



Noni Root Knot, a Destructive Disease of *Morinda citrifolia* in Hawaii

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Morinda citrifolia, called noni in Hawaiian, is a source of food, dyes, and medicines esteemed throughout the Pacific region. It once grew mainly in relatively pristine native forest and coastal ecosystems. Although still abundant in natural habitats, noni is widely grown today as an agricultural crop removed from its optimal environment. Its successful cultivation today demands more knowledge and skill than was required of Hawaii's indigenous horticulturalists; they did not encounter the problems common to modern agricultural soils that are contaminated with a wide range of introduced and invasive plant pathogens.

The most destructive soilborne pathogen of noni in Hawaii is the root-knot nematode. These tiny, parasitic roundworms cause root infections and disease that severely undermine plant health, leading even to plant death. Dozens of acres in Hawaii planted to noni have been abandoned by farmers in recent years due to root-knot disease, and the productivity of other farms has been severely compromised. This condition and its management are described here.

Recognizing the symptoms

As the disease name suggests, diseased noni roots are characteristically galled, distorted, swollen, and knotty. The root surface may be cracked and wrinkled, with a corky texture, and rotten. Diseased roots are often discolored and irregular in shape. Young lateral roots may have stubby, swollen tips. Diseased root systems are sparse and diminished in size. A soft rot may develop inside severely affected roots.

Above-ground symptoms are usually the first abnormalities noticed. Plants become stunted, with yellow leaves, sparse foliage, and unthrifty appearance. The leaves may "flag" (wilt or droop). These foliar symptoms resemble some nutrient deficiency symptoms, of the elements iron and nitrogen in particular.

The bark of basal stems at ground level may crack open and decay; plants with stems so girdled often die when opportunistic or pathogenic fungi colonize the wounded stem tissues and rot the bark.

Occurrence of symptoms in fields may be patchy, with severely affected, yellowed plants growing next to apparently unaffected plants. Symptoms can develop slowly over time and take several years to cause a significant decline in plant health, or lead to plant death. Symptoms may be exacerbated by opportunistic or pathogenic fungi and bacteria that colonize nematode-infected tissues.

Cause of noni root-knot disease

Species of the plant-parasitic root-knot nematode (*Meloidogyne* species) cause this disease in Hawaii. These parasites damage noni roots by penetrating deep into tissues, and through their feeding they cause roots to swell and crack. In addition to this direct tissue damage, these galls attract fungi and bacteria that cause root discoloration and rot.

Disease distribution

Noni root-knot disease occurs wherever noni is grown in agricultural soils in Hawaii, especially on land formerly devoted to sugarcane, pineapple, or papaya. However, the disease may also be introduced to any location where noni is grown from infected planting materials, including plants derived from seeds or cuttings.

Disease cycle

Root-knot nematodes live in soils on plants. *Meloidogyne* species have relatively broad host ranges. The members of this genus can infect more than 700 different plant hosts, including many common weeds and familiar vegetable crops. They hatch from tiny eggs and move through the soil in search of food. They are so small (0.5 mm [$\frac{2}{100}$ inch] long) that they are virtually invisible to the unaided eye. They enter root tips and establish feeding sites deep inside the roots. Using a spear-shaped mouthpart, they withdraw nutrients from root cells. Their life span is relatively brief, lasting only several weeks. Each adult female will lay hundreds of eggs in the soil or in root tissues; when these hatch, the

roots are reinfected. Nematode populations can become very large in soils where susceptible plants are grown continuously for several years. For a crop such as noni, cultivated for many years, nematode populations can reach very damaging levels.

Root-knot nematodes do not move very far under their own power. They usually are spread through the movement of infested soil, water, and plants. Their transport can occur through human activity including soiled hands, boots, equipment, and tools, or by carrying of soil and infested plants from one location to another. They also spread by running or draining water from irrigation and rainfall runoff.

Prevention and control of root-knot disease

Control noni root knot by using integrated cultural and preventive methods such as avoidance, sanitation, and appropriate cropping systems.

Symptom recognition

Learn to recognize the foliar and root symptoms of noni root knot and how to distinguish them from other diseases or conditions. The only characteristic symptom is the root gall. To diagnose the disease, brush away the top layer of soil and inspect the exposed, surface-feeding lateral roots for galls. The foliar symptoms mimic fertilizer deficiencies (nitrogen, potassium, and iron) and are often the first indication that there is something wrong with the roots. Periodically inspect plants in the field for symptoms. Nursery operators should inspect plant root systems for infestation before selling, distributing, or transplanting noni plants.

Disease-free nurseries

Avoid propagating noni in nematode-infested soil or media. Start noni seedlings or cuttings only in sterile potting media (e.g., cinder, peat, perlite, vermiculite) or heat-treated

soil. Do not use recently cultivated agricultural field soil for starting seedlings or cuttings. Grow young noni plants on raised benches to prevent root contact with soil. Minimize water splashing during irrigation to reduce spread of contaminated soil or medium between pots. Media for plant growth may be treated with heat before use. Sufficient heat (at least 150°F for 15–20 minutes) is deadly to root-knot nematodes and may be achieved with steam, fire, electricity, or solar radiation (solarization).

Prevention and avoidance

Avoid planting noni in fields where crops susceptible to root-knot nematodes have recently been cultivated. Prevent the introduction and establishment of root-knot nematodes in an uninfested nursery or field. Inspect the roots of young noni plants for root knot symptoms prior to transplanting, and prevent their planting if infected—destroy them. Limit unnecessary foot or vehicle traffic into the farm. If a portion of a noni farm becomes infested with root-knot nematodes, perform all farm operations in that section last, rather than first, to minimize the dispersal of nematodes on field implements, tractors, or vehicles.

Soil and media testing

Assess soil or media for the presence and quantity of root-knot nematodes by submitting appropriate soil samples to a diagnostic lab or the CTAHR Agricultural Diagnostic Service Center via your nearest Cooperative Extension Service office. An appropriate soil sample consists of a representative composite sample taken from areas to be planted; it should include the surface 6 inches of soil.

Preplant nematicides

Preplant soil fumigants, soil sterilants, or other approved



Yellowing of noni leaves between veins is one of the first above-ground symptoms of noni root-knot disease. The pattern of yellowing resembles iron deficiency (yellowing between veins).



Advanced, above-ground symptoms of noni root-knot disease may include wilting and almost complete yellowing of leaves. This condition can lead to plant death.

nematicides may be used to reduce initial nematode populations to non-damaging levels before planting. There are no postplant nematicides registered for use on noni in the United States.

Sanitation

Sanitation involves decontaminating objects used in noni cultivation. Tools (shovels), propagation materials (pots), clothing (boots), and farm vehicles (tires) may be a source of nematode infestation when they come into contact with nematode-infested soil. Nematodes can be eradicated from these objects by cleaning them with a strong spray of water, followed by sterilizing with a 10% solution of household bleach.

Irrigation and fertilizer management

Noni plants may wilt due to nematode attack even though soil moisture appears to be adequate. Because the damaged roots are so inefficient at the uptake of water and nutrients, some additional water and fertilizer may reduce wilting or improve plant growth. Noni plants infected with nematodes respond well to foliar fertilizers. However, it is best to avoid excessive irrigation and fertilizing of infected plants. Over-irrigating can help to spread root-knot nematodes and hasten root rot. Over-fertilizing can lead to rotting of infected roots, followed by plant decline and death.

Rogue diseased plants

Rogueing involves removing diseased plants from the nursery or field. This practice is best for new farms or when disease is detected early. Rogue (pull up and burn or discard) diseased noni plants in areas or farms where new outbreaks of root-knot disease are discovered. This will prevent or minimize the spread of nematodes from diseased plants to healthy plants along rows or between farms and nurseries. If root-knot disease is already well established and severe, rogueing will not help to stop the disease from spreading.

Composting and soil amendments

Organic composts and soil amendments deter nematodes. Preplant and postplant applications of organic soil amendments, composted plant materials (e.g., macadamia husks), and/or composted chicken manure provide some nematode control while supporting good plant nutrition and encouraging healthy plant growth. Organic amendments and composts favor biological control of root-knot nematodes by



Young noni plant with advanced symptoms of root-knot disease and fungal stem rot. The stem is completely girdled by the damage, and the roots are heavily galled and rotten. This plant had no chance for survival.



After noni stems are girdled by nematodes and fungi, an internal rot can develop that kills the plant. Here the bark is partially cut away from a noni stem to reveal the vascular rot inside.

providing a favorable environment for parasites and other organisms that compete with the nematodes. Avoid contact between mulches or composts and noni stems; the heat generated during composting can damage stem tissues and lead to rot and stem girdling.

Weed control

Control or eradicate all weed hosts of root-knot nematodes while cultivating noni and during fallow periods. Submit root samples of weeds to a diagnostic laboratory or testing service for nematode detection. Although visual inspection of weeds for the characteristic root galls may be sufficient to determine their risk, some weed hosts may have much smaller galls than the swellings commonly observed on noni roots.

Appropriate cropping system

A diverse cropping system and crop rotations interrupt the spread, reproduction, and survival of nematodes. Consider using a multicropping system combining noni with plants that are immune or highly resistant to root-knot nematodes. These plants may be interplanted with noni or used in crop rotations. For example, sunn hemp (*Crotalaria juncea*), planted in alternating strips between rows or blocks of noni, may be effective for multicropping and crop-rotation systems. Many of these nematode-resistant cover crops would make excellent green manure crops or sources of compost

for noni. Due to the wide host range of root-knot nematodes, care should be exercised in the selection of companion crops for noni.

Host-free fallow

Noni fields that are heavily infested with root-knot nematodes should be placed in host-free fallow for a minimum of 1 year prior to replanting noni, preferably much longer—up to 3 years. Fallowing is not very effective unless weed hosts for *Meloidogyne* species are controlled.

Host resistance

At present, no noni variety is thought to be resistant to root-knot nematodes.

Abandon heavily infested fields

It may not be economically feasible to continue making farm inputs in severely affected locations. In these cases, moving the farm to a new location and using disease-free planting material may be the only practical solution to the problem.



The noni plant at right died as a result of root-knot nematode infection and stem girdling. The noni plant at left shows very early symptoms of root-knot infection (yellow leaves).



Noni lateral root exposed at the soil surface, showing grotesque swelling and cracking caused by infection of the root by root-knot nematodes.



Diagnosing root-knot disease can be as simple as brushing away the soil surface to reveal the galled and rotten roots.



Basal stem is cracked open on this dying noni plant infected with root-knot nematodes. Root galls are also visible.



Early symptoms of root-knot disease on young noni roots include swellings, galls, unthrifty root growth and root rot. Each of these tiny galls contains thousands of nematodes inside. As the roots grow, the galls become larger and roots crack open.