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Invasive Species

Catalogue of Introductions of Pathogens and Nematodes for Classical Biological Control of Insects and Mites

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Introduction

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" (41). Numerous summaries of the many classical biological control programs have been published (e.g., 28, 55, 74). 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 (58).

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 (46, 59). 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.

We believe this publication is the most complete catalogue to date of classical biological control programs that have used pathogens and nematodes to control arthropod pests. It was difficult to find many of the classical biological control programs listed in the tables that follow; probably, 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 an exotic (non-native) in the area of release. We include programs where the species of microbe or nematode was exotic (introduced) as well as programs where only the strain or biotype released was exotic.

3. 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 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 25, 147].)

Organization of tables and charts

Tables

Intentional and accidental releases of entomopathogens are grouped according to specific pathogen and nematode groups, and are presented in Tables A through F. Column headings and descriptions of contents are as follows:

Pest Group and Species

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, a chromist, microsporidia and nematodes. Scientific names and synonyms are provided.

Release date (year)

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, 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 release in later years in the same general region, are included only if the initial release failed, or the pathogens used in subsequent releases were from a different source or sources. In the case of accidental introductions (Table F), the year the agent was first found is listed.

Release country, source and results from introduction

Releases are presented separately for geographically isolated areas and are listed by the country, or in a few instances by region (e.g. "Europe"), where the release was made (given in capital letters, e.g., BRAZIL). In some cases, a pathogen or nematode was released in more than one area within the same country. If release areas are isolated from one another, these introductions are considered separate introductions. For example, releases of *Romanomermis culicivorax* (originating from Louisiana) in both Maryland and California would be considered separate introductions although both are states within the same country because these release areas are geographically separated from one another and the sites differ in climate and topographies. 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.

The geographical location where the pathogen or nematode was acquired for the release follows the release country (after Ex., e.g. Ex. China). Whenever appropriate, microbes from different source locations are listed separately.

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 this catalogue, 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 could find no documentation of what happened after releases.

Pest origin

I = Introduced (exotic)

N = Native (endemic)

? = Origin unknown

Charts

Chart 1 provides the classification for pathogens and nematodes included in the catalogue either as intentional or accidental releases.

Chart 2 provides the classification for insect and mite hosts targeted by pathogens or nematodes that were either intentionally or accidentally introduced.

References

The reference list 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 A: EXOTIC VIRUSES RELEASED AND TARGET HOSTS

ORDER: COLEOPTERA

FAMILY

Scarabaeidae

SPECIES

***Oryctes rhinoceros* (L.)**

(rhinoceros beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Oryctes rhinoceros virus (OrV) (= *Rhabdionvirus oryctes* (Huger); = *Baculovirus oryctes* Huger) (Currently unassigned; previously in Baculoviridae)	1967	SAMOA (= WESTERN SAMOA) 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.	I	14, 89, 90, 145, 163
	1967	TOKELAU ISLANDS Ex. Malaysia. Released on Nukunonu Atoll. Established and by 1973 39% of beetles infected and only 1.5-6.5% of palm fronds damaged.	I	14, 145, 164
	1970-74	FIJI Ex. Samoa (= Western Samoa). Established and by 1974 57-68% of beetles infected. Damage decreased significantly 12-18 months after virus establishment.	I	12, 13, 14, 145
	1970	PALAU Ex. Samoa (= Western Samoa). Established on Babeldaob Isl., controlling beetles.	I	129, 145
	1983	PALAU Ex. Samoa (= Western Samoa). Released on Peleliu Isl. and “other places where beetle problems were evident,” resulting in beetle control.	I	129

COLEOPTERA	**Scarabaeidae**	***Oryctes rhinoceros* (L.)**	*Oryctes rhinoceros* virus (OrV)	1970-71	WALLIS ISLAND Ex. Samoa (= Western Samoa). 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.	I	14, 56, 62, 145
				1970-71	TONGA Ex. Samoa (= Western 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 (< 5% of palm crowns surveyed).	I	145, 160, 161
				1970-72	MAURITIUS Ex. Samoa (= Western Samoa). Established, beetle populations declined sharply from 1970. At least through 1976-77, damage reduced by 60-95%.	I	14, 105
				1972	AMERICAN SAMOA Ex. Samoa (= Western Samoa). Established, virus spread 0.8-1.6 km/month and damage declined.	I	14, 145
				1978-79	PAPUA NEW GUINEA Ex. Samoa (= Western Samoa). Released on 3 islands; established at nearly all sites, spread at 1 km/month.	I	53
				1983-84	INDIA Ex. India (Kerala). 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.	N	101

COLEOPTERA
Scarabaeidae
Oryctes rhinoceros (L.)

	1987	INDIA Ex. India (Kerala). 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.	N	71
	1984-85	MALDIVES Ex. Philippines, Tanzania & Malaysia. 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.	N	31, 165

SPECIES

***Oryctes monoceros* (Olivier)**

(rhinoceros beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Oryctes rhinoceros virus (OrV) (= *Rhabdionvirus oryctes* (Huger); = *Baculovirus oryctes* Huger) (Currently unassigned; previously in Baculoviridae)	1973	SEYCHELLES Ex. Samoa. Released on Mahé, Praslin Island group & La Digue. Establishment confirmed in 1986 on Praslin Island group only, with infection 70-90%.	N	86, 87
	1981-83	SEYCHELLES Ex. Praslin Island group. Established on Mahé & Ste. Anne with 20-50% infection and 30% reduction in beetle population.	N	86, 87
	1983-87	TANZANIA Ex. Philippines & Samoa (= Western Samoa). Established at 2 sites, with 40-60% infection after 1-1.5 years but reduction in frond damage not sustained by 1988.	N	123, 131

COLEOPTERA

Scarabaeidae

SPECIES

***Scapanes australis* (Boisduval)**

(rhinoceros beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Oryctes rhinoceros virus (OrV) (= *Rhabdionvirus oryctes* (Huger); = *Baculovirus oryctes* Huger) (Currently unassigned; previously in Baculoviridae)	before 1979	SOLOMON ISLANDS Ex. Fiji. Virus released on Guadalcanal but fate unknown.	N	139

ORDER: LEPIDOPTERA

FAMILY

Zygaenidae

SPECIES

***Harrisina brillians* (Barnes & McDunnough)**

(western grapeleaf skeletonizer)

BIOLOGICAL CONTROL AGENT	Release date	Country, source, and results from introduction	Pest origin	References
Harrisina brillians Granulovirus (HbGV) (Baculoviridae)	1981-1982	UNITED STATES OF AMERICA Ex. Mexico & USA (Arizona). Released in central California (Tulare Co.). Established, epizootics develop in high density host populations. Overall, lowers general equilibrium density of host populations.	I	144

FAMILY

Lymantriidae

SPECIES

***Lymantria dispar* (L.)**

(gypsy moth)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Lymantria dispar Multicapsid Nucleopolyhedrovirus (LdMNPV) (Baculoviridae)	1972	SARDINIA Ex. Serbia. Established, high levels of larval mortality year of release, > 40% infection the next year and spread over 300 hectares.	N	88

LEPIDOPTERA

Lymantriidae

SPECIES

***Lymantria monacha* (L.)**

(nun moth)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Lymantria monacha Nucleopolyhedrovirus (Baculoviridae)	1973-4	DENMARK Ex. Sweden and West Germany. Released in Silkeborg (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. In Grindsted (1974), the population collapsed the year of virus release but it is suggested that other factors, including the native virus, played important parts.	N	167

FAMILY

Noctuidae

SPECIES

***Anticarsia gemmatalis* (Hübner)**

(velvetbean caterpillar)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Anticarsia gemmatalis Multicapsid Nucleopolyhedrovirus (AgMNPV) (Baculoviridae)	1979-80	UNITED STATES OF AMERICA Ex. Brazil (Santa Catarina). Released in South Carolina. 59-86% infection the season of release but no infections found 1 year after release.	N	8, 23
	1990-91	UNITED STATES OF AMERICA Ex. Brazil. Released in soybean fields in Louisiana. Established, causing 25-100% infection the year of release and 4-49% infection for years 2-4 after release, even in rotated fields.	N	47

LEPIDOPTERA — Noctuidae

SPECIES

***Trichoplusia ni* (Hübner)**

(cabbage looper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Trichoplusia ni Nucleopolyhedrovirus (TnNPV) (Baculoviridae)	1970	COLOMBIA Ex. USA (California). Persisted after release, controlling subsequent pest generations.	I	15, 33

SPECIES

***Pseudoplusia includens* (Walker)**

(soybean looper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Pseudoplusia includens Singlecapsid Nucleopolyhedrovirus (PiSNPV) (Baculoviridae)	1975-77	UNITED STATES OF AMERICA Ex. Guatemala. Released in soybean fields in Louisiana, established, 38-63% infection 12-15 years after introduction.	N	48

SPECIES

***Agrotis segetum* (Denis & Schiffermüller)**

(turnip moth)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Agrotis segetum Granulovirus (AsGV) (Baculoviridae)	1975-80	DENMARK Ex. Austria. 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.	N	166, 168, 171

ORDER: HYMENOPTERA

FAMILY

Diprionidae

SPECIES

***Neodiprion sertifer* (Geoffrey)**

(European pine sawfly)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Neodiprion sertifer Nucleopolyhedrovirus (NeseNPV) (Baculoviridae)	1950	CANADA Ex. Sweden. Released in southern Ontario, near Strathroy. > 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.	I	19, 34, 39, 92
	1951-52	UNITED STATES OF AMERICA Ex. Canada. Released in New Jersey, established and spread (ca. 300 m from individual trees after release). Provided complete control.	I	39

HYMENOPTERA	**Diprionidae**	***Neodiprion sertifer* (Geoffrey)**	*Neodiprion sertifer*	1952	UNITED STATES OF AMERICA Ex. USA (New Jersey). Released in Illinois. By 19 days after treatment, 82-100% control. In 1953, spread was up to 80 m from treated area. Excellent control achieved. Virus from Canada released in Indiana from 1953 and reported as maintaining adequate control over several years through recurring epizootics after establishment.	I	39, 130
				1961	UNITED KINGDOM (SCOTLAND) 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.	N	35, 126

SPECIES

***Gilpinia hercyniae* (Hartig) (= *Diprion hercyniae* (Hartig))**

(European spruce sawfly)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Gilpinia hercyniae Nucleopolyhedrovirus (GhNPV) (Baculoviridae)	1943-45	CANADA Ex. Canada (Mainland). Released in Newfoundland. Established and by 1946 reported as prevalent over considerable areas surrounding release areas.	I	4, 92
	1950	CANADA Ex. Canada (New Brunswick). Released in an isolated host population in Sault Ste. Marie, Ontario, 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.	I	20

TABLE B: EXOTIC BACTERIA RELEASED AND TARGET HOSTS

ORDER: COLEOPTERA

FAMILY

Scarabaeidae

SPECIES

***Papuana huebneri* (Halmahera)**

(taro beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Paenibacillus popilliae (Dutky) (Bacillaceae)	1976	KIRIBATI Ex. Papua New Guinea & Solomon Islands. Released on So. Tarawa. Isolate from Papua New Guinea (type A1) caused infections 1 year after release.	I	149

SPECIES

***Oryctes rhinoceros* (L.)**

(rhinoceros beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Paenibacillus popilliae (Dutky) (Bacillaceae)	1951	PALAU Ex. USA (strain from Japanese beetle, *Popillia japonica* Newman). Not recovered after release.	I	145
	1957	AMERICAN SAMOA Ex. USA (strain from Japanese beetle, *Popillia japonica* Newman). Not recovered after release.	I	145

SPECIES

***Schizonycha* sp.**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Paenibacillus popilliae (Dutky) (Bacillaceae)	1956	KENYA Ex. USA (A & B strains from Japanese beetle, *Popillia japonica* Newman). Not recovered after release.	N	54

COLEOPTERA — **Scarabaeidae**

SPECIES

***Cochliotis melolonthoides* (Gerstaecker)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Paenibacillus popilliae (Dutky) (Bacillaceae)	1968	TANZANIA Ex. Probably USA. Japanese beetle, *Popillia japonica* Newman. Seemed to become established but this is not certain due to presence of an indigenous milky disease.	N	54

TABLE C: EXOTIC FUNGI RELEASED AND TARGET HOSTS

ORDER: ORTHOPTERA

FAMILY

Acrididae

SPECIES

***Phaulacridium vittatum* (Sjöstedt)**

(wingless grasshopper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Entomophaga grylli (Fresenius) Batko, pathotype I (Zygomycetes: Entomophthoraceae)	1984	AUSTRALIA Ex. USA (Arizona). Released near Canberra. Epizootics did not occur and permanent establishment questioned, efficacy unlikely.	N	96

SPECIES

Various species, including *Melanoplus bivittatus* (Say), *Melanoplus sanguinipes* (F.), *Camnula pellucida* Scudder

(twostriped grasshopper, migratory grasshopper, clearwinged grasshopper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Entomophaga grylli (Fresenius) Batko, pathotype III (Zygomycetes: Entomophthoraceae)	1989-91	UNITED STATES OF AMERICA Ex. Australia. Isolate chosen based on biology, similarity of climates and ability to infect species in both Oedipodinae and Melanoplinae, but not *Hesperotettix viridis* (Scudder). Released in North Dakota. 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.	N	18, 24, 25

ORTHOPTERA

Acrididae

SPECIES

***Melanoplus sanguinipes* (F.)**

(migratory grasshopper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Entomophaga grylli (Fresenius) Batko, pathotype III (Zygomycetes: Entomophthoraceae)	1990	UNITED STATES OF AMERICA Ex. Australia. Released in Alaska. No establishment reported.	N	24, 124

ORDER: HEMIPTERA

FAMILY

Cercopidae

SPECIES

***Aeneolamia flavilatera* (Ulrich)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	1944	GUYANA Ex. Trinidad. 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.	N	29

FAMILY

Cicadellidae

SPECIES

***Empoasca fabae* (Harris)**

(potato leafhopper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Zoophthora radicans (Brefeld) Batko (Zygomycetes: Entomophthoraceae)	1984	UNITED STATES OF AMERICA Ex. Brazil. Introduced to Illinois. No establishment.	I	65, 93

HEMIPTERA

Cicadellidae

SPECIES

Unspecified species

(leafhopper)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Unknown fungus	1906	UNITED STATES OF AMERICA Ex. Australia and Fiji, where they infected leafhopper eggs. Released in Hawaii. Establishment not confirmed.	I?	114

FAMILY

Aphididae

SPECIES

***Therioaphis maculata* (Buckton)**

(spotted alfalfa aphid)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Zoophthora radicans (Brefeld) Batko (Zygomycetes: Entomophthoraceae)	1979	AUSTRALIA Ex. Israel. Isolate chosen in part due to similar climate. Released in New South Wales. 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.	I	97, 98, 99

HEMIPTERA

Aphididae

SPECIES

***Aphis gossypii* Glover**

(cotton aphid)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Neozygites fresenii (Nowakowski) Batko (Zygomycetes: Neozygitaceae)	1994-95	UNITED STATES OF AMERICA Ex. USA (Arkansas). Released in San Joaquin Valley, California. Cycling during release seasons with infection levels that would have initiated epizootics in Arkansas but epizootics did not occur. Persisted until end of release seasons but not recovered 1997-2001, so long-term establishment questionable.	I	52, 142

SPECIES

***Metopolophium dirhodum* (Walker), plus other cereal aphids**

(rose-grain aphid)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Pandora neoaphidis (Remaudière & Hennebert) Humber (Zygomycetes: Entomophthoraceae)	1982	BELGIUM Ex. Brazil. Isolate chosen due to good in vitro growth. Limited transmission in field after release, probably because few condia are produced by isolate. Limited transmission suggests poor chance of establishment.	N	85

HEMIPTERA

Aphididae

SPECIES

***Macrosiphum solanifolii* (Ashmead)**

(potato aphid)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Probably in *Lecanicillium* (= *Verticillium*) *lecanii* species complex (Reported as *Acrostalagmus* sp.) (Ascomycetes: Anamorph of Hypocreales)	1955	UNITED STATES OF AMERICA Ex. USA (Hawaii). Released in Maine. Diseased aphids found 3 weeks after release and one infected specimen found in 1958. Unknown if permanently established.	N	132, 133

FAMILY

Aleyrodidae

SPECIES

***Singhiella citrifolii* (Morgan) (= *Dialeurodes citrifolii* Morgan)**

(cloudywinged whitefly)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Aschersonia goldiana Saccardo & Ellis (Ascomycetes: Anamorph of Hypocreales)	1924	BERMUDA Ex. USA (Florida). Considered established in 1925 but only provided efficient control in well-shaded situations.	I	109, 110

HEMIPTERA

Aleyrodidae

SPECIES

***Dialeurodes citri* (Ashmead)**

(citrus whitefly)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Aschersonia spp. (Ascomycetes: Anamorphs of Hypocreales)	1960-1964	GEORGIA Ex. 11 species and forms from China, Trinidad, Vietnam, Cuba, Japan & India. No information on whether all strains became established. The most aggressive was *A. placenta* Berkeley & Broome from Vietnam and China, giving up to 90% infection in Adzharia in favorable weather but was inhibited by drought. In 1980-84, in areas where large complexes of natural enemies occurred in citrus plantations (including fungi in this genus), the pest was kept below the economic threshold.	I	70, 120
	1961-1964	AZERBAIJAN Ex. 11 species and forms from China, Trinidad, Vietnam, Cuba, Japan, USA & India. No information on whether all strains became established. About 80% larval mortality in citrus plantations under favorable conditions and fungus spread to new plantations. In 1980-84, in areas where large complexes of natural enemies occurred in citrus plantations (including fungi in this genus), the pest was kept below the economic threshold.	I	70, 122

SPECIES

***Dialeurodes* sp.**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Aschersonia aleyrodis Webber (Ascomycetes: Anamorph of Hypocreales)	1926	BERMUDA Ex. USA (Florida). Establishment and persistence not reported.	?	111

HEMIPTERA

Aleyrodidae

SPECIES

***Aleurodicus cocois* (Curtis), *Aleurothrixus floccosus* (Maskell)**

(coconut whitefly, woolly whitefly)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Aschersonia aleyrodis Webber (Ascomycetes: Anamorph of Hypocreales)	before 1920	VIRGIN ISLANDS Ex. Unknown. No establishment due to high winds and drought.	N?	154

SPECIES

Unspecified whitefly species

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Unknown fungus	1909	UNITED STATES OF AMERICA Ex. USA (Florida). One species released in Hawaii against whitefly. Results not reported.	?	81

FAMILY

Coccidae

SPECIES

***Coccus viridis* (Green)**

(green scale)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Unidentified fungus (possibly in *Lecanicillium* (= *Verticillium*) *lecanii* species complex) (Ascomycetes: Anamorph of Hypocreales)	1928 or before	UNITED STATES OF AMERICA Ex. USA (Florida). Released in Hawaii. Established and provided effective control.	I	69, 146

HEMIPTERA

Coccidae

SPECIES

***Coccus viridis* (Green), *Eucalymnatus tessellatus* (Signoret), *Ceroplastes rubens* (Maskell)**

(green scale, tessellated scale, red wax scale)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Lecanicillium lecanii (Zimmerman) Gams & Zare (= *Verticillium lecanii* (Zimmerman); = *Cephalosporium lecanii* Zimmerman) (Ascomycetes: Anamorph of Hypocreales)	1911	SEYCHELLES Ex. Sri Lanka. Established and largely controlled scale populations.	I	1

SPECIES

Various species of lecaniine scales

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Lecanicillium lecanii (Zimmerman) Gams & Zare (= *Verticillium lecanii* (Zimmerman); = *Cephalosporium lecanii* Zimmerman) (Ascomycetes: Anamorph of Hypocreales)	before 1933	SEYCHELLES Ex. India. Well established on lecaniine scales, especially *Coccus viridis* (Green) on coffee, and spread widely.	?	139

SPECIES

Unspecified species of coccids

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Unknown fungi	1897	UNITED STATES OF AMERICA Ex. Unrecorded (Unknown). 2 species released in Hawaii against Coccidae. Establishment and spread over most parts of the islands.	?	79

HEMIPTERA

FAMILY

Diaspididae

SPECIES

***Aonidiella aurantii* (Maskell)**

(California red scale)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Fusarium coccophilum (Desmazieres) Wollenweber & Reinking (= *Fusarium episphaerea* f. *coccophila* Tul.); teleomorph = *Nectria flammea* (Tulasne & Tulasne) Dingley (Ascomycetes: Anamorph of Hypocreales)	1900	ARGENTINA Ex. USA. Established and occasionally caused up to 90% mortality in northeastern and northwestern regions.	I	32

SPECIES

***Cornuaspis beckii* (Newman) (= *Lepidosaphes beckii* (Newman))**

(purple scale, mussel scale)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Fusarium coccophilum (Desmazieres) Wollenweber & Reinking (= *Sphaerostilbe coccophila* Tul.); teleomorph = *Nectria flammea* (Tulasne & Tulasne) Dingley (Ascomycetes: Anamorph of Hypocreales)	1905 or before	UNITED STATES OF AMERICA Ex. USA (Florida). Introduced to Hawaii. Established and locally abundant but control only partial.	I	80
	1926	BERMUDA Ex. USA (Florida). Establishment and persistence not recorded.	I	111
Podonectria coccicola Petch (Ascomycetes: Tubeufiaceae)	1926	BERMUDA Ex. USA (Florida). Establishment and persistence not recorded.	I	111
Triblidium caespitosum Cooke & Masee (= *Myrangium duriaei* Montagne & Berkeley) (Ascomycetes: Triblidiaceae)	1926	BERMUDA Ex. USA (Florida). Establishment and persistence not recorded.	I	111

HEMIPTERA — Diaspididae

SPECIES

***Aspidiotus destructor* Signoret**

(coconut scale)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Fusarium juruanum P. Hennings (= *Pseudomicrocera henningsii* (Koord.) Petch) (Ascomycetes: Anamorph of Hypocreales)	1929	SEYCHELLES Ex. Sierra Leone. Did not establish.	I	40

SPECIES

***Quadraspidiotus perniciosus* (Comstock) (= *Aspidiotus perniciosus* (Comstock))**

(San Jose scale)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Fusarium coccophilum (Desmazieres) Wollenweber & Reinking (= *Sphaerostilbe coccophila* Tul.); teleomorph = *Nectria flammea* (Tulasne & Tulasne) Dingley (Ascomycetes: Anamorph of Hypocreales)	1897	UNITED STATES OF AMERICA Ex. USA (Florida). Released in California. As a result of this introduction, or a native fungus, scale nearly exterminated in southern California.	I	157
	1897	UNITED STATES OF AMERICA Ex. USA (Florida). Released in New Jersey. Established, overwintered, with abundant infection the following Sept. but this pathogen alone failed to provide adequate control.	I	134, 135
	1898	UNITED STATES OF AMERICA Ex. USA (Florida). Released in Illinois 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.	I	45

ORDER: THYSANOPTERA

FAMILY

Thripidae

SPECIES

***Thrips tabaci* Lindeman**

(onion thrips)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Neozygites parvispora (MacLeod & Carl) Remaudiére & Keller (Zygomycetes: Neozygitaceae)	1973-76	BARBADOS Ex. Switzerland. Released in onion field but no establishment.	I	29

ORDER: COLEOPTERA

FAMILY

Scarabaeidae

SPECIES

***Oryctes rhinoceros* (L.)**

(rhinoceros beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	1939	SAMOA (= WESTERN SAMOA) Ex. Java. This fungal species recovered after release but whether it was the introduced strain or a native strain is uncertain.	I	145
	1952	WALLIS ISLAND Ex. Argentina. Results from release unknown.	I	145
	1967	TOKELAU ISLANDS Ex. Samoa (= Western Samoa). Results from release unknown.	I	145
	1969	TONGA Ex. Samoa (= Western Samoa). High levels of infection directly after release, infections still present 3 years later but prevalence extremely low.	I	145, 160

COLEOPTERA
Scarabaeidae

SPECIES

***Papuana huebneri* (Halmahera)**

(taro beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	1976	KIRIBATI Ex. Unknown. Released on southern Tarawa by Latch. Establishment not confirmed.	I	95
	1995	KIRIBATI Ex. Papua New Guinea. Released on southern Tarawa. Persisted in soil through 2003, spread and exerted some control.	I	95, 149

SPECIES

***Phyllophaga smithi* (Arrow) (= *Lachnosterna smithi* (Arrow); = *Clemora smithi* (Arrow); = *Phytalus smithi* (Arrow)**

(sugar cane white grub)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Beauveria bassiana (Balsamo) Vuillemin (= *Beauveria densa* (Link) Vuillemin) (Ascomycetes: Anamorph of Hypocreales)	1932	MAURITIUS Ex. Unknown isolate from Imperial Bureau of Mycology, United Kingdom. Host population gradually declined and diseases may have played a part.	I	54, 102, 103, 104
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	1932	MAURITIUS Ex. Unknown isolate from Imperial Bureau of Mycology, UK. Host population gradually declined and diseases may have played a part.	I	54, 102, 103, 104

SPECIES

***Alissonotum impressicolle* Arrow**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	1914	TAIWAN Ex. USA (Hawaii). Numbers of scarabs greatly reduced in fields where spores were released.	N	158, 159

COLEOPTERA — **Scarabaeidae**

SPECIES

***Dermolepida albohirtum* (Waterhouse)**

(greyback cane beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	about 1914	AUSTRALIA 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 *Rhabdoscelus obscurus* (Boisduval) killed by this fungus.	N	155

SPECIES

***Lepidiota pruinosa* Wied., *Leucopholis irrorata* Chevrolat**

(white grubs in sugar cane)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	1928	PHILIPPINES Ex. Australia (Queensland). Not effective control and “undoubtedly already present.”	N	125

SPECIES

Various scarabs (including *Anoplognathus* sp., *Lepidiota* sp., etc.)

(white grubs in sugar cane)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Beauveria brongniartii (Saccardo) Petch (= *Botrytis tenella* Sacc.) (Ascomycetes: Anamorph of Hypocreales)	1894-95	AUSTRALIA Ex. France. Releases in Queensland and New South Wales. Negative results in New South Wales after dissemination.	?	155

COLEOPTERA

Scarabaeidae

SPECIES

***Adoretus tenuimaculatus* Waterhouse**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	before 1918	FIJI Ex. Unknown. Some signs that this fungus acted as a check on the beetles.	I	78

FAMILY

Curculionidae

SPECIES

***Sitona discoideus* Gyllenhal**

(sitona weevil)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Beauveria bassiana (Balsamo) Vuillemin (Ascomycetes: Anamorph of Hypocreales)	1984	AUSTRALIA Ex. France (Montpellier). Released in southern Australia. No infections ever found.	I	3

SPECIES

***Otiorhynchus nodosus* (Müller), *Otiorhynchus arcticus* (Fabricius)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Metarhizium anisopliae (Metschnikoff) Sorokin (Ascomycetes: Anamorph of Hypocreales)	2003	ICELAND Ex. Faroe Islands (Havnardalur). Released in eroded areas in Haukadalur. Too early to determine effect.	N	108

ORDER: DIPTERA

FAMILY

Culicidae

SPECIES

***Aedes polynesiensis* Marks**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Coelomomyces stegomyiae Keilin (Chytridiomycetes: Coelomomycetaceae)	1958	TOKELAU ISLANDS Ex. Singapore. Released on Nukunonu Atoll. Established, by 1963 infected larvae found in 13 of 35 habitats.	N	63, 82

SPECIES

***Culex tarsalis* Coquillett**

(western encephalitis mosquito)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Lagenidium giganteum Couch (Pythiales: Pythiaceae)*	1972	UNITED STATES OF AMERICA Ex. USA (North Carolina). Released in rice fields in Colusa County and irrigated pastures nr. Hanford, California. Recovered 3 consecutive years but dispersal from inoculation sites minimal.	N	44, 91, 152

* Member of the Kingdom Chromista, Phylum Oomycota. All other entries in this list belong to in the Kingdom Fungi.

ORDER: LEPIDOPTERA

FAMILY

Lymantriidae

SPECIES

***Lymantria dispar* (L.)**

(gypsy moth)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Entomophaga maimaiga Humber, Shimazu & Soper (Zygomycetes: Entomophthoraceae)	1910-1911	UNITED STATES OF AMERICA Ex. Japan (Nishigahara). Released in Massachusetts (Boston area). Not established.	I	138
	1985	UNITED STATES OF AMERICA Ex. Japan (Ishikawa Prefecture). Released in southwestern New York State. Not established.	I	60
	1986	UNITED STATES OF AMERICA Ex. Japan (Ishikawa Prefecture). Released in northern Virginia. Not established.	I	60
	1996	BULGARIA Ex. USA (Connecticut). Released in Levishte (northeastern Bulgaria). No infection in 1997.	N	117
	1999	BULGARIA Ex. USA (Massachusetts). Released in Karlovo (central Bulgaria). Established but negligible control.	N	118
	2000	BULGARIA Ex. USA (Connecticut). Released in Levishte. Infections found in 2002, 2003 & 2004.	N	117
	2002	RUSSIA Ex. USA (Virginia). Released in Novosibirsk region. Establishment not confirmed.	N	2

SUBCLASS: ACARI

FAMILY
Eriophyidae

SPECIES

***Eriophyes sheldoni* (Ewing)**

(citrus bud mite)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Hirsutella thompsonii Fisher var. *vinacea* Samson, McCoy & O'Donnell (Ascomycetes: Anamorph of Hypocreales)	1985	ARGENTINA Ex. USA (North Carolina). Released on lemon trees in Tucuman. Initially 92% decrease in mites but persistence unknown.	I	136, 137

SPECIES

***Eriophyes sheldoni* (Ewing), *Phyllocoptruta oleivora* (Ashmead)**

(citrus bud mite, citrus rust mite)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Hirsutella thompsonii Fisher var. *synnematosa* Samson, McCoy & O'Donnell (Ascomycetes: Anamorph of Hypocreales)	1985	ARGENTINA Ex. Zimbabwe. Released in Tucuman. About 50% infection for both mite species after release but persistence unknown.	I	136, 137

FAMILY
Tetrancychidae

SPECIES

***Mononychellus tanajoa* (Bondar)**

(cassava green mite)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Neozygites tanajoae Delalibera, Hajek & Humber (prev. referred to as *Neozygites floridana* (Weiser & Muma) Remaudiére & Keller) (Zygomycetes: Neozygitaceae)	1998-1999	BENIN Ex. northeastern Brazil. Established, epizootics occurring in 2002 & 2003 at release sites. Molecular probes developed to confirm that epizootics were caused by exotic strains of the introduced pathogen rather than a closely related native strain.	I	36, 66

TABLE D: EXOTIC MICROSPORIDIA RELEASED AND TARGET HOSTS

ORDER: ORTHOPTERA

FAMILY

Acrididae

SPECIES

Various species. Principal targets are Melanoplinae: *Dichroplus maculipennis* (Blanchard), *Dichroplus elongatus* (Giglio-Tos), *Dichroplus pratensis* Bruner, *Scotussa lemniscata* Stål

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Paranosema locustae (Canning) (= *Nosema locustae* Canning; = *Antonospora locustae* (Canning)) (Microsporidia: Nosematidae)	1978-82	ARGENTINA Ex. USA (Idaho). Released in central Argentina. Established and, in 1994-5, found 75 km from release sites. Epizootics occur with accompanying host declines but levels of infection in susceptible species usually average < 10%.	N	84

ORDER: DIPTERA

FAMILY

Culicidae

SPECIES

***Culex pipiens quinquefasciatus* Say (= *C. pipiens fatigans* Wiedemann; = *C. fatigans* Wiedemann)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Pleistophora culicis (= *Plistophora culicis)* Weiser (Microsporidia: Pleistophoridae)	1967	NAURU Ex. Nigeria (Lagos). Establishment not confirmed.	N	82

ORDER: LEPIDOPTERA

FAMILY

Pyralidae

SPECIES

***Ostrinia nubilalis* (Hübner)**

(European corn borer)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Nosema pyrausta (Paillot) (= *Perezia pyraustae* Paillot; = *Glugea pyraustae* (Paillot)) (Microsporidia: Nosematidae)	Unk.- betw. 1952 & 1960	UNITED STATES OF AMERICA Ex. USA (Iowa). Infected larvae distributed at scattered localities throughout Illinois. Disease became prevalent and kept host populations at low levels.	I	37

FAMILY

Lymantriidae

SPECIES

***Lymantria dispar* (L.)**

(gypsy moth)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Nosema portugal Maddox & Vávra (= *Microsporidium* sp.) (Microsporidia: Nosematidae)	1986	UNITED STATES OF AMERICA Ex. Portugal. Released in Maryland. Established, low levels of infection in 1987 which persisted for 3 years.	I	72, 73, 94
	1992, 1993	UNITED STATES OF AMERICA Ex. Portugal. Released in Michigan. Low levels of infection during the season of release, persistence not confirmed.	I	6, 7
Endoreticulatus sp. (= *Vavraia* sp.) (Microsporidia: Pleistophoridae)	1986	UNITED STATES OF AMERICA Ex. Portugal. Released in Maryland. Not established.	I	72, 73, 94

TABLE E: EXOTIC NEMATODES RELEASED AND TARGET HOSTS

ORDER: ORTHOPTERA

FAMILY

Gryllotalpidae

SPECIES

***Scapteriscus abbreviatus* Scudder, *Scapteriscus borelli* Gigli-Tos, *Scapteriscus vicinus* Scudder (mole crickets)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Steinernema scapterisci Nguyen & Smart (Rhabditida: Steinernematidae)	1985	UNITED STATES OF AMERICA Ex. Uruguay. Released in Florida. 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	113

ORDER: COLEOPTERA

FAMILY

Scarabaeidae

SPECIES

***Oryctes rhinoceros* (L.)**

(rhinoceros beetle)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Rhabditis sp. (Rhabditida: Rhabditidae)	1954	FIJI Ex. Sri Lanka. Results of release not reported.	I	28
	1957	FIJI Ex. Madagascar. Recovered after release, persistence not confirmed.	I	145
	1957	AMERICAN SAMOA Ex. Madagascar. Results from release unknown.	I	145
Rhabditis sp. nr. *maupasi* Seurat in Maupas (Rhabdita: Rhabditidae)	1957	SAMOA (= WESTERN SAMOA) Ex. Sri Lanka. Results from release unknown.	I	145

COLEOPTERA	Scarabaeidae	*Oryctes rhino* (L.)	*Rhabditis* sp.	1957	AMERICAN SAMOA Ex. Sri Lanka. Results from release unknown.	I	145
				1957	WALLIS ISLAND Ex. Sri Lanka. Results from release unknown.	I	145

FAMILY

Curculionidae

SPECIES

***Sitona discoideus* Gyllenhal**

(sitona weevil)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
*Heterorhabditis heliothidis (*Khan, Brooks & Hirschmann) (Rhabditida: Heterorhabditidae)	1982	AUSTRALIA Ex. New Zealand. Released in So. Australia. No infections ever found.	I	3

ORDER: DIPTERA

FAMILY

Culicidae

SPECIES

***Culex pipiens quinquefasciatus* Say**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1971-72	TAIWAN Ex. USA (Louisiana). Released in Taipei. Infection rates low after release and no indication of establishment.	N	100
	1974	TAIWAN Ex. USA (Louisiana). Released in Taipei. Recycling occurred through 196 days after release but continued persistence not confirmed.	N	27
	1972	THAILAND Ex. USA (Louisiana). Large releases in ditches and drains in Bangkok, infection 0-27%, no recycling.	N	26 (in 115)

DIPTERA — Culicidae

SPECIES

***Aedes* spp., *Ochlerotatus* spp. (10 species total)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1974	CANADA Ex. USA (Louisiana). Released in snow melt pools in Winnipeg, Manitoba. No infection.	N	49 (in 115)
	1975-76	CANADA Ex. USA (Louisiana). Released in snow melt pools in Winnipeg, Manitoba. Meager parasitism after one winter and continued persistence questionable.	N	50

SPECIES

***Aedes polynesiensis* Marks, *Aedes aegypti* (L.)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1978	TOKELAU ISLANDS Ex. USA (Louisiana). 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.	N/I	83

SPECIES

***Anopheles nyssorhynchus albimanus* Wiedemann**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1983	COLOMBIA Ex. USA (Louisiana). Released in El Valle. Established and cycled over 27 months, effectively reduced host population with coincident reduction in malaria among schoolchildren.	N	127

DIPTERA — Culicidae

SPECIES

***Anopheline* species: *Anopheles dthali* Patton, *Anopheles superpictus* Grassi, *Anopheles sergentii* (Theobald), *Anopheles turkhudi* Liston, *Anopheles culicifacies* Giles**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1984-85	IRAN Ex. USA (Louisiana). 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.	N	162

SPECIES

***Anopheles punctipennis* (Say), *Anopheles crucians* Weidemann, *Aedes vexans (*Meig.), *Culex restuans* Theobald, *Culex pipiens* L.**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1975	UNITED STATES OF AMERICA Ex. USA (Louisiana). Released in Maryland. Established, 50-100% host mortality even 2 years after release.	N	106

SPECIES

***Anopheles freeborni* Aitken, *Culex tarsalis* Coquillett**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1975-76	UNITED STATES OF AMERICA Ex. USA (Louisiana). Released in California 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.	N	115

DIPTERA

Culicidae

SPECIES

***Anopheles nyssorhynchus albimanus* Weidemann, *Anopheles punctipennis* (Say)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Romanomermis culicivorax Ross & Smith (= *Reesimermis nielseni* Tsai & Grundmann) (Mermithidae)	1977	El SALVADOR Ex. USA (Louisiana). Released in Lake Apasteque. Releases through year yielded 46-96% parasitism; up to 17x reduction in host populations. Recycling not reported, questionable.	N/I?	116, 127

SPECIES

***Culex pipiens quinquefasciatus* Say, *Aedes aegypti* (L.)**

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Octomyomermis muspratti Obiamiwe & Macdonald (Mermithidae)	1967	NAURU Ex. Zambia. After release, parasitism found in several tree holes but long-term establishment not reported.	N/I	82, 119

ORDER: LEPIDOPTERA

FAMILY

Lymantriidae

SPECIES

***Lymantria dispar* (L.)**

(gypsy moth)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Hexamermis sp. (Mermithidae)	1974	UNITED STATES OF AMERICA Ex. Austria. Released in New Jersey. Not established.	I	30
	1976	UNITED STATES OF AMERICA Ex. Japan (Hokkaido). Released in Pennsylvania. Not established.	I	30

ORDER: HYMENOPTERA

FAMILY

Siricidae

SPECIES

***Sirex noctilio* F.**

(European woodwasp, Sirex wasp)

BIOLOGICAL CONTROL AGENT	RELEASE DATE	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Deladenus siricidicola Bedding (= *Beddingia siricidicola* (Bedding)) (Rhabditida: Neotylenchidae)	1967	NEW ZEALAND Ex. New Zealand (North Island). Released on South Island. 29-76% infection reported within first year of release 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.	I	170
	1970	AUSTRALIA Ex. Hungary. Released in Tasmania. 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*.	I	9, 64
	1971	AUSTRALIA Ex. Tasmania (plus other locations). Released in Victoria. 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 in vitro production, strain lost virulence resulting in replacement of strain used for releases.	I	11, 64

HYMENOPTERA	**Siricidae**	***Sirex noctilio* F.**	*Deladenus siricidicola* Bedding	1987	URUGUAY Ex. New Zealand. Established, yielding 18% parasitism.	I	17, 121, 128
				1989, 1990, 1994	BRAZIL Ex. Australia. Principally released in 3 southern provinces. After loss of infectivity, new strain (Kamona from Tasmania) introduced in 1994, yielding 50-80% parasitism. Overall established, parasitism levels variable but provided substantial control in some areas.	I	11, 67, 68
				1995	SOUTH AFRICA Ex. Australia. Released Kamona strain in southwestern Cape Province. Established, with 23% parasitism reported in 1996. In 1998, along with cultural control, credited with containing the spread of the pest.	I	150, 151
				1999	ARGENTINA Ex. Brazil. Released in Patagonia. Established, 50-60% parasitism reported at release site in 2000.	I	76, 77

TABLE F: ACCIDENTAL INTRODUCTIONS OF PATHOGENS AND NEMATODES

ORDER: LEPIDOPTERA

FAMILY Zygaenidae

SPECIES *Harrisina brillians* Barnes & McDunnough (western grapeleaf skeletonizer)

BIOLOGICAL CONTROL AGENT	YEAR FOUND	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Harrisina brillians Granulovirus (HbGV) (Baculoviridae)	early 1950s	UNITED STATES OF AMERICA Found in San Diego Co., California, probably inadvertently introduced with parasitoids from Mexico and USA (Arizona). Infections observed in field and virus continually wiped out colonies for rearing parasitoids.	I	143, 144

FAMILY Pyralidae

SPECIES *Ostrinia nubilalis* (Hübner) (European corn borer)

BIOLOGICAL CONTROL AGENT	YEAR FOUND	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Nosema pyrausta (Paillot) (= *Perezia pyraustae* Paillot; = *Glugea pyraustae* (Paillot)) (Microsporidia: Nosematidae)	1949	UNITED STATES OF AMERICA Probably introduced from Europe, possibly with parasitoids. First found in New Jersey but subsequently found throughout the host distribution in the US. Occurring commonly, epizootics develop with high host density and widespread spatial distribution of hosts.	I	22, 61, 141

LEPIDOPTERA

FAMILY

Lymantriidae

SPECIES

***Lymantria dispar* (L.)**

(gypsy moth)

BIOLOGICAL CONTROL AGENT	YEAR FOUND	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Entomophaga maimaiga Humber, Shimazu & Soper (Zygomycetes: Entomophthoraceae)	1989	UNITED STATES OF AMERICA Ex. Japan. First found in 1989 in 7 northeastern states but spread naturally and through releases. Established in Connecticut, Delaware, Maine, Massachusetts, Maryland, Michigan, North Carolina, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Virginia, Vermont, Wisconsin, West Virginia and in Ontario, Canada. Host populations remain low the majority of years and sites, although localized increases can occur infrequently.	I	42, 57, 60, 107
Lymantria dispar Multicapsid Nucleopolyhedrovirus (LdMNPV) (Baculoviridae)	1907	UNITED STATES OF AMERICA (probably Massachusetts). Thought to have been introduced after 1900 from Europe with parasitoids released for classical biological control or with plant material and spread through the host population. Until *E. maimaiga* became established, caused epizootics in high density, defoliating host populations, resulting in spectacular population crashes. Spreads naturally after the host population spreads into new areas.	I	51, 57

ORDER: HYMENOPTERA

FAMILY

Siricidae

SPECIES

***Sirex noctilio* F.**

(European woodwasp, Sirex wasp)

BIOLOGICAL CONTROL AGENT	YEAR FOUND	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Deladenus siricidicola Bedding (= *Beddingia siricidicola* (Bedding)) (Rhabditida: Neotylenchidae)	1962	NEW ZEALAND (North Island). Thought to have arrived with host. Attributed with being the most important agent controlling host on the North Island.	I	10, 169

FAMILY

Diprionidae

SPECIES

***Gilpinia hercyniae* (Hartig) (= *Diprion hercyniae* Hartig)**

(European spruce sawfly)

BIOLOGICAL CONTROL AGENT	YEAR FOUND	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Gilpinia hercyniae Nucleopolyhedrovirus (GhNPV) (Baculoviridae)	1936	CANADA and UNITED STATES OF AMERICA Probably ex. Europe. 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 transfered 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.	I	5, 21, 34, 35, 92

HYMENOPTERA	Diprionidae	*Gilpinia hercyniae* (Hartig)	GhNPV	1970 or 1971	UNITED KINGDOM (WALES) Probably ex. Europe. Spread from small epicenter and controlled pest outbreak by 1974.	I	35, 43

FAMILY

Formicidae

SPECIES

***Solenopsis invicta* Buren**

(red imported fire ant)

BIOLOGICAL CONTROL AGENT	YEAR FOUND	COUNTRY, SOURCE, AND RESULTS FROM INTRO.	PEST ORIGIN	REFERENCES
Thelohania solenopsae Knell, Allen & Hazard (Microsporidia: Thelohaniidae)	1996	UNITED STATES OF AMERICA Ex. South America. Found in Florida. Infects mostly polygynous colonies. Chronic debilitation of infected queens yields smaller colony sizes and possibly prolonged death of colonies.	I	112, 153

CHART 1: CLASSIFICATION OF PATHOGENS AND NEMATODES PURPOSEFULLY INTRODUCED FOR CLASSICAL BIOLOGICAL CONTROL OF INSECTS AND MITES OR ESTABLISHED AFTER ACCIDENTAL INTRODUCTION [1]

Virus
- Family Baculoviridae
  - *Agrotis segetum* Granulovirus (AsGV)
  - *Anticarsia gemmatalis* Multicapsid Nucleopolyhedrovirus (AgMNPV)
  - *Gilpinia hercyniae* Nucleopolyhedrovirus (GhNPV)
  - *Harrisina brillians* Granulovirus (HbGV)
  - *Lymantria dispar* Multicapsid Nucleopolyhedrovirus (LdMNPV)
  - *Lymantria monacha* Nucleopolyhedrovirus
  - *Neodiprion sertifer* Nucleopolyhedrovirus (NeseNPV)
  - *Pseudoplusia includens* Singlecapsid Nucleopolyhedrovirus (PiSNPV)
  - *Trichoplusia ni* Nucleopolyhedrovirus (TnNPV)
- Family Unassigned
  - *Oryctes rhinoceros* Virus (Orv)

Domain Bacteria
- Phylum Firmicutes
  - Class Bacilli
    - Order Bacillales
      - Family Bacillaceae
        - *Paenibacillus popilliae*

Domain Eukarya
- Kingdom Fungi
  - Phylum Chytridiomycota
    - Class Chytridiomycetes
      - Order Blastocladiales
        - Family Coelomomycetaceae
          - *Coelomomyces stegomyiae*
  - Phylum Zygomycota
    - Class Zygomycetes
      - Order Entomophthorales
        - Family Entomophthoraceae
          - *Entomophaga grylli*
          - *Entomophaga maimaiga*
          - *Pandora neoaphidis*
          - *Zoophthora radicans*
        - Family Neozygitaceae
          - *Neozygites fresenii*
          - *Neozygites parvispora*
          - *Neozygites tanajoae*

- Phylum Ascomycota
  - Class Loculoascomycetes
    - Order Pleosporales
      - Family Tubeufiaceae
        - *Podonectria coccophila*
  - Class Discomycetes
    - Order Rhytismatales
      - Family Triblidiaceae
        - *Triblidium caespitosum*
  - Class Pyrenomycetes
    - Order Hypocreales (anamorphic/asexual forms)
      - *Aschersonia aleyrodis*
      - *Aschersonia goldiana*
      - *Aschersonia* spp.
      - *Beauveria bassiana*
      - *Beauveria brongniartii*
      - *Fusarium coccophilum*
      - *Fusarium juruanum*
      - *Hirsutella thompsonii* var. *synnematosa*
      - *Hirsutella thompsonii* var. *vinacea*
      - *Lecanicillium lecanii*
      - *Metarhizium anisopliae*
- Phylum Microsporidia
  - Class Microsporea
    - Order Nosematidida
      - Family Nosematidae
        - *Nosema portugal*
        - *Nosema pyrausta*
        - *Paranosema locustae*
    - Order Microsporida
      - Family Pleistophoridae
        - *Endoreticulatus* sp.
        - *Pleistophora culicis*
      - Family Thelohaniidae
        - *Thelohania solenopsae*

- Kingdom Chromista (= Kingdom Straminipila)
  - Phylum Oomycota
    - Class Oomycetes
      - Order Pythiales
        - Family Pythiaceae
          - *Lagenidium giganteum*

Kingdom Animalia
- Phylum Nematoda
  - Class Chromadorea
    - Order Rhabditida
      - Family Steinernematidae
        - *Steinernema scapterisci*
      - Family Neotylenchidae
        - *Deladenus siricidicola*
      - Family Rhabditidae
        - *Rhabditis* sp.
        - *Rhabditis* sp. nr. *maupasi*
      - Family Heterorhabditidae
        - *Heterorhabditis heliothidis*
  - Class Enoplea
    - Order Mermithida
      - Family Mermithidae
        - *Hexamermis* sp.
        - *Octomyomermis muspratti*
        - *Romanomermis culicivorax*

[1] Organization of domains based on Woese et al. (156). Placement of the Phylum Microsporidia in the Kingdom Fungi is a recent change (75) and, while we have adopted this change here, the higher order affiliation of this group is still somewhat in a state of flux. Nematode classification based on De Ley & Blaxter (38).

CHART 2: CLASSIFICATION OF INSECTS AND MITES TARGETED BY CLASSICAL BIOLOGICAL CONTROL PROGRAMS USING PATHOGENS OR NEMATODES, OR HOSTS OF ACCIDENTAL INTRODUCTIONS OF PATHOGENS OR NEMATODES

Kingdom Animalia
- Phylum Arthropoda
  - Class Insecta
    - Order Orthoptera
      - Family Gryllotalpidae
        - *Scapteriscus abbreviatus*
        - *Scapteriscus borelli*
        - *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*
        - *Macrosiphum solanifolii*
        - *Metopolophium dirhodum*
        - *Therioaphis maculata*
      - Family Aleyrodidae
        - *Aleurodicus cocois*
        - *Aleurothrixus floccosus*
        - *Dialeurodes* sp.
        - *Dialeurodes citri*
        - *Singhiella citrifolii*
      - Family Coccidae
        - *Ceroplastes rubens*
        - *Coccus viridis*
        - *Eucalymnatus tessellatus*
      - Family Diaspididae
        - *Aonidiella aurantii*
        - *Aspidiotus destructor*
        - *Cornuaspis beckii*
        - *Quadrispidiotus perniciosus*
    - Order Thysanoptera
      - Family Thripidae
        - *Thrips tabaci*

Order Coleoptera
- Family Scarabaeidae
  - *Adoretus tenuimaculatus*
  - *Alissonotum impressicolle*
  - *Anoplognathus* sp.
  - *Cochliotis melolonthoides*
  - *Dermolepida albohirtum*
  - *Lepidiota* sp.
  - *Lepidiota pruinosa*
  - *Leucopholis irrorata*
  - *Oryctes monoceros*
  - *Oryctes rhinoceros*
  - *Papuana huebneri*
  - *Phyllophaga smithi*
  - *Scapanes australis*
  - *Schizonycha* sp.
- Family Curculionidae
  - *Otiorhyncus arcticus*
  - *Otiorhyncus nodosus*
  - *Sitona discoideus*

Order Diptera
- Family Culicidae
  - *Aedes* spp.
  - *Aedes aegypti*
  - *Aedes polynesiensis*
  - *Aedes vexans*
  - *Anopheles crucians*
  - *Anopheles culicifacies*
  - *Anopheles dthali*
  - *Anopheles freeborni*
  - *Anopheles nyssorhynchus albimanus*
  - *Anopheles punctipennis*
  - *Anopheles sergentii*
  - *Anopheles superpictus*
  - *Anopheles turkhudi*
  - *Culex pipiens*
  - *Culex pipiens quinquefasciatus*
  - *Culex restuans*
  - *Culex tarsalis*
  - *Ochlerotatus* spp.

Order Lepidoptera
- Family Zygaenidae
  - *Harrisina brillians*
- Family Pyralidae
  - *Ostrinia nubilalis*
- Family Lymantriidae
  - *Lymantria dispar*
  - *Lymantria monacha*

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

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

References

1. Anonymous. 1919. Notes on insects in Seychelles. Ms. received fr. Colonial Off. Sept. 6, 1919. In: Rev. Appl. Entomol., Ser. A 7: 483-484.
2. Bahvalov, S. 2004. Institute of Systematics and Ecology of Animals, Siberian branch of the Russian Academy of Sciences, Novosibirsk, Russia. Personal communication to A. Sharov.
3. Bailey, P. & R. Milner. 1985. *Sitona discoideus*: A suitable case for control with pathogens? Proc. 4th Austr. Appl. Ent. Res. Conf., p. 210-217.
4. Balch, R. E. 1946. The disease of the European spruce sawfly. Can. Dept. Agric. Forest Insect Invest. Bimon. Progr. Rpt. 2(5): 1.
5. Balch, R. E. & F. T. Bird. 1944. A disease of the European spruce sawfly, *Gilpinia hercyniae* (Htg.) and its place in natural control. Sci. Agr. 25: 65-80.
6. Bauer, L. S., F. J. Sapio, M. L. McManus, J. V. Maddox, M. R. Jeffords & D. W. Onstad. 1993. Interactions of *Microsporidium* and gypsy moth in Michigan field plots. USDA, Forest Service, Gen. Tech. Rpt. NE-179: 22.
7. Bauer, L. S., F. J. Sapio, M. L. McManus, J. V. Maddox, M. R. Jeffords & D. W. Onstad. 1994. Interactions of *Microsporidium* and gypsy moth in Michigan field plots. USDA, Forest Service, Gen. Tech. Rpt. NE-188: 5.
8. Beach, R. M., G. R. Carner & S. G. Turnipseed. 1984. Field efficacy and persistence of a nuclear polyhedrosis virus of the velvetbean caterpillar in soybeans. J. Agric. Entomol. 1: 296-304.
9. Bedding, R. A. 1979. Manipulating the entomophagous-mycetophagous nematode, *Deladenus siricidicola*, for biological control of the woodwasp *Sirex noctilio* in Australia. In (W. E. Waters, Ed.) *Current Topics in Forest Entomology*, USDA, Forest Service, Gen. Tech. Pap. WO-8: 144-147.
10. Bedding, R. A. 1984. Nematode parasites of Hymenoptera, pp. 755-795. In (W. R. Nickle, Ed.) *Plant and Insect Parasitic Nematodes*, Marcel Dekker, NY.
11. Bedding, R. A. 1993. Biological control of *Sirex noctilio* using the nematode *Deladenus siricidicola*, pp. 11-20. In (R. Bedding, R. Akhurst, H. Kaya, Eds.). *Nematodes and the Biological Control of Insect Pests*. CSIRO, East Melbourne, Victoria, Australia.
12. Bedford, G. O. 1976. Use of a virus against the coconut palm rhinoceros beetle in Fiji. PANS 22: 11-25.
13. Bedford, G. O. 1977. Virus against coconut rhinoceros beetle in Fiji. South Pac. Bull. 27: 27-34.
14. Bedford, G. O. 1980. Biology, ecology, and control of palm rhinoceros beetles. Annu. Rev. Entomol. 25: 309-339.
15. Bellotti, A.C. & J.A. Reyes. 1980. South and Central America. Proc. Workshop on Insect Pest Management with Microbial Agents: Recent Achievements, Deficiencies, and Innovations, pp. 20-21. Boyce Thompson Institute, Ithaca, NY.
16. Benjamin, D. M., J. D. Larson & A. T. Drooz. 1955. The European pine sawfly on the Henderson State Forest, Illinois, with notes on its biology and control. J. For. 53: 359-362.

17. Bianchi, M. 2004. Personal communication to P. Klasmer.

18. Bidochka, M. J., S. R. A. Walsh, M. E. Ramos, R. J. St. Leger, J. C. Silver & D. W. Roberts. 1996. Fate of biological control introductions: Monitoring an Australian fungal pathogen of grasshoppers in North America. Proc. Natl. Acad. Sci. USA 93: 918-921.

19. Bird, F. T. 1955. Virus diseases of sawflies. Can. Entomol. 87: 124-127.

20. Bird, F. T. & J. M. Burk. 1961. Artificially disseminated virus as a factor controlling the European spruce sawfly, *Diprion hercyniae* (Htg.), in the absence of introduced parasites. Can. Entomol. 93: 228-238.

21. Bird, F. T. & D. E. Elgee. 1957. A virus disease and introduced parasites as factors controlling the European spruce sawfly, *Diprion hercyniae* (Htg.), in central New Brunswick. Can. Entomol. 89: 371-378.

22. Brooks, W. M. 1988. Entomogenous protozoa, pp. 1-150. In (C. M. Ignoffo, Ed.) *Handbook of Natural Pesticides. Vol. V. Microbial Pesticides. Part A. Entomogenous Protozoa and Fungi*. CRC Press, Boca Raton, FL.

23. Carner, G. R. 2004. Personal communication.

24. Carruthers, R. I. & J. A. Onsager. 1993. Perspective on the use of exotic natural enemies for biological control of pest grasshoppers (Orthoptera: Acrididae). Environ. Entomol. 22: 885-903.

25. Carruthers, R. I., M. E. Ramos, T. S. Larkin, D. L. Hostetter & R. S. Soper. 1996. The *Entomophaga grylli* (Fresenius) Batko species complex: Its biology, ecology, and use for biological control of pest grasshoppers. Mem. Entomol. Soc. Can. 171: 329-353.

26. Chapman, H. C., C. P. Pant, H. L. Mathis, M. J. Nelsen & B. Phantomachinda. 1972. Field release of the nematode *Reesimermis nielseni* for the control of *Culex p. fatigans* in Bangkok, Thailand. WHO/BC 72: 412.

27. Chen, P.-S. 1976. A study on *Reesimermis nielseni* for control of *Culex pipiens fatigens* in Taiwan. Bull. Inst. Zool., Acad. Sinica 15: 21-28.

28. Clausen, C. P. (Ed.). 1978. *Introduced Parasites and Predators of Arthropod Pests and Weeds: A World Review*. USDA, Agric. Handbook No. 480, 545 pp.

29. Cock, M. J. W. (Ed.). 1985. *A Review of Biological Control of Pests in the Commonwealth Caribbean and Bermuda up to 1982.* Commonw. Inst. Biol. Contr. Tech. Comm. 9.

30. Coulson, J. R. 1981. Nematoda: Mermithidae, pp. 370-372. In (C. C. Doane & M. L. McManus, Eds.) *The Gypsy Moth: Research Toward Integrated Pest Management*. USDA Tech. Bull. 1584.

31. Crawford, A. M., B. Zelazny & A. R. Alfiler. 1986. Genotypic variation in geographical isolates of *Oryctes* baculovirus. J. Gen. Virol. 67: 949-952.

32. de Crouzel, I. S. 1983. El control biológico en la Argentina. Symp. Contr. Biol. Contr. Integr. Plagas Latinoamerica. IX Claz Peru, Oct., pp. 169-174.

33. Cújar, A. & H. Alcaraz. 1973. La poliedrosis nuclear una enfermedad virosa del *Trichoplusia ni* (Hüber) como medida de control biologico en el algodonero. Fitotech. Latinoamer. 9: 28-35.

34. Cunningham, J. C. 1998. North America, pp. 313-331. In (Hunter-Fujita, P. F. Entwistle, H. F. Evans & N E. Crook, Eds.), *Insect Viruses and Pest Management*, Wiley, Chichester.

35. Cunningham, J. C. & P. F. Entwistle. 1981. Control of sawflies by baculovirus, pp. 379-407. In (H. D. Burges, Ed.) *Microbial Control of Pests and Plant Diseases 1970-1980*. Academic Press, London.

36. Delalibera Júnior, I., unpublished data.

37. Decker, G. 1960. Microbial insecticides---and their future. Agric. Chemicals 15(1): 30-33, 93.

38. De Ley, P. & M. Blaxter. 2002. A new system for Nematoda: Combining morphological characters with molecular trees, and translating clades into ranks and taxa. Nematology 4: 141-142.

39. Dowden, P. B. & H. B. Girth. 1953. Use of a virus disease to control European pine sawfly. J. Econ. Entomol. 46: 525-526.

40. Dupont, P. R. 1931. Entomological and mycological notes. Ann. Rep. Dept. Agric. Seychelles 1930, pp. 11-13. In: Rev. Appl. Entomol., Ser. A 19: 685.

41. Eilenberg, J., A. Hajek & C. Lomer. 2001. Suggestions for unifying the terminology in biological control. BioControl 46: 387-400.

42. Elkinton, J. S., A. E. Hajek, G. H. Boettner & E. E. Simons. 1991. Distribution and apparent spread of *Entomophaga maimaiga* (Zygomycetes: Entomophthorales) in gypsy moth (Lepidoptera: Lymantriidae) populations in North America. Environ. Entomol. 20: 1601-1605.

43. Evans, H. F. & P. F. Entwistle. 1982. Epizootiology of the nuclear polyhedrosis virus of European spruce sawfly with emphasis on persistence of virus outside the host, pp. 449-461. In (E. Kurstak, Ed.) *Microbial and Viral Pesticides*, Dekker, New York.

44. Fetter-Lasko, J. L. & R. K. Washino. 1977. A three year study of the ecology of *Lagenidium giganteum*, infections of *Culex tarsalis* in California. Proc. Pap. Calif. Mosq. Control Assoc. 45: 106.

45. Forbes, S. A. 1899. Recent work on the San Jose scale in Illinois. Univ. Ill. Agric. Exp. Stn. Bull. 56: 270-280.

46. Fuxa, J. R. 1987. Ecological considerations for the use of entomopathogens in IPM. Annu. Rev. Entomol. 32: 225-251.

47. Fuxa, J. R. & A. R. Richter. 1999. Classical biological control in an ephemeral crop habitat with *Anticarsia gemmatalis* nucleopolyhedrovirus. BioControl 44: 403-419.

48. Fuxa, J. R., A. R. Richter & P. J. McLeod. 1992. Virus kills soybean looper years after its introduction into Louisiana. La. Agric. 35: 20-24.

49. Galloway, T. D. 1975. Application of a mermithid nematode (*Reesimermis nielseni* Tsai and Grundmann) from Louisiana for mosquito control in Manitoba. Proc. Alberta Mosquito Abatement Symp., Univ. Alberta, pp. 191-205.

50. Galloway, T. D. & R. A. Brust. 1976. Field application of the mermithid nematode, *Romanomermis culicivorax* Ross and Smith, for the control of mosquitoes, *Aedes* spp., in spring in Manitoba. Manitoba Entomol. 10: 18-25.

51. Glaser, R. W. 1915. Wilt of gipsy-moth caterpillar. J. Agric. Res. 4:101-128.

52. Godfrey, K., D. Steinkraus & M. McGuire. 2001. Fungal pathogens of the cotton and green peach aphids in the San Joaquin Valley. Southwest. Entomol. 26: 297-302.

53. Gorick, B. D. 1980. Release and establishment of the baculovirus disease of *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae) in Papua New Guinea. Bull. Entomol. Res. 70: 445-453.

54. Greathead, D. J. 1971. *A Review of Biological Control in the Ethiopian Region*. Commonw. Inst. Biol. Contr. Tech. Commun. No. 5.

55. Greathead, D. J. & A. H. Greathead. 1992. Biological control of insect pests by insect parasitoids and predators: The BIOCAT database. Biocontrol News Info. 13: 61N-68N.

56. Gutierrez, J. 1981. Updating of data on economic entomology on Wallis and Futuna. ORSTOM (Noumea, New Caledonia): 24 pp.

57. Hajek, A. E., Unpublished data.

58. Hajek, A. E. 2004. *Natural Enemies: An Introduction to Biological Control*. Cambridge Univ. Press, Cambridge, UK.

59. Hajek, A. E., I. Delalibera Junior & M. L. McManus. 2000. Introduction of exotic pathogens and documentation of their establishment and impact, pp. 339-369. In (L. A. Lacey & H. K. Kaya, Eds.) *Field Manual of Techniques in Invertebrate Pathology*, Kluwer Acad. Publ., Dordrecht, Netherlands.

60. Hajek, A. E., R. A. Humber & J. S. Elkinton. 1995. Mysterious origin of *Entomophaga maimaiga* in North America. Amer. Entomol. 41: 31-42.

61. Hall, I. M. 1952. Observations on *Perezia pyraustae* Paillot, a microsporidian parasite of the European corn borer. J. Parasitol. 38: 48-52.

62. Hammes, C. & P. Monsarratt. 1974. Recherches sur *Oryctes rhinoceros* L. Cah. ORSTOM Biol. 22: 44-111.

63. Harper, J. 1978. Introduction and colonization of entomopathogens, pp.3-13. In (G. E. Allen, C. M. Ignoffo & R. P. Jaques, Eds.), *Microbial Control of Insect Pests: Future Strategies in Pest Management Systems*, NSF-USDA-Univ. Florida Workshop.

64. Haugen, D. A. & M. G. Underwood. 1990. *Sirex noctilio* control program in response to the 1987 Green Triangle outbreak. Austral. For. 53: 33-40.

65. Hodge, K. T., A. J. Sawyer & R. A. Humber. 1995. RAPD-PCR for identification of *Zoophthora radicans* isolates in biological control of potato leafhopper. J. Invertebr. Pathol. 65: 1-9.

66. Hountondji, F. C. C., C. J. Lomer, R. Hanna, A. J. Cherry & S. K. Dara. 2002. Field evaluation of Brazilian isolates of *Neozygites floridana* (Entomophthorales: Neozygitaceae) for the microbial control of cassava green mite in Benin, West Africa. Biocontr. Sci. Tech. 12: 361-370.

67. Iede, E. T., S. R. Chiarello & M. S. Pereira. 1998. Utilização do nematóde *Deladenus siricidicola* (Nematodea: Neotylenchidae) no controle biológico de *Sirex noctilio* (Hymenoptera: Siricidae), praga de *Pinus* spp. [Abstract] Primer Congres. Latinoamer. IUFRO, Valdívia, Chile.

68. Iede, E. T., S. Penteado & E. Schaitza. 1998. *Sirex* management in Brazil. Biocontrol News & Information 19(1): 4N. http://pest.cabweb.org/Journals/BNI/BNI19-1/genews.htm.

69. Illingworth, J. F. 1929. Preliminary notes on pests of agricultural crops of Kona, March 15, 1928. Proc. Haw. Ent. Soc. 7: 248-254.

70. Izhevskii, S. S. & A. D. Orlinskii. 1985. Biological suppression of citrus whitefly. Zash. Rast. 1985(4): 30-31. [English abstract in CAB Abstracts]

71. Jacob, T. K. 1996. Introduction and establishment of baculovirus for the control of rhinoceros beetle *Oryctes rhinoceros* (Coleoptera: Scarabaeidae) in the Andaman Islands. Bull. Entomol. Res. 86: 257-262.

72. Jeffords, M. R., J. V. Maddox, M. L. McManus, R. E. Webb & A. Wieber. 1988. Egg contamination as a method for the inoculative release of exotic Microsporidia of the gypsy moth. J. Invertebr. Pathol. 51: 190-196.

73. Jeffords, M. R., J. V. Maddox, M. L. McManus, R. E. Webb & A. Wieber. 1989. Evaluation of the overwintering success of two European microsporidia inoculatively released into gypsy moth populations in Maryland. J. Invertebr. Pathol. 53: 235-240.

74. Julien, M.H. & M.W. Griffiths (Eds.) 1998. *Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds, 4th ed*. CABI Publ., Wallingford, Oxon, UK.

75. Keeling, P. J. 2003. Congruent evidence from α-tubulin and β-tubulin gene phylogenies for a zygomycete origin of microsporidia. Fungal Gen. Biol. 38: 298-309.

76. Klasmer, P., E. N. Botto, J. C. Corley, J. M. Villacide & V. Fernandez Arhex. 2000. Advances in *Sirex noctilio* biological control in Patagonian region of Argentina. Ser.Tecnica IPEF 13:21-30.

77. Klasmer, P., E. N. Botto, J. C. Corley & J. M. Villacide. 2004. Evaluación del nematodo *Deladenus siricidicola* Bedding (Nematoda: Neotylenchidae) como potencial agente para el control de *Sirex noctilio* F. (Hymenoptera: Siricidae) en la Patagonia Argentina. Inv. For. Serv. Prod. II. Secr. Agric. Ganad. Pesc. Aliment., Proy. For. Desarrollo, Buenos Aires. pp. 70-73.

78. Knowles, C. H. 1919. Division of Entomology, Fiji Dept. Agric. Ann. Rpt. 1918, pp. 12-15. In: Rev. Appl. Entomol., Ser. A 8: 297-298.

79. Koebele, A. 1897. Report of the entomologist of the Hawaiian government. Planters' Monthly 16: 67-85.

80. Kotinsky, J. 1906. Report of the assistant entomologist. Haw. Board Comm. Agr. & For. Ann. Rpt. (1905), pp. 113-144.

81. Kotinsky, J. 1909. Report of superintendent of entomology for June, 1909. Haw. Forester & Agr. 6: 337-339.

82. Laird, M. 1971. Microbial control of arthropods of medical importance, pp. 387-406. In (H. D. Burges & N. W. Hussey, Eds.), *Microbial Control of Insects and Mites*. Academic Press, London.

83. Laird, M., J. Urdang & I. Tinielu. 1982. Establishment and long-term survival of *Romanomermis culicivorax* in mosquito habitats, Tokelau Islands. Mosq. News 42: 86-92.

84. Lange, C. E. & M. L. de Wysiecki. 1996. The fate of *Nosema locustae* (Microsporidia: Nosematidae) in Argentine grasshoppers (Orthoptera: Acrididae). Biol. Contr. 7: 24-29.

85. Latteur, G. & J. Godefroid. 1982. Trial of field treatments against cereal aphids with mycelium of *Erynia neoaphidis* (Entomophthorales) produced *in vitro*, pp. 2-10. In (R. Cavalloro & A. A. Balkema, Eds.), *Aphid Antagonists*. Rotterdam, NL.

86. Lomer, C. J. 1985. Ecology of *Oryctes monoceros* in the Seychelles. Antenna 9: 28-29.

87. Lomer, C. J. 1986. Release of *Baculovirus oryctes* into *Oryctes monoceros* populations in the Seychelles. J. Invertebr. Pathol. 47: 237-246.

88. Magnoler, A. 1974. Field dissemination of a nucleopolyhedrosis virus against the gypsy moth, *Lymantria dispar* L. Z. Pflkrankh. 9: 497-511.

89. Marschall, K. J. 1970. Introduction of a new virus disease of the coconut rhinoceros beetle in Western Samoa. Nature 225: 288-289.

90. Marschall, K.J. & I. Ioane. 1981. The effect of re-release of *Oryctes rhinoceros* Baculovirus in the biological control of rhinoceros beetles in Western Samoa. J. Invertebr. Pathol. 39: 267-276.

91. McCray Jr., E. M., D. J. Womeldorf, R. C. Husbands & D. A. Eliason. 1973. Laboratory observations and field tests with *Lagenidium* against California mosquitoes. Proc. Pap. Calif. Mosq. Control Assoc. 41: 123-128.

92. McGugan, B. M. & H. C. Coppel. 1962. A review of the biological control attempts against insects and weeds in Canada. II. Biological control of forest insects, 1910-1958. Commonw. Inst. Biol. Contr. Tech. Comm. 2: 35-216.

93. McGuire, M. R., J. V. Maddox & E. J. Armbrust. 1987. An epizootic caused by *Erynia radicans* (Zygomycetes: Entomophthoraceae) isolated from *Empoasca fabae* (Homoptera: Cicadellidae). J. Invertebr. Pathol. 50: 78-80.

94. McManus, M. L. 2004. Personal communication.

95. Milner, R. J. 2003. Personal communication.

96. Milner. R. J. 1985. Field tests of a strain of *Entomophaga grylli* from the USA for biocontrol of the Australian wingless grasshopper, *Phaulacridium vittatum*, pp. 255-261. Proc. 4th Australasian Conf. Grassl. Invert. Ecol., (R. B. Chapman, Ed.), Lincoln Coll., Canterbury, Caxton Press.

97. Milner, R. J. 1986. Pathogen importation for biological control: Risks and benefits, pp. 115-121. In (A. J. Gibbs & H. R. C. Meischke, Eds.), *Pests and Parasites as Migrants*, Cambridge Univ. Press, Cambridge, UK.

98. Milner, R. J. & R. S. Soper. 1981. Bioassay of *Entomophthora* against the spotted alfalfa aphid *Therioaphis trifolii* f. *maculata*. J. Invertebr. Pathol. 37: 168-173.

99. Milner, R. J., R. S. Soper & G. G. Lutton. 1982. Field release of an Israeli strain of the fungus *Zoophthora radicans* (Brefeld) Batko for biological control of *Therioaphis trifolii* (Monell) f. *maculata*. J. Aust. Ent. Soc. 21: 113-118.

100. Mitchell, C. J., P. S. Chen & H. C. Chapman. 1974. Exploratory trials utilizing a mermithid nematode as a control agent for *Culex* mosquito in Taiwan. J. Formosan Med. Assoc. 73: 241-254.

101. Mohan, K. S. & G. B. Pillai. 1993. Biological control of *Oryctes rhinoceros* (L.) using an Indian isolate of *Oryctes* baculovirus. Insect Sci. Applic. 14: 551-558.

102. Monty, J. 1978. The coconut palm rhinoceros beetle, *Oryctes rhinoceros* (L.) (Col., Dynastidae), in Mauritius and its control. Rev. Agric. Sucr. Ile Maurice 57: 60-76.

103. Moutia, L. A. 1933. Campaign against *Phytalis smithi* Arrow. Rep. Dep. Agric. Mauritius, 1932, pp. 43-51.

104. Moutia, L. A. 1934. Campaign against *Phytalis smithi* Arrow. Rep. Dep. Agric. Mauritius, 1933, pp. 25-29.

105. Moutia, L. A. & R. Mamet. 1946. A review of twenty-five years of economic entomology in the island of Mauritius. Bull. Entomol. Res. 36: 439-472.

106. Nickle, W. R. 1979. Probable establishment and overwintering of a mermithid nematode parasite of mosquitoes in Maryland. Proc. Helminth. Soc. Wash. 46: 21-27.

107. Nielsen, C., M. G. Milgroom & A. E. Hajek. 2005. Genetic diversity in the gypsy moth fungal pathogen *Entomophaga maimaiga* from founder populations in North America and source populations in Asia. Mycol. Res. (in press).

108. Oddsdottir, E., C. Nielsen, T. Levisson, S. Harding, G. Haldorddon & J. Eilenberg. 2005. Personal communication.

109. Ogilvie, L. 1926. Report of the plant pathologist for the year 1925. Rept. Dept. Agric. 1925, pp. 36-63. In: Rev. Appl. Entomol., Ser. A 14: 624-626.

110. Ogilvie, L. 1928. Notes on the growing of citrus in Bermuda. Agric. Bull. Bermuda Dept. Agric. VI (11), pp. 3-5, (12) 4-5; VII (2), pp. 3-6, (3), pp. 4-6. In: Rev. Appl. Entomol., Ser. A 16: 445-446.

111. Ogilvie, L. 1928. Report of the plant pathologist for the year 1926. Rept. Dept. Agric. Bermuda 1926, pp. 35-41. In: Rev. Appl. Entomol., Ser. A 16: 17-18.

112. Oi, D. H. & D.F. Williams. 2002. Impact of *Thelohania solenopsae* (Microsporidia: Thelohaniidae) on polygyne colonies of red imported fire ants (Hymenoptera: Formicidae). J. Econ. Entomol. 95: 558-562.

113. Parkman, J. P. & Smart, Jr., G. C. 1996. Entomopathogenic nematodes, a case study: Introduction of *Steinernema scapterisci* in Florida. Biocontr. Sci. Technol. 6: 413-419.

114. Perkins, R. C. L. 1906. Leaf hoppers and their natural enemies (introduction). Haw. Sugar Planters' Assoc. Ent. Series Bul. No. 1, 32 pp.

115. Petersen, J. J. 1985. Nematodes as biological control agents: Part I. Mermithidae. Adv. Parasitol. 24: 307-346.

116. Petersen, J. J., H. C. Chapman, O. R. Willis & T. Fukuda. 1978. Release of *Romanomermis culicivorax* for the control of *Anopheles albimanus* in El Salvador. II. Application of the nematode. Amer. J. Trop. Med. Hyg. 27: 1268-1273.

117. Pilarska, D. 2004. Personal communication.

118. Pilarska, D., M. McManus, A. E. Hajek, F. Hérard, F. E. Vega, P. Pilarska & G. Markova. 2000. Introduction of the entomopathogenic fungus *Entomophaga maimaiga* Hum., Shim. & Sop. (Zygomycetes: Entomophthorales) to a *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae) population in Bulgaria. Anz. Schadlingsk. 73: 125-126.

119. Poinar, Jr., G. O. 1979. *Nematodes for Biological Control of Insects.* CRC Press, Boca Raton, FL.

120. Ponomarenko, N. G., H. A. Prilepskaya, M. Ya. Murvanidze & L. A. Stolyarova. 1975. *Aschersonia* against whiteflies. Zashchita Rastenii 1975(5): 44-45. [English abstract in CAB Abstracts]

121. Porcile Maderni, J. F. 1998. *Sirex noctilio* F.: Present status in Uruguay, pp. 81-82. In (E. T. Iede, E. Schaitza, S. Penteado, R. C. Reardon & S. T. Murphy, Eds.), Proceedings of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA, Forest Service FHTET-98-13.

122. Protsenko, E. P. 1967. The importance of the fungus *Aschersonia* in nature and its practical use by main in the biological control of insects. Sb. Karantinu Rast. 19: 147-215. In: McCoy, C.W., R. A. Samson & D. G. Boucias. 1988. Entomogenous fungi, pp. 151-236. In (C. M. Ignoffo, Ed.) *Handbook of Natural Pesticides. Vol. V. Microbial Pesticides. Part A. Entomogenous Protozoa and Fungi*. CRC Press, Boca Raton, FL.

123. Purrini, K. 1989. *Baculovirus oryctes* release into *Oryctes monoceros* population in Tanzania, with special reference to the interaction of virus isolates used in our laboratory infection experiments. J. Invertebr. Pathol. 53: 285-300.

124. Ramos, M. E. 2004. Personal communication.

125. Rao, V. P., M. A. Ghani, T. Sankaran & K. C. Mathur. 1971. *A Review of the Biological Control of Insects and Other Pests in South-East Asia and the Pacific Region*. Commonw. Inst. Biol. Contr. Tech. Comm. No. 6.

126. Rivers, C. F. 1962. The use of a polyhedral virus disease in the control of the pine sawfly *Neodiprion sertifer* Geoffr. in north-west Scotland. Entomophaga Mém. hor. Sér. 2: 477-480.

127. Rojas, W., J. Northrup, O. Gallo, A. E. Montoya, F. Montoya, M. Restrepo, G. Nimnich, M. Arango & M. Echavarria. 1987. Reduction of malaria prevalence after introduction of *Romanomermis culicivorax* (Mermithidae: Nematoda) in larval *Anopheles* habitats in Colombia. Bull. WHO 65: 331-337.

128. Schaitza, E. 2004. Personal communication.

129. Schreiner, I. 1989. Biological control introductions in the Caroline and Marshall Islands. Proc. Haw. Ent. Soc. 29: 57-69.

130. Schuder, D. L. 1956. A specific virus disease for control of the European pine sawfly, *Neodiprion sertifer* (Geoff.). Proc. Ind. Acad. Sci. 66: 101-102.

131. Seguni, Z., B. Lohr & W. Mwaiko. 1999. Introducing *Baculovirus oryctes* Huger into *Oryctes monoceros* Oliv. populations in Tanzania. J. Appl. Ent. 123-427-431.

132. Shands, W. A., C. G. Thompson, G. W. Simpson & H. E. Wave. 1958. Preliminary studies of entomopathogenous fungi for the control of potato-infesting aphids in Maine. J. Econ. Entomol. 51: 184-186.

133. Shands, W. A., G. W. Simpson & I. M. Hall. 1963. Importance of entomogenous fungi in controlling aphids on potatoes in northeastern Maine. Maine Agric. Exp. Stn. Tech. Bull. 6: 1-42.

134. Smith, J. B. 1898. The San Jose or pernicious scale. New Jersey Exp. Sta. Rpt. 19: 443-446.

135. Smith, J. B. 1903. Report of the Entomologist. New Jersey Exp. Sta. Rpt. 24: 555-569.

136. Sosa Gomez, D. R. 1987. Control microbiano de *Phyllocoptruta oleivora* (Ashm). y *Eriophyes sheldoni* Ewing mediante pulverizaciones de conídios de tres variedades de *Hirsutella thompsonii* Fisher. XI Congr. Bras. Entomol. Res. 1: 167.

137. Sosa Gomez, D. R. & F. Moscardi. 1991. Microbial control and insect pathology in Argentina. Ciencia e Cultura 43(5): 375-379.

138. Speare, A. T. & R. H. Colley. 1912. *The Artificial Use of the Brown-tail Fungus in Massachusetts, with Practical Suggestions for Private Experiment, and a Brief Note on a Fungous Disease of the Gypsy Caterpillar*. Wright & Potter, Boston.

139. Squibbs, F. L. 1935. Work connected with insect pests and fungus diseases. Rep. Dep. Agric. Seychelles 1933, pg. 5, Victoria, Seychelles, 1934. In: Rev. Appl. Entomol., Ser A 23: 241.

140. Stapley, J.H. 1980. Annual report of the entomologist for 1979. Rept., Ministry Agric. & Lands, Solomon Islands. 30 pp.

141. Steinhaus, E. A. 1951. Report on diagnoses of diseased insects 1944-50. Hilgardia 20: 629-678.

142. Steinkraus, D. C., G. O. Boys & J. A. Rosenheim. 2002. Classical biological control of *Aphis gossypii* (Homoptera: Aphididae) with *Neozygites fresenii* (Entomophthorales: Neozygitaceae) in California cotton. Biol. Contr. 25: 297-304.

143. Stern, V. & B. Federici. 1990. Granulosis virus: Biological control of western grapeleaf skeletonizer. Calif. Agric. 44: 21-22.

144. Stern, V. & B. Federici 1990. Biological control of western grapeleaf skeletonizer, *Harrisina brillians* Barnes and McDunnough (Lepidoptera: Zygaenidae), with a granulosis virus in California, pp. 167-176. In (N. J. Bostanian, L. T. Wilson & T. J. Dennehy, Eds.) *Monitoring and Integrated Management of Arthropod Pests of Small Fruit Crops*. Intercept, Andover, Hampshire, UK.

145. Swan, D. I. 1974. A review of the work on predators, parasites and pathogens for the control of *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae) in the Pacific area. Commonw. Inst. Biol. Contrl. Misc. Publ. 7. Commonw. Agric. Bur., Farnham, Slough, UK. 64 pp.

146. Tanada, Y. 1957. An annotated list of infectious diseases of insects in Hawaii. Proc. 8th Pac. Sci. Congr., Vol. 3A. Oceanogr. Zool. National Res. Council, Manila, Phil.

147. Tanada, Y. & H. Kaya. 1993. *Insect Pathology*. Academic Press, San Diego.

148. Teakle, R. E. 1998. Australasia, pp. 303-312. In (F. R. Hunter-Fujita, P. F. Entwistle, H. F. Evans & N E. Crook, Eds.), *Insect Viruses and Pest Management*, Wiley, Chichester.

149. Theunis, W. & N. Teuriara. 1998. Biological control of *Papuana huebneri* (Coleoptera, Scarabaeidae) in Kiribati: field trials with *Metarhizium anisopliae* and *Bacillus popilliae*. J. So. Pac. Agric. 15: 46-51.

150. Tribe, G. 1998. Biological control of *Sirex noctilio* in South Africa, p. 91. In (E. T. Iede, E. Schaitza, S. Penteado, R. C. Reardon & S. T. Murphy, Eds.), Proceedings of a Conference: Training in the Control of *Sirex noctilio* by the Use of Natural Enemies. USDA, Forest Service FHTET-98-13.

151. Tribe, B. 1998. *Sirex* spreads in South Africa. Biocontrol News & Information 19(1). http://pest.cabweb.org/Journals/BNI/BNI19-1/genews.htm.

152. Washino, R. K., J. L. Fetter, C. K. Fukushima & K. Gonot. 1976. The establishment of *Lagenidium giganteum*, an aquatic fungal parasite of mosquitoes, three years after field introduction. Proc. Pap. Calif. Mosq. Control Assoc. 44: 52.

153. Williams, D. F., G. J. Knue & J. J. Becnel. 1998. Discovery of *Thelohania solenopsae* from the red imported fire ant, *Solenopsis invicta*, in the United States. J. Invertebr. Pathol. 71: 175-176.

154. Wilson, C. E. 1921. Report of the entomologist. Rept., Virgin Isl. Agric. Expt. Stn. 1920, pp. 20-35. In: Rev. Appl. Entomol., Ser. A 9: 429-431.

155. Wilson, F. 1960. *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea*. Commonw. Inst. Biol. Contr. Tech. Comm. No. 1.

156. Woese, C. R., O. Kandler & M. L. Wheelis. 1990. Towards a natural system of organisms: Proposal for the domains Archaea, Bacteria, and Eucarya. Proc. Natl. Acad. Sci. USA 87: 4576-4579.

157. Woodbridge, S. M. 1906. Diseases of scale insects. Bull. So. Calif. Acad. Sci. 5: 29-31.

158. Yasukawa, S. 1925. Experiments with the fungus *Metarrhizium anisopliae* Motsch., parasitic upon insects injurious to the sugar-cane. Dept. Agric., Formosa Govt. Res. Inst. 11, 81 pp. In: Rev. Appl. Entomol., Ser. A 13: 361.

159. Yen, D. F. 1977. Microbial control of insect pests in Taiwan. N.T.U. Phytopath. Entomol. 5: 1-14.

160. Young, E. C. 1974. The epizootiology of two pathogens of the coconut palm rhinoceros beetle. J. Invertebr. Pathol. 24: 82-92.

161. Young, E. C. & J. F. Longworth. 1981. The epizootiology of the baculovirus of the coconut palm rhinoceros beetle (*Oryctes rhinoceros*) in Tonga. J. Invertebr. Pathol. 38: 362-369.

162. Zaim, M., H. Ladonni, M. R. Y. Ershadi, A. V. Manouchehri, Z. Sahabi, M. Nazari & H. Shahmohammadi. 1988. Field application of *Romanomermis culicivorax* (Mermithidae: Nematoda) to control anopheline larvae in southern Iran. J. Am. Mosq. Contr. Assn. 4: 351-355.

163. Zelazny, B. 1973. Studies on *Rhabdionvirus oryctes*. III. Incidence in the *Oryctes rhinoceeros* population in Western Samoa. J. Invertebr. Pathol. 22: 359-363.

164. Zelazny, B. A. 1977. *Oryctes rhinoceros* populations and behavior influenced by a baculovirus. J. Invertebr. Pathol. 29: 210-215.

165. Zelazny, B., A. Lolong & A. M. Crawford. 1990. Introduction and field comparison of baculovirus strains against *Oryctes rhinoceros* (Coleoptera: Scarabaeidae) in the Maldives. Environ. Entomol. 19: 1115-1121.

166. Zethner, O. 2004. Personal communication.

167. Zethner, O. 1976. Control experiments on the nun moth (*Lymantria monacha* L.) by nuclear-polyhedrosis virus in Danish coniferous forests. Z. Angew. Entomol. 81: 192-207.

168. Zethner. O. 1980. Control of *Agrotis segetum* (Lep.: Noctuidae) in root crops by granulosis virus. Entomophaga 25: 27-35.

169. Zondag, R. 1969. A nematode infection of *Sirex noctilio* (F.) in New Zealand. New Zealand J. Sci. 12: 732-747.

170. Zondag, R. 1979. Control of *Sirex noctilio* F. with *Deladenus siricidicola* Bedding. Part II. Introductions and establishments in the South Island 1968-1975. New Zealand J. For. Sci. 9: 68-76.

171. Øgaard, L., C. F. Williams, C. C. Payne & O. Zethner. 1988. Activity persistence of granulosis viruses (Baculoviridae) in soils in United Kingdom and Denmark. Entomophaga 33: 73-80.

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