SUCCESSES AND CHALLENGES IN AUGMENTATIVE BIOLOGICAL CONTROL IN OUTDOOR AGRICULTURAL APPLICATIONS: A PRODUCER'S PERSPECTIVE

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INTRODUCTION

In North America, there is an escalating demand for commercial shipments of large volume, high-quality invertebrate biological control agents for augmentative biological control in outdoor crops. The demand far exceeds current supply. Driving forces behind this need include public pressure, expanded production of organic and pesticide-reduced crops, enlightened growers, government regulations, and pest resistance to chemical pesticides.

Historically, augmentative biological control has been more successful in greenhouse vegetable production than in outdoor crops. This is a result of the unique characteristics of greenhouse environments and the experiences of growers that manage these crops. Within some modern greenhouses, there is a precisely controlled climate where temperature, ventilation, light levels, light cycles, and carbon dioxide levels are computer controlled and monitored. The crop is sheltered from wind and rain and is usually a monoculture with a limited number of associated pests. There is generally minimal interspecific competition at each trophic level. Compared with outdoor crops, which cover literally hundreds of thousands of acres (Glenister, 1991), greenhouse crops are tiny acreages, with maximum size rarely exceeding 50 acres and typically being closer to five acres in size. In Canada and parts of the United States there is a high level of support from government researchers, extension staff, and technical consultants provided by biological control suppliers. Due to the high unit value of greenhouse crops, there is sufficient income to support extensive scouting programs for early detection of pest problems.

There have been a limited number of successful biological control agents used in outdoor crops (Table 1). This list is not exhaustive, and is intended as an illustration based on the authors' personal experience in western North America. A commercial insectary targeting the outdoor market has more operational barriers to profitability than those targeting the greenhouse industry. These

Table 1. Examples of augmentative biological control programs that have had some degree of success in outdoor crops in North America in recent years.

Biological Control Agent	Target Pest	Outdoor Crop
Amblyseius fallacis Garman	spider mites	strawberries, mint
Aphidoletes aphidimyza Rondani	aphids	fruit tree nurseries
Aphytis melinus De Bach	red scale	citrus, nuts
Cryptolaemus montrouzieri Mulsant	mealybugs	citrus, grapes
Feltiella acarisuga Vallot	spider mites	berries
Phytoseiulus persimilis Athias-Henriot	two-spotted spider mite	berries
Trichogramma sibericum Sorokina	black-headed fireworm	cranberries

barriers include seasonality of pest problems, climatic factors, movement of biological control agents away from the release site, and availability of alternative pest control methods (Ference Weicker and Company, 2000).

CASE HISTORIES

Pyrethroid Resistant Predatory Mite (*Amblysieus fallacis* Garman)

The commercial launching of a new pesticide resistant biological control agent for a major field crop pest for the first time in Canada took place in 1993-1995 and was a collaborative effort between the producer (Applied Bionomics Ltd.), a field consulting company (ES Cropconsult), Canadian government researchers (H. Thistlewood and J. Whistlecraft), and a Canadian government funding agency (Western Diversification: National Agricultural Biotechnology Initiative).

With the commercial availability of this new biological control agent, experimental field applications of *A. fallacis* were made for suppression of two-spotted spidermites and showed positive results on field strawberry, raspberry, currants, hops, and mint, as well as greenhouse pepper (Elliot, 1997). Predatory mites were also sold outside Canada in Oregon, Washington, Idaho, and Montana and for use in greenhouse crops in The Netherlands. The total number of mites sold is shown in Table 2.

Table 2. Total number (in thousands) of *Amblysieus fallacis* Garman sold and released in field trials by geographic region 1993-1995.

	Locality					
Year	British Columbia	Ontario	Quebec	USA	Europe	Total
1993	50	550	1250	0	0	1850
1994	1554	436	117	5	80	2192
1995	1996	418	179	697	308	3568
1996	856	206	460	197	492	2211
Total	4426	1610	2006	899	880	9821

The application of a new predatory mite on field and orchard crops will expand the opportunities for biological control producers, suppliers, and IPM consultants and lead to more applications of other types of biological control agents on these crops (Elliot, 1997).

Trichogramma sibericum Sorokina in Cranberries

Trichogramma sibericum Sorokina is a native North American egg parasitoid for black-headed fireworm, *Rhopobota naevana* (Hübner), in cranberries. A multi-year project funded by NRC-IRAP (National Research Council-Industrial Research Assistance Program) was conducted by ES Cropconsult in British Columbia, Canada. Field trials in Courtenay, British Columbia in 1999 and 2000 demonstrated that use of *T. sibericum* in cranberry bogs as a late season application reduced fireworm numbers in the year following the application. The application method was dictated by weather and predation. Parasitoids were mixed with pre-moistened vermiculite and distributed manually. The application was timed when parasitoids were just starting to emerge, otherwise parasitized eggs drop to the soil where they are eaten by predators. If heavy rainfall occurs during the week following application, the release is deemed a failure and another release must be made.

In spite of the many challenges in using *T. sibericum* outdoors, the product appears to suppress fireworm populations. Growers are receptive to the product and the mass-rearing methods for *T. sibericum* are ready for transfer to the commercial production industry. Unfortunately, the cranberry market is depressed in western Canada, and the number of growers committed to using this agent would only purchase product valued at an estimated Can$ 5000 annually, making commercial production unlikely at least until the economics of the crop improve.

ECONOMICS OF COMMERCIAL NATURAL ENEMY PRODUCTION

There are many constraints and limitations to the development and commercial production of biological control agents, particularly in outdoor crops. Many agents are needed only seasonally and have a very narrow window of effective use. The producer, however, must bear the costs of production for months prior to that narrow market opportunity. If climatic factors delay or eliminate pest problems or an alternative pest control method becomes available, then the producer does not realize any benefit for the time and money invested in producing the specific natural enemy. The market size can often be very small, while labor costs are high, and overhead costs are independent of product sales as supplies must be purchased year round. Research and development costs can be very large when considering that it often takes three to five years of work before a new natural enemy species becomes a viable commercial product. Labor, in both development and production, is by far the largest expense for the producer. Commercial production of natural enemies (mass-reared on natural or factitious prey) requires maintenance of three trophic levels: the host plant or medium (grain or soil mix), the prey, and the predator or parasitoid. All must be produced at commercial scales. In North America, a general rule of thumb is that for commercial production of natural enemies to be profitable, there must be a minimum market size of Can$ 10,000 in gross sales per product per month of peak production times. It is common practice for specialty or niche products to be produced at a loss to help round out biological control programs. As a rule insectaries are supported by revenue generated by a few widely used products, and any resulting profit subsidizes specialty or minor-use products developed to accommodate the end user.

From a producer's perspective, in order to expand augmentative biological control to meet global needs, many challenges must be addressed. Economics of production must allow the price per unit for commercial natural enemies to be acceptable to the consumer and sustainable for the producer. Scale and efficiency of mass-production methods must continue to improve. Market size must be sufficient to generate sufficient sales. Packaging, shipping, and regulatory constraints can be onerous, particularly for small producers. The cost of freight, losses in shipment, and any future registration fees may force small businesses into changing their sales model from direct selling to supplying a larger company. If the small company is unable to adapt business practices to absorb these costs, they may cause bankruptcy. Producers need to take into consideration, on a case-by-case basis, the ethics and risks of releasing non-endemic species into outdoor crops. New release methods need to be developed for use in outdoor crops to ensure uniform distribution in the crop to improve efficacy and efficiency. Education and receptivity of the consumer is crucial to the success of augmentative biological control. Other pest control methods used in an IPM system must be compatible with the natural enemies used.

"Commercial insectaries are labor intensive, marginal businesses with high capital costs, low profit margins, frequent product failures, inadequate financing, and no access to copyright protection. The need for a highly skilled professional willing to work at reduced wage rates who understands the complex biological systems of bugs, plants and other substances is vital. Most are led by a scientist proponent who has entered the field out of interest, not out of the desire for profit. A successful insectary requires a dedicated proponent of this type" (Ference Weicker and Company, 2000).

For augmentative biological control to be successful on a commercial scale on outdoor crops, there needs to be a concerted effort to encourage collaboration between researchers, producers, advisors, and end users (Hoffmann *et al.,* 1998). In North America, successful case studies have generally been projects where there has been external funding, researchers have studied the biology of the natural enemies, developed laboratory rearing protocols, transferred this technology to a producer for commercial scale production, and had end users willing to volunteer their crop for large scale trials.

The Association of Natural Bio-control Producers (ANBP) has developed a list of research needs that producer members agree would benefit the commercial industry and make augmentative biological control a feasible option. This association has also reviewed current USDA, Agricultural Research Service projects with the goal of giving support to projects that benefit the commercial industry. A complete document is posted on the group's web site at www.anbp.org. Producers encourage researchers to review information on widely used natural enemies, particularly population studies. There is a need to agree whether or not large scale demonstration trials are merited to help growers decide if particular natural enemies might be effective when used correctly. Such trials could increase the market for minor-use products to the point where their production would be economically justifiable.

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