MASS REARING BENEFICIAL INSECTS AND THE RENAISSANCE OF BIOLOGICAL CONTROL

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ABSTRACT - It is possible to mass rear hosts efficiently and reliably for the in vivo production of natural enemies. This can be cost effective even if the arthropod hosts must be reared on plants, as in the production of predaceous mites. Host mass rearing has been widely used to produce parasites and predators for both inoculative and inundative release. The use of natural enemies has been particularly successful where pesticides have proven ineffective due to pest distribution and resistance, and when natural enemies are preferred because of cost or the lack of environmentally-acceptable chemicals. There is little doubt that biological control is being reemphasized as environmental awareness increases, and more effort is required to prevent disease transmissior and produce food. For biological control to achieve its potential, however, a new infrastructure must be developed that extends from support for basic research through successful application, documentation and adoption. The National Biological Control Institute was founded to help build this infrastructure and provide a catalyst for creating the associated new technologies. The way to accomplish this synthesis is to incorporate biological control into IPM systems, complete the research required to deploy alternative control tactics, and provide expertise for their implementation.

Index terms: augmentation, biological control, integrated pest management, mass rearing

CRIAÇÃO MASSAL DE INSETOS BENÉFICOS E RESSURGIMENTO DO CONTROLE BIOLÓGICO

RESUMO – É possível criar hospedeiros para produção *in vivo* de inimigos naturais de maneira eficiente e confiável. Isto pode ser economicamente rentável, mesmo se os artrópodos forem criados em plantas, como na produção de ácaros predadores. A produção massal de hospedeiros tem sido amplamente empregada na criação de predadores e parasitóides, tanto para liberação inoculativa, quanto para a inundativa. O uso de inimigos naturais tem sido particularmente bem-sucedido onde os pesticidas não se mostram efetivos, devido à distribuição ou resistência da praga, e quando os inimigos naturais são preferíveis devido ao custo ou falta de produtos químicos seguros ao meio ambiente. Com o aumento da consciência ambiental, há poucas dúvidas de que o controle biológico está ressurgindo, e que mais esforços serão necessários para prevenir a transmissão de doenças e garantir a produção de alimentos. Entretanto, para que o controle biológico atinja seu potencial, uma nova estrutura deve ser criada, de modo a dar suporte, desde a pesquisa básica, até as aplicações bem-sucedidas, adoção e documentação. O Instituto Nacional de Controle Biológico foi criado para auxiliar a construir esta infra-estrutura e funcionar como catalisador para a criação das novas tecnologias. A forma de chegar a esta síntese é através da incorporação do controle biológico ao Manejo Integrado de Pragas (MIP), da complementação de pesquisas básicas necessárias ao desenvolvimento de táticas alternativas de controle, e provisão de assistência à implantação das mesmas.

Termos para indexação: Manejo Integrado de Pragas, criação massal de insetos, controle biológico, controle biológico aumentativo.

INSECT MASS PRODUCTION

Insect mass rearing for autocidal control and *in vivo* production of beneficial insects

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has become a routine technology (Leppla 1989, Leppla and Ashley 1989, Leppla and Fisher 1989). The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), has been produced reliably for long periods of time at the rate of 500 million per week, and experimentally at one billion per week at Metapa, Mexico. Other species of tropical fruit flies are mass reared with weekly yields from 30 to 200 million at Okinawa, Chile, Guatemala, Hawaii, Texas, and Florida. The United States Department of Agriculture (USDA) began mass rearing the Mediterranean fruit fly at Waimanalo, Hawaii this year with a weekly yield of 50 million. In addition to the Tephritidae, mass rearing the screwworm, *Cochliomyia hominivorax* (Coquerel), has reached 500 million per week at Tuxtla Gutierrez, Mexico and the boll weevil, *Anthonomus grandis* Boheman, 200 million per week at Mississippi State, Mississippi. Lepidopteran rearing systems range from simple methods for producing stored product pests to complex processes for *Heliothis* species; the pink bollworm, *Pectinophora gossypiella* (Saunders); the gypsy moth, *Lymantria dispar* (L.); and the codling moth, *Cydia pomonella* (L.) (Leppla et al. 1982, King and Leppa 1984). Pink bollworm production is being moved to a new facility at Phoenix, Arizona and a new codling moth rearing facility is being established in British Columbia, Canada. In the near future, gypsy moth mass production may be accomplished through contract rearing with industry. Considering all taxonomic groups, a total of about 1400 insect species have been reared in the laboratory and almost 50 of these on a large scale (Singh and Moore 1985). Edwards et al. (1986) listed 691 arthropod species maintained at 263 facilities in the U.S. and a few other countries. The existence and anticipated increase in this rearing capability inspired Knipling (1979) to state that "One of the most important advances in entomology has been the progress made by scientists in rearing insects in virtually unlimited numbers and at reasonable cost".

PRODUCTION OF BENEFICIAL INSECTS

Established large-scale production and distribution of parasitoids and predators exists in the U.S.S.R., China, The Netherlands, the U.S.A., Mexico, South Africa, Canada, France, and perhaps a few other countries. The most popular entomophagous arthropods are *Trichogramma* species for use against lepidopteran pests of cotton, corn, wheat, vegetables, and forests. Most notable, however, are the biological control-based pest management systems developed in The Netherlands for greenhouse crops (van Lenteren 1986), and in South Africa for sugarcane (Conlong and Graham 1988). One of the greatest successes has been the mass production and deployment of *Epidinocarsis lopezi* (De Santis) that has controlled the cassava mealy bug, *Phenacoccus manihoti* Matile-Ferrero, in over 2.7 million km² in Africa. The fledgling U.S. biological control industry, generally organized under the auspices of the Association of Natural Bio-control Producers (2108) Park Marina Drive, Redding, California 96001), has about 12 member companies that generate nearly 20 million dollars of business annually. This is a rapidly-growing, self-regulating industry that mainly produces coccinellids, chrysopids, *Trichogramma* spp., phytoseiid mites, and parasitic Diptera for use against filth-breeding flies. In addition to extensive research, the USDA continues parasitoid and predator production at Mission, Texas and Niles, Michigan for inoculative release against the Russian wheat aphid, alfalfa weevil, European corn borer, Colorado potato beetle, and three species of rangeland weeds. This capability can be extended to mass rear at least 20 species in the families Coccinellidae, Chrysopidae, Aphelinidae, Braconidae, Encyrtidae, Trichogrammatidae, Tachinidae, and Phytoseiidae (Morrison and King 1977) plus Pteromalidae, predatory mosquitoes, and mantids.

RENAISSANCE IN BIOLOGICAL CONTROL

In a recent address prepared for the Colombian Society of Entomology, Leppla and Guerra (1990) described an incipient renaissance in biological control, exemplified by recent events in the U.S. A UCLA International Symposium entitled "New Directions in Biological Control", which was held at Frisco, Colorado in January, 1989, linked classical biological control with emerging insect biotechnology. The USDA established the Biological Control of Pests Research Unit at Weslaco, Texas in 1989. It also held a reception and exhibit of biological control successes in Washington, D.C. in March, 1989 to inaugurate the centennial year of the introduction of the vedalia beetle, *Rodolia cardinalis* (Mulsant), to control cottonycushion scale, *Icerya purchasi* Maskell, in California citrus. This was followed by the "Vedalia Symposium of Biological Control: A Century of Success" at Riverside, California in March, 1989 and the "International Symposium on Biological Control Implementation" at McAllen, Texas in April. In March, 1990, the National Biological Control Institute was founded by the USDA to promote and support biological control enterprises. An Interagency Biological Control Coordinating Committee was also created by the USDA to increase interagency cooperation in developing and implementing biological control and in recommending policy. Finally, two international journals devoted exclusively to biological control were announced in 1990: "*Biological Control: Theory and Application in Pest Management*" (Academic Press) and "*Biocontrol Science and Technology*" (Carfax Publishing Co.).

This revival of biological control is driven by a switch from invasive pest control methods intended to maximize productivity to systems that emphasize efficiency. Justification for this change includes concern for human health and safety, economic considerations, environmental issues and biological constraints (Table 1). Chemical residues are no longer acceptable in food and water, and many vectors of human and animal disease cannot be controlled with chemical insecticides. In most cases, herbicides are unsuitable for largescale weed control. Pesticide development, registration and re-registration have become unprofitable, restricting the variety of materials available. This further exacerbates the problem of specificity and unacceptable nontarget effects. Massive amounts of petroleum are required to manufacture and deliver chemical pesticides, and this adds significantly to the expense of farming and the cost of food. This situation is forcing a reevaluation of the introduction, augmentation, and conservation of natural enemies in light of modern capabilities in foreign exploration, identification, quarantine processing, colonization, delivery, and evaluation.

TABLE 1. Justification for biological control

1. Assure food safety
2. Enhance water quality
3. Prevent disease transmission
4. Replace obsolete pesticides
5. Protect biodiversity
6. Reduce petroleum depletion
7. Increase farming profitability

PROGRESS AND PONTENTIAL OF BIOLOGICAL CONTROL

"Progress and Potential of Biological Control in the Midwest" (R. J. O'Neil, Chairman), a workshop held at Purdue University during October, 1990, provided a synthesis of activities that promote the use of natural enemies for pest management (Table 2). The first steps are to conduct biological control surveys in appropriate geographical areas (i.e., regions, states or municipalities) and to inventory suitable targets and identify

TABLE 2. Steps in the progress of biological control toward realizing its full potential in pest management

1. Conduct biological control surveys
2. Establish common target systems, priorities, and goals
3. Foster interagency and interregional cooperation
4. Increase funding and personnel
5. Conduct interdisciplinary research
6. Emphasize applied projects that solve or prevent problems
7. Improve infrastructure for delivery
8. Demonstrate success through monitoring and evaluation
9. Document, publicize, and market
10. Communicate, educate, and motivate
11. Incorporate biological control into Integrated Pest Management

applicable agents. Non-traditional urban and horticultural pest problems can provide new opportunities. Eventually this process leads to establishment of common projects and goals, and agreement on priorities. Linkages are formed to foster interagency and interregional cooperation, and encourage joint funding for research and implementation. If possible, funding is specified for biological control within the pest management system. Applied projects for which biological control offers a permanent solution are more likely to receive support than long-term, fundamental research. However, much more information is needed on the systematics, genetics, physiology, behavioral interactions, and ecology of pests and their natural enemies. Success in shifting to biological control will require improvements in the existing infrastructure, including quarantine facilities and protocols, rearing capabilities, field site security, monitoring techniques, and biological and economic evaluation. Pest management systems based on biological control will be perceived as reliable only if they are clearly demonstrated as to cause and effect, documented, publicized, and marketed. Since biological control involves complex methods with results that are not always immediate and visible, users must be informed and educated before they will be motivated to change their practices. Finally, for complete acceptance, biological control must be integrated into existing agricultural systems.

NATIONAL BIOLOGICAL CONTROL INSTITUTE

The USDA Animal and Plant Health Inspection Service established the National Biological Control Institute (NBCI) in 1990 to encourage the use of biological control as a viable pest control strategy. Its basic mission is "to promote, facilitate and provide leadership for biological control" (NBCI Brochure, Hyattsville, Maryland). It is committed to developing greater scientific and technological capabilities in this field.

To carry out its mission, the NBCI has assumed a number of discrete functions (Table 3). These functions begin with national leadership and coordination. This requires that a network of cooperators be developed to promote biological control in federal and state governmental agencies, universities, state agricultural experiment stations, and private industry. Research, development, and implementation of biological control technologies involve collective support from all these organizations, and a primary function of the NBCI is to increase and strengthen the linkages between them (Fig. 1). To enhance this linkage, the Institute is guided by a User Advisory Panel composed of representatives from those organizations that will provide guidance for staffing, planning Institute activities, and performing its functions. The network of client organizations is used to identify regional and state pest problems as targets for new projects and to facilitate their development. An Information Center is being organized to collect and disseminate general and technical information on biological control activities. Institute support is also being provided for acquiring and deploying exotic and endemic biological control agents. Technical education and training programs will be designed to strengthen the implementation of sophisticated biological control methods. Finally, through its facilitation activities, the NBCI assures the effective and efficient integration of biological control with other environmentally-sound pest control technologies.

TABLE 3. Functions of the National Biological Control Institute established by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service in 1990

1. Ensure national leadership for the development and implementation of biological control
2. Develop an effective network of federal, state, and private organizations committed to biological control
3. Solicit input from cooperating institutions in identifying potential biological control projects
4. Identify and support the technical needs of cooperators and clients
5. Collect, analyze, and disseminate general and technical information on biological control activities
6. Expedite acquisition, development, and implementation of biological control agents
7. Coordinate technical education and training programs
8. Integrate biological control with other pest management technologies

BIOLOGICAL CONTROL IN INTEGRATED PEST MANAGEMENT

Biorational pest control, or Integrated Pest Management (IPM), relies on multifaceted strategies, including host plant resistance, biological control, cultural control, behavioral manipulation, and non-traditional chemical control, which are combined in varying proportions and integrated for specific pest problems, cropping systems, and geographical regions (Fig. 2). The main tools of biological control are, of course, parasitoids, predators, and pathogens. Biological control in this IPM context can mean the fortuitous use of ambient populations of natural enemies, which may be enhanced by careful conservation, or the augmentation of natural enemy populations. However, even in ideal situations with high natural enemy populations, achieved by whatever means, biological control alone may not be sufficient to maintain specific pests at economically acceptable levels. Consequently, interdisciplinary research must be advanced to develop all IPM strategies and integrate them into cropping systems.

Integration of IPM tactics at the cropping system level is a complex problem that requires rigorous quantification in all strategic areas, particularly in biological control. Assuming that adequate numbers of natural enemies can be mass-reared for application in a system, it is also crucial to know the right time for a release and the optimum numbers needed to achieve good pest control while minimizing cost. In addition, it is important to evaluate the effectiveness of control by natural enemies quantitatively in light of the mortality achieved in the pest population, the reduction in crop loss, and the economic costs and benefits.

Grower acceptance is critical if biological control is to be a viable and significant component of IPM. Growers are understandably and justifiably risk averse. If they are to accept biological control as part of a pest control program, they must know the risks associated with relying solely or partially on natural enemies. As discussed by Tauber et al. (1985), the development of a complete biological control "delivery system" is important in gaining grower acceptance. In

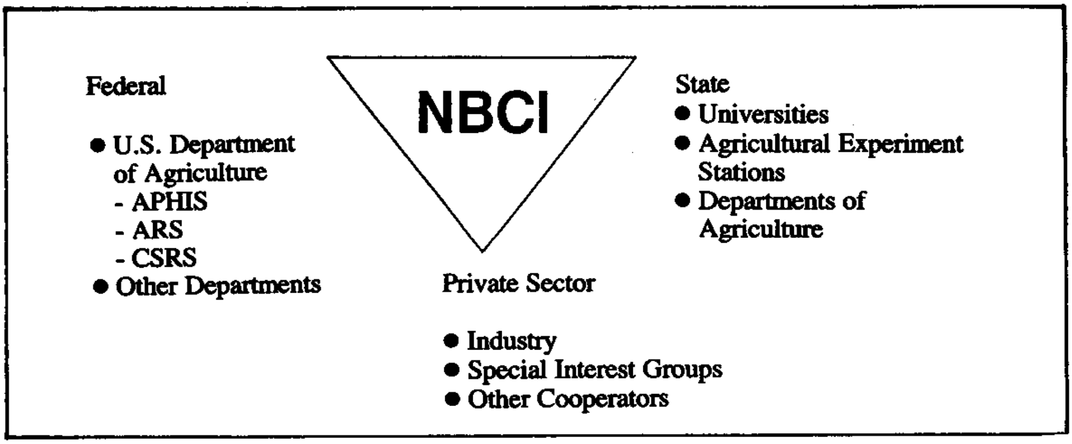

FIG. 1. Linkage of the National Biological Control Institute with other governmental and private organizations. This linkage will be expanded to incorporate the international biological control community.

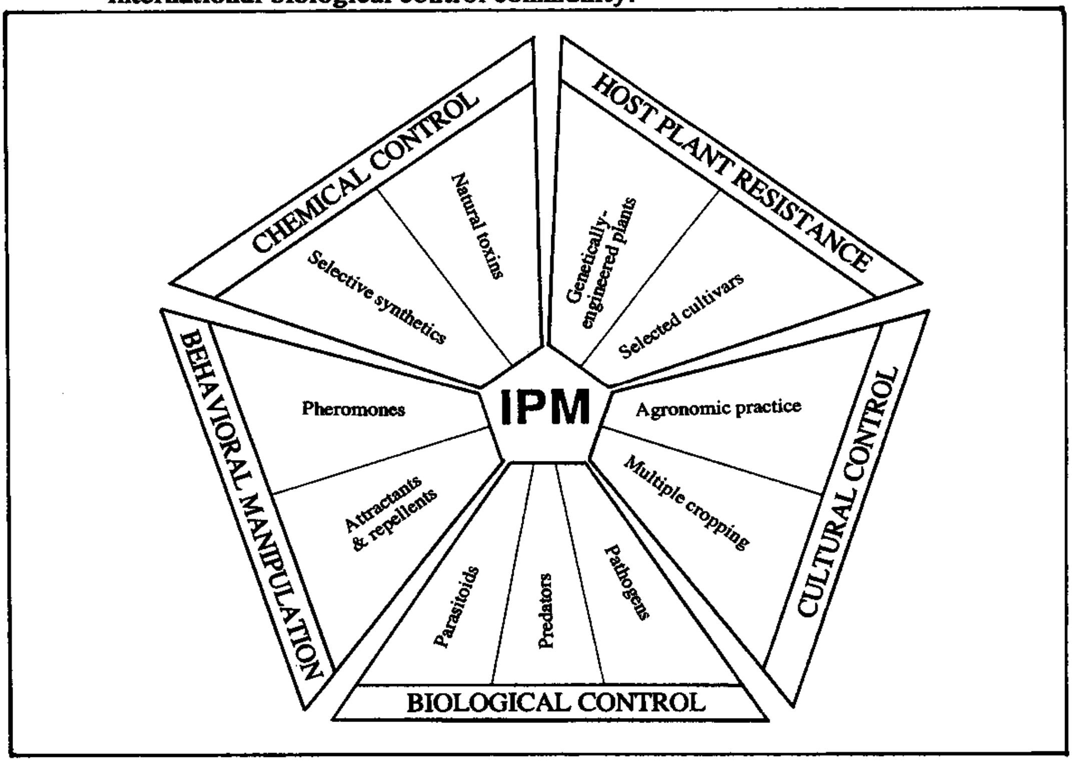

FIG. 2. The five strategic components of Integrated Pest Managment. Subdivisions within strategies give examples of some of the tools and tactics available to the IPM practitioner.

addition to the prerequisite of having readily-available supplies of high-quality natural enemies, it is necessary to (1) educate growers in how to use them, (2) market them widely and efficiently, and (3) provide service for the product sold, including follow-up calls, additional advice for use, and trouble-shooting. It is also necessary to evaluate the economics of using natural enemies in terms of their efficiency, ease of use, and relative risks and trade-offs. Integration of biological control into IPM will be truly achieved when the augmentation of natural enemies can be sold as a product with all the attendant instructions for use, service agreements, and guarantees.

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