

Rice *Oryza sativa*

Rice has a number of important nematode pests that can seriously affect growth and yield of the crop. These nematodes are either foliar or root parasites and there is a wide range of symptoms. Some of the nematodes have a restricted distribution, others occur world-wide.

The two foliar parasites are the ufra nematode, *Ditylenchus angustus*, and the white tip nematode, *Aphelenchoides besseyi*. Root parasites are particularly affected by the type of rice being grown; some genera cannot withstand flooding in lowland and deepwater rice and are only found on the upland or dry rice crop. The main nematode root parasites are the cyst nematodes (*Heterodera oryzae*, *H. oryzicola*, *H. sacchari*, *H. elachista*), the rice root nematodes (*Hirschmanniella* spp.), root knot nematodes (mostly *Meloidogyne oryzae* and *M. graminicola*), the root lesion nematodes (*Pratylenchus indicus*, *P. zaeae*), the ring nematode (*Criconemoides onoensis*), and the rice needle nematodes (*Paralongidorus australis*, *P. oryzae*). Other species of these and other genera, such as *Tylenchorhynchus*, *Hoplolaimus*, and *Xiphinema* are also reported as parasites on various rice crops.

Ditylenchus angustus

Distribution

Ditylenchus angustus originated as an important pest of deepwater rice in south and southeast Asia and, therefore, has a restricted distribution due to deepwater rice being found in only a few areas. It is a parasite of both wild and cultivated species of *Oryza* in the major river deltas of Bangladesh, Assam, Burma, and Vietnam that are prone to deep or very deep flooding in the rainy season. However, it is now widespread in Bangladesh on lowland rice systems, and may spread into the lowland crop in other countries.

Symptoms and diagnosis

In the vegetative growth stage from seedling to flag leaf, the main symptom of infection by *D. angustus* is leaf chlorosis. Plants become malformed and prominent white patches, or speckles in a splash pattern are seen during vegetative growth at the bases of young leaves (66). Necrotic brown stains may develop on leaves and leaf sheaths. Young leaf bases are twisted, leaf sheaths distorted (67), and the lower nodes can become swollen with irregular

branching. Depending on the severity of infection, chlorotic leaf areas, tillers, or whole plants will wither and die, producing a light brown appearance. When infection is very severe, the whole crop can take on this appearance (68). After heading, infected panicles are usually crinkled with empty, shrivelled glumes, especially at their bases; the panicle head and



66 White patches on the growing leaf bases of rice, the initial symptoms of 'ufra' disease caused by *Ditylenchus angustus*, Bangladesh.



67 Twisted and distorted leaves of rice infected with *Ditylenchus angustus*, Bangladesh.

68 Large brown patch of dead rice plants, field symptoms of 'ufra' caused by *Ditylenchus angustus*, Bangladesh.

69 Twisted, distorted, and empty panicles of mature rice due to infection by *Ditylenchus angustus*.

flag leaf are twisted and distorted (69). Panicles often remain completely enclosed within a swollen sheath or only partially emerge. Dark brown patches of infected plants can be observed within fields, normally after panicle initiation.

D. angustus occurs in the leaves, inflorescences, young seeds, and rolled stems of growing plants and also in crop residues but it is not seed-borne. The nematode survives in plant residues, the stem tissues, and partially or fully enclosed panicles between seasons in a desiccated state. Nematodes can migrate from diseased plants or plant residues to healthy plants in water, and by stem and leaf contact under high humidity. The nematode is spread primarily through irrigation water, although most nematodes die after a few days in water. *D. angustus* needs at least 75% humidity to migrate on the foliage and is more damaging in wetter areas. Nematodes in water can invade young rice plants within 1 hour. Greatest infection occurs at temperatures of 27–30°C and the nematode has a short life cycle of 10–20 days.



The presence of *D. angustus* can be confirmed by cutting pieces of about 5 mm long from the rolled leaf stems and placing in a small dish of water. Stem pieces are cut longitudinally and left in the water for 24 hours. The rolled leaves or young inflorescence can be teased apart in a Petri dish with water and observed directly. Numerous nematodes (hundreds to thousands) will be active from fresh material, but they require some time to resume activity from dried panicles.

Economic importance

Where *D. angustus* does occur, it can cause total losses in individual fields. In Bangladesh, annual yield losses of 4% have been estimated and in Assam and west Bengal, India, losses are estimated at 10–30% in some areas. It is also recognized as a serious problem in the Mekong delta in Vietnam. Substantial yield losses can occur when transplanted seedlings are infected, even at low percentage infection.

Management

Losses can be minimized by destruction or removal of infested stubble or straw, and burning of crop residues is very effective. Incorporation of crop residues into the soil by ploughing can reduce ufra as nematodes decline quickly in soil. Growing nonhost crops such as jute or mustard in rotation with rice can reduce ufra incidence. Extending the period of time between growing rice crops and lengthening the overwinter period (by delaying sowing, transplanting after flooding, and using early maturing cultivars) can reduce the populations of nematodes and severity of ufra disease on successive rice crops. Removal of volunteer and ratoon rice, wild rice, and other weed hosts will help prevent the carry-over of nematodes to the next crop. Improved water management can help prevent spread of ufra nematodes. Some resistance to *D. angustus* has been found in deepwater rice cultivars and will be effective if commercially available.

Identification

Females of *D. angustus* have thin bodies, 0.8–1.2 mm in length, with fine, pointed tails. The head is light and the stylet is small but distinct. Vulva is posterior. Males are common and are morphologically similar to females.

Aphelenchoides besseyi

Distribution

The nematode is seed-borne and has been disseminated to most rice growing areas of Africa, North, Central, and South America, Asia, eastern Europe, and Pacific Islands.

Symptoms and diagnosis

Characteristic symptoms are the whitening of leaf tips (70). In the field, white patches are apparent from a short distance. Young leaves of infected tillers can be speckled and leaf margins distorted and wrinkled. *A. besseyi* is one of the few seed-borne nematodes. Infected seeds are small and distorted with necrotic lesions.

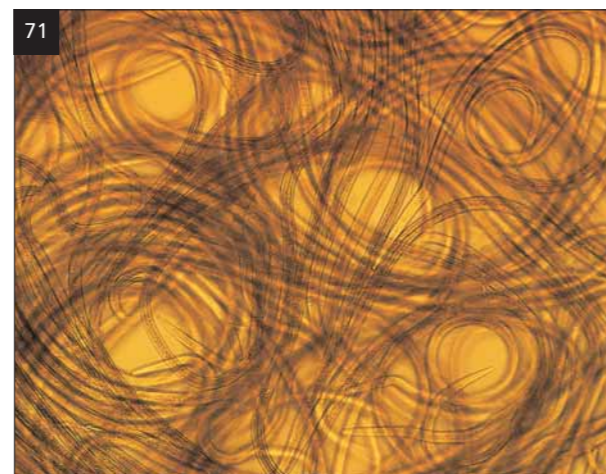
The presence of *A. besseyi* is detected mainly by soaking the seeds in a dish of water and examining directly using a dissecting microscope (71).

Economic importance

The importance and severity of *A. besseyi* can vary with country, locality, and rice environment. It is considered to be important in India and Africa, but causes little damage in the USA, Thailand, or Japan. In Bangladesh more than 50% of deepwater rice fields have been shown to be infested. Yield loss in susceptible rice depends mainly on the number of nematodes in infected seed and the percentage of nematode infected seed sown; 300 live nematodes/100 seeds has been suggested as an economic damage threshold density.



70 White tip of rice leaf caused by *Aphelenchoides besseyi*.



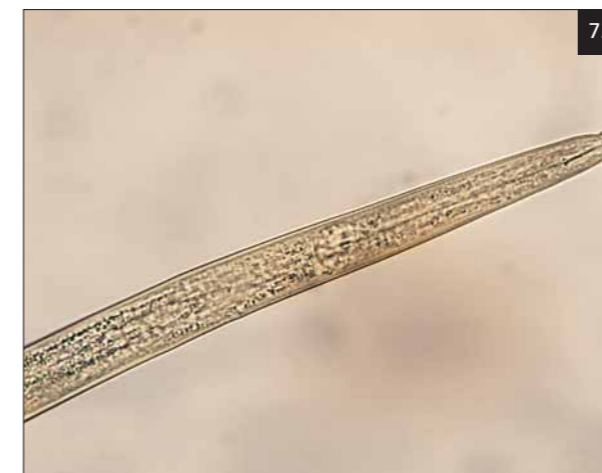
71 *Aphelenchoides besseyi* aggregating in a water drop on a microscope stage. (Courtesy of R. Plowright.)

Management

Prevention by use of clean seed or eliminating nematodes from seed prior to planting is the most effective means of preventing yield loss. Hot water treatment of seed is probably the most useful and cheapest method of reducing crop losses when seed is possibly contaminated. Seeds are pre-soaked in cool water for 18–24 hours followed by immersion in water at 51–53°C for 15 minutes. Higher temperatures (55–61°C) for 10–15 minutes are required if the seed is not pre-soaked. Seed can then be sown directly, or quickly dried and stored.

Identification

The female nematodes are thin, 0.6–0.9 mm in length, with a tapering tail tipped by 3–4 pointed mucron. The lip region is rounded and offset but not strong and the stylet is weak with small knobs (72). Vulva is in the posterior part of the body, approximately one-third of the body length from the tail tip.



72 Anterior of female *Aphelenchoides besseyi*.

Heterodera spp.

Distribution

Four species of cyst nematodes are known pests of rice in different parts of the world: *Heterodera sacchari* in west Africa and Trinidad, *H. orydicola* in India, *H. elachista* in Japan, and *H. oryzae* in west Africa and Bangladesh. With the exception of *H. oryzae*, cyst nematodes generally cannot withstand extended flooding and are mainly found on upland rice or on lowland rice where there is little or no water control.

Symptoms and diagnosis

All species cause similar symptoms. Infected plants are severely stunted and chlorotic with less tillers being produced. There is a reduction in root growth, with the roots becoming brown or black. These reduced root systems can appear to have many more small roots stimulated by the nematodes feeding. If soils are heavily infested, seedlings can be killed. Brown cysts and white lemon-shaped females can be observed on the roots without magnification, but the use of a 10× hand lens or a dissecting microscope is helpful.

Economic importance

The cyst nematodes have a limited distribution and are therefore only of local importance, but the cysts can easily be disseminated into new areas. Losses in yield of 20% and 40% have been reported for *H. elachista* and *H. orydicola*, respectively. Control of *H. sacchari* in the field has resulted in yield increases of over 60%.

Management

Rotation with nonhost plants is an effective means of reducing soil populations. Most crops other than cereals are nonhosts. Resistance to *H. sacchari* has been identified in crosses between *Oryza glaberrima* and *O. sativa*, which could prove useful in the future.

Identification

In all species, the females become obese and lemon shaped, producing brown cysts when dead varying

in size from 0.3–1.0 mm in length and 0.2–0.8 mm in width, observable with the naked eye (15, 73, 74). The active second-stage juvenile is 0.4–0.5 mm in length, with a strong head and stylet and a pointed tail (16).

Hirschmanniella spp.

There are many species of *Hirschmanniella* found on a wide variety of crops, and over a dozen of them, known as the rice root nematodes, occur on rice. The most well known species are *H. belli*, *H. gracilis*, *H. imamuri*, *H. mucronata*, *H. oryzae*, and *H. spinicaudata*.

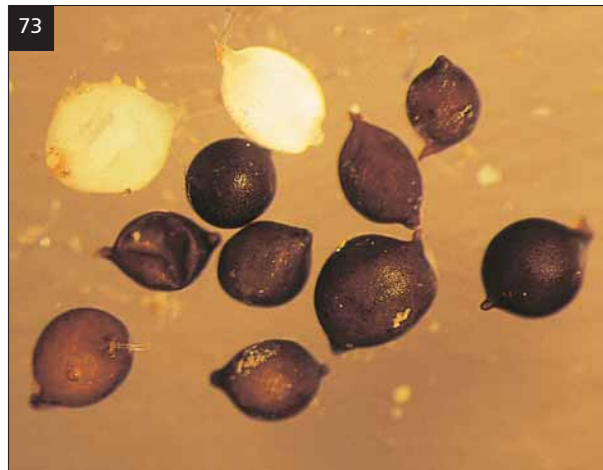
Distribution

Species of *Hirschmanniella* are found in all rice growing areas of the world and comprise one of the few groups of nematodes that can withstand anaerobic conditions such as those occurring in flooded rice fields.

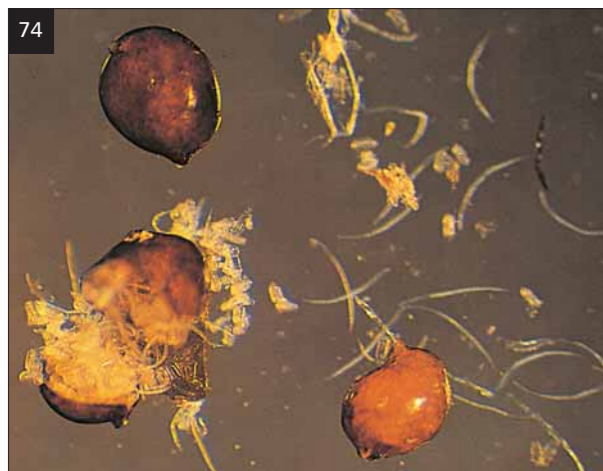
Symptoms and diagnosis

There are no specific foliar symptoms caused by *Hirschmanniella* spp.; root damage produces stunted growth and leaf chlorosis normally seen in clearly defined patches in the field. Tillering and yields are reduced. Nematodes invade roots and migrate through the cortical tissues causing cell necrosis and cavities (75, 76). Infected roots turn brown and rot.

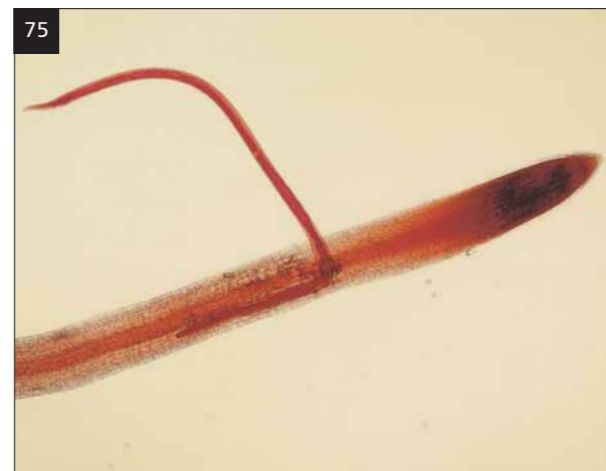
Hirschmanniella spp. are migratory endoparasites feeding on cortical cells of rice roots, invading through the epidermal layers. When roots are examined microscopically, the nematodes, being relatively large, can often be found partially embedded in the tissues in the process of invading (75). Eggs are mainly laid



73 Brown cysts and white females of *Heterodera sacchari* from rice.



74 Complete and broken cysts of *Heterodera oryzaicola* with eggs and second-stage juveniles.



75 Mature female of *Hirschmanniella oryzae* invading rice root.

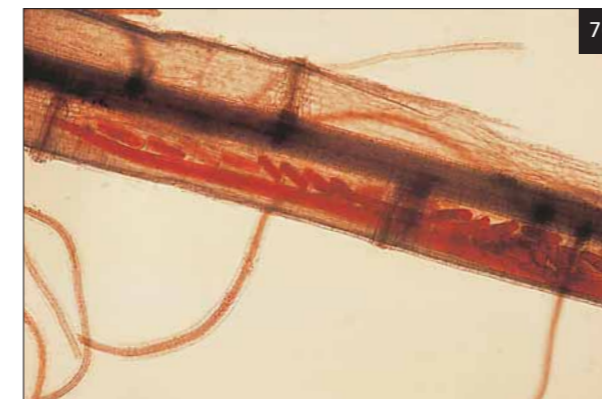
within the root cortex as the nematodes migrate through the roots feeding on the cells (76). Life cycles vary depending on the species, but are generally around 4 weeks from egg to egg.

Economic importance

Because of their ubiquitous occurrence in all rice growing fields, *Hirschmanniella* spp. may cause the most combined yield loss of any of the nematode pests of rice world-wide, although individual field losses may be less. Commonly occurring soil populations of 100–200 nematodes/litre soil can reduce rice yields by 15–30%.

Management

Absence of rice and other susceptible hosts will cause a severe decline in populations. If there is sequential cropping of flooded lowland rice with dry land crops, populations will be reduced but only if the intervals between susceptible crops are more than 1 year. Where green manure legumes are used to increase soil fertility there has been marked control of *Hirschmanniella* spp., especially with *Sesbania*



76 Stained eggs and female of *Hirschmanniella oryzae* in the cortex of rice roots.

rostrata and *Sphenoclea zeylanica*, which either act as trap crops or produce toxic root exudates. In lowland rice growing areas where the crop is grown on a regular basis, there are few cultural measures that can be used to manage populations of the nematode. The use of nematicides is not practical or economic.

Identification

Hirschmanniella spp. on rice are long, thin nematodes, females varying from 1 mm to over 3 mm in length. They have strong stylets, generally tapering, pointed tails, and a vulva in mid-body with two outstretched ovaries. Males and females are morphologically similar apart from sexual organs.

Meloidogyne spp.

A range of *Meloidogyne* spp. is parasitic on different types of rice throughout the rice growing areas. The principal species are *M. graminicola*, *M. oryzae*, *M. incognita*, *M. javanica*, *M. arenaria*, and *M. salasi*.

Distribution

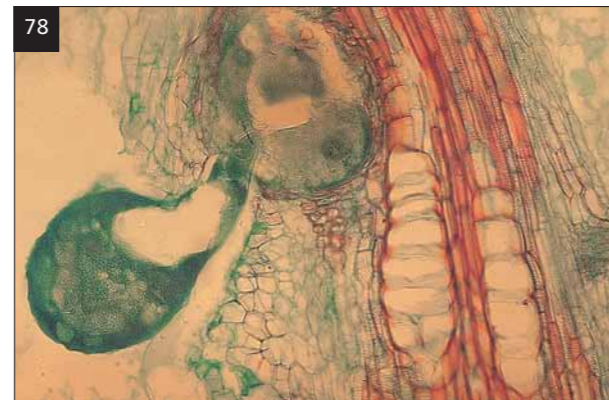
M. graminicola causes damage to upland, lowland, deepwater, and irrigated rice and is mainly found in the countries of southeast Asia, but it has also been reported on rice in the USA. *M. oryzae* has only been found in Suriname, South America on lowland irrigated rice. The other species are mainly pests of upland rice and are of less economic importance: *M. incognita*, *M. javanica*, and *M. arenaria* are reported from the Caribbean, Egypt, west and South Africa, South America, and Japan; *M. salasi* only from Costa Rica and Panama.

Symptoms and diagnosis

Symptoms caused by *Meloidogyne* spp. vary according to type of rice and nematode species. Typical symptoms are stunting and chlorosis of young plants combined with retarded maturation, unfilled spikelets, reduced tillering, and poor yield. Symptoms can often appear as patches in the field. All *Meloidogyne* spp., however, cause swellings and galls throughout the root system. Infected root tips become swollen and hooked, which prevents root

elongation. This symptom is especially pronounced on rice infected with *M. graminicola* and *M. oryzae* (77). In deepwater rice, *M. graminicola* can cause serious damage prior to flooding and when flooding occurs. Deepwater rice normally elongates rapidly in response to flooding; however, when submerged plants are severely infected with serious root galling they are unable to elongate to the water surface and become drowned out, leaving patches of open water in flooded fields.

The swollen female of *M. graminicola* (78) lays eggs in an egg mass within the cortex of the root (79), unlike other *Meloidogyne* spp. Juveniles hatch from the eggs and reinfest the same root, remaining in the maternal gall or migrating intercellularly through the parenchymatous tissue. This is an adaptation by *M. graminicola*, enabling it to continue multiplying within host tissue under flooded conditions. Juveniles, which migrate from the root in flooded soil, cannot reinvade. The life cycle of *M. graminicola* under optimum conditions at 25–30°C can be as short as 19 days.



77 Characteristic hooked, root tip galls on rice caused by *Meloidogyne graminicola*.

78 Longitudinal section through rice root showing swollen, sedentary female *Meloidogyne graminicola* feeding on giant cells.

79 Females and egg sacs of *Meloidogyne graminicola* within a developing rice root gall.

M. graminicola can survive in waterlogged soil, initially in rice root remnants, and can remain viable for at least 14 months. The nematode is not active in flooded soils and is unable to invade rice under flooded conditions, but can quickly invade rice plants when soils are drained. *M. incognita*, *M. javanica*, *M. arenaria*, and *M. salasi* are mainly parasites of upland rice and do not survive long periods in flooded soil. *M. oryzae* can survive in shallow flooded (less than 10 cm water depth) rice fields for relatively short periods. *M. graminicola* has a wide host range, which includes many common rice weeds such as *Echinochloa*, *Cyperus*, and *Panicum*. Similarly, *M. incognita*, *M. javanica*, and *M. arenaria* have a very wide host range. A number of weeds and crops are also alternative hosts of *M. oryzae* and *M. salasi*.

Economic importance

M. graminicola is a major pest of all types of rice where it occurs. *M. incognita* and *M. javanica* are of less importance. Damage can be serious on young seedlings raised in well-drained nursery soils

before transplanting, and infected transplants will disseminate the nematodes into the field. Destruction of up to 72% of deepwater rice plants by drowning out has been shown to occur with populations of 4000 juveniles/plant of *M. graminicola*.

Management

The type of rice and the species of *Meloidogyne* present will affect the management methods. The use of resistance, controlled flooding, crop rotation, and chemicals can all play a part in the management of the rice root knot nematodes. Although resistance would provide the most sustainable means of control, only relatively few rice lines are truly resistant. Cultivars of the African rice, *O. glaberrima*, are resistant to *Meloidogyne* spp. and progeny being derived from a cross between *O. sativa* and *O. glaberrima* can provide improved acceptable cultivars with resistance to these nematodes. Even relatively short periods of flooding in lowland rice will control *M. incognita*, *M. javanica*, and *M. arenaria* and probably *M. salasi*, but continuous flooding would be necessary for *M. oryzae* and *M. graminicola*. *M. graminicola* will survive normal flooding; however, crop damage can be avoided by producing seedlings in flooded soils. Some crops are reported as poor hosts of *M. graminicola* and, as such, castor, cowpea, sweet potato, peanut, maize, sunflower, sesame, turnip, and okra may be useful in a rotational cropping system. Field application of chemical nematicides is not recommended, but their use in seedling nurseries could possibly prove economically effective.

Identification

The rice root knot species of *Meloidogyne* are distinguished by the posterior cuticular or perineal pattern, and the morphometrics of the second-stage juveniles.

Pratylenchus spp.

Pratylenchus are commonly occurring nematodes and many have been found associated with rice. The most common are *P. zae* recorded on rice from Africa, North and South America, Australia, and south and southeast Asia, and *P. brachyurus* found on rice in Africa, South America, Pakistan, and the Philippines. *P. indicus* is reported damaging rice in India and Pakistan.

These migratory endoparasites cause lesions and decay of roots resulting in blackened and decreased root systems (80, 81). General nonspecific foliar symptoms are stunting, chlorosis, and reduced



80 Stained *Pratylenchus zae* nematodes in rice root cortex.



81 Brown and blackened rice roots infested with *Pratylenchus zae* on the left compared to healthy roots. (Courtesy of R. Plowright.)