PROPAGATION AND AUGMENTATIVE RELEASES OF PREDATORS AND PARASITOIDS FOR CONTROL OF ARTHROPOD PESTS

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ABSTRACT - Decreasing availability and adverse effects of pesticides on non-target organisms, particularly man and endangered species, are resulting in reduced use of conventional pesticides as therapeutic measures to suppress pest populations. Thus, alternative pest control techniques, including biological control, are receiving increased attention. Naturally occurring populations of beneficials are often too low to maintain pest populations at acceptable levels. Augmentation is one biological control technique that is particularly useful in disrupted environments. There are two basic approaches to augmentation, periodic releases of natural enemies or environmental manipulation to increase their numbers or beneficial effects. This discussion will focus on the technical and economic feasibility of augmenting selected natural enemies. Impediments to augmentation, including mass production of natural enemies at a sufficiently low cost, will also be discussed.

Index terms: biological control, augmentation, insect.

PROPAGAÇÃO DE PREDADORES E PARASITÓIDES E SEU AUMENTO PARA CONTROLE DE ARTRÓPODES-PRAGAS

RESUMO - A decrescente disponibilidade e os efeitos adversos de pesticidas sobre os organismos não alvos, mormente sobre o homem e espécies ameaçadas de extinção, resultam no reduzido emprego de pesticidas convencionais como medidas destinadas a suprimir populações de pragas. Assim, técnicas alternativas de controle de pragas, inclusive controle biológico, estão recebendo atenção cada vez maior. As populações naturais de insetos ou plantas favoráveis ao homem são, muitas vezes, pequenas demais para manter em níveis aceitáveis as populações de pragas. O seu aumento é uma das técnicas de controle biológico particularmente útil num meio ambiente perturbado. Há duas maneiras básicas de aumento: periódicas liberações de predadores, ou sua manipulação no sentido de aumentar o seu número e seus efeitos benéficos. Esta discussão focalizará a factibilidade técnica e econômica de aumentar os inimigos naturais selecionados. Serão discutidos, também, os impedimentos ao aumento, inclusive a produção em massa de inimigos naturais a preços bastante módicos.

Termos para indexação: insetos, controle biológico, aumento de populações de insetos.

INTRODUCTION

We have relied on conventional pesticides to meet most of our pest management needs since the 1940's. Today the availability of effective conventional pesticides has decreased drastically. Concern about pesticide residues in food and water and the adverse effects of pesticides on nontarget organisms, (particularly man and endangered species) have resulted in the outright banning of many chemicals and the requirement that pesticides registered prior to 1984 undergo extensive testing using today's standards. In addition, the cost of available pesticides has increased. Registration of a single pesticide for use in the U.S. costs between $20 and $50 million. Thus, while few new pesticides are being developed, companies are not reregistering old chemicals. In addition, pesticides are

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becoming obsolete as many pests become resistant. Resurgence of pests following pesticide applications is also a problem. Much of the extensive aphid problem now being experienced in cotton in the U.S. has been linked to organophosphate insecticide resistance and early season applications of pyrethroids (Hardee & O'Brien 1990). Increased damage by *Heliothis virescens* (F.) and *Helicoverpa zea* (Boddie) has been associated with applications of aldicarb. Finally, concern about the availability of oil reminds us that conventional pesticides are petroleum-based and not a renewable resource. So we see that a variety of problems are associated with our dependence on conventional pesticides (King et al. 1988). Interest in reducing this dependence increases as we become more aware of the problems associated with pesticide use and of the potential offered by alternative approaches available to the integrated pest management (IPM) practitioner.

One of the primary alternatives to conventional pesticides and an important component of a well-designed IPM program is biological control ("the actions of parasites, predators, and pathogens in maintaining another organism's density at a lower average than would occur in their absence" (DeBach 1964). There are three basic approaches to biological control: importation, augmentation, and conservation. Importation has been very successful against a wide variety of pests (DeBach 1971). There are, however, still many important pest species which do not seem to be amenable to this classical approach (Nordlund 1984). Many of these pests are native species that are found in disrupted environments such as the annual row crop agroecosystems. These cropping systems are not conducive to the establishment of long term stability, which is critical to the sucess of importation programs (Lewis & Nordlund 1980). Conservation involves actions to protect and preserve existing natural enemies, basically not taking actions that would be detrimental to these natural enemies (Rabb et al. 1976, Nordlund 1984). This presentation deals with augmentation of parasitoids and insect predators. Augmentation involves actions to increase populations or beneficial effects of parasites, predators, or pathogens (Rabb et al. 1976). Our ability to use augmentation effectively is, to a great extent, limited by our ability to propagate, transport, and effectively release large numbers of high quality biological control agents. Thus, these issues will also be addressed, as will economic feasibility and the future outlook. Our thesis is that biological control by augmentation is the most direct way of increasing natural enemy numbers and of obtaining effective biological control, particularly in annual row crop agroecosystems.

AUGMENTATION AS AN APPROACH TO BIOLOGICAL CONTROL

Their are two basic approaches to augmentation (Nordlund 1984). The first is periodic release, which can be inoculative or inundative (DeBache & Hagen 1964). Inoculative releases involve relatively few biological control agents and the benefits of the release are expected to come from the progeny of the released organisms. Inoculative releases are particularly useful in situations where an effective parasitoid cannot overwinter and requires reintroduction each spring. Inundative releases involve releasing relatively large numbers of biological control agents and the benefit is expected to come from the released agents, not their progeny.

Figure 1 depicts the events of a generalized periodic release program. Such a program begins with the identification, colonization, and study of the natural enemy followed by the development of mass propagation and release procedures. In this flow chart it is generally necessary that each event be achieved before proceeding to the next event. Lack of effective mass propagation capability is a serious impediment to widespread use of this approach to augmentation.

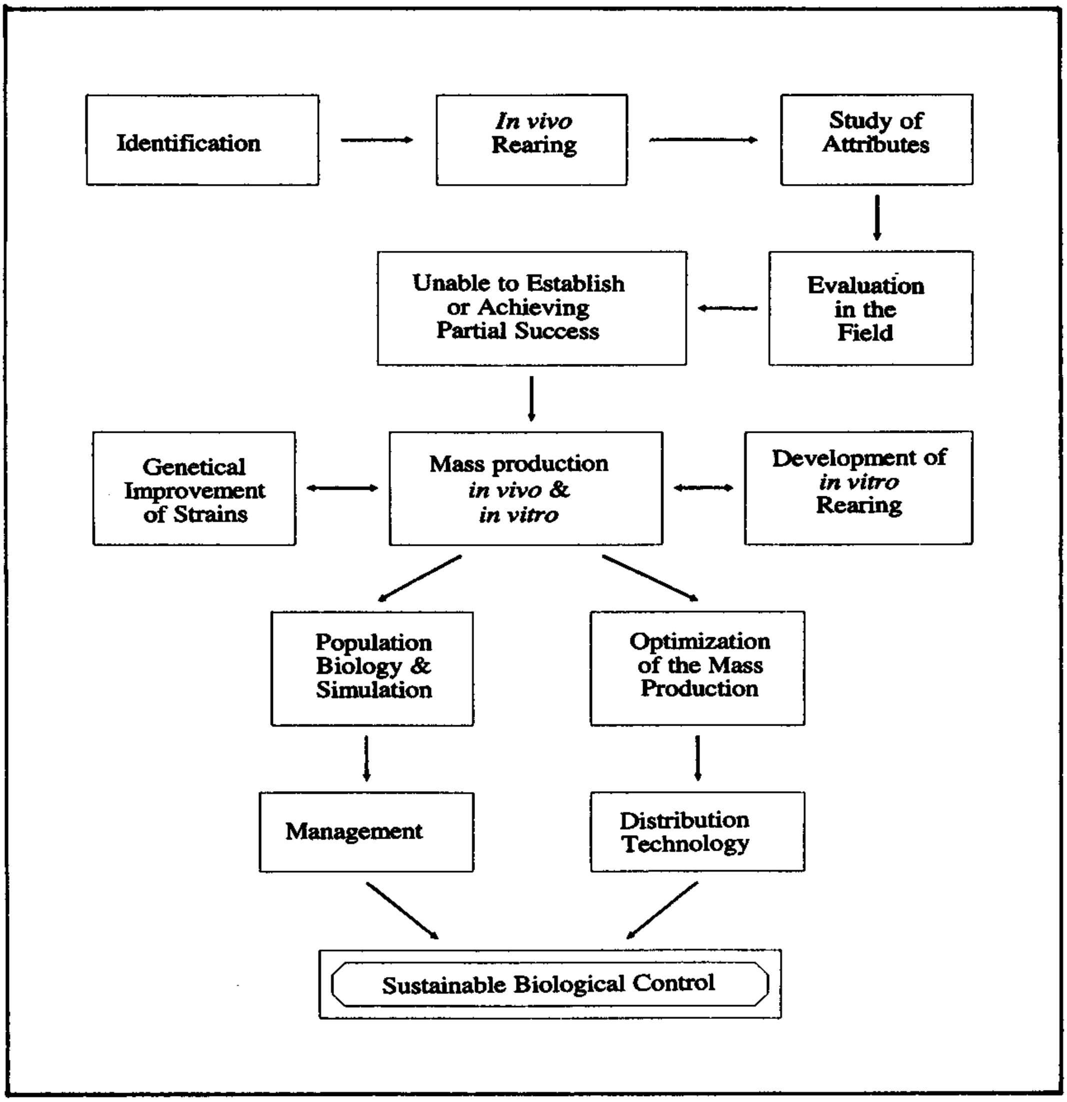

FIG. 1. Events of a generalized periodic release program.

TABLE 1. Extent and impact of *Trichogramma* spp. releases in China.

Target Pest	*Trichogramma* Species	Release Area/ Ha.	Percent Parasitism	Percent Suppression
Ostrinia furnalis	*T. dendrolimi*	606666	71-90	50-92
	T. ostriniae	1333	94	88
Helicoverpa armigera	*T. dendrolimi*	4000	78-90	70-98
	T. confusum	4000	60-90	81-89
Dendrolimus spp.	*T. dendrolimi*	93000	52-96	68

Modified from Li 1984.

Periodic release requires a continuing release program and thus, has potential as a commercial enterprise. The number of commercial suppliers of biological control agents (Lisansky 1990) is evidence of this potential.

The second approach to augmentation is environmental manipulation, which involves actions, other than releases of the biological control agents, that result in either an increase in the number of biological control agents in the target area or an increase in their beneficial effects. Increases in numbers may occur through attraction of natural enemies to the target area or through increased population growth. Increases in beneficial effects can occur through enhanced search efficiency. There are a number of approaches to environmental manipulation, some of which could be easily incorporated into annual row crop systems. Since much of the work related to environmental manipulation is still in the early stages of research this paper deals primarily with periodic release.

EXAMPLES OF SUCCESSFUL AUGMENTATION PROGRAMS

Cop and orchard systems

Trichogramma

Trichogramma spp. are minute parasitic wasps, which attack the eggs of many insect pests. They are the most widely studied and used biological control agents in the world. Over 15 million hectares are treated annually with *Trichogramma* for pest management on corn, sugarcane, rice, cotton, soybeans, sugar beets, vegetables, and pine trees (King et al. 1985a, Ridgway & Morrison 1985, Hassan et al. 1988). The U.S.S.R, People's Republic of China, and Mexico, rank first, second, and third, respectively, in use of *Trichogramma*. At least nine species are reared for use in augmentation programs (Olkowski & Zhang 1990).

Flanders (1929) was the first to rear *Trichogramma* for use in biological control. Rearing technology has advanced considerably through the years (Morrison et al. 1978, Morrison 1985). Mechanization of the production systems, using oak silkworm (*Antheraea pernyi* Guerin-Meneville) and eri silkoworm (*Philosamia cynthia ricini* Donovan) as hosts, has allowed for the extensive use of *Trichogramma* in China (Olkowski & Zhang 1990) (Table 1). The Chinese have also developed an experimental artificial egg for use in *Trichogramma* production. The artificial egg contains about 30 percent silkworm tissue (Dai et al. 1988). W.C. Nettles, of the Biological Control of Pests Research Unit (BCPRU), Weslaco, Texas, in cooperation with Ciba-Geigy Corporation, is developing an artificial diet for *Trichogramma* which will be devoid of host material. This artificial diet will make *in vitro* mass production of *Trichogramma* commercially possible. *In vitro* rearing should be more cost effective and lend itself to a mechanized mass production system.

In a pilot test conducted in North Carolina on the effectiveness of inundative releases of *Trichogramma* against *H. zea* and *H. virescens* in cotton, King et al. (1985b) found that yields and revenue increased over check plots but were not as high as in fields treated with conventional insecticides. Though this study did not demonstrate economic feasibility, technical feasibility was clearly demonstrated. Compromising factors in this test were the presence of the boll weevil (*Anthonomus grandis* Boheman) and insecticides.

Trichogramma are effective for control of *Helicoverpa* in tomato (Oatman & Platner 1971, 1978). However, the occasional presence of *Spodoptera exigua* (Hubner), the eggs of which are protected from *Trichogramma* by a covering of moth scales, results in application of insecticides. *Trichogramma* are also effectively control two common lepidopterous pests of avocado in southern California (Oatman & Platner 1985). Parker & Pinnell (1972) reported on an interesting program in which they combined periodic releases of *Thichogramma* along with releases of the pest insects (environmental manipulation) to achieve control of cabbage pests.

Chrysoperla

The genus *Chrysoperla* contains a number of important insect predators, including *Chrysoperla carnea* (Stevenson) and *Chrysoperla rufilabris* (Burmeister). Both species are widely distributed in North America (Bickley & MacLeod 1956) and *C. carnea* is cosmopolitan (except in Australia) (Zeleny 1984). *Chrysoperla* spp. have a number of attributes that contribute toward making them key predators in many agricultural systems and ideal candidates for use in periodic release programs. These insects are predaceous in the larval stage and attack a variety of pests including aphids, chinch bugs, mealybugs, scales, whiteflies, leafhoppers, lepidopterous eggs and larvae, and mites (Hydorn 1971, and references therein). These chrysopids are also found in a wide variety of cropping systems (Agnew et al. 1981). The larvae have high searching rates (Fleschner 1950) and exhibit some tolerance to insecticides (Plapp & Bull 1978, Shour & Crowder 1980, Pree et al. 1989).

The effectiveness of *Chrysoperla* spp. as biological control agents has been demonstrated in field and orchard crops (Table 2) and in greenhouses (Harbaugh & Mattson 1973), Hagley & Miles 1987).

Both *C. carnea* and *C. rufilabris* are commercially available. However, lack of cost effective mass production systems for these predators has prevented their widespread use.

A mechanized mass rearing system, which relies on artificial diet, rather than on insect eggs as the larval food source, is being developed, by D. A. Nordlund, at the BCPRU. With such a mass production system, **Chrysoperla** will begin to reach their potential in augmentation programs.

Aphytis melinus

The exotic parasitoid *Aphytis melinus* DeBach is reared in California and used in augmentation programs to control the California red scale (*Aonidiella aurantii* (Maskell)) in citrus (Lorbeer 1971, Pennington 1975, Starler & Ridgway 1976). Many southern California citrus growers rely on the release of *A. Melinus* to augment resident

TABLE 2. Examples of successful use of *Chrysoperla* spp. in release programs.

Crop	Target Pest	References
Cabbage Pepper Tomato Eggplant Peas potato	Aphids: cowpea aphid green peach aphid pea aphid buckthorn aphid	Adashkevich & Kuzina 1974 Beglyarov & Smetnik 1977 Radzivilovskaya & Daminova 1980 Shands et al. 1972
Eggplant Potato	Colorado potato beetle	Adashkevich & Kuzina 1971 Shuvakhina 1974, 1977, 1978
Apple	European red mite	Miszczak & Niemczyk 1978 Yan 1981
Pear	Grape mealybug	Doutt & Hagen 1949, 1950
Mulberry Catalpa	Comstock mealybug	Belyarov & Smetnik 1977
Cotton	Bolloworm and tobacco budworm Aphids	Lingren et al. 1968 Ridgway & Jones 1968, 1969 Kinzer 1976 Ridgway et al. 1977 Biological 1982

wasp populations as a control tactic. Releases of *A. melinus* can be more economical than traditional organophosphate treatments and diminished pesticide usage reduces the disruption of natural enemies attacking other lemon pests.

Phytoseiid Mites

A carbaryl-resistant strain of the predaceous mite *Metaseiulus occidentalis* (Nesbitt) has been developed. Releases of this predaceous mite into almond orchards cost about $49/ha and controlled two species of tetranychids. By releasing the carbaryl resistant strain, carbaryl can be used to control other pests in the orchard without eliminating the predacious mite. Actual savings in control costs the first year of one study were estimated to be $109/ha if no predators were released or $59/ha if predators were released (Croft 1990). Repeated releases of the predatory mite were not necessary over the total area in subsequent years so savings accrued at the same rate as nonrelease plots. *Phytoseiulus persimilis* Athias-Henriot is also being used for suppression of the twospotted spider mite (*Tetranychus urticae* Koch) on strawberry in southern California (Oatman et al. 1968, 1976, 1977)

Edovum puttleri

Edovum puttleri (Grissell) was imported from Colombia, South America in 1980 and found to successfully parasitize eggs of the Colorado potato beetle (Puttler & Long 1983). The parasitoid apparently cannot overwinter in the United States, and thus, can only be used in augmentation programs. Schroder &

Athanas (1985) reported that significant rates of parasitism could be achieved by releasing *E. puttleri* in potato. *E. puttleri*, however, is not effective in potato, apparently because of the way potato leaves lay on each other and protect many egg masses. This egg parasitoid is being used effectively to control Colorado potato beetle on eggplant in New Jersey (U.S) (Lashomb 1989).

Pediobius foveolatus

The eulophid, *Pediobius foveolatus* (Crawford), has been used in inoculative releases to suppress the Mexican bean beetle, *Epilachna varivestis* Mulsant (Stevens et al. 1975). This parasitoid was imported from India and is maintained in insectaries because, like *E. puttleri*, it cannot overwinter in the U.S. Early-season inoculative releases of *P. foveolatus* in Maryland have resulted in nearly 100% parasitization of Mexican bean beetle larvae and a four-fold reduction in insecticide usage. An analysis of the cost of biological control versus conventional chemical control (Reichelderfer 1979) demonstrated that inoculative releases of *P. foveolatus* do yield monetary returns greater than insecticide treatments. This augmentation program is continuing in the northeastern U.S., particularly by the New Jersey Department of Agriculture.

Lixophaga diatraeae

The tachinid, *Lixophaga diatraeae* (Townsend), was imported and established in the U.S. on the sugarcane borer, *Diatraea saccharalis* (F.). Mass production methods, using sugarcane borer larvae and an unnatural host, the greater wax moth (*Galleria mellonella (L.)*), have been developed (King et al. 1979). Periodic releases of 3-6 day-old flies over a 320 ha sugarcane field in Florida resulted in increased rates of parasitism and a decline in the overall borer population (Summers et al. 1976, King et al. 1981) (Table 3). This parasitoid is being reared and released in countries such as Cuba and Venezuela, but it is not currently being used in the U.S.

Greenhouse systems

Greenhouses are protected environments which offer pest insects an ideal habitat. The plants are close together and generally grow vigorously under favorable environmental conditions. It is also a system in which pesticide resistance can develop rapidly and where use of conventional pesticides presents worker safety problems (Hussey & Scopes

TABLE 3. Parasitization of *Diatraea saccharalis* following release of *Lixophaga diatraeae*.

Date	Number per Hectare (1000's) Sugarcane Borer	*Lixophaga diatraeae*	Other Parasitoids**	Unparasitized Sugarcane Borer
14 June*	14.6	0.0	0.4	14.2
28 June	4.1	0.4	0.3	3.5
12 July	1.5	0.9	0.3	0.3
9 Aug.	4.9	2.3	0.3	2.3
6 Sept.	1.6	1.2	0.2	0.3
11 Oct.	0.9	0.4	0.2	0.2
25 Oct.	1.9	0.7	0.3	1.0

* At time of release
** Other Parasitoids incluced *Agathis stigmaterus* and *Cotesia (=Apanteles) flavipes*.
Modified from King et al. 1984.

1976). Thus, it is also an ideal environment for augmentation programs. Hussey & Scopes (1976, 1985), Lenteren et al. (1979, 1980), 1990), and Lenteren & Woets (1988) Brodsgaard et al (1990) reviewed the use of biological control in greenhouse systems. Much of this activity is occurring in western Europe and a large industry in greenhouse biological control has developed there. A variety of biological control agents are being released in greenhouses for control of important pests (Table 4).

The predatory mite *P. persimilis* is used in greenhouses throughout western and southern Europe to control the twospotted spider mite, particularly on cucumber and tomato. This technology began in the late 1960's, largely due to lack of effective miticides to control resistant spider mites.

Augmentative technology for *Encarsia formosa* Gahan, a parasitoid of the greenhous whitefly (*Trialeurodes vaporariorum* (Westwood)) followed and paralleled that for *Phytoseiulus* because of the incompatibility of using biological control against one pest while attempting to control the other with pesticides. The total area currently under biological control using these two natural enemies approaches 10,000 ha of greenhouse. The cost for biological control is about 1/2 the cost of using conventional pesticides. Moreover, the path has been opened for biological control of other pests such as leafminers, aphids, and thrips (Gilkeson 1990, Gilkeson et al. 1990, Minkenberg & Lenteren 1990)

Stored products

The stored product environment provides an ideal situation for augmentation. Large bins of commodities can become infested with a variety of insect pests. A list of parasitoids and predators which may be useful against stored product pests is given in Table 5.

Laboratory and small scale warehouse releases demonstrated that the parasitoid *Anisopteromalus calandrae* (Howard) can effectively suppress grain weevil populations. *Xylocoris flavipes* (Reuter) suppresses a variety of stored-product beetles and moths. Commercial production and release of these natural enemies into grain bins is subject to federal regulations because they have been perceived by regulatory agencies in the U.S.

TABLE 4. Commercially produced natural enemies for biological control of greenhouse pests.

Predator or Parasitoid	Target Pest	Hectares	Biological vs Chemical Costs per Square Meter
Encarsia formosa	Whitefly	2350	$0.10 vs 0.20
Amblyseius cucumeris barkeri	Thrips	140	NA
Dacnusa sibirica	Leafminers	460	NA
Diglyphus isaea	Leafminers		
Phytoseiulus persimilis	Spider Mites	5100	$0.12 vs 0.23
Aphidoletes aphidimyza	Aphids		

Modified from Lenteren (1990)

as being filth and contaminants of food. The U.S. Food and Drug Administration recently stated that parasitoids and predators should be considered insecticides. This places regulatory authority in the hands of the U.S Environmental Protection Agency (EPA). The EPA is in the process of exempting parasitoids and predators used in grain bins from tolerances (in the case of conventional pesticides, a residue tolerance would be established), Regardless, commercial releases of these natural enemies have been suspended in the U.S, until regulatory authorities are able to establish a clear policy.

Man and animal protection

A number of parasitoids; including *Spalangia endius* Walker, *Muscidifurax zaraptor* Kogan and Legner, *Sphegigaster* spp. and *Tachineaphagus zealandicus* Ashmead; and the predator *Toxorhynchites rutilus* (Coquillett are being used in augmentation programs against insects that attack man and animals.

Augmentation of the pteromalid, *S. endius*, at a ratio of one female parasitoid to five host pupae can result in high rates of parasitization and a reduction in host pupae. This parasitoid is being used to control field populations of the house fly, *Musca domestica* L., and the stable fly, *Stomoxys calcitrans* (L.). This parasitoid is also used to control muscoid flies in cattle feedlots. It is produced in commercial insectaries in the U.S. The data from one poultry house demonstrated increased parasitism in conjunction with reduced pupal populations (Morgan & Patterson 1990). A continuing problem is that the species released, number released, time of release, and the specific environmental conditons are critical to the effective control.

IMPEDIMENTS TO ADOPTION OF AUGMENTATION IN PEST MANAGEMENT

Augmentation is little used in the U.S. The most critical impediment to large scale commercialization of this approach is lack of mass production capability. It is too costly and complex to rear most predators and parasitoids on live hosts or prey. Artificial diets will facilitate automatation of rearing systems, which will reduce contamination and disease problems, reduce rearing costs, and, hopefully, improve quality.

Production

The BCPRU is focusing its research efforts on development of automated rearing systems, based on artificial diets, for the egg parasitoid *Trichogramma*, the predator *Chrysoperla*, and boll weevil ectoparasitoids *Bracon mellitor* (Say) and *Catolaccus grandis* Burks.

We have been able to produce *Trichogramma* adults on artificial diets, which contain host hemolymph, but efforts to eliminate this component are underway. This effort is being led by W.C. Nettles, Jr.

TABLE 5. Stored-Product Natural Enemies.

Natural enemy	Target Pest
Trichogramma pertiosum	Lepidoptera
Habrocitus cerealella	*Sitotroga cerealella*
Anisopteromalus calandrae	*Sitophilus* spp.
Xylocoris flavipes	Egg/ larval, general
Bracon hebetor	Moth larvae
Pyemotes tritici	Multiple

We are particularly interested in using *Chrysoperla* for control of vegetable pests. D.A. Nordlund leads efforts to automate the rearing process. Improvements in the rearing system will make augmentation of *Chrysoperla* much move viable.

The boll weevil is a key pest of cotton in the U.S. as well as in Brazil. Attempts to introduce and establish effective natural enemies on this exotic pest have not been successful. Naturally-occurring predators and parasitoids are also ineffective in suppressing this pest. One exception is that of suppression by fire ants (Sterling 1987). Inoculative releases of the pteromalid, *C. grandis*, have resulted in high rates of parasitism and in one field the parasitoid was shown to be an efficient searcher at extremely low host densities. K.R. Summy, along with J. Morales of Texas A&M University, are conducting the field evaluations. Techniques have already been developed for production of this parasitoid on boll weevil larvae and facilities are available for mass producion of the boll weevil. We have already reared the braconid ectoparasitoid, *B. mellitor*, from egg to adult on artificial diet. We believe we can do the same with *C. grandis*. *Bracon mellitor* is a native parasite of *Anthonomus* and other curculionids. A.A. Guerra, leads our efforts on artificial diet development for the boll weevil ectoparasitoids.

Storage, transportation, and release

Conventional pesticides can be manufactured, packaged, and stored in large quantities for relatively long periods of time. Predators and parasitoids, on the other hand, can be stored for only short periods of time at reduced temperatures. Because our ability to stockpile and store large quantities of predators and parasitoids is limited, we must maximize our ability to produce and transport these agents from the production facility to the field rapidly and without exposing them to extremes in temperature, Bouse & Morrison (1985) used a portable electronic refrigerator to transport *Trichogramma* to the field. In most U.S. agricultural production systems, hand release of biological control agents is not practical, for inundative releases. Improved mechanical release systems are needed. Ridgway et al. (1977) describe several automated systems for releasing predators and parasitoids. A sophisticated aerial release system for *Trichogramma* was described by Bouse & Morrison (1985).

ECONOMIC FEASIBILITY

Commercialization of biological control in western Europe and the United States was recently reviewed by Lenteren (1989) and Dietrick (1989) respectively. There are numerous commercial producers of natural enemies in existence and a number of large agricultural companies are entering this field. Some of these organizations have been in business for years and are still experiencing respectable growth. The mite *P. persimillis*, which was first used in 1968 on less than 500 ha of greenhouse was used on over 6000 ha of greenhouse in 1988, while *E. formosa*, which was used on only a few ha in 1970 was used on almost 4000 ha in 1988 (Lenteren 1989). This indicates that there is a large market for augmentation programs.

FUTURE OUTLOOK

Development of automated rearing systems based on artificial diets is a key to commercial feasibility for mass producion of predators and parasitoids for use in augmentation programs. Genetic improvement, either by conventional or by biotechnological means, will improve the quality and efficacy of these natural enemies. Computer technology has improved our ability to predict the probability of biological control and judge the number of natural enemies required for releases into the system. Management of natural enemies will be improved as we better understand the functional response of natural enemies to pest density, including the role of semiochemicals.

Several predictions are justified:

1. Conventional pesticides will become less available and more expensive for a variety of reasons.
2. Public concern over food and water safety and effects of pesticides on nontarget organisms (particularly man and endangered species) will result in further reductions in use of conventional pesticides.
3. The need for nonchemical control technology will increase.
4. The role of augmentation for control of many of our most intractable arthropod pest problems will increase.
5. The thriving industry based on augmentation will grow dramatically in the future. This expansion will result in the emergence of a prominent industry that will market a product of assured identity and quality, along with explicit guidelines for handling and distribution.
6. Computer-based technology will improve our ability to assess and predict populations trends and the probability of effective biological control.
7. Conventional and molecular genetics will open new directions in biological control for "improving" predators and parasitoids.
8. The development of artificial diets and *in vitro* rearing systems will greatly enhance the economic feasibility of augmentation.
9. The new production technology will require interdisciplinary food processing, chemical, and mechanical engineering input to optimize automation of rearing systems.

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