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Pasteuria penetrans (Bacilli: Bacillales: Pasteuriaceae)[1]

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The Featured Creatures collection provides in-depth profiles of insects, nematodes, arachnids and other organisms relevant to Florida. These profiles are intended for the use of interested laypersons with some knowledge of biology as well as academic audiences.

Introduction

Biological control agents of plant-parasitic nematodes are typically very specific natural enemies of the target plant pest nematodes. When commercialized, growers can use these natural agents in the soil around their crop plants to limit the damage caused by harmful plant-parasitic nematodes. One of the best studied biological controls of nematodes is a bacterium in the genus *Pasteuria* (Figure 1). *Pasteuria penetrans* is an obligate parasite of root-knot nematodes (*Meloidogyne* spp.). *Pasteuria penetrans* is an endospore-forming bacterium that persists in the soil until a suitable nematode host encounters the spore. The *Pasteuria* spores adhere to the nematode cuticle (outer surface), infect the nematode and develop inside of the nematode body.

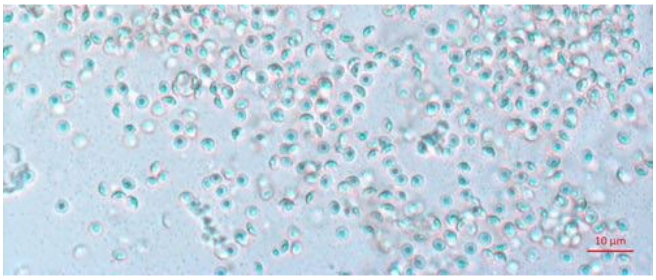

Figure 1. Endospores of *Pasteuria penetrans*.
Credit: Weiming Hu, UF/IFAS

The growth of *Pasteuria* spp. inhibits the nematode from producing eggs. It is this disruption of nematode fertility that makes *Pasteuria* spp. such a promising biological control agent for root-knot nematode. Another species of *Pasteuria* (*Pasteuria nishizawae*) infects *Heterodera glycines* (soybean cyst nematode) and is commercially available for growers in the Americas and Europe. One EPA report states that *Pasteuria* species are present in 80 countries on at least five continents (2012). Traditionally, a new isolate of bacteria was named when it could be cultured in a lab. However, with modern genomic technology, taxonomic characterization of unique bacterial isolates allows for the identification of different *Pasteuria* spp. without the need for cultures. This is important as *Pasteuria* is an obligate parasite and therefore cannot be grown outside of its host using traditional bacteria culturing techniques. This has previously limited the ability to identify and characterize more *Pasteuria* spp. despite this bacteria's wide distribution.

Distribution

Distinct species of *Pasteuria* associate with different genera of nematodes have been identified world-wide. For every plant-parasitic nematode there is potentially a specific and adapted isolate of *Pasteuria*. Root-knot nematodes have a very wide host range which includes most economically important crops produced world-wide. *Pasteuria penetrans* has been reported from, North America (Noel 1994), India (Mohan 2012), Senegal (Bekal et al. 2001), the United Kingdom (Davies et al. 2011) and Iraq (Fattah et al. 1989). There are likely many more isolates of *Pasteuria* spp. in more locations that are yet to be characterized.

Description

Pasteuria spp. are most recognizable as the mature endospore form (Figure 1). This life stage of the bacteria is used to establish ultrastructure (measurements of key features using high resolution microscopic images) and novel characteristics unique to each species of *Pasteuria* spp. Endospores of *Pasteuria penetrans* are about 3 µm in diameter and 1.8 µm in height (Chen et al. 1997). The endospores are visible as they stick to the cuticle (outer surface) of the nematode (Figure 2). As the nematode starts to feed on plant root tissues, the endospores penetrate the nematode cuticle, germinate and form microcolonies within the nematode's body. These microcolonies vary in size but are popcorn shaped and eventually mature into thalli, sporogonium, and finally mature endospores which are dispersed into the soil, ready to infect other root-knot nematodes.

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Figure 2. *Meloidogyne arenaria* nematode with *Pasteuria penetrans* endospores adhering to its cuticle.
Credit: Ruhiyyih Dyrdahl-Young, UF/IFAS

Life Cycle and Biology

Pasteuria endospores persist in the soil until a suitable host nematode comes into physical contact with the bacterium. Once the nematode begins to feed on the root tissue, the endospore germinates and grows in the body of the infected nematode. The infection process starts when a *Pasteuria* endospore adheres to the cuticle (outside covering) of the nematode (Figure 2). Next, after the nematode penetrates a host plant's roots and feeds on inner root tissues, the endospore develops a germination tube. This tube pierces through the cuticle of the nematode and begins to form mycelial-like (popcorn-shaped) balls in the ovarian tissue of the nematode. These mycelial-like balls (Figure 3) are the first of several structures that *Pasteuria* forms during sporulation.

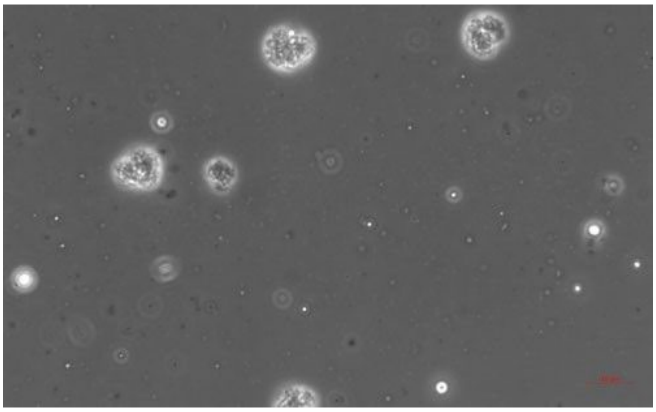

Figure 3. Mycelial-like structures of *Pasteuria penetrans*, image taken from the body contents of an infected *Meloidogyne arenaria* nematode. Image taken 15 days after exposure to *Pasteuria penetrans*.
Credit: Ruhiyyih Dyrdahl-Young, UF/IFAS

As the bacterium develops, the mycelial-like balls mature into thalli (Figure 4), sporogonium (Figure 5), and eventually more mature endospores (Figure 6). The ovarian tissue and body of the nematode fills with endospores which replace nematode eggs (Figure 7). A healthy root-knot nematode can lay up to as many as 1,000 eggs in the soil. A root-knot nematode infected with *Pasteuria penetrans* does not lay any viable eggs. This could cause the nematode population to decrease dramatically in a field with high populations of *Pasteuria* endospores and benefit the current crop as well as future plantings through population suppression.

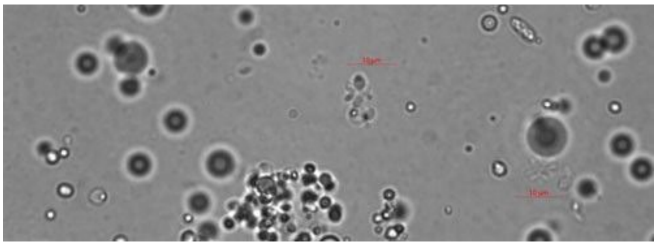

Figure 4. Thalli structure of *Pasteuria penetrans* taken from inside an infected root-knot nematode, 20 days after exposure to endospores.
Credit: Ruhiyyih Dyrdahl-Young, UF/IFAS

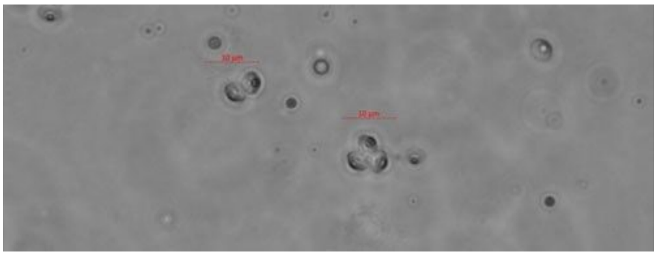

Figure 5. Sporogonium of *Pasteuria penetrans* taken 30 days after root-knot nematode exposure to *Pasteuria penetrans* endospores.
Credit: Ruhiyyih Dyrdahl-Young, UF/IFAS

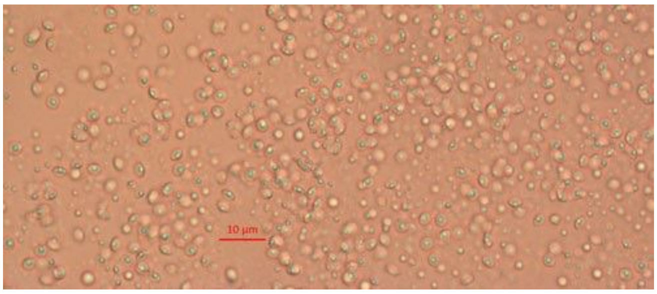

Figure 6. Mature *Pasteuria endospores*.
Credit: Weiming Hu, UF/IFAS

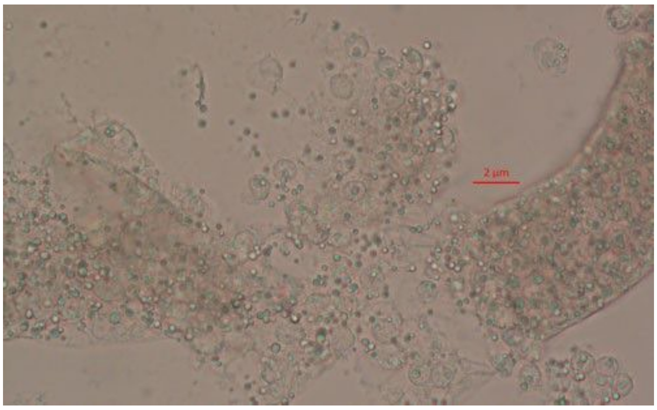

Figure 7. *Pasteuria penetrans* infected ovarian tissue of *Meloidogyne arenaria*. Image taken 30 days after exposure to *Pasteuria penetrans*.
Credit: Ruhiyyih Dyrdahl-Young, UF/IFAS

Hosts

Pasteuria has a specific and limited host range which does not include humans, or other soil organisms (like insects, mites and earth worms). There are five species of *Pasteuria* that infect plant-parasitic nematodes. They are most easily distinguished from one another by their host range. These include: *Pasteuria thorneii* that infect *Pratylenchus* spp. (lesion nematode) (Starr and Sayre 1988), '*Candidatus Pasteuria usgae*' a parasite of *Belonolaimus* spp. (sting nematode) (Giblin-Davis 2003), *Pasteuria nishizawae* that is a parasite of *Heterodera glycines* (soybean cyst nematode) (Atibalentja et al. 2004), *Pasteuria hartismeri* parasitic to *Meloidogyne ardenensis* (root-knot nematode), and *Pasteuria penetrans* that attacks *Meloidogyne* spp. (root-knot nematode) (Bishop et al. 2007).

Economic Importance

The economic impacts of *Pasteuria penetrans* are difficult to estimate, as there are no commercial products containing these endospores. At the time of publication, there is one commercially available *Pasteuria*-based nematode control. This product contains *Pasteuria nishizawae* endospores in a soybean seed coat. According to the manufacturer, the *Pasteuria nishizawae* seed coat can increase yields 2.7 bushels per acre higher (and as much as 10 bushels/acre) than seeds coated with insecticide/fungicide alone (Syngenta). In June 2018, the soybean price per bushel was $9.55 and the average yield in Florida was 60 bushels/acre. In Florida in 2018 there were 14,000 acres of soybeans harvested. At the current price of soybeans, a yield increase of 2.7 to 10 bushels/acre would translate into a $361,000 to $1.3 million increase in profits in Florida. Root-knot nematodes are one of the world's most devastating plant-parasites. The root-knot nematode *Meloidogyne incognita*, has a host range that is estimated to include over 2,000 plants including virtually all economically important Florida crops. One conservative estimate of global crop loss caused by root-knot nematode is 5% (Sasser and Sarter 1985). *Pasteuria penetrans* would potentially have a great economic impact if successfully deployed as a biological control agent.

Management

At present, management recommendations of root-knot nematodes using *Pasteuria penetrans* are premature. There are studies in micro-plots that suggest adding *Pasteuria penetrans* endospores (at a rate of 100,000/g soil) will suppress the growth of root-knot nematode populations. In one Florida field where a continuous peanut crop was established, the *Pasteuria penetrans* endospores significantly reduced the population of infective juvenile root-knot nematodes (Chen et al. 1996).

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