

Classical biological control of insects and mites: A comprehensive list of pathogen and nematode introductions (2020)

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This list is summarized in an article submitted in 2020 to the journal BioControl by Hajek, Gardescu, and Delalibera: "Summary of classical biological control introductions of entomopathogens and nematodes for insect control."

Pathogen and nematode groups of biological control agents are presented in the following order: Virus, Bacteria, Fungus, Microsporidia, Oomycota, Nematoda. Within each agent group, the list is alphabetical by (1) Biological control agent released, then (2) Target pest order, family, and species (insect or mite host), and then (3) Release country. Release countries are categorized here into 8 major global regions. Agent establishment (persistence for at least 1 year) of the pathogen or nematode in the area of release is based on interpretation of the cited publications; not all references provided such information. Control success, for the agents that were considered to have established, is defined as follows: control = pest populations decreased below a density that causes damage or problems; for agricultural systems, this would be the economic injury level; partial control = had an impact on pest populations but other control measures were still needed to reach acceptably low pest population densities; negligible control = agent establishment continued but had little effect on the pest population. Additions made after the Hajek et al. (2016) catalogue are shown in red text. A numbered list of citations is provided at the end: numbers 1-217 are as in Hajek et al. 2016; 1A-1C are from the addendum in Hajek et al. 2016; and 218-225 are references added here in 2020.

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Virus	<i>Agrotis segetum granulovirus</i>	<i>Agrotis segetum granulovirus</i> (AsGV); (Baculoviridae: <i>Betabaculovirus</i>)	Austria	Lepidoptera	Noctuidae	<i>Agrotis segetum</i> (Denis & Schiffermüller); Turnip moth	1975-80	DENMARK	Native	Europe	continent	established	negligible control	Released in Lammefjord. Caused 65-70% reduction in 211, 212, 217 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.	
Virus	<i>Anticarsia gemmatalis multiple NPV</i>	<i>Anticarsia gemmatalis multiple nucleopolyhedrovirus</i> (AgMNPV); (Baculoviridae: <i>Alphabaculovirus</i>)	Brazil	Lepidoptera	Erebidae	<i>Anticarsia gemmatalis</i> Hübner; Velvetbean caterpillar	1990-91	USA: Louisiana	Native	North America	continent	established	partial control	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.	54
Virus	<i>Anticarsia gemmatalis multiple NPV</i>	<i>Anticarsia gemmatalis multiple nucleopolyhedrovirus</i> (AgMNPV); (Baculoviridae: <i>Alphabaculovirus</i>)	Santa Catarina, Brazil	Lepidoptera	Erebidae	<i>Anticarsia gemmatalis</i> Hübner; Velvetbean caterpillar	1979-80	USA: South Carolina	Native	North America	continent	not		59-86% infection the season of release but no infections found 1 year after release.	10, 27
Virus	<i>Gilpinia hercyniae NPV</i>	<i>Gilpinia hercyniae nucleopolyhedrovirus</i> (GhNPV); (Baculoviridae: <i>Gammabaculovirus</i>)	mainland Canada	Hymenoptera	Diprionidae	<i>Gilpinia hercyniae</i> (Hartig) [= <i>Diprion hercyniae</i> Hartig]; European spruce sawfly	1943-45	CANADA: Newfoundland	Non-native	North America	island	established	control	Established and by 1946 reported as prevalent over considerable areas surrounding release areas.	6, 41, 119
Virus	<i>Gilpinia hercyniae NPV</i>	<i>Gilpinia hercyniae nucleopolyhedrovirus</i> (GhNPV); (Baculoviridae: <i>Gammabaculovirus</i>)	New Brunswick, Canada	Hymenoptera	Diprionidae	<i>Gilpinia hercyniae</i> (Hartig) [= <i>Diprion hercyniae</i> Hartig]; European spruce sawfly	1950	CANADA: Ontario	Non-native	North America	continent	established	control	Released in an isolated host population in Sault Ste. Marie, 160 km (100 miles) beyond western distribution of insect. Established and spread rapidly through infested area. Epizootics occurred yearly (1950-1959), hosts kept below economic damage level.	24, 41
Virus	<i>Harrisina brillians granulovirus</i>	<i>Harrisina brillians granulovirus</i> (HbGV); (Baculoviridae: <i>Betabaculovirus</i>)	Mexico & Arizona USA	Lepidoptera	Zygaenidae	<i>Harrisina brillians</i> Barnes & McDunnough; Western grapeleaf skeletonizer	1981-82	USA: California	Non-native	North America	continent	established	control	Released in Tulare County in central California. Established; epizootics develop in high density host populations. Overall, lowers general equilibrium density of host populations.	182, 224
Virus	<i>Lymantria dispar multiple NPV</i>	<i>Lymantria dispar multiple nucleopolyhedrovirus</i> (LdMNPV); (Baculoviridae: <i>Alphabaculovirus</i>)	Serbia, Yugoslavia	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1972	SARDINIA	Native	Europe	island	established	control	Established; high levels of larval mortality year of release, > 40% infection the next year and spread over 300 hectares.	114
Virus	<i>Lymantria monacha NPV</i>	<i>Lymantria monacha nucleopolyhedrovirus</i> (LmNPV); (Baculoviridae: <i>Alphabaculovirus</i>)	Sweden & West Germany	Lepidoptera	Erebidae	<i>Lymantria monacha</i> L.; Nun moth	1973-74	DENMARK	Native	Europe	continent	established	? (unclear)	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.	210
Virus	<i>Neodiprion sertifer NPV</i>	<i>Neodiprion sertifer nucleopolyhedrovirus</i> (NeseNPV); (Baculoviridae: <i>Gammabaculovirus</i>)	Sweden	Hymenoptera	Diprionidae	<i>Neodiprion sertifer</i> (Geoffrey); European pine sawfly	1950+	CANADA: Ontario	Non-native	North America	continent	established	control	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.	23, 40, 45, 119
Virus	<i>Neodiprion sertifer NPV</i>	<i>Neodiprion sertifer nucleopolyhedrovirus</i> (NeseNPV); (Baculoviridae: <i>Gammabaculovirus</i>)	Canada	Hymenoptera	Diprionidae	<i>Neodiprion sertifer</i> (Geoffrey); European pine sawfly	1961	UK: SCOTLAND	Native	Europe	island	established	? (unclear)	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. (The virus is potentially also native there.)	41, 163, 221

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Virus	<i>Neodiprion sertifer NPV</i>	<i>Neodiprion sertifer nucleopolyhedrovirus (NeseNPV)</i> ; (Baculoviridae: <i>Gammabaculovirus</i>)	New Jersey USA; originally Canada	Hymenoptera	Diprionidae	<i>Neodiprion sertifer</i> (Geoffrey); European pine sawfly	1952	USA: Illinois	Non-native	North America	continent	established	control	By 19 days after treatment, 82-100% control. In 1953, spread was up to 80 m from treated area. Excellent control achieved.	20, 45
Virus	<i>Neodiprion sertifer NPV</i>	<i>Neodiprion sertifer nucleopolyhedrovirus (NeseNPV)</i> ; (Baculoviridae: <i>Gammabaculovirus</i>)	Canada	Hymenoptera	Diprionidae	<i>Neodiprion sertifer</i> (Geoffrey); European pine sawfly	1953	USA: Indiana	Non-native	North America	continent	established	control	Reported as maintaining adequate control over several years through recurring epizootics after establishment.	168
Virus	<i>Neodiprion sertifer NPV</i>	<i>Neodiprion sertifer nucleopolyhedrovirus (NeseNPV)</i> ; (Baculoviridae: <i>Gammabaculovirus</i>)	Canada	Hymenoptera	Diprionidae	<i>Neodiprion sertifer</i> (Geoffrey); European pine sawfly	1951-52	USA: New Jersey	Non-native	North America	continent	established	control	Established and spread (ca. 300 m from individual trees after release). Released also in 1952. Provided complete control.	45
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	<i>Oryctes monoceros</i> (Olivier); African rhinoceros beetle or Coconut beetle	1973	SEYCHELLES (in the Indian Ocean)	Native	Indian Ocean	island	established	control	Released on Mahé, Praslin Island group and La Digue. Establishment confirmed in 1986 on Praslin Island group only, with infection 70-90%.	112, 113
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Praslin Island group, Seychelles	Coleoptera	Scarabaeidae	<i>Oryctes monoceros</i> (Olivier); African rhinoceros beetle or Coconut beetle	1981-83	SEYCHELLES (in the Indian Ocean)	Native	Indian Ocean	island	established	partial control	Established on Mahé and Ste. Anne with 20-50% infection and 30% reduction in beetle population.	112, 113
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Philippines & Samoa	Coleoptera	Scarabaeidae	<i>Oryctes monoceros</i> (Olivier); African rhinoceros beetle or Coconut beetle	1983-87	TANZANIA	Native	Africa	continent	established	negligible control	Established at 2 sites, with 40-60% infection after 1-1.5 years but reduction in frond damage not sustained by 1988.	160, 169
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1972	AMERICAN SAMOA	Non-native	Pacific / Oceania	island	established	control	Established, virus spread 0.8-1.6 km/month and damage declined.	17, 184
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1970-74	FIJI	Non-native	Pacific / Oceania	island	established	control	Established and by 1974 57-68% of beetles infected. Damage decreased significantly 12-18 months after virus establishment.	15, 16, 17, 184, 218
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Kerala, India	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1987	INDIA: Andaman Islands	Native	Indian Ocean	island	established	control	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.	90
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Kerala, India	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1988	INDIA: Lakshadweep	Native	Indian Ocean	island	established	control	Released on Andrott (Androth) Island. Successful introduction. In 1990, coconut palm crop damage measurably less and virus incidence > 60%.	61, 220
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Kerala, India	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1983-84	INDIA: Minicoy Island	Native	Indian Ocean	island	established	control	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.	130, 220
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Sumatra, Indonesia	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1976-80	JAVA (Indonesia)	Native	Indian Ocean	island	maybe or no info		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.	135, 206, 208
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Philippines, Malaysia & Tanzania	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1984-85	MALDIVES (in the Indian Ocean)	Native	Indian Ocean	island	established	control	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.	37, 209
Virus	<i>Oryctes rhinoceros nudivirus</i>	<i>Oryctes rhinoceros nudivirus (OrNV)</i> [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1970-72	MAURITIUS (in the Indian Ocean)	Non-native	Indian Ocean	island	established	control	Established, beetle populations declined sharply from 1970. At least through 1976-77, damage reduced by 60-95%.	17, 134

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	source unreported	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1989	OMAN	Non-native	Asia	continent	established	control	Established. Levels of damage steadily declined and 6 years later, only 4-6% of palm fronds were damaged by beetles.	95, 96
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1970	PALAU (in Micronesia)	Non-native	Pacific / Oceania	island	established	control	Established on Babeldaob Island, controlling beetles.	167, 184
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1983	PALAU (in Micronesia)	Non-native	Pacific / Oceania	island	established	control	Released on Peleliu Island and "other places where beetle problems were evident," resulting in beetle control.	167
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1978-79	PAPUA NEW GUINEA	Non-native	Pacific / Oceania	island	established	? (unclear)	Released on 3 islands. Established at nearly all sites, spread at 1 km/month.	62
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Malaysia	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1967	SAMOA (Western Samoa)	Non-native	Pacific / Oceania	island	established	partial control	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.	17, 80, 89, 115, 116, 184, 205
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Malaysia	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1967	TOKELAU (in the Pacific)	Non-native	Pacific / Oceania	island	established	control	Released on Nukunonu Atoll. Established and by 1973 39% of beetles infected and only 1.5-6.5% of palm fronds damaged.	17, 184, 207
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1970-71	TONGA (in Polynesia)	Non-native	Pacific / Oceania	island	established	control	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 (< 5% of palm crowns surveyed).	184, 201, 202
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1970-71	WALLIS ISLAND (in the Pacific)	Non-native	Pacific / Oceania	island	established	partial control	Established; < 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.	17, 64, 74, 184
Virus	<i>Oryctes rhinoceros nudivirus</i>	Oryctes rhinoceros nudivirus (OrNV) [= <i>Rhabdionvirus oryctes</i> (Huger); = <i>Baculovirus oryctes</i> Huger]; (Nudiviridae: <i>Alphanudivirus</i>)	Fiji	Coleoptera	Scarabaeidae	Scapanes australis (<i>Boisdual</i>); Melanesian rhinoceros beetle	1978-79	SOLOMON ISLANDS (in the Pacific)	Native	Pacific / Oceania	island	established	partial control	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.	179, 187
Virus	<i>Pseudoplusia includens</i> single NPV	Pseudoplusia includens single nucleopolyhedrovirus (PsinSNPV) ; (Baculoviridae: <i>Alphabaculovirus</i>)	Guatemala	Lepidoptera	Noctuidae	Pseudoplusia includens (Walker); Soybean looper	1975-77	USA: Louisiana	Native	North America	continent	established	control	Released in soybean fields. Established; 38-63% infection 12-15 years after introduction.	55
Virus	<i>Trichoplusia ni</i> NPV	Trichoplusia ni nucleopolyhedrovirus (TnNPV) ; (Baculoviridae: <i>Alphabaculovirus</i>)	California USA	Lepidoptera	Noctuidae	Trichoplusia ni (Hübner); Cabbage looper	1970	COLOMBIA	Non-native	South / Central America	continent	established	control	Persisted after release, controlling subsequent pest generations.	19, 39
Bacteria	<i>Paenibacillus popilliae</i>	Paenibacillus popilliae (Dutky); (Paenibacillaceae)	USA, probably	Coleoptera	Scarabaeidae	Cochliotis melolonthoides (Gerstaecker)	1968	TANZANIA	Native	Africa	continent	maybe or no info		Strain from Japanese beetle, <i>Popillia japonica</i> Newman. Seemed to become established but this is not certain due to presence of an indigenous milky disease.	63
Bacteria	<i>Paenibacillus popilliae</i>	Paenibacillus popilliae (Dutky); (Paenibacillaceae)	USA	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1957	AMERICAN SAMOA	Non-native	Pacific / Oceania	island	not		Strain from Japanese beetle, <i>Popillia japonica</i> Newman. Not recovered after release.	184
Bacteria	<i>Paenibacillus popilliae</i>	Paenibacillus popilliae (Dutky); (Paenibacillaceae)	USA	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1951	PALAU (in Micronesia)	Non-native	Pacific / Oceania	island	not		Strain from Japanese beetle, <i>Popillia japonica</i> Newman. Not recovered after release.	184
Bacteria	<i>Paenibacillus popilliae</i>	Paenibacillus popilliae (Dutky); (Paenibacillaceae)	Papua New Guinea & Solomon Islands	Coleoptera	Scarabaeidae	Papuana huebneri (Halmahera); Taro beetle	1995-96	KIRIBATI (in the Pacific)	Non-native	Pacific / Oceania	island	established	? (unclear)	Released on South Tarawa. Isolate from Papua New Guinea (type A1) caused infections 1 year after release.	188
Bacteria	<i>Paenibacillus popilliae</i>	Paenibacillus popilliae (Dutky); (Paenibacillaceae)	USA	Coleoptera	Scarabaeidae	Popillia japonica (Dutky); Japanese beetle	1990-91	AZORES: Terceira Island	Non-native	Atlantic / Caribbean	island	maybe or no info		Did not appear to be effective. Establishment is questionable.	106, 122
Bacteria	<i>Paenibacillus popilliae</i>	Paenibacillus popilliae (Dutky); (Paenibacillaceae)	USA	Coleoptera	Scarabaeidae	Schizonycha sp.	1956	KENYA	Native	Africa	continent	not		A and B strains from Japanese beetle, <i>Popillia japonica</i> Newman. Not recovered after release.	63

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Fungus	<i>Aschersonia aleyrodalis</i>	<i>Aschersonia aleyrodalis</i> Webber; (Hypocreales: Clavicipitaceae)	source unreported	Hemiptera	Aleyrodidae	<i>Aleurodicus cocois</i> (Curtis); Coconut whitefly; & <i>Aleurothrixus floccosus</i> (Maskell); Woolly whitefly	before 1920	VIRGIN ISLANDS	Native?	Atlantic / Caribbean	island	not		No establishment due to high winds and drought.	195
Fungus	<i>Aschersonia aleyrodalis</i>	<i>Aschersonia aleyrodalis</i> Webber; (Hypocreales: Clavicipitaceae)	Florida USA	Hemiptera	Aleyrodidae	<i>Dialeurodes</i> sp.; Whitefly	1926	BERMUDA	Unknown	Atlantic / Caribbean	island	maybe or no info		Establishment and persistence not reported.	143
Fungus	<i>Aschersonia goldiana</i>	<i>Aschersonia goldiana</i> Saccardo & Ellis; (Hypocreales: Clavicipitaceae)	Florida USA	Hemiptera	Aleyrodidae	<i>Singhiella citrifolii</i> (Morgan) [= <i>Dialeurodes citrifolii</i> Morgan]; Cloudywinged whitefly	1924	BERMUDA	Non-native	Atlantic / Caribbean	island	established	partial control	Considered established in 1925 but only provided efficient control in well-shaded situations.	141, 142
Fungus	<i>Aschersonia placenta</i> (#1 of 11)	<i>Aschersonia placenta</i> Berkeley & Broom; (Hypocreales: Clavicipitaceae)	China	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	established	control	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 <i>A. placenta</i> Berkeley & Broom 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 <i>Aschersonia</i> spp.), the pest was kept below the economic threshold.	88, 117, 155, 159
Fungus	<i>Aschersonia placenta</i> (#2 of 11)	<i>Aschersonia placenta</i> Berkeley & Broom; (Hypocreales: Clavicipitaceae)	Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	established	control	see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#3)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#4)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#5)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#6)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#7)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#8)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#9)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#10)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Aschersonia</i> sp./strain (#11)	<i>Aschersonia</i> sp.; (Hypocreales: Clavicipitaceae) -- total of 11 strains, multiple spp., details unclear	China, Cuba, India, Japan, Trinidad, USA, OR Vietnam	Hemiptera	Aleyrodidae	<i>Dialeurodes citri</i> (Ashmead); Citrus whitefly	1960-64	USSR: AZERBAIJAN and/or GEORGIA	Non-native	Asia	continent	not		see above	see above
Fungus	<i>Beauveria bassiana</i>	<i>Beauveria bassiana</i> (Balsamo) Vuillemin; (Hypocreales: Cordycipitaceae)	Montpellier, France	Coleoptera	Curculionidae	<i>Sitona discoideus</i> Gyllenhal; Sitona weevil	1984	AUSTRALIA	Non-native	Pacific / Oceania	continent	not		Released in southern Australia. No infections ever found.	5
Fungus	<i>Beauveria bassiana</i>	<i>Beauveria bassiana</i> (Balsamo) Vuillemin [= <i>Beauveria densa</i> (Link) Vuillemin]; (Hypocreales: Cordycipitaceae)	UK	Coleoptera	Scarabaeidae	<i>Phyllophaga smithi</i> (Arrow) [= <i>Lachnosterna smithi</i> (Arrow); = <i>Clemora smithi</i> (Arrow); = <i>Phytalus smithi</i> Arrow]; white grub in sugar cane	1932	MAURITIUS (in the Indian Ocean)	Non-native	Indian Ocean	island	maybe or no info		Unspecified isolate from Imperial Bureau of Mycology. Host population gradually declined and diseases may have played a part.	63, 131, 132, 133

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Fungus	<i>Beauveria brongniartii</i>	<i>Beauveria brongniartii</i> (Saccardo) Petch [= <i>Botrytis tenella</i> Sacc.]; (Hypocreales: Cordycipitaceae)	France	Coleoptera	Scarabaeidae	<i>Lepidota</i> sp., <i>Anoplognathus</i> sp., & other spp.; white grubs in sugar cane	1894-95	AUSTRALIA	Unknown	Pacific / Oceania	continent	not		Released in Queensland and New South Wales. Negative results in New South Wales after dissemination.	196
Fungus	<i>Beauveria hoplocheli</i>	<i>Beauveria hoplocheli</i> I. Robène-Soustrade & S. Nibouche [previously reported as <i>B. brongniartii</i>]; (Hypocreales: Cordycipitaceae)	Madagascar	Coleoptera	Scarabaeidae	<i>Hoplochelus marginalis</i> (Fairmaire); Sugarcane white grub	1987	REUNION ISLAND (in the Indian Ocean)	Non-native	Indian Ocean	island	established	control	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.	1A, 1B, 1C
Fungus	<i>Coelomomyces stegomyiae</i>	<i>Coelomomyces stegomyiae</i> Keilin; (Blastocladales: Coelomomycetaceae)	Singapore	Diptera	Culicidae	<i>Aedes polynesiensis</i> Marks	1958	TOKELAU (in the Pacific)	Native	Pacific / Oceania	island	established	? (unclear)	Released on Nukunonu Atoll. Established, by 1963 infected larvae found in 13 of 35 habitats.	75, 107
Fungus	<i>Entomophaga grylli</i> pathotype I	<i>Entomophaga grylli</i> (Fresenius) Batko, pathotype I; (Entomophthorales: Entomophthoraceae)	Arizona USA	Orthoptera	Acrididae	<i>Phaulacridium vittatum</i> (Sjöstedt); Wingless grasshopper	1984	AUSTRALIA	Native	Pacific / Oceania	continent	maybe or no info		Released near Canberra. Epizootics did not occur and permanent establishment questioned, efficacy unlikely.	125
Fungus	<i>Entomophaga grylli</i> pathotype III	<i>Entomophaga grylli</i> (Fresenius) Batko, pathotype III; (Entomophthorales: Entomophthoraceae)	Australia	Orthoptera	Acrididae	<i>Melanoplus bivittatus</i> (Say); Two-striped grasshopper; <i>M. sanguinipes</i> (F.); Migratory grasshopper; <i>Camnula pellucida</i> Scudder; Clearwinged grasshopper; & other spp.	1989-91	USA: North Dakota	Native	North America	continent	not		Isolate chosen based on biology, similarity of climates and ability to infect species in both Oedipodinae and Melanopliinae, but not <i>Hesperotettix viridis</i> (Scudder). Populations of some species declined in 1991-92 with 23% infection in 1992 at < 1 km from release, 1.7% in 1993 and no infection in 1994 when host populations were low. Long term establishment questionable.	22, 28, 29
Fungus	<i>Entomophaga grylli</i> pathotype III	<i>Entomophaga grylli</i> (Fresenius) Batko, pathotype III; (Entomophthorales: Entomophthoraceae)	Australia	Orthoptera	Acrididae	<i>Melanoplus sanguinipes</i> (F.); Migratory grasshopper	1990	USA: Alaska	Native	North America	continent	not		No establishment.	28, 161
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Connecticut USA	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1996	BULGARIA	Native	Europe	continent	not		Released in Levishte, in northeastern Bulgaria. No infection in 1997.	150
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Massachusetts USA	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1999	BULGARIA	Native	Europe	continent	established	negligible control	Released in Karlovo, in central Bulgaria. Established but negligible control.	152
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Connecticut USA	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	2000	BULGARIA	Native	Europe	continent	established	control	Released in Levishte. Infections found in 2002, 2003 & 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, & Macedonia). Fungus assumed to have spread from Bulgarian introductions.	58, 150, 216
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Virginia USA	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	2002	RUSSIA: Novosibirsk region	Native	Asia	continent	maybe or no info		Establishment not confirmed.	4
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Nishigahara, Tokyo Prefecture, Japan	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1910-11	USA: Massachusetts	Non-native	North America	continent	not		Released in Boston area. In 1911 found to be not established.	177
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Massachusetts USA	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1991-92	USA: Michigan	Non-native	North America	continent	established	control	Released as resting spores in soil and as cadavers from inoculated larvae, at sites along the leading edge of <i>L. dispar</i> 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.	174
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Ishikawa Prefecture, Japan	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1985	USA: New York	Non-native	North America	continent	not		Released in Allegany State Park in southwestern New York State. No transmission to host population detected. Not established.	67, 69
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Ishikawa Prefecture, Japan	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1986	USA: Virginia	Non-native	North America	continent	not		Released in Shenandoah National Park in northern Virginia. Very low transmission to host population. Not established.	67, 69

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Fungus	<i>Entomophaga maimaiga</i>	<i>Entomophaga maimaiga</i> Humber, Shimazu & Soper; (Entomophthorales: Entomophthoraceae)	Massachusetts & New York USA	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1991-92	USA: Virginia, West Virginia, Maryland, Pennsylvania	Non-native	North America	continent	established	control	Soil with resting spores released along leading edge of <i>L. dispar</i> 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; <i>E. maimaiga</i> had spread rapidly south and west to edge of host distribution.	68
Fungus	<i>Fusarium coccophilum</i>	<i>Fusarium coccophilum</i> (Desmazieres) Wollenweber & Reinking [= <i>Fusarium episphaerea</i> f. <i>coccophila</i> Tul.]; teleomorph = <i>Nectria flammea</i> (Tulasne & Tulasne) Dingley; (Hypocreales: Nectriaceae)	USA	Hemiptera	Diaspididae	<i>Aonidiella aurantii</i> (Maskell); California red scale	1900	ARGENTINA	Non-native	South / Central America	continent	established	partial control	Established and occasionally caused up to 90% mortality in northeastern and northwestern regions.	38
Fungus	<i>Fusarium coccophilum</i>	<i>Fusarium coccophilum</i> (Desmazieres) Wollenweber & Reinking [= <i>Sphaerostilbe coccophila</i> Tul.]; teleomorph = <i>Nectria flammea</i> (Tulasne & Tulasne) Dingley; (Hypocreales: Nectriaceae)	Florida USA	Hemiptera	Diaspididae	<i>Lepidosaphes beckii</i> (Newman) [= <i>Cornuaspis beckii</i> (Newman)]; Purple or Mussel scale	1926	BERMUDA	Non-native	Atlantic / Caribbean	island	maybe or no info		Establishment and persistence not reported.	143
Fungus	<i>Fusarium coccophilum</i>	<i>Fusarium coccophilum</i> (Desmazieres) Wollenweber & Reinking [= <i>Sphaerostilbe coccophila</i> Tul.]; teleomorph = <i>Nectria flammea</i> (Tulasne & Tulasne) Dingley; (Hypocreales: Nectriaceae)	Florida USA	Hemiptera	Diaspididae	<i>Lepidosaphes beckii</i> (Newman) [= <i>Cornuaspis beckii</i> (Newman)]; Purple or Mussel scale	1905 or before	USA: Hawaii	Non-native	Pacific / Oceania	island	established	partial control	Established and locally abundant but control only partial.	103
Fungus	<i>Fusarium coccophilum</i>	<i>Fusarium coccophilum</i> (Desmazieres) Wollenweber & Reinking [= <i>Sphaerostilbe coccophila</i> Tul.]; teleomorph = <i>Nectria flammea</i> (Tulasne & Tulasne) Dingley; (Hypocreales: Nectriaceae)	Florida USA	Hemiptera	Diaspididae	<i>Quadraspidiotus perniciosus</i> (Comstock) [= <i>Aspidiotus perniciosus</i> Comstock]; San Jose scale	1897	USA: California	Non-native	North America	continent	maybe or no info		As a result of this introduction, or a native fungus, scale nearly exterminated in southern California.	198
Fungus	<i>Fusarium coccophilum</i>	<i>Fusarium coccophilum</i> (Desmazieres) Wollenweber & Reinking [= <i>Sphaerostilbe coccophila</i> Tul.]; teleomorph = <i>Nectria flammea</i> (Tulasne & Tulasne) Dingley; (Hypocreales: Nectriaceae)	Florida USA	Hemiptera	Diaspididae	<i>Quadraspidiotus perniciosus</i> (Comstock) [= <i>Aspidiotus perniciosus</i> Comstock]; San Jose scale	1898	USA: Illinois	Non-native	North America	continent	established	partial control	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.	52
Fungus	<i>Fusarium coccophilum</i>	<i>Fusarium coccophilum</i> (Desmazieres) Wollenweber & Reinking [= <i>Sphaerostilbe coccophila</i> Tul.]; teleomorph = <i>Nectria flammea</i> (Tulasne & Tulasne) Dingley; (Hypocreales: Nectriaceae)	Florida USA	Hemiptera	Diaspididae	<i>Quadraspidiotus perniciosus</i> (Comstock) [= <i>Aspidiotus perniciosus</i> Comstock]; San Jose scale	1897	USA: New Jersey	Non-native	North America	continent	established	partial control	Established, overwintered, with abundant infection the following September but this pathogen alone failed to provide adequate control.	172, 173
Fungus	<i>Fusarium juruanum</i>	<i>Fusarium juruanum</i> P. Hennings [= <i>Pseudomicrocera henningsii</i> (Koord.) Africa Petch]; (Hypocreales: Nectriaceae)	Sierra Leone, west Africa	Hemiptera	Diaspididae	<i>Aspidiotus destructor</i> Signoret; Coconut scale	1929	SEYCHELLES (in the Indian Ocean)	Non-native	Indian Ocean	island	not		Did not establish.	46
Fungus	<i>Hirsutella thompsonii</i> var. <i>synnematososa</i>	<i>Hirsutella thompsonii</i> Fisher var. <i>synnematososa</i> Samson, McCoy & O'Donnell; (Hypocreales: Ophiocordycipitaceae)	Zimbabwe	z Acari	Prostigmata: Eriophyidae	<i>Eriophyes sheldoni</i> (Ewing); Citrus bud mite; & <i>Phyllocoptura oleivora</i> (Ashmead); Citrus rust mite	1985	ARGENTINA	Non-native	South / Central America	continent	maybe or no info		Released in Tucuman. About 50% infection for both mites after release but persistence unknown.	175, 176
Fungus	<i>Hirsutella thompsonii</i> var. <i>vinacea</i>	<i>Hirsutella thompsonii</i> Fisher var. <i>vinacea</i> Samson, McCoy & O'Donnell; (Hypocreales: Ophiocordycipitaceae)	North Carolina USA	z Acari	Order Prostigmata	<i>Eriophyes sheldoni</i> (Ewing); Citrus bud mite	1985	ARGENTINA	Non-native	South / Central America	continent	maybe or no info		Released on lemon trees in Tucuman. Initially 92% decrease in mites but persistence unknown.	175, 176
Fungus	<i>Lecanicillium lecanii</i>	<i>Lecanicillium lecanii</i> (Zimmerman) Gams & Zare [= <i>Verticillium lecanii</i> (Zimmerman)]; = <i>Cephalosporium lecanii</i> Zimmerman]; (Hypocreales: Cordycipitaceae)	India	Hemiptera	Coccidae	<i>Coccus viridis</i> (Green); Green scale; & other <i>Lecaniine</i> scale spp.	Before 1933	SEYCHELLES (in the Indian Ocean)	Non-native	Indian Ocean	island	established	partial control	Well established on lecaniine scales, especially <i>Coccus viridis</i> on coffee, and spread widely.	178

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Fungus	<i>Lecanicillium lecanii</i>	Lecanicillium lecanii (Zimmerman) Gams & Zare [= <i>Verticillium lecanii</i> (Zimmerman); = <i>Cephalosporium lecanii</i> Zimmerman]; (Hypocreales: Cordycipitaceae)	Sri Lanka (Ceylon)	Hemiptera	Coccidae	Coccus viridis (Green); Green scale; Eucalymnatus tessellatus (Signoret); Tesselated scale; & Ceroplastes rubens Maskell; Red wax scale	1911	SEYCHELLES (in the Indian Ocean)	Non-native	Indian Ocean	island	established	control	Established and largely controlled scale populations.	3
Fungus	<i>Lecanicillium lecanii</i> (possibly in species complex; Unidentified fungus)	Unidentified fungus [possibly in <i>Lecanicillium</i> (= <i>Verticillium</i>) <i>lecanii</i> species complex]; (Hypocreales: Cordycipitaceae)	Florida USA	Hemiptera	Coccidae	Coccus viridis (Green); Green scale	1928 or before	USA: Hawaii	Non-native	Pacific / Oceania	island	established	control	Established and provided effective control.	87, 185
Fungus	<i>Lecanicillium lecanii</i> (probably in species complex)	Probably in <i>Lecanicillium</i> (= <i>Verticillium</i>) lecanii species complex [Reported as <i>Acrostalagmus</i> sp.]; (Hypocreales: Cordycipitaceae)	Hawaii USA	Hemiptera	Aphididae	Macrosiphum euphorbiae (Thomas) [= <i>M. solanifolii</i> (Ashmead)]; Potato aphid	1955	USA: Maine	Native	North America	continent	established	? (unclear)	Diseased aphids found 3 weeks after release and one infected specimen found in 1958; also found in 1977. Long-term control not reported.	170, 171, 219
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Havnardalur, Faroe Islands	Coleoptera	Curculionidae	Otiorhynchus nodosus (Müller) & O. arcticus (Fabricius)	2003	ICELAND	Native	Europe	island	maybe or no info		Released in eroded areas in Haukadalur. Establishment unknown. Heathland soil in Haukadalur in 1999 found to have <i>M. anisopliae</i> in 40% of samples.	139, 140
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	source unreported	Coleoptera	Scarabaeidae	Adoretus tenuimaculatus Waterhouse	Before 1918	FIJI	Non-native	Pacific / Oceania	island	maybe or no info		Some signs that this fungus acted as a check on the beetles.	101
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Hawaii USA	Coleoptera	Scarabaeidae	Alissonotum impressicolle Arrow	1914	TAIWAN	Native	Asia	island	maybe or no info		Numbers of scarabs greatly reduced in fields where spores were released.	199, 200
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Samoa	Coleoptera	Scarabaeidae	Dermolepida albohirtum (Waterhouse); Greyback cane beetle	About 1914	AUSTRALIA: Queensland	Native	Pacific / Oceania	continent	maybe or no info		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 <i>Rhabdoscelus obscurus</i> (Boisduval), the New Guinea sugarcane weevil, killed by this fungus.	196
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Australia	Coleoptera	Scarabaeidae	Hoplochelus marginalis (Fairmaire); Sugarcane white grub	1987	REUNION ISLAND (in the Indian Ocean)	Non-native	Indian Ocean	island	established	negligible control	No control although persisting at low levels from year to year.	1B, 1C
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Queensland, Australia	Coleoptera	Scarabaeidae	Lepidota pruinosa Wied. & Leucopholis irrorata Chevrolat; white grubs in sugar cane	1928	PHILIPPINES	Native	Pacific / Oceania	island	maybe or no info		Not effective control and "undoubtedly already present."	162
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Java, Indonesia	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1939	SAMOA (Western Samoa)	Non-native	Pacific / Oceania	island	maybe or no info		This fungal species recovered after release but whether it was the introduced strain or a native strain is uncertain.	184
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1967	TOKELAU (in the Pacific)	Non-native	Pacific / Oceania	island	maybe or no info		Results from release not reported.	184
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Samoa	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1969	TONGA (in Polynesia)	Non-native	Pacific / Oceania	island	established	negligible control	High levels of infection directly after release, infections still present 3 years later but prevalence extremely low.	184, 201
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Argentina	Coleoptera	Scarabaeidae	Oryctes rhinoceros (L.); Asiatic or Coconut rhinoceros beetle	1952	WALLIS ISLAND (in the Pacific)	Non-native	Pacific / Oceania	island	maybe or no info		Results from release not reported.	184
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	source unreported	Coleoptera	Scarabaeidae	Papuana huebneri (Halmahera); Taro beetle	1976	KIRIBATI (in the Pacific)	Non-native	Pacific / Oceania	island	maybe or no info		Released on southern Tarawa by Latch. Establishment not confirmed.	124
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Papua New Guinea	Coleoptera	Scarabaeidae	Papuana huebneri (Halmahera); Taro beetle	1995	KIRIBATI (in the Pacific)	Non-native	Pacific / Oceania	island	established	partial control	Released on southern Tarawa. Persisted in soil through 2003, spread and exerted some control.	124, 188
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	UK	Coleoptera	Scarabaeidae	Phyllophaga smithi (Arrow) [= <i>Lachnosterna smithi</i> (Arrow); = <i>Clemora smithi</i> (Arrow); = <i>Phytalus smithi</i> Arrow]; white grub in sugar cane	1932	MAURITIUS (in the Indian Ocean)	Non-native	Indian Ocean	island	maybe or no info		Unspecified isolate from Imperial Bureau of Mycology. Host population gradually declined and diseases may have played a part.	63, 131, 132, 133
Fungus	<i>Metarhizium anisopliae</i>	Metarhizium anisopliae (Metschnikoff) Sorokin; (Hypocreales: Clavicipitaceae)	Trinidad	Hemiptera	Cercopidae	Aeneolamia flavilatera (Urich)	1944	GUYANA (in South America)	Native	South / Central America	continent	established	? (unclear)	Introduced by releasing infected adult froghoppers. Established, considered unsuccessful for control but < 1 year later abundant infections ca. 32 km away. Unknown whether this was due to introduced or indigenous fungus.	33
Fungus	<i>Myriangium duriae</i>	Myriangium duriae Montagne & Berkeley [1st edition listed as <i>Triblidium caespitosum</i>]; (Myriangiales: Myriangiaceae)	Florida USA	Hemiptera	Diaspididae	Lepidosaphes beckii (Newman) [= <i>Cornuaspis beckii</i> (Newman)]; Purple or Mussel scale	1926	BERMUDA	Non-native	Atlantic / Caribbean	island	maybe or no info		Released on infested citrus trees throughout the island. Found already present on <i>L. beckii</i> at one site. Establishment and persistence not reported.	143

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Fungus	<i>Neozygites fresenii</i>	<i>Neozygites fresenii</i> (Nowakowski) Batko; (Neozygiales: Neozygiteaceae)	Arkansas USA	Hemiptera	Aphididae	<i>Aphis gossypii</i> Glover; Cotton aphid	1994-95	USA: California	Non-native	North America	continent	not		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.	60, 181
Fungus	<i>Neozygites parvispora</i>	<i>Neozygites parvispora</i> (MacLeod & Carl) Remaudière & Keller; (Neozygiales: Neozygiteaceae)	Switzerland	Thysanoptera	Thripidae	<i>Thrips tabaci</i> Lindeman; Onion thrips	1973-76	BARBADOS	Non-native	Atlantic / Caribbean	island	not		Released in onion field but no establishment.	33
Fungus	<i>Neozygites tanajoae</i>	<i>Neozygites tanajoae</i> Delalibera, Hajek & Humber (prev. referred to as <i>Neozygites floridana</i> (Weiser & Muma) Remaudière & Keller); (Neozygiales: Neozygiteaceae)	northeastern Brazil	Acari	Prostigmata: Tetranychidae	<i>Mononychellus tanajoa</i> (Bondar); Cassava green mite	1998-99	BENIN (in west Africa)	Non-native	Africa	continent	established	partial control	Established, epizootics occurring in 2002 and 2003 at release sites. Molecular probes developed to confirm that epizootics were caused by the exotic introduced pathogen, rather than a closely related native strain.	42, 79
Fungus	<i>Pandora neophidius</i>	<i>Pandora neophidius</i> (Remaudière & Hennebert) Humber; (Entomophthorales: Entomophthoraceae)	Brazil	Hemiptera	Aphididae	<i>Metopolophium dirhodum</i> (Walker); Rose-grain aphid; & other cereal aphid spp.	1982	BELGIUM	Native	Europe	continent	maybe or no info		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.	110
Fungus	<i>Podonectria coccicola</i>	<i>Podonectria coccicola</i> Petch; (Pleosporales: Tubeufiaceae)	Florida USA	Hemiptera	Diaspididae	<i>Lepidosaphes beckii</i> (Newman) [= <i>Comuaspis beckii</i> (Newman)]; Purple or Mussel scale	1926	BERMUDA	Non-native	Atlantic / Caribbean	island	maybe or no info		Establishment and persistence not reported.	143
Fungus	<i>Zoophthora radicans</i>	<i>Zoophthora radicans</i> (Brefeld) Batko; (Entomophthorales: Entomophthoraceae)	Serbia	Hemiptera	Aphididae	<i>Diuraphis noxia</i> Kurdjumov; Russian wheat aphid	1992	USA: Idaho	Non-native	North America	continent	maybe or no info		To release, parasitoids <i>Aphelinus asychis</i> (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.	138, 156
Fungus	<i>Zoophthora radicans</i>	<i>Zoophthora radicans</i> (Brefeld) Batko [= <i>Entomophthora sphaerosperma</i> Fresenius]; (Entomophthorales: Entomophthoraceae)	Israel	Hemiptera	Aphididae	<i>Therioaphis maculata</i> (Buckton); Spotted alfalfa aphid	1979	AUSTRALIA: New South Wales	Non-native	Pacific / Oceania	continent	established	control	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.	126, 127, 128
Fungus	<i>Zoophthora radicans</i>	<i>Zoophthora</i> (= <i>Erynia</i>) <i>radicans</i> (Brefeld) Batko; (Entomophthorales: Entomophthoraceae)	Brazil	Hemiptera	Cicadellidae	<i>Empoasca fabae</i> (Harris); Potato leafhopper	1984	USA: Illinois	Non-native	North America	continent	not		No establishment.	77, 120
Fungus	<i>Zoophthora radicans</i>	<i>Zoophthora</i> (= <i>Erynia</i>) <i>radicans</i> (Brefeld) Batko; (Entomophthorales: Entomophthoraceae)	Serbia	Hemiptera	Cicadellidae	<i>Empoasca fabae</i> (Harris); Potato leafhopper	1990-91	USA: New York	Non-native	North America	continent	maybe or no info		Released in central New York State. Field infection confirmed but monitoring not continued in subsequent years.	77
Fungus	Unidentified fungi (2 spp.)	Unidentified fungi (2 spp.)	source unreported	Hemiptera	Coccidae	Unspecified species of Coccid scale	1897	USA: Hawaii	Unknown	Pacific / Oceania	island	established	? (unclear)	Two species released. Established and spread over most parts of the islands.	102
Fungus	Unidentified leafhopper egg fungus	Unidentified fungus	Australia & Fiji	Hemiptera	Cicadellidae	Unspecified species of Leafhopper	1906	USA: Hawaii	Unknown	Pacific / Oceania	island	maybe or no info		Fungus found infecting leafhopper eggs at source. Establishment not confirmed.	147
Fungus	Unidentified whitefly fungus	Unidentified fungus	Florida USA	Hemiptera	Aleyrodidae	Unspecified species of Whitefly	1909	USA: Hawaii	Unknown	Pacific / Oceania	island	maybe or no info		One species released. Results not reported.	104
Microsporidia	<i>Endoreticulatus schubergi</i>	<i>Endoreticulatus schubergi</i> (Zwölfer) A. Cali & El Garhy [Reported as <i>Vavraia</i> sp.]; (Clade 4, Branch B)	Portugal	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1986	USA: Maryland	Non-native	North America	continent	not		Not established.	91, 92, 121
Microsporidia	<i>Nosema lymantriae</i>	<i>Nosema lymantriae</i> Weiser; (Clade 4, Branch A)	Bulgaria	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	2008, 2010	USA: Illinois	Non-native	North America	continent	not		Not established.	151
Microsporidia	<i>Nosema portugal</i>	<i>Nosema portugal</i> Maddox & Vávra [= <i>Microsporidium</i> sp.]; (Clade 4, Branch A)	Portugal	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1986	USA: Maryland	Non-native	North America	continent	established	negligible control	Established, low levels of infection in 1987 which persisted for 3 years.	91, 92, 121
Microsporidia	<i>Nosema portugal</i>	<i>Nosema portugal</i> Maddox & Vávra [= <i>Microsporidium</i> sp.]; (Clade 4, Branch A)	Portugal	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1992-93	USA: Michigan	Non-native	North America	continent	maybe or no info		Low levels of infection during the season of release, persistence not confirmed.	8, 9
Microsporidia	<i>Nosema pyrausta</i>	<i>Nosema pyrausta</i> (Paillot) [= <i>Perezia pyraustae</i> Paillot; = <i>Glugea pyraustae</i> (Paillot)]; (Clade 4, Branch A)	Iowa USA	Lepidoptera	Crambidae	<i>Ostrinia nubilalis</i> (Hübner); European corn borer	between 1952-60	USA: Illinois	Non-native	North America	continent	established	partial control	Exact release year unknown. Infected larvae distributed at scattered localities throughout Illinois. Disease became prevalent and kept host populations at low levels.	43, 222
Microsporidia	<i>Paranosema locustae</i>	<i>Paranosema locustae</i> (Canning) [= <i>Nosema locustae</i> Canning; = <i>Antonospora locustae</i> (Canning)]; (Clade 2)	Idaho USA	Orthoptera	Acrididae	<i>Dichroplus maculipennis</i> (Blanchard), <i>D. elongatus</i> (Giglio-Tos), <i>D. pratensis</i> Bruner, & <i>Scotussa lemniscata</i> Stål	1978-82	ARGENTINA	Native	South / Central America	continent	established	negligible control	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 < 10%.	109

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Microsporidia	<i>Paranosema locustae</i>	<i>Paranosema locustae</i> (Canning) [= <i>Nosema locustae</i> Canning; = <i>Antonospora locustae</i> (Canning)]; (Clade 2)	propagated in lab in China, source unreported; commercially available agent	Orthoptera	Acrididae	Grasshoppers (incl.: <i>Dasyhippus barbipes</i> (F.-W.), <i>Bryodema luctuosum luctuosoma</i> (Stoll), <i>Angaracris barabensis</i> (Pall.), <i>Oedaleus asiaticus</i> B.-Bienko, and <i>Myrmeleotettix palpalis</i> (Zub.)	1993	CHINA: Inner Mongolia	Native	Asia	continent	established	partial control	Released in 15,000 ha in Damao County, Inner Mongolia. Persisted at least 9 years, at 14-61% infection each year and varying among hosts. One year after release several species were less abundant; later years population sizes varied and from data can't say suppressed consistently.	223
Microsporidia	<i>Vairimorpha disparis</i>	<i>Vairimorpha disparis</i> (Timofejeva); (Clade 4, Branch A)	Bulgaria	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	2008, 2010	USA: Illinois	Non-native	North America	continent	not		Not established.	151
Microsporidia	<i>Vavraia culici</i>	<i>Vavraia culicis</i> (Weiser) Weiser [= <i>Pleistophora</i> / <i>Plistophora culicis</i> Weiser]; (Clade 5)	Lagos, Nigeria	Diptera	Culicidae	<i>Culex pipiens quinquefasciatus</i> Say [= <i>C. pipiens fatigans</i> Wiedemann; = <i>C. fatigans</i> Wiedemann]	1967	NAURU (in Micronesia)	Native	Pacific / Oceania	island	maybe or no info		Establishment not confirmed.	107
Oomycota	<i>Lagenidium giganteum</i>	<i>Lagenidium giganteum</i> Couch; (Lagenidiales: Lagenidiaceae)	North Carolina USA	Diptera	Culicidae	<i>Culex tarsalis</i> Coquillett; Western encephalitis mosquito	1972	USA: California	Native	North America	continent	established	partial control	Released in rice fields in Colusa County and irrigated pastures near Hanford, California. Recovered 3 consecutive years but dispersal from inoculation sites minimal. At 1 site caused high infection 3 years after release.	51, 118, 193, 225
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Brazil	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1996, 1998-99, +	ARGENTINA: Misiones and Corrientes Provinces	Non-native	South / Central America	continent	established	partial control	Brazilian Encruzilhada do Sul strain, originally from Australia. Parasitism 0-4.8% in 1999. More releases annually, especially 2003-2009. As of 2015, average of 25% parasitism in Corrientes where greater <i>Sirex</i> attacks occur.	11, 49, 83
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Brazil & New Zealand	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1999, 2001-06	ARGENTINA: Patagonia	Non-native	South / Central America	continent	established	partial control	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 <i>Sirex</i> .	35, 83, 98, 100
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Hungary	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1970	AUSTRALIA: Tasmania	Non-native	Pacific / Oceania	island	established	control	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 <i>Sirex</i> .	12, 76
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Tasmania & other locations	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1971	AUSTRALIA: Victoria	Non-native	Pacific / Oceania	continent	established	control	Established, dispersed by woodwasps in local forests and by humans between forests. Use of this nematode became a cornerstone in the National <i>Sirex</i> 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 <i>in vitro</i> production, strain lost virulence resulting in replacement of strain used for releases.	14, 76
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Australia	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1989-90	BRAZIL	Non-native	South / Central America	continent	established	negligible control	Principally released in 3 southern provinces. Established but then lost effectiveness.	14, 84, 85, 86
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Australia: Tasmania	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1994	BRAZIL	Non-native	South / Central America	continent	established	control	New strain (Kamona from Tasmania) introduced in 1994, yielding 50-80% parasitism. Established, >70% parasitism reported in 2012, in addition to very low density <i>S. noctilio</i> populations.	14, 84, 85, 86
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Brazil & New Zealand	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	2006-09	CHILE	Non-native	South / Central America	continent	established	partial control	Released Encruzilhada do Sul strain from Brazil; Tangoio strain from New Zealand. Established, and parasitism levels increased from 2007-09.	18
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	North Island, New Zealand	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1967-74	NEW ZEALAND: South Island	Non-native	Pacific / Oceania	island	established	control	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.	215
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Australia	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	2004-06	SOUTH AFRICA: Eastern Cape and Kwa-Zulu Natal	Non-native	Africa	continent	established	partial control	Released Kamona strain. Yielded low parasitism of 5-10%. Poor results most closely associated with low moisture levels within pines. In 2015, considered established.	81, 82, 83
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	South Africa, from earlier Kamona release sites	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	2010+, 2012+	SOUTH AFRICA: Mpumalanga and Limpopo	Non-native	Africa	continent	established	partial control	Releases begun 2010 in Mpumalanga; 2012 in Limpopo. Annual inoculations in areas of low parasitism, but in 2015 considered established.	81

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	Australia	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1995-96	SOUTH AFRICA: Western Cape	Non-native	Africa	continent	established	control	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.	81, 83, 189, 190
Nematoda	<i>Deladenus siricidicola</i>	<i>Deladenus siricidicola</i> Bedding [= <i>Beddingia siricidicola</i> (Bedding)]; (Rhabditida: Neotylenchidae)	New Zealand	Hymenoptera	Siricidae	<i>Sirex noctilio</i> F.; European woodwasp, Sirex wasp	1987	URUGUAY	Non-native	South / Central America	continent	established	partial control	Established, yielding 18% parasitism.	21, 157, 166
Nematoda	<i>Heterorhabditis bacteriophora</i>	<i>Heterorhabditis bacteriophora</i> Poinar [= <i>H. heliothidis</i> (Khan, Brooks & Hirschmann)]; (Rhabditida: Heterorhabditidae)	New Zealand	Coleoptera	Curculionidae	<i>Sitona discoideus</i> Gyllenhal; Sitona weevil	1982	AUSTRALIA	Non-native	Pacific / Oceania	continent	not		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.	5, 93
Nematoda	<i>Hexameris</i> sp.	<i>Hexameris</i> sp. (Mermithida: Mermithidae)	Austria	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1974	USA: New Jersey	Non-native	North America	continent	not		Not established.	36
Nematoda	<i>Hexameris</i> sp.	<i>Hexameris</i> sp. (Mermithida: Mermithidae)	Hokkaido, Japan	Lepidoptera	Erebidae	<i>Lymantria dispar</i> (L.); Gypsy moth	1976	USA: Pennsylvania	Non-native	North America	continent	not		Not established.	36
Nematoda	<i>Octomyomermis muspratti</i>	<i>Octomyomermis muspratti</i> Obiamiwe & Macdonald; (Mermithida: Mermithidae)	Zambia	Diptera	Culicidae	<i>Culex pipiens quinquefasciatus</i> Say & <i>Aedes aegypti</i> (L.)	1967	NAURU (in Micronesia)	Non-native	Pacific / Oceania	island	maybe or no info		After release, parasitism found in several tree holes but long term establishment not reported.	107, 154
Nematoda	<i>Rhabditis</i> sp.	<i>Rhabditis</i> sp.; (Rhabditida: Rhabditidae)	Madagascar	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1957	AMERICAN SAMOA	Non-native	Pacific / Oceania	island	maybe or no info		Results of release not reported.	184
Nematoda	<i>Rhabditis</i> sp.	<i>Rhabditis</i> sp.; (Rhabditida: Rhabditidae)	Sri Lanka (Ceylon)	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1954	FIJI	Non-native	Pacific / Oceania	island	maybe or no info		Results of release not reported.	32
Nematoda	<i>Rhabditis</i> sp.	<i>Rhabditis</i> sp.; (Rhabditida: Rhabditidae)	Madagascar	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1957	FIJI	Non-native	Pacific / Oceania	island	maybe or no info		Recovered after release, persistence not confirmed.	184
Nematoda	<i>Rhabditis</i> sp. nr. <i>maupasi</i>	<i>Rhabditis</i> sp. nr. <i>maupasi</i> ; (Rhabditida: Rhabditidae)	Sri Lanka (Ceylon)	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1957	AMERICAN SAMOA	Non-native	Pacific / Oceania	island	maybe or no info		Results of release not reported.	184
Nematoda	<i>Rhabditis</i> sp. nr. <i>maupasi</i>	<i>Rhabditis</i> sp. nr. <i>maupasi</i> ; (Rhabditida: Rhabditidae)	Sri Lanka (Ceylon)	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1957	SAMOA (Western Samoa)	Non-native	Pacific / Oceania	island	maybe or no info		Results of release not reported.	184
Nematoda	<i>Rhabditis</i> sp. nr. <i>maupasi</i>	<i>Rhabditis</i> sp. nr. <i>maupasi</i> ; (Rhabditida: Rhabditidae)	Sri Lanka (Ceylon)	Coleoptera	Scarabaeidae	<i>Oryctes rhinoceros</i> (L.); Asiatic or Coconut rhinoceros beetle	1957	WALLIS ISLAND (in the Pacific)	Non-native	Pacific / Oceania	island	maybe or no info		Results of release not reported.	184
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Aedes polynesiensis</i> Marks & <i>Ae. aegypti</i> (L.)	1978	TOKELAU (in the Pacific)	Native & Non-native	Pacific / Oceania	island	established	negligible control	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.	108
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Aedes</i> spp. & <i>Ochlerotatus</i> spp.; 10 species total	1974-76	CANADA: Manitoba	Native	North America	continent	maybe or no info		Released in snow melt pools in Winnipeg, Manitoba. 1974 release: no infection. 1975-76 releases: meager parasitism after one winter and continued persistence questionable.	56, 57, 148
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Anopheles dthali</i> Patton, <i>A. superpictus</i> Grassi, <i>A. sergentii</i> (Theobald), <i>A. turkhudi</i> Liston, & <i>A. culicifacies</i> Giles	1984-85	IRAN	Native	Asia	continent	established	negligible control	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.	204
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Anopheles freeborni</i> Aitken & <i>Culex tarsalis</i> Coquillett	1975-76	USA: California	Native	North America	continent	established	partial control	Released in rice fields. Continuous partial control through rice growing season with mean weekly infection for both species > 60%. Survived chemicals, drying, harvest, winter and cultivation, and parasitized hosts next summer.	148
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Anopheles nyssorhynchus albianus</i> Weidemann & <i>A. punctipennis</i> (Say)	1977	EL SALVADOR	Native	South / Central America	continent	maybe or no info		Released in Lake Apasteque. Releases through year yielded 46-96% parasitism; up to 17x reduction in host populations. Recycling not reported, questionable.	149, 164
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Anopheles nyssorhynchus albianus</i> Wiedemann	1983	COLOMBIA	Native	South / Central America	continent	established	partial control	Released in El Valle. Established and cycled over 27 months, effectively reduced host population with coincident reduction in malaria among school children.	164
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Anopheles punctipennis</i> (Say), <i>A. crucians</i> Weidemann, <i>Aedes vexans</i> (Meig.), <i>Culex restuans</i> Theobald, & <i>C. pipiens</i> L.	1975	USA: Maryland	Native	North America	continent	established	control	Established, 50-100% host mortality even 2 years after release.	136
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	source unreported	Diptera	Culicidae	Anopheline spp. & <i>Culicine</i> spp., incl. <i>Aedes caspius</i> (Pallas), <i>Culex modestus</i> Ficalbi, <i>C. theileri</i> Theobald, <i>Uranotaenia unguiculata</i> Edwards	ca 1990	AZERBAIJAN (USSR)	Native	Asia	continent	established	? (unclear)	<i>Aedes caspius</i> (Pallas), <i>Culex modestus</i> Ficalbi, <i>C. theileri</i> Theobald, <i>Uranotaenia unguiculata</i> Edwards first reported as hosts. The nematodes survived drying of up to 2 weeks and survived the winter in some reservoirs. Longer term establishment unknown.	2, 153

Agent group	Biological control agent	Biological control agent species (Family: Genus)	Source of biological control agent	Pest Order	Pest Family	Target pest species	Year(s) of 1st release	Release country	Pest origin in release area	Release Region	Islands	Agent establishment	Control success	Results from introduction	Citations
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	source unreported	Diptera	Culicidae	Anopheline spp. incl. <i>A. superpictus</i> Grassi, <i>A. pulcherrimus</i> Theobald, <i>A. hyrcanus</i> group; & <i>Culicine</i> spp.	ca 1990	TAJIKISTAN (USSR)	Native	Asia	continent	maybe or no info		Mean infection was 46% with similar results in running and stagnant water. Infection of culicines was less than anophelines (<i>Anopheles superpictus</i> Grassi, <i>A. pulcherrimus</i> Theobald, <i>A. hyrcanus</i> group). Long term establishment unknown.	153, 191
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Culex pipiens quinquefasciatus</i> Say	1971-72	TAIWAN	Native	Asia	island	not		Released in Taipei. Infection rates low after release and no indication of establishment.	129
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Culex pipiens quinquefasciatus</i> Say	1974	TAIWAN	Native	Asia	island	maybe or no info		Released in Taipei. Recycling occurred through 196 days after release but continued persistence not confirmed.	31
Nematoda	<i>Romanomermis culicivorax</i>	<i>Romanomermis culicivorax</i> Ross & Smith [= <i>Reesimermis nielseni</i> Tsai & Grundmann]; (Mermithida: Mermithidae)	Louisiana USA	Diptera	Culicidae	<i>Culex pipiens quinquefasciatus</i> Say	1972	THAILAND	Native	Asia	continent	not		Large releases in ditches and drains in Bangkok, infection 0-27%, no recycling.	30, 148
Nematoda	<i>Romanomermis iyengari</i>	<i>Romanomermis iyengari</i> Welch; (Mermithida: Mermithidae)	source unreported; originally from India	Diptera	Culicidae	<i>Anopheles gambiae</i> Giles	2011	BENIN (in west Africa)	Native	Africa	continent	maybe or no info		Releasing monthly suppressed <i>A. gambiae</i> . Longer term establishment not reported.	1
Nematoda	<i>Romanomermis iyengari</i>	<i>Romanomermis iyengari</i> Welch; (Mermithida: Mermithidae)	source unreported; originally from India	Diptera	Culicidae	<i>Anopheles pseudopunctipennis</i> Theobald	1996, 1999	MEXICO: Oaxaca	Native	North America	continent	established	partial control	Released in Pochutla. In 1996, 85-100% parasitism, and after 2 months recovered infected mosquitos 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.	123, 146, 153
Nematoda	<i>Romanomermis iyengari</i>	<i>Romanomermis iyengari</i> Welch; (Mermithida: Mermithidae)	source unreported; originally from India	Diptera	Culicidae	Anopheline spp. incl. <i>Anopheles sacharovi</i> Favre; & <i>Culicine</i> spp. incl. <i>Culex theileri</i> Theobald	ca 1990	AZERBAIJAN (USSR)	Native	Asia	continent	maybe or no info		<i>Anopheles sacharovi</i> Favre and <i>Culex theileri</i> Theobald first reported as hosts. These nematodes could be moved to new water bodies by moving parasitized hosts. Long term establishment unknown.	2, 153
Nematoda	<i>Romanomermis iyengari</i>	<i>Romanomermis iyengari</i> Welch; (Mermithida: Mermithidae)	source unreported; originally from India	Diptera	Culicidae	Anopheline spp. & <i>Culicine</i> spp., incl. <i>A. albimanus</i> Wiedemann, <i>C. nigripalpus</i> Theobald, <i>C. quinquefasciatus</i> Say, <i>Uranotaenia sapphirina</i> (Osten Sacken)	1991	CUBA	Native	Atlantic / Caribbean	island	established	partial control	High levels of parasitism of <i>A. albimanus</i> Wiedemann, <i>C. nigripalpus</i> Theobald, <i>C. quinquefasciatus</i> Say, <i>Uranotaenia sapphirina</i> (Osten Sacken); and reduced host populations. At some sites <i>R. iyengari</i> was established for up to 5 months.	153, 165
Nematoda	<i>Romanomermis iyengari</i>	<i>Romanomermis iyengari</i> Welch; (Mermithida: Mermithidae)	source unreported; originally from India	Diptera	Culicidae	Anopheline spp. incl. <i>Anopheles superpictus</i> Grassi, <i>A. pulcherrimus</i> Theobald, <i>A. hyrcanus</i> group; & <i>Culicine</i> spp.	ca 1990	TAJIKISTAN (USSR)	Native	Asia	continent	maybe or no info		Mean infection was 46% with similar results in running and stagnant water. Infection of culicines was less than anophelines (<i>Anopheles superpictus</i> Grassi, <i>A. pulcherrimus</i> Theobald, <i>A. hyrcanus</i> group). Long term establishment unknown.	153, 191
Nematoda	<i>Romanomermis iyengari</i>	<i>Romanomermis iyengari</i> Welch; (Mermithida: Mermithidae)	source unreported; originally from India	Diptera	Culicidae	Anopheline spp. & <i>Culicine</i> spp., incl. <i>Anopheles martinus</i> Schingarev, <i>A. hyrcanus</i> group, <i>Culex modestus</i> Ficalbi, <i>Aedes caspius</i> (Pallas)	ca 1990	UZBEKISTAN (USSR)	Native	Asia	continent	maybe or no info		<i>Anopheles martinus</i> Schingarev, <i>A. hyrcanus</i> group, <i>Culex modestus</i> Ficalbi, were parasitized after releases. <i>Aedes caspius</i> (Pallas) was not. Infection from 9-67% and only effective in water bodies with low salt content.	153, 158
Nematoda	<i>Steinernema scapterisci</i>	<i>Steinernema scapterisci</i> Nguyen & Smart; (Rhabditida: Steinernematidae)	Uruguay	Orthoptera	Gryllotalpidae	<i>Scapteriscus abbreviatus</i> Scudder, <i>S. borelli</i> Gigli-Tos, & <i>S. vicinus</i> Scudder; Mole crickets	1985	USA: Florida	Non-native	North America	continent	established	control	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 > 27% reduction in hosts when persisting. <i>S. borelli</i> more susceptible than <i>S. vicinus</i> , but both can be controlled.	53, 145
Nematoda	<i>Steinernema scapterisci</i>	<i>Steinernema scapterisci</i> Nguyen & Smart; (Rhabditida: Steinernematidae)	Florida USA; originally from Uruguay	Orthoptera	Gryllotalpidae	<i>Scapteriscus didactylus</i> (Latreille) & <i>S. abbreviatus</i> Scudder; Mole crickets	2001-04	PUERTO RICO	Non-native	Atlantic / Caribbean	island	established	partial control	Establishment confirmed. <i>S. didactylus</i> in Puerto Rico about as susceptible as <i>S. borelli</i> is in Florida, but <i>S. abbreviatus</i> , for unknown reasons, is less susceptible.	53, 111

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Order: #1-217 are from Hajek et al. 2016; 1A-1C are from Addendum on final page in Hajek et al. 2016; #218-225 are additions for this current document in 2020.

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