

Root Pests of Daylilies¹

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INTRODUCTION: Daylilies (*Hemerocallis* spp.) are flowering ornamentals that beautify gardens throughout the United States. Intense breeding programs by daylily growers for many years have improved size, color, and shape of the flowers. As a result, a great number of daylily varieties (mainly of *H. fulva* L.), hybrids (among more than 20 *Hemerocallis* species), and tetraploids have been produced and marketed for the ornamental industry. Daylilies that go dormant are grown mainly in cold climates, whereas evergreen daylilies are grown in warm climates. However, daylilies with different blends of these two genetic characteristics (dormant and evergreen) have been selected and can be used in a great range of climatic conditions (Munson 1996).

Daylily root systems have both rhizomes and storage roots (Fig. 1). Elongate and fine feeder roots are produced both by the rhizomes and, in lesser number, by the storage roots. Storage roots are fleshy, swollen, fusiform, rich in starch, and allow plants to withstand long periods without vegetative growth.



Fig. 1. Daylily root system showing rhizomes (R) and storage roots (S). (Photography credit: J. Lotz)

Fig. 2. Daylily feeder root infected by the spiral nematode, *Scutellonema brachyurus* (S). (Photography credit: R. N. Inserra and J. Lotz)

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Daylilies have the peculiar capability of periodically sloughing off roots which have become non-functional for physiological or maybe pathological reasons such as fungal infections or infestations of other pests. Sloughed roots are in time replaced by adventitious roots generated by meristematic tissue at the base of the plant's stem. This defense mechanism allows daylilies to survive root attacks by pathogens and other pests. However, in spite of the ability of daylilies to tolerate root injury caused by parasitic agents, plant mortality does occur. Because of the increased number of plant problem samples received by the Bureau of Entomology, Nematology and Plant Pathology in recent years, a survey of daylily root pests was conducted by the Bureau during 1995-1997 in daylily operations of Florida. Daylily root samples were collected from declining plants and examined in the laboratory for presence of fungi, mites, and nematodes. A few samples from outside Florida (Ohio, Pennsylvania, South Carolina, the Netherlands) were also included in this survey. The objective of this circular is: 1) to provide information about the most common root pests of declining daylilies; and 2) to illustrate symptoms which characterize daylily roots parasitized by these pests.

NEMATODES: Plant-parasitic nematodes have been well known as pests of daylilies since the 1960s. Lance, lesion, reniform, ring, root-knot, spine, spiral, stubby and stunt nematodes occur commonly in daylily operations of Florida (Esser 1962). We list only the nematode species detected inside or attached to daylily roots. During our survey the most common nematodes parasitizing daylily roots were root-knot nematodes (*Meloidogyne* spp.). Spiral nematodes, *Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961 and *Scutellonema brachyurus* (Steiner, 1938) Andrassy, 1958, were also frequent. However, in spite of the ability of spiral nematodes to penetrate with the anterior portion of their body into daylily roots (Fig. 2), their economic importance on daylilies, as in other crops, is limited (O'Bannon and Duncan 1990). The lesion nematode, *Pratylenchus pratensis* (de Man, 1880) Filipjev, 1936, was detected once in daylily root material introduced into Florida from Pennsylvania. Pin nematodes (*Paratylenchus* sp.) also were found attached to daylily roots, but no information is available on the role of lesion and pin nematodes in suppressing daylily growth and flower production. The reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940, was found less commonly and only in soils conducive to infestations of this nematode. Taking into consideration the economic importance of these nematodes on the other crops, the two principal genera that should be of concern to daylily growers are reniform nematode (*R. reniformis*) and root-knot nematodes (*Meloidogyne* spp.).

Reniform Nematodes (*R. reniformis*): The vermiform females of the reniform nematode penetrate partially into daylily roots. After female maturation, the enlarged females and eggs remain attached to daylily roots (Fig. 3), and can be transported from one site to another on roots of propagative plant material. Vermiform juvenile stages of reniform nematodes can also contaminate daylily roots in soil particles adhering to the root surface. Reniform nematodes are not damaging pests of daylilies because the number of reniform nematode females and eggs per gram

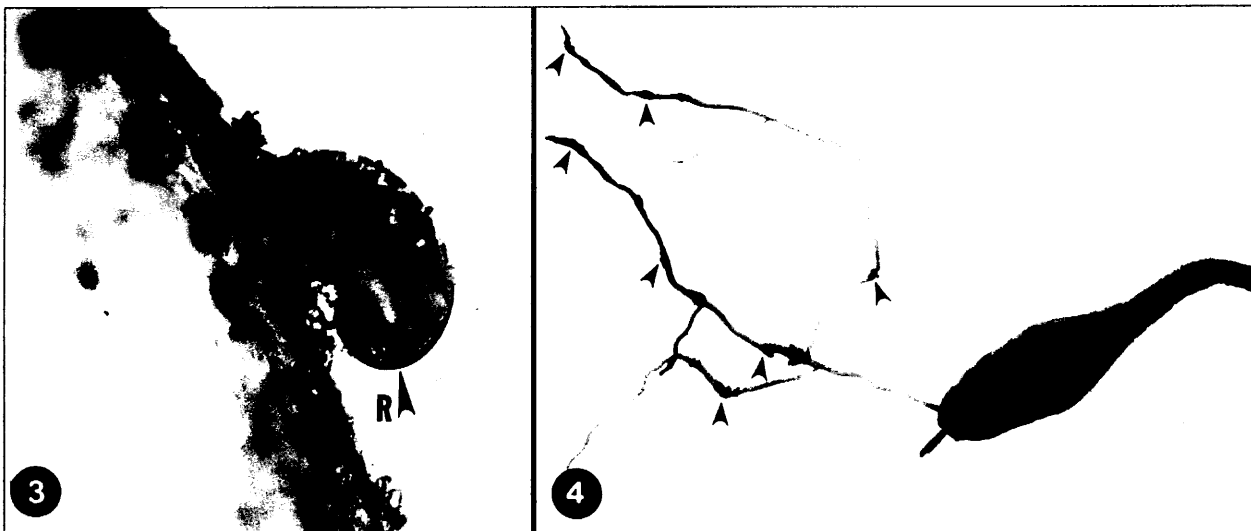


Fig. 3. Daylily feeder root infected by a swollen female of the reniform nematode, *Rotylenchulus reniformis* (R). (Photography credit: R. N. Inserra and J. Lotz)

Fig. 4. Daylily roots infected by root-knot nematodes (*Meloidogyne incognita*). Note small galls (arrows) in the fine feeder roots. No galls are visible in the swollen storage root. (Photography credit: R.N. Inserra and J. Lotz).

of daylily roots is only about one tenth the density on a good host, such as *Vigna unguiculata* (L.) Walp. (Inserra *et al.* 1995). Reniform nematodes have mainly regulatory importance for daylily growers exporting daylilies to states (Arizona, California, New Mexico) and countries (Chile, South Africa, Switzerland) which impose quarantine restrictions against *R. reniformis*. Reniform nematode infections are symptomless. The swollen nematode females of these nematodes are very small, <1 mm (1/50 inch) long, and are not visible to the naked eye when on daylily roots. They can be detected only with the aid of a microscope.

As a regulatory consideration, it is worthy of mention that in addition to *R. reniformis*, other regulated pests, such as the burrowing nematode (BN), *Radopholus similis* (Cobb, 1893) Thorne, 1949 (restricted by many states and countries), can contaminate daylilies in soil particles adhering to their roots, especially if daylilies are grown in association with one of the numerous hosts reported for BN (Esser *et al.* 1988). However, there are no records in the literature of BN infections on daylilies. The risk of daylily contamination with BN is the major reason for the BN certification required for the export of this ornamental to markets restricting BN.

Root-Knot Nematodes: These pests are very common in daylily operations of Florida. They were detected in almost all sites that were sampled during the survey. The most frequent root-knot nematode species on daylilies were *Meloidogyne arenaria* (Neal, 1889) Chitwood, 1949, *M. incognita* (Kofoid and White, 1919) Chitwood, 1949, and *M. javanica* (Treub, 1885) Chitwood, 1949. The northern root-knot nematode *M. hapla* Chitwood, 1949, was detected in a field where it probably was introduced with infected propagative material from the northern states and Canada. In Florida, however, *M. hapla* infestations are eventually replaced by established root-knot species, since *M. hapla* is adversely affected by the warm temperature of Florida soils. Root-knot nematodes are endoparasites, thus penetrating inside daylily roots as vermiform second-stage juveniles. After root penetration, juveniles establish a permanent feeding site in the stele and become swollen and sedentary, causing root swellings called galls (Fig. 4). Juveniles molt three times inside the root and become either adult swollen pear-like females (Fig. 5) or vermiform males. Males are not parasitic--- they leave the roots and mate with females. Swollen females produce egg masses consisting of more than 200-eggs mixed in a gelatinous matrix (Fig. 6). After egg hatch, the infective vermiform juvenile stages initiate another reproductive cycle.

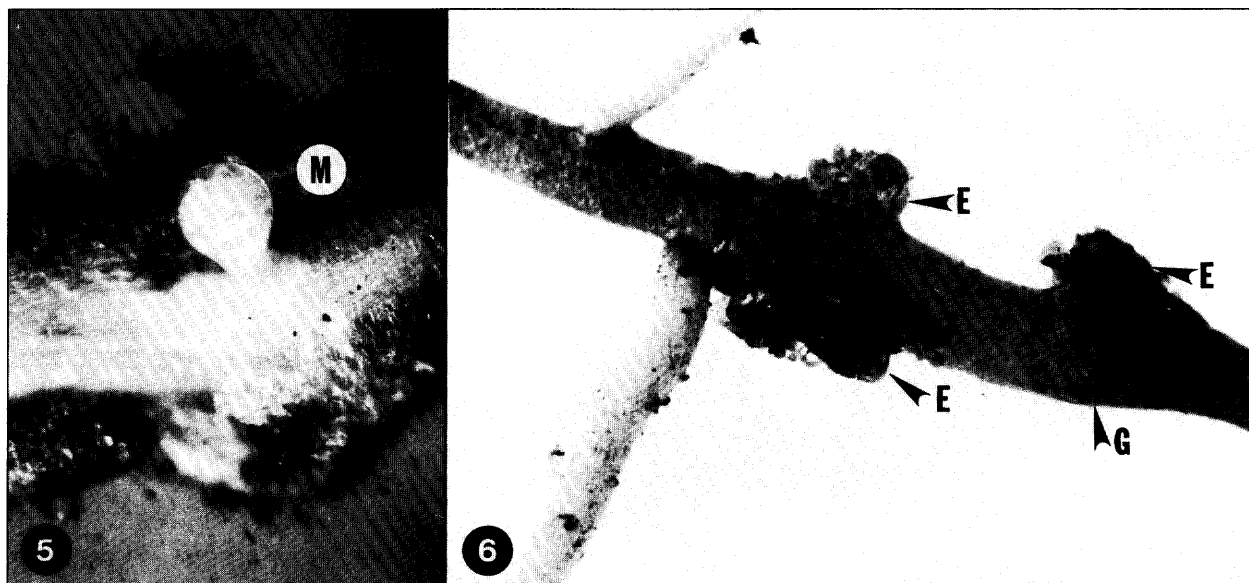


Fig. 5. A swollen root-knot nematode (*Meloidogyne* sp.) female (M) dislodged from a dissected daylily root gall. (Photography credit: R.N. Inserra and J. Lotz).

Fig. 6. Root-knot nematode (*Meloidogyne incognita*) egg masses (E) attached to daylily root galls (G). (Photography credit: R.N. Inserra and J. Lotz).



Fig. 7. Daylily storage root showing a crack (C) corresponding to a root-knot nematode infection site. (Photography credit: J. Lotz)

Symptoms: Root-knot nematode infection in daylily roots usually causes galls, which are visible only in the fine rootlets (Fig. 4). No galls are distinguishable in the enlarged storage roots. In these roots, root-knot nematode infection is usually unnoticed because nematode development and egg production occur inside the root tissues without any noticeable root swelling and any egg mass production on the root surface. In these storage roots, swollen females can be detected only by dissecting the root tissues (Fig. 5). Formation of depressions and cracks on the surface of storage roots (Fig. 7) can be observed corresponding to nematode infection points. Root galls on daylily roots can be observed with a magnifying lens, but a stereo-microscope is necessary to observe nematodes and root cracks.

Formation of galls and permanent feeding sites (giant cells) in the stele and the mechanical damage caused by root-knot nematodes in daylily roots impair root function with consequent plant stunting and dieback. During our survey, more than 50 root-knot nematode females were extracted from one gram of roots in declining daylilies as observed in tomato plants damaged by these pests.

Damage: Yield loss induced by root-knot nematodes to daylilies has not been assessed experimentally. The extent of nematode damage depends on the daylily variety and on management practices. The daylilies' capability of sloughing off nematode-infected roots combined with quick root regeneration enable daylilies to tolerate root-knot nematode infection better than many other ornamentals and vegetable crops. However, root-knot nematode damage on daylily is frequent and is often overlooked or confused with early plant dormancy or nutrient deficiency. Root-knot nematode infections predispose daylilies to attacks of other pests such as pathogenic fungi and mites, which may invade root tissues through wounds induced by the nematodes. The combined adverse effects of these pests is a major cause of daylily mortality.

Preventive Measures and Control: In Florida, daylilies destined for export to markets restricting regulated nematodes such as BN and reniform nematodes are grown in fumigated, or otherwise approved soils. In these operations, adoption of good sanitation practices is an efficient method to protect daylilies from nematode contamination. Daylily growers of South and North Florida should be particularly concerned about risks of contamination of daylilies by reniform nematodes through exposure of infected weeds or ornamentals and detritus which may contain *R. reniformis* (Inserra *et al.* 1989, 1994; Kinloch and Sprengel 1994). The exchange of reniform and root-knot nematode-infected daylily plant material should be prevented to avoid the spread of these pests in clean nurseries. The most effective sanitation practice to exclude these pests from daylily operations is to propagate daylilies from seeds or tissue culture in clean soil and in new containers not in direct contact with ground or other sources of nematode contamination. Once nematodes of regulatory importance enter into a daylily operation, nematode control

on established daylily stands is difficult because of lack of effective nematicides registered for use in ornamental nurseries. These considerations are valid also for daylily stands grown in soil infested by root-knot nematodes as it occurs commonly in landscape sites or in operations for production of plants destined for local markets. In these situations, good agronomic practices such as appropriate fertilization, irrigation, mulching, amendments with organic matter, and weed removal are effective in improving plant vigor and tolerance to nematode infections. Many nematode infected-plants can be sanitized with hot water treatments at 50° C (122° F) for at least 20 minutes. However, there is also a lack of information concerning the effect of hot water treatments on *Hemerocallis* spp. Tolerance of any daylily variety to this treatment should be tested on a small scale before implementing any method of hot water sanitization. Hot water treatments are unsuitable for some bulbous crops such as *Freesia* sp. (Muller and Hollinger 1980).

Pre-plant soil treatments with chemical compounds such as methyl bromide or steam are very effective, but are expensive and can be justified only in special situations. The use of certified pest-free daylily propagative material is imperative in these fumigated soils in order to avoid nematode re-infestation. Selection of daylily varieties tolerant or resistant to *Meloidogyne* spp. is the best approach for management of root-knot nematodes. Unfortunately, the major objective of daylily breeding programs has focused mainly on the improvement of flower quality rather than on resistance to nematodes or other pests.

MITES: During this daylily survey, roots infected by root-knot nematodes were concomitantly colonized by fungi and mites (Acari, Acariformes, Acaridae). Two genera of mites were found on daylily roots, *Rhizoglyphus* and *Sancassania*. Mites of the free-living genus *Sancassania* feed on organic matter (e.g., dead plant and animal tissue, stored products, bat guano) and are not injurious to plants. In contrast, *Rhizoglyphus* mites are commonly called bulb mites and are considered to be serious pests of bulbous crops in many areas. Some of the crops they are reported to attack include: garlic (*Allium sativum* L.), leek (*Allium* sp.), lily (*Lilium* sp.), onion (*A. cepa* L.), and tulip (*Tulipa* sp.). There are approximately 20 named species of *Rhizoglyphus* worldwide. In Florida, *R. robini* Claparède (Fig. 8) was found on daylily roots. This species was found in almost all the surveyed daylily operations of Florida, as well as daylily root samples from Ohio and Pennsylvania, and the Netherlands.

Rhizoglyphus species are tiny whitish mites, about 0.5 mm (1/50 inch) long and difficult to see without magnification. The use of a stereo-microscope or a good hand lens is necessary to detect the mites on the roots or in water washed from infected root material. The life cycle of these mites consists of egg, four immature stages (larva, protonymph, deutonymph, and tritonymph), and adult. At 27°C, the life cycle can take 11-12 days and up to 19 days at 22°C. Under normal conditions the deutonymph is bypassed, but with certain environmental conditions protonymphs molt into a highly modified, non-feeding deutonymphal instar frequently called the hypopus. The hypopus is modified for dispersal on other arthropods, especially Coleoptera and Diptera. Woodring (1969) reported that a laboratory culture of *R. echinopus* usually produced only about 1-2% of the population as hypopodes, but occasionally reached 25% hypopodes.



Fig. 8. Mating bulb mites (*Rhizoglyphus robini*) in decaying daylily root tissues. (Photography credit: R.N. Inserra and J. Lotz).

Garman (1937) noted that hypopodes of *R. echinopus* were numerous when bulbs were "well rotted" and when numerous fly larvae were present. *Rhizoglyphus* and *Sancassania* are very sensitive to humidity levels and die in 1-2 hrs in a dry environment. Soil and root tissue moisture are essential for their survival and development.

Symptoms and Damage: Bulb mites do not cause specific symptoms on daylily roots. These mites are commonly observed in dark roots damaged by fungi and root-knot nematode infections. Mite colonies are localized on the root surface and inside the root tissues or in root cracks (Fig. 8), often in association with decomposer organisms, such as enchytraeids (Annelida: Oligochaeta) and free-living nematodes (bacterivores and fungivores). Daylily growers list bulb mites as economically important and consider the damage caused by these organisms as serious enough to justify the adoption of control measures in infested daylily stands (Crooks Henley 1996). In the daylily root samples of our study, bulb mites appeared to be secondary organisms associated with pathogenic fungi and root-knot nematodes, which were the primary damaging agents of daylily root tissues. Bulb mites and *Sancassania* were not observed in healthy root tissues, but they were abundant in decaying daylily root tissues that were unsuitable for root-knot nematode infection and development. These observations suggest that on daylily roots, bulb mites were mainly feeding on fungi, free-living nematodes and other bio-products of decaying roots. These observations are also supported by results of laboratory tests showing that healthy plant (*Allium chitense* G. Don) tissues were less preferred by *R. robini* than tissues infected by fungi (*Fusarium* sp.) or mechanically injured (Okabe and Amano 1991). However, *R. robini* could invade healthy plant tissues after a long exposure to the plants (Muller and Hollinger 1980; Okabe and Amano 1991). In spite of our observations that bulb mites were not seen colonizing healthy daylily roots, the possibility of healthy daylily root infection by bulb mites cannot be excluded.

Management: Bulb mites share with root-knot nematodes and other nematodes the same soil environment and also certain root tissues during their development. Therefore, management strategies listed above for root-knot nematodes are also effective against bulb mites. Good results in sanitizing bulbous plants infected by bulb mites have been obtained by dipping the infected plant material in 'hot' water 39-41 °C for 1-2 hours (Lesna *et al* 1996). In addition, the pesticide pirimiphos-methyl (Lesna *et al* 1996; Muller and Hollinger 1980) has been listed to control bulb mites, but this pesticide is only registered for use on 'mites' on iris in the state of Washington and is not registered for use in Florida. However, these treatments do not control pre-existing fungal infections which may predispose the treated plants to subsequent bulb mite invasion. Biological control with predatory mites such as *Hypoaspis aculeifer* (Canestrini), *Lasioseius bispinosus* Evans, and *Parasitus fimetorum* (Berlese) provides promising results, but is affected by the strain of the mite predator used (Lesna *et al.* 1995). *Hypoaspis aculeifer* could suppress populations of *R. robini* on lily bulbs, but the hot water treatment for nematodes and bulb mites usually also kill all the predator mites (Lesna *et al.* 1996). Other predator mites found in our sampling of Florida daylilies included two genera of Cunaxidae and an unidentified species of Laelapidae.

Taking into consideration that daylilies are subject to a disease complex caused by concomitant infection of mites, root-knot nematodes and pathogenic fungi, the best approach to managing the disease is to control the presumably primary factors, pathogenic fungi and root-knot nematodes, which predispose daylilies to subsequent invasion and possibly injury by bulb mites.

FUNGI: Based on specimen reports compiled at the Division of Plant Industry, the most common pathogenic fungi infecting daylily roots are *Phytophthora* sp., *Pythium* spp. (notably, *P. splendens* H. Braun), *Rhizoctonia* sp., *Fusarium oxysporum* and *F. solani*.

It is difficult, if not impossible, to determine the role of each individual organism included in a disease complex. Therefore, it is often by subjective evaluation that we consider the involvement of one particular fungus to be more important than another in a confounding pest/pathogen complex. In our estimation, based on historical documentation and reputation as aggressive root rotting organisms, *Phytophthora* sp., *Pythium splendens*, and *Rhizoctonia* sp. are the most likely fungal candidates to be primary pathogens of daylily. Although *F. oxysporum* and *F. solani* are proven pathogens on the roots and crowns of a wide variety of host plants, the suspicion is that they act as opportunistic secondary invaders in declining daylilies.

Fungal root rot of daylily is characterized by dark brown roots which exhibit sloughing cortical tissue. Decaying root, crown, and meristematic tissue will cause the complete decline of the affected plant. The symptomologies of naturally sloughing roots and infected roots are identical and it may be necessary to rely on the above ground condition of the daylily (*i.e.*, foliar symptoms) to determine if root infection is likely or if the normal cycle of root degeneration and replacement is occurring. Chlorotic, unthrifty plants showing symptoms of nutritional deficiencies or those that are wilted, lodged or have an excessive amount of necrotic foliage, may be experiencing a fungal root rot.

Despite the aggressive nature of *Phytophthora* sp., *P. splendens*, and *Rhizoctonia* sp., their infection and colonization of daylily roots are most likely initiated or enhanced by the feeding wounds created by phytoparasitic nematodes. In this survey, combined infections of pathogenic fungi and root-knot nematodes were detected with more frequency than single or combination fungal infections. Solitary fungal infections or nematode/fungus disease complexes were also always associated with mite colonization of root tissues.

Although the interaction between phytopathogenic nematodes and fungal plant pathogens is important in establishing root infections of daylily, several abiotic factors and cultural problems stemming from poor nursery practices can help initiate root rot diseases. Over-watering daylilies planted in a heavy organic potting mix can cause a lack of oxygen exchange in the root zone which may lead to suffocation and eventual root infection by opportunistic fungal pathogens. The application of too much fertilizer, which causes root injury due to the release of excessive soluble salts into the root zone, provides entry wounds for pathogenic fungi. Another example of cultural mismanagement is that of planting daylilies too deep, which can lead to fungal infections in the tight whorl of leaves and associated crown tissue. Other instances of abiotic factors leading to fungal infection may be mechanical injury to roots or the damage caused by the misapplication of a pesticide or herbicide. Eliminating or minimizing cultural problems within the daylily crop will help considerably in reducing the chance of fungal root infections.

Several fungicides are legally registered for use on daylilies (Simone *et al.* 1998). Aliette® or Subdue® can control *Phytophthora* and *Pythium*. Aliette is applied as a foliar spray and is systemic downwards into the root zone. Subdue is applied as a root drench and is systemic through the roots upwards. Thiophanate methyl triazole-type fungicides (Terraguard® and Banner®) may effectively control *Rhizoctonia* and *Fusarium*. As with most fungicides, a preventative fungicidal treatment when disease conducive conditions exist will provide a better chance of controlling potential fungal infections.

LITERATURE CITED

- Crooks Henley, P. 1996.** Bulb mite alert (Pat answers). *The Daylily Journal* 51 (3): 346-350.
- Esser, R. P. 1962.** Correspondence with Dr. Hava. *The Hemerocallis Journal* 16 (2): 15-16.
- Esser, R. P., J. H. O'Bannon, and R. A. Clark. 1998.** How to detect burrowing nematode when making annual nursery inspection. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Nematology Circular No. 155. 4 p.
- Garman, P. 1937.** A study of the bulb mite. Connecticut Agricultural Experiment Station Bulletin 402: 889-907
- Inserra, R. N., R. A. Dunn, R. McSorley, K.R. Langdon, and A.Y. Richmer. 1989.** Weed hosts of *Rotylenchulus reniformis* in ornamental nurseries of Southern Florida. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Nematology Circular No. 171. 4 p.
- Inserra, R. N., R. A. Dunn, and N. Vovlas. 1994.** Host response of ornamental palms to *Rotylenchulus reniformis*. Supplement to the *Journal of Nematology* 26: 737-743.
- Inserra, R. N., W. L. Robinson, and W. W. Smith. 1995.** Nematode parasites of daylily roots. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Nematology Circular No. 211. 2 p.
- Kinlock, R. A., and R. K. Sprenkel. 1994.** Plant-parasitic nematodes associated with cotton in Florida. Supplement to the *Journal of Nematology* 26: 749-752.

- Lesna, I., M. W. Sabelis, H. R. Bolland, and C. G. M. Conijn. 1995.** Candidate natural enemies for control of *Rhizoglyphus robini* Caparède (Acari: Astigmata) in lily bulbs: exploration in the field and pre-selection in the laboratory. *Experimental and Applied Acarology* 19: 655-669.
- Lesna I., M. Sabelis, and C. Conijn. 1996.** Biological control of the bulb mite, *Rhizoglyphus robini* by the predatory mite, *Hypoaspis aculeifer*, on lilies: predator-prey interaction at various spatial scales. *Journal of Applied Ecology* 33: 369-376.
- Muller, P. J., and T. C. Hollinger. 1980.** Damage by *Rhizoglyphus* mites in some ornamental bulbous corps. *Acta Horticulture* 109: 449-457.
- Munson jr., R. W. 1996.** *Hemerocallis*, the daylily. Timber Press. Portland, Oregon. 144 p.
- O'Bannon, J. H., and L. W. Duncan. 1990.** *Scutellonema* species as crop damaging parastic nematodes. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Nematology Circular No. 179. 3 p.
- Okabe, K., and H. Amano. 1991.** Penetration and population growth of the robine bulb mite. *Rhizoglyphus robini* Claparede (Acari: Acaridae), on healthy and *Fusarium*-infected rakkyo bulbs. *Applied Entomology and Zoology* 26: 129-136.
- Simone, G. W., M. Elliott, and R. Mullin. 1998.** 1998 Florida plant disease management guide. Vol. 2: Ornamentals and Turf. University of Florida, IFAS, Florida Cooperative Extension Services, Plant Pathology Department, Gainesville, 151 p.
- Woodring, J. P. 1969.** Observations on the biology of six species of acarid mites. *Annals of the Entomological Society of America* 62: 102-108.

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