Integrated Pest Management for the Potato Tuber Moth, *Phthorimaea operculella* (Zeller) - A Potato Pest of Global Importance
Commercialization of potato tuber moth resistant potatoes in South Africa

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Abstract

The potato tuber moth (PTM), Phthorimaea opercul ella (Zeller) is a major pest problem facing potato farmers in developing countries. Currently, the primary means to control the PTM and avoid major crop losses is the use of chemical pesticides. Michigan State University, funded by the U.S. Agency for International Development through its Agricultural Biotechnology Support Project, initiated biotechnology research on the development of PTM resistant varieties in 1992. A Bacillus thuringiensis Berliner (Bt)-cry11ai gene, was obtained from ICi Seeds (now Syngenta seed company) and successfully introduced into several potato varieties, including Spunta. Transgenic lines were shown to have complete efficacy against PTM. This Bt-potato will be one of the first public sector developed products to reach farmers in developing countries and will serve as a model for the public sector deployment of insect resistant transgenic crops. The commercialization project includes six components: 1) Product development, 2) Regulatory file development, 3) Obtaining freedom to operate on intellectual property/proprietary technologies and establishing licensing relationships, 4) Marketing and technology delivery, 5) Documentation of socio-economic benefits, and 6) Public communication. The expected benefits of this Bt-potato to farmers and end-users will be increased marketable yield, improved quality, reduced storage losses, reduced post-harvest losses and reduced human exposure to pesticides.

Introduction

The Agricultural Biotechnology Support Project (ABSP), funded by the U.S. Agency for International Development (USAID), was established in 1991 as the premier US-sponsored agricultural biotechnology program designed to assist developing countries in accessing and using biotechnology to address local agricultural constraints. ABSP worked in Asia, the Middle East, Latin America and Africa to develop a number of...
crops with improved agronomic traits. ABSP, managed and implemented through Michigan State University (MSU) in collaboration with other US universities and the private sector, has integrated research, product development, and policy/regulatory development to assist developing countries in accessing and generating biotechnology and in establishing a regulatory framework for production of biotech crops (Figure 1). ABSP has also been successful in assisting with the development of appropriate policy frameworks in developing countries through technical assistance in regulatory development and intellectual property rights.

![Diagram of networking, research, ABSP, policy, and management]

**Figure 1.** ABSP’s integrated approach to biotechnology development and transfer.

Our project team believes that the tools of biotechnology, including tissue culture, molecular markers, molecular diagnostics, and genetic engineering, can be applied safely and effectively to address crop production constraints in developing countries. Managed properly and safely, biotechnology can play an important role in improving food and forage crop production, and thus enhancing food and feed security. Scientific solutions to improve crop productivity, where biotechnology can play an important role, can empower the rural sector, by boosting food production, enhancing income for the small farmer and improving nutritional security. This project has focused on developing and commercializing a Bt-potato variety to manage resistance to potato tuber moth (PTM), *Phthorimaea operculella* (Zeller). The project goals are to provide safe, economic control of PTM via Bt-based host plant resistance. With this development, farmers may be able to reduce application of chemical insecticides in the field and should be able to reduce tuber breakdown in storage due to PTM feeding.

The cultivated potato, *Solanum tuberosum* L., is one of the world’s major food crops following rice (*Oryza Sativa* L.), wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) in importance (ROSS, 1986). The potato is widely grown over many latitudes and elevations in 130 of the world’s 167 independent countries. PTM is one of the most serious insect pests of potatoes worldwide. It is of greatest importance in sub-tropical and tropical latitudes, including the southern and southwestern US. Insecticide use is the most common means of PTM control in both field and storage. Twelve to twenty insecticide applications may be used to control PTM during the growing season, and in storage, three to four insecticide sprays may be applied in storage for PTM control, with the last application within one week of marketing (MADKOUR et al., 1999).

### Bt-potato project

The introduction of the *Bacillus thuringiensis* Berliner (Bt) protein gene via genetic engineering offers a form of plant resistance against PTM. The high dose expression of *Bt* in crop plants offers an ecologically sound means to control specific crop insect pests (MCGAUGHEY and WHALON, 1992). We focused on utilizing the codon-modified *Bt-*cry1A1 gene from the Syngenta Company (formally ICI Seeds). ICI Seeds was an ABSP partner that developed the *Bt-*cry1A1 gene initially targeted for corn transformation (TAILOR et al., 1992). Through a research agreement, ICI Seeds extended the use of this gene for transformation into potato. Use of the *Bt-*cry1A1 gene provided a means to achieve our research goal of high expression of *Bt* in potato (Figure 2). Transformations in potato with a codon-modified *Bt-*cry1A1 gene (effective against both lepidopteran and coleopteran insects) have produced high levels of *Bt* expression with 80 to 100% insect mortality in detached leaf laboratory bioassays (Li et al., 1999; WESTEDT et al., 1998; MOHAMMED et al., 2000).

This research has led to germplasm that has commercial potential in the U.S. and abroad (Egypt, South Africa, Argentina, Mexico and Indonesia) (MOHAMMED et al., 2000; DOUCHES et al., 2002). With transgenic material in hand, the MSU potato research team was able to distribute the Bt-potatoes and establish field tests in Egypt (DOUCHES et al., 2004) and South Africa, and to conduct greenhouse tests in Indonesia and Peru (LAGNAOUI et al., 2001) (Figure 3). A field trial planted in 1997 was the first transgenic field trial ever conducted in Egypt. Since then, yearly trials were conducted in Egypt until 2001 and then in South Africa from 2001 to the present. Potential target countries for Bt-potato commercialization include Egypt, South Africa, Indonesia, India and Mexico.

South Africa was selected as the target country for product commercialization for various reasons. First, PTM is an important constraint in South Africa (VISSELR, 2005) and product efficacy of the Bt-potato was demonstrated in contained field trials. Secondly, the commercial potato industry in South Africa (Potatoes South Africa) is well developed and it, along with the Agriculture Research Council (ARC), has had previous in-country experience with genetically modified (GM) potato research. To complement the potato industry, there is a well established enabling environment for commercialization of GM crops — cotton (*Gossypium barbadense* L.), maize (*Zea Mays* L.) and soybean (*Glycine max* L.) have been commercialized. A functioning biosafety regulatory framework exists in South Africa.
Technology development and proof of concept were established many years before the Br-potato project reached South Africa. Consequently, product development has been a major thrust of the project in South Africa (Figure 4). In the US, agronomic trials of the Br-potato lines have been conducted since 1994. The results demonstrate that Spunta-G2 has equivalent yield, type, tuber size distribution, specific gravity and internal defects frequency as the non-transgenic Spunta. PTM efficacy trials were also conducted from 2004 to 2006 in Washington. Spunta-G2 foliage had no mining damage from the adults and the tubers were free of mining damage in post harvest assays (L. LACEY unpublished data). PTM field and storage trials have given comparable efficacy (MOHAMMED et al., 2000). Multi-location agronomic and PTM efficacy trials (field and storage) have been conducted at six sites in South Africa since 2001. Complete control of the PTM was found at all locations in all years as seen at Ceres, South Africa (Figure 5). There was no infestation in the field when examining the foliage and tubers of Spunta-G2 and no infestation was found in tubers stored up to 6 months.

![Diagram](image)

Figure 4. Transgenic product development overview.

To move beyond the first phase of research and have greater impact, the cry11a1 gene construct was used to transform two popular South African potato cultivars. We currently have produced Br-potato lines of these cultivars, confirmed by PCR and Southern analysis. In addition, we have used Spunta-G2 as a parent in our breeding program at MSU. Currently there are 15 selections, which are Br-positive and PTM resistant that are derived from crosses with late blight resistant parents (data not shown). Based on existing GM crop approvals, these Spunta-G2 derived progeny are likely to be approved under a general release approval for Spunta-G2, when this is obtained in South Africa.

With field testing in place in target areas, we are currently addressing the intellectual property rights (IPR) of the Br-potatoes, food safety and socioeconomic issues that are specific to South Africa’s regulatory approval requirements (MORRIS and KOCH, 2002).
Biosafety, food safety and IPR regulatory issues associated with *Bt*-potatoes

The safe and legal application of biotechnology requires appropriate and functioning biosafety and IPR systems. Biosafety encompasses policies and procedures to ensure environmental, food and feed safety of applications of biotechnology. The IPR and biosafety policies must be in place both at national and institutional levels to ensure safe and legal exchange of technology. Appropriate IPR agreements giving freedom to operate (FTO) must be in place before proprietary biotechnology products can be utilized.

Considering the importance of the biosafety, food safety, and IPR issues associated with *Bt*-potatoes, we have from the beginning of the project put concerted efforts into building capacity in these areas in collaborating countries. Our team views biosafety and IPR as integral parts of the technology transfer process and has always ensured that all the legal and biosafety requirements of recipient countries are met before any technology is exchanged. The technology transfer process has been carried out in a safe and legal manner. The integrated approach to technology transfer includes the following steps:

1. Preparation of biosafety permit applications.
2. Review by the National Biosafety Committee of the recipient country.
3. Development of Material Transfer Agreements (MTA) encompassing both IPR and Biosafety elements.
4. Issuance of U.S. Phytosanitary Certificates for importation of material into recipient countries.

5) Import permit applications - Plant Quarantine Department of the recipient country.
6) Transfer and storage of regulated plant materials.
7) Greenhouse and field tests in local environments, under permits for contained use or for contained field trials and the supervision of biosafety officers.

These project activities have significantly contributed to capacity building in public sector biosafety and IPR, and have helped strengthen the national biosafety and IPR frameworks in Egypt and Indonesia.

**Product commercialization approach**

There are many other components of the *Bt*-potato project besides product development that must be addressed for the project to succeed. Commercialization of a GM product requires a comprehensive approach as outlined in Figure 6. To support an application for commercial release of the *Bt*-potato, a regulatory file containing extensive safety data must be generated. Components include protein expression, toxicology evaluations, substantial equivalence testing and socioeconomic studies. A marketing strategy must be developed in consultation with the local potato industry. To have commercial impact, we also need a product delivery mechanism that must be coordinated with the potato industry and potato seed growers. It is imperative for Freedom to Operate (FTO) to be granted by the main IP holders through the development and establishment of valid licensing agreements. By developing a stewardship program potential liability issues can be identified and addressed before actual commercialization of the product. Effective and regular communication with the industry producers and consumers must occur so that transparent and scientifically sound data are made available in a timely manner. We have had to work closely with the South African potato industry and other stakeholders to address consumer acceptance strategies. Post-approval strategies addressing product stewardship and regulatory compliance (including post-market monitoring) must also be defined.
Lessons learned

Over the course of the *Bt* potato project, management aspects such as budgets, personnel, technology, regulations, etc., changed over time. Our commercialization consortium learned to adjust to these changes. Along the way, valuable lessons were learned:

- Communication between collaborating scientists is very important. Cultural differences can limit or impede communication.
- Training of developing country scientists is valuable. Training helps with effective collaboration and establishing good communication. In addition, long-term training was more valuable and effective than short-term training.
- The research program goals must provide clear actions and must address social, economic, and ethical issues surrounding the research to gain confidence of all stakeholders.
- Food safety issues of *Bt*-crops became larger than anticipated as the research progressed.
- World-wide anti-GM issues developed during the project and limited progress towards commercialization. GM plants have become more regulated rather than less regulated.
- GM crops became a trade barrier during the project and limited commercialization options due to fear of market loss in Europe.
- Close linkage between lab and field research is needed to ensure progress towards commercialization.
- Vector construction is a continuous process, not a final step. Many transgenic lines must be generated and the process needs to be an ongoing objective in the work plan.
- IPR and FTO on proprietary technology are a changing target.
- Biosafety and IPR issues are as important as research when commercialization is the final goal.
- Research drives the development of policies. Transgenic plants must be available to provide a reason for establishing field testing and food safety regulations.

Why is the *Bt*-potato project important?

The PTM resistant potato will be one of the first public sector-developed products to seek approval and deployment in a developing country. This product has the potential to have a major economic impact if released in other developing countries such as Indonesia and Bangladesh, where PTM is a serious problem. With proper commercial development, this product will become a tool available to all potato farmers in South Africa. This product will demonstrate the feasibility of efforts led by the public sector, and developing country institutions, to make biotechnology products available in Africa. Furthermore, it will demonstrate the value of developing country involvement in generating safety assessment data, from the standpoint of scientific contribution and reduced cost. Finally, the *Bt*-potato project provides important capacity building opportunities for public sector institutions with regard to the comprehensive approach that is required to commercialize transgenic crops. The expertise and know-how to commercialize transgenic products has been, almost exclusively, the domain of private companies. We intend to publish the information we have gained during this project, for the benefit of public-sector institutions.

References


