

Sivinski, J. M. 1996. The past and potential biological control of fruit flies, pp. 369-375  
In B. A. McPherson and Steck G. J. [eds.], *Fruit fly pests: A world assessment of their  
biology and management*. St. Lucie Press, Delray Beach, Florida.

## The Past and Potential of Biological Control of Fruit Flies

*John M. Sivinski*

Insect Attractants, Behavior and Basic Biology Research Laboratory, USDA-ARS,  
Gainesville, Florida

As the Mediterranean fruit fly, *Ceratitidis capitata*, began its dramatic spread across the tropics and subtropics in the later years of the 19th century an interest in its biological control followed close behind. The agricultural community of Hawaii was particularly responsive when invaded (e.g. Silvestri 1914, Pemberton and Willard 1918). It was further galvanized 36 years later when the oriental fruit fly, *Bactrocera dorsalis*, arrived to join its relative the melon fly, *Bactrocera cucurbitae* (a resident since 1895; Clausen et al. 1965). The details of the large and sometimes heroic effort to bring tephritid natural enemies to the Hawaiian Islands and from there to many other parts of the world has been documented by the above and Gilstrap and Hart (1987).

The establishment of parasitoids had a considerable effect on Hawaiian fruit flies. Following a massive exploration and introduction program, *Bactrocera dorsalis* populations were only 6% of their former peak size (Newell and Haramoto 1968). At the same time *C. capitata* larvae fell from a mean of 0.07/coffee berry to 0.03. There have been many less dramatic declines. For instance, numbers of adult Caribbean fruit flies, *Anastrepha suspensa*, in Florida dropped 40% after the introduction of the braconid *Diachasmimorpha longicaudata* (Baranowski et al. 1993).

However, the economic returns on even the more substantial fly mortalities were not always obvious (Wharton 1989; though see Clausen 1978). The economic threshold for fly damage is very low. But the classical biological control of Tephritidae also suffers from a commonly encountered set of biological difficulties (e.g. Debouzie 1989). Those that have been perceived as particularly galling are (1) low fecundity of parasitoids compared to fruit flies, (2) poor tracking of fly population growth by parasitoids, due either to relatively ineffectual foraging at low host densities or poor survival through periods when fruit and hosts are absent, and (3) refuge from parasitoid attack for fly larvae in large/thick-skinned fruit.

There are ways to overcome these difficulties. Problems (1) and (2) can be mitigated by augmenting the numbers of parasitoids at critical times and places. Knipling, in a series of widely circulated manuscripts that were later expanded to book form (1992), argued that mass-releases of parasitoids would control and even eradicate pest tephritids. A pair of USDA-ARS pilot tests have given encouraging results. Tim Wong and his colleagues in Hawaii more than tripled parasitism and substantially reduced Mediterranean fruit fly populations by releasing approximately 20,000 *Diachasmimorpha tryoni* per square kilometer per week (Wong et al. 1991). Reductions in Caribbean fruit fly numbers of 90-95% occurred after the release of 20,000 to 60,000 *Diachasmimorpha longicaudata* per square kilometer per week (Sivinski et al., submitted). This work has been

extended and expanded by personnel of the Florida Department of Agriculture, Division of Plant Industry, who are using parasitoid releases to maintain and perhaps someday expand fly-free citrus zones (Burns et al. this volume). *Anastrepha suspensa* prefers a number of widely grown "dooryard fruit", such as guavas, loquats and Surinam cherries to grapefruit or oranges. State agronomists argue that high populations of flies in urban/suburban areas are sources of infestation for the commercial citrus groves that intermingle with communities throughout densely populated south and central Florida. They reason that fly suppression in preferred host fruits will reduce immigration into fly-free zones. Parasitoids are particularly suited to these circumstances. Growers have been reluctant to support sterile-male releases because of concerns that misidentification or delayed identification of flies trapped in their orchards could jeopardize export of their fruit. The chronic application of bait-sprays to inhabited areas is even less attractive. Monitoring of parasitoid populations through recently developed traps is likely to improve the efficacy of parasitoid augmentation (e.g., Messing and Jang 1992, Messing and Wong 1992).

As interest in augmentation increases so have experiments with rearing techniques (Wong and Ramadan 1992, Ramadan et al. this volume). Irradiation of larvae prior to exposure to parasitoids prevents fertile flies from being included in mass-releases (Sivinski and Smittle 1990). Irradiation also improves parasitism rates, presumably by compromising the flies' immune system (E. Burns, unpublished data). In *Anastrepha suspensa* it is possible to separate a large proportion of female larvae through sexual dimorphism in developmental rates (Sivinski and Calkins 1990). If females are used to produce parasitoids, what is typically considered a liability in a mass-rearing program could be turned to an advantage. The production of parasitoids also provides an opportunity to improve the product. Beside the breeding of bigger, better or specialized strains there is the possibility of behavioral manipulation. A renaissance in the study of parasitoid learning is underway (e.g., Lewis and Tumlinson 1988, see Godfray 1994). There has been an attempt to limit dispersal of *D. longicaudata* by exposure to fruit odors prior to release (J. Sivinski and J. Brombila, unpublished; see Messing et al. this volume). In this case there was no discernable effect, but it seems likely that a parasitoid typically faced with such a variety of habitats would modify its behavior with experience. Further work should be rewarded with greater success. In addition to mass-rearing, the conservation and concentration of wild parasitoids by habitat manipulation might slow the growth of fly populations in important areas and at critical times (M. Aluja, this volume; parasitism of *B. oleae* in abandoned olive orchards is substantially higher than in those treated with insecticides [Fenili and Pegazzano 1970, Neuenschwander et al. 1983]).

With the availability of augmented-parasitoid suppression techniques, a new eradication tactic becomes possible: combined releases of sterile males and natural enemies. Models, again by Knippling (1992) and with support from the more general work of Barclay (1986, 1987), predict a synergistic effect and more rapid eradication when the two types of insects are applied together. Hernan Camacho of the CEE/FUNCARDI/MAG/UCR in Costa Rica has pioneered both combined releases against pest tephritids and a "grass-roots" approach to the delivery of biological control agents to the field. Growers assist in releases with an enthusiasm born from excellent suppression, although eradication has not occurred in his non-isolated sites (Camacho, poster session XI).

The braconid employed by Camacho, Sivinski et al. and many others (including a new and unprecedentedly massive Mexican program) is *Diachasmimorpha longicaudata*. Originally from the Indo-Philippine region where it attacks *Bactrocera* spp, this late instar larval-pupal parasite also develops in Mediterranean fruit fly and *Anastrepha* spp. It has been widely disseminated (e.g., Clausen 1978). While surpassed in Hawaii by related species that attack early instars and eggs of pest tephritids, it is well adapted to Meso-America. Many of the most successful Hawaiian parasites have failed to flourish or even establish themselves in the Americas. This includes *D. tryoni*, which Wong et al. (1991) used in their augmented release program (San Juana 1974, Wharton et al. 1981, Baranowski et al. 1993). On the other hand studies by Salas (1958), Guitierrez (1976), Wharton et al. (1981), Fischel (1989) and Jiron and Mexon (1989) have consistently found *D. longicaudata* to

be the most common parasitoid of Mediterranean fruit fly in Costa Rica. It is also the leading parasitoid of *Anastrepha* spp. in Chiapas, Mexico (Aluja et al. 1990). In addition, it is extremely easy to rear, an advantage to new mass-rearing programs with inexperienced personnel. Unfortunately familiarity has bred a degree of complacency. Wharton (1989) argues with justification that entomologists have been seduced by the ease of dealing with *D. longicaudata* and a handful of other cooperative parasitoids. As a result exploitation of more difficult species and exploration for new natural enemies has languished. However, there is change in the air. In Hawaii parasitoids are being reexamined for new forms of augmented release by researchers such as Mary Purcell and Russell Messing. Through quality control and standardized rearing and shipping they have much improved the delivery of both old *D. longicaudata* and mass-rearing-newcomer *Psytalia fletcheri* to the field (e.g., Messing et al. 1993, Purcell et al., in press). Exploration for Meso-American parasitoids with specialized foraging behaviors to exploit hosts at low densities is underway (J. Sivinski and M. Aluja, personal communication; see Steck et al. 1986; Hernandez et al. 1994). Comacho (poster session XI) has added the pteromalid pupal parasitoid *Pachycrepoides vindemiae* to his releases of sterile flies and braconid larval parasitoids. This is an innovative departure from previous efforts. Recall that large/thick-skinned fruit can serve as refugia for fruit fly larvae (e.g., Sivinski 1991). The absence of refugia is critical to the success of biological control (Hawkins et al. 1993). *Diachasmimorpha longicaudata* and some other Opiinae forage extensively over fallen/broken fruit and this exposes additional larvae to attack (Bess and Haramoto 1970; parasitism in fallen guavas was 80% compared to 14% in ripe fruit on trees in one sample [J. Sivinski and R. Baranowski unpublished data]). However, pupae are likely to be similarly vulnerable regardless of the size or condition of the host fruit.

Historically the establishment of pupal parasitoids has not been particularly beneficial. For example, *P. vindemiae* itself had been introduced into Florida prior to the arrival of the Caribbean fruit fly, yet it destroyed less than 1% of the fly populations' early numbers (Baranowski et al. 1993). However, Comacho has put this species in a new perspective. Many of the Diptera-pupae parasitoids, like *P. vindemiae*, are small and poor dispersers. Augmented releases seem to overcome this handicap. If so, there is a potential arsenal of chalcidoid (e.g., *Dirhinus* spp.), and proctotrupoid (e.g., *Coptera* spp.) species that have not been used to their best advantage. Comacho has also demonstrated that *P. vindemiae* can be reared economically on nontephritid hosts. Spent diet from the mass-rearing of fruit flies is used to rear "filth flies", which in turn are hosts for the parasitoid.

There is a risk that the generalism of some pupal parasitoids is a double-edged sword. It may be difficult to limit the attack of organisms with such wide tastes to targeted pests. A "third edge" is the risk of hyperparasitism. *Spalangia gemina*, for example, a member of a genus I have heard referred to as "the Cadillac" of fly-pupae parasitoids, is typically collected from *Bactrocera* spp. Unfortunately it has also been reared from the pupae of tachinids attacking Lepidoptera (Boucek 1963). While *P. vindemiae* and certain *Spalangia* spp. discriminate to one degree or another against primary hymenopteran parasitoids (van Alphen and Thunnissen 1983, Dresner 1954), a substantial proportion of examined pupal parasitoids do not (e.g., Dresner 1954).

Another form of parasitoid behavior allows access to tephritid larvae sheltered within fruit. *Aceratoneauromyia indicum*, a gregariously developing eulophid, enters damaged fruit and crawls through the softened pulp hunting late-instar larvae (Silvestri 1914). This species is again small and unlikely to be a powerful disperser but might find a new role in augmented release programs (it has induced local parasitisms of 80% in *Anastrepha* spp. following classical introduction [Jemenez cited in Hawkins et al. 1993]). In a somewhat similar manner another eulophid, *Tetrastichus giffardianus*, waits by fissures in damaged fruit for passing larvae to be exposed (Silvestri 1914, Pemberton and Willard 1918; cynipoids, such as *Ganaspis* spp., enter holes in fruit as well [M. Aluja personal communication]). And finally, there is always hope for something new and devastating, like the mysterious chalcidoid egg-parasitoid Compere (1910) called the most effective agent of fruit fly control in South India, but which was never formally described or seen again (interestingly, the

original collection of Wong et al.'s augmented parasitoid, *Diachasmimorpha tryoni*, consisted of just 50 individuals; decades later an attempt to find additional specimens failed [Clausen et al. 1965]).

Predators of fruit flies caught the eye of the earliest investigators, although their role in population regulation or which stages are most affected is still unclear. Ants are the most frequently noted. By excluding ants from collected fruit, Pemberton and Willard (1918) concluded that *Pheidole megacephala* consumed 80% or more of immature tephritids. In the field there appear to be various causes of preimaginal mortality. While ants are major predators of *Anastrepha* larvae in certain sites in southern Mexico (M. Aluja, personal communication), in other locations loss of immatures may be more commonly due to attacks on pupae, and not necessarily by ants (see Bateman 1976). Only ca. 4% of larvae on the soil surface were killed by *Solenopsis geminata*, the "fire ant", in a Hawaiian experiment (Wong et al. 1984). Up to 25% of Mediterranean fruit fly larvae are taken by *S. geminata* in Guatemalan orange groves (Eskafi and Kolbe 1990), but even here pupal mortality not caused by *Solenopsis* is higher (see Boller 1966 on pupal mortality in European *Rhagoletis*, and Bateman 1976). However, ants may consume larvae of *Rhagoletis pomonella*, the apple maggot, to a greater extent than they do pupae (Monteith 1976; see however Allen and Hagley 1990). Teneral adults fall prey to ants (Wong and Wong 1988; see however Debouzie 1989).

Staphylinid beetles can cause considerable mortality. Eskafi and Kolbe (1990) believed seven Guatemalan species were the most common predators of local *C. capitata* pupae. The carnage inflicted by large and frenetic *Xenopygus analis* on *Anastrepha* larvae in decaying fruits makes field experiments on parasitism difficult in the mountains of southern Mexico (E. Piedra, personal communication). Staphylinids and carabids are among the major predators of the apple maggot (Allen and Hagley 1990), whose pupae they locate and dig up (Monteith 1975). Several introductions of rove beetles have been attempted (Clausen et al. 1965), but their generalist feeding has made them unpredictable, and for the most part unattractive, agents of classical biological control. Habitat management might maximize and focus the impact of endemic species (see Aluja, this volume).

There is a menagerie of peculiar, localized and occasional predators. A vespid wasp is responsible for a previously unimagined slaughter of adult *C. capitata* in the Mediterranean region, particularly pheromone-emitting males (Hendrichs and Hendrichs, this volume). The cecidomyiid, *Prolasioptera berlesiana*, destroys 30-50% of *Bactrocera oleae* eggs in western Crete, partially through transmission of a fungus (Neuenschwander et al. 1983). Crickets may be important pupal predators of *R. pomonella* in Canada (Monteith 1971). The elaborate mimicry by various fruit flies of Salticidae suggests an evolutionary history of predation on adult tephritids by jumping spiders (e.g., Greene et al. 1987, Mather and Roitberg 1987). Chickens, monkeys, pigs, lizards and frogs are often overlooked until they interfere with experiments and control efforts (e.g., Clausen et al. 1965, J. Sivinski et al. personal observation). If the difficulties they then create reflects their effect on pest populations they deserve further study. Fungi, bacteria, and viruses all infect Tephritidae (e.g., Bashiruddin et al. 1988). Their usefulness as applied pathogens has attracted relatively little attention (Debouzie 1989). Nematodes (*Steinernema* spp.) have been used to kill *C. capitata*, *B. dorsalis* and *B. cucurbitae* in the field (Lindgren 1990, Lindgren et al. 1990).

There are a number of reasons to be optimistic about the future of the biological control of fruit flies. Natural enemies have been criticized for not fulfilling traditional roles in control programs. When "released and forgotten" they sometimes flourished, but still did not necessarily reduce pest populations to the extremely stringent economic threshold levels associated with fruit, particularly exported fruit. Strategies for dealing with tephritids have changed and so have expectations for parasitoids. Lowering numbers of flies, either through release of newly discovered/appreciated species or the augmentation of old favorites, can help support fly-free zones. Combined with sterile-males they may bring about cheaper and more rapid eradications. They can make palatable and locally-salable harvests that were previously destroyed by maggots. There is a sense that the applied ecology of Tephritidae is in a bright infancy and looking toward a fruitful maturity.

## ACKNOWLEDGMENTS

Chris Geden, Aldo Malavasi and Mary Purcell made numerous improvements in the manuscript.

## REFERENCES

- Allen, W. and E. Hagley. 1990. Epigeal arthropods as predators of mature larvae and pupae of the apple maggot (Diptera: Tephritidae). *Environ. Entomol.* 19:309-312.
- van Alphen, J. and I. Thunnissen. 1983. Host selection and sex allocation by *Pachycrepoides vendemiae* Rondani (Pteromalidae) as a facultative hyperparasitoid of *Asobara tabida* Nees (Braconidae: Alysiinae) and *Leptopilina heterotoma* (Cynipoidea: Eucolidae). *Netherlands. J. Zool.* 33:497-514.
- Aluja, M., J. Guillen, P. Liedo, M. Cabrera, E. Rios, G. de la Rosa, H. Celedonio and D. Mota. 1990. Fruit infesting tephritids (Dipt.: Tephritidae) and associated parasites in Chiapas, Mexico. *Entomophaga* 35:39-48.
- Baranowski, R., H. Glenn and J. Sivinski. 1993. Biological control of the Caribbean fruit fly, *Anastrepha suspensa* (Loew). *Florida Entomol.* 76:245-250.
- Barclay, H. 1987. Models of sterile insect releases for populations under attack by parasitoids. *Ecol. Model.* 36:155-169.
- Bashiruddin, J., J. Martin and C. Reinganum. 1988. Queensland fruit fly virus, a probable member of the Picornaviridae. *Arch. Vir.* 100:61-74.
- Bateman, M. 1976. Fruit flies, pp. 11-49 in: V. Delucchi (ed.), *Studies in Biological Control*. Cambridge Univ. Press, Cambridge.
- Boller, E. 1966. Der einfluss natürlicher Reduktionsfaktoren auf die kirschenfliege *Rhagoletis cerasi* L. in der Nordwestschweiz, unter besonderer berücksichtigung des puppenstadiums. *Schweiz. Landw. Forschung* 5:154-210.
- Boucek, Z. 1963. A taxonomic study in *Spalangia* Latr. (Hymenoptera, Chalcidoidea). *Acta Entomol. Mus. Nat. Pragae* 35:429-512.
- Clausen, C.P. 1978. Introduced parasites and predators of arthropod pests and weeds: a World review. USDA-ARS Agr. Handbook No. 480.
- Clausen, C., D. Clancy and Q. Chock. 1965. Biological control of the Oriental fruit fly (*Dacus dorsalis* Hendel) and other fruit flies in Hawaii. USDA-ARS Tech. Bull. 1322.
- Compere, G. 1910. Notes on parasites of fruit flies. *Hawaii Forester and Agric.* 1-2:40-43.
- Debouzie, D. 1989. Biotic mortality factors in tephritid populations, pp. 221-227 in: A. Robinson and G. Hooper (eds.), *Fruit Flies: Their Biology, Natural Enemies and Control*. Elsevier, Amsterdam.
- Dresner, E. 1954. Observations on the biology and habits of pupal parasites of the Oriental fruit fly. *Proc. Hawaiian Entomol. Soc.* 15:299-310.
- Eskafi, F. and M. Kolbe. 1990. Predation on larval and pupal *Ceratitidis capitata* (Diptera: Tephritidae) by the ant *Solenopsis geminata* (Hymenoptera: Formicidae) and other predators in Guatemala. *Environ. Entomol.* 19:148-153.
- Fenili, G. and F. Pegazzano. 1970. Contributo alla conoscenza dei parrassiti del *Dacus oleae* Gmel. *Recherche eseguite in Toscana negli anni 1967 e 1968.* *Redia* 52:1-29.
- Fischel, M. 1982. Fluctuaciones en la densidad de poblacion y parasitoidismo en la mosca del Mediterraneo (*Ceratitidis capitata*)(Diptera: Tephritidae) en las frutas de cafe (*Coffea arabica*) en la region de Santa Domingo de Heredia, Costa Rica. Thesis, Ing. Agr., Univ. de Costa Rica.
- Gilstrap, F. and W. Hart. 1987. Biological control of the Mediterranean fruit fly in the United States and Central America. USDA-ARS, ARS-56.
- Godfray, H. 1994. *Parasitoids*. Princeton Univ. Press, Princeton, New Jersey.
- Greene, E., L. Orsak and D. Whitman. 1987. A tephritid fly mimics the territorial displays of its jumping spider predators. *Science* 366:310-312.

- Guitierrez, S. 1976. La mosca del Mediterraneo *Ceratitis capitata* (Wied.). SAG, Dir. Gral. San. Veg., Mexico.
- Hawkins, B., M. Thomas and M. Hochberg. 1993. Refuge theory and biological control. *Science* 262:1429-1432.
- Hernandez-Ortiz, V., R. Perez-Alonzo and R. Wharton. 1994. Native parasitoids associated to the genus *Anastrepha* (Diptera: Tephritidae) in Los Tuxtlas, Vera Cruz, Mexico. *Entomophaga* (in press).
- Jiron, L. and R. Mexon. 1989. Parasitoid Hymenopterans of Costa Rica: Geographical distribution of the species associated with fruit flies (Diptera: Tephritidae). *Entomophaga* 34:53-60.
- Knipling, E. 1992. Principles of insect parasitism analyzed from a new perspective. USDA-ARS Agr. Handbook No. 693.
- Lewis, W. and J. Tumlinson. 1988. Host detection by chemically mediated associative learning in a parasitic wasp. *Nature* 331:257-259.
- Lindgren, J. 1990. Field suppression of three fruit fly species (Diptera: Tephritidae) with *Steinernema carpocapsae*, p. 223 in: Proc. and Abst. 5th Intern. Coll. on Invert. Path. and Micr. Cont. Adelaide, Australia.
- Lindgren, J., T. Wong and D. McInnis. 1990. Response of Mediterranean fruit fly to the entomophagus nematode *Steinernema feltiae* in field tests in Hawaii. *Environ. Entomol.* 19:383-386.
- Mather, M. and B. Roitberg. 1987. A sheep in wolf's clothing: tephritid flies mimic spider predators. *Science* 366:308-310.
- Messing, R. and E. Jang. 1992. Response of the fruit fly parasitoid *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae) to host-fruit stimuli. *Environ. Entomol.* 21:1189-1195.
- Messing, R. and T. Wong. 1992. An effective trapping system for field studies of opiine braconid parasitoids. *Entomophaga* 37:391-396.
- Messing, R., L. Klungness, M. Purcell and T. Wong. 1993. Quality control parameters of mass-reared parasitoids of tephritid fruit flies in Hawaii. *Biol. Cont.* 3:140-147.
- Monteith, L. 1971. Crickets as predators of the apple maggot, *Rhagoletis pomonella* (Diptera: Tephritidae). *Canadian Entomol.* 103:52-58.
- Monteith, L. 1975. Laboratory feeding studies of potential predators of the apple maggot, *Rhagoletis pomonella* (Diptera: Tephritidae) in Ontario. *Proc. Entomol. Soc. Ontario* 106:28-33.
- Monteith, L. 1976. Field studies of potential predators of the apple maggot, *Rhagoletis pomonella* (Diptera: Tephritidae) in Ontario. *Proc. Entomol. Soc. Ontario* 107:23-30.
- Newell, I., and F. Haramoto. 1968. Biotic factors influencing populations of *Dacus dorsalis* in Hawaii. *Proc. Hawaiian Entomol. Soc.* 20:81-139.
- Nuenschwander, P., F. Bigler, V. Delucchi and S. Michelakis. 1983. Natural enemies of preimaginal stages of *Dacus oleae* Gmel. in Western Crete. I. Bionomics and phenologies. *Boll. del Lab. Entomol. Agr. "F. Silvestri" Portici* 40:3-32.
- Pemberton, C. and H. Willard. 1918. A contribution to the biology of fruit fly parasites in Hawaii. *J. of Agr. Res.* 15:419-465.
- Purcell, M., K. Daniels, L. Whitehand and R. Messing. 1994. Improvement of quality control methods for augmentative releases of the fruit fly parasitoids *Diachasmimorpha longicaudata* and *Psytallia fletcheri*. *Biocont. Sci. and Tech.* (in press).
- Purcell, M., C. Jackson, J. Long and M. Batchelor. 1994. Influence of guava ripening on parasitism of the Oriental fruit fly, *Bactrocera dorsalis* by *Diachasmimorpha longicaudata* and other parasitoids. *Biol. Cont.* (in press).
- Salas, L.. 1958. Informe sobre el estudio de la mosca del Mediterraneo en Costa Rica. Editorial Universitaria (Seria Agron., 1), San Jose, Costa Rica.
- San Juana, S. 1974. Control biologico de las moscas de la fruta en el Canon del Tomellin, Oaxaca, Mexico. *Dir. Gen. Sanidad Vegetal, SARH.*
- Silvestri, F. 1914. Report of an expedition to Africa in search of natural enemies of fruit flies (Trypaneidae). *Terr. of Hawaii Board of Agr. and For. Bull No.* 3.
- Sivinski, J. 1991. The influence of host fruit morphology on parasitism rates in the Caribbean fruit fly (*Anastrepha suspensa* (Loew)). *Entomophaga* 36:447-455.

- Sivinski, J. and C.O. Calkins. 1990. Sexually dimorphic developmental rates in the Caribbean fruit fly (*Anastrepha suspensa* (Loew)). *Environ. Entomol.* 19:1491-1495.
- Sivinski, J. and B. Smittle. 1990. Effects of gamma radiation on the development of the Caribbean fruit fly *Anastrepha suspensa* (Loew) and the subsequent development of its parasite *Diachasmimorpha longicaudata* (Ashmead). *Entomol. exp. et appl.* 55:295-297.
- Steck, G., F. Gilstrap, R. Wharton, and W. Hart. 1986. Braconid parasitoids of Tephritidae (Diptera) infesting coffee and other fruits in west-central Africa. *Entomophaga* 31:59-67.
- Wharton, R. 1989. Classical biological control of fruit-infesting Tephritidae, pp. 303-313 *in*: A. Robinson and G. Hooper (eds.), *Fruit Flies: Their Biology, Natural Enemies and Control*. Elsevier, Amsterdam.
- Wharton, R., F. Gilstrap, R. Rhode, M. Fischel and W. Hart. 1981. Hymenopterous egg-pupal and larval-pupal parasitoids of *Ceratitis* and *Anastrepha* spp. (Diptera: Tephritidae) in Costa Rica. *Entomophaga* 26:285-290.
- Wong, A. and T. Wong. 1988. Predation of the Mediterranean fruit fly and the Oriental fruit fly (Diptera: Tephritidae) by the fire ant (Hymenoptera: Formicidae) in Hawaii. *Proc. Hawaiian Entomol. Soc.* 28:169-177.
- Wong, T., D. McInnis, J. Nishimoto, A. Ota and V. Chang. 1984. Predation of the Mediterranean fruit fly (Diptera: Tephritidae) by the Argentine ant (Hymenoptera: Formicidae) in Hawaii. *J. Econ. Entomol.* 77:1454-1458.
- Wong, T. and M. Ramadan. 1992. Mass rearing biology of larval parasitoids (Hymenoptera: Braconidae) of tephritid flies in Hawaii, pp. 405-476 *in*: T. Anderson and N. Leppla (eds.), *Advances in Insect Rearing for Research and Pest Management*. Westview Press, Boulder, Colorado.
- Wong, T., M. Ramadan, D. McInnis, N. Mochizuki, J. Nishito and J. Herr. 1991. Augmentative releases of *Diachasmimorpha tryoni* (Hymenoptera: Braconidae) to suppress a Mediterranean fruit fly (Diptera: Tephritidae) population in Kula, Maui, Hawaii. *Biol. Cont.* 1:2-7.