The application can be made directly to the soil in form of aluminum sulfate or as an aluminum sulfate-iron sulfate spray applied directly to the plant.

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CHARACTERISTICS AND OCCURRENCE OF CERTAIN NEMATODES IN FLORIDA SOILS

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In the past few years usage of the word "nematode" has become commonplace, both to the grower and to the agricultural scientist. Many people are concerned with plant injury caused by nematodes, but few know the nature of these small soil inhabiting organisms. To work with nematodes, it is necessary to distinguish them from rotifers, protozoa, oligochaetes, and other microscopic organisms that inhabit the soil as well as to separate the parasites from similar non-parasitic forms.

Inasmuch as many agricultural workers are not proficient in recognizing parasitic nematodes, it is desirable to acquaint them with the characteristics used by the nematologist in making identifications. When nematode infections are suspected it is of primal importance to have the nematode or nematodes, in question, identified because recommendations for control are becoming increasingly more specific. It is of particular importance for the horticulturist to know what species are present in the soil so that he can select plants that will be poor hosts and thereby discourage the rapid build-up of plant parasitic nematode populations. The grower should also keep in mind that where root-knot nematodes are present nutritional disturbances may then appear in plants (7). On the other hand, research has shown that plants containing a high level of potassium support a larger population of

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parasitic nematodes than plants poor in this element (6). Future investigations may show similar relationships between soil fertility and plant parasitic nematodes.

The soil as an ecological unit supports many hundred species of nematodes and other organisms, each struggling for existence. Not all soil inhabiting nematodes are parasitic. Some are saprophytes, feeding on organic matter, and thus aid in the processes of decay. Others feed on bacteria, fungi, protozoa, and other microorganisms. Certain nematodes, such as monochs and dorylaimes, are predacious on other nematodes. There are relatively few species known to be parasitic on plants, but their agricultural importance is tremendous.

Soil nematodes vary in length from a fraction of an inch to several feet. The plant parasitic forms are usually less than three millimeters long. Except for the adult female root-knot nematodes, which live in the roots of plants, they cannot be distinguished from the soil particles and roots without the aid of a microscope because of their small diameter and transparency. The difficulties involved in separating them from the soil is one of the reasons soil borne nematodes are one of the most inadequately studied groups of soil organisms.

In presenting a general description of nematodes within the confines of this paper there will be many omissions and over-simplifications. Nematodes are extremely complex and interesting animals. Only basic information that will be of service to the reader in a fuller appreciation of soil nematodes is presented. The reader may obtain additional references from the bibliography.

Nematodes, which belong to the phylum Nemathelminthes, or round worms, are often mistaken for small oligochaetes, the group of segmented worms to which the common earthworm belongs. Nematodes are characterized by being non-segmented, triploblastic or having three body layers, covered by a protective covering called the cuticle, without respiratory or circulatory system, and generally bisexual. The digestive system is a long tube that runs from mouth to anus, and is composed of buccal cavity, muscular oesophagus, intestine, rectum, and anus. The oesophagus is a pumping organ, typically composed of three regions (corpus, isthmus, and terminal bulb), which may be greatly modified in certain species. The corpus may be fusiform or thickened to form a median bulb (Figure II). The isthmus, which is usually thinner than the corpus, opens into the terminal bulb. The terminal bulb typically contains digestive glands and a valve. The size, shape, and location of these glands is of great taxonomic importance. The dorsal oesophageal gland duct may open into the oesophagus lumen in a variety of locations, depending on the species, whereas the suboesophageal gland duct opens into the median or terminal bulb.

The cuticle, or body covering, is non-cellular, is frequently covered by distinct striations, and has various "appendage-like" structures that aid it in sensation and locomotion. During the molts of the larva, the cuticle is shed and a new one secreted in its place. Metamorphosis of the larva to the mature form is thus in stages. In males the cuticle is often modified to form a fanlike bursa on the tail.

The reproductive systems of the nematodes are similar to those of many other animals where there are male and female sexes, but occasionally the male is not known to exist. In this case the females reproduce parthenogenetically. In many instances the primary function of the male is fertilization of the female. The female reproductive system consists typically of one or two ovaries, containing developing eggs, and a tubular structure composed of the oviduct (s) and uterus that opens into the vagina. The vulva, or surface opening of the female reproductive tract, opens ventrally on the body surface. The male reproductive system consists of either a single or paired testes which are connected to the vas deferans that runs posteriorly and ventral to the intestine. It narrows into the ejaculatory duct which opens into the cloaca. Ejaculatory glands may be observed in the region of the vas deferans. The cloaca contains, in addition to the digestive and genital openings, two rather prominent structures, the spicules, which aid in transferring the sperm to the female during mating. Associated with the sickle-shaped spicules is their guiding piece, the gubernaculum.

The most conspicuous component of the nematode nervous system is the nerve ring that circles the oesophagus, usually in the isthmus region. From this nerve ring, several nerves run anteriorly to innervate the head region. Two nerves, the dorsal and ventral nerve cords, run posteriorly to innervate the regions that lie behind the oesophagus.

The identification of nematodes depends upon many characteristics, depending on the level at which the identification is made. Species are separated on the basis of microscopic characteristics. As in entomology, no man is capable of becoming an authority on species of every group of nematodes. A knowledge of five general soil inhabiting nematode types will suffice for most agricultural workers (Figures I and II). Most plant parasitic and non-parasitic nematodes found in the soil can be placed into these five groups, which are based on the mouth parts and oesophagus. To be sure, there are forms that differ from any one of these groups; however, these will serve as a basis for a more detailed taxonomic study.

The least specialized type is found in the rhabdoid group (Figure 1A) of which *Rhabditis* is a representative genus. This group is composed of forms that are free-living, feeding on decaying organic matter and bacteria. The buccal cavity is poorly developed and inconspicuous in most forms. Behind the buccal cavity in the region of the corpus (first portion of the oesophagus) there is found a swelling, the median oesophageal bulb. Posterior to this structure and anterior to the intestine is a round to oblong terminal bulb containing a valve. Examination of Florida soils

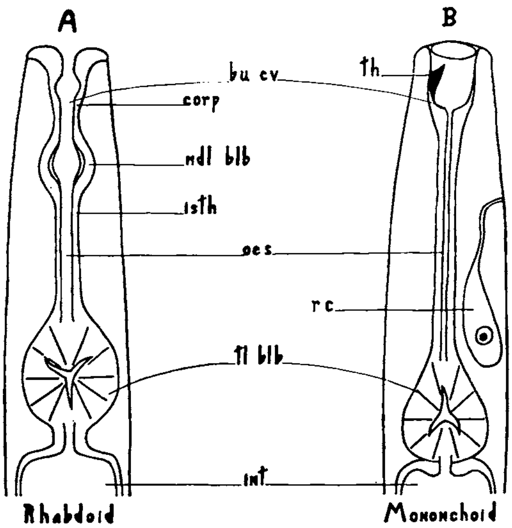

Figure I.—Diagrammatic representation of the mouth parts and oesophagus found in two large groups of nematodes that contain many species of saprophytic and predacious soil nematodes. A. Rhabdoid, B. Mononchoid. bu cv, buccal cavity; corp, corpus; int, intestine; isth, isthmus; mdl blb, median oesophageal bulb; oes, oesophagus; r c, renette cell; th, tooth; tl blb, terminal oesophageal bulb.

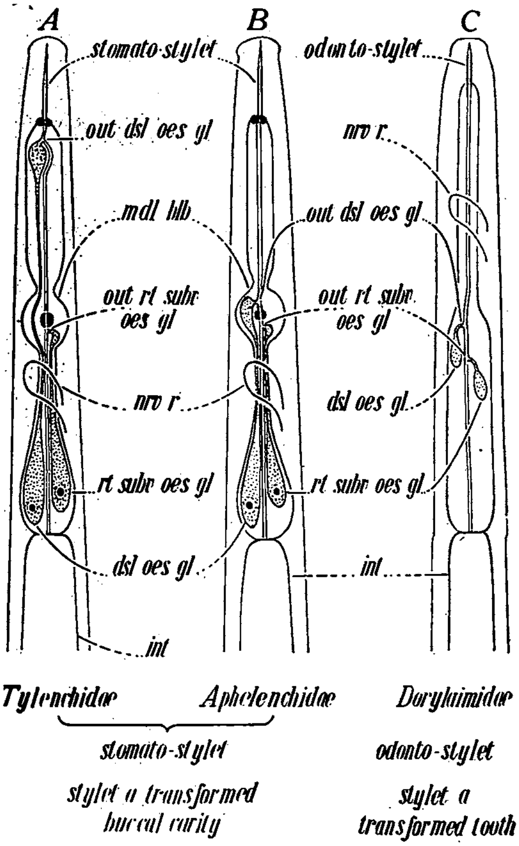

Figure II.—Diagrammatic drawings showing the main differentiating characteristics of three main groups to which most plant parasitic nematodes belong. A. Tylenchidae, B. Aphelenchidae, C. Dorylaimidae. dsl oes gl, dorsal oesophageal gland; int, intestine; mdl blb, median oesophageal bulb; nrv r, nerve ring; out dsl oes gl, outlet of dorsal oesophageal gland; out rt subv oes gl, outlet of right subventral oesophageal gland; rt subv oes gl, right subventral oesophageal gland. (Figure taken from Steiner (8)).

shows that they contain hundreds of species of rhabdoid type nematodes. This is especially pronounced in sandy soils high in decaying organic matter. The biological and economic importance of these organisms has yet to be fully established. They are not generally considered to be plant parasites, although the author has observed species of Cephalobidae living within the nodules of Ladino clover, *Trifolium repens* L. (White C.).

A second group that occurs in Florida soils is the mononchoid type (Figure IB). This group is characterized by having a large buccal cavity and one or more stout teeth. The terminal bulb may be an elongate glandular structure, or there may be a distinct valvular bulb. The feeding habits of mononchoid organisms are not clear; however, members of the genus *Mononchus* have been reported as predacious on nematodes and other soil inhabiting animals. *Mononchus papillatus* (Bastin) Cobb has been observed feeding on the citrus nematode, *Tylenchulus semi-penetrans* Cobb, and other nematodes associated with citrus (3). Accordingly, these nematodes must play an important role in the biological balance of the soil (5).

The third group of nematodes belongs to the family Tylenchidae which contains the greatest number of known plant parasitic nematodes (Figure IIA). These organisms have a stout, piercing type mouth structure known as a stomato-stylet. The oesophagus *contains a distinct* muscular median bulb that aids in the ingestion of food. Posterior to the median bulb is found a well developed terminal bulb that contains digestive glands. The duct of the right and left subventral oesophageal glands opens into the lumen of the median bulb, while the duct of the dorsal oesophageal gland empties into the oesophagus lumen immediately behind the junction of the oesophagus and stomato-stylet. Probably the most destructive and widespread plant parasitic nematode occurring in Florida is the sting nematode, *Belonolaimus gracilis* Steiner,* which can be considered a rather typical and easily studied example of the tylenchoid nematodes. Other parasites of this group that occur in Florida are *Meloidogyne* spp. (root-knot nematodes, formerly *Heterodera marioni*), *Rotylenchus* spp. (spiral nematodes), *Dolichodorus heterocephalus* Cobb (awl nematode), *Pratylenchus* spp. (meadow nematodes), *Hoplolaimus* spp. (lance nematodes), *Tylenchulus semi-penetrans* Cobb (citrus root nematode), and *Criconemoides* spp. (ring nematodes). Additional information on some of these nematodes may be obtained from Dr. G. Steiner's (8) 1942 paper on "Plant Nematodes The Grower Should Know." To this group of parasites must be added the name *Radopholus similis* (Cobb) Thorne (burrowing nematode), which has recently been shown to be associated with the spreading decline disease of Florida citrus trees (9). Another important development which has not been fully recognized in nematode researches in Florida is the revision of the genus *Heterodera* by Chitwood (1), in which he established five species of *Meloidogyne* (root-knot). Failure of the research worker to determine which nematode(s) is infecting the soil has, no doubt, led to many of the discrepancies in susceptibility of various plants to root-knot disease.

A fourth group of soil nematodes is the aphelenchoid type which is found in the family Aphelenchidae (Figure IIB). The organisms of this group are difficult to separate from the tylenchoid group, inasmuch as one of the differentiating characteristics is the position of the opening of the dorsal oesophageal gland duct. In the Aphelenchidae the dorsal oesphageal gland duct enters the oesophagus lumen in the median bulb. Foliar, stem and bulb nematodes are parasites of this group that occur in Florida soils.

The dorylaimoid type (Dorylaimidae) of nematode has an odonto-stylet that is spear shaped, usually a pronounced structure (Figure IIC). The oesophagus has a distinct terminal bulb lacking a valve. The anterior portion is often slender and sinuous. No median bulb is present. Many representatives of this group are found in Florida soils. This group is generally difficult to work with because their feeding habits are not clearly known. Some are saprophytes, others are predators, and still others are plant parasites. It appears that the most destructive nematodes of this group in Florida are *Xiphinema* spp. (dagger nematodes). The well known stubby-root nematodes, *Trichodorus* spp., appear to be widespread in Florida and of considerable economic importance. These organisms do not belong to the Dorylaimidae family, but have more characteristics of the dorylaimoid group than any of the other described groups.

Injury caused by plant parasitic nematodes in Florida is becoming increasingly more important, and injury caused by them is now more easily recognized. Intensified agricultural practices encourage the rapid build-up of plant parasitic nematodes. For successful control of these organisms there is a need for more fundamental information on taxonomy, climatic relations, microbiological interrelationships, distribution, life cycles, and host range of plant parasitic nematodes. Plant parasitic nematodes will be difficult if not practically impossible to eradicate from our sandy soils, and for this reason tolerance levels on given

* Personal communication from Dr. J. R. Christie, U. S. D. A., Sanford, Florida.

crops that will give maximum yields for minimum control cost must be ascertained. A study of soil management practices in Florida probably will give much helpful information for the control of nematodes. Nematode population studies in relation to crop rotation are now in progress. At present the utilization of existing soil nematode fumigants and resistant or tolerant host plants in conjunction with good crop rotations seems to be the best control procedure. Soil fumigants are generally not selective in that they kill or retard most of the soil organisms. For this reason many of the beneficial organisms needed to maintain biological controls are destroyed during fumigation. It is possible that this would allow the parasites to become even more devastating in the event that they were not completely destroyed during fumigation, or in the event of reinoculation of the soil with plant parasitic nematodes.

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FACTORS ASSOCIATED WITH CREASE-STEM OF TOMATO

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Introduction

Crease-stem of tomatoes is a physiological disease which has attracted considerable interest in scientific circles in the past few years. Although observed from time to time over many years in nutritional studies in the research greenhouse, no serious effort was made to investigate it further because of its infrequent appearance in commercial fields. However, in the spring of 1948 severe crease-stem occurred on Rutgers tomatoes in an experimental field at the Gulf Coast Experiment Station at Bradenton (2). Through discussion with commercial growers and technical field men at that time it was learned that this trouble had been observed on a limited scale in the past, but usually only on the Rutgers variety. In October of 1950, serious outbreaks occurred in commercial fields over a large area of the Florida West Coast (3). Since then it has appeared sporadically each season in scattered locations along the Gulf Coast from Ruskin to Fort Myers.

Experienced tomato growers have little trouble in recognizing symptoms of the disease in the field. In the early stages of the disorder the stem begins to pinch together longitudinally so that a crease is formed on opposite sides, hence the name "crease-stem." A cut lengthwise of the stem at this stage shows internal necrosis and the presence of cavities where cells have completely disintegrated (Figure 1). As the disorder develops, this creasing from the two sides becomes so deep that a hole is formed through the stem (Figure 2).

This internal breakdown is always associated with a severe stunting and dwarfing of the plant. In many cases the growing tip becomes malformed resembling a "witches-broom." After several days—usually 10-14, depending on weather conditions—a partial recovery from this condition may take place. However, the fruits from such recovered plants will not only be greatly reduced in size, but also will be late in maturing.

In the initial field observations it was thought that this malformation might be due to insect punctures at or just below the growing tip. However, subsequent observations both in the greenhouse and in the field have

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