Biological Control of Insect Pests in Canola: A case study with Bertha Armyworm.

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Introduction to Biological Control

Biological control is "the use of natural enemies, including microorganisms and parasites & predators, to control pests. The objective is to reduce a pest population to below the economic threshold. Chemical insecticides have become less acceptable due to a range concerns, including: i) human health problems due to acute and sublethal toxicity; ii) environmental problems due to the broad target-spectrum of chemical pesticides and the subsequent negative impacts on invertebrate and vertebrate non-target species; and iii) development of insecticide-resistant pests.

The host-specificity of most biological control agentsis positive from the point of view of environmental and human health safety issues. Their target specificity also makes them excellent candidates for use in integrated pest management programs.

Strategies for control of insect pest populations have to be viewed as ecological manipulations based on economic action thresholds. An integrated approach to insect pest management, "the practical control of insect populations by bringing together the best aspects of all control methods (chemical, biological, cultural, and cultivar resistance) in an ecologically sound manner", is the best strategy for insect control in modem agricultural systems.

Regulation by Natural Enemies

Insect pest populations fluctuate in response to biotic (natural enemies, competition with other species and food quality) and abiotic (climate and habitat) factors. If one or more of these factors favour population growth pest outbreaks occur.

Predators, parasites and diseases are important regulators of many plant-eating insects including the bertha armyworm. Biocigal agents are typically density-dependant: when their host populations change their population levels also increase or decrease in response (Fig. 1). These regulators are, in turn, regulated by their

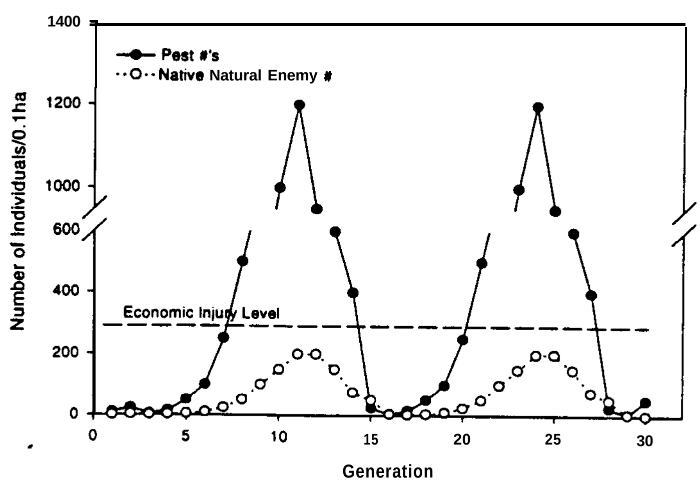
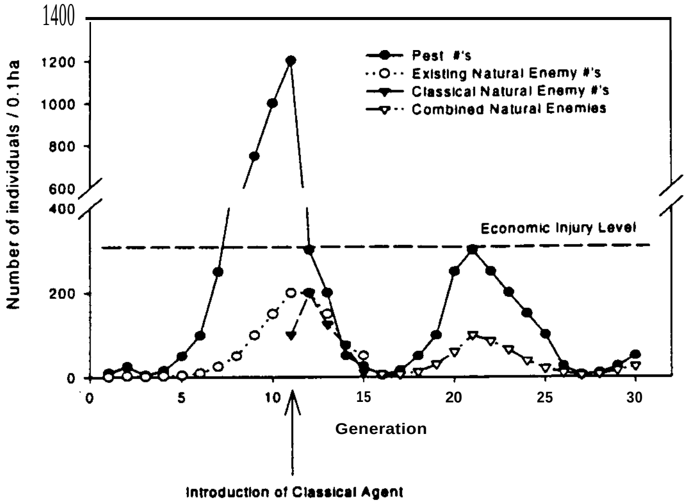


Fig. 1. Population regulation with natural enemies.

and other biotic and abiotic factors. Under crop monoculture systems practised in modem agriculture the biotic component of the regulation mechanism tends to be less important/robust than in more complex ecosystems.



Predators, most parasitoids and some diseases introduced into a new area for control of pest species are called **'Classical Biological Control Agents'.** Classical agents become established as permanent components of the target ecosystem and contribute to regulation of the pest populations (Fig. 2).

Fig. 2. Population regulation with existing and classical (introduced) natural enemies.

Diseases and some parasitoids can be utilized to flood an area just before or during pest outbreaks. These **'Inundative/Inovulative Biological Control Agents'** (Fig. 3) tend to survive in the target ecosystem temporarily and are applied as needed.

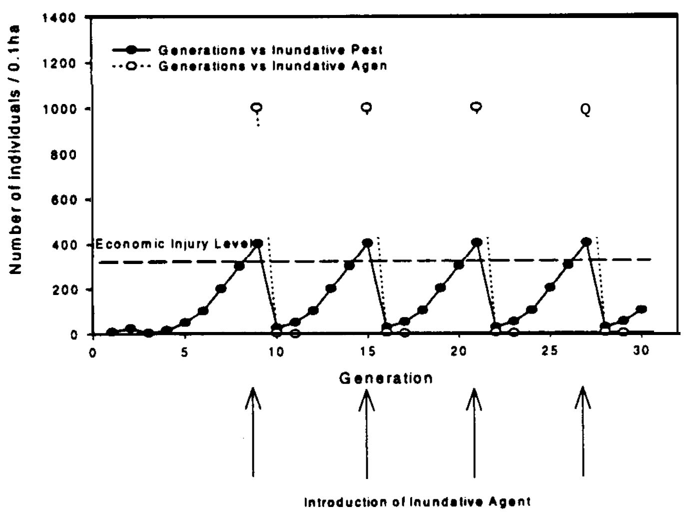


Fig. 3. Population regulation with inundative natural enemies.

Important natural enemies which attack the larvae of bertha armyworm include a nucleopolyhedrovirus (MacoNPV), a fungus (Entomophthorales), a wasp (Banchus flavescens), and a fly (Athrycia cinerea). Predators such as ground beetles, small mammals and birds also feed on bertha armyworm.

The Bertha Armyworm Problem

The bertha armyworm, *Mamestra configurata* Walker (BAW) is a significant pest of canola in western Canada. In 1994, 1995 and 1996 more than 670,000,650,000 and 250.000 ha of canola were sprayed for bertha armyworm. In 1995 insecticide and application costs averaged $25/ha and reduced producers' income by $45-52 million. Despite the current trend towards increased acreage of canola production in western Canada, canola acreages declined markedly in 1996 from that planted in 1995 due at least in part to the outbreak of bertha arrnyworm in 1994 and 1995.

Life Cycle: Adult bertha arrnyworm emerge from over-wintering pupae from early to mid-June until early July. Moths are active only at night, mate within 5 days of emergence and females lay approximately 2000 eggs. Bertha armyworm eggs are laid in single-layered clusters of 50 to 500 eggs on the under side of host plant leaves. The eggs darken as the larvae develop inside and are black in colour by the time larvae begin hatching (larvae are about 0.3 cm long). At typical temperatures, eggs hatch about one week after being laid. Larvae take approximately 6 weeks to complete development. They moult five times and pass through six growth stages. The larvae consume plant material at the greatest rate during the last two stages and this is when most crop damage occurs. When larvae mature late in August or early September, they burrow into the soil and pupate. The pupae are typically found 5 to 16 cm below the soil surface and are able to over-winter successfully, particularly when the snow cover is good.

Research

1. Insect Biological Control Agents

The most important native parasitoid guild of bertha armyworm consists. of 16 parasitoid species which attack the larval stage. Of these only one parasitic wasp, *Banchus* flavescens Cresson, and one parasitic fly species, *Athrycia cinerea* (Coquillett) are abundant enough during some years to have a significant impact on bertha arrnyworm populations. Study of the larval parasites of a closely related European species, the cabbage moth, demonstrated that two parasitic wasp and two parasitic fly species are abundant enough to have significant impact on that pest.

Classical biological control research has focused on evaluation of the European parasitic wasp, *Microplitis mediator* (Haliday) which: readily attacks and develops in BAW larva; will compete with but not eliminate native wasp species; will increase the overall number of bertha arrnyworm larvae parasitized; shows specificity within the canola ecosystem; can survive western Canadian winters; and is compatible with other control methods. It is being introduced (with support form Saskatchewan Agriculture and Agri-Food's Agriculture Development Fund).

In 1996 a native egg parasitoid, *Trichogramma inyoense* Pinto and Oatman, was discovered parasitizing eggs of the bertha armyworm. In the European relative of bertha armyworm two parasitic wasp species attack the eggs, one of which is a *Trichogramma* species. Mass production of *Trichogramma* species has been achieved and the technology has enabled development of these insects as inoculative biological control agents. Research has been initiated to evaluate the potential of ***T. inyoense*** as an effective inoculative biological control agent for bertha armyworm. Our research has indicated that T. inyoense is a good natural enemy because: it attacks and kills more than 95% of bertha armyworm eggs; it attacks eggs of varying age; produces more than one adult per bertha armyworm eg,, it competes well with other egg parasitiod species; and it successfully parasitizes the eggs of other potential pest species in the canola system.

2. **Pathogens**

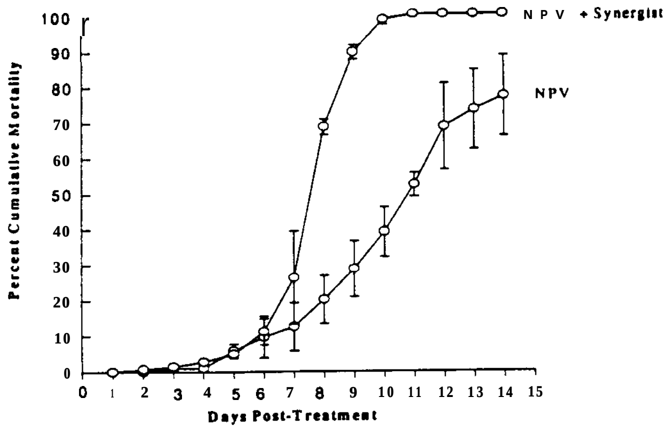
Pathogenic microorganisms, including fungi and an insect-specific virus, nucleopolyhedrovirus (NPV), have been isolated from M. ***configurata*** populations.

a. Virus (Nucleopolyhedrovirus): Study of field populations of bertha armyworm larvae indicate that NPV normally plays only a minor role in regulating bertha armyworm at low host population densities, but may infect up to 30% of larval populations at high densities. Sometimes infection levels as high as 95% in late season populations of 4th and 5th-instar larvae have been observed especially where host larval populations were high in the preceding year.

For over a hundred years, naturally occurring nucleopolyhedrovirus epizootic/epidemics have been recognized as having the capacity to regulate insect populations. NPV-infected larvae often hang from canola foliage, almost completely liquefied. Its contents will often ooze from the easily punctured cuticle. Based on observations of these natural disease outbreaks, biological control programs have attempted to create artificial NPV epizootics in pest populations before they reach an economic threshold.

Nucleopolyhedrovirus show good potential as biological control agents because: NPV have an established safety record with previously registered isolates; they are ‘biologically packaged’ in polyhedral inclusion bodies which are virus encoded protein (polyhedrin) crystals which surround the virus particles and enhance storage and field stability; they are relatively virulent with mortality occurring 5-20 days after infection; NPV are host specific usually infecting only several closely related species (Bertha armyworm specific isolates have been identified); and they have good potential for enhanced efficacy via genetic engineering!

Our research has shown that the NPV replication cycle is a complex one in which two different phenotypes of virus are produced: occluded and budded virus. The occluded virus present in the polyhedral inclusion bodies (PIB) is infectious upon ingestion by the BAW larva. The PIB is dissolved in the mid gut of the host releasing the infectious virus particles. The virus particles infect the mid gut epithelial cells and go through a complex replication cycle producing virions which are released into the blood system of the larva and subsequently other tissues including fat body become infected. Later, virus particles become occluded in the protective PIB particles.



In Fig. 4 typical mortality curves are shown for 4th instar bertha armyworm infected with BAW NPV in a laboratory bioassay with and without a chemical compound (synergist) which enhances virus activity. Mortality usually occurs 6 to 12 day after treatment in normal infection. The synergist reduces the time to mortality.

Fig. 4. MacoNPV synergist trial, mortality curves for 4th instar bertha armyworm infected with BAW NPV in the laboraotry. Means of 3 trials: 50 insects/dose/trial.

Mortality in preliminary field trials with BAW NPV are shown in Fig. 5. The BAW NPV was applied using a field track sprayer, which mimics typical ground sprayers, at a rate equivalent to $1.0\text{x}10^{12}$ PIB/ha in 35 L/ha using 800067 nozzles. The 2nd and 4th instar BAW larvae were caged on control and virus-treated plants and the mortality and level of virus infection were monitored weekly.

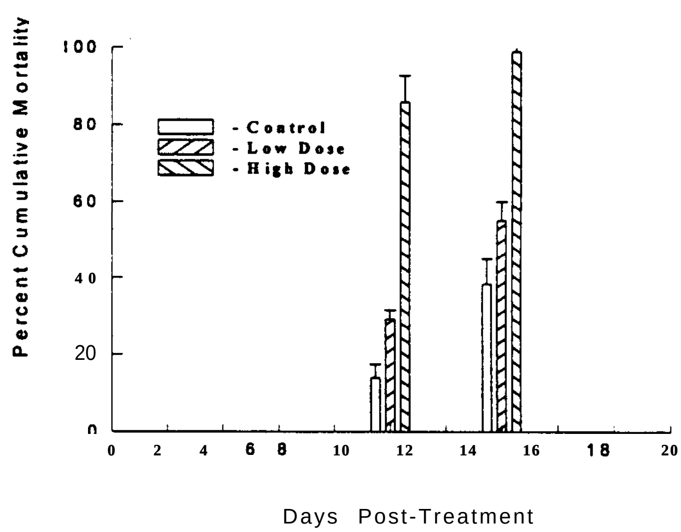


Fig. 5. Bertha armyworm - NPV field application trial.

b. Fungus

An insect-specific fungus has been isolated in late season populations of bertha armyworm on a number of occasions in Saskatchewan. The symptoms caused by this fungus are quite characteristic and are usually noticed when bertha armyworm larvae are in the 5th and 6th (final) instars. Entomophthoran fungus-infected bertha armyworm larvae will often turn a lighter brown colour just before they die. Upon death the larvae are a light beige to white colour (due to the presence of erupting fungal hyphae) and will frequently be found attached to the canola foliage. The dead larvae are characterized by their dry and brittle texture, often breaking apart when handled. The dead larvae infected with the entomophthoran fungus will either be full of resting spores or will have a short dense mat of sporulating hyphae on the surface of the body giving it a somewhat fuzzy appearance.

It is difficult to generalize about the impact that this disease has on bertha armyworm populations. However, when epidemics do occur, high rates of mortality (50-75%) have been observed among 5th and 6th instar larvae. This disease has the potential to reduce the amount of late season crop damage and will have a significant impact on the following season's bertha armyworm population by reducing the number of over-wintering pupae. This fungus is an important natural control agent but is dependent on the right environmental conditions for spore germination (high relative humidity and warm temperatures) and infection of bertha armyworm larvae. The fungus is difficult to grow and manipulate in the laboratory and along with its requirement for specific environmental conditions reduces its attractiveness as a useful biological control agent.

Summary

Significant progress has been made towards biological control of the bertha armyworm. We have identified several natural enemies which have potential as biological control agents for use in both classical and inundative strategies. These include an exotic parasite *(Microplitis mediator)* as a classical agent and a nucleopolyhedrovirus and several egg parasites as inundative agents for control. Although very different application strategies are required for each agent, it will be essential that they be implemented in a integrated pest management system if they are to be successful. Because of the host specificity of each agent, they will be very compatible in an IPM strategy.

Research continues toward understanding: 1) the role natural enemies alone and together in combinations in the regulation of BAW populations; 2) BAW population dynamics in relation to weather, crop varieties, crop phenology and control strategies; and 3) developing improved monitoring systems and predictive models.