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Abstract

The Heteroceptidae, Canestriniidae, Podapolipidae (Astigmata) and Hemisarcopidae (Prostigmata) are the mite families most commonly reported as chrysomelid associates. Heteroceptids and canestriniids are predominantly commensals on cassidines and hispines; they are probably abdominal exudatophagous or fungivorous. Podapolipids and hemisarcopidae have been found parasitising leaf beetles; their potential as biocontrol agents remains experimentally undocumented. Apparently, there are no predatory acarines specific to chrysomelids. The impact of mites on leaf beetle populations appears to be limited. Abiotic factors such as temperature, relative humidity, and biotic factors such as host plant characteristics, ant predation, and insect parasitism are probably more important than acarines in regulating leaf beetle populations.

1. Introduction

The Acari (mites, ticks, chiggers, and others) and the Chrysomelidae, or leaf beetles, are two groups of major agricultural importance. Both cause losses by their feeding and have been implicated as vectors of plant diseases (Fulton *et al.*, 1980; Lapierre, 1980; Waterworth *et al.*, 1977). In addition, more than 30,000 species have been described for each group (Krantz, 1978; Lopatin, 1984) and many more will become known to science.

The literature on the biological associations of these two groups is scarce. Apparently, the Italian acarologist Antonio Berlese (1897 *in*, OConnor, 1982) was the first to report an acari-chrysomelid association. Further citations are scattered until recently when some consideration was given to the use of mites as possible biological control agents of leaf beetles, such as the Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say) (Baker & Eickwort, 1975; Eickwort, 1982; OConnor, 1982).

The purpose of this paper is to review the literature on acari-chrysomelid associations. Most reports on mite-chrysomelid associations are limited to only mentioning the relationship; Table 1 summarizes these data. Commensal, parasitic, and predatory relations and the potential of the mites as biocontrol agents of leaf beetles will be examined. Competition will not be included as it has not been reported among these taxa although several papers report the coexistence of phytophagous mites and leaf beetles on

agricultural weeds (Balloch & Mohyuddin, 1969; Mustaque & Balloch, 1979) and in forests (Kleinert, 1976; probably an underestimation of insect and mite abundance, compare to Erwin, 1983 and May, 1990). We will also point out some of the complexities associated with the possible use of acarines as biological control agents of leaf beetle pests. Finally, we will suggest possible future research avenues on the subject.

2. Commensalism (Figs. 1–2)

Commensalism is an association between two organisms in which one obtains an energetic benefit from the relation and the other is not affected. Heteroceptid- and canestriniid-chrysomelid relations are the best known among the commensal associations.

Chrysomelid-associated, as well as other permanent entomochorous acarines usually have several morphological features associated with their life style. Generally, they have a flattened body, latigradous legs, and reduced chetotaxy. A hypopal deutonymph is absent and all stages of the mite can occur on the beetle (OConnor, 1979). The beetles live long enough to allow the transfer of acarines from one host to another.

Heteroceptids may be more common than previously suspected. Most of the known hosts of heteroceptids are chrysomelids. For example, OConnor (1979) discovered about 60 new species to be placed in 15 genera and three subfamilies of the Heteroceptidae (Astigmata).

It is speculated that heteroceptids feed mostly on the exudates (=exudatophagy) produced in the leaf beetle's subelytral space (OConnor, 1982). Other heteroceptids feed on fungi (Laboulbeniales), which are potential parasites of chrysomelids, that can grow on the beetle's tergites. OConnor (1982) suggested that this fungivory might represent a case of mutualism.

Acrotocarus is a commensal canestriniid exclusively associated with *Physonota* (Cassidinae) (Summers & Schuster, 1979a). However, the impact of these mites on the beetles is unknown.

Table 1. Associations of mites (Acari) and chrysomelids

Mite taxon and author	Host (subfamily) geographic distribution of association	Nature of association	Reference
ORDER MESOSTIGMATA			
Laelapidae Berlese, 1892			
<i>Androlaelaps</i> sp.	<i>Diabrotica virgifera</i> (Galerucinae), United States	egg, larval predator	Chiang, 1970
<i>Stratiolaelaps</i> sp.	<i>Diabrotica longicornis</i> (Galerucinae), United States	egg, larval predator	Chiang, 1970
Uropodidae Berlese, 1917			
<i>Uropoda</i> sp.	<i>Diabrotica melanocephala</i> (Galerucinae), probably South America	predator	Thompson and Simmonds, 1965
ORDER PROSTIGMATA			
Pyemotidae Oudemans, 1937			
<i>Pyemotes ventricosus</i> (Newport, 1950)	<i>Promecotheca caeruleipennis reichii</i> (Hispiinae), Fiji	larval (especially 1st instar) predator	Taylor, 1937; Thompson and Simmonds, 1965
" <i>Pyemotes ventricosus</i> "	<i>Fidia viticida</i> (Eumolpinae); <i>Promecotheca mesuleipennis</i> (Hispiinae)	egg, larval, pupal, teneral adult predator	Cross <i>et al.</i> , 1975
<i>Pyemotes</i> sp.	<i>Chaetocnema ectypa</i> (Alticinae), USA	predator	Thompson and Simmonds, 1965
Podapolipidae Oudemans, 1931			
<i>Chrysomelobia elytrosphaera</i> Fain, 1987d	<i>Elytrosphaera xanthopyga</i> (Chrysomelinae), Brazil	under elytra	Fain, 1987d
<i>C. labidomerae</i> Eickwort, 1975	<i>Leptinotarsa cacica</i> (Chrysomelinae)	adult parasite	Drummond <i>et al.</i> , 1984
	<i>L. decemlineata</i> , México	adult parasite (Fig. 5)	Eickwort 1982; Drummond <i>et al.</i> , 1984; Hsiao, <i>pers. comm.</i> to JASB, 1992
	<i>L. undecemlineata</i>	adult parasite	Drummond <i>et al.</i> , 1984
	<i>Labidomera clivicollis</i> (Chrysomelinae), North America (nature and laboratory)	adult parasite (Fig. 3,4)	Bocker and Eickwort, 1975; Eickwort, 1975
<i>C. mahunkai</i> Regenfuss, 1968	<i>Chrysolina (=Chrysomela) graminis</i> (Chrysomelinae)	adult parasite	Regenfuss, 1968
Trombidiidae Leach, 1815			
<i>Teresothrombium susteri</i> Feider, 1956 (larvae)	<i>Promecotheca atra</i> , <i>P. nemorum</i> (Hispiinae)	parasite	Feider, 1956
<i>Trombidium holosericeum</i> (Linnaeus, 1758) (larvae)	<i>Leptinotarsa decemlineata</i> (Chrysomelinae), France	parasite	Thompson and Simmonds, 1965
<i>T. parasiticum</i> (DeGeer, 1783) (larvae)	<i>Bromius obscurus</i> (Eumolpinae)	parasite	Oudemans, 1912
<i>Trombidium</i> sp.	<i>Diabrotica vittata</i> (Galerucinae)	protelean parasite	Welbourne, 1982
<i>Trombidium</i> spp.	<i>Longitarsus parvulus</i> (Alticinae), Ireland	parasite	Thompson and Simmonds, 1965
unidentified trombidiform	<i>Oulema</i> spp. (Criocerinae), Poland	egg predator	Miczulski, 1973a
Anystidae Oudemans, 1902			
<i>Anystis baccharum</i> (Linnaeus, 1758)	<i>Oulema melanopus</i> (Criocerinae), Sweden	egg predator	Borg, 1983
Erythraeidae Oudemans, 1902			
<i>Leptus ignotus</i> (Oudemans, 1903) (larvae)	<i>Phratora (=Phyllodecta) laticollis</i> (Chrysomelinae) The Netherlands	parasite	Oudemans, 1912

Table 1. (Continued)

Mite taxon and author	Host (subfamily) geographic distribution of association	Nature of association	Reference
<i>L. japonicus</i> Kawashima, 1956 (larvae)	<i>Chrysolina aurichalcea</i> , <i>Lypesthes fulvus</i> (Eumolpinae), Japan	parasite	Kawashima, 1953
<i>L. phyllotretae</i> Feider, 1956 (larvae)	<i>Phyllotreta atra</i> , <i>P. nemorum</i> (Alticinae)	parasite	Feider, 1956
<i>L. stolae</i> Haitlinger, 1987 (larvae)	<i>Stolas nudicollis</i> (Cassidinae), Brazil	parasite	Haitlinger, 1987
<i>Momorangia</i> Southcott, 1972, n.sp. (larvae)	<i>Asphaera</i> sp. (Alticinae), Minas Gerais, Brazil	parasite	Fain and Santiago-Blay, <i>in press</i> (1993)
ORDER ASTIGMATA			
Hemisarcoptidae Oudemans, 1908			
<i>Linobia coccinellae</i> (Scopoli, 1763)	<i>Chrysomela populi</i> (Chrysomelinae)	hematophagus parasite	OConnor, 1982
Acaridae Latreille, 1802			
<i>Acarus</i> sp. (the name <i>Tyroglyphus</i> has been rejected)	<i>Promecotheca caeruleipennis reichii</i> (Hispinae), Fiji	predation?	Taylor, 1937
Histiotomatidae Berlese, 1897			
new genus, new species (hypopus)	<i>Lema nigripes</i> (Criocerinae), Puerto Rico	phoretic commensal (Fig. 1)	Fain and Santiago-Blay, <i>in press</i> (1993)
Heteroceptidae Fain, 1966			
<i>Heteroceptes tarsii</i> Fain, 1966	<i>Aspidomorpha santaecrucis</i> (Cassidinae) widely distributed;	fungivorous?, commensal	OConnor, 1979, 1982
"two genera in the most primitive subfamily of Heteroceptidae"	<i>Brontispa</i> , <i>Plesispa</i> , <i>Anisodera</i> (Hispinae), Oriental Region	Laboulbeniales fungivores, commensal	OConnor, 1979
"derived" subfamily of Heteroceptidae	<i>Diclidispa</i> , <i>Exothispa</i> (Hispinae), <i>Laccoptera</i> , <i>Aspidomorpha</i> , <i>Conchyloctenia</i> , <i>Laccoptera</i> (as <i>Patrisma</i>), <i>Netosacantha</i> (Cassidinae), sub-Saharan, Africa, and Madagascar	fungivorous?, commensal	OConnor, 1979, 1982
"third subfamily" of Heteroceptidae	<i>Aspidomorpha</i> , <i>Laccoptera</i> , <i>Metriona</i> , <i>Thalspida</i> , <i>Thalspidosoma</i> , <i>Basiprionota</i> (<i>Prioptera</i> is a junior synonym of <i>Basiprionota</i>) (Cassidinae), Oriental Region	fungivorous?, commensal	OConnor, 1979, 1982
Canestriniidae Berlese, 1884			
<i>Acrotocarus alutaceus</i> (Turk, 1948)	<i>Physonota alutacea</i> (Cassidinae), Trinidad	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979a; Turk, 1948
<i>A. crataepus</i> Summers and Schuster, 1979a	<i>Physonota dilata</i> (Cassidinae)	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979a
<i>A. mirabilis</i> Banks, 1915	<i>Physonota alutacea</i> , Costa Rica, Trinidad and México; <i>Physonota gigantea</i> , <i>P. durata</i> (as <i>Platycycla durata</i>), México; <i>Physonota</i> sp., Guatemala (Cassidinae); unidentified chrysomelids, México	fungivorous or exudatophagous commensal?	Banks, 1915; Summers and Schuster, 1979a
<i>Gasuthiana abapoica</i> Haitlinger, 1989	<i>Alurnus elysianus</i> (Hispinae), Brazil	fungivorous or exudatophagous commensal?	Haitlinger, 1989
<i>G. abufarica</i> Haitlinger, 1989	<i>Coraliomela brunnea nigripes</i> (Hispinae), Bolivia; <i>Mecistomela marginata</i> (Hispinae), Brazil	fungivorous or exudatophagous commensal? (Fig. 2)	Haitlinger, 1989; Fain (this work)

Table 1. (Continued)

Mite taxon and author	Host (subfamily) geographic distribution of association	Nature of association	Reference
<i>G. coarica</i> Haitlinger, 1989	<i>Mecistomela marginata</i> , Brazil	fungivorous or exudatophagous commensal?	Haitlinger, 1989
<i>G. olareica</i> Haitlinger, 1989	<i>Alurnus bipunctatus</i> (Hispiinae), French Guyana, <i>A. boulandi</i> Colombia	fungivorous or exudatophagous commensal?	Haitlinger, 1989
<i>Grandiellina</i> Fain, 1989 n.n. (= <i>Grandiella</i> Lombardini, 1939, homonym of <i>Grandiella</i> Williams, 1928)		fungivorous or exudatophagous commensal?	Fain, 1989
<i>G. arcuata</i> (Fain, 1987b)	<i>Stolas decemguttatus</i> (Cassidinae)	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. brevispinata</i> (Summers and Schuster, 1979b)	<i>Stolas plagiata</i> (Cassidinae), Panamá	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b
<i>G. conula</i> (Summers and Schuster, 1979b)	<i>Omaspides bistrata</i> (Cassidinae), Panamá	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b
<i>G. cooremani</i> (Fain, 1987b)	<i>Canistra osculatii</i> (Cassidinae), Ecuador	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. decemcaudata</i> (Lombardini, 1950)	<i>Echoma marginata</i> (as <i>Omoplata marginata</i>) (Cassidinae) Bolivia; <i>Coptocyclus contemta</i> (Cassidinae), Paraguay	fungivorous or exudatophagous commensal?	Lombardini, 1950
<i>G. echinoderma</i> (Summers and Schuster, 1979b)	<i>Eugenysa colombiana</i> (Cassidinae), Colombia; <i>Eugenysa</i> sp., Panamá	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b; Fain, 1987b
<i>G. ecuadorensis</i> (Fain, 1987b)	<i>Canistra osculatii</i> (Cassidinae), Ecuador	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. esacaudata</i> (Lombardini, 1939)	<i>Stolas</i> sp. Mexico, Bolivia; <i>Canistra</i> sp., Bolivia (Cassidinae); <i>Echoma marginata</i> (as <i>Omoplata marginata</i>) (Cassidinae), French Guyana; <i>Stolas punicea</i> , Guatemala; <i>S. lebasii</i> , Costa Rica	fungivorous or exudatophagous commensal?	Lombardini, 1939; Summers and Schuster, 1979b
<i>G. foliacea</i> (Fain, 1987b)	<i>Stolas areolata</i> , <i>S. chalybaea</i> (Cassidinae), Brazil; <i>S. conspersa</i>	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. gambosa</i> (Summers and Schuster, 1979)	<i>Discomorpha batesi</i> , Belize (Cassidinae); <i>D. depilata</i> , <i>D. lanuginosa pubescens</i> ; <i>Discomorpha</i> sp., Panama <i>Discomorpha conspersipennis</i> (as <i>Dolichotoma conspersipennis</i>) (Cassidinae)	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b; Fain, 1987b
<i>G. jolivetii</i> (Fain, 1987b)	<i>Elytrosphaera xanthopyga</i> (Chrysomelinae), Brazil	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. kimseyi</i> (Summers and Schuster, 1979b)	<i>Discomorpha conspersipennis</i> (Cassidinae), Colombia; <i>Discomorpha</i> sp., Panamá	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b
<i>G. latipes</i> Fain, 1989	<i>Stolas inaequalis</i> (Cassidinae), South America, specific locality not defined	fungivorous or exudatophagous commensal?	Fain, 1989b
<i>G. minor</i> (Fain, 1987b)	<i>Canistra dohrni</i> (Cassidinae), Brazil	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. multifida</i> (Fain, 1987b)	<i>Stolas antiqua</i> (Cassidinae), Brazil	fungivorous or exudatophagous commensal?	Fain, 1987b

Table 1. (Continued)

Mite taxon and author	Host (subfamily) geographic distribution of association	Nature of association	Reference
<i>G. octocaudata</i> (Lombardini, 1950)	<i>Stolas chalybaea</i> (Cassidinae), Brazil	fungivorous or exudatophagous commensal?	Lombardini, 1950
<i>G. pentagona</i> (Lombardini, 1950)	Cassidinae, Venezuela	fungivorous or exudatophagous commensal?	Lombardini, 1950
<i>G. platysma</i> (Summers and Schuster, 1979b)	<i>Coptocyclus</i> sp. (Cassidinae), Panamá	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b
<i>G. quadrata</i> (Fain, 1987b)	<i>Eugenysa columbiana</i> (Cassidinae), Colombia; <i>Stolas aenea</i> (Cassidinae), Brazil; <i>S. chalybaea</i> , <i>S. conspersa</i> , Brazil; <i>S. funebris</i> Bolivia; <i>S. indigacea</i> , Brazil	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. rosascostai</i> (Lombardini, 1950)	<i>Stolas</i> sp. (Cassidinae) Bolivia	fungivorous or exudatophagous commensal?	Lombardini, 1950; Summers and Schuster, 1979b
<i>G. rugosita</i> (Summers and Schuster, 1979b)	<i>Acromis sparsa</i> (Cassidinae), Panama	fungivorous or exudatophagous commensal?	
<i>G. sicula</i> (Summers and Schuster, 1979b)	<i>Stolas</i> sp. (Cassidinae), Perú; <i>Coptocyclus nigropunctata</i> (now probably <i>Orexitia nigromaculata</i>), Colombia; <i>C. near wagneri</i> (now probably <i>Orexitia near wagneri</i>) (Cassidinae)	fungivorous or exudatophagous commensal?	Lombardini, 1950
<i>G. spicantis</i> (Summers and Schuster, 1979b)	<i>Canistra rubiginosa</i> (as <i>Canistra plagosa</i>) (Cassidinae), Brazil; <i>Stolas chalybaea</i> and <i>S. conspersa</i> (Cassidinae)	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979b; Fain, 1987b
<i>G. squarrosa</i> (Summers and Schuster, 1979b)	<i>Stolas</i> sp. (Cassidinae), Perú; <i>Eugenysa grossa</i> , French Guyana	fungivorous or exudatophagous commensal?	Lombardini, 1950
<i>G. tertia</i> (Lombardini, 1942)	Cassidinae, Brazil	fungivorous or exudatophagous commensal?	Lombardini, 1942
<i>G. tetracaudata</i> (Lombardini, 1939)	<i>Botanochara sedecimpustulata</i> and <i>Cyrtanota thalassina</i> (Cassidinae), Brazil; <i>Stolas</i> sp. (Cassidinae), Perú; Cassidinae, Brazil	fungivorous or exudatophagous commensal?	Fain, 1989; Lombardini, 1939; Summers and Schuster, 1979b
<i>G. tetracaudata omoplata</i> (Fain, 1987a)	<i>Echoma marginata</i> (as <i>Omoplata marginata</i>) (Cassidinae), French Guyana	fungivorous or exudatophagous commensal?	Fain, 1987b
<i>G. vatia</i> (Summers and Schuster, 1979b)	<i>Cyrtanota tristigma</i> (Cassidinae), México	fungivorous or exudatophagous commensal?	Summers and Schuster, 1979
<i>Grandiellopsis cyclosoma</i> Fain, 1989	<i>Cyclosoma palliata</i> (Cassidinae), French Guyana	fungivorous or exudatophagous commensal?	Fain, 1989
<i>G. canistra</i> Fain, 1989	<i>Canistra osculatii</i> (Cassidinae), Ecuador	fungivorous or exudatophagous commensal?	Fain, 1989
<i>Paramansia menthastri</i> Cooreman, 1950	<i>Chrysolina menthastri</i> (Chrysomelinae), France	fungivorous or exudatophagous commensal?	Cooreman, 1950
<i>Percanestrinia (Lombardiniella) gentilis</i> (Lombardini, 1944)	<i>Chrysolina femoralis</i> (Chrysomelinae)	fungivorous or exudatophagous commensal?	Cooreman, 1950; Lombardini, 1944

Table 1. (Continued)

Mite taxon and author	Host (subfamily) geographic distribution of association	Nature of association	Reference
<i>Pseudamansia chrysomelinus</i> (C. L. Koch, 1841)	<i>Timarcha atlantica</i> (Chrysomelinae), Maroc; <i>T. balearica</i> , Mayorca Is., <i>T.</i> <i>goettingensis</i> , France; <i>T.</i> <i>interstitialis</i> , France; <i>T. nicaeensis</i> (larvae), Mayorca Is.; <i>T. pauperata</i> , France; <i>T. punctella</i> , Maroc; <i>T.</i> <i>rugosa</i> , Algeria; <i>T. tenebricosa</i> <i>pauperata</i> , France; <i>Timarcha</i> sp., (Belgium, Italy)	fungivorous or exudatophagous commensal?	Cooreman, 1950; Jolivet, 1952; Theodorides, 1955
unidentified acarine	<i>Fidia viticada</i> (Eumolpinae)	fungivorous or exudatophagous commensal?	Krczal, 1959

Soil acarines tend to have adaptations for phoresy such as a hypopus in the life history, large chelicerae, or reduced body legs, and peritremes (Lindquist, 1975). Commensal soil mites are abundant on carabids but seem rare on chrysomelids (Samsinak, 1971).

3. Parasitism (Figs. 3-5)

Parasitism is the gathering of energy by one organism (parasite) from a larger one (host) that is sometimes followed by the death of the host. Two acarine families are common parasites of chrysomelids: the Podapolipidae and the Hemisarcoptidae.

Podapolipids tend to be located on the beetle's abdominal region and frequently exhibit a differential location on the host's body as their own development proceeds (Baker & Eickwort, 1975). *Chrysomelobia elythrospphaerae* (Fain, 1987c) immatures and adults were found under the elytra of *Elythrospphaera xanthopyga* (Chrysomelinae). Podapolipids disperse during their host's copulation and may have complicated life histories (Husband & Sinha, 1970).

Some carabid podapolipids reside in membranous sacs continuous with the host's reproductive organs, a location that has not been reported for chrysomelids. Since these mites are small (<50µm long) staining the beetle's reproductive organs with orcein has been used to visualize them (Stannard & Vaishampayan, 1971).

Chrysomelobia is the only parasitic podapolipid genus reported on chrysomelids (Regenfuss, 1973) (Figs. 3-5). Species of this group puncture the host's cuticle with their styletiform chelicerae and suck the hemolymph (Baker & Eickwort, 1975; Eickwort & Eickwort, 1986; Taylor, 1937). About ten conspecific podapolipids have been found to simultaneously parasitize the Milkweed leaf beetle, *Labidomera clivicollis* (Kirby) (Chrysomelinae) in labora-

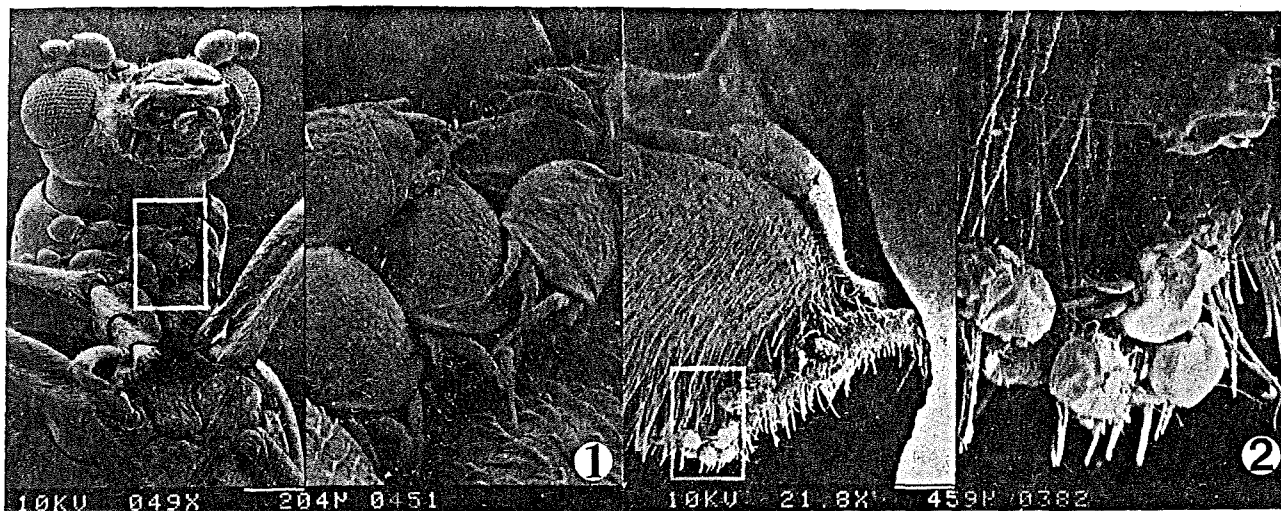
tory experiments (Baker & Eickwort, 1975) but their impact on the host's longevity, total fecundity, and daily oviposition is minimal (Eickwort & Eickwort, 1986).

Hemisarcoptids can parasitize all stages of chrysomelids except the egg (OConnor, 1982). For instance, *Linobia coccinellae* (Scopoli) is a permanent hematophagous parasite of *Chrysomela populi* L. (Chrysomelinae) (OConnor, 1982).

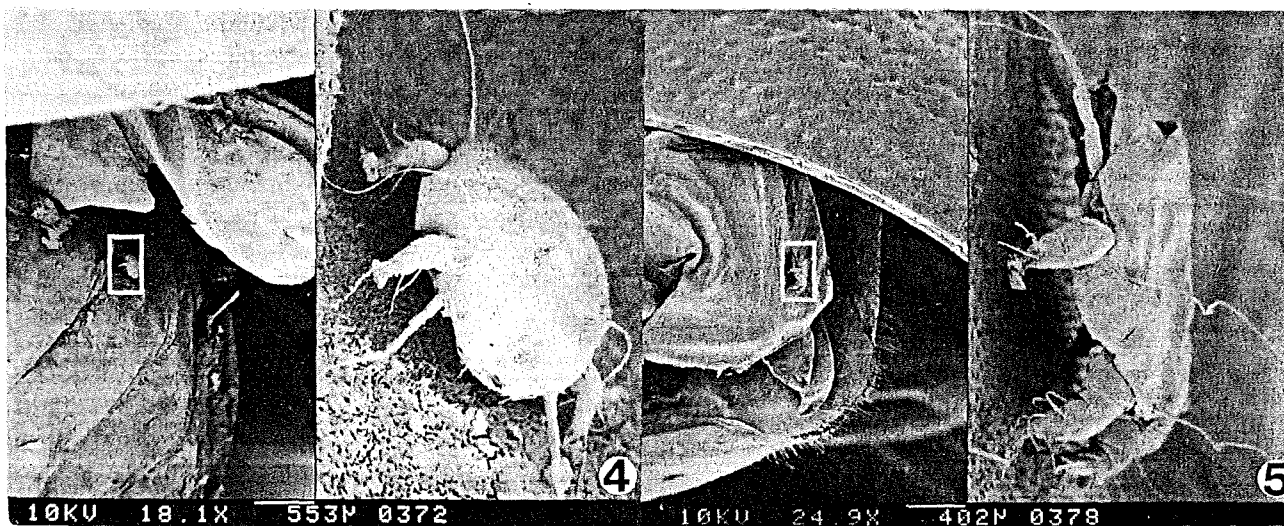
Some parasitic mites can have a significant impact on leaf beetle populations. Eickwort (1982) reported that *Chrysomelobia labidomerae* Eickwort does 'appear to affect [the Colorado potato beetle, *L. decemlineata* (Say)] mortality and fecundity and might prove of value in biological control programs'. OConnor (1982) considered that '*L. coccinellae* has the same control potential for the Colorado potato beetle as does *C. labidomerae*'. Feider (1956) reported a similar situation for *Teresothrombium susteri* parasitic on *Phyllotreta* spp. (Alticinae). According to Eickwort (1982), T. H. Hsiao (University of Utah, Longan, USA) has worked on the possible biological control of *L. decemlineata* employing *C. labidomerae*. Apparently, no report on the subject has been published yet. On the other hand, Drummond *et al.* (1984) found as much as 100% parasitization by *C. labidomerae* on several species of *Leptinotarsa* (Chrysomelinae) in México but no data describing the effects of the acarines on their hosts was included. In none of these cases has the biocontrol potential of the mites been field tested.

4. Predation

Predation is the gathering of energy by one organism (predator) from a usually smaller one (prey) followed by the death of the prey. There seems to be no predatory mite specialists on leaf beetles.



3



Figs. 1-5. (1) Deutonymphs or hypopi of Histiosomatidae (new genus and species), a phoretic commensal, on *Lema nigripes* (Criocerinae) from Puerto Rico. Insert 5 \times ; (2) *Gasuthiana abufarica*, a commensal, on *Meristomela marginata* (Hispiinae) from Brazil. Insert 5 \times . (For more information of *M. marginata*, see Chapter by Valverde de Macedo *et al.* in this book.); (3) Many *Chrysomelobia labidomerae*, an adult parasite, on *Labidomera clivicollis* (Chrysomelinae) from North America. (Photo courtesy of G. C. Eickwort.); (4) *C. labidomerae* on *L. clivicollis*, details. Insert 10 \times ; (5) *C. labidomerae* on *Leptinotarsa decemlineata* (Chrysomelinae) from México. Insert 10 \times .

Prey items of mites can ideally be identified by paper chromatography (Putman, 1965) although this method has serious limitations in comparison with the more precise immunologic precipitation tests (Dempster, 1960). (For some recent papers that use molecular techniques in agricultural entomology, see Brewer, 1991; Dary *et al.*, 1991; Hagler *et al.*, 1992; and Keating *et al.*, 1991.)

Above ground predatory acarines, such as erythraeids (Prostigmata) are abundant in some agroecosystems. Nevertheless, these mites are polyphagous and apparently feed on available prey items (Thompson & Simmonds, 1965). For instance, in the laboratory, erythraeids have even been fed on crushed *Drosophila melanogaster* (Putman, 1970).

There is a case in which manure management was followed by increased populations of laelapids (Mesostigmata). This practice presumably contributed to the observed larval population decline of two *Diabrotica* spp. (Galerucinae) in a Minnesota corn field (Chiang, 1970). However, mites predatory on rootworms were not found in a similar situation in Québec, Canada (Dominique *et al.*, 1984). Laboratory life table studies have shown that predatory laelapids have a very low intrinsic rate of growth ($r=0.05$ mites/week), a low net reproduction rate ($R=2.58$ mites/generation), and are not specific to *Diabrotica* spp. or other leaf beetle eggs or larvae (Mihm & Chiang, 1976). Taylor (1937) found that the percentage of *Promecotheca caerulipennis reichii* Baly (Hispinae) (as *Promecotheca reichi*) predated upon or parasitized by mites in Fiji's coconut plantations was negligible, especially when the beetles were spatially separated.

Entomochorous soil mites are very abundant (Lindquist, 1970) but none of them have been reported as a predator, or in any other way associated with chrysomelids, in spite of many chrysomelid larvae being soil dwellers. The distribution and some ecological aspects of soil acarines can be studied with little perturbation to the soil employing the dilute agar technique devised by Haarlov and Weis-Fogh (1953).

Most of the evidence indicates that mites do not have a strong impact on leaf beetle pest populations (Risch, 1981). Their absence in many cases of sudden leaf beetle outbreaks (Hopkins & Mueller, 1983; Jeffords *et al.*, 1983; Riley, 1983) suggests their minor role as natural control agents. Acarines that predate upon chrysomelids probably should be regarded as members of the general predator complex that serves as biological control of pests, especially of other mites (Putman, 1970). Welbourne's (1982) opinion on trombidoids may well apply here for acarines predaceous on chrysomelids: 'only a few species appear to be of potential interest for biological control'.

5. Host specificity of the mites living on chrysomelids

As expected, host specificity is greater in parasites or commensals that are permanently attached to their hosts, especially if this relationship lasts their entire life history (e.g. Podapolipidae and Canestriniidae) than in species that remain on their hosts only for a short time (e.g. phoretic mites or mites that parasitize their host only during their larval stage, such as *Trombidium* spp. and *Leptus* spp.).

In the Podapolipidae and the Canestriniidae, the specificity is very evident at the host's subfamily level. For example, the three known species of *Chryso-melobia* (Podapolipidae) are confined to the Chrysomelinae. In addition, among the named species of Canestriniidae living on chrysomelids, four species, each belonging to different genera (*Percanestrinia*, *Pseudomansia*, *Paramansia*, and *Grandiellina*), are found only on Chrysomelinae; the four known species of *Gasuthiana* are restricted to the Hispinae, and three *Acrotocarus* species, two *Grandiellopsis*, and all but one of 26 *Grandiellina* are found only on Cassidinae. The only exception, *Grandiellina joliveti*, lives on a chryso-meline.

In the Heterococtidae almost all species have cassidine and hispine hosts from the Afrotropical and Oriental Regions (O'Connor, 1982); only a few Central African species have been described from other hosts (Fain, 1987a).

6. Complexity of the interactions

Mites and chrysomelids should be studied in the context of the physical and biological environment.

Abiotic factors are probably major forces regulating the abundance and distribution of acari and insect populations, especially in annual ecosystems. High temperatures and low humidities seem to control pupal populations of the cereal leaf beetles, *Oulema* spp. (Criocerinae), (Miczulski, 1973b; Wellso & Hoxie, 1981). A balanced mineral soil fertilization can prevent leaf beetle and other pest outbreaks (Persin *et al.*, 1976). The type of soil, its relative humidity, and the availability of appropriate food are partial determinants for oviposition success of the Bean leaf beetle, *Cerotoma trifurcata* (Forster) (Helm *et al.*, 1983, Marrone & Stinner, 1983). Evidence has accumulated supporting the idea that sudden catastrophic events can be important regulators of animal populations. For example, a population crash of the Bean leaf beetle in Illinois was attributed to poor phenological synchrony between this galerucine and its host (Jeffords *et al.*, 1983).

Biological factors, such as leaf pubescence, seem to be the major cause of the diminished oviposition by

O. melanopus (L.) on wheat (Webster, 1975). Acarines tend to be very small and can easily be overpowered by most stages of leaf beetles. Other organisms such as ants (Risch, 1981; but see Ballard & Mayo, 1979), parasitic flies and hymenopterans (Borg, 1983), and pathogens (Marrone *et al.*, 1983; Miczulski, 1973a) are probably better biocontrol agents of leaf beetles than mites.

7. Recommendations

A large amount of work still needs to be done on the systematics and biology of acarines (Lindquist, 1975; Samsinak, 1966; Welbourn, 1982). Krczal (1959) reported only one mite (species unidentified) associated with leaf beetles in central Europe and by the mid-1960's only one out of more than 30 known hosts of *Chrysomelobia* spp. was a leaf beetle (Thompson & Simmonds, 1965). These figures probably reflect the lack of searching for leaf beetle associates as well as the need of enough trained personnel to accomplish these tasks.

These research areas deserve economic and technical support because they provide services to applied biology and associated fields. Genetic improvement efforts (Hoy, 1982) might prove useful but they should be employed after a good understanding of the pertinent biological traits of the control agent(s) is obtained.

We cannot foresee a major breakthrough in the biological control of leaf beetles by mites alone. Their lack of predatory specificity, apparent inability to cope with major outbreaks, and their relative minor role as natural enemies led us to generalize Miczulski's view (1973a) on the impact of acarines upon Cereal leaf beetle populations: [Mites] 'should be regarded as [an] accessory mortality factor' [of leaf beetle populations].

Unless a really promising agent (or group of agents) is discovered, we would recommend investing most of the available resources in research on the basic biology and systematics of these groups, rather than in the biological control of chrysomelids by mites that has been so unsuccessful. However, some of the information obtained might prove important for biological control research of leaf beetles by mites.

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