UF UNIVERSITY of FLORIDA
IFAS Extension

Nematode Management in Potatoes (Irish or White) [1]

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The most important nematode pests of potatoes in Florida are species of root-knot, sting, and stubby-root nematodes (principally *Meloidogyne incognita*) which infest roots and tubers, causing root injury that severely reduces yields and may accelerate the "early dying disease." Root-knot nematode galling of tubers is a serious quality defect (Figure 1). Sting nematodes cause pruning, stunting (Figure 2), and necrosis of roots, depressing yields significantly; high populations of sting nematodes are often associated with severely misshapen, scruffy, and abnormally russetted tubers. Stubby root nematodes apparently cause little direct damage to potatoes, but are important as vectors of tobacco rattle virus, which causes corky ringspot disease in the Hastings region of northeast Florida. Several other nematodes, including spiral, lesion, awl, stunt, and sheath are occasionally associated with reduced yields or quality of potatoes in Florida.

Nematode species and population levels, incidence of soil-borne diseases and insects, soil moisture at field preparation time, and the intended market for the potatoes can all affect the choice of nematode control measures. Growers should use a combination of as many different kinds of control

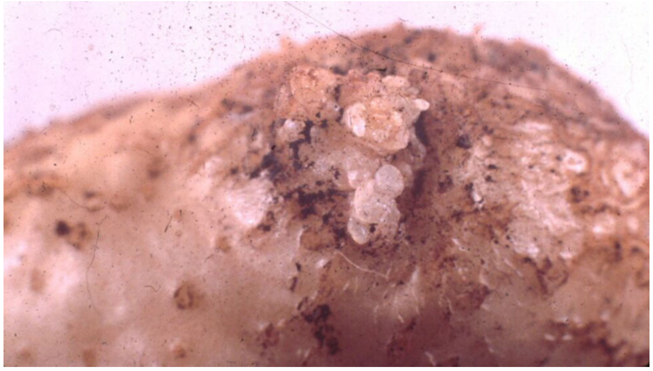

Figure 1. Root-knot nematode (*Meloidogyne* spp.) induced galls on potato giving a warty tuber surface appearance.

Figure 2. Sting nematode, *Belonolaimus longicaudatus*, induced stunting of potato.

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measures as feasible, since none provides perfect protection for the crop.

General IPM Considerations

Integrated pest management (IPM) for nematodes requires: 1) determining whether pathogenic nematodes are present within the field; 2) determining whether nematode population densities are high enough to cause economic loss; and 3) selecting a profitable management option. Attempts to manage nematodes may be unprofitable unless all of the above IPM procedures are considered and carefully followed. Similarly, some management methods pose risk to people and the environment. Therefore it is important to know that their use is justified by actual conditions in a field and that certified applicators are overseeing their use.

Symptoms

Typical symptoms of nematode injury can involve both above ground and below ground plant parts. Foliar symptoms of nematode infestation of roots generally involve stunting and general unthriftiness, premature wilting and slow recovery to improved soil moisture conditions, leaf chlorosis (yellowing) and other symptoms characteristic of nutrient deficiency. An increased rate of ethylene production, thought to be largely responsible for symptom expression in tomato, has been shown to be closely associated with root-knot nematode root infection and gall formation. Plants exhibiting stunted or decline symptoms usually occur in patches of nonuniform growth rather than as an overall decline of plants within an entire field.

The time in which symptoms of plant injury occur is related to nematode population density, crop susceptibility, and prevailing environmental conditions. For example, under heavy nematode infestation, crop seedlings or transplants may fail to develop, maintaining a stunted condition, or die, causing poor or patchy stand development. Under less severe infestation levels, symptom expression may be delayed until later in the crop season after a number of nematode reproductive cycles have been completed on the crop. In this case aboveground symptoms will not always be readily apparent early within crop development, but with time and reduction in root system size and function, symptoms become more pronounced and diagnostic.

Root symptoms induced by sting or root-knot nematodes can oftentimes be as specific as aboveground symptoms. Sting nematode can be very injurious, causing infected plants to form a tight mat of short roots, oftentimes assuming a swollen appearance. New root initials generally are killed by heavy infestations of the sting nematode, a symptom reminiscent of fertilizer salt burn. Root symptoms induced by root-knot cause swollen areas (galls) on the roots of infected plants. Gall size may range from a few spherical swellings to extensive areas of elongated, convoluted, tumorous swellings which result from exposure to multiple and repeated infections. Symptoms of root galling can in most cases provide positive diagnostic confirmation of nematode presence, infection severity, and potential for crop damage.

Damage

For most crop and nematode combinations the damage caused by nematodes has not been accurately determined. Most vegetable crops produced in Florida are susceptible to nematode injury, particular by root-knot and sting nematodes. Plant symptoms and yield reductions are often directly related to preplant infestation levels in soil and to other environmental stresses imposed upon the plant during crop growth (Figure 3). As infestation levels increase so then do the amount of damage and yield loss. In general, the mere presence of root-knot or sting nematodes suggests a potentially serious problem, particularly on sandy ground during the fall when soil temperatures favor high levels of nematode activity. At very high levels, typical of those which might occur under doubling cropping, plants may be killed. Older transplants, unlike direct seed, may tolerate higher initial population levels without incurring as significant a yield loss.

Field Diagnosis and Sampling

Because of their microscopic size and irregular field distribution, soil and root tissue samples are usually required to determine whether nematodes are causing poor crop growth or to determine the need for nematode management. For nematodes, sampling and

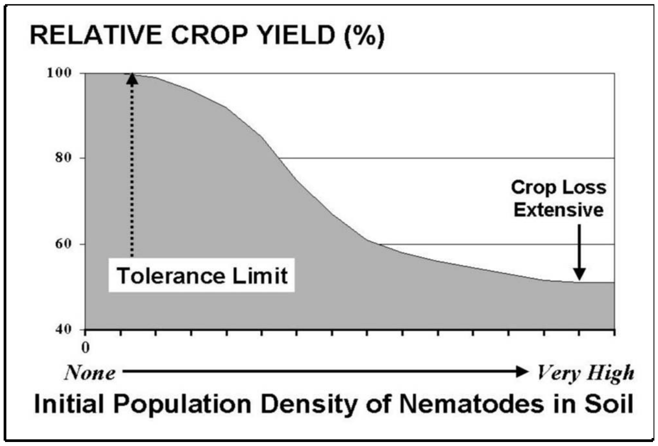

Figure 3. Typical nematode induced crop damage relationship in which crop yields, expressed as a percentage of yields that would be obtained in the absence of nematodes, decline with increased population density of nematodes in soil. The tolerance level is identified as the initial or minimal soil population density at which crop damage is first observed.

management is a preplant or postharvest consideration because if a problem develops in a newly planted crop there are currently no postplant corrective measures available to rectify the problem completely once the nematode becomes established. Nematode density and distribution within a field must therefore be accurately determined before planting, guaranteeing that a representative sample is collected from the field. Nematode species identification is currently only of practical value when rotation schemes or resistant varieties are available for nematode management. This information must then be coupled with some estimate of the expected damage to formulate an appropriate nematode control strategy.

Advisory or Predictive Sample (Prior to Planting)

Samples taken to predict the risk of nematode injury to a newly planted crop must be taken well in advance of planting to allow for sample analysis and treatment periods if so required. For best results, sample for nematodes at the end of the growing season, before crop destruction, when nematodes are most numerous and easiest to detect. Collect soil and root samples from 10 to 20 field locations using a cylindrical sampling tube, or if unavailable, a trowel or shovel (Figure 4). Since most species of nematodes are concentrated in the crop rooting zone, samples should be collected to a soil depth of 6 to 10 inches. Sample in a regular pattern over the area, emphasizing removal of samples across rows rather than along rows (Figure 5). One sample should represent no more than 10 acres for relatively low-value crops and no more than 5 acres for high value crops. Fields which have different crops (or varieties) during the past season or which have obvious differences either in soil type or previous history of cropping problems should be sampled separately. Sample only when soil moisture is appropriate for working the field, avoiding extremely dry or wet soil conditions.

Figure 4. The collection of soil samples for nematode analysis can be acquired from the field using either cylindrical sampling tubes, trowels, bucket auger, or shovel.

Diagnostics on Established Plants

Roots and soil cores should be removed to a depth of 6 to 10 inches from 10 to 20 suspect plants. Avoid dead or dying plants, since dead or decomposing roots will often harbor few nematodes. For seedlings or young transplants, excavation of individual plants may be required to insure sufficient quantities of infested roots and soil. Submission of additional samples from adjacent areas of good

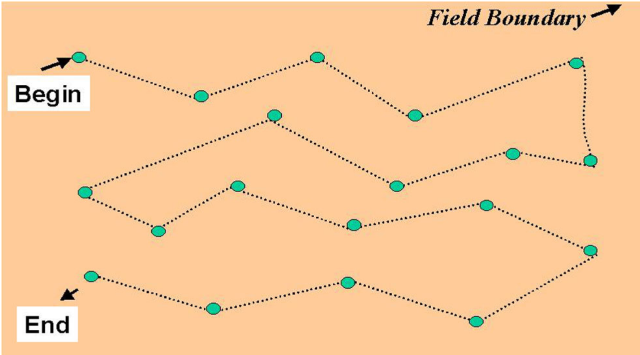

Figure 5. Suggested pattern for collecting preplant soil samples for nematode analysis based on compositing soil from 10-20 field locations.

growth should also be considered for comparative purposes (Figure 6).

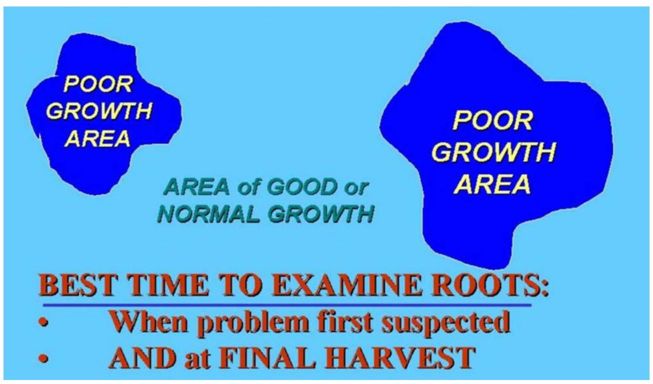

Figure 6. Suggested strategy for collecting post-plant soil samples for nematode analysis comparing sampling results from areas of good and poor plant growth.

For either type of sample, once all soil cores or samples are collected, the entire sample should then be mixed thoroughly but carefully, and a 1 to 2 pint subsample removed to an appropriately labeled plastic bag. Remember to include sufficient feeder roots. The plastic bag will prevent drying of the sample and guarantee an intact sample upon arrival at the laboratory. Never subject the sample(s) to overheating, freezing, drying, or to prolonged periods of direct sunlight. Samples should always be submitted immediately to a commercial laboratory or to the University of Florida Nematode Assay Laboratory for analysis. If sample submission is delayed, then temporary refrigerated storage at temperatures of 40 to 60°F is recommended.

Recognizing that the root-knot nematode causes the formation of large swollen areas or galls on the root systems or tubers of susceptible crops, relative population levels and field distribution of this nematode can be largely determined by simple examination of the crop root system for root gall severity. Root gall severity is a simple measure of the proportion of the root system which is galled. Immediately after final harvest, a sufficient number of plants should be carefully removed from soil and examined to characterize the nature and extent of the problem within the field. In general, soil population levels increase with root gall severity. This form of sampling can in many cases provide immediate confirmation of a nematode problem and allows mapping of current field infestation. As inferred previously, the detection of any level of root galling usually suggests a nematode problem for subsequent planting of a susceptible crop, particularly within the immediate areas from which the galled plant(s) were recovered.

General Management Considerations

Currently nematode management considerations include crop rotation of less susceptible crops or resistant varieties, cultural and tillage practices, use of transplants, and preplant nematicide treatments. Where practical, these practices are generally integrated into the summer or winter 'off-season' cropping sequence. It should be recognized that not all land management and cultural control practices are equally effective in controlling plant parasitic nematodes and varying degrees of nematode control should be expected. These methods, unlike other chemical methods, tend to reduce nematode populations gradually through time. Farm specific conditions, such as soil type, temperature, moisture, can be very important in determining whether different cultural practices can be effectively utilized for nematode management. In most cases, a combination of these management practices will substantially reduce nematode population levels, but will rarely bring them below economically damaging levels. This is especially true of lands which are continuously planted to susceptible crop varieties. In these cases some form of pesticide assistance will still usually be necessary to improve crop production. For further explanation and details of general management considerations in this document, see the section called “Nematode Management for Vegetable Crops in Florida”.

Crop Rotation

Crop rotation with unrelated crops is a sound practice for reduction of several kinds of soil-borne problems. Many potato fields which have very high numbers of damaging nematodes have been cropped annually to potatoes or many years. While it is not possible to find rotation and cover crops which will reduce populations of all nematode pests of potatoes, it might be helpful to alternate potatoes with crops which are least favorable to the root-knot nematodes, the most difficult nematodes to control with chemicals. Cabbage is a poor crop to rotate with potatoes, because it is susceptible to many of the same nematodes.

Soil Management Practices

Land should be disked as soon as possible after a crop is harvested from it, to ensure death and desiccation or decomposition of all host plant tissues. Populations of nematodes, fungi, and other soil-borne pests can continue to feed and reproduce on roots, stolons, etc. that remain alive after harvest, so prompt disking will help reduce total build-up of those pests. If other cultural considerations make it practical, a brief period of fallow during hot weather, during which the land is disked at least twice to expose additional soil to desiccation and sunlight, can reduce populations of nematodes. Prolonged periods of fallow are generally not recommended because of the potential for soil loss by erosion and loss of soil organic matter by oxidation.

Varietal Resistance

No potato varieties commercially available have resistance to any of the nematode pest encountered in Florida. However, several varieties have effective resistance to corky ringspot (CRS) disease which is transmitted by stubby-root nematodes; these should be planted in fields where CRS is known to occur. These resistant varieties include 'Pungo,' 'Green Mountain,' 'Bel Rus,' 'Hudson,' and 'Superior.' Bacterial wilt caused by the bacterium, *Pseudomonas solanacearum*, can be more severe when root-knot nematodes are present. The varieties 'Sebago' and 'Green Mountain' have tolerance to bacterial wilt, and should be used in conjunction with a fumigant nematicide where these two problems occur together.

Chemical Control

Most fields in which nematodes have previously damaged potatoes or other crops should be treated with chemical nematicides to improve potato production. Other management procedures may combine to substantially reduce population levels of nematode pests, but they will rarely bring them below damaging levels. This is especially true on land that is intensively cropped to potatoes and other crops susceptible to the same nematodes. Nematicides which may be used for potato production in Florida are listed in the following tables. Selection of a nematicide should be based on the kinds of nematodes and soil-borne diseases present in the field, field conditions at soil preparation time, and the intended market (degree of control needed). For example, if CRS is a problem, use of the CRS resistant variety 'Superior' for the table market should be considered in combination with Telone or Metham sodium soil fumigation.

Nonfumigant Nematicides

All of the nonfumigant nematicides currently registered for use in potatoes are soil applied, with the exception of Vydate, which can also be applied foliarly. They must be incorporated with soil or carried by water into soil to be effective (Figure 7). These compounds must be uniformly applied to soil, targeting the application toward the future rooting zone of the plant, where they will contact nematodes or, in the case of systemics, in areas where they can be readily absorbed and taken up into the plant. Non-fumigant materials work best in moist soils, generally above 12 to 15% moisture. Placement within the top 2 to 4 inches of soil should provide a zone of protection for seed germination, transplant establishment, and protect initial growth of plant roots from seeds or transplants. Most studies which have been performed in Florida and elsewhere to evaluate non-fumigant nematicides have not always been consistent, either for controlling intended pests or for obtaining consistent economic returns to the grower, particularly when compared with conventional preplant mulched fumigation with broadspectrum fumigants such as metham sodium or Telone. As the name implies, they are specific to nematodes, requiring integrated use of other cultural or chemical pest control measures to manage other weed and disease pests. Many are reasonably mobile and are readily leached in our sandy, low organic soils, thus requiring special consideration to irrigation practices and management.

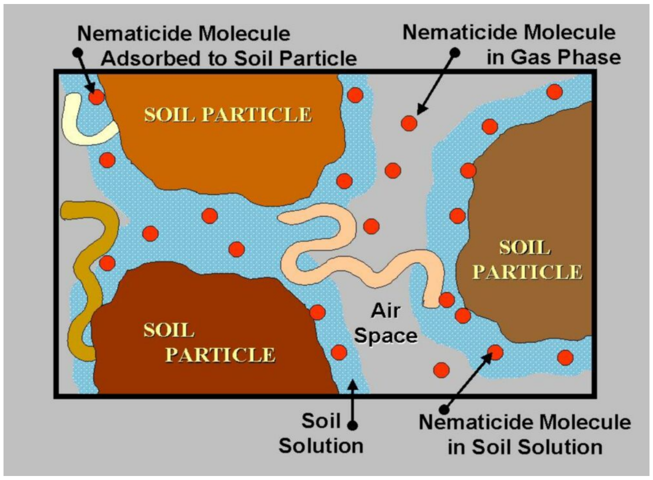

Figure 7. Nematode as aquatic organisms encountering both liquid and gas phase nematicides in soil.

Although sometimes less effective than soil fumigants, the non-fumigant nematicides listed in Table 1 can provide a profitable level of nematode control if used properly. Their active ingredients are not redistributed through the soil as gases, unlike the fumigants. Therefore, uniform distribution of the products at the time of application is very important. It is very difficult to get adequately uniform distribution by rototilling over a band application. Experience in other states suggests that the best distribution of product, hence best nematode control and least chance of phytotoxicity, is accomplished by broadcast application followed by double-disking with a finishing disk set 6 to 8" deep. The beds are formed from the soil layer into which the nematicide has been incorporated, so that it is mixed throughout the beds. Uniform application appears to be especially critical for Mocap, as poor distribution may result in very little nematode control and a net decrease in yield.

Temik has been frequently used in fields where CRS has been a reoccurring problem. Mocap EC, or Vydate L can also be used in fields in which stubby root nematode and CRS occurs. Soil fumigation does not effectively control the disease under Florida growing conditions, but these non-fumigants have significantly reduced CRS and other superficial tuber defects associated with nematode damage. Recent studies here in Florida have also indicated that nematode and disease control and potato yield increase were enhanced when the nonfumigant Mocap EC (applied on a broadcast basis) and or Vydate L (applied as late season foliar applications) were used following application of a registered fumigant nematicide (Telone II or Metham sodium).

Non-fumigants nematicides can be applied to the ridged rows used in northeast Florida by using a suitable applicator (Noble, Gandy, etc.) attached to the planter. Board off rows so that a 12 to 14" wide flattened surface is formed on the rows. Attach the spreading shoe of the applicator immediately in front of the first opening disks of the planter. Apply granules in 12 to 14" wide bands. The action of the planter incorporates the granules into the soil. Apply Temik with positive displacement system and as further directed by the product label, throwing up the bed over a 6" band of the product.

Fumigant Nematicides

In Florida, use of broadspectrum fumigants (Table 2) effectively reduces nematode populations and increases vegetable crop yields, particularly when compared with nonfumigant nematicides. Since these products must diffuse through soil as gases to be effective, the most effective fumigations occur when the soil is well drained, in seedbed condition, and at temperatures above 60°F. Fumigant treatments are most effective in controlling root-knot nematode when residues of the previous crop are either removed or allowed to decay. When plant materials have not been allowed to decay, fumigation treatments may decrease but not eliminate populations of root-knot nematodes in soil, particularly nematodes within the egg stage. Crop residues infested with root-knot nematode may also shelter soil populations to the extent that significantly higher rates of application may be required to achieve nematode control. To avoid these problems, growers are advised to plan crop destruction and soil cultivation practices well in advance of fumigation to insure decomposition of plant materials before attempting to fumigate.

Use of fumigants has been more consistently effective than non-fumigants for control of root-knot nematodes in Florida. In the fine sands of the Northeast Florida potato production area near Hastings, dry soils (no more than 12 to 15% soil moisture content) are considered favorable for soil fumigation.

For an explanation of Table 1 and Table 2 in this document, see Nematode Management in Commercial Vegetable Production.

Table 1. Non-fumigant nematicides for potatoes in Florida.

Product	Broadcast or overall rates		Row rates	
	Per acre	**Per 1000 sq ft**	**Per acre, 36" row spacing**	**Per 1000 ft. of row, any row spacing**
Mocap 15G	40 to 60 lb	0.9 to 1.4 lb	20 lb	1.4 lb
Mocap EC*	1 to 1.5 gal	2.9 to 4.4 fl oz	2 qt	4.4 fl oz
Temik** 15G	---	---	20 lb	21 oz
Vydate L***	---	---	1 to 2 gal	9.8 to 19.5 oz

*Do not apply Mocap in furrow, as it can cause crop injury when in contact with the seed piece. Do not apply Mocap where sorghum will be grown during the same year, as its residual activity may cause serious injury to sorghum. Mix into the top 2 to 4 inches of soil. Do not exceed 9 lb ai/A Mocap 15Gand 12lb ai/A for Mocap EC.

**Reporting intended use of Temik. In response to concern about potential contamination of ground water, the Florida Department of Agriculture and Consumer Services requires, at least 30 prior to the date of application, submission of form DACS 130309. Further, all applications must be made with Positive Displacement Applicators preapproved under the Bayer Crop Science equipment certification program. Consult the label for other use restrictions which apply including soils, rotation crops, grazing, irrigation, field placarding, mandatory buffer zones and PHI.

***Vydate L has registration for nematode control on potatoes only as a broadcast or in-furrow treatment. Foliar applications are registered for insect control only. For broadcast or in-furrow treatments, Vydate L should be applied in a minimum of 20 gals of water. As a broadcast treatment thoroughly incorporate to a soil depth of 4-6". As a preplant in-furrow treatment, do not apply more than 4 1/2 gallons Vydate L per acre per season. As a preplant in-furrow treatment, do not apply more than 4 1/2 gallons Vydate L per acre per season.

These products are not as consistently effective against root-knot nematodes as the fumigants, but are registered as indicated.

Table 2. Fumigant nematicides for potatoes in Florida.

Nematicide	Broadcast Application[1]		In the Row Applications
	Gallons or Lbs Per Acre	Fl oz/1000 ft/chisel spaced 12" apart	
Telone II[2,3]	9 to 12 gal	26 to 35	For any row spacing, application rates given may be concentrated in the row, but shall never exceed the labeled maximum for broadcast applications. Consult the product label for additional detail.
Telone C-17[2,3]	10.8 to 17.1 gal	31.8 to 50.2	For any row spacing, application rates given may be concentrated in the row, but shall never exceed the labeled maximum for broadcast applications. Consult the product label for additional detail.
Telone C-35[2,3]	13 to 20.5	38.2 to 60.2	For any row spacing, application rates given may be concentrated in the row, but shall never exceed the labeled maximum for broadcast applications. Consult the product label for additional detail.
Pic-Clor 60	19 to 31.5	57 to 90	For any row spacing, application rates should never exceed the labeled maximum for broadcast applications. Consult the product label for additional detail.
Vapam HL	75 gal	-	For drip or in-row chisel fumigation, consult product label for proportionately reduced overall rates, drip concentration and flow modifying directions and procedures.
KPam HL	60 gal	-	For drip or in-row chisel fumigation, consult product label for proportionately reduced overall rates, drip concentration and flow modifying directions.

[*1] Gallons /acre and Fl oz / 1000 feet provided only for mineral soils. Higher rates may be possible for heavier textured (loam, silt, clay) or highly organic soils.
[2] All of the fumigants mentioned are for retail sale and use only by state certified applicators or persons under their direct supervision. New supplemental labeling for the Telone products must be in the hands of the user at the time of application. See label details for additional use restrictions based on soil characteristics, buffer zones, and requirements for Personal Protective Equipment (PPE).
[3] Higher application rates are possible in the presence of cyst-forming nematodes.

Rates are believed to be correct for products named, and similar products of other brand names, when applied to mineral soils. Higher rates are required for muck (organic) soils. However, the GROWER has the final responsibility to see that each product is used legally; READ THE LABEL of the product to be sure that you are using it properly.