


FIGURE 12: TELOTYLENCHUS SPP.(SIDDIQI, 1960). (A) FEMALE (B) ANTERIOR OF FEMALE (C) FEMALE TAIL (AFTER SIDDIQI 1960)

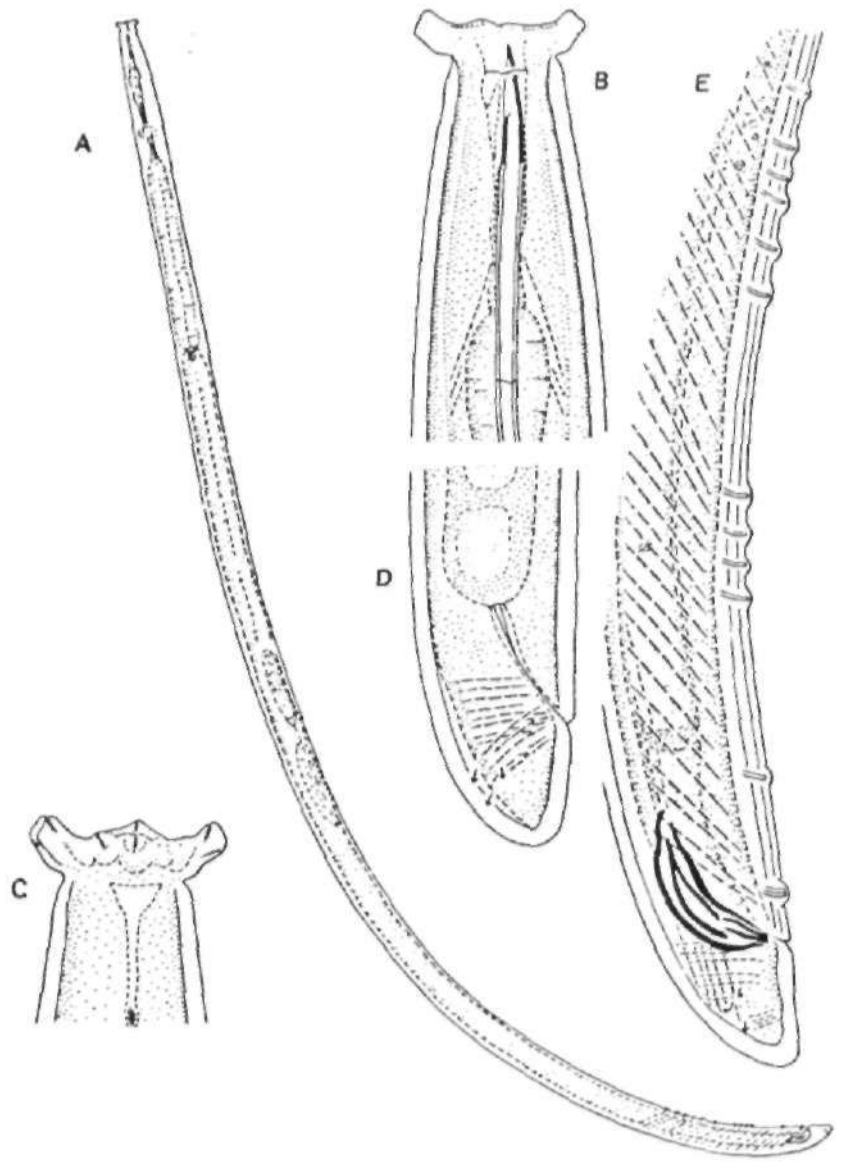


FIGURE 13: DISCOLAIMUS SPP. (COBB, 1913) (A) MALE (B) HEAD (C) SURFACE VIEW OF HEAD SHOWING AMPHID (D) FEMALE TAIL (E) POSTERIOR PART OF MALE (AFTER FURSTENBERG & HEYNS, 1966)

Oesophagus beginning as an elongate spindle-shaped swelling around the base of spear extension, then extending behind and expanding to form the main muscular portion. Dorsal gland placed rather further back than in other Doryalaims, its ducts extend a little forward before entering the oesophageal lumen. Female gonad single spicules broad slightly arcuate, lateral guiding pieces present.

Measurements
1 ♀ L = 1.8mm, a = 36, b = 1.6, c = 90, v = 75

Probably Discolaimus major Thorne, 1939 (after Goodey, 1963).

Systematic Position: Dorylaimida; Dorylaimina, Dorylamidae; Dorylaiminae Cobb, 1913.

Habitat: Found associated with Carica papaya, Citrus paradisi/Citrus limon, Citrus sinensis/Citrus limon at nearly all sample sites except Area F and College of Agriculture, Samaru.

4.13 Mononchus spp. Bastian, 1865

Description

Dorsal tooth in anterior part of stoma, powerful pointing forwards subventral teeth absent but an untoothed ventral opposing ridge present. Stoma walls parallel, base of stoma pointed. Oesophago intestinal junction non-tuberculate. Gonads paired and prodelphic.

Measurements:

2 ♀ L = 0.97 - 1.37mm, a = 25 - 34, b = 3.2 = 3.8
c = 16 - 23, v = 47 - 77.3.

Probably Mononchus papillatus Bastian 1865 (Cobb, 1916).

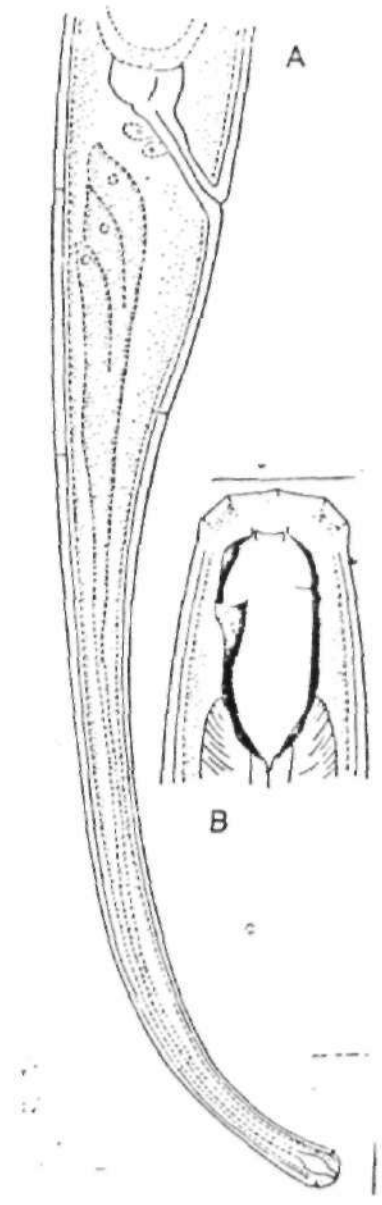


FIGURE 14: MONONCHUS SPP. (BASTIAN, 1865). (A) FEMALE (B) HEAD (AFTER COETZEE, 1968)

Systematic Position: Dorylaimida; Dorylaimina; Mononchoidea; Mononchidae; Mononchus (after Goodey, 1963).

Habitat: Found at all sites around all fruit trees sampled.

4.14 Dorylaimellus spp. Cobb, 1913.

Description:

Amphids almost completely encircling the head, lateral chords containing rather conspicuous glandular organs and similar organs can be seen in the central chord in the vicinity of oesophagus posterior to it. Spear not longer than head width with extensions in two obscurely separated sections which bear broad flanges. Spear guiding ring absent. Oesophagus with swelling just behind the spear then narrowing to a slender non muscular tube and finally enlarging to form the basal swelling surrounded by the spiral sheath. Nucleus of dorsal oesophageal gland prominent. Those of the submedians very small and obscure. Gonads single spicules very broad proximally with an abrupt ventral angle.

Measurements:

1♂ L = 0.82mm, a = 20.5, b = 3.2, c = 20

Probably Dorylaimellus demani Syn. Tylencholaimus mirabilis de Man 1876, 1880 & 1884 (Butschi, 1873) (after Goodey, 1963).

Systematic Position: Dorylaimida; Dorylaimina, Belondridae; Belondiroidge; Belondiridae; Dorylaimellus (Goodey, 1963).

Habitat: Found at all sites around Psidium guajava, Citrus paradisi, Citrus limon, Citrus reticulata and Carica papaya.

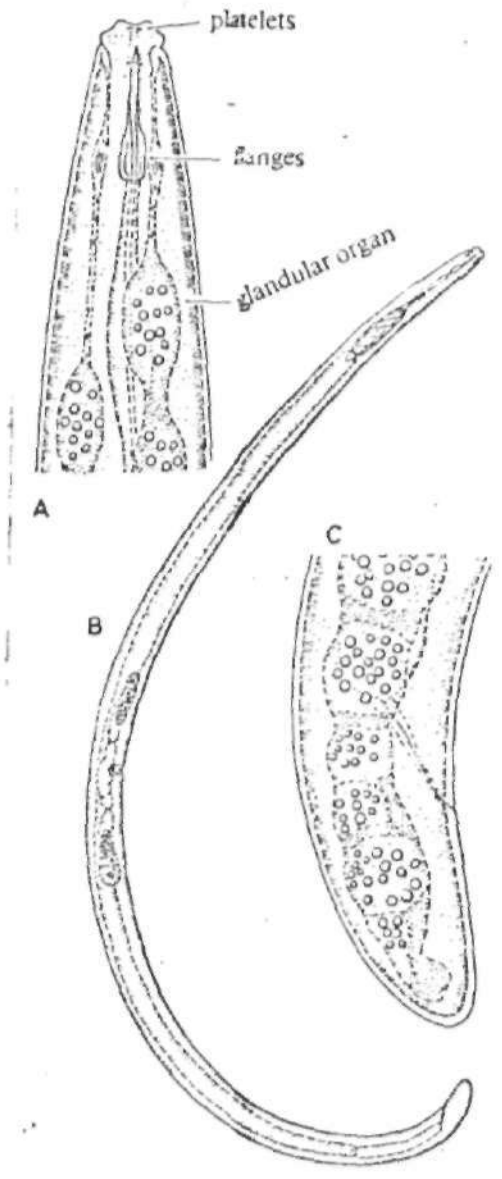


FIGURE 15: DORYLAIMELLUS SPP. (COBB, 1913) (A) HEAD (B) FEMALE (C) FEMALE TAIL (AFTER HEYNS 1963)

4.15 Diplogasteroides spp.de Man, 1912.

Description:

Cuticle with longitudinal striations bearing transverse striae. Head with six closed lips each with an apical papilla. Stoma long and narrow, about five times as long as wide. Chelostom short and slightly barrel-shaped. Dorsal meterhabdion with a median denticle, no denticles described on the subventral segments.

Amphid opening distinct at about a head width from the anterior end, expand into the corpus which forms distinct median bulb containing well developed valve plates. Isthmus swelling slightly to a rather slender valveless terminal bulb. Tail long and filiform. In females gonads are single prodelphic, reflexed nearly as far as the vulva. A post vulval sac present functioning as a receptaculum seminus.

Measurement: Inadvertently not made.

Systematic Position: Rhabditida; Rhabditina; Diplogasteroidea; Diplogasteridae; Diplogasterinae; Diplogasteroides (After Goodey, 1963).

Habitat: Found around Psidium guajava, Citrus sinensis /Citrus limon.

4.16 Ditylenchus spp-Filipjev, 1934.

Description.

Tylenchinae. Ovary single. Rudimentary posterior uterine branch present, lip region plain not annulated. Gonad cells in one or two lines, not arranged about a rachis. Lateral fields marked by 4 or 6 incisures. Basal portion of oesophagus a distinct bulb, occasionally with a short lobe extending back over

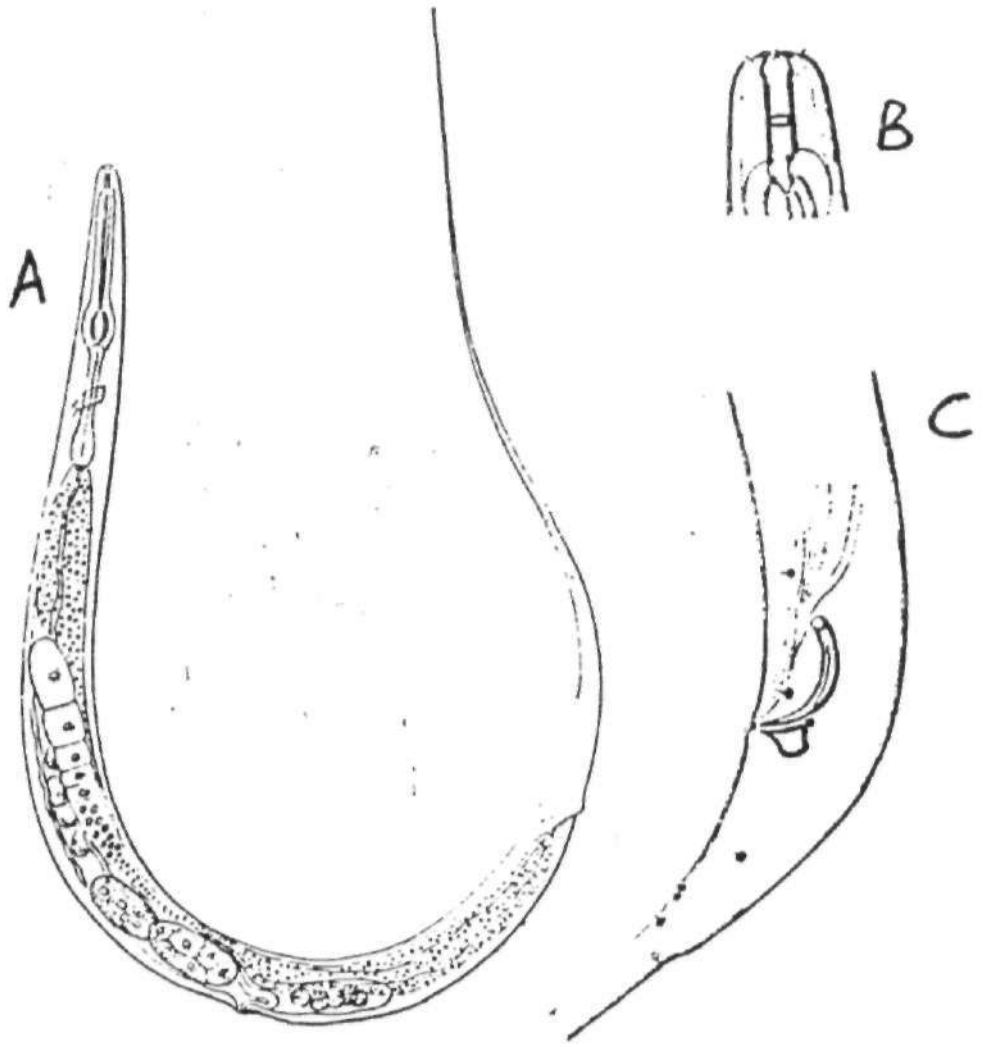


FIGURE 16: DIPLOGASTEROIDES SPP. (DE MAN, 1912) (A) FEMALE (B) HEAD END LATERAL OF FEMALE (C) TAIL END OF MALE (AFTER DE MAN, 1912)

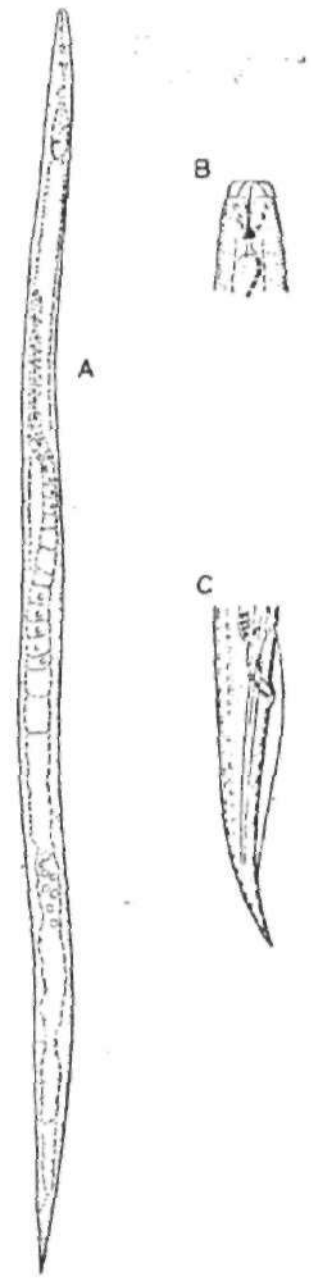


FIGURE 17: DITYLENCHUS SPP. (FILIPJEV, 1934) (A) FEMALE (B) HEAD (C) MALE TAIL (AFTER THORNE, 1961).

anterior end of intestine. Phasmids exceedingly minute if visible at all. Tail elongate conoid to acute or subacute terminus (Thorne, 1949).

Measurement: Inadvertently not taken.

Systematic Position:

Tylenchida; Tylenchoidea; Tylenchidae; Ditylenchus (Golden, 1971).

Habitat: Found in association with essentially all fruit trees around which samples were taken in residential Area A.

4.17 Scutellonema spp. Andrassy, 1958.

Description:

Hoplolaiminae. Lip region with horizontal and with or without longitudinal striations. Oesophageal glands overlap intestine dorsally and laterally. Phasmids enlarged located opposite or nearly opposite one another near anal region. Four incisures in lateral field aerolated primarily in region of phasmids and anteriorly. Female tail rounded (Sher, 1963).

Systematic position: Tylenchida; Tylenchoidea; Hoplolaimidae; Hoplolaiminae; Scutellonema spp (Hooper, 1969).

Habitat: Found in association with banana (Musa spp) in residential Area E.

4.18 Longidorus spp. (Micoletzky, 1922). Thorne & Swanger, 1936.

Description:

Tylencholaiminae. Body very long. Lips amalgamated, with the usual two circles of 6 inner and 10 outer papillae. Lateral chords comparatively broad. Lateral pores in 1 or 2 lines. Amphid apertures minute slits and very difficult to see, the

amphids proper are very large. Pouches often lobed, which practically encircles the head. Spear greatly elongated, with a guiding ring at about 1/6th of its length. Spear extension up to 2/3 length of the spear, its lumen widening a little at its base.

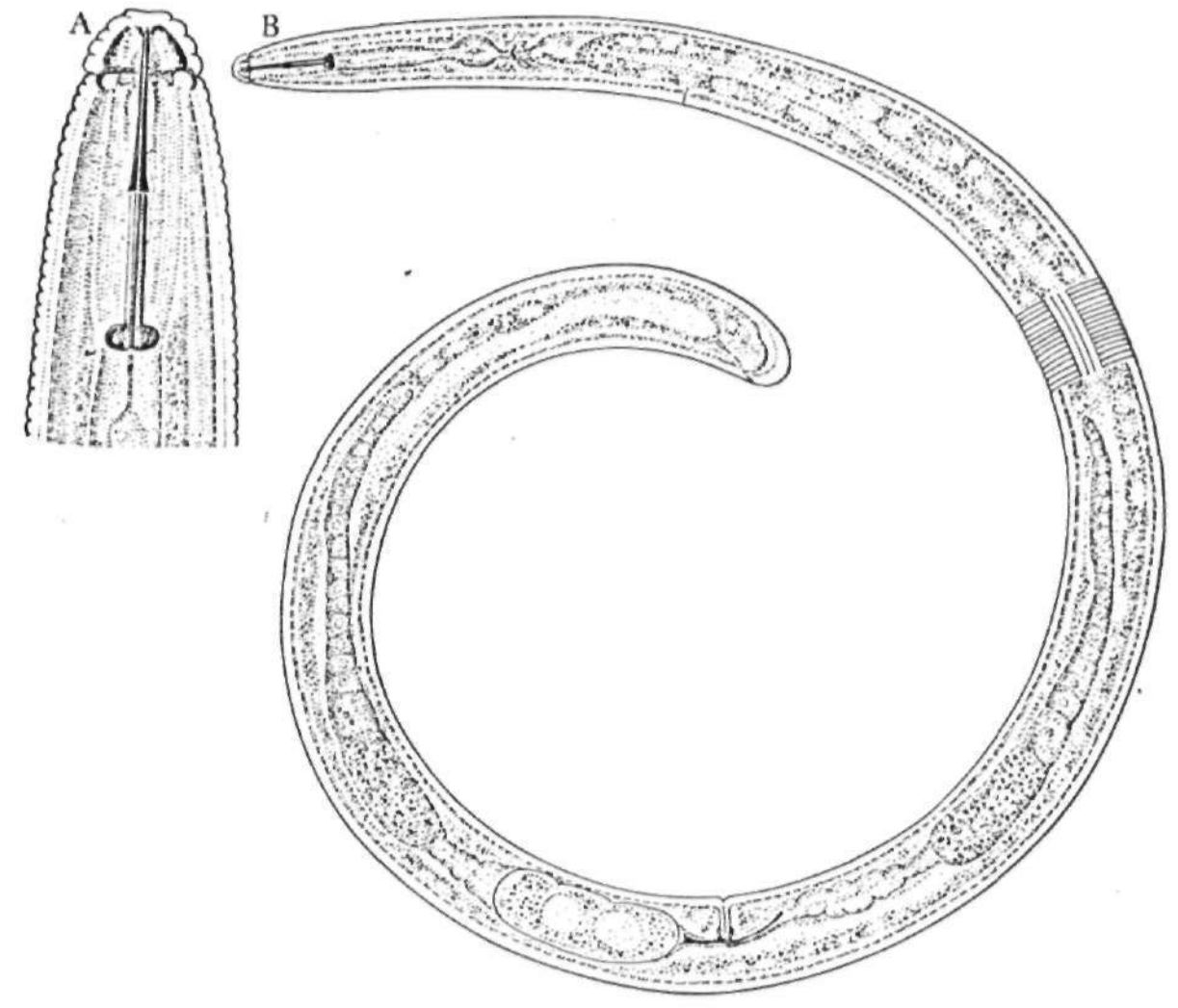


FIGURE 18: SCUTELLONEMA SPP. (ANDRASSY, 1958). (A) HEAD (B) LECTOTYPE FEMALE (AFTER A. MORGAN GOLDEN, USDA BELTSVILLE, MARYLAND, USA).

and surrounded by fairly dense muscle attachements. Anterior part of oesophagus a narrow flexible tube, posterior part wider and cylindrical. Gonads paired in all but one species, reflexed and relatively short compared with body length. Vulva transverse. Anus a transverse slit. Tails similar in both sexes.

Measurements: Inadvertently not taken.

Systematic Position: Dorylaimida; Dorylaimoidea; Dorylaimidae; Tylencholaiminae, Longidorus spp.

Habitat: Found at most sites around essentially all fruits trees from which samples were taken except in Area A, where they appeared to be non-existent. No nematodes were found in the roots analysed.

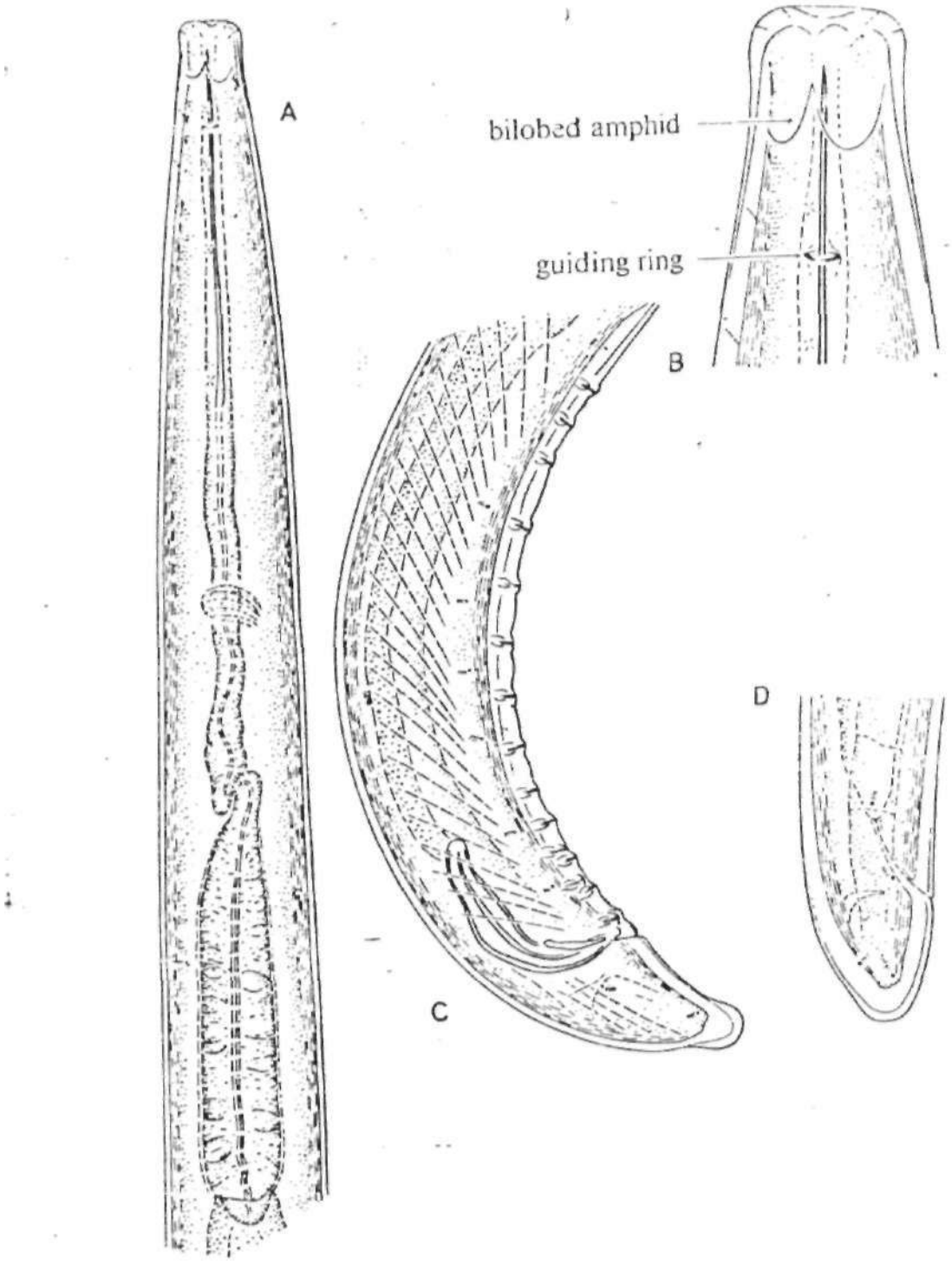


FIGURE 19: LONGIDORUS SPP. (MICOLETZKY, 1922). (A) ANTERIOR PART (B) HEAD SHOWING BILOBED AMPHID (C) MALE TAIL (D) FEMALE TAIL (AFTER HEYNS 1971)

CHAPTER FIVE

DISCUSSION

Most of the taxonomic information on plant parasitic and freeliving nametodes have been obtained from the temperate regions. It is only within the last few decades that plant nematologists have become interested in related studies in the tropics. Thus, Loos published his notes on plant parasitic and freeliving nematodes from Ceylon in 1948. Caveness (1967) collected and identified some nematodes genera from Northern Nigeria. Other works related to Nematology in Nigeria, especially Northern Nigeria include those by Bos (1978), Bridge (1972), Khan (1984), Emechebe (1980), Yisa (1985), and Babatola (1981).

A total of 17 genera of nematodes were identified in the present survey. Some of the nematode forms are same as those previously reported by Caveness (1967). In agreement with Caveness (1967), the root-knot nematode, Meloidogyne spp. described by Bos (1978) and Khan (1984), was not found associated with the roots of any of the fruit trees studied. It was also observed that nematodes are very common and widespread, occurring in varying numbers in the different areas or habitats. The nematodes observed have been grouped according to their feeding habits and the 17 genera were found to be unevenly distributed in the area of study. Ten of the seventeen genera shown in tables 1 to 5 are known parasites on plant roots, while the remaining seven genera are non plant parasitic forms. The six types of fruit trees surveyed include, Carica papaya L, Psidium guajava, Musa spp. and a series of hybrids of citrus trees namely, Citrus

sinensis L. Osb in combination with Citrus limon L. Burma; Citrus paradisi mac. F in combination with Citrus limon L. Burma; and Citrus reticulata.

In essentially all the locations sampled, at least one parasitic nematode form was found in association with the roots of Carica papaya. The nematode types found include the spiral nematode, Helicotylenchus spp. Steiner, 1949, which occurred in relatively large numbers around the fruit trees sampled; and the dagger nematode Longidorous spp. (Micoletzky, 1922) Thorne and Swanger, 1936. The two genera had the widest spread with Helicotylenchus spp occurring in all the areas sampled, namely, Areas A, BZ, E and F, and the College of Agriculture, Samaru. However, most of the specimens of Helicotylenchus spp. obtained were juveniles. An approximate estimate of the population of the species indicated about 1000 nematodes per kilogramme of soil. Longidorous spp. on the other hand, though occurring at all sample sites (except College of Agriculture, Samaru) were present in relatively lower numbers of about 100 to 500 nematodes per kilogramme of soil. The distribution of the other plant parasitic nematodes, Hoplolaimus spp., Ditylenchus spp., Scutellonema spp., Tylenchus spp., Tylenchorynchus spp., Telotylenchus spp., Rotylenchus spp. and Hemicriconemoides spp., was irregular. For instance these genera were completely absent in some sample sites, and occurred in relatively very low numbers in other sites.

Mononchus spp., a parasite on other nematodes or protozoans was found in relatively large numbers (about 1000 per kg of soil) at essentially all sample sites. This is to be anticipated since

other nematode forms were readily available at each site. Similarly, Eudorylaimus spp., was also found at all sample sites surveyed in populations of about 500 - 800 nematodes per kilogramme of soil. The other nematodes, saprophagous in nature, namely, Diplogasteroides spp., Dorylaimus spp., Discolaimus spp., and Dorylaimellus spp., were distributed in no specific pattern. Usually, their occurrence is dependent on the availability of organic material on which they feed. Acrobeles spp. was observed only at one site (Area A residential area) around Citrus sinensis L. Obs/Citrus limon L. Burma hybrid. Its occurrence could have been accidential, probably transferred to the site from the nursery from which the plant along with the soil was obtained.

Several factors are thought to affect the occurrence and distribution of nematodes. For example, Thorne (1961) noted that in the tropical region of Indonesia, not a single gravid female of the rice root nematode, Radopholus oryzae was observed among thousands collected between September and March. This was also reported to be true of the root lesion, spiral and many other nematode forms. The author also reported that even under careful regulation of temperatures and moisture, colonies disappeared for no apparent reason. The presence of certain nematode forms may result in the tendency to exclude others. Thus, Pratylenchus spp. and Tylenchorynchus spp. are known to be susceptible to sporozoan parasites such as Duboscquia penetrans (Thorne, 1961). Similarly, the population of Radopholus oryzae failed to develop to expected levels because Mononchus longicaudatus had been accidentally introduced, and had increased to such numbers as to reduce the population of the plant parasitic nematodes.

Other factors which may have influenced the distribution of nematode fauna in the areas studied include soil type, weather conditions (as sampling was done in the dry season between January and March), environmental temperatures, as well as, unchecked transfer of nematodes from nurseries to new sites by transplanting or from tools used in the transplants. For example, Bird and Wallace (1965) showed that Meloidogyne hapla occurs more frequently in colder climates, while M. javanica is more prevalent in hotter regions.

The type of species of fruit tree did not appear to influence the distribution of nematodes in the various areas studied. Thus, the lance nematode, Hoplolaimus spp. was found occurring only at one sample site (Area E residential area) in association with Musa spp., with an approximate population of about 500 - 800 nematodes per kilogramme of soil. Even though Musa spp were sampled at other locations, Hopolaimus spp. was not present around them. Other nematode types that occurred at only one or two sites include, Rotylenchus which occurred only in Area E in association with Psidium guajava and Carica papaya; Tylenchorynchus spp. in the College of Agriculture, Samaru orchard, around Psidium quajava with an approximate population of about 500 - 800 nematodes per kilogramme of soil; Tylenchus spp. which occurred only around Musa spp. at a single site in Area E, with an approximate population of about 100 - 500 nematodes per kilogramme of soil; Telotylenchus spp, found around Psidium guajava and Citrus sinensis L. Obs./Citrus limon L. Burma in the College of Agriculture Samaru, sample site, with an approximate population of about 500 - 800 nematodes per kilogramme of soil.

Similarly, Hemicriconemoides spp. was found in low populations of about 100 - 500 nemas/kg of soil in Area A only around Citrus paradisi/Citrus limon L. Burma, Musa spp. and Carica papaya. Scutellonema spp. was observed in Area A only around Musa spp., Ditylenchus was found in low populations around all trees sampled in area A. It is difficult to account for why a nematode species found around one fruit tree species in one area was not necessarily observed around the same tree species in other areas. This is particularly so as no data are available showing the ages of the various fruit trees sampled, the original sites from which they were raised and transplanted, or the nematode fauna native to the environment to which the trees were transplanted. Bridge (1972), working in Northern Nigeria, also observed that nematode forms found associated with a given type of irrigated crop in one sample site were not necessarily found with the same crop in all locations sampled. Sometimes cropping history determines nematode associations.

Examination of tables 1 to 5 shows that over all areas sampled, 10 genera of nematodes were observed around Psidium guajava L; Citrus sinensis L Obs/Citrus limon L. Burma and Carica papaya; while 8 genera were found around Citrus paradisi macf/ Citrus limon L. Burma and Musa spp. Only six genera were found around Citrus reticulata.

CHAPTER SIX

SUMMARY AND CONCLUSION

The present survey was carried out to increase the data available on the nematode fauna associated with fruit trees in the private gardens and orchards in the Ahmadu Bello University, Main Campus, Samaru. 17 genera of nematodes have been identified, 10 of which are known plant parasitic nematodes, while the remaining 7 genera consists of freeliving and soil nematodes. The plant parasitic forms found are: Longidorus spp., Scutellonema spp., Hoplolaimus spp., Tylenchorynchus spp., Helicotylenchus spp., Rotylenchus spp., Hemicriconemoides spp., Tylenchus spp., Telotylenchus spp., and Ditylenchus spp. The other nematodes identified include Mononchus spp., Discolaimus spp., Dorylaimus spp., Dorylaimellus spp., Diplogasteroidea spp., Acrobeles spp. and Eudorylaimus spp. These genera are generally in agreement with those reported by Yisa (1985) for soil samples taken from other locations in the Zaria area.

The most widely distributed genera are Helicotylenchus spp. which was obtained in all areas sampled in relatively high populations. The distribution of the various nematode forms among the various fruit trees over all sample sites was not uniform. All the soil and freeliving nematode forms were not found in all sample sites.

Only approximate estimates of the population of various nematodes were made. Accurate population counts would require more sophisticated instruments which were not available as well as information on important factors that affect populations, such

as: the age of the fruit trees, the original nursery from which they were obtained; information on other plants in the environment of the trees sampled and previous plants grown in the sample areas, and hence the dormant nemic population in the soils.

Most specimens obtained in this study were juveniles, since sampling period fell within the dry season (January to March), and most of the fruit trees were irregularly irrigated. In fact seasonal variations are known to affect nematode populations and emergence of larvae. This probably accounts for the low value of 'n' used for measurements aimed at identifying the nematode to the specie.

The survey has shown the presence of nematode forms which are known plant parasites. Furthermore, the sudden incidence of various species of the root-knot nematode Meloidogyne spp. (Khan, 1984) might not be unconnected with the fact that the northern parts of Nigeria have witnessed in recent years a tremendous increase in fruit trees planting both as backyard orchards and orchards for commercial purposes. This increase has probably encouraged the transportation of nematode pests from their native regions to the northern parts of Nigeria. Unfortunately, there is a general lack of knowledge about nematode problems and quarantine regulations in Nigeria, since the problems these nematodes cause in most cases are not always immediately obvious. In fact information on the pathogenicity and the effect on fruit crop yield of the known plant parasitic nematodes in the Zaria area is lacking. It is therefore suggested that studies be carried out on:-

(i) recognition of diseases of fruit crops and yield losses due to nematode infestation in the Zaria area;

(ii) nematode/host relationships and the distribution on each of the identified nematode parasites;

(iii) longetivity and survival of the nematodes;

(iv) determination of fruit plant varieties which are resistant to nematode attacks; and

(v) determination of methods of control of the pests.

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