



Technical Bulletin

Control of Potato Tuber Moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae)

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Aim

This report is in response to a request from Potatoes New Zealand for a review of scientific publications from the last 10 years on potato tuber moth research, focusing on management options – including alternate hosts – particularly over winter, chemical resistance, IPM strategies – cultural practices etc. The report covers this but includes references from before 2010 as some important older studies are still highly relevant.

Introduction

The Pest

Potato tuber moth (*Phthorimaea operculella* (Zeller)) (referred to from here in this document as PTM) is a cosmopolitan pest that originated in South America (Kroschel and Lacey 2008; Rondon and Gao 2018). It has now been recorded in over 90 countries worldwide (Kroschel and Schaub 2013). It is in the family Gelechiidae as is the related pest tomato leafminer or tomato pinworm (*Tuta absoluta*). *T. absoluta* is a serious pest of tomatoes in many parts of the world and is resistant to many insecticides but it is not found in either Australia or New Zealand (CABI 2019a). There is possible confusion with the common names as PTM is known as tomato leafminer in northern Queensland (Abbott and Abbott 1999). In the USA PTM is also known as potato tuberworm (Rondon and Gao 2018).

Larvae of PTM feed either on tubers of potato or within the leaves of potato plants. The leaf-mining aspect makes them difficult to control with many insecticides and control failures have been reported many times. This is in part because of where they feed but also because of insecticide resistance. Also, spraying the foliage may kill caterpillars but damage can still be serious (Foot 1974; Rondon 2010).

In Australia and New Zealand PTM is primarily a field pest of potatoes as harvested tubers are kept in cool stores (Foot 1979, Horne 1990). However, in countries where cool storage is not available it is a more serious pest after harvest as populations of PTM continue to develop. Research has been conducted for both in-field control and reducing damage in warm-stores.

PTM is believed to not develop when temperatures are constantly below 10°C (Beukema and Zaag 1990) but other authors have found the lower threshold for development to range between 4.25°C and 13.5°C (Rondon 2010; Rondon and Gao 2018).

Host Range

PTM feeds on a range of food plants, mainly those in the family Solanaceae. Das and Raman (1994) reported PTM feeding on 60 species of plants worldwide. The main crops attacked are potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum* or *Lycopersicon esculentum*), and tobacco (*Nicotiana tabacum*) but the pest also attacks eggplant (*Solanum melongena*), bell pepper (*Capsicum annuum*) and Cape gooseberry (*Physalis peruviana*). Also attacked are wild species of Solanaceae, including weeds (eg, black nightshade (*Solanum nigrum*), apple of Peru (*Nicandra physalodes*) and thornapple (*Datura spp.*). However, they have also been reported as feeding on non-solanaceous plants such as sugar beet (*Beta vulgaris* L.) in the family Chenopodiaceae while other host plants belong to the families Scrophulariaceae, Boraginaceae, Rosaceae, Typhaceae, Compositae and Amaranthaceae (Das and Raman 1994).

Although there is a wide host range, potato, followed by eggplants are the preferred hosts on which the female moths oviposit (Meisner et al 1974). Also, although there are records of PTM on this wide range of hosts, field studies have demonstrated that it can only reproduce if caterpillars feed on potato, tomato and eggplant (Rondon 2010; Rondon and Gao 2018).

Control options

Control measures for any agricultural pest can be broadly categorised as either 1. Biological (invertebrate natural enemies and pathogens), 2. Cultural or management techniques or 3. Pesticides. The use of a compatible set of measures from these three categories is described as Integrated Pest Management or IPM. These categories are used to arrange the results of the review.

Biological controls (invertebrates)

PTM is not native to either Australia or New Zealand and although it is attacked by generalist predators such as damsel bugs (*Nabis kinbergii*) (Horne et al 2002), parasitoid wasps were introduced into both countries as classical biological control agents. In Australia, three species of wasps – *Orgilus lepidus*, *Apanteles subandinus* and *Copidosoma koehleri* are well established and provide significant levels of control (Horne 1990 and 1993; Horne and Page 2008). CABI (2019b) lists these species as being present in New Zealand but Herman (2008a) records that of 17 species introduced as biological control agents for PTM, only *A. subandinus* became established. *A. subandinus* has been recorded as reaching parasitism rates of over 80% in New Zealand potato crops where broad-spectrum insecticides are not applied (Herman 2008a).

Biological controls (pathogens)

Microbial control of PTM was summarised by Lacey and Arthurs (2008) and the use of biopesticides including microbial pesticides for control of potato pests was reviewed by Sporleder and Lacey (2013). The main pathogens studied have been the bacteria *Bacillus thuringiensis* (Bt) and granulosus virus. Bt is sold commercially for control of a range of caterpillars under several different trade names including “Dipel”, “Delfin” and “XenTari” and with two subspecies (*Bt kurstaki* and *Bt aizawai*).

Bacteria and Viruses

Bt

Although some publications report that Bt has been successfully used against potato moth (Lacey and Arthurs 2008; Sporleder and Lacey 2013) others such as Rondon (2010) concludes that it is not particularly effective under field conditions because of degradation by UV and wash-off by irrigation or rainfall. It is a stomach poison and must be ingested. So, an additional problem with it in the field is that PTM caterpillars feed for almost all of their life protected within the leaf and would not be exposed to a surface application except briefly in the first instar stage. Given the rapid degradation of Bt and PTM populations producing almost continuous batches of eggs (and first instars), it would require multiple applications of Bt to target newly hatched caterpillars before they enter the leaf.

Another use of Bt has been to isolate the gene for the Bt toxin and genetically modify potato plants to produce varieties containing this toxin. When it was discovered that there were genes responsible for the production of crystal proteins (the toxins) these were given the abbreviation “cry proteins” for (crystal proteins). As more types of proteins were discovered, those active on lepidopterans were given the numbers 1 and 2, with major variations allocated uppercase letters and minor variations designated by lowercase letters. Eg Cry1Aa, Cry1Ab. In 1995 the EPA in the USA approved the commercial production of four Bt crops; corn, cotton, tobacco and potato. However, the bulk of production is corn and cotton (Abbas 2018).

There have been varieties of potatoes producing Bt that are effective on PTM (Douches et al 2002) and another strain of Bt (*Bt tenebrionis*) for control of Colorado potato beetle. GM potato varieties such as Spunta G2 have been developed and although they are approved in some countries including the USA, many other countries have progressively banned the use of such varieties (Abbas

2018). Although they may be effective on PTM the varieties have not been used widely because of issues with differing perceptions about the safety of GM crops on humans (Abbas 2018).

Granulosis virus

Viruses have been developed as commercially available products for some caterpillar pests such as “Madex” and “Cydex” for codling moth, “Gemstar” and “Vivus” for *Helicoverpa* and “Spod-X” for *Spodoptera exigua*. Sporleder and Lacey (2013) have reviewed the potential of different biopesticides and there are granulosis viruses that have been used against potato moth but there has been no large-scale production. It is commonly referred to as *PhopGV* or *PoGV* and some trials report over 90% mortality in laboratory trials (Lacey et al 2011). In some cases (eg in Peru), government agencies have produced this as a pesticide for use by potato farmers. Granulosis viruses have spread around the world with potato moth and has been found in Australia and New Zealand (Teakle 1998). Trials have largely been focused on potato storage in developing countries (Lacey and Arthurs 2008; Sporleder and Kroschel 2008) but also in the field in Australia (Reed and Springett 1971).

Granulosis viruses used as insecticides have similar problems to Bt, with degradation by UV and wash-off by water. However, it has also been shown that there is the potential for PTM to rapidly develop resistance to granulosis virus (Briese and Mende 1981).

Fungi and Nematodes

Several species of fungi and nematodes have been shown to be effective in killing PTM (Rondon and Gao 2018). Sporleder and Lacey (2013) summarise the available products against PTM and list *Beauveria bassiana* as being commercially available in Europe and the USA. Other fungi tested against PTM are *Isaria fumosorosea* and *Metarhizium flavoviride* (Sabbour 2015).

Nematodes *Steinernema carpocapsae*, *S. feltiae* and *Heterorhabditis bacteriophora* have been shown to kill

PTM larvae in laboratory trials (Hassani-Kakhki 2012; Sporleder and Lacey 2013; Kepenecki et al 2013) but these have not been commercially produced.

Cultural controls

In a review of PTM control it is stated that although current methods of control rely heavily on the use of pesticides, early control of this pest should focus on cultural methods (Rondon 2010). Such methods have been known for many years and include variety selection, deeper planting of seed, producing a large hill, irrigation to prevent soil cracking and early harvest. Rowe (1993) states in a manual on potato production (in the USA) that “the moths cannot reach tubers covered with more than 2 inches of soil, unless it is deeply cracked”. Goldson and Emberson (1985) recommended that in New Zealand deeper planting should be done to help control PTM. Some of the best-known work on cultural control of PTM was conducted in New Zealand by Marion Foot (1974, 1976). Other cultural controls include elimination of cull piles, controlling volunteer potatoes, and rolling (Rondon 2010).

Pesticides

Pesticides are often applied to control pests of potatoes including PTM and this has long been the case. Herman (2008a) reported that in the North Island of New Zealand where PTM is a major pest, control was “dominated by applications of broad-spectrum insecticides at 10 – 14 day intervals”.

Insecticides targeting PTM in the foliar stage can be effective but many studies (summarised by Rondon 2010) have shown that this does not ensure that there will be no damage to the tubers. Kuhar et al (2013) describe the efficacy of insecticides on PTM as “unpredictable”. This is because caterpillars can access the tubers through cracks in the soil and so soil conditions are critical in determining the level of control (see section on cultural controls). In New Zealand it has been found that crops with bad tuber infestations sometimes had relatively

little foliar infestation (Herman 2008b) and it is the same in Australia (Horne – unpublished data). As noted by New Zealand researchers, (Foot 1974, 1976 and Herman 2008a,b), even if there is control of a PTM population in the foliar stage, there can still be significant damage to tubers if appropriate cultural controls are not utilised.

Insecticide resistance

Resistance by PTM to insecticides is known to occur in various parts of the world. This includes the USA (Kuhar et al 2013) where resistance to insecticides including fipronil and synthetic pyrethroids has been reported. PTM was one of the first pests that became resistant to DDT in the 1950's including in Australia (Champ and Shepherd 1965). In Queensland, Australia, while not saying PTM was resistant, Abbot and Abbot (1999) stated that the currently registered insecticides (at that time) were unable to provide an acceptable level of control. In Egypt, PTM was recorded as resistant to several organophosphates, carbamates, synthetic pyrethroids and imidacloprid (El-Kady, H. 2011).

A recent review of resistance to diamide insecticides (eg “Belt” and “Coragen”) recorded resistance by several lepidopteran species, but this does not include PTM (Richardson et al 2020). However, the related species *Tuta absoluta* has developed resistance to this group.

In a recent review of Bt genetically modified crops (Abbas 2018) it was suggested that their use was probably nearing the end, partly because of concerns about human safety but also because of the development of resistance to GM crops by some species of caterpillars.

Attract and kill

The use of pheromones to attract PTM to a container with insecticide (“attract and kill”) has been developed (Kroschel and Zegarra 2010) and commercialised by CIP in Peru (Sporleder and Lacey 2013). The insecticide used is usually a synthetic pyrethroid with rapid knock-down, but it is not disruptive to biological control as it is not sprayed over the crop. This approach catches only male moths and so would need to be done on a district-wide basis to be effective in suppressing a population. This is

because female moths that have already mated could fly into paddocks where the males have been trapped.

IPM

Integrated Pest Management (IPM) is simply using biological, cultural and chemical control options in a compatible manner, rather than relying on insecticides as the mainstay of pest control. IPM involves trying to use these options in a compatible way and using biological and cultural options as the mainstay of control with chemical options used only as support tools when necessary (Horne and Page 2008; Page and Horne 2012). Selecting the pesticide that will cause least disruption to biological control agents is important rather than selecting a product that might be most effective against the target pest but is disruptive to biological control agents.

However, to develop an IPM strategy to suit a farmer in any crop the first thing to be done is to look at the range of pests present. This will be different in different locations and can also differ between farms in the same locality due to different perceptions of “what is a pest of importance”. IPM needs to deal with all pests that the farmer is worried about, not just one pest (FAO 2000; Trumble 1998). Therefore, there is IPM for potatoes but not, for example, IPM for aphids.

An IPM strategy for potatoes was described by Horne and Page (2008) and such an approach can be built for any potato grower in any region in the world. Once the list of pests is established then all of the available control options can be listed. It is often important to emphasise that all options, despite the possible costs, be listed, as the expenditure changes markedly (reduced) when there is little requirement for insecticides. This means a single expensive insecticide may be far more cost-effective if it is the only intervention required and it supports biological controls.

In a recent (2019) article in Potatoes Australia magazine, a grower described his experience of using IPM, starting in 1995. (<https://ausveg.com.au/app/uploads/publications/PA%20Feb%20Mar%202019%20Web.pdf>).

His conclusion to the article is the most telling, where he states, “In the last 20 years I have used fewer insecticide applications on all paddocks than I might have used in a single season per crop before IPM”. His experience is typical of growers in Australia who have changed to using IPM from regular applications of insecticides (he previously sprayed insecticides every 10-14 days). Another grower with the same experience estimated that he had saved \$55,000 in five years (from 1995 to

2000) by adopting IPM and using much less insecticide without compromising quality (O’Sullivan and Horne, 2000).

The point is that insecticide applications similar to those currently being applied in North Island potato crops were the standard practice in Australia 20 years ago. This has been turned around by adoption of IPM in Australia.

Summary

Scientific studies around the world have documented that there are options for controlling PTM in all three available methods – biological, cultural and pesticides. In developing countries without access to cool stores, losses to PTM are more serious after harvest while in developed countries with access to cool stores damage is more likely to be in-field.

Biological control options include parasitoid wasps, and these have been shown to be present and able to contribute significantly to control of PTM in New Zealand. However, they are highly disrupted by non-selective insecticides. Other species such as *Orgilus lepidus* could be introduced, but this would not improve control unless changes in pesticide applications were widely adopted.

Other biological control options have been shown to have some potential (pathogens and nematodes) but have not been made commercially available in most countries, including New Zealand.

Researchers have repeatedly stressed that if cultural controls (in particular soil management and irrigation) are ignored then pesticide applications in the foliar stages of the crop cannot be expected to provide acceptable levels of control. This research has been conducted and confirmed in New Zealand as well as in other countries.

PTM is capable of developing resistance to insecticides but so far there is no evidence to suggest that PTM is resistant to the newer insecticides of the Group 28. Control of PTM in the foliar stage of the crop is likely to be good. Instead, crop protection failures are more likely to be attributable to failures in cultural controls. This conclusion is the same as what New Zealand entomologists Marion Foot and Tim Hermann have previously described. The need to adopt an IPM strategy that involves using all three control options and not just a reliance on pesticides during crop growth is once again emphasised.

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