Section IV

New Mexico Pesticide Applicator Training
Agricultural Pests and Agricultural Weeds

Control of Nematodes

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CONTROL OF NEMATODES
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I. INTRODUCTION

This study guide has been prepared specifically for those working in the area of pest management which involves nematodes as parasites of plants. It is not been the intention of the authors to provide an exhaustive study on the subject. However, the study guide covers basic information pertaining to nematodes as pests of cultivated crops in New Mexico, the major economic species, and control methods which have proven effective. A description of the more commonly recommended pesticides used in the state as nematicides is also included. Again, this does not cover all materials available for the purpose but rather those labeled and used most frequently for normal infestations of nematodes attacking commonly cultivated crops in the state.

A. GENERAL INFORMATION

Nematodes are small nonsegmented worms, usually of microscopic size, that must obtain their food from other living organisms. Some are parasitic on plants, others on animals, and still others feed on soil microbes. For the most part nematodes are aquatic organisms that live in soil in a film of water. The plant parasites can attack crops planted for food, fiber, or ornamental purposes. While some species attack the above-ground portions of the plant, the most frequent damage is caused by those species that feed either upon or within the root system. They usually do not kill plants but reduce plant growth, lower crop yields, and damage crop quality. Many species of nematodes in soil are not plant parasites but provide a beneficial function by feeding on soil microoganisms and helping to stimulate nutrient cycling. Approximately 200,000 nematode species have been identified. Of these, more than 3,000 species feed on roots, tubers, stolons, corms, stems, or foliar parts of higher plants.

Characteristics of the nematode esophagus indicate what the nematode will eat. All plant parasitic nematodes have a hollow, needle-like spear called a stylet. Behind the stylet is a muscular esophagus that contains several digestive glands. When a nematode feeds, it inserts its stylet into a plant cell and withdraws plant juices into the esophagus. Sometimes a fluid enzyme from its digestive glands is secreted through the stylet into the plant cell, causing predigestion before ingestion. When the plant juices have been ingested by the nematode, they pass into the intestine where absorption of nutrients occurs.

B. REPRODUCTION

Many nematodes reproduce sexually. Some are hermaphroditic, producing sperm as well as ova, while others reproduce parthenogenetically (that is without males). Males may therefore be rare to non-existent in some species.

The typical life cycle of plant parasitic nematodes is as follows:

1. Females usually produce eggs in the soil or in plants where they feed.

2. Eggs mature into first-stage juvenile nematodes, which molt once and emerge from the egg as second-stage juveniles.

3. The second-stage juveniles locate host plants, begin feeding, and develop through two additional juvenile stages, each separated by a molt of the cuticle.

4. After the last molt, adult females (and males, where they occur) are sexually mature and able to reproduce.

The period of time needed to complete a life cycle varies from species to species and is dependent on the host plant and environmental conditions. The minimum life cycle for root knot nematodes (*Meloidogyne* species) is 18 to 21 days, while the dagger nematodes (*Xiphinema* species) may take up to two years to complete their development. The ability to survive periods of unfavorable environmental conditions also varies from species to species. Since juveniles do not develop unless they feed on a host, they subsist in the meantime on a reserve food supply that originated in the egg. This food reserve lasts longer if the soil is dry or cool; it is soon depleted in warm, moist soils.

With a few exceptions, damage to plants from parasitic nematodes is dependent on high populations. Freezing of the soil diminishes (but does not abolish) the soil population in all temperate climates. Also, cool spring and fall weather retards the nematode metabolism and lengthens the reproductive cycle. In climates where the soil remains warm throughout the year, nematode populations may reach very high numbers. A single female root knot nematode may produce more than 300 eggs; even if only a limited number of these survive to reproduce, given an average life cycle of 25 to 30 days, it is easy to see how a large field population can occur during one growing season.

Some species of plant parasitic nematodes are geographically limited to warm climates. Some are very specific as to the hosts they will attack, while others have a wide host range. Occasionally, a given species of nematode will feed on a plant but appear to be unable to reproduce. In such a situation, the nematode population does not increase and does little, if any, damage. Such plants, or plants where feeding does not occur, are termed "resistant" to a specific nematode. Plants often show various degrees of resistance. Susceptible plants, on the other hand, allow normal nematode reproduction.

C. SYMPTOMS

The above-ground symptoms of nematode damage are seldom specific. The decline of affected plants sometimes goes unrecognized, particularly in the early stages of infection.

Once decline is realized, diagnosis of the nematode species is usually accomplished in the laboratory and pathogenicity is determined by comparing numbers of nematodes from symptomatic plants with numbers from healthy, nearby plants. Superficial examination of the foliage alone is seldom sufficient to determine the causal agent, as only the roots may be

attacked or damaged. Symptoms may be divided into those which appear above ground and those below ground.

1. Above ground symptoms

Stunting is one of the most common above-ground symptoms of nematode damage to the host. This causes a reduction in yield and often in quality. The stunting is more obvious early in the season before the crop canopy closes. If susceptible crops are replanted in successive years, the damage may become increasingly severe, and the infested areas become enlarged. Since nematodes are seldom evenly distributed throughout the field, the symptoms are most often associated with large populations in spotty patches throughout the field.

Abnormal coloration of the foliage, characteristic of nutrient or mineral deficiencies, often results from nematode damage to the roots. The foliage is most often light green and chlorotic, but may show various shades of red, purple, or bronze. Dieback may be associated with foliar discoloration present in plantings of apple, peach, pecan, and other deciduous fruit. The nutritional deficiency is a direct result of root injury that prevents or reduces mineral and fertilizer uptake by the plant. Nematode injury also results in early senescence of annual crops at the end of the growing season.

Wilting of plants with injured roots often occurs under stressed conditions even when adequate soil moisture is present. At first the wilting may be temporary, generally occurring during the heat of the day, with a recovery in the evening. With severe root injury, the infected plants may be killed. Failure to recognize this condition as nematode related may result in unnecessary irrigations which can enhance root rots.

2. Below-ground symptoms

A reduced and necrotic root system is the most common below-ground symptom caused by those nematode species that feed in or on the roots. The amount of root reduction varies with the plant and species of nematode. **Extensive rotting** is probably the result of other pathogens that have invaded the roots and contributed to the overall root decay.

A reduced root system without necrosis or other symptoms may occur from the feeding injury from some ectoparasitic nematodes such as stubby-root nematodes (*Trichodorus* spp.) or sting nematodes (*Belonolaimus* spp.). It is not uncommon to find a reduction of lateral roots and almost total lack of root hairs under such conditions.

Abnormal growth is sometimes found on nematode-infected plants that have few lesions and no general root decay. This is often exhibited as a root proliferation that may appear like a witch's broom. It is also common to find a sprangled root system, in which the meristematic tip of the root is inhibited, and lateral roots are thereby formed. Such crops as beets, onions, or carrots may have normal appearing foliage and yet have a sprangled root system, which makes them totally unmarketable.

Galls may be formed on the roots of many dicotyledenous (broad leaf) plants. Galls may vary in number and range from the size of a pinhead to a nickel. This is probably the most easily recognized symptom produced by plant parasitic nematodes. Galls are most commonly produced by species of root knot nematodes (*Meloidogyne* spp.).

II. PARASITIC HABITS OF PLANT NEMATODES

Plant parasitic nematodes may be conveniently grouped according to their feeding habits into ectoparasites and endoparasites. Ectoparasitic nematodes feed without actually entering the root by inserting their stylets into root tissues. Endoparasitic nematodes invade, feed, and become established within the root tissue. Some nematodes bury only their heads or the forward portion of their bodies in host roots; these forms are called semi-endoparasites.

A. ECTOPARASITES

Ectoparasitic nematodes usually feed on cells in the root primordium or more developed root tissue where the cortex remains functional. These nematodes do not penetrate into root tissue. Their eggs are laid singly in soil near roots; the adults, as well as the juveniles, are capable of moving to new feeding sites throughout their life. Root damage consists of restricted root elongation, accompanied by swelling and blinding of root tips, cell necrosis, and death of feeder roots. If high nematode populations are present, the development of normal roots may be prevented in seedling plants. In general, the presence of ectoparasitic species cannot be diagnosed on the basis of root symptoms alone; it is necessary to verify their presence by comparative soil sampling. Some ectoparasitic species such as *Xiphinema*, *Longidorus* and *Trichodorus* are also vectors of certain plant viruses.

B. ENDOPARASITES

Endoparasitic nematodes can be divided into two types: migratory and sedentary. Sedentary endoparasites are characterized by females which are swollen and saccate (pear-shaped), and partially or completely embedded in plant tissue. Active second-stage juveniles in the soil are usually the infective stage. Once inside the root, these juveniles induce host tissue to change into specialized feeding sites that act as nutrient reservoirs on which the nematode feeds throughout the remainder of its life. These tissue changes disrupt normal root uptake of water and nutrients. Root galls which form around root knot nematodes are easily seen by visual examination. Cyst nematodes do not form root galls, and adult females are exposed on root surfaces.

Migratory endoparasites differ from sedentary forms in that all stages of the life cycle remain vermiform. All stages are infective and may be present in the roots or soil, although most will be present in the roots where feeding occurs. The principal plant injury by migratory endoparasites is destruction of cortical tissue. In some host plants, however, colonies of nematodes in the larger roots cause necrotic areas or lesions, which may girdle even very large roots. Migratory endoparasites also cause wounds that allow other pathogens to invade and further damage roots.

III. NEMATODES OF IMPORTANCE IN NEW MEXICO

While many species of plant parasitic nematodes may be recovered from plant and soil samples in New Mexico, only one genus causes widespread damage for the agricultural producer and the homeowner-- *Meloidogyne* spp. or root knot nematodes. Another species, *Ditylenchus dipsaci* (alfalfa stem nematode) has been reported in the state and is a potentially serious pest of onions and alfalfa.

A. ROOT KNOT NEMATODES

A serious problem for New Mexico agriculture is the root knot nematode, *Meloidogyne* spp. Plants infected by root knot nematodes have reduced root systems and poor top growth; the foliage is frequently chlorotic (yellow) because essential elements are not taken in and transported by the impaired root system. Supplying additional fertilizers may correct the chlorosis but will not increase growth and crop yields to satisfactory levels.

1. Life cycle and pathogenicity

Second-stage infective juveniles hatch from eggs and invade roots in the region of elongation near the root tip. They migrate between and through cells and position themselves with their head in the differentiating vascular tissue. Cell damage occurs as a result of juvenile migration and feeding. During feeding, several cells near the head of the nematode begin to enlarge and become multi-nucleate feeding sites. These are called giant cells, and usually three to six of these cells are associated with each nematode. Galls are formed by an increase in the number and size of cortical cells surrounding the developing sedentary endoparasitic nematode.

As giant cells form, the xylem becomes disrupted and the flow of water and nutrients in the plant is interrupted. The nematodes undergo the second, third, and fourth molts to become adults. Mature females, which are swollen and saccate, lay eggs into a gelatinous matrix. This matrix may protrude from the surface of small roots or be contained entirely within the gall. Eggs hatch in about seven days after favorable conditions; at 70°F, the entire life cycle is completed in 20 to 25 days. Males are vermiform and not required for reproduction. Root galls may be very small, or large and massive, depending on the root knot species involved and the host plant. In many instances, secondary organisms contribute to root decay.

2. Distinguishing features

a. Numerous small, spindle-shaped to large, spherical galls may appear on roots of all sizes. Galls are numerous in highly infested plants of most dicotylendous (broad leaf) crops. Galls are small or absent entirely in most monocots (grains).
b. Small brown pits in galls containing nematodes (eggs, juveniles, or adults) are visible with a hand lens or, preferably, a dissecting microscope or low power of a compound microscope, when galls are sectioned with a sharp razor blade. Galls formed by *Rhizobium* nitrifying bacteria do not form these pits and are pink or greenish in cross section.
c. Microscopic jellybean-shaped eggs, embedded in a gelatinous mass, may often be seen on tiny feeder roots.

3. Field symptoms

While there are some rather definite symptoms in the tops of nematode-infested plants, it is never safe to make a diagnosis without checking the root systems of the plants in question. Wilting in the afternoon, when soil moisture is adequate, is the first symptom. Death of seedlings, usually from *Rhizoctonia* or other fungi, following nematode infection, may greatly reduce the stand (as in cotton); or plants may be stunted or unproductive as a result of early infection. Very susceptible succulent annuals (vegetables and flowers) often suffer severe leaf burn and die in mid-season. Annual crops may mature earlier in the season and show reduced yield due to root knot nematode infection. When woody plants are unthrifty, **check the roots.**

4. Host plants

Approximately 5,000 plant species and varieties are hosts of root knot nematodes, including most cultivated crops and ornamentals. These include tomato, squash, melons, carrots, cotton, beans, chile, sugarbeets, alfalfa, lettuce, celery, soybean, peach, grapes, pecans, almonds, fig, olive, turf grasses, potatoes, sweet potato, barley, corn, rice, and roses.

5. Distribution

The distribution of root knot nematodes is worldwide, but more common in temperate, subtropical, and tropical areas. The cosmopolitan distribution of some species is the result of the movement of rooted plants in commerce. Locally, infestations are spread through movement of irrigation water, soil, equipment, and rooted seedlings. Practically all cultivated acreage in the state has been contaminated with root knot nematodes. However, these pests rarely persist in heavy textured soils with less than 50 percent sand content.

6. Species

a. *Meloidogyne incognita:* In New Mexico this root knot nematode is prevalent throughout the state. It is the principal nematode pest and probably responsible for greater economic losses than those caused by all other species of nematodes combined. It can be a serious root pathogen of all annual crops in sandy soils. High soil temperatures and extended growing seasons of such crops as cotton and chile favor the development of the maximum number of root knot generations. Optimum conditions are available for the nematode during the summer months, and as many as five generations have been recorded from a cotton crop. Although found in higher elevations in the state, it is of less concern in those areas because there are fewer cultivated crops. It is frequently a problem to the homeowner, however, as a pest of ornamentals and vegetable crops.

b. *Meloidogyne hapla:* The infrequent occurrence of this root knot species indicates that it also has been introduced into the state through infested soil or on plant material. This species has been associated with disease problems in peanuts, but poses a threat to beans, carrots, onions, and alfalfa as well. Unlike *Meloidogyne incognita,* this species will not develop on grasses or grain crops.

7. Control measures

Unfortunately no crops grown in New Mexico are non-hosts, and resistant varieties are only available in alfalfa at this time.

Some nondormant varieties of alfalfa developed in the Southwest appear to have excellent tolerance to *M. incognita*. Semi-dormant varieties, however are all susceptible to the pest. Furthermore, there is progress in developing and selecting cultivars that have complete immunity to the root knot species. This will allow these crops to be grown profitably for several successive years, with a susceptible crop following, and no need for chemical control.

Summer fallowing is highly effective for controling root knot nematodes. However, weeds or volunteer plants must be removed before the nematodes complete a life cycle to prevent a population increase, which serves as inoculum for the following crop. Where winter vegetables are planted in late summer or early fall, the general practice is to use chemical controls when populations have increased. Winter-grown potatoes, with the growing season extending into an unseasonably warm spring, can be severely galled, with serious economic losses. If this crop is to follow one infested with root knot nematodes, growers are advised to apply nematicides, since even a light infection may reduce quality, resulting in nonedible potatoes. *M. incognita* and *Verticillium albo-atrum* both attack cotton in the field; however, only under greenhouse conditions has it been possible to prove an additive relationship between the two pathogens. Damping-off of seedlings caused by *Rhizoctonia* was considered at one time to be more severe when root knot nematodes were present. Effective control of fungal seedling diseases by fungicide seed treatment has reduced infections. Research is currently underway in New Mexico to investigate the relationship between root knot nematodes, other pathogens, and weeds; and to identify and transfer nematode resistance into locally important chile and cotton cultivars.

Control of root knot nematodes attacking greenhouse-grown crops is relatively simple. First, precaution should be taken to use only healthy transplants and fumigated or sterilized planting soil. If infestation of the premises does occur, use of a volatile soil fumigant such as 1,3-dichloropropene is recommended before the next susceptible crop is planted.

Where annual crops are grown in New Mexico nematicides must be applied prior to planting, when needed. Chile is the crop most frequently damaged by root knot nematode, but cotton and onions may also benefit from control of this pest. For control in perennial crops such as grape, preplant and/or postplant applications of nematicides are required and recommended.

B. Alfalfa Stem Nematodes

The alfalfa stem nematode, *Ditylenchus dipsaci,* is an alfalfa pest that could significantly reduce hay yields in New Mexico. This nematode is most active during the wetter, cooler fall and spring months, although they are present in the plant throughout the year. Free moisture on the plant favors nematode movement and infection. Fortunately, these conditions seldom occur when temperatures are favorable for nematode development, which may explain why this pest has not become a serious problem in the state. Populations increase only when conditions are optimum for nematode reproduction, and alfalfa growth is subsequently retarded. Stands are thinned as many infected plants die. Plant death is a direct result of nematode infection and weakening, which makes the plant more susceptible to other pathogenic organisms.

The alfalfa stem nematode has the unique ability to survive for extended periods of time during unfavorable weather conditions. In preadult form, the worms can become completely inactive and survive for over 15 years in a dessicated, quiescent stage. When sufficient moisture is available, they revive; however, the surviving population is greatly reduced. Under field conditions, where nematodes are protected by host tissue, they can remain alive but inactive for several months during hot weather. With fall rains and reduced temperatures, the worms revive and reproduction begins immediately. Each female produces up to 500 eggs, which hatch in two to seven days after being deposited in the stem and bud tissue upon which the female has been feeding as a migratory endoparasite. The juveniles may feed in the area where they hatch, or they may move to upper stems of the plant in a film of water.

Chemical control measures are difficult because the nematode is protected by its habit of feeding under the leaf sheaths and in developing buds.

Cultural practices can greatly help reduce infection or spread of the population throughout the entire field. Hay should be harvested when the top 5-8 cm of soil is dry. Avoid irrigation immediately following cutting. Additionally, a two to three year crop rotation with non-hosts such as grains, beans, or corn usually reduces the population below detection levels.

Care should also be exercised in transferring sheep from infected fields to noninfected fields, as contaminated hay and soil may adhere to the fleece and hooves. Equipment used in infected fields can also transfer these nematodes. Balers and hay-hauling trailers can also transport the nematode, which is present and viable in cut alfalfa. Varieties resistant to the stem nematode are usually winter dormant types and adapted only for higher elevations in New Mexico.

IV. OTHER NEMATODE SPECIES IN NEW MEXICO

While other species of plant parasitic nematodes can be recovered from soil and root samples of crops grown in the state, they usually occur in such low populations that they are of little economic importance to the grower. Present control measures are usually not recommended because the economic damage from the pest is often less than the cost of available chemical control measures.

Root lesion nematodes, *Pratylenchus* spp., can be recovered from many plant hosts throughout the state. Significant stunting and seedling death occurs occasionally in corn, wheat, and carrots due to this pest in New Mexico. Populations can increase in great numbers, especially in perennial crops such as grapes, alfalfa, peach, and apple. They can also be recovered from annual crops such as cotton, peanuts, and milo. In spite of certain difficulties, control of these migratory endoparasitic nematode species is possible through crop rotation, fallowing, and chemical control measures.

The American dagger nematode, *Xiphinema americanum*, is another ectoparasitic species commonly recovered from New Mexico soils. It parasitizes practically all cultivated crops and many native plants. Large populations can occur on ornamentals, alfalfa, and grape. Chemical control of the nematode has not increased yields in these crops. A related species, *X. index,* has never been reported in the state, which is fortunate as it is capable of transmitting fan leaf virus of grape.

The stubby root nematode, *Trichodorus* spp., is a migratory ectoparasite. It can be a serious seedling pest of alfalfa and vegetables. Attempts to control this nematode with nematicides have been successful, but effects are limited to the immediate crop and season.

V. CONTROL OF PLANT PARASITIC NEMATODES

In general, measures for combating these pests fall into four broad categories: chemical control, crop rotation, cultural practices, and resistant varieties. It should be emphasized that it is impossible to eradicate nematode infestations under field conditions. This fact intensifies the problem for growers of perennial plants such as fruit and nut trees and vines, because pest resurgence can occur in a relatively short time even after effective treatment. Farmers who grow annuals such as cotton or chile may fumigate the soil before planting the susceptible crop--a highly effective method of reducing nematode populations.

The particular method used to reduce nematode injury must be selected with knowledge of the life cycle of the species involved, the reproductive potential of that species, the type of crop, the soil characteristics and, most importantly, the degree of control necessary to give economic yields of the crop to be planted. There are two types of nematicides that help control nematodes: soil fumigants and non-fumigant nematicides.

A. SOIL FUMIGANTS

Soil fumigants must be used only as preplant treatments. These materials are liquids that turn into gases in the soil and kill nematodes, as well as many insects, fungi, weed seeds, and roots of living plants. Any fumigant still present in the soil at the time of seed germination will also damage the emerging plant. Different fumigants vary in efficacy against other pests such as weeds and fungi. Refer to the label when considering use of such a product for multiple pest control.

1. Conditions for preplant application of fumigants

Proper soil preparation prior to fumigation is a fundamental part of the procedure. An applied fumigant is only as good as the prior soil preparation.

The first important step is to get all crop residue plowed under and decomposed well before fumigation. This is a "must" because the fumigant cannot penetrate the plant material, allowing those nematodes inside to escape. This is particularly true with the root knot nematodes, *Meloidogyne* spp., and the root lesion or meadow nematodes, *Pratylenchus* spp., which live inside the plant tissue. Particular care should be taken with fleshy crops such as potatoes and carrots, which may remain alive in the soil after harvest and harbor nematodes. In most cases a month should be allowed between the time of plowing or discing the residues under and the fumigation. In addition to harboring nematodes, any trash on a field will be picked up by the injection shanks and reduce the efficiency of the operation.

Another important step in soil preparation is breaking up large clods. Soil fumigants do not penetrate large clods easily. Clods also leave the soil too loose and open, permitting rapid escape of the fumigant from the soil and reducing lateral and downward penetration. Breaking up any hard spots or plow layers also helps. A fumigant will penetrate only so far from its injection point, and any barrier will reduce the distance of maximum diffusion.

Once the soil has been properly prepared, the two most important factors in determining the degree of success of a fumigation are moisture and temperature.

Soil moisture at time of fumigation should be comparable to that at planting, that is, approximately 50 percent of field capacity or its moisture equivalent, depending on soil texture. A proper soil moisture content to the desired depth of penetration enables the fumigant to diffuse readily through the soil. Very high soil moisture hinders fumigant penetration around the soil particles and restricts proper aeration. Very low soil moisture permits the fumigant to leave the soil too rapidly to be effective.

Soil temperature at time of fumigation should range between 50° and 80°F at the point of injection. Higher temperatures result in a rapid movement of the fumigant through the soil, and lethal concentrations cannot be maintained. Lower temperatures result in a slow rate of fumigant movement and hinder proper aeration, necessitating a longer waiting period between fumigation and planting.

It should be remembered that the most effective fumigation will be obtained in warm, moderately dry soils.

2. Application methods

There are two methods of application used in the Southwest in field scale operations: broadcast or overall, and row treatment. To prepare for broadcast application, the soil should be worked as soon after harvest as possible, and at intervals prior to fumigation. This insures that the soil will be reasonably free of plant residues, clods, and lumps. In short, the procedure is the same as preparing a good seed bed. When the soil moisture and temperature are within the ranges given above, the soil is ready for fumigation.

For row fumigation, most commonly used in the Southwest for row crops such as chile and cotton, the soil is prepared as described above. The soil is then bedded up. The fumigant is applied only under the rows where the crop is to be planted or on either side of the seed bed, the distance depending upon the particular nematicide being applied.

In broadcast or row application of fumigants, chisel cuts or injection holes are formed. Unless these are filled and sealed, some fumigant will escape. Sealing can be accomplished in several ways. With broadcast treatment, sealing can be done by using a harrow, followed by a drag or float. Cultipackers work equally well. Sealing row fumigation on beds can best be accomplished with a ring-roller fitting the contour of the bed.

3. Exposure period

The exposure period necessary for adequate control differs with the various fumigants, and with the different organisms against which they are used. Consult the label for the latest recommendations. In general, however, the liquid fumigants require a one-week exposure period to control nematodes adequately, plus time to allow phytotoxic residues to decrease in the soil. The exposure period may need to be increased if fumigation is followed by cold or wet weather.

In summary, successful soil fumigation depends principally on the soil condition at time of fumigant application. The soil must be in good seed bed condition; it must not be either too wet or too dry, and the soil temperature must be in the range between 50 and 80°F. Proper filling and sealing of the cuts made by the applicator chisels is also important.

B. NON-FUMIGANT NEMATICIDES (CONTACT AND SYSTEMIC)

These nonvolatile compounds can be applied by broadcast or banding over the seed bed followed by mixing into soil, in the seed furrow, or side dressing in the bed. They are usually distributed by water movement in the soil. In the case of systemics, the material is taken up by the plant and remains toxic to the nematode for various periods of time, depending upon the specific compound. **In recommending such agricultural chemicals, the pest control advisor should be thoroughly familiar with the label and make sure the product has been cleared for use on the crop to be treated.**

C. IMPORTANCE OF PROPER PREPARATION

Regardless of the method of nematicide application, it is important to emphasize that the most important step in effective control of plant parasitic nematodes is proper soil preparation. Important considerations include preventing clods to ensure even fumigant distribution, hinder rapid escape, reduce particle size of crop residues and expedite decomposition, early preparation to ensure complete decomposition of previous plant residues, allowing extra time for fibrous or large storage roots to decompose, in warmer zones, eliminating weeds that may be hosts to nematodes, and ensuring correct moisture content and temperature of soil. All are important to obtain satisfactory control of nematode pests.

Having followed the essential preparation rules, the next step is to select the application method that will give the greatest degree of control, is most economical, and can best be used under the particular cultural situation.

VI. PRODUCTS RECOMMENDED AS NEMATICIDES

This list is intended to familiarize you with products that are recommended for nematode control by the manufacturer. The listing is not an endorsement and you should always read and follow label instructions.

Soil Fumigants

Chemical Name: 94% 1,3-dichloropropene
Formulation: A clear liquid for pre-plant treatment of soil to control plant parasitic nematodes and other soil pests for vegetable, field, tree, ornamental, and nursery crops.

Chemical Name: Metam Sodium
Formulation: Water-soluble liquid that is recommended to control certain weeds, nematodes, and soilborne diseases.

Systemic Insecticide-Nematicide

Chemical Name: Aldicarb
Formulation: Granule

Chemical Name: Carbofuran
Formulation: Granule, flowable, wettable powder

Chemical Name: Fenamiphos
Formulation: Emulsifiable concentrate, granule, oil-in-water emulsion

Chemical Name: Oxamyl
Formulation: Water soluble liquid 2 lbs/gal

Chemical Name: Terbufos
Formulation: Granule

Non-Systemic Insecticide/Nematicide

Chemical Name: Ethoprop
Formulation: Emulsifiable concentrate, granules

VII. CULTURAL CONTROL

Rotations that include resistant plants can be effective in reducing the damage caused by many nematodes. Frequently, for low-value crops this may be the only practical method.

A crop that is harvested in late fall such as cotton or chile and is followed by a clean summer fallow may permit the grower to return in the early fall or the following spring with susceptible crops with minimal fear of economic losses. The high temperatures in desert soils are effective in reducing most species of nematodes, provided the fields are free of weeds, and especially if the soil is disced once or twice during the summer months. Where possible, discing should follow summer rains, thereby reducing possible establishment of weeds that may serve as nematode hosts.

Another practice that should be stressed under cultural control methods is that crops damaged by root-infecting nematodes of any kind should not be allowed to stand in the field for a long time after harvest. These should be destroyed immediately to expose the roots to the drying action of the wind and sun. This is a highly desirable practice, whether or not the field is to be fallowed or treated with nematicides.

Although usually impractical for large-scale use, the addition of organic matter and mulching may create conditions that help reduce nematode populations. This may result in increased plant vigor, or provide favorable conditions for growth and reproduction of natural enemies. In home gardens, nurseries, or high-cash crops on limited acreage, consideration may be given to this method of control.

GLOSSARY

cultivar - an accepted term for a variety of a man-made selection of a particular plant.

ectoparasitic - feeding on exterior of roots.

endoparasitic - penetrating into the root and feeding there.

hermaphroditic - having both male and female organs.

meristematic - pertaining to the area of plant tissue dividing and responsible for growth.

multi-nucleate - having many nuclei.

necrosis - dead tissue.

parthenogenetic - capable of reproducing without fertilization.

pathogenic - able to incite a condition that results in disease.

pest control advisor (PCA) - individual who is qualified to make recommendations for use of agricultural chemicals.

phloem - plant tissue responsible for conducting nutrients through plants.

Rhizobium - beneficial bacteria that produce root galls and provide nitrogen for plant use.

Rhizoctonia - one of several fungi responsible for damping-off.

saccate - globose, pear or lemon shaped.

semi-endoparasitic - partially penetrating and feeding on root.

vermiform - wormlike in appearance.

Verticillium albo-atrum - fungus causing wilt disease.

xylem - woody tissue of a plant that gives firmness and conducts water.

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