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Introduction of exotic parasitic wasps for the control of *Liriomyza trifolii* (Dipt., Agromyzidae) in Senegal

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Abstract. *Liriomyza trifolii* Burgess had first been reported from Senegal in 1980. Field surveys in 1982 revealed its presence in all vegetable growing areas of the country, heaviest damage being registered in the Cap Vert. Five indigenous eulophids (larval parasitoids) plus five other rare parasitoids, frequently parasitized over 90% of the flies. These rates were higher in insecticide free fields. and very much above the 30-40% reported for 1981. The most important parasitoids were *Hemiptarsensus semialbiclava* (Girault), which dominated in the second half of the dry season. and two *Chrysonotomyia* spp., which were more abundant in the rainy season Surveys for exotic parasitoids indicated *Diaulinopsis callichroma* Crawford from Trinidad to be a promising species for introduction in the New World. This parasitoid, together with eight other chalcidoids (mostly larval parasitoids) and two braconids (larval-pupal parasitoids), were collected in the field or received from established insectary cultures. They were studied and shipped for rearing and release in Senegal. Nine species were released at the end of 1982 and in 1983. Many were recovered shortly after release, but only Opius *dissitus* Muesebeck was recovered in later samples and became relatively abundant.

Introduction

In Senegal a large scale attack by an agromyzid leafminer, later identified as *Liriomyza trifolii* Burgess, was reported from the Cap Vert region near Dakar in December, 1980 By April 1981, severe damage had occurred, mainly on the African vegetables diakhatou (*Solanum aethiopicum*) and okhra (-gombo) (*Hibiscus esculentus*), and on potatoes. Parasitization rates by indigenous eulophids were low (Bourdouxhe, 1982).

The presumed origin of this fly (until recently confused with *L. sativae* Blanchard) is in America, especially Florida and the Carribean (Spencer, 1973). The fly had been introduced accidentally into Kenya on *Chrysanthemum* sp. cuttings around 1970. Later it reached the Canary Islands, Malta, southern France, and commercial greenhouses in central and northern Europe (D'Aguilar and Martinez, 1979). In 1978 it was first reported from Mauritius and Réunion, where it did damage to a wide range of tropical garden crops (Vercambre, 1980). In addition to the countries mentioned. *L. trifolii* also occurs in South Africa, Israel, Japan. the Philippines, and some Pacific Islands (CIE map 450, 1984).

In America, *L. trifolii* and other *Liriomyza* spp. have become major pests because of insecticide misuse. The mines of the larvae and feeding punctures by the adult flies often lead to severe defoliation. However, under natural conditions most species are reasonably well controlled by their parasitoid complex (Spencer, 1973; Parrella and Keil, 1984), which has been recently reviewed (Murphy, 1984). Parasitoids of *Liriomyza* spp. have been studied in order to develop integrated control (Stegmaier, 1972; Johnson *et al.*, 1980; Allen and Charlton, 1981). Biological control of indigenous agromyzid leafminers has also received much attention in European glasshouse cultures (Hendrikse *et al.*, 1980. Woets and van der Linden, 1982). Recently, these studies have been extended to the exotic *L. trifolii* (J. P. Lyon, pers. comm.).

There have been two classical biological control attempts against *Liriomyza* spp., where natural enemies trom the original home of an accidentally introduced pest were transferred for permanent establishment in the field. These were limited to Hawaii, where both *L. trifolii* and *L. sativae* were controlled on vegetable crops by exotic parasitoids introduced from the southern U.S.A. and Central America (Lai, 1983), and to the Republic of South Africa where attempts are presently being made to control *L. trifolii* on *Chrysanthemum* spp. and tomatoes using Neotropical parasitoids (H. van Hamburg. pers. comm.).

A biological control project, funded by FAO, was conducted at the CDH in Senegal, where the first studies on *L. trifolii* had been done. Parasitoids of *L. trifolii* on vegetables were to be introduced from the New World into Senegal in collaboration with the CIBC West Indian Station. Given the short duration of this pilot project, only Trinidad and a few other areas in the Americas could be searched. Other parasitoids were received from established insectary cultures in the U.S.A. Meanwhile, in Senegal, insectary facilities were constructed, and the extent of *L. trifolii* distribution and the abundance of indigenous parsitoids of this exotic host were evaluated. The present text describes the first results and reports on releases of exotic parsitoids and first recoveries.

Materials and methods

Field surveys in Senegal

From July 1982 to July 1983, frequent surveys for *L. trifolii* and its parasitoids were conducted in the Cap Vert region of Senegal, while other areas were searched only occasionally. Mean rainfail at the Cap Vert during the last 30 years was 518mm per year, but has recently dropped to about 400mm (De Lannoy, 1982). The rainy season lasts from June to October with the heaviest rains in August-September. The long dry season is marked by low temperatures in January (mean minimum around 17°C) and high temperatures in August-September-October (mean maximum around 33°C). From November to March a northeastern wind ('harmattan') sometimes lowers relative hurnidity to below 20%.

The Cap Vert is the main vegetable growing area of the country. Vegetables are grown mostly in fertile valleys ('niayes') between the coastal dunes at sea level. They are irrigated throughout the dry season by hand with water from wells. The main vegetables grown are potatoes, tomatoes and other Solanaceae, various beans, cabbages and leafy vegetables, all of which are hosts of *L. trifolii.*

Infestation by *L. trifolii* varied very much from field to field. In each plot it was short lived, and sampling was often interrupted by leaf fall or harvest. It was therefore not possible during the short period of the project to develop proper quantitative sampling plans for the different substrates. Wherever living infestations were highest, leaves were collected and brought to the laboratory. Infested plant material was stored in translucent cellophane bags which were placed over plastic pots and stored in a horizontal position so that the humidity remained favourable. The emerging flies and parasitoids were collected and counted. Percent parasitism was calculated from the number of emerged flies and parasitoids.

Field surveys in the New World

Surveys for natural enemies of *L. trifolii* and other *Liriomyza* spp. on vegetables were made in low altitude horticultural areas in Trinidad, Colombia and Texas, U.S.A. In Triniclad, the dry season lasts from January to May and is characterized by high temperatues and little rain. During the rainy season from the end of May to December. heavy rains fall only for the first few months. The surveys were conducted from October 1982 to July 1983, principally in the three market gardens in the northern part of the island: Aranguez Gardens, Macoya Gardens, and the University of the West Indies Field Station. Among the many vegetables grown at these sites, tomatoes and beans are particularly mportant and are grown throughout the year.

Infested leaves of all types of vegetables were collected every two weeks from October to February, and on an approximately monthly basis from April to July, and transported in cloth bags. In the laboratory they were held in ventilated plastic containers until all flies and their parasitoids had emerged. To estimate the frequency of leafminers in Aranguez, 10 branches of tomatoes and 50 cowpea leaves were taken at random from the respective bags. All dipterous leafminers and their parasitoids were counted.

Two short collecting trips were made in late April/early May 1983 to the Cauca Valley, Colombia, and in late May to the Rio Grande Valley, Texas, U.S.A. Besides the CIBC surveys, collections of *Liriomyza* spp. parasitoids were made by the University of Florida, Homestead, in southern Florida, and by the State Department of Agriculture, Hawaii, and sent to the CIBC West Indian Station for quarantine. Additional parasitoids were supplied from existing cultures at the University of California, Berkeley and Riverside.

Samples of all dipterous leafminers and their parasitoids from the surveys in America and Africa were sent to the CAB International Institute of Entomology (CIE) in London for identification and comment.

Rearing and life-history studies of L. trifolii *and exotic parasitoids*

Cultures of *L. trifolii* were maintained in Trinidad and Senegal. In Senegal, various plants (but mainly tomatoes and beans) were grown in an insect-proof screenhouse. They were then placed in a screened room of several m^3 where the leaves were stung by the flies. When leafmines had reached the stage required by the parasitoids, the potted plants were placed in screened wooden cages in the laboratory where the fly larvae were exposed to the different parasitoids. In order to maintain cultures, various studies were conducted on the life-history of the fly, including the effects of cold storage on larval and pupal development and adult longevity.

At the CIBC West Indian Station, flies were reared in large cages in the laboratory. Attempts were made to rear all the parasitoids received from surveys and existing cultures at 22 and 27 ± 2°C in the following way: a small number of mated females (usually 5–10) were introduced into a 7.5 litre glass jar containing cut bean leaves in a glass of water. The leaves were infested with *L. trifolii* larvae of suitable age. The parasitoids were allowed to search and oviposit for 3-4 days before being transferred to a new jar. Studies were conductd on their life-histories in order to assess their suitability for introduction to Senegal.

Shipment, release, and recovery of parasitoids

Adult parasitoids were sent to Dakar by air freight. All parcels were cleared by the Senegalese quarantine authorities. Whenever surviving parasitoids were numerous, some were released directly. The rest were taken to the CDH for culture and for further study. Releases of a few hundred adults of each species were made on several occasions. For monitoring, emergence samples were taken on about a monthly basis.

Results

Prerelease studies in Senegal

In the 1982 survey, which covered most of the vegetable growing areas of the country, *L. trifolii* was found in abundance all over the Cap Vert to Mboro in the north-west (100 km from Dakar) and Mbour in the south east (70 km from Dakar). A very few, probably isolated, infestations were recorded from Kaolack (200 km south-east) ancl from Djibelor in the Casamance in the extreme south (500 km south), as well as from a few gardens in Saint Louis in the extreme north of the country (250 km north).

L. trifolii was reared from potato (*Solanum tuberosum*), tomato (*Lycopersicum esculentum*), diakhatou, okhra and egg plant (*S. melongena*), where it did severe economic damage. Flies were also reared from the following vegetables on which they caused minor damage: varrous cabbages (*Brassica napus*), squash (*Citrullus vulgaris*), cucumber and melon (mainly the cotyledons; *Cucumis sativa* and *C. melo*), celery (*Apium graveolens*), beans (*Phaseolus vulgaris*), onion (*Allium cepa*), and carrot (*Daucus carota*). In the wild vegetation around the gardens, *L. trifolii* was at tirnes common on khekhem (*Ricinus communis*) and on wild cowpea (*Vigna coerulea*). Occasionally, this fly was also found on green and bell pepper (*Capsicum frufescens* and *C. annuum*), cowpea (*Vigna unguiculata*), different peas (*Canavalia ensiformis* and *Pisum sativum*), beet (*Beta vulgaris*), lettuce (*Lafuca sativa*), passion fruit (*Passiflora foefida*), basil (*Ocimum basilicum*), spinach (Amaranthus viridis and Perisfrophe *bicalyculata*), maize (Zea *mays*), cotton (*Gossypium herbaceum*), and *Cessia occidentalis*, as well as on the ornamentals and weeds *Datura metel*, *Tagefes patula*, and *Sonchus brunneri*. Some of these hosts had already been reported earlier from Senegal (Bourdouxhe, 1982) and Réunion (Vercambre, 1980). Worldwide. the species has Ibeen found. on 47 genera in 10 families (Stegmaier, 1966).

L. trifolii infestations were most severe during the second part of the dry season, and almost non-existant during the rainy season and in the early part of the next dry season. *L. brassicae* (Riley) was also reared from cabbage in the Cap Vert and Saint Louis.

In the 1982 season, the original list of two parasitoids found on *L. trifolii* (Bourdouxhe, 1982) was extended to the following nine species:

- Hemiptarsenus *semialbiclava* Girault (Eulophidae)
- *Chrysonotomyia* sp., *formosa* group (Eulophidae)
- *Chrysonofomyia* sp. near *leptocera* Waterston (Eulophidae)
- *Cirrospilus* sp. near *cinctiventris* Ferrière (Eulophidae)
- *Diglyphus isaea* Walker (Eulophidae)
- *Eucoilidea* fetura Quinlan (Eucoilidae)
- *Nordlanderia plowa* Quinlan (Eucoilidae)
- *Allophrys* sp (Ichneumonidae)
- An unidentifiable braconid.

The last five species were recovered only on a few occasions from leaves with mines. *C. cinctivenfris* is perhaps hyperparasitic, and never common. The first four eulophids exhibited strong fluctuations in their relative abundance (Table 1). *Chrysonofomyia* sp. near *formosa* was dominant in the rainy season, and *H. semialbiclava*, in the second half of the dry season. The three main species were common on all host plants and throughout the region.

Parasitism rates varied widely, but were usually lower on insecticide treated than on untreated fields (Table 2). No influence of fungicide treatments on parasitoids could be detected in the sampling data.

Survey and collection of parasitoids in the New World

Trinidad

L. trifolii was the only dipterous leafminer found. Its distribution on the different crops is shown in Table 3. The leafminer was found on a wide variety of vegetables in all three gardens. but tomato and cowpea (bodibean. *Vigna sesquipedalis*) suffered the most severe infestation. Other species, like gub gub bean (cowpea, *V. sinensis*), hyacinth bean (*Lablab niger*), ancl the other vegetables listed in Table 3, showed only minor damage. After the onset of the rainy season in early May 1983, the overall abundance of *L.* trifolii fell drastically in ail gardens and the fly became restricted to tornato and cowpea.

The following parasitoids were recovered, the first two being the most common:

- *Diaulinopsis callichroma* (Eulophidae)
- *Closterocerus purpureus* Howard (Eulophidae)
- Chrysonotomyia sp.F (Eulophioae)
- ?*Chrysocharis* sp.J (Eulophidae)
- *Chrysocharis caribae* Bouček (Eulophidae)
- *Elachertus* sp.L (Eulophidae)
- *Halticoptera circulus* Walker (Pteromalidae).

Levels of parasitism (Figure 1) were lower during the two wet periods of the survey than in the dry season C.

Table 1. Relative abundance of indigenous parasitoids of Liriomyza trifolii *in the Cap Vert region of Senegal*

Period	Total number of parasitoids (= 100%)	*Hemiptarsenus*	*Chrysonotomyia* formosa	*Chrysonotomyia* leptocera	*Cirrospilus*
July-Sept. 82	629*	34.3	53.1	12.1	0.5
Oct.-Dec. 82	137	18.2	43.1	35.8	2.9
Jan.-March 83	2355	51.3	39.0	9.0	0.7
April-June 83	598	65.0	25.8	8.7	0.5

* plus 1 *Diglyphus isaea.*

Table 2. *Percentage parasitism by indigenous parasitoids* on Liriomyza trifolii in *the Cap Vert of Senegal, or? insecticide treated and untreated fields*

	Insecticide treated field			Untreated field		
Month	Locality*	Total flies and parasitoids	Percentage parasitism	Locality*	Total flies and parasitoids	Percentage parasitism
July 82	a	163	26.4	a	13	53.8
	e	54	33.3	d	52	55.8
	f	77	10.4			
Aug 82	b	142	38.0	b	145	68.3
	a	46	39.1	b	167	50.9
				b	156	96.2
Sept.- Nov. 82		0**			0**	
Dec 82	a	20	45.0			
Jan. 83				a	65	98.0
Feb 63				a	55	67.2
March 83	a	1036	96.7	c	48	98.0
	b	434	57.8			
April 83	a	133	98.5	c	16	97.6
	b	737	18.9			
May 83	a	9	77.7	b	159	91.3
	c	104	88.4			
June 83	b	6	50.0	a	11	82.3
				c	98	79.4

* a Camherene CDH. b Pikine-Yeumbeul, c Thiaroye sur mer, d Malika, e Niaga, f Berr-Tialane.
* * fly populations very low.

Table 3. *Distribution of* Liriomyza trifolii *and associated parasitoids in* relation *to vegetable crops in Trinidad.*

Vegetable	*L. trifolii*	*C. purpureus*	*D. callichroma*	*Chrysonotomyia* sp.F	*?Chrysocharis* sp.J	*C. caribea*	*Elachertus* sp.L	*H. circulus*
Cowpea		t	t	+	t			
Gub gub bear	t		t					
Hyacinth bean	t	+	+	+	+		+	
Tomato	+	+	+	?-	-t			
Sweet pepper	t		t	+				
Eggplant	+		+					
Celery	+	+	t					
Cucumber	+	+	t					
Okhra	t	+	+			t		+

present

purpureas favoured the rainy season. when it was often the most abundant parasitoid. During the dry season *D. callichroma* was the only abundant parasitoid. On tomatoes, parasitism by this wasp exceeded 60%. The other species parasitized a maximum of *5%* of all *L. trifolii* larvae. Unfortunately. insecticides were used regularly in all of the gardens on most of the vegetables, thereby sometimes abruptly lowering the levels of parasitism.

Colombia and United States

In Colombia, dipterous leafminers were scarce and only *Diglyphus begini* was collected near Piendano (Table 4). In the Rio Grande Valley of Texas, *Liriomyza ?sativae* was common on all vegetables irrespective of whether they had been sprayed with insecticide or not. Various parasitoids were found associated with this leafminer (Table 4), the only common ones being *Chrysonotomyia* sp. W. and *Diglyphus websteri.* Some of the species recorded were similar to those found by Chandler (1982) on melon and sweet pepper.

The *Liriomyza* parasitoids collected by the University of Florida and the State Department of Agriculture, Hawaii, are listed in Table 4. The parasitoids collected from horticultural areas in Hawaii for this project had originally been introduced from North, Central and South America in the late 1970's for the control of *L. trifolii* and *L. sativae* (Lai, 1983). The six species listed became established and are now quite common in the field. In addition, the parasitoids sent by the University of California, Riverside and Berkeley, from existing cultures are indicated. The four institutions provided cultures of nine species.

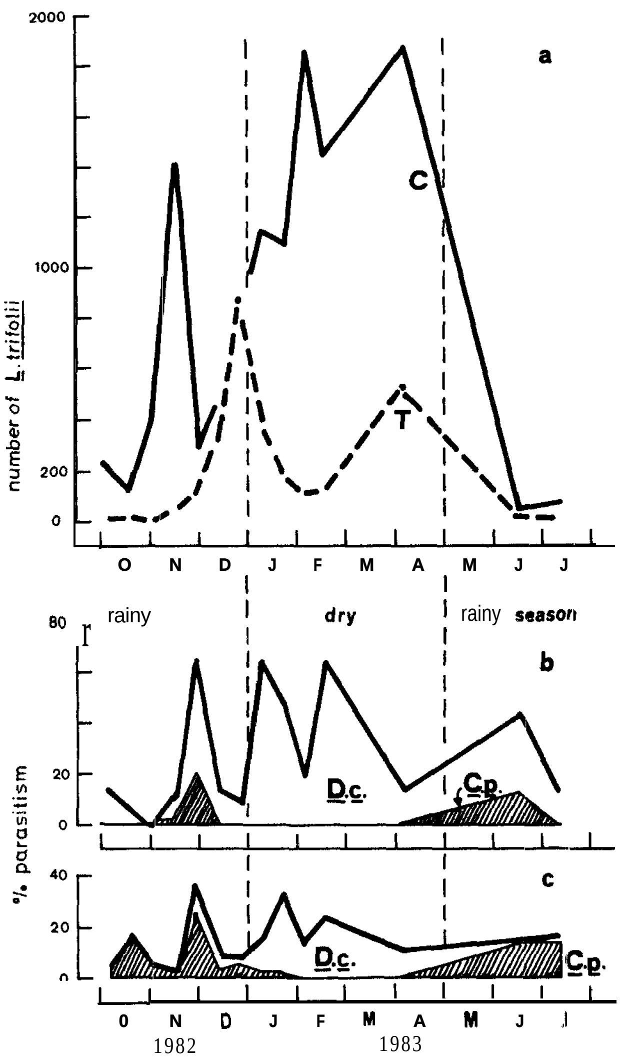

Figure 1a. *Number of* Liriomyza trifolii larvae *on 10 branches of fomato (T) and 50 cowpea leaves (C), together with cumulative parasitization rates by* Diaulinopsis callichroma *(D.c.) and* Closterocerus purpureus *(C.p.) on 1b. tomato and 1c. cowpea, at Aranguez Gardens, Trinidad.*

Life-history *studies*

Liriomyza *trifolii*

At 27 + 2°C, the eggs of *L. trifolii* hatched within 2-3 days, and the 3 larval instars fed for 4 days inside their leafmines before dropping to the ground for pupation. Adults emerged about 6-8 days later, whereby emergence was limited to the period from 6 a.m. to 2 p.m. with a marked peak from 10-l 1 a.m. This life-cycle of 12-15 days was not altered significantly when cut bean or tomato leaves were used, provided that proper humidity was maintained. These results are in accordance with those reported by Charlton and Allen (1981).

At 27°C, mean survival of unfed adults was 2 days. Flies provided with sugar water lived 16 days which corroborates more extensive data by Vercambre (1980). When flies were given the opportunity to make nutritional stings on tomato leaves, survival was 10 days with, and only 2 days without, sugar. Protein hydrolysate (Buminal[R]) was not accepted and did not prolong the life span. Thus, flies fed with sugar water alone survived longer than those having access to plants, and oviposited and aged faster. In the refrigerator, survival at 12°C was 3 or 7 days according to whether they were fed or not before cooling. At 4°C, survival was 8 and 10 days, respectively. It is concluded that adults cannot be stored for a long time and need sugar water or honey even when they have access to plants.

Cool storage of pupae depended on their age (Table 5). Before the pupal moult inside the puparium, the larvae proved very sensitive to cold. Pupae held at 12°C, l-3 days after puparium formation, survived better, but because of early emergence in the refrigerator, cool storage beyond 1 month is not recommended. When pupae were stored at 4°C, survival was only 1% after 2 weeks. Similarly, larvae inside the leaves could not be stored; all died within 2-4 weeks at 12°C. This information allowed us to ensure a reliable supply of flies in the insectary.

Exotic parasitoids

The life-history characteristics, host age preference, and developmental time of parasitoids brought successfully into culture, are listed in Table 6. All species attack and ovipost in/on the host larvae and are solitary. Most of the eulophids kill the host in its mine, but the braconids and the pteromalid do not kill it until it has formed a pupa from which the adult parasitoid eventually emerges. Some of the species listed seem to prefer a particular instar for oviposition.

Shipment, culture, release and recovery in Senegal

Species shipped from the Americas to Senegal, and their condition at arrival and in subsequent cultures in the insectary, are indicated in Table 7. Of the 11 species received, two were lost before releases could be made. Most were kept in culture for a few generations for releases on later dates, *Opius dissitus* remained in a viable culture for more than a year.

A few specimens of most species were recovered within a few weeks of release, indicating successful breeding in the field. Only *Opius dissitus* was found regularly. The first small samples taken in May-July 1983 in the release fields (which are not the same as the extensively sampled fields in Tables 1 and 2) indicate that this exotic parasitoid became the third most important parasitoid, after the indigenous *H. semialbiclava* and *Chrysonotomyia* sp. near *formosa.*

Discussion

Following its accidental introduction into Senegal, *L. trifolii* spread throughout the main vegetable growing area of the Cap Vert region which grows about 4500 ha of vegetables. Additional isolated infestations were found throughout the country. In the Cap Vert, losses in 1981 had been dramatic and parasitization rates by *H. semialbiclava* and *Chrysonotomyia* sp. were relatively low, at 30-40% (Bourdouxhe, 1982). By the time the biological control project was initiated in 1982, losses had diminished

Table 4. Survey for parasitoids of Liriomyza *spp. in America*

Species	Origin	Host plant	Host fly*
Eulophidae:			
Chrysocharis caribea Bouček	Hawaii	vegetables	L.t., L.s.
Chrysocharis sp. nr. *caribea***	Texas	tomato	L.?s.
Chrysocharis parksi (Crawford)	Hawaii	vegetables	L.t., L.s.
	southern California	chrysanthemum●	L.t.
Chrysonotomyia punctiventris (Crawford)	Hawaii	vegetables	L.t., L.s.
Chrysonotomyia sp W	Texas	tomato, sweet pepper, melon	L.?s.
Closterocerus purpureus (Howard)	Texas	sweet pepper	L.?s.
Diglyphus begini Ashmead	central California	?●	L.t.
	Colombia	chrysanthemum	L.t.
Diglyphus intermedius (Girault)	southern California	chrysanthemum●	?
	Florida	beans	L.?t.
Diglyphus websteri (Crawford)	Texas	tomato, sweet pepper	L.?s.
Pteromalidae:			
Halticoptera ?circulus (Walker)§	Hawaii	vegetables	L.t., L.s.
Eucoilidae:			
?*Disorygna* sp.§§	Hawaii	vegetables	L.t., L.s.
?*Disorygna* sp. BB	Texas	tomato	L.?s.
Braconidae:			
Opius dimidiatus (Ashmead)	Florida	chrysanthemum●	?
Oprus dissitus Muesebeck	Florida	beans	L.?t.
	Hawaii	vegetables	L.t., L.s.

* L.t. L. *trifolii*, L.s. : L. *sativae*. ** sent as *Chrysocharis* sp. near *giraulti* Yoshimoto. § sent as *Halticoptera patellana* (Dalman). §§ sent as *Cothonaspis* sp. ● from established laboratory cultures.

Table 5. Emergence and mortality of Liriomyza trifolii *larvae (L_3) and pupae (P) of different ages following cold storage of 3 months at 72°C. 300 insects per treatment (= 100%) Cambéréne, 7982*

Age at start of cold storage in days	Percentage mortality as: L_3 and P	Adults inside the puparium	Adults emerged in cold storage*	Percentage Flies emerged at 25°C**
L_3 untreated	0	3.0	—	97.0
L_3	99.0	1.0	0	0
P 1/4 d-old	40.0	55.0	2.0	3.0
1	a.7	69.0	3.7	18.6
2	3.7	63.3	23.7	9.3
3	1.7	45.7	41.3	11.3

* after an average of 4.7 weeks for 3 d-old pupae to 7.0 weeks for 1/4 d-old pupae. ** after an average of 2.3 d for 3 d-old pupae to 3.9 d for 1/4 d-old pupae. Control = 5.9 d.

somewhat, and parasitization rates by indigenous parasitoids surpassed the 1981 *values* in all sampled fields which had not been treated with insecticides. Rates of parasitism seemed even higher in thefirst half of 1983. It is conciuded that indigenous eulophids had transferred successfully from other leafminers to this new host within a relatively short period. This confirms the polyphagy shown by many agromyzid parasitoids (Stegmaier, 1972; Murphy, 1984). Thus, rates of parasitism in Africa often surpassed those recorded from Trinidad (see Figure 1) and other countries in the Americas (Pohronezny et *a/.*, 1978; Tryon and Poe, 1979; Johnson et *al.*, 1980) where insecticide pressure is probably higher than in the Cap Vert. In fact, the African *H. semialbiclava* has been chosen for introduction into France (J. P. Lyon, pers. comm.).

Some of the parasitoids received had already been investigated in the Americas and shown promising attributes. In Trinidad, *Diaulinopsis callichroma* reached the highest level of parasitism among seven species. *Chrysocharis parksi* had been reported to have a density dependent relationship to *L. trifolii* populations (Johnson et *a/.*, 1980) and is now being used in European glasshouses (J. Woets and A. van der Linden, pers. comm.). *Diglyphus begini* was the most abundant parasitoid in Southern California (Allen and Charlton, 1981), and *Halticoptera* sp. listed as *aenea* (Walker) was dominant in Arizona (Hills and Taylor, 1951). The two *Opius* spp., which were received from other insectaries, are larval-pupal parasitoids of

Table 6. *Life-histories of* Liriomyza *parasitoids*

Species	Life-history	Host instar preferred for oviposition	Develepment time*	Additional reference
Chrysocharis parksi	Larval-pupal endoparsitoid	Early instars	13 d at 27°C	a
Chrysonofomyia sp.w	Larval ectoparasitoid?	Early instars	11 d ai. 27°C	
Diaulinopsis callichroma	Larval ectoparasitoid?	Middle-late instars	Males 11 d Females 13-l 4 d at 27° C	
Diglyphus begini	Larval ectoparasitoid	Late instars	12 d ai 22°C 11-13 d at 29°C	b,c
Diglyphus intermedius	Larval ectoparasitoid	Late instar	13 d at 22°C 14-15 d at 29°C	d,e
Halficopfera circulus	Larval-pupal endoparasitoid?	Early instars	19-23 d at 29°C	
Opius dimidiatus	Larval-pupal endoparasitoid	All instars	10 d at 27°C 13-14 d at 29°C	f
opius dissitus	Larval-pupal endoparasitoid	First instar	11 d at 27°C 12-14 d at 29°C	

* egg to adult; at 22 and 27°C from CIBC, Trinidad, at 29°C from CDH, Senegal. a Christieand Parrella. 1982; b Doutt, 1957; c Allen and Charlton, 1981; d Hendrickson and Bath, 1978; e Gordh and Hendrickson, 1979; f Lema and Poe, 1979.

Table 7. *Origin, survival, release, and recovery of* Liriomyza trifolii *parasitoids sent from America to Senegal*

Species	Origin	Total number dispatched	Number of shipments*	Percentage survival at arrival	Quality of culture in Senegal**	Local ity and dates of releases§	Recovery
C caribea	Hawaii	750	3	85	a	C 4-83	*
C parksi	Hawaii	1360	3	65	b	D 12-82; C 4-83	*
	California	154	2	5			
C. punctiventris	Hawaii	1100	3	90	a	c 4-83	*?
c. sp. w	Texas	95		50	a		
D. callichroma	Trinidad	885	4	95	b	A l-83 (2x); D l-83, 2-83	*
D. begini	California	100	1	90	b	D 10-82; E 2-83	*?
	Colombia	163	2	70			
D. intermedius	Florida	292	2	95	b	B 2-83, 4-83: C 5-83 (2x); E 5-83	*§§
	California	65	1	80			
H. circulus	Hawaii	1250	3	90	a	A 12-82, 3-83; B 4-83; C 4-83. 5-83 (2x)	*§§
Disorygna sp.	Hawaii	500	1	20	a		
0. dimidiafus	Florida	52	1	95	c	C 9-83 (2x)	*?
0. dissitus	Florida	808	[illegible]	90	c	A l-83 (2x), 3-83 (4x), 4-83; B 3-83. 4-83 (2x); C 4-83, 5-83 (3x), 6-83 (2x): E 2-83	*§§
	Hawaii	700	[illegible]	90			

* all parcels arrived within 2-4 d. **a = lost after a few generations in culture; b = maintained at low numbers in a steady culture; c = good culture. § A Cambérène, B Pikine, C Thiaroye sur mer, D Yeumbeul, E Gueno Mbao. §§ recovery confirmed by CIE specialist.

which 0. ***dimidiatus*** at least does not prefer the same host stages for oviposition as some other species, e.g. *Chryso-****notomyia*** sp. (Lema and Poe, 1979). Therefore these species fill an ecological niche which was virtually unoccupied in Africa and have a special interest for introduction. However, a literature review by Murphy (1984) shows that many more candidate species should be tried which could not be imported into Senegal during this preliminary study.

The first results of the biological control project reported here indicate that most species passed through at least one generation in the field following release. *Opius dissitus* did especially well during the first dry season. Possible reasons for this achievement are its successful culture and frequent releases at many sites over a long period, as well as the fact that it could fill an unoccupied ecological niche. The greatest difficulty for these exotic parasitoids in achieving permanent establishment will be the rainy season when host populations are exceedingly low. Permanent establishment of any of the exotic species, their competition with indigenous parasitoids, and, finally, their eventual efficiency remain to be evaluated.

Biological control with indigenous and exotic parasitoids seems particularly promising for *L. trifolii* in Africa because insecticide use is still less frequent than in Europe and North America, and because *Liriomyza* spp. seem to reduce yield of vegetables like tomatoes only at very high infestation levels (Levins et *al.*, 1975).

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