

The feasibility of classical biological control of two major cowpea insect pests

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Abstract

Biological control, as a key component of biointensive IPM in cowpea, is evaluated for its practical feasibility. The case study of one of the major insect pests, the bean flower thrips *Megalurothrips sjostedti* (Trybom) (Thysanoptera, Thripidae), is used to indicate the most important criteria for this evaluation: the nature of the pest and the release habitat, the availability and effectiveness of biological control agents, and the current status of biocontrol against the target pest. Although taxonomic aspects need further consideration, present knowledge suggests a southeast Asian origin for *M. sjostedti*. In the savannas of West Africa, cultivated and wild host plants are always available to sustain the feeding and reproduction of the pest throughout the year, while the locally present natural enemies are unable to control its population. A first exploration in search of *M. sjostedti* and efficient natural enemies, undertaken in Malaysia in November-December 1994, yielded an endophagous larval parasitoid, tentatively identified as *Ceranisus menes* Walker (Hymenoptera, Eulophidae). This parasitoid was able to parasitize up to 70% of the larvae of the closely related species, *M. usitatus*, found in flowers of *Pueraria phaseoloides*, a commonly grown cover crop. In a second, less detailed case study, the biocontrol feasibility for another key pest, the legume pod borer, *Maruca vitrata* Fabricius (previously *M. testulalis* Geyer) (Lepidoptera, Pyralidae), is assessed, using the same criteria.

These feasibility studies indicate that (1) both pests might be of foreign origin; (2) the alternative host plant habitat is conducive to the perennial presence of the pests; (3) the indigenous antagonists are not effective in controlling the pests; and (4) potential natural enemies of both pests have been identified in southeast Asia. Additional foreign explorations are needed to substantiate the results of these studies.

Introduction

Severe yield losses of cowpea, *Vigna unguiculata* (L.) Walp., are caused in tropical Africa by the interplay of abiotic (e.g., drought, and poor soil fertility) and biotic (e.g., arthropod pests, diseases, birds, and rodents) constraints. Ranked first among the latter group, a wide array of insect pests can cause total yield failure in cases of severe attack (Jackai and Daoust 1986). Two of them are among the most noxious and least amenable to available control measures (with the exception of chemical control): the bean flower thrips, *Megalurothrips sjostedti* Trybom (Thysanoptera, Thripidae), and the legume pod borer, *Maruca vitrata* Fabricius (formerly *M. testulalis* Geyer) (Lepidoptera, Pyralidae).

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At present, the only method for the effective control of these insect pests (and thus for maintaining reasonable yield levels) is the use of synthetic insecticides. This, however, is not a sustainable practice and should be used only in emergency situations (Jackai and Adalla 1997, this volume). The approach adopted by IITA to sustainable pest control in cowpea is to develop a biointensive IPM strategy (Jackai and Adalla 1997), in which the key components are host plant resistance, cultural control, and biological control. Reviews on the use of cultural practices to control insect pests in cowpea have been provided by Ezueh (1991) and Jackai (in press). Biological control is discussed in the remainder of this paper.

Present status of biological control in cowpea

First, we would like to clarify the term “biological control”, to avoid misinterpretation. As outlined in Huffaker and Smith (1980), biological control is defined as both the undisturbed activity of antagonists naturally present in a given ecosystem (“naturally occurring biological control”), and the manipulation of natural enemies in order to achieve better control levels (“applied biological control”). Generally, when we talk about biological control as an intervention tactic, we refer to the latter form and, more specifically, to “classical biological control” as the introduction of exotic antagonists against exotic pests. One of the best documented examples of classical biological control is the successful introduction of the solitary endoparasitoid *Epidinocarsis lopezi* (De Santis) (Hymenoptera, Encyrtidae) to control the cassava mealybug *Phenacoccus manihoti* Mat.-Ferr. (Homoptera, Pseudococcidae) in Africa (reviewed by Herren and Neuenschwander 1991).

In the literature concerning pest control in cowpea, the term “biological control” has usually been used to indicate the naturally occurring interactions between pests and their antagonists (Daoust et al. 1985; Jackai and Daoust 1986; Singh et al. 1990; Ezueh 1991). Therefore, recommendations for biological control were merely aimed at preserving the available natural enemies (Ezueh 1991). Up to now, classical biocontrol has never been adequately evaluated for cowpea, although there have been attempts at introducing and establishing natural enemies for *M. testulalis*, a pest of other legumes in areas where cowpea is not cultivated or of minor importance (Waterhouse and Norris 1987).

In this paper, the feasibility for classical biological control in cowpea is assessed, using three criteria discussed in Barbosa and Segarra-Carmona (1994):

1. the nature of the pest and release site, which includes information concerning both the origin of the pest and the host plant habitat;
2. the availability of biocontrol agents, i.e., the inventory and impact of natural enemies;
3. the current status of biocontrol against the target pest.

This approach is illustrated in more detail with *M. sjostedti*, which has been the object of in-depth ecological investigations more recently.

The feasibility study presented in this paper focuses only on the use of introduced arthropod beneficials. Although entomopathogens could in principle be of great potential value against cowpea pests from a biological perspective (Jackai, in press), there are predictable technical, economic, and institutional constraints regarding their production,

formulation, and application (Moore and Prior 1993). In fact, biocontrol by means of predators and parasitoids is easier to implement in the field than the application of myco-insecticides; as opposed to entomopathogens, arthropods are able to spread actively from the original release site and effectively colonize other areas. Also, once the natural enemies have become established, no further introductions are required, particularly if parasitoids are released. Nevertheless, the use of entomopathogens for the control of cowpea pests might gain importance in the future, if the difficulties concerning their production and application are overcome.

The bean flower thrips, *M. sjostedti*

Nature of pest and release site

As with many other successful examples of classical biological control, including that of the cassava mealybug, the discovery of the appropriate natural enemy was only possible after the pest's native home had been correctly identified. Hence, investigation of the origin of the pest is probably the most crucial step in assessing the feasibility of a biocontrol project (Bellows and Legner 1994). This information is relatively easy to gather in the case of recent pest introductions, due mainly to the existence of worldwide databases on agricultural pests. However, for organisms such as *M. sjostedti*, for which there is no historical record of an earlier introduction, and which are, therefore, considered indigenous pests, it is difficult to ascertain their origin from the available literature on taxonomy and distribution.

Since its first description in East Africa in 1905 (Trybom 1908), *M. sjostedti* has never been found outside the African continent (Palmer 1987). However, the fact that six other distinct species of *Megalurothrips* are uniquely found in tropical Asia, while *M. sjostedti* is the only species of this genus present in Africa (Palmer 1987), suggests that, in all probability, the center of origin of the genus *Megalurothrips* is tropical Asia. In addition, *M. sjostedti* is the only species of this genus that is considered an important crop pest, whereas none of the Asian species is considered an agricultural pest (Kalshoven and van der Vecht 1950; Litsinger et al. 1978; Singh et al. 1990). In fact, ecological studies in Southeast Asia indicate that *Megalurothrips* spp. are pollinators (Velayudhan et al. 1985), and only seldom cause feeding damage on flowering structures.

On the other hand, the strongest argument against an Asian origin of *M. sjostedti* is that it has never been found there. However, taking again the example of the cassava mealybug, that insect was not known to science in its native habitat until it was accidentally introduced into Africa without its natural enemies and became a pest. A comparable example is given by the *Megalurothrips* species described as most similar to *M. sjostedti*, *M. typicus* Bagnall, which is a rarely collected insect (Palmer 1987) and is not present on commonly sampled legume flowers. Similarly, if present in Asia, *M. sjostedti* might be confined, e.g., by interspecific competition, to host plants of no agricultural importance and might, therefore, have never been observed. Evidently, the present knowledge on the taxonomy and distribution of *M. sjostedti* does not allow us to draw a definitive conclusion about its origin but, together with the apparent lack of co-evolution in its environment as presented in the following sections (i.e., the inefficacy of available natural enemies and substantial damage on wild host plants), it leads us to hypothesize a southeast Asian origin for this insect (Tamò et al. 1993b; in press).

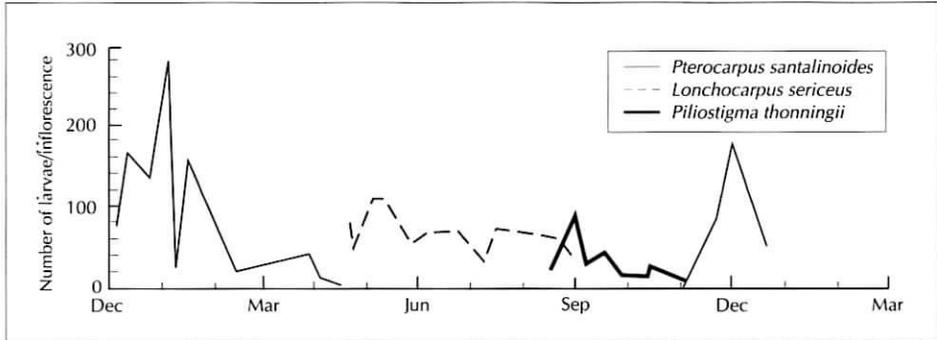


Figure 1. Seasonal abundance of larvae of *Megalurothrips sjostedti* on three alternative host plants in southern Benin.

Once a suitable biological control candidate has been identified in the pest's area of origin, and released in the new environment, its successful establishment depends largely on the availability of perennial habitats where it can find hosts during periods when the crop plant (i.e., cowpea) is not cultivated.

For *M. sjostedti*, there is already a long list of alternative host plants (Tamò et al. 1993b) where this insect can be found during their respective flowering periods. This list, though far from exhaustive, shows that, from the coast in the south to the dry savanna areas in the north of West Africa, there are a number of host plants which play an important role in the population dynamics of the pest. Using as examples the three most common wild host plants in the moist savanna, we observed (Fig. 1) that there is always a plant at the flowering stage to ensure survival and reproduction of the thrips, even in the complete absence of cowpea. This observation will have implications for the establishment and survival of the hypothetical natural enemy to be released against *M. sjostedti*: populations of *M. sjostedti* with a suitable demographic profile will be available throughout the year, but the biocontrol candidate should be able to recognize most of these plants as being hosts for *M. sjostedti*.

Availability of biological control agents

The mortality inflicted by natural enemies is an important factor regulating pest populations in tropical climates, and we would expect to find well-adapted antagonists if *M. sjostedti* was of African origin. Although the search for natural enemies associated with *M. sjostedti* yielded a number of antagonists (Table 1) comparable to the numbers for other flower thrips (e.g., Lewis 1973), the only quantitative data available for both parasitoids and pathogens indicate a minor influence on the population dynamics of *M. sjostedti* (Tamò et al. 1993b).

Mortality rates due to the activity of egg parasitoids of the genus *Megaphragma* (Hymenoptera, Trichogrammatidae), although reaching peaks > 30% on cowpea and 53% on one alternative host plant, *Pueraria phaseoloides* (Leguminosae, Fabaceae), are inconsistent throughout the season and differ greatly from region to region. A reason for this inefficacy can be sought in the ephemeral character of *Megaphragma* sp., the smallest insects known, whose movements and survival on the host plant are largely influenced by

Table 1. Parasitoids and predators of *Megalurothrips sjostedti* from West Africa.

Organism	Stage affected [†]	Country	Source
Parasitoids			
Hymenoptera			
Eulophidae			
<i>Ceranisus menes</i>	L	Benin	Tamò et al. (1993b)
Trichogrammatidae			
<i>Megaphragma</i> sp.	E	Benin	Tamò et al. (1993b)
<i>Oligosita</i> sp.	E	Benin	Tamò et al. (1993b)
Predators			
Acari			
Phytoseiidae			
<i>Iphyseius</i> sp.	E	Benin	Tamò et al. (1993b)
Coleoptera			
Coccinellidae			
<i>Cheilomenes sulphrea</i>	L	Benin	Tamò et al. (1993a)
Staphilinidae			
<i>Paederus sabeus</i>	L	Benin	Tamò et al. (1993b)
Hemiptera			
Anthocoridae			
<i>Orius</i> sp.	E, L, A	Nigeria Benin	Matteson (1982); Rösingh (1980) Tamò et al. (1993b)

† E = egg; L = larva; A = adult.

the microclimate. Also, *Megaphragma* spp. are known to be rather nonspecific. They parasitize eggs of several thrips species in the Terebrantia (Lewis 1973) and *M. sjostedti* may not be the primary host.

In 1992, an indigenous larval parasitoid of *M. sjostedti* was recorded for the first time in Benin Republic in the flowers of an exotic shrub, *Tephrosia candida* (Leguminosae, Fabaceae). The solitary endoparasitoid was tentatively identified as *Ceranisus menes* (Hymenoptera, Eulophidae) (Tamò et al. 1993b), although the authority stated clearly that, for this genus, there were no keys for species outside Europe (J. LaSalle, British Museum, personal communication). Further studies on *M. sjostedti* larvae collected from cowpea revealed very low parasitism rates. After having reared over 12,000 thrips larvae, sampled from different ecological zones in Benin Republic, with a total parasitism rate of < 1%, we are now convinced that *C. menes* cannot effectively recognize cowpea as a host plant for *M. sjostedti*. Also, the low parasitism rates observed on naturally occurring alternative host plants (Table 2), which represent a much more stable ecosystem than the cowpea field, indicate that *C. menes* is not an efficient natural enemy of *M. sjostedti*.

Our laboratory experiments, conducted in small rearing jars under no escape conditions, revealed a parasitization rate of only about 15%, indicating low host acceptance. Often the parasitoid inside the attacked larva could not complete its life cycle (Tamò, unpublished data). All these facts suggest that the parasitoid is more likely to be associated with other thrips than with *M. sjostedti*, and that it is probably more attracted to *T. candida* than to cowpea or indigenous alternative host plants.

Table 2. Parasitism rates of larvae of *Megalurothrips sjostedti* and *Maruca vitrata* collected on major alternative host plants in Benin (Tamò and Arodokoun, unpublished data).

Host plant	% larval parasitism	
	<i>M. sjostedti</i>	<i>M. vitrata</i>
<i>Piliostigma thonningii</i>	0.30	–
<i>Lonchocarpus sericeus</i>	1.71	1.87
<i>Pterocarpus santalinoides</i>	3.82	20.97
<i>Tephrosia platycarpa</i>	–	2.38

The interactions between a hypothetical parasitoid, the larval population of *M. sjostedti*, and the yield of cowpea have been evaluated using simulation models (Tamò et al. 1993a), and the results indicate that a parasitoid that can kill 35% of the larval population should have a beneficial effect in the cowpea field.

Current status of classical biocontrol

As mentioned earlier, there has never been any attempt to implement classical biological control against cowpea pests in the past. Very recently, to test the foreign origin hypothesis for *M. sjostedti* and its implications for biological control, an exploration in search of both *M. sjostedti* and efficient natural enemies was undertaken by the first author in Peninsular Malaysia in November–December 1994.

The search did not yield a specimen of *M. sjostedti*, but some rare female specimens of *M. usitatus* were collected which had asymmetrical positioning of the median postero-marginal setae on sternite VII, one seta being on the posterior margin (which is typical of *M. sjostedti*), and the other being anterior to it (typical of *M. usitatus*).

During the same exploration, an endophagous larval parasitoid, also tentatively identified as *C. menes*, was found in flowers of different cultivated and cover crops, together with populations of *Megalurothrips* spp., mainly *M. usitatus*. Up to 70% parasitism was observed from *Megalurothrips* spp. larvae collected from flowers of *Pueraria phaseoloides*, a commonly grown cover crop (Table 3). This parasitoid did recognize long beans (*V. sesquipedalis*), whose flowers are quite similar to those of cowpea, as a host plant for *Megalurothrips* spp. However, preliminary observations (Table 3) indicate that the application of insecticides affected the presence of this parasitoid on cultivated legumes.

The suitability of using the collected strain of *C. menes* as a biological control agent for *M. sjostedti* is now being studied under quarantine.

Table 3. Parasitism of larvae of *Megalurothrips* spp. by *Ceranisus menes* in peninsular Malaysia.

Total collected	Larvae of <i>Megalurothrips</i> spp.			
	Parasitized	Pathogens	other	% parasitism
Sprayed beans 215	1	19	31	0.5
Unsprayed beans 326	146	33	35	44.8
Unsprayed cover crop 188	129	14	11	68.6

The legume pod borer, *M. vitrata*

Nature of pest and release site

The origin of the pod borer, *M. vitrata* (syn. *M. testulalis*), a cosmopolitan pest in the tropics, is uncertain (Waterhouse and Norris 1987). In addition, the taxonomic classification of this genus is still unclear and needs to be revised. In the past, several species of the genus were considered as a complex, but later all were synonymized under *M. testulalis* (Taylor 1967). Apart from the widespread species *M. vitrata*, the genus *Maruca* includes only two other species: *M. amboinalis* (Feld and Rog), and *M. nigroapicalis* (De Joannis). These two other species have been exclusively observed in the Indo-Malaysian and Tonkin area, and the latter has never been found again after the first description (Ghesquière 1942). Nevertheless, the Indo-Malaysian region was given as the most probable area of origin of the genus *Maruca*, including *M. vitrata* (Prof. Munroe, Ottawa, Canada, personal communication).

Detailed studies on the importance of alternative host plants for the population dynamics of *M. vitrata* have revealed that this insect is oligophagous, feeding and reproducing on a number of cultivated and wild host plants, all of which belong to the Fabaceae (Leumann 1994; Arodokoun 1996). Further, the alternation of the flowering pattern of these plants on a south-north gradient has been found to influence the migration of *M. vitrata* from the coast to the dry savannas of West Africa (Bottenberg et al. 1997, in this volume). During this migration, the population of *M. vitrata* finds favorable conditions for multiplying on the different host plants, thereby increasing the size of each new generation. When this huge population reaches the main cowpea growing areas in the northern regions, it is too late to intervene unless highly resistant varieties are available, or intensive pesticide use is envisaged. To prevent the buildup of such large populations, a suitable biocontrol agent should be able to arrest their migration from the south to the north. Therefore, any efficient biocontrol candidate should be able to recognize the most important host plants for *M. vitrata*, in order to follow the pest migration through host switching.

Availability of biocontrol agents

Although *M. vitrata* is attacked by several different natural enemies (Table 4 lists the parasitoids and predators that have been recorded in Africa), the available quantitative data indicate that the overall parasitism rates on cowpea are low, mostly between 5 and 15% (Taylor 1967; Okeyo-Owuor et al. 1991). On the most common alternative host plants for *M. vitrata* in the moist savanna, recent investigations (D.Y. Arodokoun, unpublished data) indicate significantly higher parasitism rates in these more stable ecosystems, often averaging over 20% (Table 2). However, the same study suggests that, despite the higher biotic mortality, these wild host plants suffer considerable feeding damage through *M. vitrata* larvae.

A life tables study by Okeyo-Owuor and Oloo (1991) indicates very high mortality rates from egg to adult in western Kenya. Although disappearance accounts for > 50% of the compounded mortality, the impact of pathogens is considered an important mortality factor, as confirmed by the data of Otieno et al. (1983) and Odindo et al. (1989). Still, field data on pest infestation strongly indicate that the available biotic mortality is not sufficient to keep *M. vitrata* populations under the damaging level.

Table 4. Parasitoids and predators of *Maruca vitrata* in Africa.

Organism	Stage affected†	Country	Source
PARASITOIDS			
Diptera			
Muscidae			
<i>Musca domestica</i> f. <i>callara</i>	L	Nigeria	Taylor 1967
Tachinidae			
<i>Pseudoperichaeta laevis</i>	L	Nigeria	Usua 1975; Usua and Singh 1978; Ezueh 1991
<i>Thelaitrodoms palposum</i>	L	Nigeria	Usua 1975; Usua and Singh 1978; Ezueh 1991
undetermined	P	Kenya	Okeyo-Owuor et al. 1991
undetermined	P	Benin	Arodokoun (unpub. data)
Hymenoptera			
Braconidae			
<i>Apanteles</i> sp.	L	Kenya	Okeyo-Owuor et al. 1991
<i>Bracon</i> sp.	L, P	Kenya	Okeyo-Owuor et al. 1991
<i>Braunsia</i> sp.	L	Nigeria	Taylor 1967; Usua 1975; Usua and Singh 1978; Ezueh 1991
<i>B. kriegeria</i>	P	Kenya	Okeyo-Owuor et al. 1991
<i>Chelonus</i> sp.	L	Benin	Arodokoun (unpub. data)
<i>Phanerotoma</i> sp.	L	Kenya	Okeyo-Owuor et al. 1991
	L	Nigeria	Taylor 1967; Usua 1975; Usua and Singh 1978
<i>Pristomerus</i> sp.	E, L	Benin	Arodokoun (unpub. data)
	L	Benin	Arodokoun (unpub. data)
Chalcididae			
<i>Antrocephalus</i> sp.	P	Kenya	Okeyo-Owuor et al. 1991
<i>Brachymeria</i> sp.	P	Benin	Adango 1994
Eulophidae			
<i>Tetrastichus</i> sp.	L	Nigeria	Usua 1975; Usua and Singh 1978; Ezueh 1991
<i>T. sesamiae</i>	P	Kenya	Okeyo-Owuor et al. 1991
Trichogrammatidae			
<i>Trichogrammatoidea</i> sp.	E	Benin	Tamò (unpub. data)
PREDATORS			
Aranea			
Selenopidae			
<i>Selenops radiatus</i>	L, A	Nigeria	Usua 1975; Usua and Singh 1978; Ezueh 1991
Dermaptera			
<i>Diaperasticus erythrocephala</i>	L, P	Kenya	Okeyo-Owuor et al. 1991
Dictyoptera			
Mantidae			
<i>Polyspilota aeruginosa</i>	A	Nigeria	Usua 1975; Usua and Singh 1978
<i>Spodromantis lineola</i>	A	Nigeria	Usua 1975
Hymenoptera			
Formicidae			
<i>Campanotus sericeus</i>	L	Nigeria	Usua 1975; Usua and Singh 1978; Ezueh 1991
<i>C. rufoglaucus</i>	L	Kenya	Okeyo-Owuor et al. 1991

† E = egg; L = larva; P = pupa; A = adult.

Current status of classical biocontrol

Based on the taxonomist's assumption that *M. vitrata* is native to southeast Asia, we would expect to find in that region more efficient natural enemies for this pest. In fact, in the Indo-Malaysian region, *M. vitrata* has been reported in the past only as a minor pest (Kalshoven and van der Vecht 1950). The same authors indicate a larval parasitoid, *Phanerotoma philippinesnsis*, and a pupal parasitoid, *Bassus* sp. (Hymenoptera, Braconidae), as the natural enemies responsible for this low occurrence. More recently, however, *M. vitrata* has become one of the key pests on legumes in southeast Asia. Personal observations by the first author in Malaysia suggest that *M. vitrata* is probably an induced problem, caused by the misuse of pesticides in vegetable legumes. In fact, in regions where vegetable farmers apply an average of two sprays a week with combinations of up to three pesticides, it is easy to imagine the buildup of pesticide resistance and loss of natural enemies.

The next logical step for the assessment of the feasibility of biocontrol would be to test both the efficacy and specificity of *M. vitrata* parasitoids from southeast Asia, and introduce the most promising ones into Africa. Though the long list in Table 4 indicates that there are already many parasitoids in Africa, careful ecological studies would be needed before any releases are made.

It is important that there are no known parasitoids recorded from South America, where *M. vitrata* was first discovered. One implication of this could be that *M. vitrata* is economically more important in Africa than in other geographical regions, and it is consequently better investigated there. Another could be that *M. vitrata* is not a big problem in South America because it is kept under control by antagonists, whose identity is not yet known. Evidently, the actual knowledge about the regional distribution and importance of natural enemies of *M. vitrata* presents some gaps, which need to be filled before further assumptions concerning the origin and the chances of biocontrol can be made.

At the same time, one should keep in mind the unsuccessful attempts at biological control of *M. vitrata* cited in Waterhouse and Norris (1987), and learn from the possible causes of these failures.

Conclusions

There is, thus, a potential for biocontrol against the two major cowpea pests discussed. The investigation of pest origin, one of the most important assumptions for classical biological control, has revealed that both *M. sjostedti* and *M. vitrata* might have originated in Southeast Asia. This hypothesis is further strengthened by the apparent lack of co-evolution in their natural environment, as indicated by the frequent severe damage on the flowering structures of alternative host plants, as well as the overall low biotic mortality inflicted by natural enemies. Also, given the case that exotic natural enemies are to be released, the alternative host plants available throughout the year could be critical for their survival when cowpea is not available.

The discovery and collection of a first larval parasitoid from a related thrips species in Malaysia is encouraging. However, further exploration elsewhere in tropical Asia is needed to ascertain the presence of different strains of *C. menes*, or of other parasitoid species.

Concerning the search for biocontrol candidates for *M. vitrata*, it is recommended that explorations be conducted on wild alternative host plants in its area of origin, to avoid interferences caused by excessive pesticide applications.

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