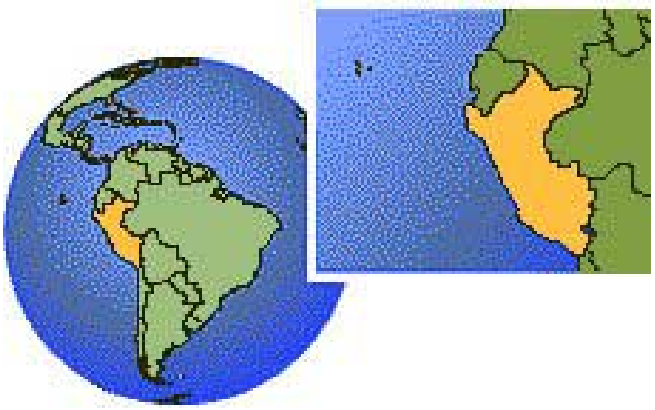
A Whole New World



Rachael Collier

Burlington, Iowa

2003 Borlaug-Ruan World Food Prize Internship

International Potato Center (CIP)

A Whole New World Lyrics

I can show you the world
Shining, shimmering, splendid
Tell me, princess, now when did
You last let your heart decide?

I can open your eyes
Take you wonder by wonder
Over, sideways and under
On a magic carpet ride

A whole new world
A new fantastic point of view
No one to tell us no
Or where to go
Or say we're only dreaming

A whole new world
A dazzling place I never knew
But when I'm way up here
It's crystal clear
That now I'm in a whole new world with you
Now I'm in a whole new world with you

Unbelievable sights
Indescribable feeling
Soaring, tumbling, freewheeling
Through an endless diamond sky

A whole new world
Don't you dare close your eyes
A hundred thousand things to see
Hold your breath - it gets better
I'm like a shooting star
I've come so far
I can't go back to where I used to be

A whole new world
Every turn a surprise
With new horizons to pursue
Every moment red-letter
I'll chase them anywhere
There's time to spare
Let me share this whole new world with you

A whole new world
That's where we'll be
A thrilling chase
A wondrous place
For you and me

Evaluation of Pesticides and *Phthorimaea operculella* Zeller granulovirus (PoGV) Formulation on Two Species of Potato Tuber Moth, *Phthorimaea operculella* and *Symmetrischema tangolias* (Lepidoptera: Gelechiidae) in Peru

Rachael Collier
Mediapolis High School
International Potato Center
July 2003

This experiment was designed to determine the effect of controlling the *Phthorimaea operculella* and *Symmetrischema tangolias* with Bt pesticide, two chemical pesticides, and *Phthorimaea operculella* Zeller granulovirus (PoGV). Pesticides Dimilin, Atabron, and MVP were diluted with water into five concentrations. Fifteen tubers were treated with each pesticide dosage. Ten tubers were infected with *Phthorimaea operculella* neonates and five tubers with *Symmetrischema tangolias* neonates. Larval mortality was recorded after pupation.

Sixty larvae diseased with PoGV were purified and homogenized. Four hundred micro liters of isolation was applied with a micropipette to 200 eggs on a filter paper, allowed to dry, and placed into a labeled petri dish and sealed. After emergence fifty larvae were transferred to each tuber. When pupation began, the number of diseased larvae, healthy larvae, and pupa was evaluated.

ACKNOWLEDGEMENTS

This wonderful experience that I am now trying to summarize in only 15 pages would not have been possible without the support of many people. Iowa teens, such as myself, would never have the wonderful opportunity to explore international research at cites throughout the world focusing upon achieving world food security without the Borlaug-Ruan World Food Prize Internship. The effort put forth by Norman Borlaug, John Ruan, and the World Food Prize makes this opportunity available each year and to them I must send my deepest gratification for allowing me to see a whole new world. Lisa Fleming was wonderful in her guidance, reassurance, and watchful eye before, during, and after the internship. Her reassurance and kindness made the seemingly impossible attainable. For assistance in developing and completing my experimentation I would like to give my appreciation to Dr. Dapeng Zhang, Veronica Canedo, and Octavio Zeggar. For a wonderful place to call home I must thank Ida Bartollini. I also would like to send my deepest gratification to my teacher, Nancy Carter, for her unending support through the struggles of this past year, science fair, and this internship. Last I must thank my parents for giving me the confidence and support to venture into a foreign country for a lifetime experience. This wonderful opportunity would have never been possible, or even a great success, without the support of all these people. Thank you very much!

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EXPERIENCE

In school we are shown pictures of starving children without food, clean water, or clothing in Africa. But we are never told about the starving people in South America, Asia, or even those in the United States. In a large United States city one may find beggars greeting them at every corner asking for money for food and clothing. It is no different in a big city of a foreign country. But you still do not realize the severity of hunger until you travel beyond the cities touched by American influence. Before arriving in Peru I read guidebooks, surfed the Internet, and talked to Peruvians living in the United States. I believed that this would prepare me for what I would see and hear in Peru. But it did not, nothing in my life could have.

My life began in Burlington, Iowa on June 3rd, 1986. I was born as Rachael Theresa Collier, the daughter of Phil and Lynette Collier. Now, seventeen years later, I still live in the same small-protected world in the same house in the same town with the same name. While Burlington is not a small town, it is also not very large in comparison to Chicago. You never see poor people sitting with a newspaper over their head in downtown Burlington, in fact you rarely see anyone in downtown Burlington. While I live in Burlington, I attend school in a very small town fifteen miles North of Burlington, which is called Mediapolis, where I am a senior. In Mediapolis one would never see a beggar because the town is barely large enough to have a 'downtown' or even appear on a map. In developing countries these small towns are a different story. Five-five percent of Peru's total poor reside in these small urban towns living with a severity of poverty that is very high.

I truly did not know very much about the severe problem of food security until my talented and gifted (TAG) teacher, Nancy Carter, approached me with information regarding a World Food Prize Youth Summit that is held in Des Moines every October. Due to my extreme interest in science, as shown through my six years involved in science research, my teacher believed this would be a wonderful new area of exploration.

My science research for the past three years has focused upon Bt corn. Bt corn is a genetically engineered crop resistant to the European corn borer (ECB), the most damaging insect pest to corn in the United States and Canada. The goal of Bt corn is to prevent crop damage by the ECB and increase corn yield. It seemed simple to me- more corn, more food for struggling countries. Only the problem is much greater then simply producing enough food. The world has enough food to feed every person at least 4.3 pounds of food each day. But it is not the quantity of food that is causing world hunger it is the distribution.

My involvement in the World Food Prize Youth Institute in 2001 forced me to realize we must not simply find ways to increase the quantity of food. We must discover ways to grow the food and increase yield and nutrition where the food is most needed- in developing countries with depleted soil, pest infestation, and few seeds. The Youth Institute sparked my new found interest in science research being completed to increase food nutrition and crop yield throughout the world. At the Youth Institute I also learned

of an opportunity to complete international research through the Borlaug-Ruan International Internship. The opportunity sounded too amazing to be real. So after I attended the World Food Prize Youth Institute again in 2002, I applied for the internship hoping for the best. I knew that this internship would give me the opportunity to take my science research to the next level. I did not imagine I would find myself traveling to Peru for eight weeks to complete research at the International Potato Center (CIP).

It was not until June 12th, 2003 that I left my comfortable, familiar home in the United States to make Lima, Peru my new home and worksite. Upon arriving at the airport in Lima, I had a picture in my mind of an airport exactly as you would see on in the United States. I was in for a reality shock! As I exited the plane I found a staircase, not a terminal. I climbed down the staircase wrapped in darkness with the knowledge that this was not a United States airport. The smells were different, everything appeared dirtier, and for once I was a minority. Confused on I where I was supposed to go I blindly followed the crowd, as if I were a sheep. They led me past signs I could not understand, through the customs exit, and to the luggage claim where I found the luggage had already been unloaded and placed on the conveyor belt in the time I had followed the maze of halls to customs. My expensive brand name luggage stuck out from the many duffel bags and old vinyl suitcases like a sore thumb. I quickly grabbed my two suitcases and begin to try to maneuver through the mass of people to find the CIP driver. When my eyes were greeted with a hand stretched over a fence holding a sign clearly stating "CIP Melissa Fox Rachael Collier" I gave a sigh of relief. I had made it safely to Peru. But at that time how was I to know that this experience would change me? I left Iowa actively involved in science fair trying to save the monarch, I would return to Iowa hoping to continue research investigating the most beneficial method of controlling the potato tuber moth. I would come back a changed person with expanded horizons and a more genuine knowledge of poverty that could never be acquired from the safety blanket of the United States.

On the Monday after my arrival in Peru I began my first day of work at the International Potato Center (CIP). CIP is part of the global agricultural research network known as the Consultative Group on International Agricultural Research (CGIAR). CIP's

headquarter is located in Lima, Peru with a mission to reduce poverty and achieve food security on a sustained basis in developing countries through scientific research on the potato, sweet potato, and other root and tuber crops. My first step upon arriving at CIP was to meet my supervisor, Dr. Zhang. In this introduction Dr. Zhang told Melissa, a fellow World Food Prize intern, and I that we could spend the first week exploring the areas of research at CIP. We were given the opportunity to select and develop our own project in any area of research at CIP. I explored the many options before hearing about a Bt potato that is targeted to be resistant to the potato tuber moth. I was very interested in the Bt potato because of my previous work with Bt corn. But because CIP did not have any Bt potatoes at that time I was unable to complete a project at CIP involving Bt potatoes. After a great deal of preponderance I got the courage to ask if I could complete any research with the potato

tuber moth. A short phone call and it was settled, I would work in entomology. One week after my arrival in Peru I had selected a project area, entomology. During the next seven weeks I would carry out two independent projects focusing on the control of the potato tuber moth.

Throughout the next seven weeks I would not only explore the world of research- I would see a whole new world, a dazzling place I never knew. On my magic carpet ride in Peru I was given the opportunity to see three cities in Peru- Nazca, Cusco, and Chiclayo each with a hundred thousand things to see. At each site I found myself soaring, tumbling, and freewheeling due to unbelievable sights and indescribable feeling. The changes in people's behavior, house construction, and geography were amazing.

Nazca was a very small town surrounded by mountainous desserts, a burning sun, and the dry winds of a dessert. The attraction of this small town was the Nazca Lines. The Nazca Lines, as viewed from the air, are gargantuan and unbelievable. These lines, sketched into the dessert floor 2,000 years ago, are remarkable in their perfection. How could the people of the Nazca culture built these perfectly straight and symmetrical shapes and lines without the assistance of today's technology? More surprising was the drastic change in homes and people as I rode the bus from Lima to Nazca. Houses in Lima are large American homes surrounded by protective walls and secured with locked gates. The houses beyond Lima in comparison appeared to be poor homes made simply of clay with a roof of tile or even at times no roof. People were seen bent over in the fields with mules weighted down by large loads.

Cusco, although in the same country, was amazingly different. I flew to Cusco one morning and as I stared out of my small window to this new world I saw large jagged mountains instead of the dessert and large city of Lima that I knew. The city of Cusco is a large city climbing the mountains of the Andes. The streets were wide enough for one car and busy with the traffic of cars and pedestrians. The houses were much smaller than those of Lima and sandwiched side by side on the mountainsides of the valley. Later, as I anxiously sat on a train heading to Machu Piccho these mountains only became taller, more jagged, and more breathtaking. When I arrived at Machu Piccho I found myself in an area 'populated' by tourists. And to explain the wonders of Machu Piccho in a very short summary, a near impossible task, the intelligence of the Inca's was amazing. The large granite stones, some weighing several tons, were perfectly cut and placed. Some of these large stones, weighing several tons, were transported from a quarry several miles away and up the mountain on which it now resides. Amazingly the Incans only worked on the construction of these wonderful, perfectly built, and durable cities four months out of the year. The geography and sites of Cusco were made more enjoyable by the very friendly atmosphere of Cusco. In Lima as you usher a taxi down you must first stick your head in the passenger side window to ask "Cuantos cuesta?" (How much does it cost?) Usually you would then spend several seconds bargaining and at times it took several taxis to obtain a reasonable price. In Cusco the

taxis were much different. All taxis in Cusco charged only two sol and as you slid into the back seat of the taxi the driver would always greet you with either Buenos dias (Good morning), Buenos tardes (Good afternoon), or Buenos noches (Good night). A friendliness you never see expressed in the busy Americanized city of Lima.

Thinking I had seen this whole new world I soon found myself in the backseat of Ida's car on my way to a northern city of Peru, Chiclayo. Chiclayo is the fourth largest city in Peru. After an exhausting 11 hour car ride where I caught glimpses of passing cities, the rolling mountains of the dessert, the ocean, and even a sunset I was in Northern Lima. This city was unlike all the others. It was not a tourist site as Nazca and Cusco had been. The only tourist attractions were the pyramids of the Moche culture. The pyramids at first glance appear to be large dirt piles. A deeper look and you see the large pyramids that they must have been before the effects of wind and rain. My favorite site of Chiclayo, was not the amazing artifacts and pyramids, but the ocean. The ocean was such a deep clear beautiful blue it seemed as if it were a painting. The reed boats propped up, drying up on the beach made the blue ocean too picture perfect. The city of Chiclayo itself was also very wonderful and different. The residential streets in the city were not the paved streets you see in the city of Lima but bumpy dirt roads. The houses were much smaller and not surrounded by a large protective wall as are the homes in Lima.

It was not through the opportunity filled United States where I learned more about who I truly am and what I would like out of the rest of my life, it was Peru. But when I left Peru I felt as if those wonderful eight weeks of my life had not changed ME. How wrong I was. In eight weeks I changed my perspective on life. I first began to notice the small changes, such as, taking my lunch to school so I could eat well-balanced meals as I had eaten in Peru. After I began to notice the small changes I noticed a very different perspective on how I was going about selecting a college and a major. To be honest I used to look at the salary of a career before I look at what the career truly was. But after seeing a Peruvian woman in Peruvian dress working in a field weighted down with a blanket of overflowing crops, I know that you should not select a career based upon salary but based upon what you love to do. I saw families in Peru that were working very hard to survive. But they were still happy because they were working for their families, the ones they loved. Peru taught me happiness cannot be bought. As a result of this realization I am exploring careers that I find interesting. I know my passion is science research, but now it is a matter of what type of research would I like to focus upon in a career? At this time I am currently very interested in environmental research. The environment is very important to crop production, human health, as well as plants and animals. As an animal lover and someone who would like to help humans as well as the environment I find myself now not looking at the salary of a career but what type of work I would carrying out.

In addition to this drastic change in career selection, I also found that I learned what my true priorities in life are. In Peru I did not miss my stereo system, television, car,

materialistic things, I missed my family, cat, and my boyfriend. I left Peru thinking, I've traveled away from home before this will be easy. How wrong I was again. Despite my claim to very infrequent crying I found myself in tears often while in Peru. It was very difficult because I couldn't call and tell my parents or boyfriend about something exciting that had happened that day. Yes, I could email, but I missed hearing their voices and feeling their warm hugs. In Peru I learned what was truly more important- my loved ones, not my loved things.

While I was yearning for those I loved, I found myself living as I had never before- sharing my living space with another- Melissa. I left the United States wary of how I would adapt to sharing my personal space. But after a day, Melissa and I had a schedule worked out. Every other morning I would wake up and take the first shower. Of course on the mornings when I rose first the snooze button was hit several times before I grudgingly got out of bed at an alarmingly early 5:30 when the sun hadn't even risen! After a shower, breakfast, and packing my backpack for work, I would unlock the protective door to the world outside our new home and we would begin our long trek to the bus. After 9 hours at work we would walk this same trek and plan our evening. Cautiousness about wandering around a city of 8 million people, who did not speak our language, was soon forgotten as my adventurous side shown through. I will admit we did get lost in Lima several times, but each time we were uncertain I found myself growing closer to this person who had been thrown into this whole new world with me. After 8 weeks I found myself and my perspective on life changed, not only because of Peru, but because of the differences in Melissa and I. Melissa came to Peru listening to classical music, quite a contrast to my fast paced hard rock. We returned listening to quite the opposite. I found myself listening to Shedds Aquarium, while Melissa was sitting next to me listening to Linkin Park. Melissa changed me, she taught me the virtue of patience and emotions. Melissa taught me the importance of sitting back and enjoying life. The fast track life that I led in the United States did not allow me to sit back and enjoy the wonders of the world we live in. I forgot, maybe intentionally, to simply sit back and enjoy the flowers, the stars, the birds, friends, and time of contemplation. Peru would not have been the same without her. It has been now been 8 weeks since Melissa and I last said good bye and I find myself yearning for the time we had to contemplate together. Without this wonderful trip to Peru I would not have meet one of my greatest friends, who helped teach me who I truly am and what this life is truly for.

With a new perspective on my life and priorities, I also found a different view on the small things in life we often take advantage of and ignore. In Peru I saw stars maybe five times. Now that I am back in rural Iowa I find myself often staring up at the dark sky sparkling with stars. Before Peru I would not stop speeding through life to simply look up and appreciate the wonders that we can see billions of miles away. I also gained a great appreciation for faucets. The first week I was home I had difficulty using the faucet. I often found myself looking for bottled water when I was preparing to brush my teeth, or even just to rinse my face. In the United States we take advantage and do not appreciate how wonderful it is that we are insured safe water flowing through our faucets. Stars and

faucets are not the only thing I gained an appreciation for. When Melissa and I attempted to make chocolate chip cookies, the family had apparently never had them, I found

myself not working with the fancy convection oven I have in my home in the United States, but I found myself staring at a small oven holding a match. Luckily the family lit and managed the oven because I was baffled! And while the oven was baking our strange 'cookie' concoction, I found myself yearning for a cold drink! It seems that the United States is one of the few countries that uses ice and drinks cold drinks! Drinking warm milk was a challenge, but it was obviously safe because I am here alive and healthy today. I will admit that while I was adjusting to these many changes I did not feel as if they had changed me, I felt as if I was simply adapting. But now that I am back I do as Melissa said, I stop and smell the flowers she so passionately pointed out each morning on our walk. I stretch out on the cold grass to enjoy the black, sparkling night above. I enjoy not having to trek back from a grocery store towing four large bottles of water. I appreciate the conveniences we have in our United States home, such as a convection oven and safe running water. My appreciation for life was changed by a serious car accident last September, my appreciation for the wonders of the world was changed by Peru.

Not only did I return finding a new perspective on life, I found myself rethinking my future. I left for Peru thinking I wanted to a biomedical engineer, I returned from Peru wondering why I ever wanted to a biomedical engineer! I took anatomy my sophomore year and did not enjoy it. The science area that has intrigued me the most has been similar to what my science research has focused on the past four years- the environment. But now as I explore the majors which involve the environment and will hopefully one day lead me to where I want to, a scientist, I find myself torn between majors. Majors of biology (in case I decide in college that I still would like to carry out veterinary medicine), environmental science, or environmental engineering. Along with my change in career choices, I also find myself changed in my perspective of what college I would like to pursue my undergraduate. Since August I have been on a roller coaster considering majors and colleges. What specific career and college I would like changes everyday. Do I want a big fast paced college as I like to lead my life? Or a smaller college where I can create strong relationships with my professors as I have in my high school? Despite my unsettling uncertainty, I find myself welcoming all these changes in my life. Peru made me truly realize who I am. This internship showed me a whole new world. I'm like a shooting star, I've come so far, I can't go back to where I used to be.

EVALUATION OF PESTICIDES AND *PHTHORIMAEA OPERCULELLA* ZELLER GRANULOVIRUS (POGV) FORMULATION ON TWO SPECIES OF POTATO TUBER, *PHTHORIMAEA OPERCULELLA AND SYMMETRISCHEMA TANGOLIAS (LEPIDOPTERA: GELECHIIDAE) IN PERU*

INTRODUCTION

World Hunger

Twenty-four thousand people die each day due to persistent chronic hunger. Over 840 million people are suffering from undernourishment (An end to world hunger n.p.). Yet enough food is currently produced for each human being to have at least 4.3 pounds of food everyday worldwide. The problem of world hunger is not an issue of crop quantity but an issue of crop distribution. Agriculture development is essential to increase the production of crops where it is most needed.

Peru

Among the third world countries plagued with world hunger is Peru. Covering 1,285,220 sq. km. Peru is located in Western South America bordering the Pacific Ocean between Chile and Ecuador. Nearly 28 millon people live in Peru and over 50% of this population is living below the poverty line. As well as a large percentage of poverty, Peru is also burdened with a widespread unemployment rate of nine percent. The labor force consists of only 7.5 million people with occupations in agriculture, mining, quarrying, manufacturing, construction, transportation, and services. But Peru's economics relies primarily on agriculture, with the country's primary exports being raw materials chiefly of minerals, fishmeal, and farm products.

In Peru there are three very diverse terrains varying from the western coastal plain (the costa), the central high and rugged Andes (the sierra), to the eastern lowland jungle of the Amazon Basin (the selva). Of this diverse terrain only three percent of the land in Peru is fit to cultivate. These limited agricultural areas are also suffering extensive damage to transportation and agricultural systems due to periodic earthquakes, landslides, El Nino, and other natural disasters. The agricultural yield of these limited areas are not meeting the needs of Peru's rapidly increasing population.

Potato

A very important crop to Peru and third world countries throughout the world is the potato. The potato (*Solanum tuberosum*) originated in South America and was brought to Europe by the Spaniards in the 16th century (Potato n.p.). By the 21st century the potato has become the second most

wide cultivated crop and the fourth most important food crop in the world. Annually there are approximately 300 million tons of potatoes grown throughout the world (About potato n.p.). The wildely grown potato provides more edible food annually than the combination of the world's output of fish and meat. (Potato CGIAR) One single medium-sized potato contains half the daily adult requirement of vitamin C, more protein than maize, and nearly twice the calcium of maize (About potato n.p.). The potato is a very nutritional crop that is important to ending world hunger.

But each year the world potato crop is plagued with pests and diseases. "Potato's susceptibility to pests and diseases makes the crop the number two user of agricultural pesticides worldwide, following cotton." Insect pests are a severe problem for potato farmers across the world. The widely distributed potato tuber moth *Phthorimaea operculella* is one of the most devastating potato pests. The moth damages plants above and below the ground. Mining into potato leaves results in stunted growth and infesting potato tubers in storage results in potato tubers unusable for consumption or use as a seed. Despite this infestation the improvement of potato yields in Peru and developing countries is essential to achieving economic independence and food security. The improvement of potato yields throughout the world can be attained with improved methods of and application of pest control.

Control

The potato tuber moth (*Phthorimaea operculella* Zeller) is be far the most important constraint to potato productivity. Control of the potato tuber moth is necessary for the protection of the world's important potato crop production. There are numerous methods of control of the potato tuber moth including pesticides, Bt pesticides, host plant resistance, *Phthorimaea* baculovirus, and other integrated methods of control.

Traditionally, and almost exclusively, the potato tuber moth has been controlled by means of pesticides. Very toxic pesticides are sprayed in field and storage conditions. Developing countries spend nearly $740 million dollars on pesticides for potatoes alone. Until recently, the first line of defense against the potato tuber moth was heavy doses of chemical pesticides. But continuing crop losses led farmers to adopt integrated pest management measures that rely on a mix of environmentally safe methods and minimal chemical sprays. Despite the development of numerous defenses against the potato tuber moth, pesticides are still applied to potatoes in the field and storage. Due to this continued application of pesticides it is necessary to obtain an understanding of what pesticides and at what concentration best control the devastating potato tuber moth.

The potato tuber moth is also controlled with Bt pesticides. Bt is a natural borne soil bacterium found worldwide. Bt produces a protein that selectively kills specific groups of insects. Once eaten, the protein is activated into a toxic form that binds to specific "receptors" on the intestinal lining causing the cells to rupture. As a result the insect will die of starvation within several days. Bt pesticides are the most commonly used pesticide because Bt has no detrimental impact upon non-target organisms. Bt

pesticides also leave no poisonous residue upon crops and readily degrade in the environment (B.t. petition n.p.).

Yet, "[h]ost plant resistance is the key component of integrated pest management programs to reduce pesticide usage in storage" (Development and Management n.p.). Host plant resistance is the easiest and cheapest mean of pest management. Host plant resistance is also compatible with biological, cultural, and chemical pest control tactics (Entomology 896 n.p.). The Agricultural Biotechnology Support Project (ABSP) successfully achieved host plant resistance with the development of a potato resistant to the potato tuber moth with the use of a toxic gene from Bt. But genetically modified organisms, such as the Bt potato, are faced with a problem of global confrontation and opposition.

Despite this opposition an increase in crop production and a decrease in pesticide use is required to obtain global food security. Alternative pest control tactics must be developed and used. Because the greatest damage and crop loss due to the potato tuber moth is in tuber storage a baculovirus "virus [may] play a key role in the management of potato tuber moth in storage" (Potato tuber moth control n.p.). A baculovirus of *Phthorimaea operculella* Zeller (PoGV) has good prospects for pest control in the field and storage. PoGV is a granulosis-type of virus of the Baculoviridae family, which is highly specific to insect pests, and high recommended by the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the Oxford Virology Institute. This baculovrius only impacts the potato tuber moth larvae after the viral particles have been eaten. Once eaten the virus initially infects the midgut cells through the dissolution of the protective proteinaceous matrix of the midgut This dissolution causes the larvae to become creamy white, become slightly swollen, and move slowly before dying 12 to 21 days later. Virus infected *Phthorimaea operculella* are unable to pupate and continue reproduction. This baculovirus dust formulation can be produced by farmers by using selected ground virus infected potato tuber moth larvae suspended and water and a dispersing agent. The bacoluvirus formulation can also be used to manage potato tuber moth infestation in storage, where the potato tuber moth larvae commit the greatest damage to the potato crop.

In addition the potato tuber moth can also be controlled with other integrated pest management tactics, including repellent plants, biological controls, and pheromones.

There are many methods of controlling the potato tuber moth. Methods of controlling the potato tuber moth include chemical pesticides, Bt pesticides, host plant resistance, *Phthorimaea operculella* baculovirus, repellent plants, biological controls, and pheromones. An understanding of how to use and apply these methods must be acquired to maintain human health safety and optimized pest control.

Limitations to Control

Each method of controlling the potato tuber moth has its biological and economical advantages and disadvantages. Many rural poor farmers are faced with a great number of pests, diseases, and soil problems that result in poor yields. These poor

farmers do not have the money to afford the pesticides and fertilizers necessary to increase crop production. In some areas throughout the world, the potato tuber moth has also begun to develop insect resistance to these heavily applied pesticides. Another pesticide commonly applied is Bt pesticides, which overcomes chemical pesticides negative toxicity on the environment. But Bt pesticides only have a short-term impact. This short-term impact is conquered by genetically engineered Bt potatoes, which continuously express Bt within the plant tissues. But if exposed to continuous, massive doses of *B.t.* over a long period of time, the potato tuber moth can develop resistance to Bt pesticides and Bt potatoes. Widespread use of transgenic Bt plants could permanently destroy Bt's effectiveness in controlling the potato tuber moth. The control of the potato tuber moth with the granulosis virus *Phthorimaea operculella* Zeller granulovirus (PoGV) is also limited in the field by its rapid inactivation due to UV radiation. Each method must be appropriately applied and used with pest management to maintain effectiveness.

Purpose

Many controls are used to decrease and eliminate potato tuber moth infestation. Each method of control has many advantages and disadvantages. The purpose of this study is to compare the impact of methods of controlling the potato tuber moth with a Bt pesticide and two chemical pesticides in five concentrations and a PoGV formulation. Pesticide controls will be analyzed by the mortality obtained. The PoGV virus impact will be analyzed by number of diseased and healthy larvae. Each control will be analyzed based upon biological and economical advantages and disadvantages in addition to the impact of each method of control.

METHODS

Mass Rearing of Potato Tuber Moth

Mass rearing of the potato tuber moth was necessary for the completion of this bioassay. Potato tuber moth larvae were collected and placed in a plastic box (33 x 23 cm) lined with paper towel and potato tubers and stored at 10 degrees Celsius. Craft paper cartridges were placed on the tubers for pupation. When the larvae had completed pupating the pupas were harvested and placed in a plastic container sealed with a mesh cloth. After the potato tuber moths had emerged the moths were captured and placed into an oviposition container. The oviposition container had a mesh cloth covering the top opening of the plastic container. Honey drops and a filter paper weighted by 2 petri dishes were placed on the upper mesh cloth. The filter paper was removed after oviposition and placed into a sealed plastic container. After one week the filter paper would be place inside a plastic box lined with towel paper and potato tubers. The continuation of this cycle was necessary for the mass rearing of the potato tuber moth.

Dilution of Pesticides

Before preparation of tubers, three pesticides, Dimilin, Atabron, and MVP, were diluted into five concentrations. Five concentrations were prepared using a powder pesticide (Dimilin). Fifty grams of the pesticide was weighed and added to 498.75 ml of distilled water and 1.25 ml of Agridex and mixed well. When thoroughly mixed, 50 ml of Concentration 1 was added to 448.75 ml of distilled water and 1.25 ml of Agridex to prepare Concentration 2. This was continued to prepare 3 additional concentrations, each containing 448.75 ml of distilled water and 1.25 ml of Agridex. To prepare five concentrations using liquid pesticides (Atabron and MVP), 100 ml of pesticide was diluted in 148.75 ml of distilled water and 1.25 ml of Agridex. After mixing well, 25 ml of Concentration 1 was placed into a container with 223.75 ml of distilled water and 1.25 ml of Agridex. This was continued to prepare 3 additional concentrations, each containing 223.75 ml of distilled water and 1.25 ml of Agridex.

Application of Pesticides

Before treating tubers, the tubers were sterilized and cleaned with bleach and water. Sterilized tubers were treated with Atabron, Dimilin, and MVP (Insectida Biológico Suspensión Acuosa). The products were diluted and placed into small plastic buckets. Fifteen tubers were placed into plastic netting and placed into the plastic buckets for ten seconds to obtain an even coating of the pesticide. The treated tubers were allowed to dry for two hours before being placed in a plastic cup and labeled with treatment, dosage, and type of potato tuber moth. Each cup was infected with ten neonate larvae using a camel hair paint brush. For each pesticide dosage ten cups were infected with ten *Phthorimaea operculella* neonates and five cups were infected with *Symmetrischema tangolias* neonates. Larval mortality was recorded after ten and fifteen days.

Multiplication of PoGV

Purification of PoGV

PoGV diseased larvae were collected from potato storages in a valley of Bolivia. To purify one virus inoculation sixty diseased larvae were weighed and macerated in an equivalent volume of distilled water. The suspension was filtered through a muslin cloth to remove gross debris. The filtered liquid was centrifuged for ten minutes at 15,000 rpm to remove lipids and soluble material. After removing the liquid from the centrifuge, the supernatant was

discarded and the remaining pellet was suspended in a small volume of water. This suspension was centrifuged a second time on sucrose gradients of 45, 60, and 80% for one hour at 25,000 rpm. After one hour, the band containing the virus was collected and with a pipette and diluted in distilled water (3:1). Residual sucrose was removed by centrifuging the suspension for fifteen minutes at 15,000 rpm. After fifteen minutes, the supernatant was discarded and the remaining pellet was suspended in distilled water and stored at –20 °C.

Obtaining Potato Tuber Moth eggs

One hundred pupae of the potato tuber moth were placed in a plastic dish (500 cc). Gauze secured with two rubber bands covered the dish. Upon the emergence of the adults, four days later, a piece of filter paper was placed on the cloth. Two petri dishes were placed over the filter paper to facilitate the adherence of eggs to the filer paper. A sugar solution of water and honey (5:1) was placed in drops around the filter paper. The filter paper with eggs was collected daily and the application of the sugar solution was replicated daily for five days.

Infestation

A concentration of inoculates was homogenized on a vortex. Four hundred micro liters of the isolation was applied to 200 eggs on a small section of filter paper with a micropipette moved in a circular motion. The eggs were allowed to dry for one hour at room temperature. After one hour the filter paper was placed in a petri dish and sealed with parafilm. Each petri dish was labeled with virus isolation, date of infection, and the host used.

Transfer

After emergence, or approximately 27 days, the larvae were transferred to upbringing boxes. The boxes will be lined with paper towels and contained 2 tubers. Each tuber was infected with 50 larvae. The boxes were secured with a lid and remained at temperature of 20 degrees Celsius. When pupation began the number of diseased larvae, healthy larvae, and pupa was counted.

RESULTS

Effect of Atabron

Potato tuber moth survival for larvae feeding on tubers chemically treated with Atabron showed a significant difference to the control for all dosages. No significant difference was indicated between Atabron dosages 1, 2, or 3 (Table 1). A significant difference was found between dosages 1, 2, and 3 to dosages 4 and 5. Therefore, laboratory bioassays of Atabron dosage 3 maintained the optimal control of the potato tuber moth with minimal pesticide application.

Table 1. Comparison of potato tuber moth survival exposure to five dosages of three pesticides: Atabron, Dimilin, and MVP.

Pesticide	Mean Mortality	Standard Deviation of Surviving
Atabron 1	54[a]	0.00
Atabron 2	52 [a]	0.00
Atabron 3	35 [a]	2.31
Atabron 4	83 [b]	27.00
Atabron 5	45.33 [b]	15.50
Dimilin 1	0 [a]	0.00
Dimilin 2	0 [a]	2.08
Dimilin 3	3.33 [a]	0.00
Dimilin 4	35.67 [b]	17.70
Dimilin 5	51.67 [b]	3.51
MVP 1	0 [a]	0.00
MVP 2	2 [a]	1.00
MVP 3	15 [a b]	11.27
MVP 4	30.67 [b]	4.93
MVP 5	37.67 [b]	6.51
Control	97	1.73

[1] Means in a column with the same letter are not different using 95% confidence intervals based on 0.0045 pooled standard deviation.

Effect of Dimilin

Potato tuber moth survival for larvae feeding on Dimilin treated tubers showed a significant difference to the control (P=0.05). Dosages 1, 2, or 3 did not indicate a significant difference (Table 1). A significant difference was indicated between dosages 1, 2, 3 to dosages 4 and 5. Therefore, laboratory bioassays of Dimilin dosage 3 maintained the optimal control of the potato tuber moth with minimal pesticide application.

Effect of MVP

MVP treated tubers showed a significant difference to the control (P=0.05). Dosages 1, 2, and 3 did not show a significant difference of potato tuber moth survival (Table 1). No significant difference was shown between dosages 3, 4, and 5. A significant difference was found between dosages 1 and 2 to dosages 4 and 5. Therefore, laboratory bioassays of MVP dosage 3 maintained the optimal control of the potato tuber moth with minimal pesticide application.

Effect of Baculovirus

Laboratory bioassays of 4 baculovirus inoculations infecting *Phthorimaea operculella* eggs indicated an average control of 56%. No significant difference was found between the four bacoluvirus inoculations (Table 2). The impact of baculovirus compared to the optimal application of pesticide did not indicate any significant difference (P=0.05).

Table 2. Comparison of potato tuber moth survival exposure to three *Phthorimaea operculella* virus isolations.

Virus Isolation	Virus Infected	Pupas	Absent
29.28	54 [a]	9	37
29.24	52 [a]	6	42
29.24 (B)	35 [a]	27	38
29.37	83 [a]	10	7

[1] Virus infected PTM in a column with the same letter are not different using 95% confidence intervals based on 0.0045 pooled standard deviation.

DISCUSSIONS AND CONCLUSIONS

This research evaluating the control of three pesticides on the potato tuber moth indicated no pesticide obtained an optimal control significantly better than any other pesticide (Table 3). Traditionally the potato tuber moth is controlled by very toxic pesticides, which cost nearly $740 million dollars each year. Continued application of heavy doses of chemical pesticides has resulted in resistance development and caused serious health problems. A interdisciplinary and interinstitutional team of scientists concluded health problems caused by pesticides are severe and are affecting a high percentage of rural populations (Yanggen). The biological control, *Phthorimaea operculella* baculovirus inoculationndecreases the negative impact of chemical pesticides on human health and did not show a significant difference to the optimal application of pesticide (Table 3). The baculovirus can also be produced by farmers to overcome the negative economic impact of costly pesticides on poor rural farmers. The intervention of integrated pest management using environmentally safe techniques of control and biological controls of the potato tuber moth is necessary to decrease the negative impact of chemical pesticides on humans. Integrated pest management intertwining the use of chemical pesticides and environmental safe techniques to decrease the negative impact of potato tuber moth infestation and the negative impact of toxic chemical pesticides on human health is necessary to attaining food security. Further investigation of the impact of the Bt potato in comparison to chemical pesticides and the biological control of the potato tuber moth is necessary.

Table 3. Comparison of potato tuber moth survival exposure to optimal application of three pesticides (Atabron, Dimilin, MVP) and *Phthorimaea operculella* baculovirus.

Control	Mean Impacted PTM	Standard Deviation
Atabron 3	93.33 [a]	2.31
Dimilin 3	96.67 [a]	2.08
MVP 3	81.67 [a]	10.02
Baculovirus	56.00 [a]	19.92

[1] Means in a column with the same letter are not different using 95% confidence intervals based on 0.0045 pooled standard deviation.

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