The potato tuber moth, *Phthorimaea operculella* (Zeller), in South Africa: potential control measures in non-refrigerated store environments

by

Diedrich Visser

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Department of Zoology & Entomology
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DECLARATION

I the undersigned hereby declare that the dissertation submitted herewith to the University of Pretoria contains my own original work and has not previously in its entirety or part been submitted for any degree at any other university.

Diedrich Visser
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SUMMARY

The potato tuber moth, *Phthorimaea operculella* (Zeller), in South Africa: potential control measures in non-refrigerated store environments

For Degree: Doctor of Philosophy (Entomology)

Student: Diedrich Visser

Promoter: Dr. A S Schoeman

Department of Zoology & Entomology in the Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria

Cull potatoes beneath the soil could give rise to potato tuber moths throughout the winter months. These moths may move to store environments where the conditions are favorable for fast reproduction and subsequent damage to tubers in storage.

Carbaryl, permethrin, gamma-BHC, *Bacillus thuringiensis* (*Bt*), and a domestic baby powder (as the control) were tested against the potato tuber moth on stored potatoes. All the treatments protected the tubers from moth attacks immediately after treatment. However, it was only carbaryl and *Bt* that protected the tubers 60 days after treatment.

Aluminium phosphide (Phostoxin®) was tested against all stages of the potato tuber moth at a dosage of four grams phosphine/m^3. Exposure time was 48 hours inside an airtight plastic container. In all tests, aluminium phosphide was lethal to all stages of the potato tuber moth. Aluminium phosphide can therefore effectively be used to rid infested potatoes and/or potato stores of any stage of the potato tuber moth.

It was found that a local strain of the tuber moth virus remained virulent for at least nine years when stored at -20 °C and at least two weeks when kept in suspension at 25-28 °C. A concentration of one to five pulverized diseased larvae per liter of water resulted in the mortality of nearly all larvae that fed on treated potato tubers.

Crude plant extracts from the exotic invasive tree, *Melia azedarach*, (syringa), were tested against first instar larvae of the tuber moth in the laboratory. Bioassays showed that pupal weight was negatively influenced and that growth of tuber moth larvae was retarded after feeding on potato leaves dipped in 10g/ℓ syringa leaf extracts.

Two pheromone formulations (monitor capsules and an attracticide), both containing the potato tuber moth pheromone E,Z,Z-4,7,10-tridecatrienyl acetate and E,Z-4,7-tridecatrienyl acetate (0.4/0.6 mg), were evaluated. The pheromone rubber capsules were only effective when high numbers of tuber moths were released (> 10 moths per m^2). The attracticide, on the other hand, was only effective when low numbers of tuber moths were released (< 10 moths per m^2), and did not give any control when 20 moths per m^2 were released.

Potatoes containing one of two *Bacillus thuringiensis* (*Bt*) genes were evaluated against the potato tuber moth under laboratory and storage conditions. The two genes were *Bt-cry1c* and *Bt-cry5* (synonym *Bt-cry1la1*). Both no-choice and free-choice experiments were carried out in an insectary and a diffused light store with artificial tuber moth infestations. In all these tests the transgenic lines nearly always yielded 100% control. It is concluded that the resistant *Bt*-transgenic potatoes will result in excellent control (if not absolute) against the potato tuber moth under storage conditions in South Africa.

Rearing methods for the potato tuber moth are described. These include a program for small-scale rearing where as little as 500 moths are reared and a medium scale rearing where 10 000 moths are produced per month. An overview of the literature on rearing techniques and the biology of the tuber moth under laboratory conditions is given.

GENERAL INTRODUCTION

Background

The potato, (*Solanum tuberosum* L.) is the most widely planted vegetable crop in South Africa. Between 55 000 and 60 000 hectares are planted annually in all nine provinces of which 16% is utilized for seed production (Potatoes South Africa 1999). Nearly 80% of all potato plantings are irrigated with an average yield of approximately 40 tons per hectare (A. Visser, personnel communication). The total average yield (including non-irrigated farms), is approximately 30 tons per hectare. Seventy percent of all potatoes are planted with seed certified to be disease and virus free (Steyn 1999).

The potato plant is adapted to a cool climate, originating from the Andes Mountains in South America. However, new cultivars were bred to adapt to warmer agricultural environments. These warmer areas where potatoes are cultivated are ideal for most pests and diseases (Steyn 1999). The most important biotic constraints for the potato plant during the growing season in South Africa are fungal diseases like early and late blight, virus diseases, and insect pests like potato leafminer and the potato tuber moth.

The most important part of a potato plant is the tuber. Potatoes are planted, harvested, stored and consumed in the vegetative state, the tuber. Except for the first two weeks after planting, progeny tubers are always present whenever the plants are growing. When tubers are harvested, they are removed from the relatively protected environment (soil) and are then especially vulnerable during storage to insect attack. The only insect that can do significant damage to stored potato tubers is the potato tuber moth.

The potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), is a ubiquitous pest on all continents, except the arctic. It is most serious on potatoes, but has also become increasingly important on tobacco (Van Vuuren *et al.* 1998) and tomato (Gilboa & Podoler 1994). Damage has also been reported on eggplant and other Solanaceous crops and weeds (Rahalkar *et al.* 1985). The potato tuber moth larvae are miners or tunnelers. They mine in potato leaves during the growing season, but also move down cracks in the soil to reach tubers under the ground when the foliage start dying off naturally at the end of the season. They tunnel through the tubers, filling the tunnels with frass and webbing and allowing the entry of pathogens (Ferro & Boiteau 1993). These damaged tubers are only noticed at harvest time. Potatoes to the value of approximately R40 million are lost every year by South African potato farmers due to tuber moth damage in the field (D. Visser, unpublished data).

A third stage in potato production where potatoes are vulnerable to tuber moth attack is during storage. Potato tubers are stored in various ways, depending on their destination and whether they are utilized by commercial or small-scale farmers. Most commercial farmers plant large areas (more than 30 hectares) per season, and are well equipped with expensive infrastructure, including large cold storage facilities. Those farmers without cold storage facilities collaborate with co-operatives that provide these facilities as part of their seed distribution channels. However, small-scale farmers usually plant for subsistence only, do not have expensive equipment or infrastructure and rely on traditional methods of storing. The inputs of small-scale farmers are therefore significantly lower, but the overall quality of their product is also lower compared to that of commercial potato farmers.

Commercial farmers rarely store table potatoes because they have the infrastructure to send potatoes to the market directly after harvest and sorting. They only store seed potatoes, and then only in cold storage facilities. The temperature inside these facilities normally runs at 2 to 3 °C while the tuber moth larvae need temperatures above 10 °C to develop (Ferro & Boiteau 1993). Seed tubers are therefore protected from potato tuber moth attacks and damage in such facilities (Raman *et al.* 1987). There are, however, times when seed potato tubers have to be left in open stores for lengthy periods. This include the in-transit scenarios when seed tubers are send from co-operatives to farmers, the two to four week period that seed tubers have to be taken out of cool storage for sprouting or "reconditioning" purposes (Dean 1994), and the time tubers have to wait for the sorting process after harvest. At all of these stages the tubers are vulnerable to attacks from the potato tuber moth. It has also happened that a seemingly uninfested batch of potatoes suddenly started to show infestation symptoms while no tuber moths were present

(J. van Vuuren, personal communication). This is sometimes due to "latent" infestations – eggs or first instar larvae were present on or inside the tubers when the seed were bought, but not noted until the damage became more visual days later (Kroschel & Koch 1994).

The potato tuber moth is the major pest of potatoes stored under traditional storage systems in Africa (Roux *et al.* 1992). These small-scale farmers store both seed and table potatoes. They use self-made diffused light stores (Raman *et al.* 1987) or rustic shelters (Roux *et al.* 1992) to store potatoes for consumption or seed. Some farmers cultivate their own seed, which they store for a few months until planting commences (Kroschel & Koch 1994). Potatoes in such stores are vulnerable to attacks by the potato tuber moth originating from dumping sites (Daiber 1989) or from infested tubers stored unknowingly with healthy tubers (Kroschel & Koch 1994). Seed bought from such sources will almost certainly be infested by various stages of the potato tuber moth. If left untreated, the contents of a potato store may be completely destroyed by potato tuber moth larvae (Fuglie *et al.* 1991; Ferro & Boiteau 1993).

Pesticides are often used on seed tubers to protect them from diseases (Dillard *et al.* 1993; Dover & Ingram 1999) and insects (Roux *et al.* 1992). The efficacy of these pesticides is mostly based on unsupported information and little research has been done to evaluate them under controlled conditions. Twenty-three insecticides were registered in South Africa for tuber moth control in the field in 2002 (Nel *et al.* 2002), but no insecticide has been registered for post harvest applications. Because of long storage times, any insecticide that can potentially protect potatoes in a non-refrigerated store has to have a long residual action. Chemical companies are therefore reluctant to test their chemicals on a potential edible crop because of the dangers of human poisoning.

Concern for the lack of research for the protection of seed potatoes against the potato tuber moth in stores has been expressed by Daiber (1989), and is still one aspect of potato production that has received no attention in South Africa. The potato farmers in South Africa have expressed their concerns about the lack of control measures to protect tubers in storage. Control measures used by small-scale farmers to protect stored potatoes are inefficient and sometimes huge losses still occur. For control of potato pests, the International Potato Center (CIP) emphasizes the value of using and adopting integrated pest management procedures that provide adequate control while reducing dependence on insecticides (Raman *et al.* 1987). There is thus a pressing need for alternative methods to control the potato tuber moth in store environments. This was therefore an important aspect of potato production that needed urgent attention to the benefit of the commercial potato industry and small-scale potato farmers in South Africa.

Motivation and Objectives

The main objective of this study was to evaluate different control strategies against the potato tuber moth attacking potatoes under storage conditions. The aim was to find those control strategies that could be used by the small-scale as well as the commercial potato farmer. Depending on the situation, the following scenarios can be expected relating to stored tubers:

- infested potato tubers arrive in the store after severe field infestations during the previous season
- a batch of freshly harvested potato tubers have to be stored temporarily before sorting facilities become available
- tubers have to be transported to remote destinations in containers that are not insect proof
- already sprouted seed tubers have to be taken out of cool storage and kept at room temperature for at least three days for reconditioning purposes before planting
- dormant seed tubers have to be taken out of cool storage and kept at room temperature for two to four weeks for sprouting purposes
- subsistence farmers have to store potato tubers for lengthy periods without the convenience of cold storage facilities
- sometimes a farmer have to use an infested batch of seed tubers and needs to kill the larvae inside tubers before planting

The following objectives were pursued in an effort to expand our understanding of the pest and to address the problems the potato tuber moth may cause relating to the above scenarios.

1. to monitor potato tuber moth numbers with synthetic pheromones to quantify the relationship between temperature, rainfall and seasonal flight activity
2. to evaluate potential insecticidal powders to be used to prevent potato tuber moth attacks in those situations where no other methods are effective, e.g. severe tuber moth pressure
3. to evaluate fumigation with aluminium phosphide for those situations when a large batch of seed tubers became infected and needs to be cleaned from potato tuber moth larvae infection before planting proceeds
4. to evaluate the potential of UV light-assisted insect electrocuter traps to control newly emerging tuber moths in a potato store
5. to evaluate the potential of crude extracts of a potent insect virus for protection of stored potato tubers
6. to evaluate the potential of crude aqueous extracts of syringa tree leaves for protection of stored potato tubers
7. to evaluate the potential of mating disruption and attract-and-kill techniques with pheromones in store environments
8. to evaluate the potential of genetically modified potatoes against severe potato tuber moth attacks in potatoes stored for lengthy periods
9. to report on alternative and simplified rearing techniques of the potato tuber moth

Aim and rationale of this study

The aim of this study was to address the lack of control strategies relating to the control of the potato tuber moth in non-refrigerated store environments. The control measures currently used by most farmers are ineffective. This study attempts to address these shortcomings by providing alternative and novel strategies that can be used by both the commercial and small-scale potato farmer to control the potato tuber moth in potato stores.

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