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Development of sustainable control of diamondback moth in cabbage and cauliflower by public–private partnership

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Most biotechnology research and development focuses on major agricultural crops. There is an urgent need for improvements in vegetable production, especially in developing countries where the economic, health and environmental benefits of bioengineered vegetables could be great. This chapter outlines a strategy to realize this potential, involving initiating an innovative public–private sector project for developing and releasing an integrated solution to an immense insect problem in cabbage and cauliflower. It describes the basic aspects of the concept, as well as the challenges experienced in its deployment.

1 Introduction

Cabbage and cauliflower are important cash crops for farmers throughout tropical and subtropical areas of Asia, Africa, Latin America and the Caribbean. They are also important staple foods, rich in vitamin C and other micronutrients. The production of these crucifers (a family that also includes broccoli, radish, kale and mustard) is severely affected by the diamondback moth, *Plutella xylostella*, especially in resource-poor regions.[2] Diamondback moth now occurs wherever crucifers are grown, and control of the pest worldwide is estimated to cost US$1 billion each year. Losses of cabbage and cauliflower due to the moth can reach 90% without the use of insecticides. Even when insecticides are used, the losses can be substantial. In tropical areas where pest pressure is high, it is not uncommon for insecticides to be applied every other day, posing hazards to farmers, consumers and the environment.

This paper provides an insight into the efforts of and challenges experienced by a public–private partnership to deploy a new strategy to develop and release a sustainable solution

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2 Talekar and Shelton (1993).

to an immense insect problem in cabbage and cauliflower cultures in developing countries.

Natural enemies are essential in any integrated pest management programme to control the diamondback moth. Although considerable research has gone into enhancing the role of the moth's natural enemies, they are rarely sufficiently effective, and so must be supplemented with other control tactics. Once established in newly planted areas, moth populations grow too fast for naturally occurring control agents to be effective. In tropical climates, where host plants are available year round, more than 20 generations of diamondback moth may be produced. The intensive use of broad-spectrum insecticides exacerbates this situation, as they also destroy the moth's natural enemies. The high reproductive rate, coupled with intensive insecticide use, has led to the creation of biotypes of the moth that are resistant to many common insecticides. Such resistance must be taken into account when planning new control strategies.

2 A technical solution

Diamondback moth caterpillars feed on above-ground portions of crucifers, frequently in parts that are inaccessible to crop protection sprays. The development of varieties with built-in resistance would have a number of benefits, including reducing yield losses and the incidence of diseases that enter the plant following insect damage. Resistant varieties would also reduce the need for frequent insecticide applications and the reliance on broad-spectrum insecticides, thus allowing an increased role for the moth's natural predators. Despite considerable research, however, plant breeders have not been able, by conventional breeding, to develop crucifer germplasm with sufficiently high levels of resistance to the diamondback moth to be considered useful for commercial programmes.

The approach proposed here is to develop cabbage and cauliflower varieties with built-in, consistent and sustainable protection from the diamondback moth through the insertion of two genes from the soil bacterium *Bacillus thuringiensis* (Bt). Over the past eight years various genes for Bt toxins have been deployed in corn and cotton, with great success. In 2003 the total area planted with Bt crops worldwide was 18 million ha, without significant environmental or health problems emerging.[3] Nonetheless, plant materials developed via this approach would be rigorously tested for their biological, social and economic impacts on small-scale farming systems before any move to commercialization is pursued.

The approach recognizes the potential benefits of using Bt crucifers as a safe and effective control strategy, but also acknowledges the concern that diamondback moth populations have the capacity to develop resistance to Bt proteins, as has already occurred in some areas due to Bt foliar sprays. However, theoretical models show that if two Bt genes producing different proteins that target different binding sites in the insect are used simultaneously in the plant, the evolution of resistance can be dramatically

[3] James (2003).

delayed relative to single gene plants used sequentially or simultaneously. Recent greenhouse tests with diamondback moth produced results that are consistent with this theory.[4]

3 A delivery solution

The diversity of vegetable markets, the short life time of particular varieties of the crops in question, and the regulatory costs of bringing such novel plant material to market make the process of developing, testing, assessing and gaining regulatory approval for (stacked-gene) Bt brassica prohibitive for even the largest commercial vegetable seed company. Today the costs involved in collecting the necessary data to prove the human and environmental safety of transgenic plant material, including the preparation of the regulatory dossier required for international registration, can exceed the development costs by more than four times.

For fresh produce like cabbage and cauliflower, the situation with respect to consumer acceptance and public commitment to transgenic varieties remains unclear. Due to this uncertainty, together with the high costs and relatively low acreages planted with vegetable crops compared with those devoted to the main commodity crops, biotech companies have focused their attention on corn, cotton and soy, and not on vegetables.

Sharing the responsibility for ensuring that developed plant material meets the highest regulatory standards would reduce the costs to each participant. Including strong public participation, as well as funding, would give the 'public' the opportunity to lever private investments in the direction of products that would benefit farmers and consumers in developing countries, and ensure the fair availability of plant material to all stakeholders. The combination of private and public expertise, addressing technical as well as socio-economic aspects, would help to guarantee the best outcome of the work, increase public confidence in the developed material and, therefore, acceptance of the strategy.

The magnitude of potential benefits to producers and consumers worldwide makes the development of such material of considerable public interest. For this reason a public–private initiative has been launched to develop Bt cabbage and cauliflower varieties resistant to diamondback moth. The use of public funding would help to ensure the appropriateness of the developed material for small-scale farmers and consumers in developing countries, and that the developed germplasm is accessible to vegetable breeders in developing countries.

The developed material will be deployed within a comprehensive integrated pest management (IPM) framework designed by expert entomologists. The distribution of the plant material will be accompanied by an extensive farmer training programme aimed at ensuring the appropriate and sustainable use of the technology, and maximum yields for farmers.

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[4] Zhao *et al.* (2003).

Project history

The history of this specific cabbage and cauliflower case dates back to 2000, when the Natural Resources Institute (NRI) in the UK was looking for a private partner to join in the development of a sustainable solution to the alarming increase in the use of insecticides to control pests in vegetables in India and Southeast Asia. The NRI had been involved in the development and deployment of Bt cotton and was aware of the serious situation in vegetable growing. What they were looking for was an experienced partner that could deliver locally adapted Bt varieties that could be used as the basis for improving the sustainability of vegetable cultivation.

At a first technical meeting in late 2001, participants from all over the world discussed the problems in cabbage and cauliflower and the possibilities for changing the situation. The outcome was a definition of a 'best approach', detailing minimum requirements to deal with the specific case of the diamondback moth.

A number of potential sponsors, most of them European development agencies, expressed their interest in the initiative, which appeared to be technically and environmentally sound, but they were nervous about joining a project involving the development and release of transgenic material. Another major drawback may have been the likely duration of the project – it is expected to take at least eight years from the start of technical work to the release of the developed plant material. It is difficult for ministries to commit to (aid) projects that will continue far beyond their electoral period.

The private company was an invited partner and agreed to work 'behind the scenes' as a material supplier only. It was appreciated that the plant material would take time to develop. Thus, at the end of 2003, the company started the preparatory development work, following the advice of international scientific opinion on the technical approach. In the interim, NRI and the company continued to develop their public–private partnership (PPP) concept and encouraged leading international organizations to support the initiative.

Project concept

The concept of the project was based on the following. The public sector had seen the need for the considerable regulatory and testing hurdles in the development and registration of transgenic plant material. It was therefore appropriate that the public sector should share the costs of bringing the benefits to poor farmers and consumers who would otherwise be excluded from the market due to the high cost of development and registration. However, if public funds were to be used, significant public benefits had to be ensured.

Rather than simply sharing the intellectual property – with all the accompanying problems in terms of regulatory constraints – the intention was to offer the technology in the form of locally adapted varieties that would perform well under local conditions to breeders and seed producers free of technology fees. This development programme

would not stop with the development and selection of the physical material, but would continue to full registration of the material in the target countries.

The private company would carry the cost of 'making the product', which would include the introduction of the resistance genes in the cabbage and cauliflower varieties, testing and selecting their performance under local conditions, and performing the basic characterization studies to confirm stability and ensure full traceability. For their part, the public sector partners would bear the costs of 'releasing' the product. This would involve extensive field testing of the new varieties for effects on target and non-target insects, studies of human and environmental safety issues, and evaluations of the socio-economic impacts of the solution and the supporting integrated pest management (IPM) programme. This IPM programme would be based on an optimal mix of plant-based insect resistance in order to reduce insect pressure, and well planned agricultural practices, including natural predators and the selective use of insecticides if needed.

Both the insect-resistant plant material and the regulatory dossier would be transferred to a public organization that would make it available to local farmers and breeders. However, based on the same resistant plant material the company would be entitled to develop its own hybrids that may be released in parallel with the public varieties.

By making these concept principles clear from the beginning, the consortium believed that the work would lead to a clear and acceptable win–win situation for both the public and private partners, as well as for farmers and consumers in developing countries.

Project milestones

Based on the project concept outlined above, a number of project milestones were set. First, it was recognized that for such an extensive project it was essential to have the commitment of scientific experts who would make it clear that the best approach was being taken to create a sustainable solution to the insect problem. A group of scientists was asked to prepare a statement detailing the scientific rationale for the concept and to submit it to international experts for comment. The statement, which was modified slightly to take into account the comments received, not only established the scientific support for the concept, but also identified further environmental and other studies that would need to be undertaken in order to ensure the sustainability of the end product.

Second, it was necessary to make sure that the economic assumptions justifying the project were not based on personal perceptions. Independent institutions were therefore requested to undertake studies of the socio-economic impacts of the insect pest on cabbage and cauliflower production, the actual pest management systems currently in use, and the potential impact of the concept under development. Along with the scientific statement, these socio-economic studies provided the technical justification for starting the work.

Third, a clear condition set by the private company and the financial sponsors approached was that a clearly formulated request was received from stakeholders in developing countries. This project was not meant as a technology looking for a problem to address,

but rather as a well prepared solution to the problem of managing a serious insect pest. Thus the clear commitment of local stakeholders would provide to all participants the best guarantee of an acceptable and accepted product.

Finally, once the international experts had defined the 'best approach', it would be up to the scientists to demonstrate its technical feasibility. This technical 'proof of concept' is a prerequisite for finalizing the project timeline and budget. As a major part of the work will be done by local public sector partners, it will be essential to identify which local institutions would be involved in what part of the project, to ensure that optimal use is made of available resources, and to bring together international and local expertise for their mutual benefit. Having an agreement on the concept and the commitment of stakeholders, potential financial sponsors are now being asked to indicate their interest in joining the consortium as financial partners.

Project timeline

The total time span of the project will be about eight years. It will take five years to introduce the resistance genes into the cabbage and cauliflower and to test and select the material in the field. The performance and stability of the trait, as well as the developed varieties, will need to be field tested in the target region over several seasons under different environmental conditions and genetic backgrounds.

Partly overlapping this development phase will be a three-year period of research, tests and analyses of human safety, including toxicity and allergenicity testing, studies of the environmental effects of the material on target and non-target insects, and assessments of the potential impacts on local ecosystems. This will lead into a series of official field trials, conducted jointly with local authorities, to confirm the quality and safety of the material.

All the results will be compiled in a regulatory dossier that will be submitted to the authorities responsible for granting approval, which should lead to the release of the product. In anticipation of movements of the material across national borders, similar procedures will have to be followed in all countries for which the developed material is relevant.

4 The challenges ahead

It is now recognized that public-private partnerships are probably the only way to ensure that technologies and intellectual property developed in both private and public sectors can be brought together for the benefit of developing countries. In the case of this project, however, it has proved to be difficult to finalize the preparation phase and get started with the technical work. This is a classic case of 'not being allowed into the water until you can swim'. Partners and funders would prefer to see answers to questions before committing themselves, yet these answers can only come from the work that needs to be undertaken and for which their support is required. Individual donors and sponsors are

now coming forward to ‘put a toe in the water’, and this has bolstered the confidence of others in being a part of the partnership.

From the perspective of potential private partners, there are several major challenges.

Ownership of the material and of the regulatory dossier
What kind of organization can or will accept ownership of the genetically modified material on a licensing in/licensing out basis under conditions that are acceptable to both public and private partners? Transfer of ownership should also mean transfer of liability, so that what is captured with ‘the material’ needs to be carefully defined. An essential aspect of genetically modified material is its safety assessment and regulatory approval. It does not make sense to develop a product without taking care of this necessary hurdle to ensure its practical use. The regulatory dossier and its approval should be seen as part of the material and therefore transferred to the new owner.

Financial support
Even if the private partner covers a significant part of the costs, it is necessary that the major part of the costs be sponsored by the public partners in the project. This financial support can be sought for the overall project concept or for individual aspects that may be performed by different (sub)contracting partners. This would have the advantage that not every sponsor needs to commit itself to the eventual release of transgenic material. Initial support may be sought for parts of the process of determining the technical and social acceptability of the concept. By adopting such a phased approach, potential sponsors can be reassured that there will be ‘stop or go’ points en route to commercialization, and that they will be part of this decision-making process.

Project management and consortium hosting
Managing many international consortium partners and international sponsors will need special skills that may not necessarily be available to the (technical) partners. It may therefore be worthwhile to look for special expertise in both international project management and financial management and reporting.

Stewardship
Making material freely available introduces additional challenges with respect to stewardship, in order to ensure the safe and sustainable use of the material. A balance needs to be found between ‘free access for all’ and ‘responsible stewardship’, which should support farmers while ensuring that environmental and health risks are minimized.

Choice of material to be released
Linked to the issue of stewardship is the question of the form of material that will be made available to farmers and breeders. Environmentalists may request the use of male sterile material that can be biologically confined, whereas other groups may emphasize the importance of ensuring that farmers have free access to the plant material by releasing freely pollinating material. In the case of cabbage and cauliflower, farmers do not normally save their own seeds, as the plants are harvested before they seed. A final decision on the relative merits of these cases must be made by the consortium rather than

just the private partner, in order to avoid accusations of a double agenda should the material be released in a form that limits its free propagation.

Local project but global registration of plant material
Even though the project will commence as a local project to develop material for a specific region, it should be recognized that the material can 'travel' as seed and as end products. To avoid export problems or local concerns if farmers in neighbouring countries start growing material that is not registered in their country, a registration system at the global level must be anticipated. For countries with similar environmental conditions (for growing the material), and/or concerns about exports of fresh or processed products, a global registration strategy must be developed and a timeline and cost overview prepared.

Manage 'contest' of material flow versus registration
Farmers and distributors, convinced of the quality of the varieties, may try to obtain the material in their own countries, even before registration is completed in these countries. It will be a challenge to restrict the movement of material to countries where the regulatory registration has been completed. To avoid unnecessary delays in approved countries, timely interactions with the different governments will be necessary.

Proactive communication strategy
Although it is recognized that all participants in this project, including the private partner, have the best intentions for all stakeholders, it will be a challenge to define a strategy to communicate this to organizations that are likely to see only the negative aspects. A careful selection of trustworthy advocates who can disseminate clear and honest information in developing countries, and in parts of the world where activists have their roots, should help to maintain the balance in an open and fair discussion of the pros and cons of the concept.

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