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Review of the Successful Classical Biological Control Programs in Sultanate of Oman

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ABSTRACT

The history of the classical biological control against insect pests in Oman is not yet properly documented. During the last 23 years there were many successful classical biological control programs conducted in Oman. These programs were designed and applied against many serious insect pests in both, outdoor crops, fruit trees (Omani lime, coconut, guava, caster apple, avocado and pomegranate) and greenhouse crops (cucumber, tomato, sweet pepper and lettuce). This paper is reviewing the successful classical biological control programs which were implemented in Oman during the period from 1984 to 2007. The first project was conducted in 1984 by releasing the parasitic wasp, *Encarsia opulenta* Silvestri, against the Citrus Black Fly, *Aleurocanthus wogluni* Ashby. In 1985, the second successful biological control project was applied using the coccinellid predatory beetle, *Chilocorus nigritus* (Fabricius), to control the coconut scale insect, *Aspidiotus destructor* Sign. In 1989, very important project was successfully applied to control the coconut rhinoceros beetle, *Oryctes rhinoceros* L., by using the specific virus, *Rhabdionvirus oryctes* Hüger. In 1994, the mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant, was used successfully to control the citrus mealybug, *Planococcus citri* (Risso), and the Pink Hibiscus Mealybug, *Maconellicoccus hirsutus* (Green). In 2002, three natural enemies were imported and released to control the two common aphids' species in Jabal Akhdar, the pomegranate aphid, *Aphis punicae* (Passerini), on pomegranate and the melon aphid, *Aphis gossypii* (Glover), on different fruit trees such as: pomegranate, apple and pear. These three natural enemies were the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville (about 200 thousands beetles were released), the parasitic wasp, *Aphidius colemanii* Viereck (about 5 thousands adults were released) and the multicolored Asian lady beetle, *Harmonia axyridis* Pallas (about 37,500 thousands beetles were released). From 2003, biological control of the pomegranate butterfly, *Virachola livia* Klug, which is the most destructive insect pest attacking pomegranate in Jabal Akhdar was successfully achieved by seasonally releases of the egg parasitic wasps, *Trichogramma* spp. On the other hand, from 1994 till 2007, a number of the common greenhouse pests such as: thrips, whiteflies, mites and leaf-miners were successfully controlled in Royal Gardens and Farms in Oman, by using different bio-agents, *i.e.*, the predatory mites, *Amblyseius cucumeris*, *A. swirskii* and *Phytoseiulus persimilus*, the predatory bugs, *Orius laevigatus* and *Macrolophus caliginosus* and mixture of the parasitic wasps, *Dacnusa sibirica* and *Diglyphus isaea*.

Key Words: Classical biological control, *Aleurocanthus wogluni*, *Aspidiotus destructor*, *Oryctes rhinoceros*, *Virachola livia*, Greenhouse pests.

INTRODUCTION

Historically, classical biological control was known and applied long time ago. More than 200 years ago, it is recorded that the farmers in Yemen accustomed to brought colonies of predaceous ants from the mountains and placed them on the date palm trees for control of another ant species which attacking date palms. Although, there were several trials that have been made to introduce natural enemies of insect pests from one country to another, the real beginning of the successful classical biological control was recorded in USA when the Vedalia beetle, *Rodolia cardinalis*, was imported from Australia in 1888 and released into California to control the cottony-cushion scale, *Icerya purchasi* Mask. Immediately after the great success of this effort and the good results obtained, there were many efforts allover the world in this matter.

It has long been known that, classical biological control consider to be one of the most important method to use against insect pests which invaded new area, because when an insect pest of foreign origin established in a new area, through trade channels or by other accidental means, the natural enemies that attack it in the country of origin are usually left behind.

After the 70's of last century, Oman imported many plants from different countries. Accordingly, many adventives agricultural pests were accidentally introduced and established in Oman without their natural enemies. From the 80's, many projects and trials were conducted by the entomologists to introduce foreign natural enemies into Oman to control these pests. Many of these classical biological control programs succeeded in Oman.

Here we review the history of the successful classical biological control programs in Oman, which conducted from 1984 till 2007.

Biological control of citrus blackfly

The citrus blackfly (CBF), *Aleurocanthus wogluni* Ashby (Homoptera: Aleyrodidae), is a citrus feeding whitefly of Asian region (Ashby, 1915; Dietz and Zetek, 1920). The CBF was found in Pakistan, Malaysia, Indonesia, Philippines, Taiwan, China, Korea (Clausen and Berry, 1932). It was first found in the new world in Jamaica in 1913 and was discovered in Florida in 1934 (Weems, 1962). In Oman, during 70's and 80's CBF was spread allover the country and considered to be the most destructive insect pest attacking citrus trees. Considering the widespread success of biological control of CBF by using the parasitic wasps (Smith *et. al.*, 1964; Bedford and Thomas, 1965; Quezada, 1976; Hart *et. al.*, 1978; Ketner and Rosier, 1978; Dowell *et. al.*, 1979 and Summy *et. al.*, 1983), it was suggested to introduce parasitoids of CBF as a part of integrated control program of CBF and that included an eradication attempt (Kinawy and Hussein, 1987). This was the first project to introduce foreign natural enemies into Oman to use in classical biological control program.

In January 1984, the parasitic wasp, *Encarsia opulenta* Silvestri, (Hymenoptera: Aphelinidae), was imported from USA (Florida) and released in the southern region of Oman against (CBF). Kinawy and Hussien (1987), mentioned that total of about 350 adults of *E. opulenta* were released in a heavy infested citrus orchard with CBF. This parasitic wasp recovered very quickly (two months after release) and a sharp increase in the rate of parasitism was observed during 1984. Data in Table (1) shows the percentage of parasitism with *E. opulenta* on CBF in the release site (El-Karad region) during three successive years (1984-1986). Mean % of parasitism was dramatically increased. It reached 53.6, 90.7 and 96.8 % during 1984, 1985 and 1986, respectively. Also, it was clear that the parasitic wasp, *E. opulenta* was well established in the southern region of Oman and spread very quickly to all regions in Dhofar province. Table (2).

The previous results clarify that the parasitic wasp, *E. opulenta*, which released against CBF is quickly established in south Oman and provide an excellent control to that serious pest. During the last ten years, it is very rare to observe any infestation with the CBF in south Oman.

Biological control of coconut scale insect

In the southern region of Oman (Dhofar province) the coconut scale insect, *Aspidiotus destructor* Sign. (Homoptera: Diaspididae), is one of the most serious pests attacking coconut trees. Considering the widespread success of biological control of the coconut scale insect through the use of different predators and parasites (Taylor and Paine, 1935; Moutia and Mamet, 1946; Reyne, 1948; Simmonds, 1960; Lever, 1964 and Cochereau, 1965), the introduction of the major common coccinellid beetle, *Chilocorus nigritus* (Fabricius), was suggested and a study of the visibility of biological control of the coconut scale insect *A. destructor* in south Oman was planned.

Table (1): Percent of parasitism of the parasitic wasp, *Encarsia opulenta* Silvestri, released against CBF, in Oman during three successive years (1984-1986).

Date of inspection		No. of examined pupae	No. of alive pupae	No. of parasitized pupae	% parasitism (months after release)	Mean
1984	March	250	138	112	44.8 % (2 months)	53.6 %
	August	185	64	121	65.4 (7 months)	
1985	March	135	16	119	88.1 (14 months)	90.7 %
	August	90	5	85	94.4 (19 months)	
1986	March	73	3	70	95.9 (26 months)	96.8 %
	August	22	0	22	100 (31 months)	

(Source: Kinawy and Hussein, 1987)

Table (2): Percent of parasitism of the parasitic wasp, *Encarsia opulenta* Silvestri, released against CBF in different regions in south Oman during, 1986.

Region	Distance from release site (in Km)	% of parasitism (31 months after release)
El-Karad	Zero	96
El-Hafa	1	92
Salalah	2	85
El-Wadi	5	88
Aukad	10	82

(Source: Kinawy and Hussein, 1987)

Kinawy (1991), mentioned that total releases of only 683 adults of the coccinellid beetle, *C. nigritus* during 1985, controlled successfully the coconut scale insect *A. destructor* over the Dhofar plain in the southern region of Oman in only 24 months after the last release. The coccinellid beetle *C. nigritus* was introduced from India, through the Commonwealth Institute of Biological Control (Indian Station, Bangalore, India), and was released in the Royal Razat farm, Table (3). Data in Table (4) illustrate the rather rapid decline in the population of the coconut scale insect *A. destructor* in six locations in south Oman, following the release of the coccinellid predator, *C. nigritus*. Also, data in Table (5) clarify the rapid build-up of the coccinellid predator *C. nigritus* after 6 and 12 months from the last release, while it relatively decreased after 18 and 24 months in the release site (El-Dhareez) and up to 12 km distance. These results were logical because the host of the predator, *i.e. A. destructor* had also decreased to the minimum numbers after 18 and 24 months from the last release. It was also observed that, in Taqa, which far about 16 km from the release site with a desert barrier of 12 km from the cultivated area, no stages of the coccinellid predator *C. nigritus* were recorded after 6 and 12 months from the last release, while it was recorded later due to the transfer of the coconut seedlings from the release site to Taqa location. Generally, the danger of the coconut scale insect, *A. destructor* was greatly reduced in the southern region of Oman after releasing the coccinellid beetle, *C. nigritus*. Also, since 1987 pesticides against the coconut scale insect have no longer needed in the southern region of Oman.

Table (3): Number of adults of the coccinellid beetle, *Chilocorus nigritus* (Fabricius), released in the southern region of Oman (Dhofar province) during 1985

Date	Number of adults released
27th of January	240
3rd of March	276
10th of April	167
Total	683

(Source: Kinawy, 1991)

Table (4): Population of the coconut scale insect, *Aspidiotus destructor* Sign., following release of the predator coccinellid beetle, *Chilocorus nigritus* (Fabricius) in the southern region of Oman (Dhofar Province)

Location	Median† number of the coconut scale insect per square inch of frond				
	Before predator was released	After predator was released			
		6 months	12 months	18 months	24 months
El-Dhareez	245	121	98	23	7
El-Karad	253	128	65	12	Nil
El-Hafa	285	157	76	42	15
Salalah	179	145	85	31	18
Aukad & El-Wadi	204	160	123	96	25
Taqa	195	185	150	103	50

† Median of 30 reading (10 palms x 3 fronds per palm). (Source: Kinawy, 1991)

Table (5): Population of *Chilocorus nigritus* (Fabricius) after release against the coconut scale insect, *Aspidiotus destructor* Sign., in the southern region of Oman (Dhofar Province).

Location	Distance from release site (in km)	Median† number of *Chilocorus nigritus*‡ / tree			
		After predator was released			
		6 months	12 months	18 months	24 months
El-Dhareez	0	145	175	88	19
El-Karad	2	148	157	94	11
El-Hafa	5	115	150	79	32
Salalah	8	53	160	80	44
Aukad & El-Wadi	12	38	132	65	18
Taqa	16	Nil	Nil	51	74

† Median of 10 trees. (Source: Kinawy, 1991)

‡ 20-minutes observation time, for larvae and adults combined.

Biological control of Coconut rhinoceros beetle

The notorious rhinoceros beetle, *Oryctes rhinoceros* L. (Coleoptera: Scarabaeidae), is the most destructive insect pest attacking coconut palms (*Cocus mucifera* L.) allover the costal region of Dhofar province in the southern region of Oman. The adult beetles fly to the central crown of the palm, crawl down the axle of the young frond and bore through the heart of the palm into the unopened fronds. Later when unfold, it shows tattering and V-shaped cutting of the leaflets. Damage of the coconut rhinoceros beetle is often severe, and a single attack may be sufficient to kill or seriously affect the vigor of the tree. On the other hand, the larvae feed in rotting vegetable material such as dead coconut palms, manure heaps, compost pits and sawdust piles. In Oman, the infestation of the rhinoceros beetle, *O. rhinoceros*, was increased from 30 % in 1983 to 68 % in 1986. This situation could be attributed to the increase and widespread of the breading sites along Dhofar province, Kinawy (1987). The chemical and mechanical control measures did not give sufficient control against the rhinoceros beetle. In addition, the previous strategy was difficult to apply with the tall coconut palms (more than 8 meter tall), which are common in Dhofar plain, and also was expensive.

Successful biological control of *O. rhinoceros* is attributed largely to the dissemination of the *Rhabdionvirus oryctes* Hüger (baculovirus). The simplest, most economical and direct method of virus dissemination was to release virus-infected beetles. This virus was used successfully as a microbial control agent against *O. rhinoceros* in many countries. It was released into Western Samoa (Marshal, 1970 and Hüger, 1973), Wallis Island (Hammes, 1971), Tonga (Young, 1974), Fiji Island (Bedford, 1976), Philippines (Zelazny, 1977), Mauritius (Monty, 1974) and Papua New Guinea (Gorick, 1980). The safety of using this virus was tested in France in 1975 using purified virus as mentioned by FAO (1987).

During 1989, a total of 900 adult-inoculated beetles were released at six sites allover Dhofar plain. Two months after release, the incidence and spread of the virus to local population of *O. rhinoceros* using the rapid smear technique was confirmed (Kinawy 2004). Data in Table (6) clarify that out of 123 beetles collected from the local population there were 50 beetles infected with the *R. oryctes* virus, *i.e.* 40.7 % of the local population became infected with that virus.

Kinawy (2004) studied the changes in beetle damage that occurred at the six locations at Dhofar province for a period extended for six successive years following virus release, Table (7). After 16 months from virus introduction, (December, 1990), dramatic reduction in beetle's damage occurred in all locations of Dhofar plain. Two years after virus introduction, (August, 1991), marked reduction in rhinoceros beetle damage to coconut palms was recorded, since percent of fronds damage ranged from 24 to 37%, and palm damage ranged from 19 to 43%. Three years after virus introduction, (August, 1992), the damage of *O. rhinoceros* beetle's damage was highly reduced dramatically to about half of the percentage of the previous year. Then, in the forth, fifth and sixth years after virus introduction, the percentage of beetles damage were very low. The really lowest percent levels of *O. rhinoceros* beetle's damage was recorded in the fifth and the sixth years after virus introduction, (during 1994 and 1995), Table (8). Up to 2006, the coconut rhinoceros beetle was still under control in Dhofar province due to the spread of the *R. oryctes* virus, but more study must be done to insure that the virus is still active in the larval breeding sites in all locations.

Biological control of Mealybug

Many species of mealybug are attacking fruit trees in the southern region of Oman (Dhofar). The Citrus Mealybug, *Planococcus citri* (Risso), is a cosmopolitan species that attacks a wide range of crops in Dhofar, such as: guava, custard apple, grapes, and citrus. Also, the Egyptian or Breadfruit Mealybug, *Icerya aegyptiaca* (Douglas) and the Hibiscus Mealybug, *Maconellicoccus hirsutus* (Green) are very common mealybug species in Dhofar and causing serious damage to many fruit trees and ornamental plants.

The mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant, (Coleoptera: Coccinellidae), was imported into more than 40 countries, where it preys on at least 17 species of mealybug (Leeper, 1976, Bartlett, 1978 and Booth & Pope, 1986). As known, the predator was imported into the United States in 1891 from Australia by one of the early biological control pioneers, Albert Koebele, to control citrus mealybug in California. In a few countries, it failed to become established permanently, mainly because the winters were too cold. Due to the optimum weather conditions in the southern region of Oman, it was suggested to introduce the predator for release in Dhofar province.

A total of 14,000 adult beetles of *C. montrouzieri* Mulsant, were released during 1994 and 1997 in Razat farm in El-Dhareez district, in Dhofar, Table (9). The mealybug destroyer was established in the area and controlled the previous mentioned mealybug species. It was observed that the predator was not only

Table (6): Numbers of virus-infected beetles, *Oryctes rhinoceros* L., released in the southern region of Oman, during 1989.

Location	Release date	No. of virus-infected adult beetles released		
		Female	Male	Total
Aukad & El-Wadi	30th and 31st July	103	92	195
Salalah	1st and 2nd August	50	50	100
El-Karad	3rd – 7th August	93	89	182
El-Hafa	8th and 9th August	54	70	124
El-Dhareez	10th – 14th August	70	138	208
Taqa	15th and 16th August	34	57	91
Total		404	496	900

(Source: Kinawy, 2004)

Table (7): Percentages of infected beetles in the local populations after two months from releasing the virus-infected beetles in Dhofar province.

Location	Number of collected beetles			% of infected beetles
	Uninfected	Infected	Total	
Aukad & El-Wadi	12	9	21	42.9
Salalah	13	9	22	40.9
El-Karad	10	8	18	44.4
El-Hafa	14	10	24	41.7
El-Dhareez	11	9	20	45.0
Taqa	13	5	18	27.8
Total	73	50	123	40.7

(Source: Kinawy, 2004)

Table (8): Change in rhinoceros beetles damage to coconut palms at six locations in the southern region of Sultanate of Oman (Dhofar), for a period extended to six years after virus introduction

Date of survey	% of coconut damage at six locations												Mean ± S.D.	
	Aukad & El-Wadi		Salalah		El-Karad		El-Hafa		El-Dhareez		Taqa			
	DS	RDS	DS	RDS	DS	RDS	DS	RDS	DS	RDS	DS	RDS	DS	RDS
Before virus introduction	85	88	94	95	98	91	88	85	78	94	68	43	85.2 ± 10.9	82.7 ± 19.8
16 months After virus introduction	48	43	46	42	58	50	53	59	35	30	48	39	48.0 ± 7.7	43.8 ± 9.9
2 years After virus introduction	32	27	30	22	28	43	34	23	24	19	37	32	30.8 ± 4.6	27.7 ± 8.8
3 years After virus introduction	18	12	10	8	17	14	18	10	12	9	25	28	16.7 ± 5.3	13.5 ± 7.4
4 years After virus introduction	8	5	7	6	10	5	12	4	6	4	19	15	10.3 ± 4.8	6.5 ± 4.2
5 years After virus introduction	5	3	5	8	5	4	5	3	4	5	10	12	5.7 ± 2.2	5.8 ± 3.5
6 years After virus introduction	3	1	3	2	3	5	5	6	3	2	8	5	4.2 ± 2.0	3.5 ± 2.1

DS = Detailed Survey (Number of fronds above the horizontal level in the crown of each palm which showed beetle cuts / 20 – 30 palms in each site). (Source: Kinawy, 2004)

RDS = Rapid Damage Survey (Only the central 3–5 fronds of the crown / 100 palms in each site).

Table (9): Number of adult beetles of *Cryptolaenus montrouzieri* Mulsant, released in the southern region of Oman (Dhofar)

Year	Date	Number of adult beetles released
1994	15th of March	3,500
	17th of July	3,500
1997	23rd of March	3,500
	24th of August	3,500
Total number		14,000

established in the release site but also spread allover the costal region in Dhofar plain providing good control to the mealybug pests in both fruit trees and ornamental plants.

Biological control of Aphids in Jabal Akhdar

The most important aphid species attacking fruit trees in Jabal Akhdar in Oman are the pomegranate aphid, *Aphis punicae* (Passerini), which attacks pomegranate and the melon aphid, *Aphis gossypii* (Glover), which attacks pomegranate, apple and pear. These two common aphids are causing serious damage to pomegranate trees, the most important cash crop in Jabal Akhdar. Although, many predators and parasitoids were recorded attacking aphids in Jabal Akhdar, (Mokhtar, 2005), the role played by these natural enemies to control aphids attacking pomegranate trees were still limited.

Data in Table (10) show the classical biological control programs applied in Jabal Akhdar in Oman. During 2002, the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville (Coleoptera: Coccinellidae) was imported and released in Jabal Akhdar (about 200 thousands beetles). Unfortunately, the lady beetles could not be established and migrated after one month from releasing. Due to their innate tendency to disperse most lady beetles will soon leave the site where they are released, even if aphids are abundant. These results are also emphasized by Raupp *et. al.* (1994) and Dreistadt & Flint (1996), since they mentioned that releasing sufficient numbers of lady beetles can temporarily reduce aphid numbers in greenhouses and on small plants in localized areas, but large scale releases in the field have not been shown to be effective. Also, during 2002, the parasitic wasp, *Aphidius colemani* Viereck (Hymenoptera: Braconidae), was introduced to control the previous mentioned aphids, and about 5000 adults were released. Fortunately, the parasitic wasp (*A. colemani*) was established very quickly and remained in high population. Recently, this parasitic wasp is the most important bio-agent against aphids in Jabal Akhdar and controls successfully aphids and always keeping the aphids populations to the minimum level.

On the other hand, during 2005, the multicolored Asian lady beetle, *Harmonia axyridis* Pallas, was imported and release in Jabal Akhdar as a biological control agent against the previous two aphid species. A total of 37,500 thousands beetles were released in four groups during June, July and August, 2005. This coccinellid beetle is known to be a predator of aphids and scales. The Asian lady beetle, *H. axyridis* has more than 100 forms with different spots and colors, but the two common orangish forms are the forms with 19 dark spots and a form without spots. From our observations, it seemed that the use of the coccinellids in the classical biological control programs of aphids must be restricted to the release of larvae because adults tend to fly away from the release site, especially when their was no food enough (aphids) to the adult beetles.

Biological control of Pomegranate butterfly

The tiny egg parasitic wasps *Trichogramma* spp. are the most widely used insect natural enemy in the world (Li-Ying, 1994), partly because they are easy to mass rear and they attack many important insect eggs, especially eggs of moths and butterflies. In many countries *Trichogramma* species (Hymenoptera: Trichogrammatidae) are released to control different caterpillar pests attacking corn, rice, sugarcane, cotton, vegetables, sugar beets, fruit trees and pine and spruce trees.

The pomegranate butterfly, *Virachola* (*Deudorix*) spp. is a fruit borer and considered being one of the most destructive insect pests attacking pomegranates in many countries, *e.g.* Egypt, India and Oman. In India the pomegranate fruit borer, *Deudorix isocrates* was successfully controlled by releasing the egg parasitoid *Trichogramma chilotraeae* (Singh, 2001).

In Oman, during1999 and 2000, preliminary studies were conducted to use the egg parasitic wasp, *Trichogramma brassicae*, against the pomegranate fruit borer, *Virachola livia* Klug (Lepidoptera: Lycaenidae), in Jabal Akhdar and it was very effective. The parasitic wasp, *T. brassicae*, was imported and released during the activity of the pomegranate fruit borer, from May till August, and it was very effective.

From 2005, mass production of the egg parasitic wasps, *Trichogramma* spp., was started in Oman. The grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae), used as a host to rear *Trichogramma* spp. on its eggs. Data in Table (11) presented the total number of the egg parasitic wasps, *Trichogramma* spp., produced and released by Ministry of Agriculture (Mokhtar, 2007) and by Royal Gardens and Farms (Kinawy, 2007), during three successive years, 2005, 2006 and 2007. During 2006 and 2007 more than 175 million of the egg parasitic wasps, *Trichogramma* spp., were releases in Jabal Akhdar in Oman, during the activity season of the pomegranate fruit borer at weekly intervals.

Now, there was no doubt that, the integrated pest management against the pomegranate fruit borer,

Table (10): Biological control agents introduced to control aphids, which attacking pomegranate trees in Jabal Akhdar in Oman, during 2002 and 2005

Year	Biological control agent	Release date	No. of adults released	Total
2002	*Hippodamia convergens* (Coleoptera: Coccinellidae)	15th of June	100,000	200,000
		20th of July	100,000	
2002	*Aphidius colemanii* (Hymenoptera: Braconidae)	15th of June	002,500	5,000
		25th of July	0002,500	
2005	*Harmonia axyridis* (Coleoptera: Coccinellidae)	20th of June	012,500	37,500
		11th of July	006,250	
		25th of July	06,250	
		15th of Aug.	0012,500	

Table (11): Total number of the egg parasitic wasps, *Trichogramma* spp., released in Jabal Akhdar in Oman during last three successive years (2005-2007)

Year	Total number of the egg parasitic wasps, *Trichogramma* spp., released in Jabal Akhdar in Oman (in millions)		Total (in millions)
	T. evanescens (by Ministry of Agriculture)	*T. brassica and T. evanescens* (by Royal Gardens & Farms)	
2005	074	2.5	76.5
2006	175	3.5	178.5
2007	187	4.5	191.5

Table (12): The biological control agents, used successfully against greenhouse pests, in Royal Gardens and Farms in Oman from 1994 till 2007

Target Pest	Biological Control Agent		Rate of release
	Scientific name	type	
Whitefly: *Bemisia tabaci*	*Encarsia formosa*	Parasitic wasp	3 / m^2
	Eretmocerus eremicus	Parasitic wasp	3 / m^2
	Amblyseius swiriskii	Predatory mite	Sachet / plant
Onion thrips: *Thrips tabaci*	*Amblyseius swiriskii*	Predatory mite	Sachet / plant
	Amblyseius cucumeris	Predatory mite	Sachet / plant
	Orius laevigatus	Predatory bug	5 / m^2
Leaf miners: *Liriomyza trifolii* *Liriomyza sativa*	*Dacnusa sibirica*	Parasitic wasp	¼ / m^2
	Diglyphus isaea	Parasitic wasp	¼ / m^2
Spider mite: *Tetranychus urtica*	*Phytoseiulus persimilus*	Predatory mite	6 / m^2
	Macrolophus caliginosus	Predatory bug	10 / m^2

V. livia, in Jabal Akhdar, is mainly depending on the classical biological control by releasing the egg parasitic wasp, *Trichogramma* spp.

Biological control of Greenhouse pests

On the other hand, from 1994 till 2007 in Royal Gardens and Farms in Oman, the strategies to control the common greenhouse pests such as: thrips, whiteflies, mites and leaf-miners were successfully depending only on biological control agents, *i.e.*, the predatory mites, *Amblyseius cucumeris*, *A. swirskii* and *Phytoseiulus persimilus*, the predatory bugs, *Orius laevigatus* and *Macrolophus caliginosus* and mixture of the parasitic wasps, *Dacnusa sibirica* and *Diglyphus isaea*. These biological control agents, used against greenhouse pests in Oman, their target pests and rate of release are shown in Table (12). These biological control agents successfully controlled the greenhouse pests and kept their populations and damages at the minimum.

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الملخص العربى

استعراض برامج المكافحة الحيوية الناجحة في سلطنة عُمان

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إن تاريخ المكافحة الحيوية التقليدية ضد الآفات الحشرية في سلطنة عُمان لم يوثق كما يجب حتى الآن، علي الرغم أنه خلال ٢٣ عاماً الماضية كانت هناك العديد من مشاريع المكافحة الحيوية التقليدية الناجحة التي تمت في عُمان. وهذه المشاريع كانت قد صممت وطبقت ضد عدد من الآفات الحشرية الخطيرة علي أشجار الفاكهة (الليمون العُماني، النارجيل، الجوافة، المستعفل الأفوكادو، الرمان) وكذلك ضد عدد من آفات الصوب الزراعية علي محاصيل الخضر المختلفة (الخيار، الطماطم، الفلفل الحلو، الخس). وتستعرض هذه الورقة أهم مشاريع المكافحة الحيوية التقليدية الناجحة والتي طبقت بسلطنة عُمان خلال الفترة من عام ١٩٨٤م وحتي عام ٢٠٠٧م. وفيما يلي أهم هذه المشاريع:

- عام ١٩٨٤م تم استيراد وإطلاق نوع من الدبابير المتطفلة، وهو: *Encarsia opulenta* وذلك ضد حشرة ذبابة الموالح السوداء *Aleurocanthus woglumi*، حيث تم السيطرة علي هذه الآفة ومن ثم استئصالها من السلطنة.
- عام ١٩٨٥م كان المشروع الثاني الذي استخدم فيه أحد أنواع خنافس أبو العيد المفترس وهو: *Chilocorus nigritus* وذلك لمكافحة حشرة النارجيل القشرية *Aspidiotus destructor* . ولقد نجح هذا المفترس في السيطرة علي هذه الآفة.
- عام ١٩٨٩م تم بنجاح تنفيذ مشروعاً هاماً لمكافحة حشرة خنفساء النارجيل السوداء *Oryctes rhinoceros* وذلك عن طريق استخدام الفيروس المتخصص عليها والمسمي: *Rhabdionvirus oryctes* .
- عام ١٩٩٤م تمت السيطرة علي نوعين من حشرات البق الدقيقي وهما: بق الموالح الدقيقي *Planococcus citri* وبق الهبسكس الدقيقي *Maconellicoccus hirsutus* علي العديد من أشجار الفاكهة، وقد تم ذلك عن طريق إطلاق خنفساء الكربتوليمس *Cryptolaemus montrouzieri*.
- عام ٢٠٠٢م تم استيراد ثلاثة أعداء حيوية هي: نوعين من حشرات أبو العيد هما: *Hippodamia convergens* and *Harmonia axyridis* ونوع من الدبابير المتطفلة هو: *Aphidius colemani* حيث تم إطلاقها بالجبل الأخضر لمكافحة نوعين من حشرات المنّ الشائعة والمنتشرة وهما: مَنّ الرمان *Aphis punicae* علي أشجار الرمان، ومنّ القرعيات *Aphis gossypii* علي أشجار الرمان والتفاح والكمثري.
- ومنذ عام ٢٠٠٣م وحتي الآن يتم بنجاح تطبيق برنامج المكافحة الحيوية ضد فراشة الرمان *Virachola livia* بالجبل الأخضر، وذلك عن طريق الإطلاق المنتظم لطفيل *Trichogramma* spp.
- أما من ناحية مشاريع المكافحة الحيوية لآفات الصوب الزراعية فمنذ عام ١٩٩٤م وحتى عام ٢٠٠٧م يتم بنجاح مكافحة العديد من آفات الصوب الزراعية والتي منها: حشرات التربس والذباب الأبيض والأكاروسات وصانعات الأنفاق، وذلك بعمل إطلاقات دورية بعديد من الأعداء الحيوية لهذه الآفات مثل: العناكب المفترسة *Amblyseius swirskii, Phytoseiulus persimilus* والبق المفترس *Orius laevigatus, Macrolophus caliginosus,* والدبابير المتطفلة *Dacnusa sibirica, Diglyphus isaea, Encarsia formosa Eretmocerus eremicus*