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Dagger Nematode *Xiphinema* spp. (Cobb, 1913) Inglis, 1983 (Nematoda: Enoplea: Dorylaimia: Dorylaimina: Xiphinematinae)[1]

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Introduction

Nematodes of the genus *Xiphinema*, commonly called dagger nematodes, parasitize plants. Many of these nematodes, the majority of which belonging to the *Xiphinema americanum*-group, can transfer viruses to plants during feeding (Taylor and Brown 1997, Gozel et al. 2006). Dagger nematodes can cause economic damage and death of host crops through feeding on the roots and also by spreading viral mosaic and wilting diseases (van Zyl et al. 2012, Jones et al. 2013). From a practical standpoint, it is a major challenge to control viral diseases in susceptible crops, partly because of a lack of resistant cultivars that should reduce populations of the virus vectors, *Xiphinema* spp.. However, field studies have shown that some control measures, such as biofumigation and rotation of crops, targeting reduction in population of virus vectors, dagger nematodes, can be effective to some extent (Evans et al. 2007). Field surveys are required in order to implement appropriate and timely nematode management decisions that will minimize crop losses.

Distribution and Hosts

Species of the genus *Xiphinema* are widely distributed in both temperate and tropical areas. They occur in South America, North America, Europe, Asia, Australia, New Zealand, and Africa. In the US, *Xiphinema* spp.. are classified as moderate pests on turfgrasses in landscapes in Massachusetts, Arkansas, California, the Carolinas (Robbins 1993, Ye et al. 2012), and Florida.

Five species belonging to the *Xiphinema americanum*-group have been detected on tomato, grape, oak, sea grape, pines, hackberry, Brazilian pepper, and citrus in Florida and Morocco (Gozel et al. 2006, Mokrini et al. 2014). Other hosts include Sudangrass (sorghum), cotton, pearl millet, turfgrasses (Wick 2012, Ye et al. 2012), legumes, sugarcane, chili pepper, banana, sugar beet, corn (Shurtleff 1980), weeds, cassava (Rosa et al. 2014), and many more.

Life Cycle and Biology

Dagger nematodes have six life cycle stages (Figure 1). Parthenogenesis, a form of reproduction that does not require males, is common in many, but not all, species. Females lay eggs in soil. The life cycle of a dagger nematode is similar to other ectoparasitic, vermiform nematodes. Juveniles hatch from eggs and molt four times, increasing in size with each molt until they become adults. As vector-capable juveniles feed on virus-infected plants and mature into adults, they can acquire plant-pathogenic viruses, commonly known as nepoviruses (nematode polyhedral viruses). The viruses form a lining in the pharynx-stylet tube (Figure 2) and are

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injected into root tissues during feeding (Lamberti and Roca 1987).

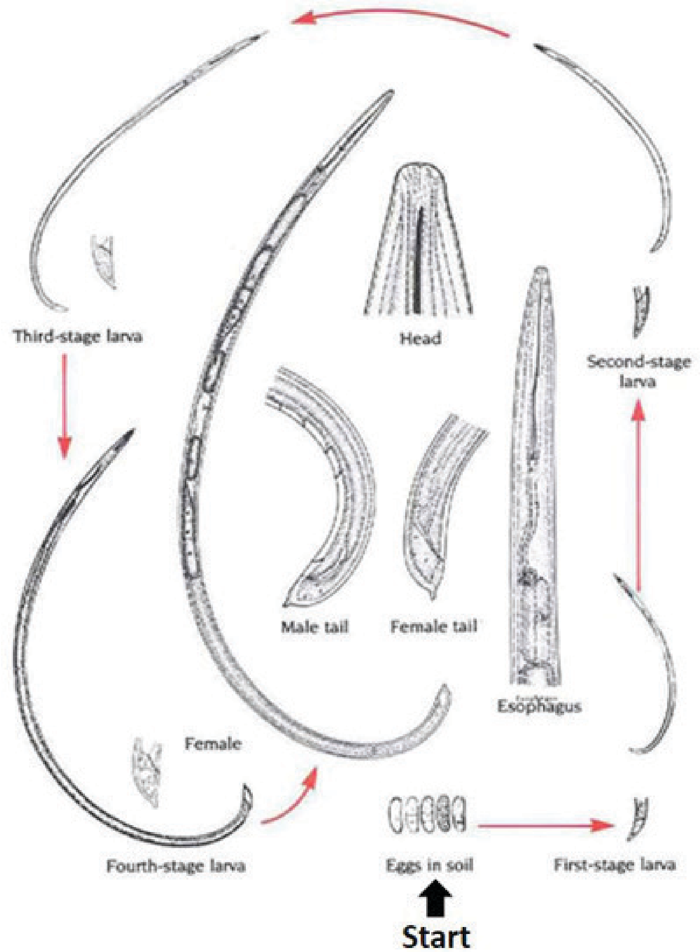

Figure 1. A typical life cycle of a dagger nematode, *Xiphinema* spp., with detailed features.
Credits: Nemaplex, University of California, Davis. Used with permission

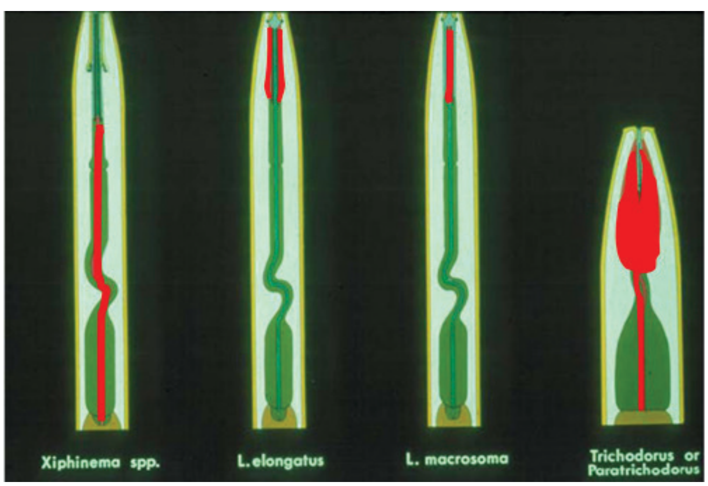

Figure 2. Viral particles (in red) in the pharynx-stylet tubes of plant virus vector nematodes: A dagger nematode, *Xiphinema* spp.; Needle nematodes, *Longidorus elongatus* and *Longidorus macrosoma*; Stubby nematodes, *Trichodorus* and *Paratrichodorus*.
Credits: Nemaplex, University of California, Davis. Used with permission

Dagger nematodes are ectoparasitic, which means that all stages, except eggs, attack and feed on the roots of the host plants. The nematode inserts its long stylet deep into the root while the body remains outside the root, in the soil. The stylet punctures cell walls as it penetrates plant tissues. During feeding, enzymes are secreted to digest plant cell contents. Plant parasitic nematodes produce enzymes such as cellulases, pectinases, hemi-cellulases, and chitinases, which are similar to those produced by bacteria and fungi (Jones et al. 2005, 2013), that digest and destroy root cells resulting in malformed root tissues (Figures 3 and 4). Root cells eventually collapse due to feeding.

Species of *Xiphinema* are sensitive to changes in soil temperature and moisture (Malek 1969) and will migrate vertically away from desiccating conditions in topsoil; most dagger nematodes can live and survive deep in soil (Feil et al. 1997).

Symptoms

The damage dagger nematodes cause to root systems is similar to that of other plant ectoparasitic nematodes. The feeding at the meristematic root-tips destroys root cells (Figure 3) and reduces root volume. Terminal galling of roots of woody plants is common (Figure 4). The above-ground effects of damaged roots are stunted growth of crops and patchy fields.

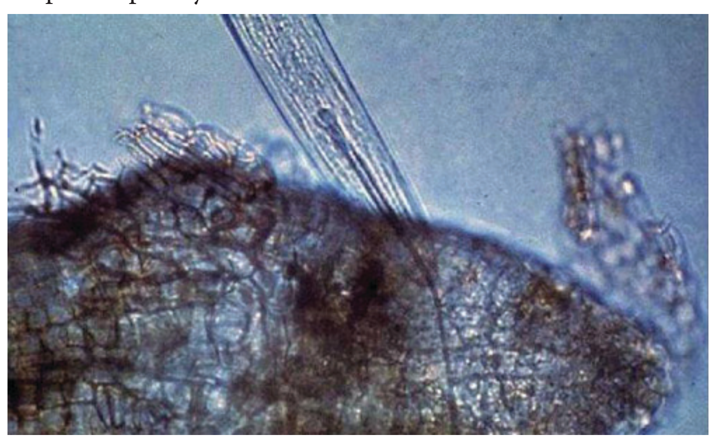

Figure 3. A dagger nematode, *Xiphinema* spp., feeding at fig root tip.
Credits: Nemaplex, University of California, Davis, USA. Photograph used with permission

Dagger nematodes transmit numerous viruses to plants. *Cherry rasp leaf virus*, *Tomato ringspot virus*, and *Tobacco ringspot virus* are some of the viruses transmitted by dagger nematodes during feeding. According to van Zyl et al. (2012), bermudagrass is a potential reservoir for GFLV (*Grapevine fanleaf virus*), which is transmitted by dagger nematodes. However, symptoms of viral infections, which include yellow mosaic and wilting shoots (Figures 5, 6, 7, and 8) are more visible in woody plants than in grasses because grasses show few or no symptoms (Hogmire 1995, Izadpanah et al. 2003, Palomares-Rius et al. 2012).

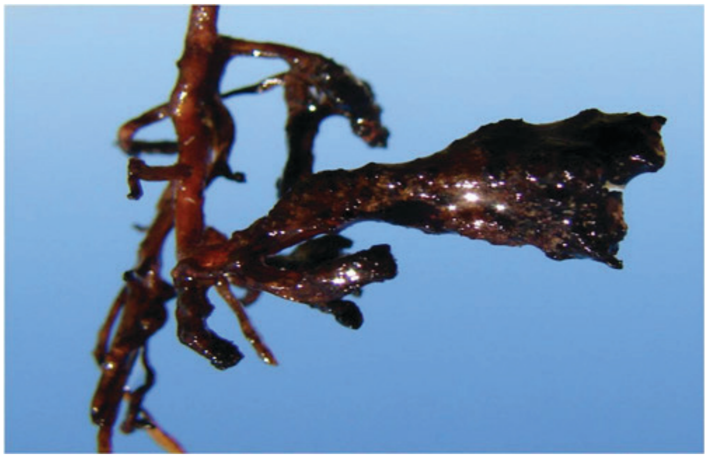

Figure 4. Terminal galling of grapevine root caused by a dagger nematode, *Xiphinema* spp.
Credits: Pablo Castillo, Institute for Sustainable Agriculture, CSIC, Córdoba, Spain

Figure 5. Yellow mosaic disease caused by *Grapevine fanleaf virus* transmitted by dagger nematode, *Xiphinema* spp.
Credits: Pablo Castillo, Institute for Sustainable Agriculture, CSIC, Córdoba, Spain

Figure 6. Leaves of Viking red currants showing symptoms of *Tomato ringspot virus* transmitted by dagger nematodes, *Xiphinema* spp.
Credits: Joseph Postman, Plant Pathologist, USDA-ARS National Clonal Germplasm Repository, Corvallis, Oregon

Figure 7. Damaged leaves of *Pelargonium hortorum* infected with *Tomato ringspot virus* transmitted by dagger nematodes, *Xiphinema* spp.
Credits: State Plant Pathology Institute of Denmark Archive, Bugwood.org. Photograph used with permission

Figure 8. Potato plants heavily infected with *Tobacco ringspot virus* transmitted by dagger nematodes, *Xiphinema* spp.
Credits: International Potato Center Archive, Bugwood.org. Photograph used with permission

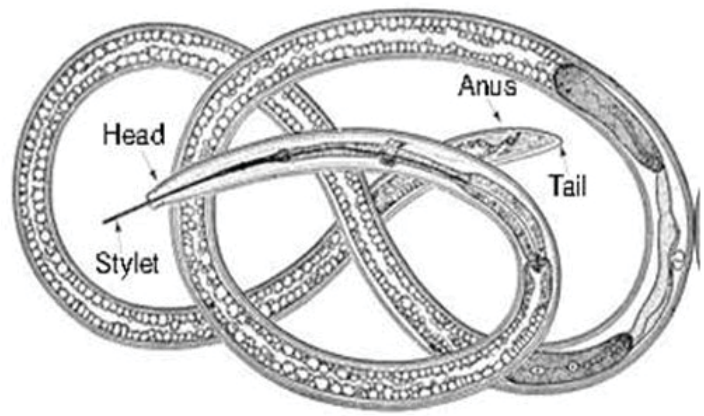

Figure 9. Schematic diagram showing detailed morphological features of a dagger nematode, *Xiphinema* spp.
Credits: Nemapix (vol. 2) from Patton et al. 2010. Used with permission

Identification

Xiphinema spp. belong to the sub-family Xiphinematinae, which has diverse groups of species (Coomans et al. 2001). An adult dagger nematode has a long body (2 to 6 mm) and a flat and smooth lip region (Goodey et al. 1960; Brown and Topham 1984, 1985; Siddiqi and Lenne 1990) (Figure 9). The head is not offset (Figure 10).

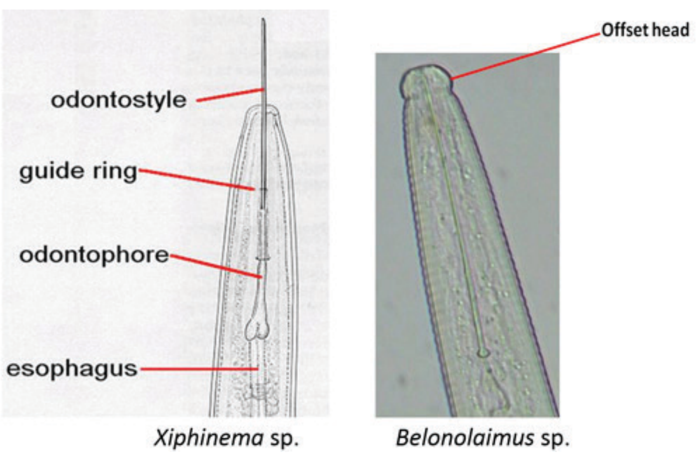

Figure 10. A drawing comparing anterior regions of a dagger nematode, *Xiphinema* spp. to a sting nematode, *Belonolaimus* sp. Sting nematode has an offset head region and a stylet with basal knobs; dagger nematodes do not have an offset head region and the basal region of the stylet has flanges.
Credits: Nemaplex, University of California, Davis. Used with permission

Species of the genus *Xiphinema* have a long stylet called an odontostyle (Decraemer and Gerart 2006). The stylet has no stylet knobs but rather flanges, which support (anchor) the basal part of the odontophore (the rear part of the long stylet) (Figures 10 and 11D). The guiding ring in the middle holds the long stylet in position.

It is difficult to use the tail region (Figure 11A, B) to identify dagger nematodes, but the sexes can be differentiated using their tail regions. An adult male has paired spicules (Figure 11A, arrow a) and cloaca (Figure 11A, arrow b). Adult female dagger nematodes have an anus at the tail region (Figure 11B, arrow c) and a vulva (Figure 11C, arrow d) located mid-body, but at different locations depending on species. It is not possible to distinguish sexes of juveniles because sex organs are not developed. The tail ends of both adult males and females of some species, for example *Xiphinema vuittenezi, Xiphinema israeliae*, etc., have a small mucron (Luc et al. 1964, 1982).

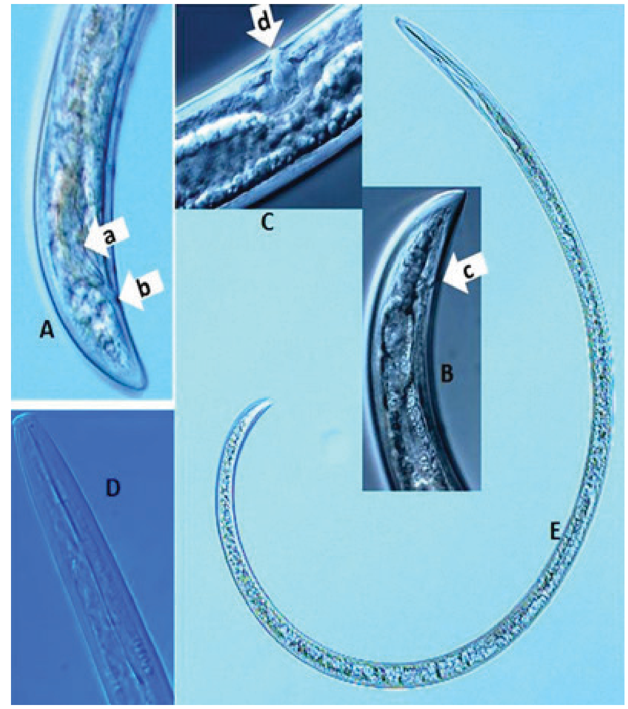

Figure 11. Photographs of a dagger nematode, *Xiphinema* spp. A: lateral view of a male tail region with paired spicules (arrow a) and cloaca (arrow b); B: lateral view of anus (arrow c) at the tail region of a female; C: lateral view of vulva (arrow d) of a female; D: a head region showing full stylet; E: a full body length view.
Credits: Tesfamarian Mengistu, UF/IFAS

Detection and Density Estimation

In infested fields, nematode problems occur in patches. Figure 12 shows a typical example of how plant parasitic nematodes should be sampled in a field. As many samples as possible are taken along the marked lines in a zig-zag manner. In dry conditions, samples should be taken from depths up to 60 cm using wider shovels. Soil samples taken from shallow depths may not include dagger nematodes. However, in wet seasons, soil samples can be taken up to a 40 cm depth using core samplers because dagger nematodes move upward when moisture content of topsoil is high.

Dagger nematodes are retrieved from soil samples using the Baermann funnel methods (OEPP/EPPO 2009, 2013), and sugar floatation method (Lawrence and Zehr 1978) among others. Population densities of dagger nematodes extracted from samples are analyzed or diagnosed for management decision-making.

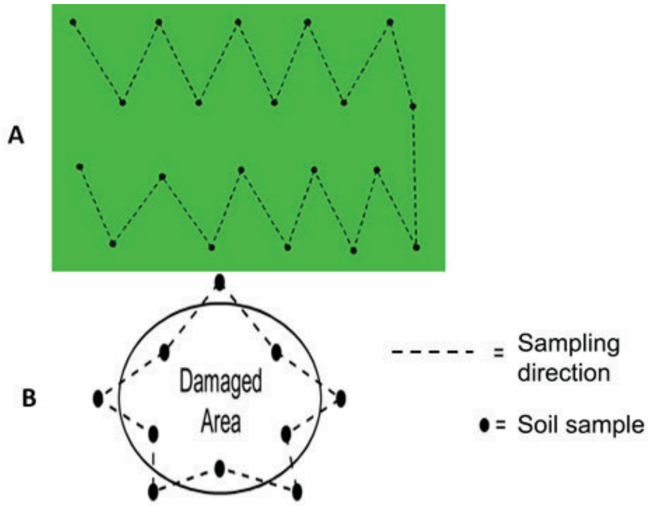

Figure 12. Patterns of sampling in fields A) for survey B) with suspected plant parasitic nematode problems in symptomatic spot.
Credits: (A) by William T. Crow, UF/IFAS; and (B) by Ministry of Agriculture, Food and Rural Affairs, Ontario, Canada, used with permission

Economic Importance

Population densities in landscape areas can range from 0 to nearly 500 per 100cm^3 of soil but the direct attack and feeding on roots by dagger nematodes cause only moderate damage to susceptible landscape plants (e.g., creeping bentgrass) (Moseley et al. 2010, Patton et al. 2010, Ye et al. 2012). However, *Xiphinema* spp. are the eighth most economically important plant parasitic nematode group to agricultural crops worldwide (Jones et al. 2013). Damage to roots causes up to 65% root weight loss and this can result in severe yield reduction (Anonymous 2014). Viruses transmitted to food crops such as tomato, grapevine, pepper, cassava, and potato can cause more than 50% crop losses because the virus limits plant development (Evans et al. 2007, Anonymous 2014). As a result, virus-vectoring dagger nematodes are on quarantine lists for many countries (Nicol et al. 2011). There are no cultivars available resistant to dagger nematodes.

Management

The main objectives of managing plant parasitic nematodes are to keep their population densities below damage thresholds and minimize economic losses. Several recommendations have been suggested to manage plant parasitic nematodes. Unfortunately, no single method is completely effective. Combining different management practices is more effective for reducing plant parasitic nematode density than using any method alone.

Dagger nematodes spread to fields through the use of contaminated equipment, planting of infested plants/sod, and contaminated irrigation water or run-off. So, sanitation is critical. Chabrier and Quénéherve (2008) observed that man-made ditches intercepting run-off across steep slopes effectively reduced incidence of plant parasitic nematodes in fields. Clean equipment such as tractors, planters, and ridgers should be used in order to minimize transfer of nematodes to fields.

Fumigation has proved to be a good strategy. White, black or red plastic sheets are normally used to cover the soil surface following soil fumigation. However, clear plastic sheets allow sunlight to pass through and generate heat that kills and reduces plant parasitic nematodes in soils before planting (McSorley and Gill 2010).

Decomposing organic mulch or straw, green manure, and trap crops such as *Crotalaria* and *Sesbania* can be used to encourage fungi like *Pochonia* that kill plant parasitic nematodes (Wildmer et al. 2002). Mustard bran and mustard seed meal, as well as products from *Euphorbia* spp., can be incorporated into soils because these plants contain nematicidal elements (Moseley et al. 2010).

Marigolds (*Tagetes* spp.) can be grown as cover crops and are effective in reducing populations of nematodes. According to Evans et al. (2007), marigolds used in crop rotation plans significantly reduced populations of dagger nematodes and severity of *Soybean severe stunt virus* in soybeans. Marigolds produce root exudates (containing alpha-terthienyl) that suppress plant parasitic nematodes, pathogenic fungi, and bacteria (Wang et al. 2007, Krueger et al. 2010).

Robust and healthy plants are more tolerant of plant parasitic nematodes than highly stressed plants. Application of fertilizers and adequate water are important to maintain healthy plants.

Weed control is important because some weeds are also good hosts to dagger nematodes and the plant virus they transmit (Nemabase 2013).

For current management of plant parasitic nematodes on crops and landscape plants, refer to the latest recommendations on EDIS.

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