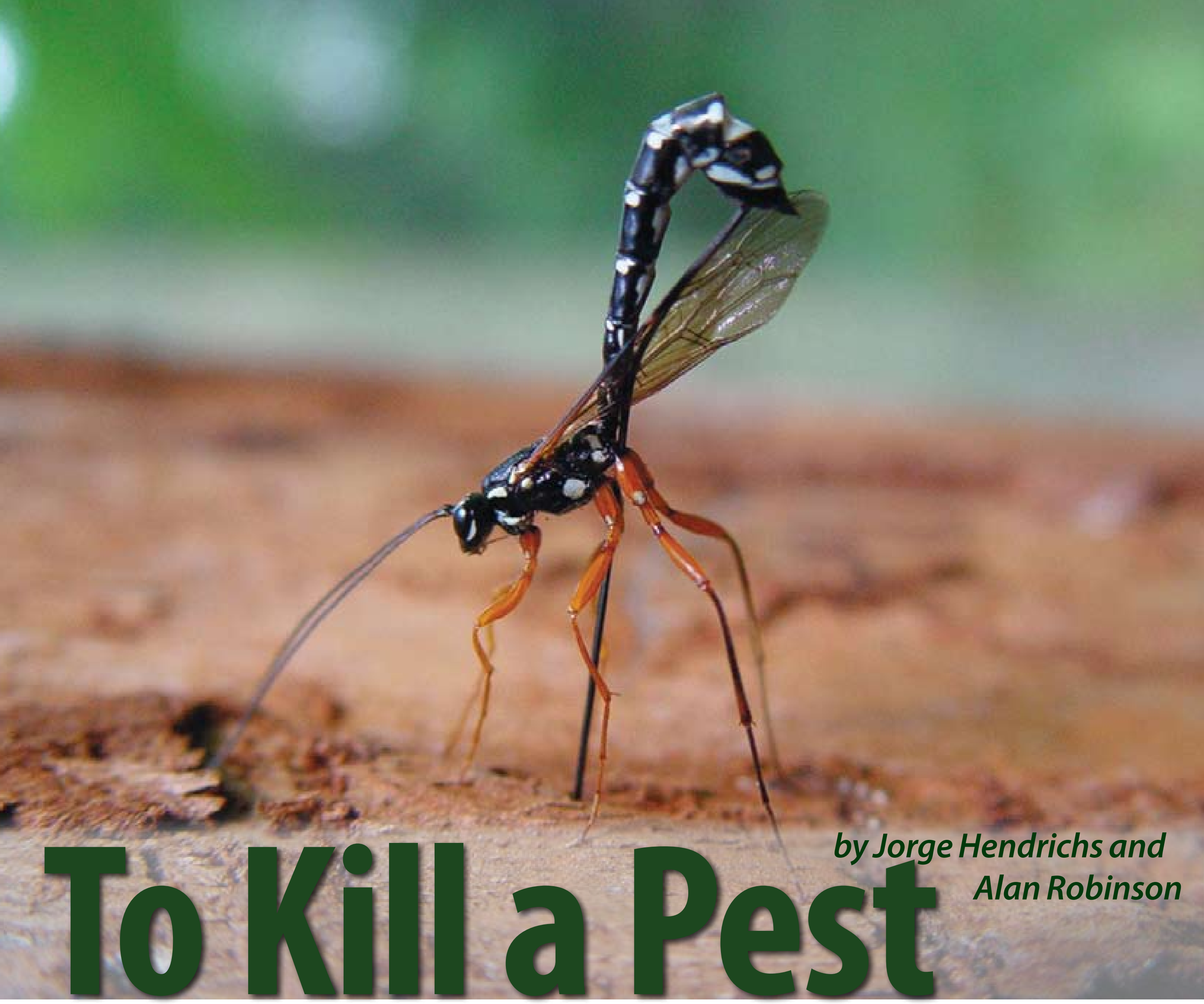

To Kill a Pest

by Jorge Hendrichs and Alan Robinson

The use of radiation is improving the biological control of insect pests.

A giant ichneumon wasp adult boring the surface of fir trunk infested with wood wasp larvae. (Photo: Boris Hrasovec, Faculty of Forestry, Bugwood.org)

The IAEA's support to Member States in the field of insect pest control has mainly focused on the Sterile Insect Technique (SIT), which is a type of insect birth control, where mass reared and systematically released sterile males of the target pest insect mate with wild females in the field, thereby interfering in an environment-friendly way with the reproduction of the pest population. This approach effectively reduces the use of insecticides and has been successfully used to manage, and in some cases eradicate, populations of major pest insects. Nevertheless, there are other areas where Member States can benefit from radiation in the field of entomology. One of these is biological control.

What is Biological Control?

Despite centuries of technological development, insect pests continue to exact a very high toll on agricultural production and human health. A well-established, successful approach to this problem is the use of natural enemies, called biological control agents, to manage pest populations. The biological control agent can be a predator, a parasitoid, a bacterium, a fungus or a virus. In this article we will concentrate on predators, which eat the pest (prey), and parasitoids, which parasitize the pest (host) by stinging and thereby laying eggs into it.

When insects escape their native natural enemies, either because they invade new countries leaving behind their biological control agents or as a result of the disturbance of these natural enemies, they become pests. As shown in Box 1, if appropriately applied, biological control offers one of the most promising, environmentally-sound, and sustainable tools for control of such insect pests. However, there are many constraints to the expansion of biological control programmes, related to the production, shipment and release of biological control agents. The commercial and public biological control industry is growing but still represents less than 3% of pest control sales. Regulatory, technical and other constraints have kept the market share relatively small. The challenges include the high cost of production, adequate quality control and assurance, trade barriers and regulations that complicate shipping.

There are several ways in which nuclear techniques can address these constraints and the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture has now completed a Coordinated Research Project on this topic with the participation of 18 research teams from 15 countries.

Regulating Biological Control Agents

Lack of international harmonization among countries and availability of enabling regulations is probably the most important barrier to the wider implementation of biological control, 'gatekeeper' regulations place barriers in the way of efficient introduction and application of biological control agents. However, the Secretariat of the International Plant Protection Convention, of the Food and Agriculture Organization of the United Nations (FAO) has published a revised International Standard for Phytosanitary Measures (ISPM) on 'Guidelines for the export, shipment, import, and release of biological control agents and other beneficial organisms', which should help to solve some of these problems and increase trans-boundary trade in biological control agents.

Safeguarding Biodiversity

At times, the biological control agent chosen to be released is an exotic species to the environment. One of the key concerns in this approach is the question of specificity of the biological control agent in its new ecosystem, i.e. will the introduced biological control agent remain associated with the pest or will it expand its range to impact on other species in the ecosystem and so affect biodiversity or even attack beneficial species or commercial crops? There are numerous examples where introduced biological control agents have 'jumped species'. Since such mistakes are permanent in time and space, the feasibility of such introductions need therefore to be carefully assessed before the introduction of any biological control agent is undertaken. One of the best-known of these mistakes is the cane toad in Australia, which was introduced to control pest insects in sugar cane, however, it very quickly began to feed on other species and multiplied in numbers until it became a pest itself. Once biological control agents are released, they cannot be recalled and, as they are fertile, they have the

Biological Control of the Cassava Mealybug

This insect became a devastating pest of cassava in Sub-Saharan Africa following its introduction into Congo from South America in the 1970s and its rapid spread to the rest of the subcontinent. Cassava is the prime source of carbohydrates, proteins and vitamins for 200 million Africans. A natural parasitoid (insert image) of the cassava mealybug was identified in Paraguay, the origin of the pest in South America, and transferred to the International Institute for Tropical Agriculture, in Ibadan, Nigeria where it was mass reared. It was released from over 150 sites in the region, became established and brought the pest under control in 95% of all fields.

Screening Exotic Biological Control Agents to Safeguard Biodiversity

- In the USA the field evaluation of an exotic herbivore in sterilized form, for the eventual biological control of the Brazilian pepper tree, a major weed that has been accidentally introduced.

- Also assessment of irradiated cactus moths, a pest of different native cactus plant in some locations, and a biological control agent of introduced cactus weeds in others, to confirm under natural conditions oviposition preferences to predict the host range, the ability of larvae to survive and cause damage on related native plants, as well as to study possible interactions with natural enemies.

Top: Mucidifurax raptor wasp on a fly puparium. Once the female chooses a suitable puparium host, she lays a single egg in it. The egg hatches, and the wasp larva feeds on the fly pupa.
(Photo: USDA ARS Photo Unit, USDA Agricultural Research Service, Bugwood.org)

Bottom: Braconid wasps: parasitoids on sphinx or hawk moths.
(Photo: David Cappaert, Michigan State University, USA. Bugwood.org)

opportunity to reproduce and increase in numbers. This is fine if they remain "locked onto" the pest species but can be disastrous if they find new non-pest hosts in the new ecosystem.

Radiation can play an important role in the safe evaluation of the potential host range of a biological control agent in a new ecosystem. It provides a way to sterilize and release biological control agents in the field without establishing them permanently and without affecting their behaviour, and to assess what they eat and do not eat, what hosts they parasitize, and where they go. Repeated releases of sterilized biological control agents will provide without risk critical information under natural conditions in order to improve decision making relating to eventual fertile release.

Improving Mass Production

As a biological control agent preys on or parasitizes another insect species, it follows that both species have to be reared in order to produce the biological control agent for release, in other words it is a two component biological system. This is in contrast to the SIT where only one species needs to be reared. This increased complexity makes the mass rearing of biological control agents logistically demanding and more expensive.

Improved Mass Production of Biological Control Agents

- In Bulgaria, an irradiated factitious host used to rear the wasp that parasitizes moth pests in mills and grain warehouses.
- In Pakistan, irradiated moth eggs utilized as a prey substitute to feed a predator for area-wide control of cotton and sugarcane pests.
- In Poland, radiation used to successfully extend the shelf-life of parasitoids to control stored grain moths causing damage in grain warehouses.
- In Turkey, an irradiated factitious host used to mass rear a parasitoid of the olive fly for use in an area-wide pilot project in an olive production area.

Often the natural prey or host species are themselves difficult or expensive to rear in large numbers and the use of more readily available substitutes would be an advantage – the so called factitious species. However, these types of species are not always as acceptable as the natural prey or host; this is especially the case for biological control agents which lay eggs in living hosts which are then subject to its immune response. Radiation can be used to suppress the immune response of the host making it more suitable for parasitism.

A host is often suitable for parasitism only within a very small window of time during development and radiation can be used to enlarge this window by reducing the speed of development of the host. The limited shelf life of hosts and prey also restricts their use during mass-production and for certain species radiation can be used to arrest development and thus allow for storage and stockpiling of hosts or prey to be used when required by the customers (farmers, greenhouses, grain mills, poultry houses, etc.).

There is also the use of the controversial phenomenon known as 'radiation hormesis', i.e. the use of very low doses of radiation to stimulate biological processes. There is some preliminary evidence that this process can increase parasitisation rates and reproduction.

Facilitating Handling, Shipment, Trade and Release

A major headache for producers of biological control agents is the continued development and emergence of some pest insects, in the form of non-parasitized hosts and unused prey insects, among the mass produced natural enemies. This "contamination" of the final biocontrol product can create major problems in terms of efficiency of the mass-production process. It requires additional handling steps involving the removal of significant numbers of non-parasitized hosts or unused prey individuals from the rearing process before they are shipped and emerge as pest insects with farmers using the biological control agents. Radiation can be used to sterilize prey, hosts, and factitious hosts to prevent further development of the pest insects and thus remove the need for labour intensive separation procedures.

When biological control agents are shipped to other countries, the fact that shipments often include fertile pests, either as prey or hosts, brings with it a real or perceived risk that this could lead to the introduction of non-native, pesticide resistant or new strains of pest insects into new areas or countries. This risk can be translated into ever more stringent quarantine regulations and permits required for their shipment. Irradiation of hosts and prey can ensure that, even if not all the hosts are parasitized and all the prey eaten, customers receive shipments free of fertile pest insects.

There is also the need to safely ship hosts and prey between different facilities; for example large production facilities may decide to ship hosts/prey to smaller satellite facilities which concentrate only on rearing the biological control agent and not the hosts or prey. This procedure can be made safe by irradiating the material before shipment as is now routinely done in SIT programmes, where sterile pupae are shipped to large emergence and release facilities. The use of radiation in this way will lead to increased efficiencies in the production of biological control agents and will help to standardize the use of strains of host/prey material to ensure product quality.

Supplementing Biological Control Agents in the Field

♦ In China, irradiated moths released into field crops where their sterile eggs served as hosts for wild parasitoids resulting in parasitoid population increase.

♦ In Czech Republic, irradiated moth eggs distributed in a natural forest to serve as hosts for wild biological control agents.

♦ In Czech Republic, sterile moth larvae deployed in forests to monitor the density and type of parasitoids and pathogens.

♦ In Pakistan, irradiated hosts placed in the field early in the season to increase populations of parasitoids to effectively manage sugarcane pests in an area of 40,000 hectares.

Handling, Shipment, Trade and Release of Biological Control Agents

♦ In Argentina, radiation of housefly pupae used to mass rear egg and pupal parasitoids for deployment in chicken houses and cattle feedlots.

♦ In Mexico, irradiation of immature stages of fruit flies to mass rear ca. 100 million fruit fly parasitoids each week, as part of the area-wide release of the parasitoids.

♦ In the USA, irradiation of prey for the production of predatory mites for the control of vegetable pests in greenhouses.

Supplementing Biological Control Agents in the Field

In the field, insect pests go through population cycles as do their biological control agents. Unfortunately these cycles are often not in synchrony and the biological control agent populations generally lag behind the pest populations. If the number of biological control agents could be increased prior to the increase in the pest population then much better control would follow. This can be achieved by distributing prey or hosts, sterilized by radiation, into the field early in the season so

Pink spotted ladybird predator feeding on eggs of Colorado potato beetle.

(Photo: Whitney Cranshaw, Colorado State University, Bugwood.org)

that the numbers of biological control agents can be safely built up on the pest insects deployed.

In biological control programmes it is necessary to monitor the biological control agent in the field to assess its population levels, survival, distribution etc., and this again can prove to be quite difficult as the numbers of hosts can be low in an effective programme. However, radiation sterilized hosts can be safely introduced into the target location as sentinels to increase the chance of correctly evaluating the presence and levels of the biological control agent and so increase programme efficiency.

Exploring for, and collection of, new exotic biological control agents in countries of origin can be a very difficult task as hosts can be rare or difficult to locate or both. Radiation sterilized hosts can be deployed in the field at strategic locations and so increase the chances of collecting new biological control agents.

Integrating Biological Control with SIT

Many years ago, the father of the SIT, E.F. Knipling, suggested that it would be advantageous to combine the release of sterile insects with the release of biological control agents. He suggested that a synergistic response in reducing the size of the target population could be achieved as the sterile males mate with the adult females in the wild assuring no offspring, whilst the biological control agents target the other developmental stages of the pest insect, i.e. the egg, larva or pupal stages.

Such an integration of sterile insects and other beneficial organisms has now been achieved in a number of crop and pest situations, and there is great potential to expand this integrated and fully environment-friendly biological approach.

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Integrating Biological Control Agents and Sterile Insects

In Mexico, sterile fruit flies and parasitoids released simultaneously as part of a large national campaign that has eliminated fruit flies from northwestern Mexico and suppresses them effectively in other areas.

In Syria, simultaneous releases of egg parasitoids and sterile moths synergistically reduced field populations of the potato tuber moth.

In South Africa, simultaneous releases of egg parasitoids and sterile moths synergistically reduced field populations of the false codling moth in citrus orchards. These findings have encouraged the establishment of a private company by the South African citrus expert industry.

In India, entomopathogenic nematodes released together with irradiated moths to control pests of cotton.

In Israel, by-products of insect mass-rearing used for the production of predators of greenhouse pests and parasitoids of houseflies.