Classical Biological Control of Insects and Mites:
A Worldwide Catalogue of Pathogen and Nematode Introductions
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Cover Image
Dr. Vincent D'Amico, Research Entomologist, U.S. Forest Service, Urban Forestry Unit, NRS-08, Newark, Delaware.

Cover image represents a gypsy moth (Lymantria dispar) larva silking down from the leaves of an oak (Quercus) tree and being exposed to a diversity of pathogens (a fungus, a bacterium, a virus and a microsporidium) and a nematode that are being released by a human hand for biological control (not drawn to scale).

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Classical Biological Control of Insects and Mites: A Worldwide Catalogue of Pathogen and Nematode Introductions

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We thank Vince D’Amico for designing the lovely cover images for the first and second editions of the catalogue.
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Classical biological control is a strategy that has been defined as “The intentional introduction of an exotic biological control agent for permanent establishment and long-term pest control” (Eilenberg et al. 2001). Numerous summaries of the many classical biological control programs have been published (e.g., Cock et al. 2016, Hajek et al. 2007, Winston et al. 2014). This strategy has been used extensively to control weeds and arthropods pests. For control of weeds phytophagous arthropods have principally been used and for control of arthropod pests parasitoids and predators have principally been used (Hajek 2004).

Most programs using pathogens and nematodes for control of insects and mites have focused on mass production and inundative release. As long-term solutions for insect and mite pests (i.e., use in classical biological control programs), pathogens and nematodes have been used much less frequently when compared with parasitoids and predators (Hajek et al. 2007). Interestingly, while some classical biological control programs using pathogens and nematodes have been very successful in controlling insect and mite pests, some accidental introductions of entomopathogenic agents have also yielded substantial and long-term control.

This publication is an updated version of the catalogue of classical biological control of pathogens and nematodes published in 2005 (Hajek et al. 2005). For both this revision and the initial version, it has been difficult to find many of the classical biological control programs listed in the tables that follow; possibly, we have not listed them all. Likewise, it was often difficult determining whether a release program should be included in this catalogue, particularly when a program was implemented many years ago and/ or not thoroughly documented. Thus, we used the following criteria for including programs in this catalogue:

1. The target pest was an insect or mite.
2. The microbial pathogen or nematode was not native (an exotic) to the area of release. We have included programs where the species of microbe or nematode was exotic (introduced) as well as programs where only the strain or biotype released was exotic.

We included programs for which, whether the releases were successful or not, the establishment of the microbe appeared to be a goal (i.e., long-term establishment and control) and establishment was either investigated or discussed or, for older programs, we can infer that establishment of the pathogen or nematode was a goal of the program. Note: Intentionally, we did not include examples of early widespread introductions of entomopathogens that were later shown to be questionably pathogenic, or widespread introductions where contaminants were actually released instead of the intended organisms (e.g., see Carruthers et al. 1996, Hostetter and Dysart 1996, Tanada and Kaya 1993).

**Organization of the Tables**

Intentional releases of entomopathogens against target insect or mite pests are grouped according to specific pathogen and nematode groups, and presented in Tables A through F. Table G summarizes accidental introductions. The following categories of information are covered for each introduction:

**Pest Group and Species**

Within each table the information is organized by the order and family of pest species (hosts) as laid out in the Table of Contents and Appendix II; within a family, the species entries are alphabetical. Only pestiferous insect and mite hosts are included. Taxonomic grouping, scientific names and synonyms for species names used in the publications cited or in the literature, are provided. If known, common names for pests are included.
**Biological Control Agent**

All natural enemies listed are exotic to their respective areas of release, i.e., either the species or the strain released was exotic, and include viruses, bacteria, fungi (including microsporidia in a separate table), an oomycete, and nematodes. For the majority of these groups, the higher order classification is presently not known or is being revised and Appendix I was constructed accordingly. Scientific names and synonyms are provided, and the family of the pathogen or nematode (or clade, for microsporidia). Higher levels of taxonomic classification are provided in Appendix I.

**Release Country or Region**

Releases are presented separately for geographically isolated areas and are listed by the country where the release was made. In some cases, a pathogen or nematode was released in more than one area within the same country. If release areas are geographically isolated from one another, these introductions are considered separate introductions. The exception to this would be the release of a pathogen or nematode on proximate islands of the same country, e.g., in the many island groups in the south Pacific. If it appears that the introductions of pathogens or nematodes on proximate islands within a group were part of the same program, only the initial introduction is listed.

**Year of Release**

The year of release is listed, providing the intent of the release was to establish the pathogen or nematode in the release area. In some cases, after release the pathogen or nematode levels declined over time, so agents were re-introduced. In other cases, pathogens have been re-introduced throughout a region over a period of years because the agents spread slowly on their own. In both cases, we list only the year or years of the initial releases; the dates of second or third introductions, or releases in later years in the same general region, are included only if the initial release failed or establishment was highly questionable, or the pathogens used in subsequent releases were from a different source or sources. For multiple releases of a biological control agent against the same target pest, table entries are ordered chronologically by year of first release. In the case of accidental introductions (Table G), the year the agent was first found is listed.

**Source of the Biological Control Agent**

The geographical location where the pathogen or nematode was acquired for the release is provided, if known (e.g., *ex China*). Whenever appropriate, microbes from different source locations are listed separately. In some cases, the origin of the natural enemies that were released is not known and the area where the natural enemy is native is given with an explanation. This can happen when natural enemies are introduced to one location (X) and then collected from location X for release in another location (Y), instead of directly acquiring them from the area where they are native.

**Results from Introduction**

Results of introductions are provided as brief summaries of establishment, control, and persistence. We found that it is not always easy to classify control programs by strategy (i.e., classical biological control vs. inundative augmentation) and there are multitudes of programs where pathogens and nematodes have been released inundatively. For studies to be included in Tables A-F, there must be some documented evidence that, whether the pathogen persisted or not after release, the intent of the program was to establish the pathogen in the release area for long-term, not temporary, control. Some older, poorly documented programs are exceptions and are included when we inferred the goal was establishment. Clear summaries of results from introductions cannot always be found. In some cases, this is because not enough time has transpired since the release to see an effect. Unfortunately, in other cases, especially in earlier programs, we simply could find no documentation of what happened after releases.

**Pest Origin**

For each pest species, its status in the country of release of the biological control agent is listed as either Introduced (exotic); Native (endemic); or Unknown. In some cases of widespread distribution within a region or continent, the species is assumed to be native if no other information was readily available.
References (within Tables)
Citation numbers for each table entry are provided, corresponding to the numerical list of references given before the index.

Appendices
Following Tables A-G, Appendix I provides the classification for pathogens and nematodes included in the catalogue. Appendix II provides the classification for insect and mite hosts, targeted by pathogens or nematodes that were either intentionally or accidentally introduced.

References
The full list of numbered references that follows the Appendices does not include every mention of a classical biological control introduction of a pathogen or nematode. Rather, it includes selected sources providing the information presented in this catalogue. If the information included in the catalogue has not been published, the individual providing the information is cited.
<table>
<thead>
<tr>
<th>Target pest species</th>
<th>Biological control agent</th>
<th>Release country or region</th>
<th>Year of release</th>
<th>(Source of biological control agent) Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COLEOPTERA: SCARABAEIDAE</strong></td>
<td></td>
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<tr>
<td>Oryctes monoceros (Olivier); African rhinoceros beetle or Coconut beetle</td>
<td>Oryctes rhinoceros nudivirus (OrNV) [= Rhabdionvirus oryctes (Huger); = Baculovirus oryctes Huger]; (Nudiviridae: Alphanudiviridae)</td>
<td>SEYCHELLES (in the Indian Ocean)</td>
<td>1973</td>
<td>(ex Samoa) Released on Mahé, Praslin Island group and La Digue. Establishment confirmed in 1986 on Praslin Island group only, with infection 70-90%.</td>
<td>Native</td>
<td>112, 113</td>
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<td></td>
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<td></td>
<td>1981-83</td>
<td>(ex Praslin Island group, Seychelles) Established on Mahé and Ste. Anne with 20-50% infection and 30% reduction in beetle population.</td>
<td>Native</td>
<td>112, 113</td>
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<tr>
<td>Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle</td>
<td>Oryctes rhinoceros nudivirus (OrNV) [= Rhabdionvirus oryctes (Huger); = Baculovirus oryctes Huger]; (Nudiviridae: Alphanudiviridae)</td>
<td>SAMOA (Western Samoa)</td>
<td>1967</td>
<td>(ex Malaysia) Established in 1 year and spread. Between 1973-75, adult infection decreased from 63 to 35% and although total population density also declined, damage was noticed again. Virus was re-released 1975-1978 with a resulting decline in damage. 40 years later, in some areas, heavy palm damage suggests a second control breakdown.</td>
<td>Introduced</td>
<td>17, 80, 89, 115, 116, 184, 205</td>
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<td></td>
<td>TOKELAU (in the Pacific)</td>
<td>1967</td>
<td>(ex Malaysia) Released on Nukunonu Atoll. Established and by 1973 39% of beetles infected and only 1.5-6.5% of palm fronds damaged.</td>
<td>Introduced</td>
<td>17, 184, 207</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Biological control agent; (Family: Genus)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td>COLEOPTERA: SCARABAEIDAE (continued)</td>
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<td></td>
<td>Oryctes rhinoceros (L.)</td>
<td>FIJI</td>
<td>1970-74</td>
<td>(ex Samoa) Established and by 1974 57-68% of beetles infected. Damage decreased significantly 12-18 months after virus establishment.</td>
<td>Introduced</td>
<td>15, 16, 17, 184</td>
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<td></td>
<td>(continued) Oryctes rhinoceros nudivirus (OrNV) (continued)</td>
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<td></td>
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<td>PALAU</td>
<td>1970</td>
<td>(ex Samoa) Established on Babeldaob Island, controlling beetles.</td>
<td>Introduced</td>
<td>167, 184</td>
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<td></td>
<td>1983</td>
<td>(ex Samoa) Released on Peleliu Island and “other places where beetle problems were evident,” resulting in beetle control.</td>
<td>Introduced</td>
<td>167</td>
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<td></td>
<td>WALLIS ISLAND</td>
<td>1970-71</td>
<td>(ex Samoa) Established; &lt; 2 months after release spread over entire island. In 1 year beetle populations decreased by 60-80% and damage decreased by 82%. Average number infested palms reduced from 60% in 1967 to 20% in 1981.</td>
<td>Introduced</td>
<td>17, 64, 74, 184</td>
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<td>TONGA</td>
<td>1970-71</td>
<td>(ex Samoa) Released in Tongatapu. Established, epizootics developed in 5 months and virus spread at 2-3 km/month, beetles and damage reduced. After 7 years, 84% of adult beetles infected throughout population and damage remained low (&lt; 5% of palm crowns surveyed).</td>
<td>Introduced</td>
<td>184, 201, 202</td>
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<td>MAURITIUS</td>
<td>1970-72</td>
<td>(ex Samoa) Established, beetle populations declined sharply from 1970. At least through 1976-77, damage reduced by 60-95%.</td>
<td>Introduced</td>
<td>17, 134</td>
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<td></td>
<td>AMERICAN SAMOA</td>
<td>1972</td>
<td>(ex Samoa) Established, virus spread 0.8-1.6 km/month and damage declined.</td>
<td>Introduced</td>
<td>17, 184</td>
</tr>
</tbody>
</table>
### Table A: Exotic Viruses Released, by Target Pest

**PEST ORDER: FAMILY**

<table>
<thead>
<tr>
<th>Target pest species</th>
<th>Biological control agent; (Family: Genus)</th>
<th>Release country or region</th>
<th>Year of release</th>
<th>(Source of biological control agent) Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COLEOPTERA: SCARABAEIDAE (continued)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Native</td>
<td>135, 206, 208</td>
</tr>
<tr>
<td>Oryctes rhinoceros (L.) <strong>(continued)</strong></td>
<td>Oryctes rhinoceros nudivirus (OrNV) (continued)</td>
<td>JAVA (Indonesia)</td>
<td>1976-80</td>
<td><em>(ex Sumatra, Indonesia)</em> Released in the Province of Central Java. Clear reduction of damage in next 3 years (and not in untreated areas), but no sweeping spread. 1987 survey: low infection in release and untreated areas; suspected virus and beetle resistance present before 1976.</td>
<td>Native</td>
<td>135, 206, 208</td>
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<td>PAPUA NEW GUINEA</td>
<td>1978-79</td>
<td><em>(ex Samoa)</em> Released on 3 islands. Established at nearly all sites, spread at 1 km/month.</td>
<td>Introduced</td>
<td>62</td>
</tr>
<tr>
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<td></td>
<td>INDIA: Minicoy Island</td>
<td>1983-84</td>
<td><em>(ex Kerala, India)</em> Released on Minicoy Island. Established within 9 months, pest suppressed to low levels and damage reduced. Pest remained at low levels 3.5 years after release.</td>
<td>Native</td>
<td>130</td>
</tr>
<tr>
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<td></td>
<td>MALDIVES (in the Indian Ocean)</td>
<td>1984-85</td>
<td><em>(ex Philippines, Tanzania, and Malaysia)</em> Established and caused highly significant reduction in palm damage on most islands where released. Different strains released and one strain (X2B) consistently yielded better infection and pest reduction.</td>
<td>Native</td>
<td>37, 209</td>
</tr>
<tr>
<td></td>
<td></td>
<td>INDIA: Andaman Islands</td>
<td>1987</td>
<td><em>(ex Kerala, India)</em> Released at 4 locations on Andaman Islands. Palm damage reduced by 90% within 43 months of release, large reduction in numbers of adults and numbers of breeding sites. Virus spread at 1 km/year. By 1996, beetle populations remained at low levels.</td>
<td>Native</td>
<td>90</td>
</tr>
<tr>
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<td></td>
<td>INDIA: Lakshadweep</td>
<td>1988</td>
<td><em>(ex Kerala, India)</em> Released on Andrott (Androth) Island. Successful introduction. In 1990, coconut palm crop damage measurably less and virus incidence &gt; 60%.</td>
<td>Native</td>
<td>61</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Family: Genus)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
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<tr>
<td><strong>COLEOPTERA: SCARABAEIDAE (continued)</strong></td>
<td><strong>Oryctes rhinoceros</strong> (L.) (continued)</td>
<td><em>Oryctes rhinoceros nudivirus</em> (OrNV) (continued)</td>
<td>OMAN</td>
<td>1989</td>
<td><em>(source unknown)</em> Established. Levels of damage steadily declined and 6 years later, only 4-6% of palm fronds were damaged by beetles.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td><strong>Scapanes australis</strong> (Boisduval); Melanesian rhinoceros beetle</td>
<td><em>Oryctes rhinoceros nudivirus</em> (OrNV) [= <em>Rhabdionvirus oryctes</em> (Huger); = <em>Baculovirus oryctes</em> Huger]; (Nudiviridae: <em>Alphanudivirus</em>)</td>
<td>SOLOMON ISLANDS (in the Pacific)</td>
<td>1978-79</td>
<td><em>(ex Fiji)</em> Released in plantations on New Georgia Island and Kolombangara Island (Western Province), Guadalcanal Island (Guadalcanal Province). Some reduction in host population next year, possible decline in damage, but not consistently.</td>
<td>Native</td>
</tr>
<tr>
<td><strong>LEPIDOPTERA: ZYGAENIDAE</strong></td>
<td><strong>Harrisina brillians</strong> Barnes &amp; McDunnough; Western grapeleaf skeletonizer</td>
<td><em>Harrisina brillians granulovirus</em> (HbGV); (Baculoviridae: <em>Betabaculovirus</em>)</td>
<td>USA: California</td>
<td>1981-82</td>
<td><em>(ex Mexico and Arizona USA)</em> Released in Tulare County in central California. Established; epizootics develop in high density host populations. Overall, lowers general equilibrium density of host populations.</td>
<td>Introduced</td>
</tr>
<tr>
<td><strong>LEPIDOPTERA: EREBIDAE</strong></td>
<td><strong>Anticarsia gemmatalis</strong> Hübner; Velvetbean caterpillar</td>
<td><em>Anticarsia gemmatalis multiple nucleopolyhedrovirus</em> (AgMNPV); (Baculoviridae: <em>Alphabaculovirus</em>)</td>
<td>USA: South Carolina</td>
<td>1979-80</td>
<td><em>(ex Santa Catarina, Brazil)</em> 59-86% infection the season of release but no infections found 1 year after release.</td>
<td>Native</td>
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<td>USA: Louisiana</td>
<td>1990-91</td>
<td><em>(ex Brazil)</em> Released in soybean fields. Established, causing 25-100% infection the year of release and 4-49% infection for years 2-4 after release, even in rotated fields.</td>
<td>Native</td>
</tr>
<tr>
<td></td>
<td><strong>Lymantria dispar</strong> (L.); Gypsy moth</td>
<td><em>Lymantria dispar multiple nucleopolyhedrovirus</em> (LdMNPV); (Baculoviridae: <em>Alphabaculovirus</em>)</td>
<td>SARDINIA</td>
<td>1972</td>
<td><em>(ex Serbia, Yugoslavia)</em> Established; high levels of larval mortality year of release, &gt;40% infection the next year and spread over 300 hectares.</td>
<td>Native</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Family: Genus)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
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</tr>
<tr>
<td><strong>LEPIDOPTERA: EREBIDAE (continued)</strong></td>
<td><strong>Lymantria monacha</strong> L.; Nun moth</td>
<td><em>Lymantria monacha nucleopolyhedrovirus</em> (<strong>LmNPV</strong>); (Baculoviridae: <em>Alphabaculovirus</em>)</td>
<td><strong>DENMARK</strong></td>
<td>1973-74</td>
<td><em>(ex Sweden and West Germany)</em> Released in Silkeborg in 1973: 90% infection year of release and, in 1974, no serious defoliation within and directly around virus-release stands while insecticides had to be applied to other areas. In 1975, no virus was found in the few larvae collected. Released in Grindsted in 1974: the population collapsed that year but it is suggested that other factors, including the native virus, played important parts.</td>
<td>Native</td>
</tr>
<tr>
<td><strong>LEPIDOPTERA: NOCTUIDAE</strong></td>
<td><strong>Trichoplusia ni</strong> (Hübner); Cabbage looper</td>
<td><em>Trichoplusia ni nucleopolyhedrovirus</em> (<strong>TnNPV</strong>); (Baculoviridae: <em>Alphabaculovirus</em>)</td>
<td><strong>COLOMBIA</strong></td>
<td>1970</td>
<td><em>(ex California USA)</em> Persisted after release, controlling subsequent pest generations.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td><strong>Pseudoplusia includens</strong> (Walker); Soybean looper</td>
<td><em>Pseudoplusia includens single nucleopolyhedrovirus</em> (<strong>PsinSNPV</strong>); (Baculoviridae: <em>Alphabaculovirus</em>)</td>
<td><strong>USA: Louisiana</strong></td>
<td>1975-77</td>
<td><em>(ex Guatemala)</em> Released in soybean fields. Established; 38-63% infection 12-15 years after introduction.</td>
<td>Native</td>
</tr>
<tr>
<td></td>
<td><strong>Agrotis segetum</strong> (Denis &amp; Schiffermüller); Turnip moth</td>
<td><em>Agrotis segetum granulovirus</em> (<strong>AsGV</strong>); (Baculoviridae: <em>Betabaculovirus</em>)</td>
<td><strong>DENMARK</strong></td>
<td>1975-80</td>
<td><em>(ex Austria)</em> Released in Lammefjord. Caused 65-70% reduction in damage soon after release and thought to have spread 10 m from release. One year after release, ca. 99% of infectivity of virus applied to soils had been lost.</td>
<td>Native</td>
</tr>
<tr>
<td><strong>HYMENOPTERA: DIPRIONIDAE</strong></td>
<td><strong>Gilpinia hercyniae</strong> (Hartig) [= <em>Diprion hercyniae</em> Hartig]; European spruce sawfly</td>
<td><em>Gilpinia hercyniae nucleopolyhedrovirus</em> (<strong>GhNPV</strong>); (Baculoviridae: <em>Gammabaculovirus</em>)</td>
<td><strong>CANADA: Newfoundland</strong></td>
<td>1943-45</td>
<td><em>(ex mainland Canada)</em> Established and by 1946 reported as prevalent over considerable areas surrounding release areas.</td>
<td>Introduced</td>
</tr>
<tr>
<td>Target pest species</td>
<td>Biological control agent; (Family: Genus)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
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<tr>
<td><em>Neodiprion sertifer</em> (Geoffrey); European pine sawfly</td>
<td><em>Neodiprion sertifer nucleopolyhedrovirus</em> (<em>NeseNPV</em>); (Baculoviridae: <em>Gammabaculovirus</em>)</td>
<td>CANADA: Ontario</td>
<td>1950+</td>
<td>(ex Sweden) Released in southern Ontario near Strathroy. Over 90% mortality 14 days after release and virus persisted. Widely distributed for release in pine plantations, e.g., one introduction in 1951 controlled an infestation over 100 acres within 3 years. After introduction, this virus replaced insecticides for controlling hosts and provided long term control. Today, host is a minor pest of plantations and ornamentals but occasionally can increase locally as natural spread and effectiveness of the virus is much reduced at low host densities.</td>
<td>Introduced</td>
<td>23, 40, 45, 119</td>
</tr>
<tr>
<td>USA: New Jersey</td>
<td>1951-52</td>
<td>(ex Canada) Established and spread (ca. 300 m from individual trees after release). Released also in 1952. Provided complete control.</td>
<td>Introduced</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA: Illinois</td>
<td>1952</td>
<td>(ex New Jersey USA; originally Canada) By 19 days after treatment, 82-100% control. In 1953, spread was up to 80 m from treated area. Excellent control achieved.</td>
<td>Introduced</td>
<td>20, 45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA: Indiana</td>
<td>1953</td>
<td>(ex Canada) Reported as maintaining adequate control over several years through recurring epizootics after establishment.</td>
<td>Introduced</td>
<td>168</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK: SCOTLAND</td>
<td>1961</td>
<td>(ex Canada) 85% of colonies had infected individuals 24 days after release, resulting in very good control. In 1962, found to persist in treated areas but minimal spread.</td>
<td>Native</td>
<td>41, 163</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Biological control agent; (Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
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<tr>
<td>COLEOPTERA: SCARABAEIDAE</td>
<td></td>
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<tr>
<td>Cochliotis melolonthoides (Gerstaecker)</td>
<td>Paenibacillus popilliae (Dutky); (Paenibacillaceae)</td>
<td>TANZANIA</td>
<td>1968</td>
<td>(ex USA, probably) Strain from Japanese beetle, Popillia japonica Newman. Seemed to become established but this is not certain due to presence of an indigenous milky disease.</td>
<td>Native</td>
<td>63</td>
</tr>
<tr>
<td>Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle</td>
<td>Paenibacillus popilliae (Dutky); (Paenibacillaceae)</td>
<td>PALAU (in Micronesia)</td>
<td>1951</td>
<td>(ex USA) Strain from Japanese beetle, Popillia japonica Newman. Not recovered after release.</td>
<td>Introduced</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMERICAN SAMOA</td>
<td>1957</td>
<td>(ex USA) Strain from Japanese beetle, Popillia japonica Newman. Not recovered after release.</td>
<td>Introduced</td>
<td>184</td>
</tr>
<tr>
<td>Papuana huebneri (Halmahera); Taro beetle</td>
<td>Paenibacillus popilliae (Dutky); (Paenibacillaceae)</td>
<td>KIRIBATI (in the Pacific)</td>
<td>1995-96</td>
<td>(ex Papua New Guinea and Solomon Islands) Released on South Tarawa. Isolate from Papua New Guinea (type A1) caused infections 1 year after release.</td>
<td>Introduced</td>
<td>188</td>
</tr>
<tr>
<td>Popillia japonica (Dutky); Japanese beetle</td>
<td>Paenibacillus popilliae (Dutky); (Paenibacillaceae)</td>
<td>AZORES: Terceira Island</td>
<td>1990-91</td>
<td>(ex USA) Did not appear to be effective. Establishment is questionable.</td>
<td>Introduced</td>
<td>106, 122</td>
</tr>
<tr>
<td>Schizonycha sp.</td>
<td>Paenibacillus popilliae (Dutky); (Paenibacillaceae)</td>
<td>KENYA</td>
<td>1956</td>
<td>(ex USA) A and B strains from Japanese beetle, Popillia japonica Newman. Not recovered after release.</td>
<td>Native</td>
<td>63</td>
</tr>
<tr>
<td>PEDEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
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<tr>
<td>ORTHOPTERA: ACRIDIDAE</td>
<td>Melanoplus sanguinipes (F.); Migratory grasshopper</td>
<td><em>Entomophaga grylli</em> (Fresenius) Batko, pathotype III; (Entomophthorales: Entomophthoraceae)</td>
<td>USA: Alaska</td>
<td>1990</td>
<td><em>(ex Australia)</em> No establishment.</td>
<td>Native</td>
</tr>
<tr>
<td></td>
<td>Melanoplus bivittatus (Say); Two-striped grasshopper; <em>M. sanguinipes</em> (F.); Migratory grasshopper; <em>Camnula pellucida</em> Scudder; Clearwinged grasshopper; and other spp.</td>
<td><em>Entomophaga grylli</em> (Fresenius) Batko, pathotype III; (Entomophthorales: Entomophthoraceae)</td>
<td>USA: North Dakota</td>
<td>1989-91</td>
<td><em>(ex Australia)</em> Isolate chosen based on biology, similarity of climates and ability to infect species in both Oedipodinae and Melanoplinae, but not <em>Hesperotettix viridis</em> (Scudder). Populations of some species declined in 1991-92 with 23% infection in 1992 at &lt; 1 km from release, 1.7% in 1993 and no infection in 1994 when host populations were low. Long term establishment questionable.</td>
<td>Native</td>
</tr>
<tr>
<td></td>
<td>Phaulacridium vittatum (Sjöstedt); Wingless grasshopper</td>
<td><em>Entomophaga grylli</em> (Fresenius) Batko, pathotype I; (Entomophthorales: Entomophthoraceae)</td>
<td>AUSTRALIA</td>
<td>1984</td>
<td><em>(ex Arizona USA)</em> Released near Canberra. Epizootics did not occur and permanent establishment questioned, efficacy unlikely.</td>
<td>Native</td>
</tr>
<tr>
<td>HEMIPTERA: CERCOPIDAE</td>
<td>Aeneolamia flavilatera (Urich)</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>GUYANA (in South America)</td>
<td>1944</td>
<td><em>(ex Trinidad)</em> Introduced by releasing infected adult froghoppers. Established, considered unsuccessful for control but &lt; 1 year later abundant infections ca. 32 km away. Unknown whether this was due to introduced or indigenous fungus.</td>
<td>Native</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
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<tr>
<td>HEMIPTERA: CICACDELLIDAE</td>
<td>Empoasca fabae (Harris); Potato leafhopper</td>
<td>Zoophthora (= Erynia) radicans (Brefeld) Batko; (Entomophthorales: Entomophthoraceae)</td>
<td>USA: Illinois</td>
<td>1984</td>
<td>(ex Brazil) No establishment.</td>
<td>Field infection confirmed but monitoring not continued in subsequent years.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>USA: New York</td>
<td>1990-91</td>
<td>(ex Serbia) Released in central New York State. Field infection confirmed but monitoring not continued in subsequent years.</td>
<td>Introduced</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Unspecified species of leafhopper</td>
<td>Unidentified fungus</td>
<td>USA: Hawaii</td>
<td>1906</td>
<td>(ex Australia and Fiji) Fungus found infecting leafhopper eggs at source. Establishment not confirmed.</td>
<td>Unknown</td>
</tr>
<tr>
<td>HEMIPTERA: APHIDIDAE</td>
<td>Aphis gossypii Glover; Cotton aphid</td>
<td>Neozygites fresenii (Nowakowski) Batko; (Neozygitales: Neozygitaceae)</td>
<td>USA: California</td>
<td>1994-95</td>
<td>(ex Arkansas USA) Released in San Joaquin Valley. Cycling during release seasons with infection levels that would have initiated epizootics in Arkansas but epizootics did not occur in California. Persisted until end of release seasons but not recovered 1997-2001, so long term establishment questionable.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td>Diuraphis noxia Kurdjumov; Russian wheat aphid</td>
<td>Zoophthora radicans (Brefeld) Batko; (Entomophthorales: Entomophthoraceae)</td>
<td>USA: Idaho</td>
<td>1992</td>
<td>(ex Serbia) To release, parasitoids Aphelinus asychis (Walker) were inoculated or sporulating cultures were added to colonies. The fungus only made resting spores within cadavers and no subsequent surveys were conducted to evaluate establishment.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td>Macrosiphum solanifolii (Ashmead); Potato aphid</td>
<td>Probably in Lecanicillium (= Verticillium) lecanii species complex [Reported as Acrosta lagmus sp.]; (Hypocreales: Cordycipitaceae)</td>
<td>USA: Maine</td>
<td>1955</td>
<td>(ex Hawaii USA) Diseased aphids found 3 weeks after release and one infected specimen found in 1958. Unknown if permanently established.</td>
<td>Native</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
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<tr>
<td><strong>HEMIPTERA: APHIDIDAE (continued)</strong></td>
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<tr>
<td>Metopolophium dirhodum (Walker); Rose-grain aphid; and other cereal aphid spp.</td>
<td>Pandora neaphidis (Remaudière &amp; Hennebert) Humber; (Entomophthorales: Entomophthoraceae)</td>
<td>BELGIUM</td>
<td>1982</td>
<td>(ex Brazil) Isolate chosen due to good in vitro growth. Limited transmission in field after release, probably because few conidia are produced by isolate. Limited transmission suggests poor chance of establishment.</td>
<td>Native</td>
<td>110</td>
</tr>
<tr>
<td>Therioaphis maculata (Buckton); Spotted alfalfa aphid</td>
<td>Zoophthora radicans (Brefeld) Batko [= Entomophthora sphaerosperma Fresenius]; (Entomophthorales: Entomophthoraceae)</td>
<td>AUSTRALIA: New South Wales</td>
<td>1979</td>
<td>(ex Israel) Isolate chosen in part due to similar climate. Became widely distributed in New South Wales and southern Queensland, causing epizootics in late summer/autumn; only the first aphid outbreaks in spring likely to escape infection.</td>
<td>Introduced</td>
<td>126, 127, 128</td>
</tr>
<tr>
<td><strong>HEMIPTERA: ALEYRODIDAE</strong></td>
<td></td>
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<tr>
<td>Aleurodicus coccus (Curtis); Coconut whitefly; and Aleurothrixus floccosus (Maskell); Woolly whitefly</td>
<td>Aschersonia aleyrodis Webber; (Hypocreales: Clavicipitaceae)</td>
<td>VIRGIN ISLANDS</td>
<td>Before 1920</td>
<td>(source unknown) No establishment due to high winds and drought.</td>
<td>Native?</td>
<td>195</td>
</tr>
<tr>
<td>Dialeurodes sp.; Whitefly</td>
<td>Aschersonia aleyrodis Webber; (Hypocreales: Clavicipitaceae)</td>
<td>BERMUDA</td>
<td>1926</td>
<td>(ex Florida USA) Establishment and persistence not reported.</td>
<td>Unknown</td>
<td>143</td>
</tr>
<tr>
<td>Singhiella citrifolii (Morgan) [= Dialeurodes citrifolii Morgan]; Cloudywinged whitefly</td>
<td>Aschersonia goldiana Saccardo &amp; Ellis; (Hypocreales: Clavicipitaceae)</td>
<td>BERMUDA</td>
<td>1924</td>
<td>(ex Florida USA) Considered established in 1925 but only provided efficient control in well-shaded situations.</td>
<td>Introduced</td>
<td>141, 142</td>
</tr>
</tbody>
</table>
### TABLE C: EXOTIC FUNGI RELEASED, BY TARGET PEST

<table>
<thead>
<tr>
<th>PEST ORDER: FAMILY</th>
<th>Target pest species</th>
<th>Biological control agent; (Order: Family)</th>
<th>Release country or region</th>
<th>Year of release</th>
<th>(Source of biological control agent)</th>
<th>Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
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<tbody>
<tr>
<td>HEMIPTERA: ALEYRODIDAE (continued)</td>
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<tr>
<td><strong>Diaurodes citri</strong> (Ashmead); Citrus whitefly</td>
<td><em>Aschersonia</em> spp.; (Hypocreales: Clavicipitaceae)</td>
<td>USSR: AZERBAIJAN and GEORGIA</td>
<td>1960-64</td>
<td>(ex China, Cuba, India, Japan, Trinidad, USA, and Vietnam) Multiple species, at least 11 strains, were released in citrus plantations; no information on which became established. About 80% mortality of nymphs under favorable conditions and fungus spread to new plantations. The most aggressive was <em>A. placenta</em> Berkeley &amp; Broome from Vietnam and China: up to 90% nymphal mortality in Adzharia, Georgia in favorable weather, but inhibited by drought. In 1980-84, in areas of Georgia and Azerbaijan where large complexes of natural enemies occurred in citrus plantations (including <em>Aschersonia</em> spp.), the pest was kept below the economic threshold.</td>
<td></td>
<td>Introduced</td>
<td>88, 117, 155, 159</td>
<td></td>
</tr>
<tr>
<td><strong>Unspecified species of whitefly</strong></td>
<td>Unidentified fungus</td>
<td>USA: Hawaii</td>
<td>1909</td>
<td>(ex Florida USA) One species released. Results not reported.</td>
<td></td>
<td>Unknown</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>HEMIPTERA: COCCIDAE</td>
<td></td>
<td></td>
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<tr>
<td><strong>Coccus viridis</strong> (Green); Green scale</td>
<td>Unidentified fungus [possibly in <em>Lecanicillium</em> (= <em>Verticillium</em> lecanii species complex); (Hypocreales: Cordycipitaceae)</td>
<td>USA: Hawaii</td>
<td>1928 or before</td>
<td>(ex Florida USA) Established and provided effective control.</td>
<td></td>
<td>Introduced</td>
<td>87, 185</td>
<td></td>
</tr>
<tr>
<td><strong>Coccus viridis</strong> (Green); Green scale; <em>Eucalyymnatus tessellatus</em> (Signoret); Tesselated scale; and <em>Ceroplastes rubens</em> Maskell; Red wax scale</td>
<td><em>Lecanicillium lecanii</em> (Zimmerman) Gams &amp; Zare [= <em>Verticillium lecanii</em> (Zimmerman); = <em>Cephalosporium lecanii</em> Zimmerman]; (Hypocreales: Cordycipitaceae)</td>
<td>SEYCHELLES (in the Indian Ocean)</td>
<td>1911</td>
<td>(ex Sri Lanka (Ceylon)) Established and largely controlled scale populations.</td>
<td></td>
<td>Introduced</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
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<tr>
<td>HEMIPTERA: COCCIDAE (continued)</td>
<td><strong>Coccus viridis</strong> (Green); Green scale; and other <strong>Lecaniine</strong> scale spp.</td>
<td><em>Lecanicillium lecanii</em> (Zimmerman) Gams &amp; Zare [= <em>Verticillium lecanii</em> (Zimmerman); = <em>Cephalosporium lecanii</em> Zimmerman]; (Hypocreales: Cordycipitaceae)</td>
<td>SEYCHELLES (in the Indian Ocean)</td>
<td>Before 1933</td>
<td><em>(ex India)</em> Well established on lecaniine scales, especially <em>Coccus viridis</em> on coffee, and spread widely.</td>
<td>Introduced</td>
<td>178</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Unspecified species of coccid scale</strong></td>
<td>Unidentified fungi</td>
<td>USA: Hawaii</td>
<td>1897</td>
<td><em>(source unreported)</em> Two species released. Established and spread over most parts of the islands.</td>
<td>Unknown</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>HEMIPTERA: DIASPIDIDAE</td>
<td><strong>Aonidiella aurantii</strong> (Maskell); California red scale</td>
<td><em>Fusarium coccophilum</em> (Desmazieres) Wollenweber &amp; Reinking [= <em>Fusarium episphaerum</em> f. <em>coccophila</em> Tul.]; teleomorph = <em>Nectria flammea</em> (Tulasne &amp; Tulasne) Dingley; (Hypocreales: Nectriaceae)</td>
<td>ARGENTINA</td>
<td>1900</td>
<td><em>(ex USA)</em> Established and occasionally caused up to 90% mortality in northeastern and northwestern regions.</td>
<td>Introduced</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Aspidiotus destructor</strong> Signoret; Coconut scale</td>
<td><em>Fusarium juruanum</em> P. Hennings [= <em>Pseudomicrocera henningsii</em> (Koord.) Petch]; (Hypocreales: Nectriaceae)</td>
<td>SEYCHELLES (in the Indian Ocean)</td>
<td>1929</td>
<td><em>(ex Sierra Leone, west Africa)</em> Did not establish.</td>
<td>Introduced</td>
<td>46</td>
<td></td>
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<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td>HEMIPTERA: DIASPIDIDAE (continued)</td>
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<tr>
<td>Lepidosaphes beckii (Newman) [= Cornuaspis beckii (Newman)]; Purple or Mussel scale</td>
<td>Fusarium coccophilum (Desmazieres); Wollenweber &amp; Reinking [= Sphaerostilbe coccophilum Tul.]; teleomorph = Nectria flammea (Tulasne &amp; Tulasne) Dingley; (Hypocreales: Nectriaceae)</td>
<td>USA: Hawaii</td>
<td>1905 or before</td>
<td>(ex Florida USA) Established and locally abundant but control only partial.</td>
<td>Introduced</td>
<td>103</td>
<td></td>
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<td></td>
<td></td>
<td>BERMUDA</td>
<td>1926</td>
<td>(ex Florida USA) Establishment and persistence not reported.</td>
<td>Introduced</td>
<td>143</td>
<td></td>
<td></td>
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<tr>
<td>Podonectria coccicola Petch; (Pleosporales: Tubeufiaceae)</td>
<td></td>
<td>BERMUDA</td>
<td>1926</td>
<td>(ex Florida USA) Establishment and persistence not reported.</td>
<td>Introduced</td>
<td>143</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myriangium duriae Montagne &amp; Berkeley [1st edition listed as Triblidium caespitosum]; (Myriangiaceae)</td>
<td></td>
<td>BERMUDA</td>
<td>1926</td>
<td>(ex Florida USA) Released on infested citrus trees throughout the island. Found already present on L. beckii at one site. Establishment and persistence not reported.</td>
<td>Introduced</td>
<td>143</td>
<td></td>
<td></td>
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<tr>
<td>Quadraspidiotus perniciosus (Comstock) [= Aspidiotus perniciosus Comstock]; San Jose scale</td>
<td>Fusarium coccophilum (Desmazieres); Wollenweber &amp; Reinking [= Sphaerostilbe coccophilum Tul.]; teleomorph = Nectria flammea (Tulasne &amp; Tulasne) Dingley; (Hypocreales: Nectriaceae)</td>
<td>USA: California</td>
<td>1897</td>
<td>(ex Florida USA) As a result of this introduction, or a native fungus, scale nearly exterminated in southern California.</td>
<td>Introduced</td>
<td>198</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>USA: New Jersey</td>
<td>1897</td>
<td>(ex Florida USA) Established, overwintered, with abundant infection the following September but this pathogen alone failed to provide adequate control.</td>
<td>Introduced</td>
<td>172, 173</td>
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<td></td>
<td></td>
<td>USA: Illinois</td>
<td>1898</td>
<td>(ex Florida USA) Released by tying twigs with infected scales to trees. Overwintered and many scales infected but healthy scales still abundant. Hypothesized this fungus could add to effects of other natural enemies to provide a permanent check of scale populations but the level of fungus activity would depend on rainfall levels.</td>
<td>Introduced</td>
<td>52</td>
<td></td>
<td></td>
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<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td>THYSANOPTERA: THRIPIDAE</td>
<td><em>Thrips tabaci</em> Lindeman; Onion thrips</td>
<td><em>Neozygites parvispora</em> (MacLeod &amp; Carl) Remaudière &amp; Keller; (Neozygitales: Neozygitaceae)</td>
<td>BARBADOS</td>
<td>1973-76</td>
<td>(ex Switzerland) Released in onion field but no establishment.</td>
<td>Introduced</td>
<td>33</td>
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<tr>
<td>COLEOPTERA: SCARABAEIDAE</td>
<td><em>Adoretus tenuimaculatus</em> Waterhouse</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>FIJI</td>
<td>Before 1918</td>
<td>(source unknown) Some signs that this fungus acted as a check on the beetles.</td>
<td>Introduced</td>
<td>101</td>
<td></td>
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<tr>
<td></td>
<td><em>Alissonotum impressicolle</em> Arrow</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>TAIWAN</td>
<td>1914</td>
<td>(ex Hawaii USA) Numbers of scarabs greatly reduced in fields where spores were released.</td>
<td>Native</td>
<td>199, 200</td>
<td></td>
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<td></td>
<td><em>Dermolepida albohirtum</em> (Waterhouse); Greyback cane beetle</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>AUSTRALIA: Queensland</td>
<td>About 1914</td>
<td>(ex Samoa) Released in Queensland but before release, had already been found infecting this host in Queensland. Post release, at times considerable numbers of grubs of intended host and <em>Rhabdoscelus obscurus</em> (Boisduval), the New Guinea sugarcane weevil, killed by this fungus.</td>
<td>Native</td>
<td>196</td>
<td></td>
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<tr>
<td></td>
<td><em>Lepidiota pruinosa</em> Wied., and <em>Leucopholis irrorata</em> Chevrolat; white grubs in sugar cane</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>PHILIPPINES</td>
<td>1928</td>
<td><em>(ex Queensland, Australia)</em> Not effective control and “undoubtedly already present.”</td>
<td>Native</td>
<td>162</td>
<td></td>
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<tr>
<td></td>
<td><em>Lepidiota</em> sp., <em>Anoplognathus</em> sp., and other spp.; white grubs in sugar cane</td>
<td><em>Beauveria brongnartii</em> (Saccardo) Petch [= <em>Botrytis tenella</em> Sacc.; (Hypocreales: Cordycipitaceae)</td>
<td>AUSTRALIA</td>
<td>1894-95</td>
<td><em>(ex France)</em> Released in Queensland and New South Wales. Negative results in New South Wales after dissemination.</td>
<td>Unknown</td>
<td>196</td>
<td></td>
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<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<td><strong>COLEOPTERA: SCARABAEIDAE (continued)</strong></td>
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<td><em>Oryctes rhinoceros</em> (L.); Asiatic or Coconut rhinoceros beetle</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>SAMOA (Western Samoa)</td>
<td>1939</td>
<td><em>(ex Java, Indonesia)</em> This fungal species recovered after release but whether it was the introduced strain or a native strain is uncertain.</td>
<td>Introduced</td>
<td>184</td>
<td></td>
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<td></td>
<td></td>
<td>WALLIS ISLAND (in the Pacific)</td>
<td>1952</td>
<td><em>(ex Argentina)</em> Results from release unknown.</td>
<td>Introduced</td>
<td>184</td>
<td></td>
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<td></td>
<td></td>
<td>TOKELAU (in the Pacific)</td>
<td>1967</td>
<td><em>(ex Samoa)</em> Results from release unknown.</td>
<td>Introduced</td>
<td>184</td>
<td></td>
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<td></td>
<td></td>
<td>TONGA (in Polynesia)</td>
<td>1969</td>
<td><em>(ex Samoa)</em> High levels of infection directly after release, infections still present 3 years later but prevalence extremely low.</td>
<td>Introduced</td>
<td>184, 201</td>
<td></td>
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<td><em>Papuana huebneri</em> (Halmahera); Taro beetle</td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>KIRIBATI (in the Pacific)</td>
<td>1976</td>
<td><em>(source unknown)</em> Released on southern Tarawa by Latch. Establishment not confirmed.</td>
<td>Introduced</td>
<td>124</td>
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<td></td>
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<td></td>
<td>1995</td>
<td><em>(ex Papua New Guinea)</em> Released on southern Tarawa. Persisted in soil through 2003, spread and exerted some control.</td>
<td>Introduced</td>
<td>124, 188</td>
<td></td>
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<td><em>Phyllophaga smithi</em> (Arrow) [= <em>Lachnosterna smithi</em> (Arrow); = <em>Clemora smithi</em> (Arrow); = <em>Phyalus smithi</em> Arrow]; white grub in sugar cane</td>
<td><em>Beauveria bassiana</em> (Balsamo) Vuillemin [= <em>Beauveria densa</em> (Link) Vuillemin]; (Hypocreales: Cordycipitaceae)</td>
<td>MAURITIUS (in the Indian Ocean)</td>
<td>1932</td>
<td><em>(ex UK)</em> Unknown isolate from Imperial Bureau of Mycology. Host population gradually declined and diseases may have played a part.</td>
<td>Introduced</td>
<td>63, 131, 132, 133</td>
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<td></td>
<td><em>Metarhizium anisopliae</em> (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td></td>
<td></td>
<td></td>
<td>Introduced</td>
<td>63, 131, 132, 133</td>
<td></td>
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<tr>
<td>Pest Order: Family</td>
<td>Target Pest Species</td>
<td>Biological Control Agent; Order: Family</td>
<td>Release Country or Region</td>
<td>Year of Release</td>
<td>Source of Biological Control Agent</td>
<td>Results from Introduction</td>
<td>Pest Origin</td>
<td>References</td>
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<td><strong>Coleoptera: Curculionidae</strong></td>
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<td>Otiorhynchus nodosus (Müller), and <em>O. arcticus</em> (Fabricius)</td>
<td>Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)</td>
<td>Iceland</td>
<td>2003</td>
<td>(Ex Havnardalur, Faroe Islands) Released in eroded areas in Haukadalur. Establishment unknown. Heathland soil in Haukadalur in 1999 found to have <em>M. anisopliae</em> in 40% of samples.</td>
<td></td>
<td>Native</td>
<td>139, 140</td>
<td></td>
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<tr>
<td>Sitona discoideus Gyllenhal; Sitona weevil</td>
<td>Beauveria bassiana (Balsamo) Vuillemin; (Hypocreales: Cordycipitaceae)</td>
<td>Australia</td>
<td>1984</td>
<td>(Ex Montpellier, France) Released in southern Australia. No infections ever found.</td>
<td></td>
<td>Introduced</td>
<td>5</td>
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<td><strong>Diptera: Culicidae</strong></td>
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<tr>
<td>Aedes polynesiensis Marks</td>
<td>Coelomomyces stegomyiae Keilin; (Blastocladiales: Coelomomyctaceae)</td>
<td>Tokelau</td>
<td>1958</td>
<td>(Ex Singapore) Released on Nukunonu Atoll. Established, by 1963 infected larvae found in 13 of 35 habitats.</td>
<td></td>
<td>Native</td>
<td>75, 107</td>
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<td><strong>Lepidoptera: Erebidae</strong></td>
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<td>Lymantria dispar (L.); Gypsy moth</td>
<td>Entomophaga maimaiga Humber, Shimazu &amp; Soper; (Entomophthorales: Entomophthoraceae)</td>
<td>USA: Massachusetts</td>
<td>1910-11</td>
<td>(Ex Nishigahara, Tokyo Prefecture, Japan) Released in Boston area. In 1911 found to be not established.</td>
<td></td>
<td>Introduced</td>
<td>177</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>USA: New York</td>
<td>1985</td>
<td>(Ex Ishikawa Prefecture, Japan) Released in Allegany State Park in southwestern New York State. No transmission to host population detected. Not established.</td>
<td></td>
<td>Introduced</td>
<td>67, 69</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>USA: Virginia</td>
<td>1986</td>
<td>(Ex Ishikawa Prefecture, Japan) Released in Shenandoah National Park in northern Virginia. Very low transmission to host population. Not established.</td>
<td></td>
<td>Introduced</td>
<td>67, 69</td>
<td></td>
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<tr>
<td>PEST ORDER: FAMILY</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<td>LEPIDOPTERA: EREBIDAE (continued)</td>
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<tr>
<td><strong>Lymantria dispar</strong> (L.) (continued)</td>
<td>Entomophaga maimaiga Humber, Shimazu &amp; Soper (continued)</td>
<td>USA: Virginia, West Virginia, Maryland, Pennsylvania</td>
<td>1991-1992</td>
<td>(ex Massachusetts and New York USA) Soil with resting spores released along leading edge of <em>L. dispar</em> spread, in Virginia, West Virginia, Maryland, western Pennsylvania. Epizootics developed in 1992 in the majority of 1991 release sites, and infections also detected in most control plots; <em>E. maimaiga</em> had spread rapidly south and west to edge of host distribution.</td>
<td>Introduced</td>
<td>68</td>
<td></td>
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<tr>
<td>USA: Michigan</td>
<td></td>
<td>1991-1992</td>
<td>(ex Massachusetts USA) Released as resting spores in soil and as cadavers from inoculated larvae, at sites along the leading edge of <em>L. dispar</em> distribution. One site had infected larvae in 1991; infection also low in 1992; in 1993 infection from 20-99% at release sites and in some control sites, and host populations declined at release sites.</td>
<td>Introduced</td>
<td>174</td>
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<td></td>
<td></td>
<td>1999</td>
<td>(ex Massachusetts USA) Released in Karlovo, in central Bulgaria. Established but negligible control.</td>
<td>Native</td>
<td>152</td>
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<td></td>
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<td>2000</td>
<td>(ex Connecticut USA) Released in Levishte. Infections found in 2002, 2003 and 2004 and fungus was subsequently redistributed within Bulgaria. By 2013 found in nearby countries (including Serbia, Croatia, Hungary, Slovakia, Bosnia and Herzegovina, western Turkey, Greece, and Macedonia). Fungus assumed to have spread from Bulgarian introductions.</td>
<td>Native</td>
<td>58, 150, 216</td>
<td></td>
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<tr>
<td>RUSSIA: Novosibirsk region</td>
<td></td>
<td>2002</td>
<td>(ex Virginia USA) Establishment not confirmed.</td>
<td>Native</td>
<td>4</td>
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<tr>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td><strong>SUBCLASS ACARI: ORDER PROSTIGMATA: ERIOPHYIDAE</strong></td>
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<td>Eriophyes sheldoni (Ewing): Citrus bud mite</td>
<td>Hirsutella thompsonii Fisher var. vinacea Samson, McCoy &amp; O'Donnell; (Hypocreales: Ophiocordycipitaceae)</td>
<td>ARGENTINA</td>
<td>1985</td>
<td>(ex North Carolina USA) Released on lemon trees in Tucuman. Initially 92% decrease in mites but persistence unknown.</td>
<td>Introduced</td>
<td>175, 176</td>
<td></td>
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<tr>
<td>Eriophyes sheldoni (Ewing); Citrus bud mite; and Phyllocoptruta oleivora (Ashmead); Citrus rust mite</td>
<td>Hirsutella thompsonii Fisher var. synnematosa Samson, McCoy &amp; O'Donnell; (Hypocreales: Ophiocordycipitaceae)</td>
<td>ARGENTINA</td>
<td>1985</td>
<td>(ex Zimbabwe) Released in Tucuman. About 50% infection for both mites after release but persistence unknown.</td>
<td>Introduced</td>
<td>175, 176</td>
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<tr>
<td><strong>SUBCLASS ACARI: ORDER PROSTIGMATA: TETRANYCHIDAE</strong></td>
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<tr>
<td>Mononychellus tanajoa (Bondar); Cassava green mite</td>
<td>Neozygites tanajoae Delalibera, Hajek &amp; Humber (prev. referred to as Neozygites floridana (Weiser &amp; Muma) Remaudiére &amp; Keller); (Neozygitales: Neozygitaceae)</td>
<td>BENIN (in west Africa)</td>
<td>1998-99</td>
<td>(ex northeastern Brazil) Established, epizootics occurring in 2002 and 2003 at release sites. Molecular probes developed to confirm that epizootics were caused by exotic, the introduced pathogen, rather than a closely related native strain.</td>
<td>Introduced</td>
<td>42, 79</td>
<td></td>
<td></td>
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<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Clade)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent)</td>
<td>Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td>ORTHOPTERA: ACRIDIDAE</td>
<td><strong>Dichroplus maculipennis</strong> (Blanchard), <strong>D. elongatus</strong> (Giglio-Tos), <strong>D. pratensis</strong> Bruner, and <strong>Scotussa lemniscata</strong> Stål</td>
<td><strong>Paranosema locustae</strong> (Canning) [= Nosema locustae Canning; = Antonospora locustae (Canning)]; (Clade 2)</td>
<td><strong>ARGENTINA</strong></td>
<td>1978-82</td>
<td>(ex Idaho USA) Released in central Argentina. Principal targets in Melanoplinae. Established and, in 1994-95, found 75 km from release sites. Epizootics occur with accompanying host declines but levels of infection in susceptible species usually average &lt; 10%.</td>
<td>Released in central Argentina. Principal targets in Melanoplinae. Established and, in 1994-95, found 75 km from release sites. Epizootics occur with accompanying host declines but levels of infection in susceptible species usually average &lt; 10%.</td>
<td>Native</td>
<td>109</td>
</tr>
<tr>
<td>DIPTERA: CULICIDAE</td>
<td><strong>Culex pipiens quinquefasciatus</strong> Say [= C. pipiens fatigans Wiedemann; = C. fatigans Wiedemann]</td>
<td><strong>Vavraia culicis</strong> (Weiser) [= Pleistophora / Plistophora culicis Weiser]; (Clade 5)</td>
<td><strong>NAURU</strong> (in Micronesia)</td>
<td>1967</td>
<td>(ex Lagos, Nigeria) Establishment not confirmed.</td>
<td>Establishment not confirmed.</td>
<td>Native</td>
<td>107</td>
</tr>
<tr>
<td>LEPIDOPTERA: CRAMBIDAE</td>
<td><strong>Ostrinia nubilalis</strong> (Hübner); European corn borer</td>
<td><strong>Nosema pyrausta</strong> (Paillot) [= Perezia pyrausta Paillot; = Glugea pyrausta (Paillot)]; (Clade 4, Branch A)</td>
<td><strong>USA: Illinois</strong></td>
<td>Between 1952-60</td>
<td>(ex Iowa USA) Exact release year unknown. Infected larvae distributed at scattered localities throughout Illinois. Disease became prevalent and kept host populations at low levels.</td>
<td>Infected larvae distributed at scattered localities throughout Illinois. Disease became prevalent and kept host populations at low levels.</td>
<td>Introduced</td>
<td>43</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Biological control agent; (Clade)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent)</td>
<td>Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td><strong>LEPIDOPTERA: EREBIDAE</strong></td>
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<tr>
<td><strong>Lymantria dispar</strong> (L.); Gypsy moth</td>
<td><em>Nosema portugali</em> Maddox &amp; Vávra (= <em>Microsporidium</em> sp.); (Clade 4, Branch A)</td>
<td>USA: Maryland</td>
<td>1986</td>
<td><em>(ex Portugal)</em> Established, low levels of infection in 1987 which persisted for 3 years.</td>
<td>Introduced</td>
<td>91, 92, 121</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>USA: Michigan</td>
<td>1992-93</td>
<td><em>(ex Portugal)</em> Low levels of infection during the season of release, persistence not confirmed.</td>
<td>Introduced</td>
<td>8, 9</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td><em>Endoreticulatus schubergi</em> (Zwölfer) A. Cali &amp; El Garhy [Reported as <em>Vavraia</em> sp.]; (Clade 4, Branch B)</td>
<td>USA: Maryland</td>
<td>1986</td>
<td><em>(ex Portugal)</em> Not established.</td>
<td>Introduced</td>
<td>91, 92, 121</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Nosema lymantriae</em> Weiser; (Clade 4, Branch A)</td>
<td>USA: Illinois</td>
<td>2008, 2010</td>
<td><em>(ex Bulgaria)</em> Not established.</td>
<td>Introduced</td>
<td>151</td>
<td></td>
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</tr>
<tr>
<td></td>
<td><em>Vairimorpha disparis</em> (Timofejeva); (Clade 4, Branch A)</td>
<td>USA: Illinois</td>
<td>2008, 2010</td>
<td><em>(ex Bulgaria)</em> Not established.</td>
<td>Introduced</td>
<td>151</td>
<td></td>
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</tr>
</tbody>
</table>
## TABLE E: Exotic Oomycete Released, by Target Pest

<table>
<thead>
<tr>
<th>PEST ORDER: FAMILY</th>
<th>Target pest species</th>
<th>Biological control agent; (Order: Family)</th>
<th>Release country or region</th>
<th>Year of release</th>
<th>(Source of biological control agent) Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIPTERA: CULICIDAE</td>
<td>Culex tarsalis</td>
<td>Lagenidium giganteum; (Lagenidiales: Lagenidiaceae)</td>
<td>USA: California</td>
<td>1972</td>
<td>(ex North Carolina USA) Released in rice fields in Colusa County and irrigated pastures near Hanford, California. Recovered 3 consecutive years but dispersal from inoculation sites minimal.</td>
<td>Native</td>
<td>51, 118, 193</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td><strong>ORTHOPTERA: GRYLLOTALPIDAE</strong></td>
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<tr>
<td><em>Scapteriscus abbreviatus</em> Scudder, <em>S. borelli</em> Gigli-Tos, and <em>S. vicinus</em> Scudder; Mole crickets</td>
<td><em>Steinernema scapterisci</em> Nguyen &amp; Smart; (Rhabditida: Steinernematidae)</td>
<td>USA: Florida</td>
<td>1985</td>
<td><em>(ex Uruguay)</em> Established. Host populations declined by 85-98%, by 1988 infected hosts collected 23 km from release site. Establishment on golf courses not as successful but &gt; 27% reduction in hosts when persisting. <em>S. borelli</em> more susceptible than <em>S. vicinus</em>, but both can be controlled.</td>
<td>Introduced</td>
<td>53, 145</td>
<td></td>
</tr>
<tr>
<td><em>Scapteriscus didactylus</em> (Latreille) and <em>S. abbreviatus</em> Scudder; Mole crickets</td>
<td><em>Steinernema scapterisci</em> Nguyen &amp; Smart; (Rhabditida: Steinernematidae)</td>
<td>PUERTO RICO</td>
<td>2001-04</td>
<td><em>(ex Florida USA; originally Uruguay)</em> Establishment confirmed. <em>S. didactylus</em> in Puerto Rico about as susceptible as <em>S. borelli</em> is in Florida, but <em>S. abbreviatus</em>, for unknown reasons, is less susceptible.</td>
<td>Introduced</td>
<td>53, 111</td>
<td></td>
</tr>
<tr>
<td><strong>COLEOPTERA: SCARABAEIDAE</strong></td>
<td></td>
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<tr>
<td><em>Oryctes rhinoceros</em> (L.); Asiatic or Coconut rhinoceros beetle</td>
<td><em>Rhabditis</em> sp.; (Rhabditida: Rhabditidae)</td>
<td>FIJI</td>
<td>1954</td>
<td>*(ex Sri Lanka (Ceylon)) Results of release not reported.</td>
<td>Introduced</td>
<td>32</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1957</td>
<td><em>(ex Madagascar)</em> Recovered after release, persistence not confirmed.</td>
<td>Introduced</td>
<td>184</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1957</td>
<td><em>(ex Madagascar)</em> Results from release unknown.</td>
<td>Introduced</td>
<td>184</td>
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</tbody>
</table>
### TABLE F: EXOTIC NEMATODES RELEASED, BY TARGET PEST

<table>
<thead>
<tr>
<th>PEST ORDER: FAMILY</th>
<th>Biological control agent; (Order: Family)</th>
<th>Release country or region</th>
<th>Year of release</th>
<th>(Source of biological control agent) Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
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</thead>
<tbody>
<tr>
<td><strong>COLEOPTERA: SCARABAEIDAE (continued)</strong></td>
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<tr>
<td><em>Oryctes rhinoceros</em> (L.) (continued)</td>
<td><em>Rhabditis</em> sp. nr. <em>maupasi</em>; (Rhabdita: Rhabditidae)</td>
<td>SAMOA (Western Samoa)</td>
<td>1957</td>
<td><em>(ex Sri Lanka (Ceylon)) Results from release unknown.</em></td>
<td>Introduced</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMERICAN SAMOA</td>
<td>1957</td>
<td><em>(ex Sri Lanka (Ceylon)) Results from release unknown.</em></td>
<td>Introduced</td>
<td>184</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WALLIS ISLAND (in the Pacific)</td>
<td>1957</td>
<td><em>(ex Sri Lanka (Ceylon)) Results from release unknown.</em></td>
<td>Introduced</td>
<td>184</td>
</tr>
<tr>
<td><strong>COLEOPTERA: CURCULIONIDAE</strong></td>
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<tr>
<td><em>Sitona discoideus</em> Gyllenhal; Sitona weevil</td>
<td><em>Heterorhabditis bacteriophora</em> Poinar [= <em>H. heliothidis</em> (Khan, Brooks &amp; Hirschmann)]; (Rhabditida: Heterorhabditidae)</td>
<td>AUSTRALIA</td>
<td>1982</td>
<td><em>(ex New Zealand) Released in southern Australia. No infections found. This species thought not to occur in Australia when introduced, but now known to have been present, although this is still an example of introduction of an exotic strain.</em></td>
<td>Introduced</td>
<td>5, 93</td>
</tr>
<tr>
<td><strong>DIPTERA: CULICIDAE</strong> [listed in order of country of release]</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td><em>Romanomermis iyengari</em> Welch; (Mermithida: Mermithidae)</td>
<td>AZERBAIJAN (USSR)</td>
<td>ca 1990</td>
<td><em>(source unknown; originally from India) <em>Anopheles sacharovi</em> Favre and <em>Culex theileri</em> Theobald first reported as hosts. These nematodes could be moved to new water bodies by moving parasitized hosts. Long term establishment unknown.</em></td>
<td>Native</td>
<td>2, 153</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
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<tr>
<td><strong>DIPTERA: CULICIDAE (continued) [listed in order of country of release]</strong></td>
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<tr>
<td>Anopheles gambiae Giles</td>
<td>Romanomermis iyengari Welch; (Mermithida: Mermithidae)</td>
<td>BENIN (in west Africa)</td>
<td>2011</td>
<td>(source unknown; originally from India) Releasing monthly suppressed A. gambiae. Longer term establishment not reported.</td>
<td>Native</td>
<td>1</td>
</tr>
<tr>
<td>Aedes spp. and Ochlerotatus spp.; 10 species total</td>
<td>Romanomermis culicivorax Ross &amp; Smith [= Reesimermis nielsen Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>CANADA: Manitoba</td>
<td>1974-76</td>
<td>(ex Louisiana USA) Released in snow melt pools in Winnipeg, Manitoba. 1974 release: no infection. 1975-76 releases: meager parasitism after one winter and continued persistence questionable.</td>
<td>Native</td>
<td>56, 57, 148</td>
</tr>
<tr>
<td>Anopheine spp.; and Culicine spp.</td>
<td>Romanomermis iyengari Welch; (Mermithida: Mermithidae)</td>
<td>CUBA</td>
<td>1991</td>
<td>(source unknown; originally from India) High levels of parasitism of A. albimanus Wiedemann, C. nigripalpus Theobald, C. quinquefasciatus Say, Uranotaenia sapphirina (Osten Sacken); and reduced host populations. At some sites R. iyengari was established for up to 5 months.</td>
<td>Native</td>
<td>153, 165</td>
</tr>
<tr>
<td>Anopheles nyssorhynchus albimanus Wiedemann</td>
<td>Romanomermis culicivorax Ross &amp; Smith [= Reesimermis nielsen Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>COLOMBIA</td>
<td>1983</td>
<td>(ex Louisiana USA) Released in El Valle. Established and cycled over 27 months, effectively reduced host population with coincident reduction in malaria among school children.</td>
<td>Native</td>
<td>164</td>
</tr>
<tr>
<td>Anopheles nyssorhynchus albimanus Wiedemann and A. punctipennis (Say)</td>
<td>Romanomermis culicivorax Ross &amp; Smith [= Reesimermis nielsen Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>EL SALVADOR</td>
<td>1977</td>
<td>(ex Louisiana USA) Released in Lake Apasteque. Releases through year yielded 46-96% parasitism; up to 17x reduction in host populations. Recycling not reported, questionable.</td>
<td>Native</td>
<td>149, 164</td>
</tr>
<tr>
<td>Anopheles dthali Patton, A. superpictus Grassi, A. sergentii (Theobald), A. turkhudi Liston, and A. culicifacies Giles</td>
<td>Romanomermis culicivorax Ross &amp; Smith [= Reesimermis nielsen Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>IRAN</td>
<td>1984-85</td>
<td>(ex Louisiana USA) Established, 56-61% parasitism immediately post-release but only minor reductions in host populations. 8% parasitism at 1 of 13 sites 1 year after release. Effective long term control unlikely.</td>
<td>Native</td>
<td>204</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td>DIPTERA: CULICIDAE (continued) [listed in order of country of release]</td>
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<tr>
<td><strong>Anopheles pseudopunctipennis</strong> Theobald</td>
<td><em>Romanomeris iyengari</em> Welch; (Mermithida: Mermithidae)</td>
<td>MEXICO: Oaxaca</td>
<td>1996, 1999</td>
<td>(source unknown; originally from India) Released in Pochutla. In 1996, 85-100% parasitism, and after 2 months recovered infected mosquitoes at 9 of 44 release sites. In 1999 released at 4 large breeding areas: parasitism 46-100%, mosquito populations decreased, and at 2 of the sites, nematodes recycled and persisted for 5 months.</td>
<td>Native</td>
<td>123, 146, 153</td>
</tr>
<tr>
<td><strong>Culex pipiens quinquefasciatus</strong> Say and <strong>Aedes aegypti</strong> (L.)</td>
<td><em>Octomyomermis muspratti</em> Obiamiwe &amp; Macdonald; (Mermithida: Mermithidae)</td>
<td>NAURU (in Micronesia)</td>
<td>1967</td>
<td>(ex Zambia) After release, parasitism found in several tree holes but long term establishment not reported.</td>
<td>Introduced</td>
<td>107, 154</td>
</tr>
<tr>
<td><strong>Anopheline spp. and Culicine spp.</strong></td>
<td><em>Romanomeris iyengari</em> Welch; (Mermithida: Mermithidae)</td>
<td>TAJIKISTAN (USSR)</td>
<td>ca 1990</td>
<td>(source unknown; originally from India) Mean infection was 46% with similar results in running and stagnant water. Infection of culicines was less than anophelines (<em>Anopheles superpictus</em> Grassi, <em>A. pulcherrimus</em> Theobald, <em>A. hyrcanus</em> group). Long term establishment unknown.</td>
<td>Native</td>
<td>153, 191</td>
</tr>
<tr>
<td><strong>Romanomeris culicivorax</strong> Ross &amp; Smith [= <em>Reesimermis nielseni</em> Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td></td>
<td>TAJIKISTAN (USSR)</td>
<td>ca 1990</td>
<td>(source unknown) Mean infection was 46% with similar results in running and stagnant water. Infection of culicides was less than anophelines (<em>Anopheles superpictus</em> Grassi, <em>A. pulcherrimus</em> Theobald, <em>A. hyrcanus</em> group). Long term establishment unknown.</td>
<td>Native</td>
<td>153, 191</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent) Results from introduction</td>
<td>Pest origin</td>
<td>References</td>
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<tr>
<td><strong>DIPTERA: CULICIDAE (continued) [listed in order of country of release]</strong></td>
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<tr>
<td><strong>Culex pipiens quinquefasciatus</strong> Say</td>
<td><em>Romanomermis culicivorax</em> Ross &amp; Smith [<em>Reesimermis nielseni</em> Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>TAIWAN</td>
<td>1971-72</td>
<td><em>(ex Louisiana USA)</em> Released in Taipei. Infection rates low after release and no indication of establishment.</td>
<td>Native</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>(ex Louisiana USA)</em> Released in Taipei. Recycling occurred through 196 days after release but continued persistence not confirmed.</td>
<td>Native</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>THAILAND</td>
<td>1972</td>
<td><em>(ex Louisiana USA)</em> Large releases in ditches and drains in Bangkok, infection 0-27%, no recycling.</td>
<td>Native &amp; Introduced</td>
<td>108</td>
</tr>
<tr>
<td><strong>Aedes polynesiensis</strong> Marks and <em>Ae. aegypti</em> (L.)</td>
<td><em>Romanomermis culicivorax</em> Ross &amp; Smith [<em>Reesimermis nielseni</em> Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>TOKELAU (in the Pacific)</td>
<td>1978</td>
<td><em>(ex Louisiana USA)</em> Released on Fakatao Atoll in tree holes and man-made containers. Established in 35 of 41 sites with 14-22% infection. Persisted at least 3 years.</td>
<td>Native</td>
<td>30, 148</td>
</tr>
<tr>
<td><strong>Anopheles freeborni</strong> Aitken and <em>Culex tarsalis</em> Coquillett</td>
<td><em>Romanomermis culicivorax</em> Ross &amp; Smith [<em>Reesimermis nielseni</em> Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>USA: California</td>
<td>1975-76</td>
<td><em>(ex Louisiana USA)</em> Released in rice fields. Continuous partial control through rice growing season with mean weekly infection for both species &gt; 60%. Survived chemicals, drying, harvest, winter, and cultivation, and parasitized hosts next summer.</td>
<td>Native</td>
<td>148</td>
</tr>
<tr>
<td><strong>Anopheles punctipennis</strong> (Say), <em>A. crucians</em> Weidemann, <em>Aedes vexans</em> (Meig.), <em>Culex restuans</em> Theobald, and <em>C. pipiens</em> L.</td>
<td><em>Romanomermis culicivorax</em> Ross &amp; Smith [<em>Reesimermis nielseni</em> Tsai &amp; Grundmann]; (Mermithida: Mermithidae)</td>
<td>USA: Maryland</td>
<td>1975</td>
<td><em>(ex Louisiana USA)</em> Established, 50-100% host mortality even 2 years after release.</td>
<td>Native</td>
<td>136</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent)</td>
<td>Results from introduction</td>
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<tr>
<td>DIPTERA: CULICIDAE (continued)</td>
<td>Anopheline spp. and Culicine spp.</td>
<td>Romanomermis iyengari Welch; (Mermithida: Mermithidae)</td>
<td>UZBEKISTAN (USSR)</td>
<td>ca 1990</td>
<td>(source unknown; originally from India)</td>
<td>Anopheles martinius Schingarev, A. hyrcanus group, Culex modestus Ficalbi were parasitized after releases. Aedes caspius (Pallas) was not. Infection from 9-67% and only effective in water bodies with low salt content.</td>
</tr>
<tr>
<td>LEPIDOPTERA: EREBIDAE</td>
<td>Lymantria dispar (L.); Gypsy moth</td>
<td>Hexamermis sp. (Mermithida: Mermithidae)</td>
<td>USA: New Jersey</td>
<td>1974</td>
<td>(ex Austria) Not established.</td>
<td>Introduced</td>
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<td></td>
<td></td>
<td>USA: Pennsylvania</td>
<td>1976</td>
<td>(ex Hokkaido, Japan) Not established.</td>
<td>Introduced</td>
</tr>
<tr>
<td>HYMENOPTERA: SIRICIDAE</td>
<td>Sirex noctilio F.; European woodwasp, Sirex wasp</td>
<td>Deladenus siricidicola Bedding [= Beddingia siricidicola (Bedding)]; (Rhabditida: Neotylenchidae)</td>
<td>NEW ZEALAND: South Island</td>
<td>1967-74</td>
<td>(ex North Island, New Zealand) Released strain that sterilizes female wasps, infesting eggs before oviposition. Within first year, 29-76% infection reported, and by 1970, natural spread of ca. 50 km. Releases continued at least through 1974. Lack of establishment at some sites linked with low density host populations.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AUSTRALIA: Tasmania</td>
<td>1970</td>
<td>(ex Hungary) Established, reached high levels of parasitism rapidly. In one forest, six years after release of 50 parasitized females, trees were no longer being killed by woodwasps. Spread to nearby forests and also released in other areas. Considered the key biological agent controlling Sirex.</td>
<td>Introduced</td>
</tr>
</tbody>
</table>
## Table F: Exotic Nematodes Released, by Target Pest

<table>
<thead>
<tr>
<th>PEST ORDER: FAMILY</th>
<th>Target pest species</th>
<th>Biological control agent; (Order: Family)</th>
<th>Release country or region</th>
<th>Year of release</th>
<th>(Source of biological control agent) Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYMENOPTERA: SIRICIDAE (continued)</td>
<td>Sirex noctilio F. (continued)</td>
<td>Deladenus siricidicola Bedding (continued)</td>
<td>AUSTRALIA: Victoria</td>
<td>1971</td>
<td><em>(ex Tasmania and other locations)</em> Established, dispersed by woodwasps in local forests and by humans between forests. Use of this nematode became a cornerstone in the National Sirex Control strategy. Released over many years in many areas; 147,000 radiata pines inoculated in the Green Triangle in 1987 alone. With over 20 years of <em>in vitro</em> production, strain lost virulence resulting in replacement of strain used for releases.</td>
<td>Introduced</td>
<td>14, 76</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>URUGUAY</td>
<td>1987</td>
<td><em>(ex New Zealand)</em> Established, yielding 18% parasitism.</td>
<td>Introduced</td>
<td>21, 157, 166</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BRAZIL</td>
<td>1989-90, 1994</td>
<td><em>(ex Australia)</em> Principally released in 3 southern provinces. After loss of infectivity, new strain (Kamona from Tasmania) introduced in 1994, yielding 50-80% parasitism. Established, &gt;70% parasitism reported in 2012, in addition to very low density <em>S. noctilio</em> populations.</td>
<td>Introduced</td>
<td>14, 84, 85, 86</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SOUTH AFRICA: Western Cape</td>
<td>1995-96</td>
<td><em>(ex Australia)</em> Released Kamona strain. Established, with 23% parasitism reported in 1996. In 1998, along with cultural control, credited with containing the spread of the pest in the Western Cape region. Later studies documented more variable levels of parasitism, but still established in 2015.</td>
<td>Introduced</td>
<td>81, 83, 189, 190</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SOUTH AFRICA: Eastern Cape and Kwa-Zulu Natal</td>
<td>2004-06</td>
<td><em>(ex Australia)</em> Released Kamona strain. Yielded low parasitism of 5-10%. Poor results most closely associated with low moisture levels within pines. In 2015, considered established.</td>
<td>Introduced</td>
<td>81, 82, 83</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Target pest species</td>
<td>Biological control agent; (Order: Family)</td>
<td>Release country or region</td>
<td>Year of release</td>
<td>(Source of biological control agent)</td>
<td>Results from introduction</td>
<td>Pest origin</td>
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<tr>
<td>HYMENOPTERA: SIRICIDAE (continued)</td>
<td><strong>Sirex noctilio</strong> F. <strong>Deladenus siricidicola</strong> Bedding (continued)</td>
<td>SOUTH AFRICA: Mpumulanga and Limpopo</td>
<td>2010+, 2012+</td>
<td><em>(ex South Africa, from earlier Kamona release sites)</em> Releases begun 2010 in Mpumulanga; 2012 in Limpopo. Annual inoculations in areas of low parasitism, but in 2015 considered established.</td>
<td>Introduced</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ARGENTINA: Patagonia</td>
<td>1999, 2001-06</td>
<td><em>(ex Brazil and New Zealand)</em> Established, 50-60% parasitism reported at release site in 2000, nearly 100% parasitism in 2007, although overall parasitism highly variable. Inoculations 2001-2006 did not slow the spread of Sirex.</td>
<td>Introduced</td>
<td>35, 83, 98, 99, 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHILE</td>
<td>2006-09</td>
<td><em>(ex Brazil and New Zealand)</em> Released Encruzilhada do Sul strain from Brazil; Tangoio strain from New Zealand. Established, and parasitism levels increased from 2007-09.</td>
<td>Introduced</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>
**TABLE G: Accidental Introductions of Pathogens and Nematodes, by Pest Species**

<table>
<thead>
<tr>
<th>Pest Order: Family</th>
<th>Pest Species</th>
<th>Pathogen/Nematode; (Group)</th>
<th>Country or region of first observation</th>
<th>Year found</th>
<th>(Likely origin) Results from introduction</th>
<th>Pest origin</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEPIDOPTERA: ZYGAENIDAE</strong></td>
<td><em>Harrisina brillians</em> Barnes &amp; McDunnough; Western grape skeletonizer</td>
<td><em>Harrisina brillians granulovirus</em> (HbGV); (Baculoviridae: Betabaculovirus)</td>
<td>USA: California</td>
<td>Early 1950s</td>
<td><em>(probably from Mexico and/or Arizona USA)</em> Found in San Diego Co., California, probably inadvertently introduced with parasitoids. Infections observed in field and virus continually wiped out colonies for rearing parasitoids.</td>
<td>Introduced</td>
<td>182, 183</td>
</tr>
<tr>
<td><strong>LEPIDOPTERA: CRAMBIDAE</strong></td>
<td><em>Ostrinia nubilalis</em> (Hübner); European corn borer</td>
<td><em>Nosema pyrausta</em> (Paillot) [= <em>Perezia pyraustae</em> Paillot; = <em>Glugea pyraustae</em> (Paillot)]; (Microsporidia: Clade 4, Branch A)</td>
<td>USA: New Jersey</td>
<td>1949</td>
<td><em>(probably from Europe)</em> Possibly introduced with parasitoids. First found in New Jersey but subsequently found throughout the host distribution in the USA. Occurring commonly, epizootics develop with high host density and widespread spatial distribution of hosts.</td>
<td>Introduced</td>
<td>26, 73, 180</td>
</tr>
<tr>
<td><strong>LEPIDOPTERA: EREBIDAE</strong></td>
<td><em>Lymantria dispar</em> (L.); Gypsy moth</td>
<td><em>Lymantria dispar multiple nucleopolyhedrovirus</em> (LdMNPV); (Baculoviridae: Alphabaculovirus)</td>
<td>USA: northeast</td>
<td>1907</td>
<td><em>(probably from Europe)</em> Thought to have been introduced after 1900 with parasitoids released in Massachusetts for classical biological control or with plant material and spread through the host population. Until <em>E. maimaiga</em> became established, caused epizootics in high density, tree-defoliating populations of <em>L. dispar</em>, resulting in spectacular population crashes. Spreads naturally after the host population spreads into new areas.</td>
<td>Introduced</td>
<td>59, 65, 72</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Pest species</td>
<td>Pathogen/Nematode; (Group)</td>
<td>Country or region of first observation</td>
<td>Year found</td>
<td>(Likely origin)</td>
<td>Results from introduction</td>
<td>Pest origin</td>
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<tr>
<td>LEPIDOPTERA: EREBIDAE (continued)</td>
<td><em>Lymantria dispar</em> (L.) (continued)</td>
<td><em>Entomophaga maimaiga</em> Humber, Shimazu &amp; Soper; (Entomophthorales: Entomophthoraceae)</td>
<td>USA: northeast</td>
<td>1989</td>
<td>(from Japan; apparently sometime after 1971; not same strain as 1985-86 releases; very unlikely from 1910-11 releases)</td>
<td>First found in 1989 in 7 northeastern states (Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Vermont). By 1990 in 3 more states and Ontario, Canada; by 1992 across contiguous host distribution in northeast. Spread naturally and through releases. By 2005 established in: Delaware, Maine, Maryland, Michigan, North Carolina, Ohio, Rhode Island, Virginia, Wisconsin, West Virginia, the first 7 states and Ontario. Host populations remain low the majority of years and sites, although localized increases occur infrequently especially in some regions. Spreads naturally after the host population spreads into new areas.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GEORGIA (in Eurasia)</td>
<td>2005</td>
<td>(source unknown; originally from Japan)</td>
<td>High levels of infection found in an outbreak host population. Slight molecular differences with US strains so spread from Bulgaria (where US strains introduced) questionable.</td>
<td>Native</td>
</tr>
<tr>
<td>HYMENOPTERA: SIRICIDAE</td>
<td><em>Sirex noctilio</em> F.; European woodwasp, Sirex wasp</td>
<td><em>Deladenus siricidicola</em> Bedding [= <em>Beddingia siricidicola</em> (Bedding)]; (Nematoda: Rhabditida: Neotylenchidae)</td>
<td>NEW ZEALAND: North Island</td>
<td>1962</td>
<td>(source unknown; Europe?)</td>
<td>Thought to have arrived with host. Attributed with being the most important agent controlling host on the North Island, where the <em>Deladenus</em> strain that sterilizes the female (infesting the eggs before oviposition) was first found in introduced <em>Sirex</em> populations.</td>
<td>Introduced</td>
</tr>
<tr>
<td>Pest Order: Family</td>
<td>Pest species</td>
<td>Pathogen/Nematode; (Group)</td>
<td>Country or region of first observation</td>
<td>Year found</td>
<td>(Likely origin)</td>
<td>Results from introduction</td>
<td>Pest origin</td>
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<tr>
<td>HYMENOPTERA: SIRICIDAE (continued)</td>
<td>Sirex noctilio F. (continued)</td>
<td>Deladenus siricidicola Bedding (continued)</td>
<td>NEW ZEALAND: North Island</td>
<td>1971</td>
<td>(source unknown)</td>
<td>In the northern end of the North Island a non-sterilizing strain was found in 1971 and 1973; assumed to be a separate accidental introduction from the sterilizing strain.</td>
<td>Introduced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CANADA and USA</td>
<td>2007-11</td>
<td>(source unknown; Europe?)</td>
<td>Non-sterilizing strain found in S. noctilio in Ontario 2007-08 and 2011 in New York and Pennsylvania. Believed brought in by S. noctilio (first found in 2004 in NY; 2005 in Ontario). Nematodes in the reproductive tract remain outside the eggs of the host; infected adult females tend to be smaller and produce fewer eggs. A lower proportion of adult males was infected. In New York and Pennsylvania the non-sterilizing strain was at all 7 sites that had S. noctilio, but not in all trees or host adults.</td>
<td>Introduced</td>
</tr>
<tr>
<td>HYMENOPTERA: DIPRIONIDAE</td>
<td>Gilpinia hercyniae (Hartig) [= Diprion hercyniae Hartig]; European spruce sawfly</td>
<td>Gilpinia hercyniae nucleopolyhedrovirus (GhNPV); (Baculoviridae: Gammabaculovirus)</td>
<td>CANADA and USA</td>
<td>1936</td>
<td>(probably from Europe)</td>
<td>Believed introduced with parasitoids. Virus first found in New Brunswick and then Maine, Vermont, and New Hampshire, after which it spread from south to north and first found in Quebec in 1940. Also transferred to sites in Quebec and Ontario but some transfers were unsuccessful and virus spread on its own. By 1942, virus was distributed throughout most of the infested areas and was credited as cause of rapid decline in pest outbreak after 1942. Virus plus parasitoids appear to have permanently solved problems due to this pest in eastern North America.</td>
<td>Introduced</td>
</tr>
<tr>
<td>PEST ORDER: FAMILY</td>
<td>Pest species</td>
<td>Pathogen/Nematode; (Group)</td>
<td>Country or region of first observation</td>
<td>Year found</td>
<td>(Likely origin)</td>
<td>Results from introduction</td>
<td>Pest origin</td>
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</tr>
<tr>
<td>HYMENOPTERA: DIPRIONIDAE (continued)</td>
<td>Gilpinia hercyniae (Hartig) (continued)</td>
<td>Gilpinia hercyniae nucleopolyhedrovirus (GhNPV); (continued)</td>
<td>UK: WALES</td>
<td>1970/71</td>
<td>(probably from Europe)</td>
<td>Spread from small epicenter and controlled pest outbreak by 1974.</td>
<td>Introduced</td>
</tr>
<tr>
<td>HYMENOPTERA: FORMICIDAE</td>
<td>Solenopsis invicta Buren; Red imported fire ant</td>
<td>Thelohania solenopsae Knell, Allen &amp; Hazard; (Microsporidia: Clade 3)</td>
<td>USA: Florida</td>
<td>1996</td>
<td>(from South America)</td>
<td>Found in Florida. Infects mostly polygynous colonies. Chronic debilitation of infected queens yields smaller colony sizes and possibly prolonged death of colonies.</td>
<td>Introduced</td>
</tr>
</tbody>
</table>
APPENDIX I: Taxonomic List of the Pathogens and Nematodes

Virus, Group I (dsDNA)

**Family Baculoviridae**
- Genus *Alphabaculovirus*
  - *Anticarsia gemmatalis multiple nucleopolyhedrovirus* (AgMNPV)
  - *Lymantria dispar multiple nucleopolyhedrovirus* (LdMNPV)
  - *Lymantria monacha nucleopolyhedrovirus* (LmNPV)
  - *Pseudoplusia includens single nucleopolyhedrovirus* (PsinSNPV)
  - *Trichoplusia ni nucleopolyhedrovirus* (TnNPV)
- Genus *Betabaculovirus*
  - *Agrotis segetum granulovirus* (AsGV)
  - *Harrisina brillians granulovirus* (HbGV)
- Genus *Gammabaculovirus*
  - *Gilpinia hercyniae nucleopolyhedrovirus* (GhNPV)
  - *Neodiprion sertifer nucleopolyhedrovirus* (NeseNPV)

**Family Nudiviridae**
- Genus *Alphanudivirus*
  - *Oryctes rhinoceros nudivirus* (OrNV)

**Domain Bacteria**

- Phylum Firmicutes
  - Class *Bacilli*
    - Order *Bacillales*
      - **Family Paenibacillaceae**
        - *Paenibacillus popilliae*

**Domain Eukarya**

- **Kingdom Fungi**
  - Phylum Blastocladiomycota
    - Class *Blastocladiomycetes*
      - Order *Blastocladiales*
      - **Family Coelomomyctaceae**
        - *Coelomomyces stegomyiae*
  - Phylum Entomophthoromycota
    - Class *Entomophthoromycetes*
      - Order *Entomophthorales*
    - **Family Entomophthoraceae**
      - *Entomophaga grylli*
      - *Entomophaga maimaiga*
      - *Pandora neoaphidis*
      - *Zoophthora radicans*
    - Class Neozygитomycetes
      - Order Neozygitales
    - **Family Neozygitaceae**
      - *Neozygites fresenii*
      - *Neozygites parvispora*
      - *Neozygites tanajoae*
  - Phylum Ascomycota
    - Class *Dothideomycetes*
      - Order *Myriangiales*
    - **Family Myriangiaceae**
      - *Myriangium duriae*
    - Class *Sordariomycetes*
      - Order *Hypocreales*
    - **Family Clavicipitaceae**
      - *Aschersonia aleyrodis*
      - *Aschersonia goldiana*
      - *Aschersonia spp.*
      - *Metarhizium anisopliae*
    - **Family Cordycipitaceae**
      - *Beauveria bassiana*
      - *Beauveria brongniartii*
      - *Lecanicillium lecanii*
    - **Family Nectriaceae**
      - *Fusarium coccophilum*
      - *Fusarium juruanum*
    - **Family Ophiocordycipitaceae**
      - *Hirsutella thompsonii var. synnematosa*
      - *Hirsutella thompsonii var. vinacea*
Domain Eukarya (continued)

**Phylum Microsporidia**

- **Clade 2**
  - *Paranoa locustae*
- **Clade 3**
  - *Thelohania solenopsae*
- **Clade 4**
  - **Branch A**
    - *Nosema lymantriiae*
    - *Nosema portugal*
    - *Nosema pyrausta*
    - *Vairimorpha disparis*
  - **Branch B**
    - *Endoreticulatus schubergii*
- **Clade 5**
  - *Vavraia culicis*

**Supergroup SAR**

- (includes stramenopiles, alveolates and Rhizaria)
- **Phylum Heterokontophyta** (Heterokonta; Stramenopiles)
  - **Class Peronosporomycetes** (Oomycota)
  - **Order Lagenidiales**
    - **Family Lagenidiaceae**
      - *Lagenidium giganteum*

**Kingdom Animalia**

- **Phylum Nematoda**
  - **Class Enoplea**
  - **Order Mermithida**
    - **Family Mermithidae**
      - *Hexamermis sp.*
      - *Octomyomermis muspratti*
      - *Romanomermis culicivorax*
      - *Romanomermis iyengari*

**Class Chromadorea**

- **Order Rhabditida**
  - **Family Rhabditidae**
    - *Rhabdittis sp.*
    - *Rhabdittis sp. nr. maupasi*
  - **Family Heterorhabditidae**
    - *Heterorhabditis bacteriophora*
  - **Family Steinernematidae**
    - *Steinernema scapterisci*
  - **Family Neotylenchidae**
    - *Deladenus siricidicola*

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1. Higher order classification of numerous of these groups has recently been changed or is in a state of flux and we have received guidance from experts working on these different groups. Classification for viruses is in keeping with King et al. (2012), and higher order classification of Microsporidia is presently based on clades (Vossbrinck et al. 2014).

2. In the Hypocreales, the anamorph names are listed here; generic names are in flux and some may be replaced in the future with names of teleomorphic genera.

3. Within Clade 4 of Microsporidia the designation of letters for branches is informal and only provided to show differences.

4. The placement of SAR and classification within the group is in a state of flux.

Kingdom Animalia
Phylum Arthropoda
Class Insecta

Order Orthoptera
Family Gryllotalpidae
Scapteriscus abbreviatus
Scapteriscus borelli
Scapteriscus didactylus
Scapteriscus vicinus

Family Acrididae
Camnula pellucida
Dichroplus elongatus
Dichroplus maculipennis
Dichroplus pratensis
Melanoplus bivittatus
Melanoplus sanguinipes
Phaulacridium vittatum
Scotussa lemniscata

Order Hemiptera
Family Cercopidae
Aeneolamia flavilatera

Family Cicadellidae
Empoasca fabae

Family Aphididae
Aphis gossypii
Diuraphis noxia
Macrosiphum solanifolii
Metopolophium dirhodum
Theroaphis maculata

Order Thysanoptera
Family Thripidae
Thrips tabaci

Order Coleoptera
Family Scarabaeidae
Adoretus tenuimaculatus
Alisssonotum impressicolle
Anoplognathus sp.
Cochliotis melolonthoides
Lepidiota pruinosa
Lepidiota sp.
Leucopholis irrata
Oryctes monoceros
Papuana huebneri
Popillia japonica
Phyllophaga smithi
Scapanes australis
Schizonycha sp.

Family Curculionidae
Oxycanus servatus
Oxycanus seriatus
Oxycanus virgatus

Order Diptera
Family Culicidae
Aedes aegypti
Aedes caspius
Aedes polynesiensis
Aedes spp.
Aedes vexans
Anopheles albimanus
Anopheles crucians
Anopheles culicifacies
Anopheles dhalii
Anopheles freeborni
Anopheles gambiæ
Anopheles hyrcanus group
Anopheles martinius
Anopheles nyssorhynchus albimanus
Anopheles pseudopunctipennis
Anopheles pulcherrimus
Anopheles punctipennis
Anopheles sacharovi
Anopheles sergentii
Anopheles superpictus
Anopheles turkhdii
Culex modestus
Culex nigrrippus
Culex pipiens
Culex pipiens quinquefasciatus
Culex quinquefasciatus
Culex restuans
Culex tarsalis
Culex theleri
Ochlerotatus spp.
Uranotaenia sapphirina
Uranotaenia unguiculata
Kingdom Animalia (continued)
Phylum Arthropoda (continued)
Class Insecta (continued)

Order Lepidoptera
- Family Zygaenidae
  - Harrisina brillians
- Family Crambidae
  - Ostrinia nubilalis
- Family Erebidae
  - Anticarsia gemmatalis
  - Lymantria dispar
  - Lymantria monacha

Order Hymenoptera
- Family Noctuidae
  - Agrotis segetum
  - Pseudoplusia includens
  - Trichoplusia ni
- Family Siricidae
  - Sirex noctilio
- Family Diprionidae
  - Gilpinia hercyniae
  - Neodiprion sertifer
- Family Formicidae
  - Solenopsis invicta

Class Arachnida: Subclass Acari
Order Prostigmata
- Family Eriophyidae
  - Eriophyes sheldoni
- Family Tetranychidae
  - Phyllocoptruta oleivora
  - Mononychellus tanajoa


42. Delalibera Júnior, I. Unpublished data.


65. Hajek, A.E. Unpublished data.


# Insect and Mite Pests: Species

## A
- Adoretus tenuimaculatus 17
- Aedes aegypti 28, 29
- Aedes caspius 26, 30
- Aedes polynesiensis 19, 29
- Aedes spp. 27
- Aedes vexans 29
- Aeneolamia flavilatera 11
- Agrotis segetum 8
- Aleurodicus cocois 13
- Aleurothrixus floccosus 13
- Alissonotum impressicolle 17
- Anopheles albimanus 27
- Anopheles crucians 29
- Anopheles culicifacies 27
- Anopheles dhalii 27
- Anopheles freeborni 29
- Anopheles gambiae 27
- Anopheles hyrcanus 28, 30
- Anopheles maritimus 30
- Anopheles nyssorhynchos albimanus 27
- Anopheles pseudopunctipennis 28
- Anopheles pulcherrimus 28
- Anopheles punctipennis 27, 29
- Anopheles sacharovi 26
- Anopheles sergentii 27
- Anopheles superpictus 27, 28
- Anopheles turkudii 27
- Anoplognathus sp. 17
- Anticarsia gemmatalis 7
- Aonidiella aurantii 21
- Aphis gossypii 12
- Aspidiotus destructor 15
- Aspidiotus perniciosus 16

## C
- Camnula pellucida 11
- Ceroplastes rubens 14
- Cleomora smithi 18
- Coccus viridis 14, 15
- Cochliothorax melolonthoides 10
- Cornuaspis beckii 16
- Culex fatigans 22
- Culex modestus 26, 30
- Culex nigripalpus 27
- Culex pipiens 29
- Culex pipiens fatigans 22
- Culex pipiens quinquefasciatus 22, 28, 29
- Culex quinquefasciatus 27
- Culex restuans 29
- Culex tarsalis 24, 29
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| **Hoplochelus marginalis** (Fairmaire); Sugarcane white grub | ** Beauveria hoplocheli**
I. Robène-Soustrade & S. Nibouche [previously reported as B. brongniartii]; (Hypocreales: Cordycipitaceae) | REUNION ISLAND (in the Indian Ocean) | 1987 | (ex Madagascar) Successful control was achieved where released but since use was in sugarcane crops that are not permanent, this fungus is mass produced and used for augmentation. | Introduced | 1A, 1B, 1C |
| | ** Metarhizium anisopliae**
(Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae) | REUNION ISLAND (in the Indian Ocean) | 1987 | (ex Australia) No control although persisting at low levels from year to year. | Introduced | 1B, 1C |


