Can Area-Wide Control of the Mediterranean Fruit Fly Using Sterile Insects Lead to Establishing Pest Free Areas in the Near East?

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Abstract

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Recent improvements in control of the Mediterranean Fruit Fly or "Medfly", *Ceratitis capitata* (Wiedemann) [DIPTERA: Tephritidae] using area-wide application of the Sterile Insect Technique (SIT) now make it possible to suppress this pest effectively. The use of male-only genetic-sexing strains of sterile Medflies, better attractants and detection methods, improvements in mass-rearing processes and quality product provide a cost-effective means of suppression. Systematic application of SIT over large areas also can lead to eradication of this pest providing that a sound plant health infrastructure is in place within a given country to conduct monitoring, impose regulatory controls and take emergency measures to protect these areas. Effective suppression of Medfly within Middle East countries would open the door to eliminate this pest completely and lead to establishing Pest Free Areas (PFAs) within the region. This would increase agricultural development and food security, reduce pesticide use and associated pollution, lower production costs, and expand trade opportunities. The new International Standard for Pest Free Areas, adopted through the Secretariat of the International Plant Protection Convention, provides a basis for phytosanitary certification and movement of plants, plant products, and other regulated articles in international commerce without the need to apply additional phytosanitary measures. A regional proposal for suppression aimed at future elimination of the Medfly from the Near East, developed at the request of Near East Member States by the Joint Food & Agriculture Organization/International Atomic Energy Agency Division for Nuclear Techniques in Food and Agriculture, will be presented.

Recent technological improvements coupled with the adoption of new international phytosanitary standards opens new possibilities for dealing with age-old pest problems such as the Mediterranean Fruit Fly or Medfly, *Ceratitis capitata* (Wiedemann) (Figure 1). Can area-wide control of the Medfly using sterile insects lead to establishing pest free areas in the Near East? The answer to this question is yes.

The Medfly Problem

The Medfly is the single most important pest species affecting fresh fruits and vegetables with the Mediterranean, especially the Near East. Without repeated use of pesticides, Medfly infestations can range from 50 up to 90% for many commercial hosts (1). Those hosts hardest hit are most citrus varieties, mangoes, grapes, apples, peaches, apricots, pears, plums, figs, persimmons, papayas, peppers, dates and tomatoes. Back-yard and garden production of fruits also is difficult, if not impossible (6).

The presence of this pest in the Near East region severely limits the degree to which agricultural and economic development can occur (6, 8). Each year these countries incur high economic losses, reduced availability of foodstuffs and elevated pest control costs. Host fruits in Israel, Territories Under Jurisdiction of the Palestinian Authority, and Jordan produce approximately U.S.$611 million per year in revenues. Under the current control programs, the direct and indirect damage attributed to the Medfly amounts to U.S.$192 million per year (3). Efforts to control the Medfly also disrupt IPM and biological control efforts resulting in higher losses from increased pest control costs and damage.

Recent Improvements in Pest Control Technologies

The Sterile Insect Technique or SIT was developed by scientists over 30 years. Its effectiveness as a pest control technology has clearly been demonstrated on numerous occasions over the years. SIT offers many advantages over other types of pest control, particularly those that rely upon pesticides. For one thing, it is a target specific remedy that does not cause environmental pollution.

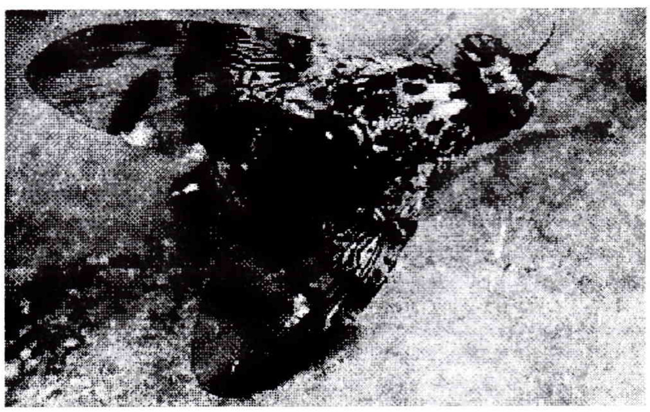

Figure 1. Adult Female Medfly

Even so, this technology still has not been embraced by the agricultural community to control pests for various reasons. Some reasons include the lack of commercial rearing facilities that can deliver sufficient numbers of insects to the client, the presence of sterile female fruit flies that potentially could scar fruit through oviposition, relatively high operational costs associated with production and release of sterile insects, and the lack of plant health infrastructure within developing countries to conduct area-wide projects.

SIT Successes

New World Screwworm - completely eradicated from the USA (1957-80), Mexico (1991), Guatemala &Belize (1992), Honduras & El Salvador (1993), Nicaragua and most of Costa Rica (1997), Libyan Arab Jamahiriya (1990-92).

Tsetse Fly - completely eradicated from Zanzibar, Tanzania in 1997.

Melon Fly - completely eradicated from Japan in 1993.

Medfly - completely eradicated from Chile, USA (California, Texas, Florida) and Mexico (Chiapas). Barrier program maintained along border between Mexico and Guatemala since 1977.

Males-Only Strains Developed

Recognizing this, the Joint Food & Agriculture Organization/International Atomic Energy Agency Division for Nuclear Techniques in Food & Agriculture embarked on a research program in 1980 to develop genetic sexing strains that would eliminate the presence of the female prior to its release. Presumably, this would address many of the barriers mentioned above and could stimulate the construction of large rearing facilities that could meet customer needs.

Ten years later, a major breakthrough occurred in the rearing of Medfly within the Entomology Unit at the IAEA Seibersdorf Laboratories in Austria through the use of a genetic transformation system that relies upon the presence of a temperature sensitive lethal (*tsl*) gene. Through classical genetic crossings, IAEA scientists were able to link this gene to the female. Thus, applying heat to Medfly eggs in a water bath at 34°C prevents female larvae from hatching. The efforts to develop a practical method for genetic sexing along with the advantages associated with male-only releases are cited in Hendrichs *et al.* (11). Males-only strains have proven to be more effective than mixed-sex releases of sterile flies (2, 10, 15, 16, 18).

Advantages of Genetic Sexing Strains, taken from J. Hendrichs *et al.* (11)

- No damage to host fruits.
- Operational savings in production and release of insects.
- Increased biosecurity without females.
- Increased effectiveness of SIT through greater dispersal, competition, and utilization of sperm.
- Simplified field monitoring possible with female attractants.
- Increased quality and viability of males.
- Increased applicability of SIT.

Improvements in Mass-Rearing Processes

Apart from development of a temperature sensitive lethal strain of Medfly, existing rearing practices had to be modified so that sufficient number of insects could be produced for control purposes. These changes include more stringent control over the temperatures during each phase of the rearing process, and a larger egging colony to compensate for a 50% reduction in egg production.

These strains were developed after many hours of selection and tedious back-crossing. Therefore, their stability over time depends on where the translocation occurred. As a result, they are subject to recombination and the potential loss of the selected genetic traits, such as the temperature sensitive lethal gene. A new system of rearing under less rigorous and stressful conditions is required to minimize recombination and unintended selection. A smaller colony must be maintained to preserve the characteristics of the strain. This is referred to as a "filter rearing system". This system also can be used for introducing new strains of any kind into mass-rearing facilities with the possibility of a much shorter time frame.

Construction of New Medfly Rearing Facilities

As interest in the use of SIT for pest control increases, so does the interest in the construction of mass-rearing facilities to address the demands of the customer. Examples of this include a modular facility that recently was built in Guatemala with a capacity to produce approximately 1 billion sterile *tsl* Medflies per week. Most of the production currently goes to maintaining a biological Medfly barrier that lies along the border between Mexico and Guatemala. However, they also sell sterile Medflies to the State of California for use in their on-going preventive release program. Other clients included the State of Florida for eradication of a new Medfly introduction in Tampa during 1997.

A facility was constructed in Mendoza Province, Argentina in 1991 with a production capacity of 250 million Medfly pupae per week. They use a white pupal strain that separates the sexes mechanically using colour. From this, they yield approximately 90-100 million male-only adults for release. Another new factory was inaugurated in 1997 in Camacha, Madeira, Portugal. This facility has a capacity to produce up to 40 million *tsl* Medflies per week for use in a campaign to suppress Medfly population in the Autonomous Region of Madeira. Madeira will sell 8 million *tsl* pupae per week to Israel for release in the Lower Jordan Rift Valley.

Plans also have been prepared for the construction a facility on the island of Sicily, Italy, to provide between 250-500 million pupae per week for suppression there. Additional locations and levels of production are cited in Hendrichs *et al.* (11). Other important advances include the modular design of new facilities which allows better control over environmental conditions. Furthermore, it allows one to construct, in simple fashion, a rearing facility best suited to the overall demands of the client.

Product Quality Standards Revised and Updated

The Joint FAO/IAEA Division together with the United States Department of Agriculture convened a group of consultants in 1997 to revise and update the product quality control procedures that first were established in 1985. Greater emphasis was given to assessing behavioral aspects of compatibility and competitiveness and less emphasis placed on routine tests that were arbitrarily established to measure mating performance.

A Coordinated Research Program (CRP) on Medfly mating behaviour has focused on examining the sequence of behaviours leading up to successful pairing by males and females. High speed filming of courtship behaviour combined with sound recordings have enabled scientists to compare mating behaviour of Medflies from different geographic regions and to examine if there are differences between wild populations and lab-adapted colonies from mass-rearing facilities.

Assessments of mating competitiveness and compatibility also are performed in the field using caged host plants as an arena for making observations. Again, comparisons have been made with Medfly strains from different geographic locations. Thus far, all mass-reared strains appear to be fully compatible with wild flies regardless of location. The end result of these efforts is to insure the end-users of SIT that the sterile insects readily and successful compete with native male Medflies.

Better Attractants and Detection Methods

Another technological advance occurred in the area of synthetic attractants to monitor both native and sterile Medfly populations. In the past, population monitoring relied mostly on the use of parapheromones that attract male Medflies only. Since millions of male Medflies are released each week in an SIT program, the task of separating sterile flies from native, wild flies becomes extremely tedious and costly.

The Joint FAO/IAEA Division supported a CRP for better attractants that would trap mostly females rather than males (13). A chemist from the US Department of Agriculture identified three compounds that achieve this: putrescine, trimethylamine, and ammonium acetate. Now that an attractant has been developed, attentions will be placed on the most effective trap design. Its potential as a bait station for attracting and killing females also is under study. Not only does this avoid massive recapture of sterile male Medflies, but also can provide a measure of SIT effectiveness. Apart from monitoring the number of females captured on a weekly basis, these flies can be examined for egg viability or evidence of mating with sterile or fertile male Medflies. Adult females also can be captured live and placed with host fruit to see if they deposit fertile eggs.

Area-Wide Control of the Total Population Versus Farm-by-Farm Crop Protection

Within the Near East Region, the most common form of pest control is independent farm-by-farm application of conventional cover sprays on a calendar basis mostly using highly-residual organophosphates. In Jordan alone, an average of 94 tonnes of insecticide are used each year for Medfly control at a cost of US$2.1 million. Despite this enormous usage, fruit infestation averages 29%. Farmers are forced to pick the fruit as quickly as possible while it is still green to avoid higher losses. This results in lower quality fruit for the market place. Direct and indirect losses within Israel, Jordan, and the Territories Under the Jurisdiction of the Palestinian Authority totals US$192 million per year with current control practices (3).

What is needed is an area-wide approach to controlling the Medfly aimed at suppressing the total population. This would include applying control efforts in both commercial and non-commercial hosts. Generally, SIT control actions are intensified when the pest population declines. The combination of biotic and abiotic factors potentiates SIT effectiveness. Area-wide SIT relies upon detained information regarding pest distribution and population levels, host phenology, etc. This approach differs from farm-to-farm crop protection or integrated pest management (IPM) that defers control actions until an economic threshold is reached. These actions usually are limited to the crop and the fruiting season. Fruit flies are not good candidates for IPM approaches because the biological controls are not very effective, and, in many instances, the importing country has a zero tolerance with regard to pest presence. Since you are constantly attacking the population under area-wide SIT, greater suppression is possible and could lead to complete eradication if applied intensively over several generations. This brings us to the issue of International Phytosanitary Standards and establishment of a Pest Free Area in the Near East.

International Standards developed for Pest Free Areas

In 1994, the North American Plant Protection Organization (NAPPO) became the first group on an regional level to set a standard for establishment of a pest free area (17). NAPPO is an international organization comprised of the heads of national plant protection organizations within the United States of America, Mexico and Canada. This standard defined the basic requirements that must be met to certify agricultural commodities for importation into those three NAPPO countries. A mutually acceptable work plan must be developed between the national plant protection organizations of the importing and exporting countries. Rather than limit the movement of agricultural commodities, this standard provides a basis for phytosanitary certification and movement of plants and other regulated articles in commerce. The European Plant Protection Organization also adopted similar standards for pest free areas (19).

Subsequently, the Secretariat of International Plant Protection Convention (IPPC) of the Food & Agriculture Organization (FAO) of the United Nations (UN) published a specific international standard dealing with requirements for the establishment of pest free areas (9). Under the World Trade Agreement, the IPPC Secretariat of the UN/FAO was given responsibility for developing international standards for phytosanitary measures, also known as ISPM (7). This standard provides broad guidance on what steps the exporting country could take to gain recognition of an area as pest free within a part of a country, parts of two or more countries or the entire country with details determined by the trading partners based on commodity and assessment of pest risk.

Factors Favoring Pest Free Areas in the Near East

- The ocean and/or desert surrounding agricultural areas provide natural barriers to the threat of Medfly reintroduction by natural migration.
- Only one economically important fruit fly with a broad host range, the Medfly, is present in the Near East unlike other areas of the world that must contend with multiple species.
- Lack of alternate host plants within the arid expanses. Hosts are limited to irrigated areas.
- Reintroduction could be avoided by establishing effective exclusion measures at key locations, i.e., ports-of-entry, or by continuous releases of relatively few sterile insects.

These measures should be viewed as opportunities to control pests using the newest and most environmentally-friendly technologies while reaping the benefit of increased agricultural development and trade.

Subregional Proposals Developed by the Joint FAO/IAEA Division to Implement SIT in the Near East

In 1994, a meeting was convened in Vienna at the request of the Directors General for the UN/FAO and UN/IAEA with technical representation from among Near East countries to discuss the possibility of conducting a regional project to control the Medfly. A proposal was developed calling for the use of SIT to suppress and eliminate the Medfly from the Near East (12). In follow-up to this meeting, expert consultants prepared an operational plan that included an estimate of operational costs. The plan divided the region into three independent, subregional projects: 1.) Cyprus Med, 2.) Egypt Med, and 3.) East Med (14). The proposed subregional projects could be implemented independent from one another depending upon the level of internal and external support and commitment. The projected cost of Cyprus Med came to U.S. $22.9 million over a period of 4 years. Egypt Med would cost U.S. $133.6 million over a period of 6 years. East Med subregion consists of a small portion of Egypt, the Hashemite Kingdom of Jordan, the State of Israel, Territories Under the Jurisdiction of the Palestinian Authority, Syrian Arab Republic and Lebanon. The projected cost totalled U.S. $286.2 million over a period of 9 years. Each of these projects called for an incremental approach that would progress from year to year starting with a pre-eradication phase, eradication phase (18 months), post-eradication phase (6 months), and verification phase.

Requirements for Subregional SIT Project:

- Mass rearing facility with a capacity to meet client needs.
- Mutual interest to cooperate within the region on more effective control measures.
- A substantial show of interest and support, as well as initiative in seeking funding on the part of agricultural producers and the governments of the respective countries within the Subregion.
- Commitment should be demonstrated by investments from local producers, together with significant contributions from the participating Near East governments.

Strong economic and environmental justifications for using SIT to control Medfly within the Near East can be found in the recent assessments prepared by Imperial College Centre for Environmental Technology. Studies have been completed for the Hashemite Kingdom of Jordan, Lebanon, State of Israel, the Syrian Arab Republic, and the Territories Under the Jurisdiction of the Palestinian Authority (3, 4, 5). They examined three improved Medfly control alternatives: population suppression using bait sprays (Bait-SUPP), population suppression using massive releases of sterile male flies (SIT-SUPP), and population eradication also using massive releases of sterile male flies (SIT-ERAD). Results of these studies indicate that the 3 area-wide control options are technically and economically feasible and all are better than the current control programs. The most favorable benefit cost ratio over a 9 years time frame was shown to be SIT-SUPP (Table 1). The second best option according to benefit to cost ratio and net benefit figures was SIT-ERAD. Using a longer time frame of 14 years or more, the highest benefit indices shift to SIT-ERAD option. The added benefits would be eliminating entirely the use of insecticides to control the Medfly along with better market opportunities in both the traditional markets and the more discriminating pest- and pesticide-free markets that pay a higher price for quality fruits and vegetables.

Table 1. Economic indices of Medfly control options for a 9-year project in Near East with 25% market gain.

Control Option	Net Benefits (US$Millions)	Benefit to Cost Ratio	Pay-back Period
BAIT – Suppression	1,540	13.9	1
SIT – Suppression	2,211	25.7	1
SIT – Eradication	2,067	15.2	4

Taken from Enkerlin and Mumford (5)

IAEA-Sponsored National Projects Underway

Since 1995, IAEA has contributed a total of US$613,465 to Near East countries to assess the feasibility of using SIT in Lebanon to control the Medfly. Within the next two years, an additional US$1,198,615 will be invested by IAEA in Technical Co-operation projects aimed at implementation of SIT on a national level. This funding covers expenses for outside experts, fellowships/scientific visits, and key equipment or supplies. Contributions on the part of the Member State include staffing, facilities, vehicles, operating expenses and other items that are readily available in the local marketplace.

Examples of national projects currently underway include the feasibility of integrated control of Medfly using SIT. The national counterpart is the Agricultural Research Institute at Fanar. Agency funding date totals US$235,975 which included the purchase and installation of a cobalt irradiator for sterilizing Medfly pupae, microscopes, cages and other equipment for rearing Medflies on a pilot-scale for conducting field testing. A portion of the funding was used to train the professional staff through fellowships to Guatemala, Madeira, Crete and Austria. Expert consultants also travelled to Lebanon to provide advise on planning, implementation, the newest methods and technology transfer.

In 1997, national projects were initiated separately within Israel and Jordan. Activities include monitoring Medfly populations through trapping and fruit sampling, specimen identification, Medfly suppression with bait sprays, and release of sterile Medflies to achieve control. Actions will be concentrated within the Lower Jordan Rift Valley in accordance with the recommendations made to the IAEA by a group of experts. Sterile fly releases will be initiated on the Israeli-side of the border in December 1997. Sterile fly release could be initiated on the Jordanian-side as early as 1998. Both projects are approved through the year 2000. Eradication of the Medfly from the Lower Jordan Rift Valley can be accomplished within 4 years providing that both countries impose regulatory measures to prevent its reintroduction or continue to release sterile Medflies as a preventive measure.

Benefits to be Derived from Medfly Eradication Using SIT

Below are some of the key benefits that will accrue once the Medfly is eliminated from the Near East:

- Elimination of the most destructive insect pest within the Near East and the losses associated with it.
- Elimination of more than 194 tonnes of pesticide usage each year.
- Reduction in adverse environmental impacts caused by current pesticide usage.
- Reduction in pesticide residues in water and the environment associated with Medfly control.
- Enhanced agricultural and industrial development plus greater trade opportunities.
- Increased revenues from higher production and better quality fruits and vegetables.
- Increased availability of nutritious foodstuffs for local consumption.
- Improved plant health infrastructures within the region to exclude or control pests.
- Enhanced use of biological alternatives to control other pests within the region.
- Regional cooperation to combat pests on an area-wide basis.
- Exclusion and detection of exotic fruit flies not known to occur in the area and emergency action plans for dealing with potential outbreaks in the future.

الملخص

جوميز، ب. 1997. هل بإمكان المكافحة على نطاق واسع لذبابة البحر المتوسط للفاكهة باستخدام الحشرات العقيمة أن تسهم في إنشاء مناطق خالية من الحشرات في الشرق الأدنى؟. مجلة وقاية النبات العربية. 15(2): 134-139.

مكنت التحسينات الحديثة في مكافحة ذبابة البحر المتوسط للفاكهة (Wiedemann) *Ceratitis capitata* من رتبة ذات الجناحين وفصيلة Tephritidae، بالاستخدام الواسع لتقنية الحشرات العقيمة من الحد من هذه الآفة على نحو فاعل. إذ يتيح استخدام سلالات ذكرية وراثيا من الحشرات العقيمة، واتباع تقنيات جذب وكشف محسنة، وإدخال التحسينات في عمليات التربية الجماعية ونوعية المنتج طرائق مجدية اقتصاديا في الحد من الآفة. وقد يؤدي الإستخدام المنظم لتقنية الحشرات العقيمة على مناطق شاسعة إلى استئصال هذه الآفة شريطة توافر بنيات تحتية سليمة لصحة النبات في الدولة المعنية من شأنها القيام بعمليات الرصد، وفرض إجراءات المكافحة المنظمة، واتخاذ إجراءات الطوارئ لحماية تلك المناطق. وقد يفتح الحد الفاعل للذبابة في دول الشرق الأوسط الباب لاستئصال هذه الآفة نهائيا، ويقود إلى إرساء مناطق خالية من الآفات ضمن هذه الدول. ومن شأن ما تقدم زيادة التنمية الزراعية والأمن الغذائي، وخفض استخدام المبيدات وتلوث البيئة الذي يرافقه، وخفض تكاليف الإنتاج وزيادة فرص التجارة. ويتيح المعيار الدولي للمناطق الخالية من الآفات، والذي تم تبنيه من خلال أمانة المدونة الدولية لوقاية النبات، الأساس للشهادات الصحية وانتقال النباتات ومنتجاتها وغيرها من المواد الخاضعة لإجراءات تنظيمية في التجارة الدولية دونما حاجة لتطبيق إجراءات صحية نباتية إضافية. وسيعرض الباحثون مشروعا إقليميا للحد من الآفة يهدف إلى استئصالها من منطقة الشرق الأدنى في المستقبل. وقد تم تطوير هذا المشروع بناء على طلب تقدمت به دول الشرق الأدنى الأعضاء وأعدته منظمة الأغذية والزراعة وشعبة التقاني النووية في الزراعة التابعة للهيئة الدولية للطاقة الذرية.

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The Code of Conduct for the Import and Release of Exotic Biological Control Agents and its Implementation

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Abstract

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The Code addresses the importation of exotic biological control agents capable of self-replication (parasitoids, predators, parasites, herbivores, antagonists, competitors and pathogens) for classical biological control, inundative releases and research including the use of biological pesticides. It lists the responsibilities of parties concerned; the authorities, the importers and the exporters. The Code was endorsed by the FAO Conference as an International Standard for Phytosanitary Measures under the IPPC in November 1995. The overall objective of the Code is to provide harmonized guidelines for the import and release of exotic biological control agents with due consideration for environmental and quarantine concerns. The need for this Code is explained and the process of its formulation is briefly described. An overview is given of the contents of the Code. Experiences in applying the Code in FAO-funded biocontrol projects in the Caribbean, Yemen and West Africa are reported. Activities to promote the observance of the Code are discussed.

Introduction

In November 1995 the Code of Conduct for the Import and Release of Exotic Biological Control Agents was endorsed by the 28th Session of the FAO Conference as an international standard (8). Before discussing the need for this code, its development and contents, some explanation of the terminology is given.

Recommendations, guidelines and codes (or standards) are instruments used by international organizations for harmonization among members. These three instruments are not legally binding. It is up to the member to decide to bring them into practice. A code however is the strongest instrument of the three. It defines the standards of good behaviour that is to be expected from a well governed state.

A biological control agent is a natural enemy, antagonist or competitor or another self-replicating biotic entity, used for pest control:

- A natural enemy is an organism that lives at the expense of another organism and which may limit the population development of its host. This includes parasitoids, parasites, predators and pathogens. Most experiences with biological control are based on the use of natural enemies. Therefore, this paper will be focused on this component of the biological control strategy. For information on the use of antagonists and competitors, the author would like to refer readers to other references (1, 2).
- Intentional introduction aiming at the permanent establishment of an exotic (not native to a country) biological control agent is known as classical biological control. Exotic biological control agents can also be released in large numbers to achieve a rapid reduction of pest numbers without necessarily achieving continuing impact. These are called inundative releases. Biological pesticides, usually pathogens formulated and applied in a manner similar to a chemical pesticide for a rapid reduction of a pest population, are also considered to be biological control agents.

The need for a Code of Conduct

It is generally accepted that classical biological control started in 1889 with the introduction of the Vedalia lady beetle *Rodalia cardinalis* Mulsant from Australia into California to control the cottony cushion scale *Icerya purchasi* Maskell, a serious introduced pest of citrus. Because of its success, classical biological control became more and more the preferred method to deal with introduced