Assessing Plant Biopharming in New Zealand: Knowledge from the arable sector

Carolyn Morris
Joanna Goven
Jack A. Heinemann
Lesley M. Hunt

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Biopharming, Risk Assessment and Regulation
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Executive Summary

The research presented here is premised on the assumption that in order to evaluate the risks and benefits, the desirability and ethics of a technology, we must know how it is likely to interact with its context. Rather than asking people whether or not they think biopharming should be introduced, we explore with people who have experience and expertise in the identified contexts how they would work with such a technology were one to be introduced. The aim of this research is to consider whether such an approach would yield information that would be useful in assessing whether a new biotechnology should be introduced.

Using biopharming as a case study, and the Canterbury/North Otago arable/seed sector as the likely context, the research explores how key actors positioned at different places in the industry understand and evaluate the potential risks and benefits presented by biopharming, and whether and how such risks can be managed. This sector was chosen as it was considered that people experienced in growing open-field crops where issues of containment and contamination were paramount would have knowledge relevant for growing biopharm crops.

Plant biopharming is defined here as the growing of crops that have been genetically modified to produce pharmaceutical compounds for use by humans: “common crop plants such as corn and tobacco increasingly being programmed with recombinant DNA techniques to produce high-value-added pharmaceuticals, a process dubbed ‘biopharming’. The plants are harvested and the drug is then extracted and purified” (Miller 2003: 480). Biopharming includes both crops in which the pharmaceutical is expressed, and the replication of seeds of such plants to enable commercial production. Internationally plant biopharming is under development, though there is no commercial production as yet: “there are around 400 biopharm products in development, and more than 300 open-air trials have been conducted in America” (http://www.biosafety-info.net). According to EMBO, “several PDP [plant-derived pharmaceutical] products for the treatment of human diseases are approaching commercialisation” and “molecular farming is reaching the stage at which it could challenge established production technologies” (Ma et al. 2005: 593).

Biopharming is one of several methods that can be used to produce the class of drugs known as biopharmaceuticals: “these drugs, known as biologics, include any protein, virus, therapeutic serum, vaccine and blood component” (Elbehri 2005: 18). Major drivers for the development of biopharming internationally are its potential to lower the costs of drug production, the greater ease of upscaling and downsizing production, an anticipated shortage of manufacturing capacity using other production methods, the potential to address some of the limitations of other production methods, and the desire to strengthen or evade patent restrictions. There is no plant biopharming development in New Zealand currently. Uncertainties remain regarding the potential benefits and hazards of biopharming. These include: cost-effectiveness in relation to competing platforms, unresolved technical problems, patent and regulatory issues, potential risks to human health, issues of gene spread into the wild and into other crops, and the potential contamination of the food chain.
Actors in the arable/seed industry grow a wide variety of crops from staple grains such as wheat to hybrid vegetable seeds. They identify a wide range of potential risks, both on and off farm, that arise in the process of growing, harvesting and transporting such crops. Risks that result from arable farming practices include: cross-pollination, seed build up in the soil resulting in the contamination of future crops and the escape of plants into the wild or into other crops through a variety of routes. Often, they point to potential ways for managing these risks. They point out that different crops present very different risks, and require different management practices to manage those risks. The industry has developed an array of practices which enable them to produce uncontaminated crops, including on-farm agronomic practices, post-harvest cleaning techniques, third party traceability and certification schemes and co-operative industry-operated GIS systems for managing crop isolation distances. As a result of their experience of successfully managing risks of contamination and containment in relation to existing crops, arable sector actors consider that they could grow biopharm crops with a high degree of security and, moreover, that they would be willing to consider the option should it become possible.

Scientists and science managers, on the other hand, consider it unlikely that biopharming will develop from within New Zealand science because of capacity and the ways in which scientific research is funded. Like growers and production companies, scientists and science managers identify public negativity towards GM crops as a major barrier to biopharming development.

Research findings suggest that information that would be of great value in assessment procedures can be gained through talking to actors in likely contexts about their practices and knowledge.
Chapter 1: Introduction

This report represents the findings of part of a research project\(^1\) that asks: What do we need to know in order to make competent decisions about biopharming in New Zealand? The overall goal of the research on biopharming is to identify regulatory and governance needs and implications associated with biopharming and related technologies. In the current neo-liberal climate “where the state governs through contingent and loose bundlings of differently located actors” (Higgins and Lawrence 2005: 7) and where evidence-based policy is paradigmatic, government organisations are compelled to consult around important decisions. There has been significant critique of these procedures. Ma et al. note that “[t]he regulatory systems in most parts of the world deal principally with scientific risk assessment and are not usually set up to consider socio-political questions” (2005: 597). Critiques of attempts to incorporate “other” knowledges into decision making around new technologies show that many consider science to be the only form of relevant knowledge in this field. Understandings that do not draw on scientific epistemology are routinely dismissed as “perceptions”, with the implication that such perspectives are untrue, commonly on the grounds that the public either does not understand the issues and/or has not had enough information to come to the ‘right’ conclusion.

Studies such as Wynne (1996) have demonstrated that local knowledge, such as that of farmers, is relevant to understanding the risks presented by technologies, but these studies have been post-fact studies. Our approach draws on that of Wynne in that its focus is on the knowledge of relevantly positioned actors, but where we differ is that we hope to incorporate this knowledge into risk assessment procedures, i.e. \textit{before} a new technology is introduced. The assumption that underlies this project is that actors located in fields likely to be sites of biopharming development will possess knowledge relevant both to understanding potential benefits and harms of plant biopharming and to the practicalities of managing risks.

Dixon’s (1999) cultural economy model provides a practical approach to undertaking such a project. Dixon extends Friedland’s (1984) commodity systems analysis approach to argue that in order to understand the contours of the contemporary food system, it is necessary to understand the links between the production, exchange and consumption of a particular commodity. In practice this means tracing a particular commodity throughout its life, which produces a map of the network created by the commodity. Cultural economy analysis “demands an actor-orientation and is context and case specific” (Dixon 1999: 151) and as such appears to be a relevant model. By exploring an existing commodity system likely to be implicated in biopharming development it is possible to identify actors who are likely to have practical knowledge of local (and not so local) realities, and of the likely risks and likely outcomes of introducing a biopharm crop into the network. The aim of cultural economy analysis is not only to describe networks, but to analyse power within them in order to develop an account of the path of the commodity through the network and why it is structured like it is.

\(^1\) This research constitutes one part of the Constructive Conversations/Kōrero Whakaaetanga project; Foundation for Research, Science and Technology contract UOCX0221.
Given the nature of the industry we considered that seed farmers would be very likely to be involved in biopharming if it were to be developed commercially in New Zealand. The aim of this study was twofold: First, to elicit the knowledge of seed farmers in order to uncover risks that would arise during the process of growing a biopharm crop and to explore their assessment, as knowledgeable and interested actors, of the potential costs and benefits of biopharming. Second, to assess whether our assumption that such actors would indeed possess knowledge relevant to risk assessment was correct and to explore what “imagined commodity chain analysis” offers as a practical risk assessment procedure.

The information presented in this report derives from interviews with industry participants, particularly scientists, science managers, farmers and merchant seed companies. The rationale for including significant detail in the words of participants themselves is to illustrate precisely how knowledgeable and insightful these positioned actors are about all facets of the industry, from on-farm practices, to the structure and history of the industry, to the contours and issues of the international market they supply. What this shows is that local actors have more than knowledge of the local, and have the ability to think insightfully about the implications of growing biopharm crops at a variety of levels.

1.1. Plant Biopharming

Plant biopharming is defined here as the farming of transgenic plants genetically modified to produce “humanised” pharmaceutical substances for use in humans. Biopharming is also known as “molecular farming”. The most common plants currently being researched for biopharming include corn, soybeans, rice, tobacco, and potatoes (see Table 1), modified to produce the substance, usually a protein, in their fruit, leaves, seeds or tubers. Because of concerns about the risks of Transmissible Spongiform Encephalopathies (TSEs) in animal biopharming, plant biopharming is seen as having an advantage by not being animal-based (MoRST n.d.: 5). Due to concern about the use of food crops to produce pharmaceuticals there has been a partial move towards the use of non-food crops such as tobacco (Elbehri 2005: 21) and duckweed to reduce the chance of such crops ending up in the food chain, although much biopharming development is still utilising major food crops (presumably because knowledge of their genetics, structure and function is well developed).

Internationally, no products derived from plant biopharming have yet reached the stage of commercial production. Many are in various stages of the research, development and approval process (see Table 1). According to APHIS from 1991 to 2004, 176 field testing permits were granted for plants producing novel proteins and 117 for pharma plants² (Elbehri 2005: 22).

The pharmaceutical compounds produced through biopharming are a subset of the class of pharmaceuticals known as biopharmaceuticals. Biopharmaceuticals are medical drugs produced through biotechnology (rather than through chemical synthesis), by means other than direct extraction from a native (non-engineered)

² No indication is given to whether the novel proteins were to be produced from transgenic plants or whether the pharma plants are transgenic.
biological source. They are typically manufactured through fermentation processes involving bacteria, yeasts, fungi or algae, or through cell cultures from insect, plant or animal cell systems (Elbehri 2005; Dyck et al. 2003). Biopharming is thus one method, or “production platform”, for the production of biopharmaceuticals.

Table 1: Therapeutic proteins produced in transgenic plants currently in commercial development

<table>
<thead>
<tr>
<th>Production Plant</th>
<th>Companies</th>
<th>Products</th>
<th>Developmental Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agracetus/Monsanto</td>
<td>Corn</td>
<td>Medicines for trauma patients who need a blood transfusion.</td>
<td></td>
</tr>
<tr>
<td>Applied Phytologics</td>
<td>Rice</td>
<td>Human -1- antitrypsin is a protein of therapeutic potential in cystic fibrosis, liver disease and haemorrhages.</td>
<td></td>
</tr>
<tr>
<td>Biolex</td>
<td>Duckweed</td>
<td>α-interferon and other proteins.</td>
<td>Investigational new drug (IND) filing this year.</td>
</tr>
<tr>
<td>Biolex Inc</td>
<td>Lemna (duckweed)</td>
<td>Locteran (controlled-release α-interferon for hepatitis B and C), completed Phase 1; fibrinolytic clot buster, preclinical.</td>
<td></td>
</tr>
<tr>
<td>Biosource</td>
<td>Tobacco mosaic virus Tobacco etch virus</td>
<td>Beta-haemoglobin - origin: human.</td>
<td></td>
</tr>
<tr>
<td>Biosource Technologies and Stanford University</td>
<td>Plant virus based transient expression system</td>
<td>Developed a technology to produce a tumour specific vaccine for the treatment of malignancies. Biosource Technologies is now named the Large Scale Biology Corporation.</td>
<td></td>
</tr>
<tr>
<td>Boyce Thompson</td>
<td>Potatoes</td>
<td>Hepatitis B.</td>
<td></td>
</tr>
<tr>
<td>Chlorogen, Inc</td>
<td>Tobacco chloroplasts</td>
<td>Cholera vaccine. Human serum albumin. Interferon (hepatitis C). TGF-β for treatment of ovarian cancer. Origin: not stated.</td>
<td>By expressing proteins in the chloroplasts of plant cells, Chlorogen is able to greatly increase the availability of proteins without concern that gene will transfer to other plants via pollen.</td>
</tr>
<tr>
<td>Cobento</td>
<td>Arabidopsis Thaliana</td>
<td>Human intrinsic factor (rhIF for diagnostics), in</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Plant Material</td>
<td>Product Details</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>----------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Cornell University</td>
<td>Potato</td>
<td>Edible vaccine for Hepatitis B.</td>
<td></td>
</tr>
<tr>
<td>CropTech Corp and Prodigene- Cramer</td>
<td>Maize</td>
<td>Avidin. β-glucuronidase.</td>
<td>Mechanical gene activation (MeGA) system that was developed. First commercial molecular-farming venture.</td>
</tr>
<tr>
<td>Dow (Dow Plant Pharmaceuticals) (DowPharma)</td>
<td>Corn</td>
<td>Phosphinothricin acetyl transferase*. Confidential business information - origin: human. RiVax.</td>
<td>Dow offers contract development and manufacturing of proteins in transgenic plants. RiVax was developed to protect against exposure to ricin toxin.</td>
</tr>
<tr>
<td>Dow AgroSciences</td>
<td>Maize</td>
<td></td>
<td>Described an adenosine deaminase selection system.</td>
</tr>
<tr>
<td>Emlay and Associates</td>
<td>Safflower</td>
<td>Phosphinothricin acetyl transferase.</td>
<td></td>
</tr>
<tr>
<td>EpiCyte</td>
<td>Corn</td>
<td>Monoclonal antibodies (plantibodies). EPI19 (bronchonliotis/pneumonia in infants).</td>
<td>A full-length humanised IgG1 that recognises herpes simplex virus (HSV)-2 glycoprotein B has been expressed in this antibody, along with an IgG that recognises the R9 protein of respiratory syncitial virus.</td>
</tr>
<tr>
<td>EpiCyte pharmaceuticals and ProdiGene</td>
<td>Plants</td>
<td>Antibodies.</td>
<td></td>
</tr>
<tr>
<td>Garst</td>
<td>Corn</td>
<td>Acetolactate synthase*. confidential business information - origin: human and mouse.</td>
<td></td>
</tr>
<tr>
<td>Greenovation Inc., Freiburg</td>
<td>The moss</td>
<td>Physcomitrella</td>
<td></td>
</tr>
<tr>
<td>Hawaii Agriculture Research Centre</td>
<td>Sugarcane</td>
<td>Confidential business info; origin: human.</td>
<td></td>
</tr>
<tr>
<td>Horan Bros. Agri. Enterprises</td>
<td>Corn</td>
<td>NptII*.</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Crop</td>
<td>Biologic Product</td>
<td>Details</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Large Scale Biology Corp</td>
<td>Tobacco</td>
<td>Aprotinin (protease inhibitor)</td>
<td>Completed phase 1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genes inserted through use of tobacco mosaic virus.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alpha galactosidase.</td>
<td></td>
</tr>
<tr>
<td>Lemnagene</td>
<td>Duckweed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limagrain</td>
<td>Corn</td>
<td>Phosphinothricin acetyl transferase*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Procollagen - origin: human</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>G glycoprotein Serum albumin - origin: human</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alpha-haemoglobin - origin: human</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beta-haemoglobin - origin: human</td>
<td></td>
</tr>
<tr>
<td>Medicago (Canada)</td>
<td>Alfalfa</td>
<td>Haemoglobin (for blood banks)</td>
<td>To treat pancreatic insufficiency associated with cystic fibrosis in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Origin: human</td>
<td>phase 2a –Meripase - is in field trials and testing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lactoferrin is in phase 1.</td>
</tr>
<tr>
<td>Meristem Therapeutics (France)</td>
<td>Corn</td>
<td>Gastric lipase (cystic fibrosis)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tobacco</td>
<td>Haemoglobin; gastric lipase (cystic fibrosis, pancreatitis; Phase II).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>Albumin (heart surgery).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alfalfa</td>
<td>Cancer therapeutic antibodies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Meripase (cystic fibrosis and lipid-storage disorders).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lactoferrin (gastrointestinal disorders).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Origin: not stated</td>
<td></td>
</tr>
<tr>
<td>Monsanto</td>
<td>Soybean</td>
<td>IgG anti-herpes simplex virus.</td>
<td>Thyroid-stimulating hormone receptor.</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td>C transcriptional activator.</td>
<td>Thyroid-stimulating hormone receptor (diagnosis of Graves disease),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>projected marketed in 2006.</td>
</tr>
<tr>
<td>Nexgen Biotechnologies</td>
<td>Potato</td>
<td>Thyroid-stimulating hormone receptor.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cucumber</td>
<td>Haemorrhagic fever virus antigens for diagnosis.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oriental Melo</td>
<td>Poultry vaccine for avian influenza (H5N1), epidermal growth factor, albumin fusion protein.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tobacco</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phytomedics</td>
<td>Tobacco</td>
<td></td>
<td>Manufacturing process secretes biologics from roots. Current product focus on plant extracts.</td>
</tr>
<tr>
<td>Planet Biotechnology</td>
<td>Tobacco</td>
<td>CaroRx, RhinoRx, Antibodies- SIgA anti-S. mutans, Anti-Streptococcus mutans secretary IgA (SIgA) plantibody.</td>
<td>CaroRx, proteins for tooth decay, in phase 2. RhinoRx, for common cold, in preclinical testing. Anti-Streptococcus mutans secretary IgA</td>
</tr>
<tr>
<td>Company</td>
<td>Method</td>
<td>Substrate/Plant</td>
<td>Product/Function</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------</td>
<td>-----------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Protalix</td>
<td>Plant cell culture</td>
<td>Glucocerebrosidase. Fully humanized IgG.</td>
<td>Glucocerebrosidase for Gaucher disease is in Phase 1. Fully humanised IgG is in preclinical development.</td>
</tr>
<tr>
<td>ProdiGene</td>
<td>Corn Maize</td>
<td>Antibody for Traveller’s diarrhoea Laccase Subunit vaccines, recombinant antibodies and further technical enzymes, such as aprotinin and laccase.</td>
<td>Antibody for Traveller’s diarrhoea completed phase 1. Laccase which acts on lignine and could have applications in paper and textile production. This company demonstrated that feeding pigs an edible maize vaccine protects them from the transmissible gastroenteritis virus (TGEV). This company is an industry leader in cereal-based commercial protein.</td>
</tr>
<tr>
<td>ProdiGene and EPIcyte Pharmaceuticals (strategic partnership)</td>
<td>Corn</td>
<td>Antibodies.</td>
<td></td>
</tr>
<tr>
<td>RJ Reynolds</td>
<td>Tobacco mosaic virus</td>
<td>Safflower</td>
<td>Antibesity peptide; somatotropein Insulin. Apolipoprotein A-1. Immunospheres.</td>
</tr>
<tr>
<td>SemBioSys</td>
<td>Safflower</td>
<td>Human insulin and apolipoprotein in preclinical development. Hirudin.</td>
<td>The oleosin-fusion platform developed, in which the target recombinant protein is expressed in oilseed rape or safflower as a fusion with oleosin.</td>
</tr>
<tr>
<td>Spanz</td>
<td>Potatoes</td>
<td>Make proteins that will help the body repair itself after heart or circulatory system surgery or nervous diseases.</td>
<td>Spanz (Singapore and NZ) Biotech the 50-50 “biopharming” venture. Have since ceased operations.</td>
</tr>
<tr>
<td>Syngenta</td>
<td></td>
<td>Six protein compounds all in areas that are currently</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1: Examples of Protein-Cultivated in Bioreactors

<table>
<thead>
<tr>
<th>University/State/Institution</th>
<th>Crop/Technology</th>
<th>Description/Origin</th>
<th>Benefits/Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Kentucky</td>
<td>Tobacco</td>
<td>Confidential business info; origin: human and mouse.</td>
<td>The idea is to isolate recombinant proteins from the rapidly developing sprouts cultivated in bioreactors.</td>
</tr>
<tr>
<td>UniCrop</td>
<td>Oilseed technology platform</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventria Bioscience</td>
<td>Rice</td>
<td>Product for iron deficiency and acute paediatric diarrhoea in safety testing. Targeting Lactoferrin and lysozyme. Origin: not stated.</td>
<td>Have been conducting field trials, growing GM rice as a means for producing food additives with medical uses.</td>
</tr>
<tr>
<td>Virginia Tech and State University and CropTech; Cramer and colleagues.</td>
<td>Transgenic tobacco</td>
<td>Glucocerebrosidase production.</td>
<td>Their studies ‘strongly support’ the future commercial viability of transgenic plants for the production of glucocerebrosidase, and of other lysosomal enzymes, for enzyme replacement therapy.</td>
</tr>
</tbody>
</table>

**Sources:** Kaye-Blake *et al.* 2007: 54-56; Keefer *et al.* 2007; Echelard *et al.* 2006: 38; Schmidt 2006.

### 1.2. Knowledge for assessing plant biopharming: structure of this report

In order to carry out such a prospective assessment of a future development, it is necessary to understand the likely developmental trajectory of the technology. What shape is it likely to take in New Zealand if and when it goes beyond the field-testing stage to commercial production? Chapter 2 presents a discussion of these drivers and the associated claims that are made about the future of biopharming. Because much of biopharming’s economic and medical promise is yet to be demonstrated, in Chapter 3 we present findings from the international literature concerning the uncertainties and unknowns surrounding the potential benefits and harms of plant biopharming. Chapter 4 describes the structure of the seed sector in New Zealand from the perspective of those involved. It pays particular attention to factors influencing relationships within the industry, as the structure of the industry has considerable impact on the future development of biopharming. An analysis of the possible trajectory of biopharming requires some understanding not only of what is technically possible, but also of the economic and social drivers behind the development of the technology. In Chapter 5 we outline and discuss the risks identified through discussions with production companies and in Chapter 6 the risks identified through discussions with arable farmers. In Chapter 7 we conclude by discussing the
implications of our findings for the prospects of plant biopharming in New Zealand, for its practical management and for its regulation.
Chapter 2: Drivers and Prospects for Plant Biopharming

This chapter presents the various claims, prospects and forces influencing the development of plant biopharming. The first part of this discussion highlights findings from the international science and technology literature, as well as “grey literature” (such as working papers, policy advice and commissioned research reports), on biopharming and related technologies. This is followed by a discussion of New Zealand-specific issues, based upon New Zealand literature and interviews with key actors. We end the chapter with a discussion of New Zealand-based plant biopharming research and development.

2.1. Generic drivers

2.1.1. Lowering production costs

A major advantage claimed for producing drugs through plant biopharming is lower production costs for pharmaceuticals. Current production methods (fermentation and cell cultures) are characterised as inefficient, expensive and time-consuming processes, while biopharming promises significantly lower infrastructure and operating costs (Elbehri 2005).

Elbehri (2005: 20) estimates that costs of production from plants would be “four to five times lower than the mammalian cell culture method”. It is claimed that plant biopharming will be a simpler, more efficient and cheaper system with lower set-up costs:

[B]iopharming’s great promise lies in the ability of recombinant DNA techniques to make old plants do new things, and in the potential economy of the process. The energy for the manufacturing process comes from the sun, and its primary raw materials are water and carbon dioxide; moreover, doubling the acreage of a crop requires far less capital than doubling the capacity of a factory, making biopharmed drugs potentially less expensive than ones produced in a conventional way. (Miller 2003: 480)

According to Richard McCloskey, from biotechnology firm Centocor, the extent of cost savings (or whether there are cost savings at all) would depend on the particular case, but could in some cases amount to more than 80%: “McCloskey cited figures showing that it costs $80 million to produce 300 kilograms of antibodies in mammalian cells, but genetically modified corn might be capable of producing the same amount for $10 million” (Fernandez et al. 2002: 6).

Moreover, it is claimed, biopharming has the potential to improve access to pharmaceuticals in the developing world: “one of the most important goals in molecular farming is the development of new drugs and vaccines targeting important diseases in both developed and developing countries” (Ma et al. 2005: 597). The absence of opportunities for significant profits has resulted in a “lack of investment in research and development focusing on health technologies for the poor” (ibid: 597) by
pharmaceutical companies. Ma et al. (2005) claim that biopharming offers a solution to this, as the technology is “low-tech and inexpensive”.

This could allow the participation of a wider audience beyond the well-established multinational pharmaceutical companies. Hopefully, developing countries would be involved, and the focus would shift to specific regional diseases that do not otherwise feature prominently in current drug development. *(ibid: 394)*

2.1.2. Capacity shortage and flexible supply

It has been argued that fermentation-based production capacity is insufficient for what is projected to be an increased demand for protein-based drugs; manufacturing capacity is said to be a major constraint on future supply (Elbehri 2005; Nevitt *et al.* 2006; Fernandez *et al.* 2002). According to Nevitt *et al.* (2006: 104), “demand for affordable protein-based therapies has already outpaced production capacity”, and this pressure on capacity is expected to increase.

Industry analysts expect an average of six or seven new large-molecule drugs to reach the market each year over the next several years (Ginsberg, Bhatia, & McMinn 2002). These monoclonal antibodies, which require a large production capacity, are expected to make up about a third of all new therapeutics … Current cell culture facilities are unlikely to meet the expected demand (Elbehri 2005: 19).

According to Elbehri (2005: 19, citing Fernandez *et al.* (2002)),

> each newly approved monoclonal antibody requires 100,000 kg of production annually requiring new fermentation capacity to be built. To meet the expected demand for new drug production, more than three times the current production capacity may be required. It is estimated that 20–50% of potential therapeutics industry wide could be delayed due to the lack of manufacturing capacity.

The use of transgenic plants to produce biopharmaceuticals is presented as a way of addressing this predicted shortfall in manufacturing capacity.

This focus on capacity was sparked by the case of Enbrel, a drug produced by Immunex that treats rheumatoid arthritis. Enbrel is produced in 10,000 litre bioreactors of cultured Chinese hamster cells. It was approved by FDA in 1998 and experienced a supply shortage by 2001 (Thiel 2004; Elbehri 2005). By 2002 there was a waiting list of 13,000 patients, and Immunex began rationing it.³

Plant biopharming is seen as better able to respond to rapid changes in demand, simply by increasing or decreasing the amount of land planted with biopharm plants.

> There is little doubt that transgenic plants offer an unparalleled potential for scalability. Growing plants in the field provides opportunities for virtually unlimited production, and even if the growing sites were strictly isolated to

³ Others question whether this case points to a more general shortage of capacity, for example, Thiel (2004). See section 3.1.2. below.
avoid mixing or cross-pollination with other crops, there are still many areas in
the world where large-scale production could take place. Even under
containment, it would be possible to grow a large number of pharmaceutical
plants; immense greenhouse facilities are already used routinely by the
horticultural and food industries. (Ma et al. 2005: 594)

This is in contrast to the need, when using current fermentation or cell-culture
methods, to build expensive new facilities in order to increase production.

It may be naïve, but I conceive that the husbandry principles for 100,000 acres
of a plant are not much different than for 1,000 acres of a plant … where I can
tell you that going from an 8 liter (mammalian cell) reactor to an 200 liter or a
1,000 liter reactor is not sometimes so simple. (Richard McCloskey, quoted in
Fernandez et al. 2002: 7)

Moreover, seeds “are natural storage organs, with the optimal biochemical
environment for the accumulation of large amounts of protein” (Ma et al. 2005: 598),
and they can be stockpiled easily (Elbehri 2005: 20-21).

2.1.3. Potential for new and better drugs

Another argument driving biopharming is its potential to produce biopharmaceuticals
that cannot be produced in other ways (Thiel 2004). Dyck et al. (2003: 395) note
problems with other production platforms (bacteria, yeast, and insect, metazoan and
mammalian cells) and suggest that transgenic plants (and animals) may avoid these
problems, thus presumably enabling successful production of drugs that could not (or
would not) otherwise be produced. According to Ma et al. (2005:594):

[A] fundamental advantage of plants has always been the range and diversity
of recombinant molecules that they can potentially produce. As higher
eukaryotes, plants are able to synthesize small peptides, polypeptides and
complex multimeric proteins, many of which cannot be made in microbial
systems (Ma et al. 2003).

Some see other advantages to transgenic plant sources of proteins with medical and
research applications. Currently, complex therapeutic molecules cannot be
synthesised, or practically synthesised, outside of an organism (be it microbe, plant,
fungus or animal). For some compounds, transgenic plants might provide protection
against undesirable contaminants derived from microbes or mammals (Ma et al. 2003;
Twyman et al. 2003).

Saint-Jore-Dupas et al. (2007) suggest that recent advances in the manipulation of
plant glycosylation may result in plants that do not add molecules known to increase
immunoreactivity to proteins. The ability to alter plant glycosylation also means that
plants could produce recombinant pharmaceutical proteins with patterns of sugar
subunits more common to those found in humans (Ma et al. 2003). They see this as
providing the advantages of mammalian cells and animal production systems without
the same risks of potentially transmitting a virus or prion diseases. It is argued that
with plant-made pharmaceuticals (PMPs) there is no risk of passing on harmful
animal or human viruses, and no plant viruses are known to cause disease in humans
(2007), this is an advantage of using plant, rather than animal, bioreactors, on the grounds that unexpected pathological changes are more likely to be transmissible to humans from animals than from plants.\(^4\)

### 2.1.4. Opportunities for patent-enhancing and patent-busting

Rather than producing new medicines, biopharming may be seen instead as a way to undermine or reinforce patents on existing medicines. Biopharming may enable companies to “bust” the existing patents of other companies by developing a new process to produce a substance whose patent is associated with another method of production. Conversely, biopharming may enable a company to extend patent protection for a drug by acquiring a new patent for it based on a new production method.

The fact that a number of biopharmaceuticals are due to come off-patent in the near future (Schmidt and Strupp 2006) has been linked to opportunities for biopharming. Laible and Wells’ (2007: 113) argument for animal biopharming could apply equally to plants:

[T]he expiration of the patents for many first generation biopharmaceuticals, predominantly produced in cultured mammalian cells, provides additional opportunities for the production of ‘biosimilars’, essentially equivalent recombinant proteins of previously approved pharmaceuticals[,\] from transgenic animals.

These prospects are heavily dependent on regulatory and patent-agency decisions.

### 2.2. New Zealand drivers

New Zealand has traditionally relied on efficient production methods to produce large quantities of commodities that are price-competitive in overseas markets. It is argued that as other countries, particularly in Asia and South America, become more efficient commodity producers, New Zealand’s primary-production sector will become considerably less profitable. Producing pharmaceuticals in plants (and animals) has been seen as one option for meeting the oft-cited need for New Zealand’s agricultural sector to shift from the production of commodity goods to higher-value-added goods for export, thus increasing New Zealand’s economic competitiveness.

According to the Biotechnology Task Force (2003: 53),

New Zealand has extensive knowledge of the biology of industrially significant plants – grasses and other pastoral plants, trees and crops (both arable and horticultural). This includes access to unique germplasm and rapidly growing genome databases, and offers this country the chance to use plant biotechnologies (including transgenesis) in the following ways:

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\(^4\) However, see below, section 3.2.1. “Humanised” plants may pose their own risks in this regard, as “plant viruses passing through humanized plants might have altered infectious ranges for both plants and animals” (Heinemann 2007:45).
• To dramatically improve the efficiency of our primary producers;
• To generate new agri-biotechnology enterprises based on applications that modify plant growth, health and physiology;
• To use plants in bio-remediation; and
• To create transgenic plants for use in producing biopharmaceuticals.

Many of the arguments about the supposed benefits of biopharming outlined earlier in this chapter are also present in discussions of plant biopharming in New Zealand, namely the economic benefits of plant biopharming, and its safety advantages over animal biopharming. New Zealand researchers have argued that “non-animal origin [is] a key advantage by avoiding disease contamination of animal and human products” (Conner and Ashby 2003: 1) while a presentation by HortResearch (2003) associated plant biopharming with cheap production and scale up, cheap purification and safety. The Ministry of Research, Science and Technology (MoRST) notes that “[b]iopharming from plants, while in its infancy in New Zealand, has the particular advantage of producing pharmaceuticals from a non-animal source” (MoRST n.d.).

In a paper delivered to the Royal Society’s Biopharming Symposium, Neil Barton of Federated Farmers suggested that New Zealand seed growers, as “market focussed producers”, and New Zealand’s arable and seed farming systems have particular advantages for biopharming (Barton 2003: 2, 5). He listed among the New Zealand seed industry’s competitive advantages for biopharming:

• Counter (to the northern hemisphere) seasonal production suitable for producing seed crops.
• Infrastructure designed for small volume crops minimising post production mixing.
• Regulatory system set up for case by case assessment.
• Market focussed producers (ibid: 2).

It was also argued by a scientist we interviewed that New Zealand’s reputation in general and its lack of enemies in particular constitute an advantage in this area:

I’d say the main thing, biggest thing is that we’re seen to be friendly and clean and nice, so a product coming out of New Zealand would be well respected. We possibly have some advantage, there are some advantages in biosecurity, certainly less than there were, but I mean we do have water all around us so we’ve got more chance of keeping things in or out. But I think the biggest thing is worldwide, we’re seen as being nice, I don’t think anybody hates us. And we’d be one of the few countries, probably like that … so a product that had a New Zealand label on it would be accepted.

Another singled out New Zealand farmers’ positive orientation toward innovation:

I think our farmers are, they’re very good farmers. They’re very capable farmers. So they’re looking always to improve things. …I think compared to a lot of other farming communities around the world, they are very technologically literate. … So when there is a new crop of some sort or a new
breakthrough in terms of a production technology, then it is taken up. They are looking for opportunity to change and to add value to their own operation.

2.3. Plant biopharming research and development in New Zealand

According to FoRST records and our interviews with scientists, there is currently no plant biopharming research being carried out in New Zealand. Until recently, however, there was one such project, which received considerable publicity. In the 2002 FoRST funding round, Dr. Tony Conner of Crop and Food Research, was granted $2,882,475 for a programme titled *Knowledge and Economic Benefit from Sustainable PGT* (Plant Gene Technologies). One of the project’s three aims was to investigate “GM plants as ‘solar powered’ bioreactors for producing and extracting high-value pharmaceuticals and nutraceuticals with medical and health applications” (FRST 2002). The research programme was tied to FoRST’s vision of New Zealand science: benefits would accrue to the “country’s emerging biotechnology industry, as well as have flow-on advantages for existing sector-based industries”, offering “new, value-added, export opportunities for the primary production sectors” (*ibid*.

A 2003 New Zealand Herald article, *Potatoes Being Transformed to Medical Protein Factories*, reported the promised benefits:

The 50-50 "biopharming" venture, Spanz (Singapore and NZ) Biotech, will use potatoes to make proteins that will help the body repair itself after heart or circulatory system surgery or nervous diseases. Each gram of the protein, extracted from about seven potato plants, is worth more than $1 million. The new company is just one of 10 joint ventures Crop and Food is using to shift New Zealand's primary sector into higher-valued products. …

"We are using very complex proteins which could not be inserted in such primitive systems as bacteria. You probably need a plant or organism [sic] to make them," [Crop and Food’s Tony Conner] said. "They could be synthesised artificially, but at huge cost." After a decade of collaboration, Conner and Liew have finally succeeded in getting potatoes to produce the protein and are submitting it for tests at the Christchurch Hospital laboratory in the next month.

However, a potential problem was also signalled:

"At this point we are not happy with the level of accumulation," Conner said. "At the moment we are extracting enough protein to ask the question, 'does the protein we make in the plants retain its full function?'" (Collins 2003).

The 2004/2005 report to FoRST was positive about results and looked forward to a bright future for New Zealand biopharming:

Our research underpinning plants as factories (Objective 1) is moving along well, and we are discussing the development of a major new national programme in biopharming with other New Zealand institutes and companies (FoRST 2005a).
However, the 2005/2006 report takes a somewhat different tone. It reiterates the claim of significant progress, but there is no specific mention of Objective 1, the “plants as factories” biopharming objective. According to the senior researcher on the project, it was discontinued for commercial rather than scientific reasons:

> Crown Research Institute Crop and Food Research was working on several projects to produce specialised proteins in potatoes. But those experiments ended several years ago without progressing. Senior researcher Tony Conner says the science is not the problem. “We could produce the plants that made useful compounds and we achieved that to some extent,” says Conner. But trying to find the right commercial links to pharmaceutical companies proved problematic — even though Crop and Food was working in conjunction with well-connected Singaporean partners. “Producing the plants was just a very small step in the big continuum.” (Bingham 2007)

He elaborated on this in an interview with us:

> We have made a rational decision that it is probably not something that we want to get involved with. While it is a huge opportunity to do those things, it’s more than just producing a vaccine or a useful medical compound or any health-benefiting compound in the plant. When it comes to medicines, there’s a huge cost downstream… The next step is you’ve got to bring on these big multi-national partners and unless you’ve got good connections it’s not going to work. And there’s no point starting out, unless you’ve got those connections. And those connections need to be well and truly entrenched in place before you need to start. Because although you might have a bright idea, if there’s a real market for it, some other bugger’s already thought of it and is already doing it. And while we had some good targets for a while there, I think that we have resolved in our own mind that…it’s probably not a useful thing to do for us.

While there is currently no research explicitly focused on plant biopharming being undertaken in New Zealand, there is some evidence of continuing interest in the area, and there are projects underway in which the scientific skills necessary for biopharming are being developed. A speaker at the 2008 NZBio conference indicated that AgResearch was considering the possibility of producing pharmaceuticals in plants through the genetic modification of endophytes. At that conference there was the general impression that such applications would be likely to emerge if public attitudes toward genetic modification became more positive.

Our interviews with scientists did not reveal a desire within the plant research community to pursue biopharming. Instead, there was something of a consensus that it was not the right path for New Zealand agricultural science. As noted above, the discontinuation of the potato biopharming project was linked to the financial resources need to bring a biopharmaceutical to market, and the difficulties in establishing the kinds of relationships that might facilitate this. Many questioned whether New Zealand has the capacity, in terms of expertise as well as capital, to excel in biopharming.
I think we need to be careful about biopharming from the New Zealand perspective. Are we really the right country, and have the right expertise around producing high value pharmaceuticals within crops? And the reasons for that – do we have the land area that we can devote, for example, to a monoculture of a crop that would contain a valued pharmaceutical product? Do we grow the sorts of crops that would be attractive to using in a biopharming sense? I don’t know that we do, necessarily, or in a volume or the acreage that would be needed. And I think the other dangerous thing for us around biopharming of crops, it’s probably from a perceived safety perspective. We need to be careful not to mix up the pharmaceutical development with the food development. And so therefore, it’s probably more appropriate to choose non-food crops for biopharming, and I don’t know that we have a great expertise in non-food crops. Pine trees, probably, but I don’t know that that’s a suitable biopharming candidate.

I don’t know that New Zealand’s got anything specific that’s an advantage over anyone else. I like to think that we’ve got good skills and some good expertise in our scientists but then we don’t necessarily have a great track record in producing these things, so it’s not like we’ve got a world class unit that just keeps on churning these things out. That’s the way I see it, anyhow.

There was a more positive attitude toward functional foods or nutriceuticals.

I think our expertise and our focus, our strategy as a country, should be around food, functional foods and nutriceuticals.

Functional foods, premium foods for global markets is New Zealand’s strategy and it must be New Zealand’s strategy.

However, not all felt that this was an appropriate focus for public science.

I wonder do I want to be doing this, is this really what I went into science for? And I’m battling that right now….To go into gourmet foods, …is it really what I want to do? Is it why I went into science, coming up with new products for the rich, basically? I liken it [to] doing cosmetic surgery.
Chapter 3: Uncertainties and Unknowns

The potential benefits and harms of plant biopharming are characterised by significant uncertainties and unknowns. The scientific research that may be necessary for a competent evaluation of the risks of commercial production is underdeveloped. Market demand as well as the rules and regulations for the development and use of biopharm products are yet to be tested. These uncertainties are reflected in the lack of investor interest noted by Ledford (2006: 16): “Venture capitalists have largely shied away from the technology, and bigger pharmaceutical companies have not embraced it either.”

According to McCloskey, “[t]ransgenic plants may fall short of their potential … if there are ‘unanticipated purification problems’, if therapeutic substances made in plants are not as effective as those made in mammalian cells, or if cost savings do not pan out” (Richard McCloskey cited in Fernandez et al. 2002: 7). McCloskey also noted that “the development of pharma plants could be hampered by legal barriers or by marketing issues related to negative public perceptions that have surrounded the entire field of genetic engineering” (ibid. 2002: 8).

This chapter covers the uncertainties associated with the potential benefits and hazards of biopharming. When risk assessments are carried out, potential hazards that are identified are typically weighed against potential benefits. For this process to be robust, the uncertainties around the potential benefits, as well as the potential hazards, must be evaluated.

3.1. Uncertainties regarding benefits

3.1.1. Cost savings

A major economic argument in support of biopharming claims that it will lower production costs. However, Dyck et al. (2003: 394-5), who argue that transgenic technology offers the lowest-cost method for producing biopharmaceuticals, also acknowledge that it is difficult to carry out a direct comparison because there are so many unknowns. These include “lack of data on protein yield, purification rates and production scale … [and] specific recombinant protein being produced” (ibid.). They posit that the cost of purification once the protein has been produced will be similar whatever the production system.

The claim of low-cost production has been contested. For example,

Barry Holtz of Large Scale Biology, a leading biopharm company⁵, discounts glib predictions of “$5 dollar a gram proteins,” estimating that even high-volume plant-grown drugs would cost “hundreds to thousands of dollars a gram” to produce. (http://www.biosafety-info.net)

There is some evidence to support the sceptical position.

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⁵ Large Scale Biology filed for bankruptcy in 2006.
Contrary to industry’s oft-repeated promise of cheap drugs and chemicals, one of the only commercialized plant-grown products, the research chemical avidin, actually costs the same as the conventional version extracted from eggs, $46-47 per 5 mg, or over $9,000/gram. (http://www.biosafety-info.net)

Thiel (2004: 1371) relates an industry participant doubts that there will be significant cost savings once containment costs, the need for purification facilities, and the possibility that additional purification steps may be required are figured in. This is reinforced by a second participant:

[T]he cost advantage boasted by transgenics will dwindle as traditional cell culture manufacturing becomes more productive with new, more efficient cell lines … There are a lot of hidden costs in producing transgenics that I’m not sure anyone really understands, and I’m not sure they will until they do it at scale. (ibid.: 1371)

Elbehri (2005) argues that “[t]he cost structure of pharmaceutical crops is determined mostly by [the demands of] risk minimization, noting that “[t]heir cultivation in the field is predicated on the requirement of total isolation and confinement from the food supply.” Risk minimisation requires:

(a) sophisticated risk management to avoid potential gene outflow and minimize impact on nontarget organisms as well as workers’ health; (b) identity preservation based on a tight closed-loop system to avoid any possibility of commingling with food supply; and (c) a set of quality control procedures with a tight chain of custody to satisfy the isolation and confinement requirement. (ibid.: 22)

Spök (2007) argues that the major costs of drug production derive from processing, particularly purification, and these costs are unlikely to be lower for pharmaceuticals produced by plants.

3.1.2. Capacity and scalability

As noted above, one of the major economic arguments for biopharming is a purported lack of production capacity to meet the potential future demand for biopharmaceuticals. However, in a review of these arguments in the journal Nature Biotechnology, Thiel (2004) suggests that the biopharmaceutical manufacturing bubble may have burst. He argues that the shortage of Enbrel was an aberration rather than indicative of the situation within the industry as a whole, even suggesting that there may now in fact be some excess manufacturing capacity worldwide.

Future capacity needs will also be affected by changes to biomanufacturing technologies. Improvements have been made in cell-line yields, and disposable bioreactors have been developed, introducing more flexibility into lab-based production.

Traditional cell-line manufacturing, whether in microbial or mammalian hosts, is advancing in ways that could dramatically change how facilities are built and operated. Potentially revolutionary but commercially unproven transgenic
production platforms, meanwhile, may become a tougher sell to industry… [R]apid advancements in cell-based manufacturing technologies and strategies… pose considerable threats to companies hoping to do contract manufacturing in transgenic plants or animals… [B]iotech companies looking at options for commercial production of biologics see available capacity and a future of increasing efficiency in traditional cell-line production…. [T]here is little immediate pressure for companies to move to alternative platforms that are as yet commercially unproven. (Thiel 2004: 1365, 1368, 1370)

It is perhaps worth noting that the Texas-based firm Agennix claims that it can produce recombinant human lactoferrin through microbial fermentation processes at costs similar to those expected to be incurred by Ventria Bioscience’s plant biopharming platform (rice engineered with the genes for the production of human lactoferrin) (Wisner 2005: 16, 27). This suggests the possibility that biopharming’s putative cost advantages may be whittled away by competing platforms.

In addition to improvements in traditional manufacturing processes, Ma et al. (2005: 595) note that low product yield from biopharm plants remains a concern. This may cast doubt on the ease with which production of the pharmaceutical proteins can be expanded through plant biopharming, as low yield may require the planting of unrealistically large land areas to meet expanding demand.

3.1.3. Safety

An argument frequently encountered for using plants rather than animals as cellular platforms for drug development is that the large evolutionary divergence between plants and animals should imply a similarly large divergence between the viruses or other infectious elements that normally infect either plants or animals (Spök 2007: 143). This assumed difference, however, lacks rigorous testing.

Despite the apparent organismal differences between plants and animals, they share significant similarities at the cellular level, which is the level most relevant to considering the risk created by viruses and toxins. What differences there are may at times be overcome. There is informed speculation that “filoviruses [such as the Ebola virus] may be plant viruses, perhaps even involving transmission by arthropod vectors” (Swaneepoel et al. 1996: 139). While this remains speculative, to date the possibility has not been excluded (Peterson et al. 2004: 140). There is solid evidence that at least one plant virus was able to switch to an animal host through recombination with an animal virus (Gibbs and Weiller 1999: 136).

This apparently unlikely combination of events implies that plant and animal viruses can infect multiple species even if they rarely cause symptoms in all species that they infect, or that they replicate to only very low numbers. Nevertheless, provided time or human assistance, they may eventually adapt to a new species and begin causing disease. These issues are discussed further in section 3.2.1.

Moreover, the number of modifications induced in the pharma plant and the concentration of the introduced protein in it are much higher than for first-generation genetically modified plants. This is expected to increase the number of unintended effects on the plant and therefore the potential for harm to human health and the
environment. The resulting additional assessment and risk-management costs could significantly reduce the cost advantages of plant biopharming (Spök 2007).

### 3.1.4. Patents and regulatory uncertainty

As noted above, biopharming is seen by some as a profitable way to avoid or extend patents by producing existing drugs in new ways. However, the future for these so-called biosimilars (or “biogenerics”) is still unclear. It is not yet clear whether regulators will require biosimilar drugs produced through biopharming to go through the same approval process as new drugs (Somers 2007; RSNZ News 2006; FDA n.d. a), thus eroding their profitability and attractiveness to drug producers. If biosimilars are regarded as new drugs, the costs of production are likely to be significantly increased.

Regulatory agencies face particular challenges when it comes to evaluating biosimilars, however they are produced.

> For regulatory agencies, a key question is how similar the physiochemical characteristics of the biosimilar and its patented counterpart need to be to qualify for the biosimilar route of marketing authorization. Even if the biosimilar product has the same gene sequence, vector, host cell line, culture conditions and purification methods as the innovative protein, it can still differ substantially in its biological and clinical properties. (Schellekens 2004: 1358)

If this is true of biosimilars using the same production methods as the original biopharmaceutical, it will presumably apply *a fortiori* to those using a different production platform.

While the regulation of biosimilars is still under debate in the U.S. (Somers 2007), the European Medicines Agency (EMEA) has produced guidelines for evaluating biosimilars (Hirschler 2005). According to Schellekens (2004: 1357), under these guidelines, the biosimilars developer may not have to repeat all of the toxicity studies undertaken by the developer of the innovator product. To make major costs savings, however, it would be necessary to avoid repeating expensive clinical studies of efficacy. The EMEA guidelines require that the biosimilar be shown to be similar to the original product “for every indication” (*ibid.*). Schellekens notes:

> [S]ome of the efficacy studies for a biosimilar may need even more patients than the original studies because efficacy must be shown to be equivalent to the original protein. In addition, a generic manufacturer will have to generate additional data on physiochemical comparability, bioequivalence in animals and patients, and clinical data on immunogenicity. Thus, the biosimilar route may turn out to be of even greater complexity than that for a new protein therapeutic. (*ibid.*: 1359)

Meeting such requirements may be very costly; however, because there has been no commercial development to date, it is not yet clear what impact such requirements would have on the profitability of biopharming.
3.1.5. Who benefits?

There is considerable uncertainty around who is likely to benefit from biopharming, should it prove feasible and profitable.

As noted above, the discussion in New Zealand has focused on benefits for the primary sector. Others have also claimed that biopharming could benefit farmers: Ann Marie Thro, from the USDA, argued that “there could be benefits from pursuing a more diverse group of crops [than the usual corn]… allowing more rural farm communities to gain income via production of transgenic pharmaceutical plants” (in Fernandez et al. 2002: 12).

Whether or not farmers will actually benefit from biopharming depends on a number of factors, including ownership or management arrangements, the impact of patents, and the degree of market power. In a report on the potential benefits and hazards for farmers and rural communities of plant biopharming, Wisner (2005) asserts that the claims made for pharmaceutical crops are inflated and that farmers will not be the beneficiaries. Rather, pharmaceutical companies are likely to be the prime beneficiaries of plant biopharming.

There are several reasons for this. First, farmers will not be in a position of strength to negotiate with pharmaceutical companies, and international competition will be such that farmers will not be able to make reasonable profits. Second, the amount of acreage required to grow pharmaceutical crops will be so small compared with commodity crops that it will not affect most farmers. He also did not see rural communities as gaining any benefits unless the related research was carried out in nearby universities and processing companies were located in the community. Likewise Freese (2002: 62) argues that the likely small scale of biopharming means that few farmers will be involved, and that pharmaceutical companies are likely to retain profits for themselves by “keep[ing] production costs, including payments to contract farmers, to an absolute minimum”.

Kaye-Blake et al. (2007:17) report on a peer-reviewed analysis of the economics of biopharming focusing on the production of human serum albumin (HSA) in tobacco (Kostandini et al. 2006).

The market for HSA was modelled with linear supply and demand functions, and the results of a price reduction on the market were estimated both when the producer had monopoly power due to its innovation and when it did not. In the first case, the innovation resulted in excess (monopoly) profits for the firm. It did not benefit consumers, however. In addition, tobacco farmers were either unaffected or left worse off; they provided the tobacco at cost as a result of the relative market power of the farmers and the innovating firm. The latter case, without the monopoly, is assessed as unrealistic: the firm would not pursue the innovation unless it could secure monopoly pricing power. This modelling suggests that control of the innovation is important, and that widespread welfare gains from biopharming may be unlikely.

It has also been argued that biopharming could provide consumers with cheaper drugs. Even if biopharming does prove to be a cheaper method for producing drugs, it does not necessarily follow that either patients or health services will benefit from
lower drug costs. As Ma et al. (2005: 594) note: “‘Cost of goods’ has relatively little impact on the market price of new pharmaceuticals.” Moreover, complex biopharmaceutical production processes may mean that cheaper generic drugs will be harder to produce, in which case it is possible to question whether the cheaper production methods of biopharming will necessarily lead to a greater availability or affordability of drugs for patients (Herrera 2004). Indeed, MoRST (2005: 90) has suggested that pharmaceutical companies will focus on biopharming as a novel way of producing purer drugs that are harder to copy. In this case, biopharming is unlikely to provide cheap drugs for poor countries as has been suggested.

According to Mich Heim of Epicyte Pharmaceuticals, Inc., risk management and processing requirements limit the potential benefits of biopharming for developing countries:

He noted that producing the vaccine would still involve both state-of-the-art manufacturing facilities and careful regulatory review, neither of which are generally available in the developing world. Therefore, Hein said, the benefits pharma plants may hold for developing countries may be less dramatic than what was contemplated several years ago.6 (Fernandez et al. 2002: 12)

3.2. Uncertainties regarding hazards

3.2.1. Health risks for humans from biopharm drugs

Amy Rosenberg, supervisory medical officer with the U.S. Food and Drug Administration’s (FDA) Center for Drug Evaluation and Research, places health risks from biopharm drugs into four categories: infection; allergenic responses; immunogenic responses; and “autoimmune reactions arising should transgenic proteins break tolerance to their endogenous, self-protein counterparts” (quoted in Schmidt 2006).

Many have focused on the potential for drugs made with animal bioreactors to transmit disease and argue that for plants this is nullified. However, as Elbehi (2005: 21) suggests, there is the potential for plants to pass on new contaminants from soil fungi, bacteria and/or pesticides. Moreover, compounds produced in plants can also cause allergenic or immunogenic responses and have the potential to adapt viral pathogens to humans.

The risk of using biological products sourced from any living organism is that they may not be sufficiently purified away from other material that could cause harm in recipients. For example, the purification of antibiotics from the microorganisms that produce them carries the demonstrated risk of transferring the antibiotic and the genes for antibiotic resistance simultaneously to patients, where the gene may be acquired by the bacteria in a patient (Heinemann 1999).

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6 He is referring here to ideas such as the vaccine banana, which are now considered to be unlikely developments largely because of the impossibility of controlling doses.
In considering the risk of pathogens accompanying the material being purified, it may be more useful to consider virus types rather than the species of the biofactory. This is because, first, some viruses have large host ranges and thus can more easily jump species boundaries; and second, some viruses may more easily adapt to a transmission route supported by human technologies (Heinemann 2007).

The context in which a protein is produced can have significant impacts on its functioning, impacts which are difficult to detect (let alone assess the risk they might pose):

[Biopharmaceutical proteins] are in general 100-1,000 times larger than small molecules [produced through chemical synthesis], they can’t be fully characterized physiochemically by current analytical methods, which are often insufficiently sensitive, and their mode of action can confound biological characterization \textit{in vitro}. Unlike the chemical processes used to synthesize the small molecules, therapeutic proteins are manufactured in living cells, which are very sensitive to culture conditions.

Even under the most stringently controlled culture conditions, proteins show a high degree of heterogeneity... Often, modifications occur as a result of abnormal processing because the recombinant proteins are unnatural products for the cellular expression system used. Extraction and purification involves \textit{sic} many steps that can also introduce protein modifications that influence biological activity or clinical properties....Production normally involves many hundreds of control steps, which involve numerous in-house standards. This complexity is the basis of the claim in pharmaceutical biotechnology that process is the product....

A major problem for generics manufacturers is the lack of access to production details, in-house controls and material from different stages of production … at the innovator company. (Schellekens 2004: 1357, 1358)

It is possible, then, that different manufacturing platforms and processes will produce unexpected transformations in proteins, and these transformations may be harmful. For example, an Australian group found that the expression in peas of a protein normally produced in beans induced an immune response in mice, whereas the same protein produced in beans or in chickpeas did not (Prescott \textit{et al.} 2005; Prescott and Hogan 2006). This difference in reaction was attributed to differences in glycosylation in bean and pea plants (see Box 1). As noted above, the inducement of multiple modifications and the higher concentrations of the induced protein can be expected to increase the number of unintended effects on the plant.

The types of contaminants that must be removed are not always obvious even when they may be detectable. An example is provided by the manufacture of the common amino acid tryptophan using genetically modified bacteria. In the late 1980s, the introduction of these bacteria was associated with 37 deaths in the United States and retrospectively associated with 97-100% of all cases of eosinophilia-myalgia syndrome. The change in the manufacturing process increased the concentration of otherwise low levels of hazardous compounds (Sustainability Council 2007).
Box 1: Post-translational modifications and glycoproteins

The primary structure of proteins is the linear order of amino acids which compose them. Proteins are more than just a sequence of amino acids, however. They may also be modified by addition of different kinds of molecules to various amino acids. This is relevant to risk assessment because the modifications can alter protein structure and function, as well as change the potential for the protein to be a toxin or allergen.

There are many forms of post-translational modifications. Most are the addition of molecules, but some modifications result from removing amino acids or re-folding a protein into an alternative three-dimensional structure. The range of potential post-translational modifications varies by species, tissue and stage of development (Gomord et al. 2005).

Post-translational modification has medical and food relevance because, for example, proteins modified in plants can be immunogenic in humans (e.g. Prescott et al. 2005) and may cause cross-reactivity to similar epitopes (i.e., immunogenic regions) that occur in proteins from animal sources.

More than 300 different types of chemical modifications are known, and are distributed among the following types: ubiquitination, halogenation, phosphorylation, farnesylation, glycosylation, glycoxidation, acetylation and methylation (Manzi et al. 2000; Zasloff 2002). Over half of all proteins are glycosylated (Van den Steen et al. 1998). No modification is exclusive, so multiple isoforms of the “same” protein, distinguished by different combinations of modifications and groups of modifications, can co-exist (Lane and Beese 2006; Jensen 2004). Detecting different forms can be very difficult.

Glycoforms of a protein are sugar-modified variants of the same primary amino acid polymer. The three main post-translational protein modifications that use sugars are N- and O-linked glycosylation and glycosyl phosphatidylinositol (GPI) anchors (Van den Steen et al. 1998). Linkage to the polypeptide is made at serine, threonine and hydroxylysine amino acids (O-linked) or via the amide nitrogen of asparagine (N-linked) (Bardor et al. 1999; Mitra et al. 2006).

3.2.2. Contamination of the food supply

A major recognised risk of plant biopharming is the possibility of biopharm products entering the food supply. This could have effects on human health, exports of food products, the ability of consumers and producers to decide what to purchase or sell, and consumer confidence in particular brands and the food system as a whole (Fernandez et al. 2002: 15). That is, aside from the obvious health risks, contamination also represents a significant economic risk.

The food industry fears that gene transfer or ‘volunteer’ biopharmed plants in the field could contaminate the food supply with vaccines, drugs and other products, triggering costly recalls and presenting thorny liability issues (Miller 2003: 480). According to Miller (2003: 481), “the sophistication of modern agriculture enables us to safely
cultivate crops for food and for new pharmaceuticals, and to ensure that ne’er the
twain shall meet – at least in a way likely to cause injury”.

Recombinant DNA-modified plants for food and fiber have for several years been
grown worldwide on more than 100 million acres annually, and more
than 60% of processed foods in the United States contain ingredients derived
from recombinant DNA organisms. There has not been a single mishap that
resulted in injury to a single person or ecosystem. Building on the admirable
safety record of traditional agriculture – including the production of medicines
– both theory and experience confirm the predictability and safety of
recombinant DNA technology and its products. (ibid.: 481)

From this position it is argued that use of food crops in biopharming should not
automatically be ruled out, particularly if the target molecule poses little or no
environmental risk: “…dry seed crops, such as maize, rice, wheat, barley, soybean
and pea, offer huge benefits in terms of scalability” (Ma et al. 2005: 598). Indeed,
corn is the most common crop used in biopharming trials in the United States
(Fernandez et al. 2002: 2) because it is one of the crops “where we have the most
data, we know the most, and we can control the system the best” (Mich Hein, Epicyte

However, this confidence appears misplaced in the face of the reality of multiple
instances of contamination and the seeming inevitability of such events. Existing
eamples of accidental contamination of the food supply by genetically engineered
crops also shed some light on the potential costs of such contamination. In 2000, GM
Starlink corn, which was not approved for human consumption, was detected in
human foods in the United States. It cost approximately US$1,000,000,000 to recall
the contaminated food, clean the processing and storage facilities, and settle lawsuits
(Smyth et al. 2002). Japan temporarily ceased importing U.S. corn from October 27,
2000, until they were confident that testing procedures for Starlink were adequate. It
has been estimated that the Starlink episode resulted in losses of between $26 and
$288 million dollars for producers in the U.S. (Schmitz et al. 2005).

In 2002, ProdiGene was fined for contamination of other crops with a biopharm corn.

[T]est plots of [biopharm] corn [were] being raised under contract by local
growers, one farm in Nebraska and another in Iowa. In the Nebraska case,
officials realized that some 500,000 bushels of harvested soybeans were
contaminated with small amounts of GM corn, which had been grown during

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7 The argument that a lack of evidence of harm from the consumption of GM food in the United States
demonstrates its safety also seem spurious, given that GM foods are not labelled as such in the U.S. and
there are no systematic efforts to monitor their health effects. There is also no “control” population in
the U.S. against which health outcomes can be compared. As Schubert (2008) has noted, “[w]ithout
proper epidemiological studies, most types of harm will not be detected, and no such studies have been
conducted.”

8 The Starlink gene Cry9C was found in a sample of Taco Bell shells on September 18, 2000 (Schmitz
et al. 2005). The gene was detected later in other foods.

9 Mullholland et al. v. Aventis Crop Science USA Holding, Inc. was a case filed by non-Starlink corn
growers who claimed damages from contamination. This involved loss of market value as well as
storage and transportation costs resulting from contamination (Schmitz et al. 2005: 392). The case was
settled for $110 million in 2003.
2001 on the same plot, because the farmer did not weed "volunteer" plants from the field in which the soy was grown. In Iowa, federal officials required a local producer to destroy some 155 acres of corn because it could have been cross-pollinated by ProdiGene's engineered corn being raised in a nearby field. (Fox 2003: 3)

It was considered in both cases that the errors had occurred because ProdiGene had not followed the protocols issued by APHIS. ProdiGene was fined US$250,000 and paid about $3m reimbursement to the USDA for the clean up and disposal of contaminated corn and soybeans (Elbehri 2005: 23). The settlement reached with the USDA also required ProdiGene to post a US$1 million bond (Fox 2003).

In August 2006, as harvesting began, many American rice growers discovered through an announcement from the USDA that they had inadvertently planted rice contaminated by Bayer’s GM rice resistant to its herbicide Liberty. This rice had never proceeded beyond testing between 1998 and 2001 and had never been approved. The company selling the seed rice, Riceland Foods, had first heard of the problem in January, after which it tested seed and found it positive. They had tested again in May and again received positive results which were confirmed by Bayer, but had not notified farmers. Different groups of farmers proceeded to file class actions against Bayer Crop Science and Riceland Foods (Verderosa 2006; Bennett 2006; Farm Futures Staff 2006).

Incidents like these have led the journal *Nature Biotechnology* to take a firm position against using food crops to produce pharmaceuticals. Its stance, argued in 2004, was reaffirmed by the editor in 2007:

> The production of drugs or drug intermediates in food or feed crop species bears the potential danger that pharmaceutical substances could find their way into the food chain through grain admixture, or pollen-borne gene flow (in maize, at least) or some other accidental mix-up because of the excusably human inability to distinguish between crops for food and crops for drugs. The ‘contamination’ of soybeans and non-GM corn in 2002 with a corn engineered by Prodigene to produce an experimental pig vaccine shows just how plausible this is. This position is not anti-GM (something industry should appreciate)—we should be concerned about the presence of a potentially toxic substance in food plants. After all, is this really so different from a conventional pharmaceutical or biopharmaceutical manufacturer packaging its pills in candy wrappers or flour bags or storing its compounds or production batches untended outside the perimeter fence (p. 133 Editor, 2004)? ... Although industry organizations, such as the Biotechnology Industry Organization (BIO), continue to support food crops for PMP/PMIP [plant-made pharmaceuticals and plant-made industrial products] expression systems, we hold to our original view that they pose too many problems. (Editor 2007: 167).

### 3.2.3. Containment

Containing biopharm crops is considered a fundamental challenge for their successful use. Contamination, either in the form of the mixing of crops and seeds or in the form of gene transfer, may occur in a variety of ways and at a variety of places along the
chain: “Biopharm traits could spread through pollen carried by wind or insects, spilled seed, unharvested seed sprouting the next year (‘volunteers’), and biopharm seed residues carried by farm equipment to conventional fields” (http://www.biosafety-info.net). Containment is necessary not only to prevent contamination of the human food supply but also to prevent wider environmental exposure, for example, the ingestion of plant material containing pharmaceutical compounds by wildlife.

The containment risks and potential mitigation strategies vary according to the plant in question. Plant population geneticist Norman Ellstrand described “the worst possible plant with regard to confining its genes” as one that:

- routinely breeds with related crop varieties;
- produces large amounts of pollen and seed (and the seeds are particularly small);
- serves as an important food and feed crop;
- spontaneously mates with wild relatives and
- is widely planted throughout the world (Fernandez et al. 2002: 2).

The plants that are most commonly modified for biopharming, such as corn, soybeans, rice and oil-seed crops meet many of the above criteria.

Containment issues extend beyond the plant in the field. As noted above, harvesting and transport pose containment risks, but there are also questions around the disposal of biopharm plants, including the fate of the waste remaining after the purification process (HortResearch 2003).

Moreover, not only heritable material in the form of pollen, seeds and propagules, but also genetic material in the form of nucleic acids (DNA, RNA) needs to be considered for containment of plants producing truly potent pharmaceuticals. The implications of horizontal (or lateral) gene transfer (HGT) for the feasibility of biopharming may be significant as “there is no explicit strategy, physical or biological, to prevent horizontal gene transfer” (Heinemann 2007: 54).

Once a transgene has been placed into a novel context in a new genome, it may have different opportunities for HGT. The plant will be routinely infected by pathogens and parasites that may not have been encountered by the original source of the gene. Each of these pathogens and parasites may become a vector for further dissemination of the gene. Thus, consideration must be given to both a characterisation of the potential hazards posed by the primary biopharm plant and its escape as well as the potential hazards of other organisms that might acquire the transgene but not be part of the monitored agroecosystem.

Biopharm plants may impact significantly on microbiota in other ways. For example, the farming of plants modified to produce antibiotic substances could in fact aggravate the problem of antibiotic-resistant bacteria by encouraging resistance in populations of soil bacteria or gut bacteria in animals (particularly insects) that feed on these plants. Many therapeutic compounds have antimicrobial properties in addition to their intended action, meaning that many biopharm plants may have this effect on bacteria (Heinemann et al. 2000).
3.2.3.1. Containment strategies

Containment strategies can be categorised as physical or biological. Physical containment strategies include enclosures such as netted cages, glasshouses and laboratory facilities; specified distances between the biopharm source crop and any non-biopharm recipient crop that could cross with it; and the use of barrier crops around source and/or recipient crops to serve as screens and as sources of competing pollen (decreasing the ability of the source pollen to reach the recipient crops) (Heinemann 2007). So-called sentinel plots, plots of a non-modified version of the GM source crop, can be planted at a distance from the modified crop and checked regularly for evidence of cross-pollination (Fernandez et al. 2002: 14).

Biological containment includes temporal isolation (ensuring non-overlapping flowering times between the source crop and its potential gene-flow recipients); prevention of flowering through physical removal of flower buds; and utilisation of natural barriers to reproductive spread present in some crops (e.g., alloplody and the use of plants that rarely if ever outcross).

Ma et al. argue that “most of the steps that prevent pharmaceutical crops becoming mixed with food crops involve relatively low-tech measures such as meticulous planning and execution of each step in the production process” (2005: 596). These would encompass, in addition to the strategies noted above, strict handling and traceability systems.

In addition to these measures, a number of more technologically complex strategies have been devised. These include sterilisation technologies, such as GURTs, to prevent the production of viable pollen or seed; the “development of phenotypic markers” on the source plant, such as unusually coloured fruit, that would make any spread visible to the human eye (Ma et al. 2005: 595); and inducing genes to produce therapeutic proteins only after harvest. Another strategy involves introducing the transgene into the chloroplast rather than into the nucleus of the cell. This could keep the transgenes out of the plant’s pollen, as chloroplasts are inherited maternally (Heinemann 2007: 61).

3.2.3.2. Effectiveness of containment strategies

Human error combined with stochastic events are a powerful force for containment compromise. The incidents related in section 3.2.2 suggest that human error should not be unexpected; as noted by Ma and colleagues above, containment strategies for biopharm crops require meticulous attention to detail along the entire production chain.

Moreover, such strategies need to be underpinned by adequate knowledge of the hazard being managed, and there remains considerable uncertainty in a number of areas of importance to containment, including gene flow. For example, research in 2004 on GM creeping bentgrass showed that pollen could be transported by wind

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10 GURTs, or genetic use restriction technologies, involve the further genetic modification of the plant in a way that hampers the reproduction of the plant or expression of a trait. For example, some plants have been engineered in a way that induces the plant to produce sterile seeds. This type of GURT is colloquially known as Terminator technology.
much further than previously assumed, resulting in cross-pollination up to 21 kilometres away from the source plant.

[Researchers from the U.S. EPA] collected seeds from wild grasses growing for tens of kilometres around the experimental plots, then grew the seeds in greenhouses and tested the growing grasses for transgenes and resistance to Roundup. They found extensive gene contamination up to 2 kilometres downwind of the experimental plots. Contaminated grass seeds also turned up across 310 square kilometres, with the most distant find 21 kilometres from the source. (Pearce 2004, citing Watrud et al. 2004)

The wider environment poses further risks of containment breach. For example, rodents, insects and birds that gain access to seed may either move the seed to new and hospitable environments or increase the chances of germination.

[S]eeds consumed by frugivorous birds are excreted or regurgitated at varying distances from the parent plant. Some of these seeds may then germinate. Recent work has shown that other animals contribute to a secondary pathway by which such seeds find new locations. These animals not only move the seeds from fecal deposits or the vomit of primary dispersers (e.g. birds) to more hospitable locations with lower seed densities, but aid in embedding the seed into the soil. “These secondary seed movements often result in patterns of seedling recruitment that are quite different from the patterns of primary seed dispersal generated by frugivorous animals” (p. 282-283 Vander Wall et al., 2005). Rodents move relatively large seeds, >25mg, a few meters and bury them to a germination range of about 8mm deep. Ants demonstrate a preference for smaller seeds and tend to bury them deep within the nest (Vander Wall et al., 2005). “Caching by rodents does not move seeds far relative to that achieved by bird dispersal, so the colonization of new patches is unlikely to be an important benefit of phase-two dispersal. However, caching places seeds in conditions that often favor seedling establishment. Once cached, seeds are relatively safe from other sources of seed mortality such as ants, beetles, and birds that act as seed predators. Two-phase seed dispersal has the potential to increase the overall effectiveness of seed dispersal over any single means of seed dispersal” (p. 286 Vander Wall et al., 2005). (Heinemann 2007:18)

Any of these events can result in establishing a “beach head” for further amplification of the unwanted plant (although the length of time a seed remains viable in the soil will depend in part on the particular plant in question).

Seeds don’t stay in place either. They can persist in the soil seed bank. They can mix in the nooks and crannies of harvesting equipment. They can bounce out of vehicles transporting them and germinate on roadsides (e.g. Pessel et al., 2001). The movement of unwanted crop genes into the environment may pose more of a management dilemma than unwanted chemicals. …[A] single crop allele has the opportunity to multiply itself repeatedly through reproduction, which can frustrate attempts at containment. When crop genes arrive in locations for which they were not intended, they sometimes persist and at times spread (Ellstrand, 2001, 2003). The spread of weeds between
continents is a good example of how difficult it is to contain plants. (Ellstrand 2003: 1771)

Each of the more technologically complex strategies proposed also has a failure frequency. For example, the use of GURTs as a containment strategy assumes an unrealistically low mutation rate in plants at the scales of most commercial activities. Similarly, “gene transfer from the chloroplast to the nucleus can happen at high frequencies (Huang et al., 2003)” (Heinemann 2007: 61). Moreover, in most plants, chloroplasts are not strictly maternally inherited and perhaps are not exclusively maternally inherited in any plant species (ibid.: 61).

In tobacco, chloroplast containment failed at frequencies of 1 in 10,000 to 1 in $10^8$. At normal seed densities, these frequencies result in 1-70 failures per hectare with as little as 1 transgenic plant per 10,000 (i.e. 0.01%) as the source, that is 4 million to 280 million worldwide per year (Ruf et al. 2007; Svab and Maliga 2007).

Transgene-based transgene containment remains largely untested, and there are few or no natural analogues from which an experience of this approach can be extrapolated.

A recent UNFAO-commissioned study concluded:

Due to environmental variation and human error, it is likely that no single containment strategy can be completely effective. It may be that no combination of containment strategies will achieve the level of containment necessary to avoid all harm, so the nature of the harm and the severity of consequences must be considered when evaluating a containment strategy…Containment strategies are new and very little testing has been done to verify their long-term effectiveness. However, these strategies may restrict flow to below legislated threshold limits of transgenes outside of approved crops and products, and meet local or international requirements for safety depending on the transgene and the type of GM plant. (Heinemann 2007: 54)

3.2.3.3. Pollen inhalation

Regardless of how well the plant and its heritable material are kept away from the human food supply, the question of inhalation exposure remains. Containment of pollen for the purposes of preventing breeding does not necessarily prevent the production of pollen. Even impotent grains of pollen can carry transgenes and pharmaceutical products that may be inhaled by people and animals or ingested by insects that feed on pollen or pollen-contaminated plant tissues (Andow and Zwahlen 2006).

Pollen viability tends to be brief and is highly variable, largely due to sensitivity to desiccation (Fonseca and Westgate 2005). Since most studies measure pollen dispersal by its ability to fertilise recipient plants, to determine separation distances for effective containment, they will necessarily underestimate the longevity of the pollen particle as a source of released pharmaceutical and therefore potential allergen, immunogenic substance or toxin.
Inhalation exposure can be many times more effective at sensitising a susceptible individual to an allergen than is oral exposure. A recent study investigating insecticidal proteins produced from transgenes as potential allergens in rats found that control rats not fed the relevant transgenic plant material reacted as frequently to the insecticidal protein as those rats that were fed the relevant material. The investigators found that even minute quantities of airborne dust from the rat feed were sufficient to induce an immune response (Kroghsbo et al. 2008).

3.3. The New Zealand context

In contrast to many developed nations, New Zealand’s economy continues to be reliant on the primary sector. Among the factors of particular relevance to New Zealand is the potential impact of biopharming on our existing primary sector industries and export markets.

In a study of the potential economic impacts of biopharming carried out for the Constructive Conversations project, Kaye-Blake et al. note the importance of considering spill-over effects and opportunity cost for New Zealand.

New Zealand’s economy has a significant portion that is based on natural resources. The agricultural sector depends on the biological resources to produce not only food and fibre for the domestic population but also for a large percentage of the country’s exports. International tourism also depends on the country’s natural resources, its biology and landscape, and adds significantly to the country’s export earnings. Tourism exploits New Zealand’s image as a clean and green destination.

Biopharming also depends on natural resources, and is thus a potentially competing claim on these resources. Whether the net impact on the New Zealand economy is positive, negative, or neutral depends on the ability of these different industries to use the resources productively. It also depends on potential spill-over effects – externalities in the language of economists – and how large those effects are. (Kaye-Blake et al. 2007: 13)

They point out that “analyses that project future financial benefits from biopharming tend…to assume that technical, regulatory, political, and consumer issues are resolved” (ibid.: ix).

The economic potential of these products varies tremendously, depending on the overall size of the potential market, control of technology or proprietary information, and other factors. However, it is clearly early days for these products. The future impact of consumer concerns is unknown and contested. The regulatory regime and practices needed to segregate novel products from other food have not been set up and are untested. The potential contributions to cost savings or other benefits of the technology have not been quantified. (Ibid.: x)
They note the results of a study using the Lincoln Trade and Environment Model (LTEM) on the trade impacts on New Zealand of the adoption of GM crops more generally.

[It simulated] various scenarios relating to adoption of GM crops in NZ, including reduced costs of production, premiums for and against GM and bans for GM products in key markets Japan and the EU (Saunders & Cagatay, 2001, 2003). The results of the scenarios in which New Zealand adopted GM crops were generally negative for NZ, even when a preference for GM products and/or increased productivity was modelled. Saunders & Cagatay (2001) outlined their findings as being generally negative for the adoption of GM in primary production sectors. Further modelling work has in general supported these conclusions (Saunders, Kaye-Blake, & Cagatay, 2003). (Kaye-Blake et al. 2007: 14)

This suggests that an adequate analysis of the potential benefits and hazards of biopharm crops in New Zealand must take into account impacts on natural resource-based industries, and particularly primary-sector trade and tourism. This is an area characterised by a high level of uncertainty.

In our interviews with scientists it was also suggested that benefits would not accrue to New Zealand for pharma plants (or animals) developed by Crown Research Institutes (CRIs), because of the way in which CRIs are constituted:

[W]e’re not allowed to market our own plant breeding. It’s got to be licensed to another company … We sell it, we get a royalty on it, but we’re not allowed to do any of our own marketing.

I think that is one of the problems with the CRI setup, is that basically CRIs, as soon as they get a product, they’re forced to sell it off. I would imagine if a company like [CRI] came up with one of these magic foods, plants, that as soon as we’d showed that it was of value, we would be forced to sell it to a multinational who would just make big money on it.
Chapter 4: The New Zealand Seed Sector

4.1. The Seed Commodity System

The commodity system we chose to explore was the seed commodity system. The reasons for this choice were several. First, seed growers, who replicate seeds in the northern hemisphere off-season, deal with issues of containment and contamination in growing open-field crops, and as such would be aware of risks and of the strategies that can be deployed to minimise these risks. Second, the industry is highly integrated with links into northern hemisphere multinational companies, and, as most biopharm development is taking place there, this is a potential trajectory for biopharming development in New Zealand. Third, the industry has sophisticated systems of traceability and methods (both on and off farm) of achieving crop purity, again making it a likely player, if biopharming were to eventuate.

According to the participants in our study, the vegetable seed industry has developed in New Zealand for reasons of geography and history:

New Zealand has quite an important part to play in the world because it’s English speaking, fertile soils, reliable climate, reliable social structure.

The fundamental reason why vegetable seed production’s done in this latitude is, as you can imagine, Korea, Japan, Holland and the States – are the same latitude which is about 42 north, and you flip that over the southern hemisphere and it’s us, and a hell of a lot of ocean. … And part of the reason they came to New Zealand was they had all their eggs in one basket. I mean a lot of the production was done in Italy, if Italy had a poor year, they were buggered for a year. So they had to look for other areas, so that’s where we come into it.

Growing in the northern hemisphere off-season allows seed breeding companies to double the annual rate of seed replication:

We do a lot of re-modification crops, off season style so that people get two generations of a crop in a year – northern hemisphere, southern hemisphere.

Moreover, the practices of the arable sector in New Zealand makes it an ideal location for seed replication, as this participant explains:

One of the reasons that seed production is so good is because they grow grass seed there. Grass seed, grass seed. And vegetable seed is not a big part of their act. Here it’s all about pastoral farming, about sheep and beef. … But it will rotate in and out of arable: silage, pasture for four years, an arable crop for three, and then he’ll grow coriander. And as part – the anchovies in his

11 Consistent identifiers such as pseudonyms or numbers are not supplied with quotations from participants in order to protect the identity of participants in a relatively small industry.
salad, it’s not his main thing. But then that’s very good for seed farming. Because we don’t want somebody’s variety of coriander to be in the paddock that we’re going to put coriander in three years hence. (A) for disease reasons; and (B) because that damn stuff, it will multiply and come up in the other person’s coriander, and you’re never going to be able to tell the difference. The customer will – say: ‘what are all these light green ones?’ So our rotational system is ideal for seed production.

Furthermore, one participant expressed the view that New Zealand farmers have a great deal of experience, and success, in growing seed, which makes New Zealand an attractive option for international seed breeding companies:

Because we’ve always had this certification system. We probably are world leaders in that type of control over what we’re doing. And a lot of other countries, particularly Eastern European countries and South American, Asian countries, they’re quite surprised by the level of expertise here. And the proprietary seed companies find that if they go to get stuff grown somewhere else, because they find that we won’t grow it because it won’t yield well enough or something, that they just can’t get that level of expertise elsewhere to do it.

4.2. The Mid-Canterbury Arable Sector

The arable sector in Canterbury as a whole consists of 300 grain farms and 190 mixed grain and stock farms. The table below summarises production and income for the 2007/2008 season for the mid-Canterbury region.

<table>
<thead>
<tr>
<th>CROP</th>
<th>Area (ha)</th>
<th>Production (tonnes)</th>
<th>Price per tonne ($2008)</th>
<th>Total farm gate value 2008, $million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milling wheat</td>
<td>9010</td>
<td>72000</td>
<td>380</td>
<td>27.4</td>
</tr>
<tr>
<td>Other wheat</td>
<td>13000</td>
<td>123000</td>
<td>370</td>
<td>45.5</td>
</tr>
<tr>
<td>Barley</td>
<td>16100</td>
<td>112700</td>
<td>360</td>
<td>40.6</td>
</tr>
<tr>
<td>Oats</td>
<td>2360</td>
<td>10600</td>
<td>300</td>
<td>3.2</td>
</tr>
<tr>
<td>Other cereals</td>
<td>860</td>
<td>4900</td>
<td>400</td>
<td>2.0</td>
</tr>
<tr>
<td>Field peas*</td>
<td>2900</td>
<td>10200</td>
<td>550</td>
<td>5.6</td>
</tr>
<tr>
<td>Other pulses†</td>
<td>730</td>
<td>1300</td>
<td>600</td>
<td>0.8</td>
</tr>
<tr>
<td>Herbage seeds</td>
<td>16354</td>
<td>20770</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryegrass seeds</td>
<td></td>
<td>11200</td>
<td>2000</td>
<td>22.4</td>
</tr>
<tr>
<td>Clover seeds</td>
<td></td>
<td>6075</td>
<td>5000</td>
<td>30.4</td>
</tr>
<tr>
<td>Other forage seeds</td>
<td></td>
<td>2375</td>
<td>3000</td>
<td>7.1</td>
</tr>
<tr>
<td>Vegetable seeds</td>
<td>3400</td>
<td></td>
<td></td>
<td>25.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>64714</td>
<td></td>
<td></td>
<td>210.0</td>
</tr>
</tbody>
</table>

* Dry peas (combined) including marrowfats, blues, yellows, maples and garden pea seed.
† lentils, beans etc (combined).
Source: Enterprise Ashburton 2008
While the grain industry is primarily domestic, the seed industry has a long history of exporting. Historically exports have been dominated by pasture seed (traditionally ryegrass seed and clover seed). In recent decades vegetable seeds have become more important:

50% of the world’s carrot seed is grown in Canterbury. 50% of the world’s hybrid radishes are grown in Canterbury

In terms of dollar values in seeds for sowing, the major categories: ryegrass is by far the biggest, followed by white clover. Then for vegetables: it’s radish, carrots, peas for sowing, cabbage, rape seed, oil seeds, a few more grasses, turnip, mustard seed, onions, beetroot, silver beet.

The development of the vegetable seed industry is connected to the opening of new markets. In the last 20 years Asian markets have expanded considerably providing new opportunities for growers:

We send vast quantities of seed vegetables to China and they will be cabbages, bok choi, what we call Asian brassicas. We send cabbage, radish and brassicas again to Hong Kong. We send cabbage, onion, radish, turnip to Japan. You’ll laugh when you know there’s a market in silver beet – silver beet is one of the largest… The whole Asian world buys our silver beet.

The table below presents New Zealand’s, and Mid-Canterbury’s, seed exports for the 12 months ending 30 June, 2008.

<table>
<thead>
<tr>
<th>CROP</th>
<th>NEW ZEALAND EXPORTS $ MILLION</th>
<th>MID CANTERBURY SHARE %</th>
<th>MID CANTERBURY EST. EXPORTS $ MILLION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryegrass</td>
<td>33</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>Clover</td>
<td>23</td>
<td>60</td>
<td>14</td>
</tr>
<tr>
<td>Vegetable seed</td>
<td>40</td>
<td>80</td>
<td>32</td>
</tr>
<tr>
<td>Other seed</td>
<td>17</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>Peas</td>
<td>25</td>
<td>28</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>128</td>
<td>67</td>
<td>83</td>
</tr>
</tbody>
</table>

Source: Enterprise Ashburton 2008

4.3. Structure of the Seed Industry

The structure of the arable/seed industry consists of a network of contractual relationships between plant breeders, seed production companies, growers, transport companies, merchant companies, third-party certifiers, government agencies and an array of industry organisations. All of these players are positioned differently within networks, with differing interests, goals and strategies. At times these interests are in conflict, at times they coincide. As such, networks are fluid and changing as differently positioned actors work to achieve their goals. The industry is also highly
integrated, with tightly structured chains around particular crops and in some instances particular players occupying multiple positions on those chains.

The way in which the industry is structured has significant implications for biopharming futures. The structure of the industry is likely to facilitate biopharming were it to be introduced into New Zealand. Middle-man seed production companies who are used to negotiating with multiple breeders and producing multiple types of seed are in place, as are growers who are experienced with growing a wide variety of crops under a variety of different contracts, and who are used to considerable surveillance of their on-farm practices.

The arable/seed industry can be understood as a series of commodity chains, each of which is organised somewhat differently. In this section we describe three chains (wheat, rye grass seed and vegetable seed) to illustrate the kinds of contractual and structural relationships that exist in the industry. Paying attention to industry structure, and to power relations within the industry, is important because industry organisation potentially presents risks in and of itself. First, the transfer of seed between actors in the industry provide sites where seed escape is possible. Second, it is possible that how the relationships between actors are understood, as competitive or cooperative, as based on trust or mistrust, are connected with levels of risk, in terms of such things as growers following production company agronomic guidelines and how problems that do arise are dealt with. Furthermore, how the industry is structured provides important insights into how biopharming might develop if it were to be introduced into New Zealand, and provides the basis for speculation about biopharm futures by growers and production companies.

4.3.1. Wheat

The wheat commodity network is a local network, with breeders, growers and end users all being located domestically. A participant described the process by which wheat seed comes onto the market:

On the wheat side traditionally varieties were bred up at Crop and Food, DSIR in the old days, and those varieties would then be issued to a merchant who would breed the seed up to get certain volumes over a couple of years. Then they would contract a farmer to produce seed for them for the following year. Then it would go from that farmer to a processor. They would process that seed and then make it available to farmers for sowing out for the next year.

Government entities are not the only kind of organisation involved in developing new seed. Some of the larger seed merchants are also involved in breeding:

The merchants and the breeders are very involved in that process, but tend to be one and the same in New Zealand. It’s because you’ve got the likes of, now, PGG Wrightsons, both PGGs and Wrightsons and Agricon to a certain extent, who are under the same banner now, are all breeders. But they’re also merchants… they were the breeder and the merchant, so when you bought that seed, they formed a couple of legs in the value chain.

There are two ways in which wheat contracts are organised. Many farmers contract to sell their wheat crop to a merchant at harvest at a set price when they buy the seed.
The benefit of forward contracting is that the grower knows what their income is likely to be (though this will depend on yield). The downside is that the price may have increased by the time the crop is finally harvested:

You sign your contract in say April, May 07 – harvest your crop in February, March 08 – that crop would then be delivered from normally say April through till January the following year. So what you’re actually committing to back here is a delivery period which takes you right out to 18 months after you signed the contract. So there’s very little chance that the price you signed up there is actually going to be relevant at all when you get to here.

As a result, not all growers forward contract their wheat crops, but instead wait until they have harvested the crop and market it then. The option a particular farmer takes will depend on the state of the market and his willingness and ability to deal with financial risk:

It depends on the farmer a bit. We’ve got a mix of free traders and more conservative contractors, people that contract in the industry. Probably 70-80% of wheat crops would actually be contracted, around the time that they’re planted. So back in, say, April and May, the major users like Western Milling and Goodman Fielder in Christchurch and Tegal Foods come to us for the likes of our feed, and would all come out with a contract saying this is what we’re going to pay you for the result crop of next February, March’s harvest.

4.3.1.1. Power in the Wheat Chain
As both sellers of seed and buyers of crops, wheat merchants have a considerable amount of power in this network, which is further enhanced if they also breed seed. Growers are, in some ways, at the mercy of seed merchants:

We’re very much reliant on those merchants as our information source, which is always an interesting concept because otherwise they’re trying to buy our product as cheap as they can, you know, the ones that are trying to sell us….You can hear that I’m a little bit sceptical, but that’s just the way it works. So, you’re reliant on that. ...In the wheat system there’s not a lot of negotiation really. It’s: this is the contract, do you want it or not? In the past there often wasn’t enough contractor tonnage for all the stuff that could be grown, so most people signed it up on the spot and said: I want to be in. And sometimes 20% of the contracts would be sent back because they were overdone on the volumes that were going into the flour mills in particular.

However, merchant control has been undermined more recently because of increased demand for wheat:

That’s changed now quite significantly, but people have still got this culture that they want to know where their grain’s going. And for the last two years anyway it’s been completely the wrong thing to do, because back in the autumn you sign up a wheat contract at round about $300 a ton. If you wait until now it might be worth $400 a ton. But that’s just the way the commodity cycles are. Mainly because of the dairy influence – both taking land out of arable production and also demanding grain themselves, there is a lot more
demand for wheat than there is actually wheat grown now in Canterbury in particular. And 90% is grown in Canterbury.

Increased demand for wheat has meant that instead of forward contracting some farmers will grow crops and wait until after harvest to sell:

Most of us have got sufficient storage and silos. Once it’s in the silo we don’t panic about selling it. We think why should we be like lemmings and sell it all straight off the header for no profit and at a very cheap rate, whereas if you hang on for three or four months the price will go up? Last year the feed wheat started at $240 a tonne ex-harvest, by August, September we were getting $350 a tonne in silo. This year the feed wheat started at $265, and that was delivered to Timaru, and at present I’m just putting a deal together for $400 a tonne in silo. …I haven’t signed any wheat crop up for next year yet.

Some also bypass the merchants altogether:

We don’t deal with the merchants selling our wheat to a flour mill. I have a relationship with the flour mills. I just take my samples up after harvest and say ‘what do you think it’s worth?’ He’ll give me a price. I’ll say ‘no, we’ll sit on it.’ So we might sit on it a couple of months, see what the international prices do, go back to him, see how desperate he is. And some will do that and actually wait right through to December before they sell it. But very rarely they get less than the contract, and quite often they’ll get more.

The growers who do this are of a particular kind:

It’s a certain type of grower I guess. Different risk profile, they’re comfortable with that, and enjoy the challenge … you’ve got to have the appetite for that.

One grower explained how the arable industry had changed under deregulation, but noted that not all growers had adjusted to this new situation:

It goes back to the old days of the New Zealand Wheat Board where every March, April, the farmers’ representative on the New Zealand Wheat Board would go and negotiate with the government members of the Wheat Board to set the price for wheat for the following year. Under the de-regulated market, that’s all gone. And so as a farmer you have to market your produce yourself. … They’re [growers who forward contract] acting in the Fonterra mode. And that’s why so many people like this Fonterra thing, because they go to Fonterra, it’s like going to the nanny state – I mean Fonterra shepherd you all the way through, and then all you’ve got to do is milk the cows. That’s it.

The wheat chain is not a likely model for biopharming development because it is a domestic commodity chain and is not linked into international networks in which the technology is being developed.
4.3.2. Rye Grass Seed

Farmers grow both proprietary and non-proprietary rye grass seed. Non-proprietary seed is open access seed, i.e. the seed is not patented. The production system is much the same as for wheat:

In the non-proprietary, which is the traditional method of growing here, we’ve got a grass seed called nui, which is a commons, or a non-proprietary [seed]. It was bred originally by AgResearch, I suppose, or its predecessor, and it’s effectively owned, or maintained, by farmers. We pay what we call a non-proprietary herbage seed levy under the Commodity Levy Act. Those funds are then passed on to AgResearch to maintain that, so everyone’s got that if they ever want to grow nui. And I think probably 40-50% of the perennial ryegrass production would be nui.

Farmers who grow nui rye grass do not necessarily have forward contracts:

In the nui non-proprietary stuff, you’d be planting in February, March, coming out of say a wheat crop or a pea crop. Not normally committing them forward in a contract, but sometimes the contracts are available. But generally the people that are growing nui take the risk on that price. And then either contract approaching harvest or after harvest when they know what they’ve got… there’d be maybe 10 or 15 smaller companies that you would have the opportunity to sell your nui to [as well as the larger merchants].

On the other hand, proprietary seed is, in the words of a participant, “completely owned and tied up by these breeder / merchant seed companies”:

It’s all very much controlled by the Plant Variety Rights legislation, they’ll come out with a contract in February or March, and if you’re happy to sign it, you’ll sign it and they’ll give you the seed to plant. They own the seed.

Growers express a degree of negativity about what they consider to be the control of the industry by merchants who sell the seed to growers and purchase the crop. What emerges in this context is evidence of strategising by growers to maximise their own advantage.

The companies that own the proprietary seed, or the production companies who are their agents, have considerable power:

They will nominate the price or the contract conditions. It’s quite a different system, and you know what your price is going to be right at the start but they will tell you how much you’re allowed to grow.

A grower explained how the seed was owned by the seed company, and that grower autonomy was limited as a result:

They issue the seed. You never really own the seed, although you pay for it we buy the seed off them. The contract says that that seed remains their property even though it’s growing in your ground. Then everything, all the resultant
crop must be delivered to them. You’re not allowed to keep any of that\textsuperscript{12}. And most guys accept that, that’s part of the system. So not only do we buy the seed, we pay for the cleaning of the seed, we pay for the bags to put it in which are all branded in their marketing as well, so that’s a bit of a sore point for arable farmers.

With non-proprietary seed there are only two or three links in the chain, depending on whether the seller of the seed is also the buyer of the crop. With proprietary seed third party certifiers are also involved. AssureQuality (formerly AgriQuality, formerly MAF) provides an independent certification system, which assures buyers that the seed they are buying is in fact what it says it is. Certification is based on systems of traceability which are well established in the industry. This system inserts another actor into the grass seed network, and results in greater surveillance of grower practices. One grower explained the paper trail that follows a batch of seed in order to ensure crop purity:

We get contracted to grow it. And they’ll supply us with the seed and we pay for it and we keep these tickets… the ticket’s on the bag of the seed, and it gets sown and then we keep the ticket and there’s an application form we’ve got to fill out with the history of the paddock, the size, and we send it off. And then it goes into the system. …We’ve got to be a registered grower. So each paddock has got – the farm’s got a number and then there’s a paddock number and letter as well, and that’s all on record, they’ve got all the histories from it. [The system has] been around for a long time.

Growers seek proprietary seed contracts because of the economic returns, the “premium over the commodity, or the non-proprietary pricing”. The benefit of proprietary seeds is that the company contracts to buy the full crop, so income is assured. However, with proprietary seed the grower has very limited options:

You really haven’t got too many rights in selling it. So X has got an example of that from last harvest – the germination of the seed has to meet generally a 90%, but down to about 80% or 85% standard. He got a bit of frost I think it was, and it came out at 69. So instead of $1.90 that was on the contract, they offered him 50¢. But he couldn’t do anything, because it had to go to them. I guess it’s their intellectual property, they can do what they like. But he just held off on that actually, and the most recent offer he’s had from them is $1.25, so he actually can’t do much else with it, but all he can do is hold out.

With proprietary seed, growers consider that power lies with the companies because of the companies control contracts, meaning that grower independence is limited:

Participant: No one ever talks about it, but you feel obliged to buy the inputs – the sprays and things. Some seed companies just don’t – they give advice on what to spray on, but they don’t supply the chemical so that’s the difference, whereas [another company] will supply the seeds and the fertiliser. We buy it through them. But we don’t have to buy it through them. But if we want to

\textsuperscript{12} This is one of the key differences between proprietary and non-proprietary seed. With non-proprietary seed growers can, and often do, retain a portion of the seed they grow for their own use.
keep getting the contracts we’ve got to get through the business with them. There’s sort of that unwritten obligation.

Interviewer: So if you went and bought all your inputs off someone else the company, might…

Participant: ...say ‘why do we deal with this nutter? If he’s not supporting us, why will we support him?’.

4.3.2.1. Power in the rye grass seed chain

There are differences in power in this chain depending on whether the seed is proprietary or non-proprietary. With non-proprietary seed the situation is very much the same as for wheat. With proprietary seed growers have less autonomy, as they have no flexibility with regards to who they sell the crop to, must grow to the standards set by the contracting merchant, and cannot retain seed for themselves. Further, with proprietary seed merchant companies are likely to be much more involved in monitoring the progress of the crop and determining the on-farm practices of farmers:

They’re not too dictatorial on how you grow it, although they like to be involved in that process. Their reps come out and check out. For some people they’d keep more of an eye on it I suppose if they’re not experienced in growing it. Others they just come out and say ‘it looks good, that’s fine.’.

However, this situation has changed recently with the boom in commodity prices:

Right at the moment they’re [grass seed contracts] actually lagging behind by about 20%. That’s a relatively recent thing.

Most people are very scared they’re not going to get grass allocated for next year, so they do just generally sign up the contract. And while there’s plenty of people queuing up to grow the stuff, that’s fine, but one day it will change, with people having plenty of options, and the next couple of years are going to be like that, because of the increase in commodity prices generally. A lot of it’s export driven. Even perennial ryegrass going to Europe in particular at the moment, just non-proprietary stuff, there’s contracts available for two years at $2.20. After the last harvest we were seeing about $1.40. So that’s quite a significant increase.

4.3.3. Vegetable seed

The vegetable seed chain differs from the previous two described in that it originates and is driven by off-shore companies and is entirely export oriented.

4.3.3.1. Plant Breeders

At one end of the seed production chain are vegetable breeding companies who produce new vegetable varieties with the aim of bringing them to market. Such companies occupy two sites in the seed production chain:
These people are the ones that actually make the varieties. So they’re breeding the lines. On the one hand they’re plant breeders, on the other side they are actually salesmen themselves. They produce the seed, we produce the cross, they then sell the resulting seed as well. So it’s a sort of integrated system.

New Zealand participants consider that ultimately these breeding companies drive the industry:

The history of the vegetable seed industry in New Zealand stems back to significant companies worldwide who breed the seed. Interestingly enough, a lot of those companies are now owned by the likes of Monsanto and Bayer and those sort of people who are driving the industry from behind the scenes with some of this new technology. In the vegetable seed industry there’s probably something like 60 or 70 companies worldwide, be they in Korea, Japan, Holland, France, and the US, from little family businesses who have their own radish varieties right through to the big fellows who are multi national companies now. Monsanto and those sort of companies got involved, initially, probably 15, 20 years ago maybe, and then got out of it, and then have subsequently got back in again. So there is almost a cartel behind the scenes. A lot of people don’t realise that Monsanto own this company, this company and this company. …So a little bit hidden from public view probably, but we in the industry know who they are and where they are.

The rationalisation of the industry is driven by a desire by multinational companies to own valuable germ plasm:

Groups and the old family owned seed companies have been increasingly eaten by multinational, sometimes publicly traded companies. Seminis, for example, is the largest vegetable seed company in the world. Seminis is owned by Monsanto. As they become rationalised or consolidated, there is more and more intellectual property contained in the seed – it’s like selling CDs: the CD has no intrinsic value in itself, it’s the message that the seeds convey that has a value.

Not all plant breeders are international. New Zealand has its own highly developed and long standing plant breeding industry:

The big firms, like Pines and Wrightsons, they’ve got their own research farms where they’re testing and breeding new varieties all the time.

These New Zealand companies operate somewhat differently to the internationals in that they focus more on arable crops than they do on vegetable seed. As such, they do not tend to employ middleman companies to organise the replication of the seed, but contract directly to growers themselves.

4.3.3.2. Seed Production Companies

Production companies organise the replication of seed for new plant varieties or produce hybrid seeds:
They’ll want 10 tonne of a particular radish seed grown. It’s our job then to place that 10 tonne with one or two or three or four or five farmers, in the greater Canterbury area.

Seed production companies link international plant breeders and growers.

[Independent production companies don’t] own any intellectual property, we act as a middle man between our plant breeding customers overseas, and our farmers in New Zealand who produce the seeds.

Seed production companies work with a variety of international clients because, unlike firms who are also involved in breeding, they own no plant varieties themselves:

Our role is as contract manufacturers, and we take other people’s intellectual property, in the form of varieties or hybrids, and produce more of what it is they gave us. …[W]e’re kind of low in the feeding chain in the intellectual property business, and renounce the ownership of intellectual property for ourselves because it doesn’t put us in a situation of conflict where someone trusts us with their germplasm, and we compromise it. So, by saying we don’t sell seed, we just sell service. We’re distinguishable from producers.

There are a number of different kinds of seed production companies in the industry. At one end of the scale there are large companies such as PGG Wrightson who have extensive interests as agricultural merchants as well as involvement in breeding and production, and at the other end small specialist companies, “one or two man bands”:

You get companies that have a niche market and they specialise in one particular type of seed. They may specialise in onion seed or pumpkin seed, just one or two things, and they don’t cover the whole range.

One company described the extent of their interests “in the production and marketing of arable and specialist seed crops, primarily for export markets”:

If you start at the commodity end, there’s the wheat and barley we’re very much involved with. That is an internal market, producing that for sale locally. A lot of peas for export, particularly to Asia – dried peas. …The lower value herbage seeds, forage seed – rye grasses and clovers, a lot of which is exported, primarily to Europe. Some high value clover seed, through a joint venture. …And then a lot of high value vegetable seeds. …A lot of brassicas – pak choi and bok choi to Asia. And there’s been a big emphasis put on carrot seed production here and red beet. … It’s very high value seed. It’s very high value seed – hybrid seeds.

The other, much smaller, player in the seed production sector is New Zealand agencies for large international companies:

They set up a small operation in New Zealand and they seek to grow their own market for their overseas owner.
A good example to use is high sugar grasses. They are marketed in New Zealand by a company called Germinal which is a UK-owned company. And has, I think, a staff of three or four in New Zealand, maybe more. And they are seeking to penetrate the market for pasture seed in New Zealand with their UK-originating seeds.

One production company is also engaged in seed trials:

We will have tents where there is just a few hundred seeds are planted in a small area, only twice the size of this room … There are other companies doing that but not all companies would do trial work like we do. They don’t have the facilities like we have here.

Another company owns an organic farm of its own. For this company, the organic farm simply meets one more market niche, and there was not the existing infrastructure within the industry to meet the demand by the usual practice of contracting growers:

There was a need for organic seed. This farm became available so the firm decided to buy it, converted it to organics, and then, again, the surety of supply of organic seeds. So we grow the organic carrot seed and beet seed and whatever on that property and we can be sure that there is always somewhere we can grow it for our overseas customer. Because there aren’t that many organic farms in Canterbury for producing seed. I can only think of about three or four.

The structure of the vegetable seed industry is complex with a variety of companies linked into the international trade in different ways. There is also a locally based network in which some companies are linked into New Zealand research and retail institutions. What this indicates is that there are a number of ways in which a biopharming industry could develop. Furthermore, the variety of interests and growing expertise, from traditional arable crops to numerous specialty seed, would suggest that there is agronomic knowledge within the industry to produce any modified crop that would grow in New Zealand conditions. What is also suggested is that seed production companies are likely to be open to new opportunities.

4.3.3.3. Relationships with growers

In order to make a living and meet obligations to breeding companies, seed production companies need to develop relationships with growers. While in the past there has been a grower demand for seed contracts, the expansion in dairying and rising wheat prices have meant that currently growers have options. Because of this pressure, production companies work hard to develop, and maintain, relationships as good growers. Good growers are interested in crop farming, have the right land and equipment and will follow instructions:

The core of growers are the guys that are keen and interested, are the ones we want. They’ve got water – irrigation, good soils, that sort of thing, and some of the gear. But they don’t need all the gear because we own a lot of the specialist gear that we need to do the job. We don’t expect the farmer to have every little bit. But he’s got to be accurate with what he does, he’s got to be timely with
what he does, I mean if our guys go in and say ‘you’ve got to spray this tonight’, it’s got to be done tonight, not next week, because then the damage is done.

What production companies seek is farmer buy-in to the process of seed growing:

We don’t necessarily want a farmer who has to just sit back and be told everything. It’s got to be a two way street. I think probably 95% of our guys are very involved with what they’re doing, they’ve involved with our reps, they get on very well with them, and that’s all part of it as well….I think that’s part of our success …[W]e’ve managed to keep a very strong core of growers simply because of that. They see that we will always try and treat them fairly. That’s all they’re asking.

Production companies acknowledge that growers are primarily driven by relative economic returns, over which seed production companies have little control. Thus they work to secure grower loyalty by constituting the relationship as a partnership, rather than simply a contractual relationship, and as being about more than just money:

We always say to our guys we think it’s a partnership, we think we’re in partnership with them to get the seed grown, and we’re there to help, not hinder. And I think we do it different to other companies. I think the relation is a little bit different. …I think it’s a much closer relationship with the farmers. I mean the farmers will actually come here and see their seed being cleaned. …they will turn up, saying, I want to come and see my radish being cleaned. And ‘I’ve seen it going into a container, I want to meet the customer.’ Because the customer’s around here all the time, they get an opportunity to rub shoulders with these guys, and that’s helpful as well. …I mean, at their expense, we took a group of farmers to France about 3 years ago now, 2 seasons ago. A French company that we deal with brought some of their growers down to New Zealand and did a tour around, and met all the farmers here, and so we reciprocated and took our guys up there. There’s a lot of very strong relationships.

What is of interest is that production companies present themselves as having parallel interests to growers: if there is a problem, “we certainly don’t walk away and say ‘stuff it, it’s not our problem, it’s yours’”.

Participant: Growers are a pretty resilient bunch. They take it on. I mean it’s the whole risk and return thing, and I think there’s very, very good returns out of hybrid seed. But equally to get high returns is obviously the higher risk than growing traditional stuff.

Interviewer: So who bears the risk?

Participant: In our case it’s probably shared between ourselves and the grower. …we would never leave a grower in the lurch. I mean if something untoward happens, we don’t just walk away and say ‘tough’. Because I mean we miss out on our commission as well….
Production companies were very aware of what motivated growers. They noted that growers were motivated by economics, but that being a good grower was also important:

All of our seed growers are in the business to make money, but also they take pride in their crop that they’re growing.

Likewise, success as a grower requires the maintenance of relationships with others in the industry:

Our difficulty – we’ve got to grow the crop and we’ve got to market it, and we’ve got to have a relationship with the companies we deal with. And there’s all those aspects to it. Whereas the dairy farmer, he just doesn’t worry – the market’s not a big deal for him. We’ve got a lot of balls up in the air, and we’ve got to sort of jolly people along and try – have a relationship with the companies. Well, I always make a point of knowing the decision makers, having that link in there.

Contracts are seasonal, and though longer term relationships between producer companies and growers do develop, these relationships are not fixed by contract, but are secured through continued performance. One strategy to maximise the chances of obtaining contracts is to develop long-term relationships with a particular merchant or production company:

There are quite a number of farmers very dedicated to one merchant, and always have been. I’ve got a friend whose family’s always been with PGG Wrightsons, they won’t buy anything anywhere else, and all of their product goes through PGGs – and they’re a shareholder of PGGs, or they were before the changes. So you’ve got that cultural aspect too, that people are very dedicated to their merchant.

This may mean that growers have a greater likelihood of securing contracts when there is competition for them. On the other hand, this may mean they accept lower prices on their contracts. However, with a number of production companies seeking competent growers, and pressure on the industry because of land use changes, other growers choose to deal with a number of companies:

We take a more business-like approach I suppose, that we’ve got to spread our risks, and we deal with PGG Wrightsons, and Crop Mark at the moment. We did deal with three, Agricom was the other one – it got swallowed up by PGG Wrightsons. So we’re in a less comfortable position than we were, or we think we are.

This is a strategy to minimise the power of the merchant companies:

We like to keep a wee bit elsewhere as well just to keep them honest. So we probably do 80% of our business with our main one, but then 20% with a couple of others.

Sometimes [the crops a farmer is growing] are just not flavour of the month. So if Wrightsons came to us and said, as they did a few years ago, we’re just
not selling well on the market, you can’t grow anything this year – we’ve got nowhere to go. And that’s the control they’ve got. …We’d been growing something like 120 hectares of perennial ryegrass for them, and then we got down to 26 over a five year period. So that’s the downside of the proprietary system, is that it’s completely out of your control.

4.3.3.4. Power in the Vegetable Seed Network

Both growers and seed production companies indicated that the international breeders had a considerable amount of power in the system:

It’s a fickle business because depending on the northern hemisphere harvest whether they want to grow any down here. What happens if the market’s short and the price is high, they say ‘we’ll have a southern hemisphere.’ Because it’s a short season crop they can shoot down here to New Zealand and grow a crop in 90 days.

The merchant is contracted to overseas to supply a set tonnage. So he’s got to figure it out, how many hectares he needs and who’s going to grow this for him, and who’s he going to get the set tonnage. Because again it’s all controlled by the seed companies – and he’ll have a penalty whether he delivers more or less.

Breeder power is further secured by the fact that the seed is proprietary:

The unique side is that if our customer wants 10 tonne of seed he doesn’t want 20 tonne of seed, and equally doesn’t want 5 tonne of seed. He wants 10 tonne of seed. So the aim is to produce enough to give him the 10 tonne of seed. So it’s not a tradable – I mean we can’t go out and think it’s a great idea to plant 200 hectares of radish and hope like heck we can sell it. …[W]hatever the customer wants.

Production companies must meet their contractual obligations and failure to do so may impact on future contracts. This is another source of breeder power:

We really have to have everything cleaned and on the water – as in containers going up to the northern hemisphere by mid-June at the latest, mid to late June at the latest. The Koreans for instance want their seed for their spring sowing, so they need the seed delivered to them by about the middle of May. And this last harvest that we went through, most of the seed was probably still sitting out in the paddock about the 15th of April. And they couldn’t figure out why things weren’t happening. Well, it wasn’t happening because we couldn’t get it harvested because it was raining. But their problem is of course that if they don’t get the seed in the season they want it in, they actually really don’t want it, because it’s going to be another full 12 month cycle before they need that seed, and in the meantime we’ve produced another crop as well. So it does, if we don’t get out here and get things done, then it does affect next year’s orders.

Breeder company power is further enhanced by the presence of a large number of seed production companies in the local market:
There are a lot of grain and seed merchants in New Zealand which, to me, is far too many. There’d be getting close to somewhere between 20 and 30 – different sizes. Some of them range from one man, some of them specialise and that...But there is quite a lot. It creates real problems because there’s a lot of growers, a lot of merchants, very few end buyers – and you know what the end buyer’s going to do, don’t you? Play everybody off.

Breeders also seek to reduce the power of others in the chain by contracting with a number of production companies: “they want to spread their risk”. However, it is not always possible for them to achieve this:

Like last year Europe was toast, you know, it just got so hot, they lost a lot of seed crop. And Australia had similar issues. So suddenly we’re very popular.

Production companies consider that power in the vegetable seed industry lies with them, and they consider that farmers are misguided if they think that they have much control. This is one of the ways in which farmer buy-in is secured:

I suppose it lies with the production companies. They would be the ones that would have to be responsible for the running of the system.... So I think the farmer would probably like to think he controls things, but the reality will be that pretty much the production companies hold the stick. I mean they set the prices.

Grower power has increased as the amount of land available decreased because of the comparative economic benefits of dairying, and more recently commodity grain production. Like breeders, growers spread their risk by dealing with a number of production companies:

They tend to spread their risk a bit these days; they’ll tend to be dealing with two or three merchants.... Probably going back 20 or 30 years ago when the traditional stock firms were around – Pyne Gould, Wrightsons and Dalgety's, that’s the three big players. The farmers used to get all their finance from the firm. So they had all their seasonal finance there. The working capital if you like was provided by the merchant firm. And for that they were pretty well kept under the thumb. They had to do all their business back the other way. A lot of that’s gone now. They tend to do their financing separately with the merchant banks so they are much more at liberty to deal with who they like.

There is no consensus in the industry about where power lies. Production companies are in some sense the meat in the sandwich between breeders and growers, but, in turn both breeders and growers rely on production companies to make the links between them. The multiplicity of these links, and their fluidity implies that it is likely that an international breeder of biopharm plants would find a production company with the skills to produce what they needed, either by doing it themselves, whether in open-field or in glasshouses, or by contracting growers.
4.4. Discussion

The vegetable seed network is characterised by multiple contractual linkages and comparatively short chains with relatively few players. Power is considered by growers to be located in the international breeder companies, and to a lesser extent in the merchant and production seed companies. However, because of changing arable markets and broader transformations in New Zealand agriculture leading to land use change, grower power is increasing. Control is more entrenched in areas where one player occupies multiple positions in the network and where growers have fewer options. However, the deregulation and diversification within the industry from the 1990s, and rising wheat prices (which is a crop where growers have greater growing and marketing autonomy) mean that farmer flexibility is increased and the economic advantage of growing specialised crops (and thereby production company power) is reduced.

In tandem with, but in contradiction to, discourses of the dislike of production company power, is a discourse which suggests that growers and production companies have similar interests. In particular, the surveillance of grower practice in regards to growing both certified seed crops and specialist vegetable seed crops means that production companies and growers are structurally encouraged to work together, creating “two way” interdependence.

As such, the way in which the arable/seed industry is structured presents no significant barriers to the introduction of biopharming: indeed, it could well facilitate it. Growers are used to growing a constantly changing variety of crops through contracts with a variety of different companies in response to changing market opportunities. There is a sense that growers imagine themselves as strategic players. Although there are tensions among the different players these are minimised and growers do not position themselves in opposition to others in the chain. Rather in some sense all players are seen to have the same interests. Thus, biopharm crops would not be likely to become a site through which tensions and contradictions in the industry were expressed. Conflict or mistrust between differently positioned actors in the network is likely to increase risk, by reducing incentives for compliance. Conversely, lack of conflict and the existence of trust may also contribute to risk, because of the levels of confidence in the competence and integrity of others.
Chapter 5: Industry Knowledge: Risks and Risk Management

This chapter considers the risks presented by biopharming, and potential strategies for dealing with these risks, identified by seed production companies and by the arable farmers who grow the crops. The chapter will highlight what has been learned from interviews with seed production company representatives and seed growers about practices in the arable sector that may have a bearing on the implementation of protocols developed to manage potential hazards. The chapter also explores industry assessments of the likely costs and benefits of biopharming and its potential trajectory in New Zealand.

For seed production companies, and for individual growers, the goal is to produce seed that is genetically true to kind, and is not contaminated with other seed. It is this demand that drives production practices in the seed industry:

What they’re looking for is seed that’s uniform when it’s put in to grow the vegetable itself: at 10 days, it’s all this long, doesn’t have all sorts of variances in it. It’s all this round and it’s all the same colour, and it’s everything else.

Company and grower focus is therefore on strategies to avoid incoming contamination of their own crop, rather than the movement of seeds or pollen off their land.

It’s more someone else’s seed that’s going to cross on theirs. Or the pollen’s going to cross. Probably not hellishly worried if theirs disappears over the fence, because a radish is a radish is a radish.

However, biopharm radishes are not simply radishes but drug factories, and as such potentially pose much greater risk to the environment, and to human and animal health, if they escape. Nonetheless, many of the techniques used by growers to avoid having their crops contaminated actually help prevent those crops from contaminating others as well. Strategies to avoid contamination have been developed because of the economic consequences of failure. As described in Chapter Four, if growers or production companies do not produce uncontaminated crops they do not obtain further contracts.

Production companies face a number of challenges in achieving the goal of non-contamination: cross-pollination, seed burden in the soil, and contamination during harvesting, storage, transportation and processing. However, while noting that something can always go wrong, the industry considers that it can control the risks in seed production to a considerable degree, and in practice the industry is able to meet the stringent requirements of the seed breeding companies.

This chapter takes the form of a commodity chain analysis, following the seed as it loops from the production company to the grower and back to the production company. We discuss the points at which containment can fail and contamination can occur, and describe current practices within the industry designed to mitigate these risks. Finally, we discuss industry ideas about biopharming futures. What we will see
is a significant number of potential ways in which biopharm plant genetics could escape into the environment. However, we will also see high industry confidence in their ability to deal with risks, because of their experience in successfully producing uncontaminated crops. In terms of biopharming futures, we will see that while there is some variation in thought, in general industry actors are not theoretically against biopharming, and many said they would be interested in growing such a crop, providing economic returns were sufficient. They also considered that they would be able to do it as safely as is humanly possible. However, there was a consensus that biopharming was not likely to develop, in large part because of public resistance to genetically modified crops in New Zealand.

5.1. Sources of risk

Participants indicated a variety of risk points in the seed production process. At the paddock level, the key sources of contamination/escape were identified as cross-pollination, seed dispersal, and seed burden in the soil. At harvest, key risks are contaminated machinery and escape during storage or transport. Once the seed has been removed from the farm, key risk points are during the seed cleaning process, transport and storage. A further potential risk factor is labour relations, both on-farm and at seed processing sites. Different crops present different challenges in terms of the points at which things can go wrong, in large part because of the different ways in which different plants reproduce and because of the kinds of seeds they have. These botanical realities have important implications for the development of biopharming protocols, as some plants present far greater risks than others.

5.1.1. Cross pollination

Possibly the most difficult seed crops to keep uncontaminated are brassicas. Brassicas, which include a wide range of vegetables such as swedes, turnips and radishes, cauliflower and broccoli, canola or rape seed, and cabbage, including Chinese cabbages such as bok choi and pak choi, reproduce through wind or insect pollination and as such are at high risk to contamination through cross-pollination:

In Canterbury here we haven’t got a huge area and there’s a lot of vegetable seed produced in Canterbury and the big issue is isolation. Cross pollination.

Plants which reproduce by pollination require the transfer of pollen between male and female plants, which is usually achieved by wind or insects, particularly bees. Pollination opens up the possibility of cross pollination, that there will be the mixing of undesirable pollens, resulting in a crop that is not genetically true to kind. Brassicas, we were told, are particularly problematic, as they are somewhat promiscuous:

[Canola] will cross with turnips. It will cross any yellow flowering. That’s the big issue ...There’s kale, there’s swedes, there’s some of the pak chois, heaps of them.

Some of those species will actually only cross within themselves anyway, but some of them will actually out-cross to other species as well. So there’s some issues there.
Wind is a key vector of cross-pollination in Canterbury: “I mean when our wind blows it blows big time”, stated one participant, referring to the famous Canterbury nor’wester winds:

[I]n the Canterbury Plains, I don't know how you ever restrict that. Because I mean if you’re growing a GE crop for instance is grown here, it’s probably likely that the outcross is going to be not just 10 yards down the road, but probably 10k or 15k down the road. So 3k or 5k isolation’s probably a waste of time.

Wind is not the only vector of pollination. Pollen is also be transferred by insects, particularly bees. Bees are critical in growing some crops:

Artificial pollination does not work because the flowers do not flower at the same time. So you need insects to do it.

Growers said that bees will travel for considerable distances. According to one, “[bees] have been known to have travelled a kilometre”, while another declared, “I’m sure a bee can go for 5km if they want to.”

Moreover, bees are not readily containable:

I’ve never known a way yet to keep a bee inside a paddock. And that’s what it comes down to. Bees don’t recognise boundaries.

As such bees are sources of cross-pollination and in the context of biopharming present a risk. We asked if contamination by bees was a potential problem:

Participant: For sure. Again it’s part of that 2km isolation distances. And that’s to prevent the bees flying, and then [cross-pollinating] the ones that are bee pollinated.

Interviewer: How far will a bee fly?

Participant: I don't know.

Interviewer: 2km is the industry standard?

Participant: For some crops, yeah.

This is one of the points at which the seed industry intersects with another industry, the honey industry, which could be affected if a biopharm crop that relied on bee pollination was to be grown. Further, bees are a potential vector for the transfer of biopharm genetics into wild plant populations or into other crops and into the food chain:

We have a relationship with our apiarist, who, depending on the crops we’re growing, will bring bees in to pollinate them. Now the varieties of crops that we’ve grown lately have been beneficial to the bee keeper. He’s made as much money as we have. Borage honey – he took 10 000 kilos of borage honey which is about $30 000, from quite a large area of borage. So it was mutually beneficial, because he had a very good honey yield, and we had a very good
seed yield possibly because of the good pollination. And the borage was attracting bees from other hives as well. You can follow where the bee goes – they take a direct line of flight from their hive to the crop. So if you’re standing in the road and you see bees going across the road, you can follow them back. So we were being serviced not only by our beekeeper’s hives, but from others as well. Quite a way away. And wild bees as well.

The problem of bee hives as sources of cross-pollination is dealt with through processes of rotation similar to crop rotation:

Once they’ve been somewhere else for a period, they will tidy it up….Usually they just do the one crop then they just go back into the woods or the clover paddock or whatever.

Furthermore, “pollen doesn’t last too long - most pollens don’t last more than a couple of hours”, so contamination from hives is not considered to be a serious problem.

It is also important to note that bees are not the only insects that are involved in pollination:

Participant 1: Most of these species are insect pollinated as opposed to wind. … Carrots and coriander are – I guess there’s more flies.

Participant 2: Coriander is – bees pollinate that, but they just love coriander. Yeah, carrots, every little insect that comes along seems to, whereas bees, they’re not attracted to the carrot at all. But yeah we do put bees in the field with carrots, in order to attract the others.

Participant 1: Because we can’t get hive of flies, we wouldn’t be very popular with the neighbours anyway. I’ve heard people throwing offal into the carrot paddock pulling flies in. It would be great to live downwind, wouldn’t it!.

One strategy for dealing with the problem of bee and other insect pollination would be to enclose the crop:

We’ve had experience of doing stock seed production where we’ve had to build cages and that sort of thing. …Insect proof. Things where you put the insects in there and you leave them in there, but no other insect can get in from the outside. It’s a huge expense, a huge hassle, huge everything else. So if that was what was required I’m not sure that we’re tooled up to do it, or whether we’d want to tool up to do it.

However, even in greenhouse conditions, there is the possibility of escape:

We have net houses…. And the net houses are translucent, fine mesh that we put over the trials, and put a beehive inside. Now everything inside is internally pollinated and there’s no contamination. Now, when I say ‘no’, I’m sure when you open the flap, two or three smart alec bees take off, and go and visit some flowers. So nothing’s 100%.
Another source of cross-pollination is from plants in the wild:

For instance, there’s a lot of wild carrot grown around …It’s just escaped… just driving down the road, if you’re thinking about it you’ll see them …And it’s the same with the brassicas. You’ve got to make sure that there’s no wild turnips and mustard growing around it, if that’s what you’re growing, within 2km. We’re talking about fair distances.

The problem is not restricted to just wild plants, domestic gardens too can present problems:

You get problems with somebody’s let some silver beet go to seed and they’re home grown, which you weren’t aware of, and the pollen can flow 2km to a red beet crop and it doesn’t look too good when they find it out.

The biggest source of potential contamination in the future is from biofuel development, something that is of concern to the seed industry:

Actually, the one that our industry’s been very concerned about recently was this biofuel business that’s been kicked off. Because that is canola, which is rape seed, which is a brassica. Which can cross with a lot of the brassicas that we’re growing for export. …So we’ve been very concerned about that because in those sort of crops there tends to be much less attention to detail. …But that’s the one major one. We do know of a few backyard people that are fiddling around with it, particularly up in North Canterbury. They are dealing with lifestyles and anything could happen.

5.1.2. Seed persistence or seed burden

A second major source of crop contamination is seed persistence or the build-up of seed burden in the soil as a result of repeatedly growing crops in the same field. The level of risk this poses depends on the crop in question, as different seeds last in the soil for different time periods:

[Wheat] germinates quite quickly in the ground, so if it does spread it tends to grow and then can be eaten by [stock] or sprayed, so it won’t hang around for years and not germinate. Whereas a lot of other crops will sit around un-germinated for several seasons then keep on popping up. So if you grow wheat, and next year you grow some peas – you kill the wheat, spray it out. And then you grow some rye grass and we’re going to kill the wheat. And the third year, there’ll be no wheat [coming] up. But if you have an oilseed crop, a brassica crop, so a seed that has oil in it, two years time it will be: oh, this crop is coming up again. And 20 years later perhaps: it’s coming up again. And we’re seeing that.

Because brassica seed is an oily seed it can remain viable in the soil for considerable periods of time:
Oilseed rape, any of the vegetable seeds, have a life in the soil of, some of them up to twenty years. And if any one time if it strikes a bit of light or the right condition, it kicks in and away it goes.

Because there is a long, if sporadic, history of rape growing in Canterbury, there may be a considerable rape burden in the soil:

Canterbury has been growing both hybrid and open pollinated oilseed rape for multiplication for European companies etc and for some of the United States companies as well where they actually wanted to guarantee it was GE free and had to have it multiplied here. So it’s not a new crop. We’ve been growing it off and on for 30 years.

Existing seed in the soil has the potential to contaminate a biopharm crop, but also, because of the length of time such seeds last in the soil, and because of the issue of cross-pollination for brassicas, there is the possibility that reservoirs of biopharm seed could lie dormant in a paddock and present a source of risk for many years after the crop had been harvested:

That’s the thing with radishes, it’s a similar type [to canola], sort of an oily type of seed. If you plough too deep, that’s what sort of tends to happen with a paddock that’s not really been turned over for 10 years, and you’ve got to turn it over, [it] comes to the top, and you look round, and: oh, where did all that come from?.

5.1.3. Seed dispersal

While wind and insects disperse pollen, wind also potentially disperses seed. Again, whether this is a risk depends on the crop in question. A grower discussed the potential for the escape of rye grass seed:

Grass seed is a similar type approach to growing it [to wheat]. …[J]ust at the end it’s usually cut, let lie on the paddock for a week or ten days just till it dries down, then it’s brought into a silo, or most farmers would deliver direct to a seed cleaner from the paddock. So what we do is we don’t leave it sitting down too long because the nor’wester will blow it away.

He notes that this is a potential problem, but that it is not that likely:

It would take quite a bit to blow a seed out of a paddock. It could happen to some extent. Sometimes rye grass seed – it’s mown before it’s harvested, and in a very large gale could pick up these – especially Canterbury – and blow them away. Not unheard of… The seed’s actually quite heavy compared to all the rubbish.

Other growers told me that the spread of grass seed is not much of a problem:

Participant: These grass seeds, the isolation is 100m between two grasses, because it doesn’t cross pollinate, it self pollinates. You can grow it right next door but you can either cut those strips out and harvest them separately, and
they can go into an uncertified line; or you can keep this crop here and mow this down and bale into hay or something. You’ve got to have that break.

Interviewer: So it doesn’t spread, that rye grass seed?
Participant: Not really. No.
Interviewer: It’s not wind blown in that sense?
Participant: A little bit, probably, but not too big a deal”.

Birds are another means by which seed is dispersed:

Birds come and eat the seeds. That’s the other thing that can be a [source of] contamination is that the birds can pick up the seeds and it can pass through the bird and when it flies away the seeds fall off wherever they do their business. It can transfer them around.

The spread by birds is another major thing... We’ve got some canary grass, which is like a wee millet, it’s a bad weed, it’s quite oily, birds quite like it and it’s spread. I should have pulled the first one out the day I saw it, I thought ‘no, big deal, what’s that?’ And now it’s a major problem. We have to spray every year. I’ve noticed in that field that has a power line going across the corner – all under there, it’s going through the birds. So that’s a containment issue. You can ring fence with whatever, but if you’ve got birds transferring it round...So you can make no assumptions that anything will stay.

A solution to the bird problem is to cover crops:

Maybe what will happen in the biopharming is it is contained, it’s netted. Some of these seed crops, they are netted for the birds. They’ll cover the rape – all that crop up there, they wouldn’t be far away from netting it. Net the whole field. ...You can grow it up through the field and when it gets to a certain stage you can net it. Cover. They do it with the grapes, don’t they, keep the birds off. And maybe you keep the bees out.

Birds are not the only animals who potentially spread seed:

Participant: If we were to go down to my dryer [silo] and lift the grate up there’d be a dead mouse, and lots of mouse poos, and seeds of different crops. ...Yeah, you’re going to have mice round grain. You’re going to have birds, you’re going to have mice, you’re going to have rats. I would think a mouse would eat the crop and by the time its excreted, there’s nothing alive in there.

Interviewer: So a mouse wouldn’t pass a seed through?
Participant: I wouldn’t think so. Somebody would know that, I wouldn’t think so. You’ve got rabbits and hares as well. And you’ve got people’s sheep and cows that get into crops as well. So somebody’s got this crop and then some heifers get in. Now in the meantime have they eaten some seed? I don't know! There’s a whole lot of things can happen.
Such risks could be dealt with by trapping, and by cleaning out the bottom of silos. However, in the case of a biopharm crop it is unlikely that growers would store the crop.

5.1.4. Machinery
Another likely source of contamination is equipment:

You get contamination with contractors’ machinery coming in.

It can get through various places. It can get through other farmer’s crop lines – harvesters, if they don’t clean it up enough at harvest time: augers, silos and dryers – seed cleaning plants. It’s just something that the seed companies have to be very aware of.

Growers noted that a potential site of risk was machinery. Arable farmers tend to own their own machinery:

Most arable farmers around New Zealand have their own gear, there’s not a lot of large scale contractors doing it.

Growers tend to plant seed themselves, and to own the necessary equipment for harvesting:

There’s a few contractors around but 90-95% of arable crops in Canterbury would be harvested by the farmer’s own combine harvester.

This is because harvesting happens in a comparatively short time period. The exception to this general rule of grower ownership appears to be spraying:

It’s quite common to use a contractor for the spraying side of it, it’s probably 50%. I guess it’s because it’s quite a specialised job. The equipment’s relatively expensive for the amount of period that you actually spray.

Sprayers can also transfer seed:

The other thing is that you’re spraying crops regularly too. Not so much near harvest, but sometimes you need to desiccate a crop, which is to artificially ripen it with herbicides. So, for example, with canola, just a common variety, they’ll spray that with a herbicide to ripen it up. So you’re going to have some machines in that crop almost prior to harvest, when some seeds are going to be viable.

However, most discussions were around combine harvesters. These machines are used by growers to harvest all of their crops (generally), and as such they present a site where seeds from different crops can mix:

Well one of the things is the machinery that does the work. Like when I go from one crop to the next, there’s always some seed that stays in the header.
The normal practice is that if you’re going from wheat to wheat, and it’s all feed wheat, it doesn’t matter, you clean it out. But if seed contamination is an issue, say you’re heading peas, like my white peas that I grow, my field peas and then my garden peas. They don’t like field peas in the garden peas because they’re not eating peas. So that’s an issue.

One solution to this is to discard the first part of the new crop that grows through the harvester:

Normally you just put some seed through, you take the first half a tonne out or something. …Cleaning better and then the first half tonne that goes through the header is bagged off, taken off and dumped, treated separately. The best way to clean the header is actually to stick some more seed through. So if you just take the first, yeah, sort of cubic metre I suppose.

Another strategy is to clean machines thoroughly:

When we tried [purple wheat], we kept everything separate, we cleaned all our trucks and trailers and combine harvesters out because of having purple and white does not look good…We still do it with our coriander, clean our headers right out, get all the cereals out. Blow it down. Some of the other specialist crops that are grown around here, they have big vacuum cleaners that suck it all out of the headers because when you’re blowing it you tend to blow it from one ledge to the other. Washing it – water floats it out.

However, cleaning a combine harvester is not a simple task:

Participant: Oh yeah, it’s hard, it’s hard. So you have to clean it out, and of course when you’re heading everything goes up there, and…it’s full of nooks and crannies and what have you. And I know for a fact that when I empty my tank there’s half a bag, about 25kg of cereal still left in the bottom of the tank. There’s about 25kg of grain, cereal left in that tank when it stops flowing out here.

Interviewer: How do you get it out?

Participant: We just blow it out, and undo all the latches and it falls out, and shifts it out. The best thing is a vacuum cleaner, a big compressor. And all inside here is sieves and chaff boxes and things like that. …You can get in there with air and what have you. If you had to make it spotless it would take probably two to three hours with two men, and you’d be using a big vacuum cleaner that just sucks everything. And I mean – don’t wear a hat!.

To avoid spreading seed between paddocks machinery could be cleaned in the paddock itself:

So you’ve got a machine coming in, that’s going to leave the field. So maybe it gets blown down in the field and cleaned, and maybe the combine does as well. So straight away is eliminating a lot of the risk, but is every seed…? You know, from that windrow, is there going to be a wee bit hiding in there?
And around the back of the flange thing that’s going to fall off down the road possibly. Probably, I would think.

Apparently, newer combine harvesters are easier to clean than older ones:

The modern combines are easier to clean than the old ones because of inspection hatches, and I think, depending on brand, are designed to be cleaned out. You can get in. But, still, there’s a lot of lateral ledges and pieces. They’re not new forever, so things rust a wee bit and a bit of dirt sticks on it, so a seed will stick to that. And if they’re brand new and shiny then it falls off. I think there’s some issues between contamination, it will be within that combine. Especially if we’re talking very low margins – if a seed is important as opposed to some seed.

The last two quotes indicate that growers consider that it is difficult to ensure that a combine harvester is one hundred percent clean. When asked if proper cleaning of equipment can be ensured, one respondent replied:

I think you could. You’ve got to have the right people dealing with it, and you’ve got to reward them well… As long as people understand how important it is.

Grower willingness to clean thoroughly depends, as does almost everything else according to growers, on the financial returns:

People importing combines from overseas, they have them spotlessly clean, but it takes them maybe two days because they’re pulling panels out, water blasting things and blowing air out. So the practicalities of spending even eight hours cleaning a combine between crops – it would have to be a good margin and people aren’t going to do it just for… It could be done. So if the crop is lucrative and someone said ‘this is the deal, this is the arrangement that we need to inspect your combine before and after you harvest this crop.’ and they say ‘oh, I don't think so.’ ‘For $20 000 a hectare, would you do it?’ – ‘no trouble at all!’.

However, growers also said that there are circumstances which might mitigate against them cleaning harvesters as well as they perhaps should:

Farmers tend – they’re practical people cracking on with the job. So they’re not looking at their ISA9000 quality control manual… it’s not sloppiness or anything like that. But it’s just the practical operation of things.

Participant: You’ve got this window of harvest that you can’t just wait for weeks and weeks and weeks. Things need to happen quite promptly. And I think because of the present situation, that’s where there’s room for error and contamination. Cleaning the combine down, maybe a good job does take some hours, but an hour would look pretty good. Are you going to spend another three hours in the sunshine, you could be combining and the rain’s forecast for the next day? Probably not. In practical terms, because people would say
you’re right, ‘this combine will be cleaned…’, but when you think there’s only so many days of harvest there…

Interviewer: So people will be quite likely under various circumstances to push it a bit.

Participant: I think they would. I can give you the PC answer, ‘no, no, we signed the documents and we’ll do that.’ I think in practical terms corners get cut.

Production companies, it seems, may be aware of this potential issue, and will inspect machines before crops can be harvested:

Usually the machine is inspected by the contract merchant anyway. They’ll have a look, say ‘you’ve done a good job, away you go and start on a different crop.’

In order to avoid this potential issue entirely, some of the specialist seed companies have their own designated equipment:

Some of those specialist brassicas they bring their own header. They’re specially set up just to head that brassica.

In the case of some of this high value seed we’ve got our own gear to do it. Mostly vege seed people do it themselves, …because of the importance of getting it right. Timing and all those sorts of issues. …We employ our own people to do all the planting and a lot of the weed control is done by us too, not all of it, but a lot. The spraying. But that’s about as far as we take it.

5.1.5. Transport

One of the key risk points for seed escape is when the seed is transported from the farm:

There could be some contamination at some stage from the harvesting, transport processing side, [but] it’s probably decreased over time as people become more aware of the needs.

Seeds fall from trucks and establish themselves along roadsides. They then represent a potential source of contamination for later crops:

You know, a bit gets spilt off the truck as it’s carted down the road and sheds on to the side of the road. I mean your roadside’s the worst place for weeds because it’s never managed, that’s where some of our worst weeds come from is off the side of the road because it’s just left to go rank.

Another possible source of transport contamination is the mixing of seed in trucks that have not been properly cleaned. This can be dealt with by having trucks with “bathtub bottoms”, which makes them easier to clean thoroughly:
One company specifies that they be bathtubs – [the containers] are rounded, like a bathtub bottom, because there’s less room for contamination there. The other type have sides that are straight, and there’s a lip there and seed can fall into there.

5.1.6. Storage

Storage, and the processes of storing, present possible escape/contamination points. It is common for growers to store harvested grain in silos on their farms. A grower explained the process of storing grain post-harvest:

So the other part of it is that when the crop’s harvested, it doesn’t just go straight on the truck to the store. Very seldom does that happen. Usually it goes into a farmer’s holding silo before it goes off. And it needs to be cooled or dried or conditioned. So it has air blown through it. …So when we harvest our rye grass seed crops, we blow air through them to cool them down. So I have silos with false floors, with air vents under them that can condition them, blow air through those crops. …It shoots it up through the crops, big floor about the size of this room with lots of little holes in it, put the rye grass about 2m deep, huge fan blows air through it with heating elements like a hairdryer.

He went on to explain how this posed a risk in terms of being a reservoir of seed:

So it’s going through a drying system which has got holes in the floor which seed can fall through. So it could be sitting in the floor of this dryer. It might sit there for ten years. It probably won’t grow, but one day someone will clean that out. So it’s like a big sieve, and it needs to be permeable to get the air through it, and as a result of that sometimes some seed…Not all of it, but a little bit.

Silos themselves are also places where seeds could be mixed:

You go to some farmer and he’s taken it out of the silo, or he’s forgot that he’s put a bit in the bottom of the silo because it wouldn’t fit in the last silo, and he’s got two varieties in the paddock.

However, in the case of a biopharm crop it is unlikely that the crop would be stored by a grower. This already happens with some vegetable seeds:

A lot of these special brassicas that you do, they go straight off the farm anyway. A lot of these small jobs, those specialist jobs, the grain either goes straight off the farm on a truck down to the seed plant, and I suppose that’s where you run the issue down there because it might accidentally mix.

5.1.7. Seed Cleaning

One of the methods for achieving crop purity is post-harvest seed cleaning. Seed cleaning technology is well established:

That technology is at least 50 or 60 years old, and it’s not really changed at all.
The seed cleaning process is really just cleaning out the impurities from the seed. So it’s a combination of just riddling over slotted screens and things to drop out the small seeds and take out the bigger seeds ...So a bit of wheat would normally come out of ryegrass because it was a bit bigger, and a clover seed would drop out the bottom because it’s a bit smaller. And it takes out dust and straw. And then we’ve got a thing called a cylinder – because it is a cylinder I suppose – that has a whole lot of little holes in it that actually separates on length. So it has a centrifugal force, carries the seed round and it drops. And you speed it up and it will go a little bit further and drops. But the stuff that’s longer will drop before the stuff that’s shorter.

It comes in with all pods and chaff and rubbish, you name it, and the machines have different sieves and basically that’s what it is, I mean the size of things. And what falls through is seed, and what comes out the bottom is what you’re looking for and all the rest of it disappears out with the offal. So you might have 20 tonne of product come in, and you might have 5 tonne of clean seed that comes out. ...The seed cleaning machines are just no different to the traditional grass seed type machines. Exactly the same system. ...We’ve done fancy things with them to suit what we do, but pretty much you don’t go out and buy a vegetable seed machine as against a grass seed machine, they are the same machine.

Some seed production companies have their own facilities and do their own seed cleaning, while others do not:

There are several around that we use. A lot of farmers have their own, but in the case of the high value seed, they tend to go to one or two specialist plants that are properly geared up to do it, the proper equipment to handle our needs.

The benefit of having your own facilities is that you can further guarantee crop purity:

All the system you see here is set up to do our own seed. We don’t do anybody else’s, we don’t do any contract cleaning for anybody else, everything’s all our own product.

Production companies said that the only hand sorting of seed that they did was for samples, but that you could sort small commercial quantities by hand if necessary:

I mean if we got down to a very difficult line, that would be hand picking, going through, physically taking something out, then we’d do it. It’s certainly more cost effective to do it [than have a contaminated crop], and you certainly wouldn’t do it on a 10 tonne line, it would drive you mad.

A few farmers also have their own seed cleaning plants:

There were just certain benefits of having your own, and the timeliness of having product available for sale, the non-proprietary stuff. And also you’ve got more control over the quality of the product too.

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Production companies and growers alike noted the risk that seed might become mixed at cleaning plants. One grower stated that he thought that risks beyond the farm gate were greater than on the farm:

The next step on like in the seed and the handling and the process is more of an issue than just on the farm.

While seed cleaning is a potential site of seed contamination through inadvertent mixing, we were told that such cases, while they have occurred, are relatively rare.

Well, there was that famous case you’ve probably heard about with [company], was it turnip and swede seed? That’s the absurd example where some warehouse mistake was made and one little black seed looks like another little black seed. Until you’ve sold and found out that half of them were swedees and the other half was…whoops!.

The mixing of different seeds would be caused by human error, but, this grower argues, such a mistake would be picked up through testing processes:

It’s all meant to be traceable, paper traceable and what have you. But you do get hiccups because – it’s labourers more than anything and seed dressing places and what have you put the wrong documentation on the pallet or something like that, or even put the wrong bags on the pallet. …But it should be picked up somewhere along the line before it even gets out to the seed.

However, it is always possible that there will be some contamination. The likelihood of this depends on what particular crops are mixed:

Again, it’s a numbers game. If I send a sample of borage that’s got 1% wheat in it, it’s probably going to get that out. If it’s 50% wheat, some of it’s going to get through. So the less contaminants you have, the easier it is. And some contaminants are very hard to get out. If you’re growing clover seed and you’ve got nodding thistle, the seeds are very similar so there’s a chance it will get through.

Seed cleaning, like harvesting generally, produces “rubbish” and, we were told, this rubbish gets dumped. Where growers have their own seed cleaning plants the rubbish is likely to be dumped on the farm somewhere. This would potentially present a risk in terms of biopharming by creating a reservoir of genetically modified seed:

If it’s on a farm, they’re probably going to the farm dump which is a hole down the back. I don't think they’d be going in a wheelie bin. You’re talking about, perhaps in rye grass seed, 15-20% would be rubbish. So for every tonne of seed that leaves my farm, 200 kilos will be going to a dump somewhere. There’ll be seed in that…. If you’re talking about specialist genetically modified, it needs to be very contained…. For example I grow some wheat and there’s an escape oil seed in it. It could end up going to that landfill.

If I was a seed dressing plant on the outskirts of Christchurch I would have an arrangement with a farmer to take the waste – rather than pay huge amounts in
land fill fees, I’d be talking to Joe Bloggs, and Joe would come and take it away and there’d be no questions asked, and technically he could spread that on his field as a top fertiliser. It’s organic matter. And if a farmer’s not too worried about having weed seeds, they would drill them up. And dairy stock will eat grass seed too, so there has been talk about mixing that with higher protein and palletising it. So there’s certainly a route for contamination there, quite obvious I would have thought. Maybe half of that junk’s viable seed.

Alternatively, rubbish is dumped at urban landfills. It is unlikely that the rubbish from a biopharm crop would be disposed of in this way; but, as the grower above noted, seeds from volunteers that have mixed in with other crops even years later might escape this way.

In order to reduce the chances of mixing, the seed cleaning machinery itself is then thoroughly cleaned after each batch of seed:

We’ve got to clean machines down after every line, so it’s basically: finish that line that you’re working on, and then spend five hours blowing everything out, vacuuming everything out, clean everything out.

At the production company, systems of traceability designed to make sure that seed is not mixed come into play:

Pretty much it all comes in here, tipped into boxes, all recorded. All boxes are recorded and line numbers, that sort of thing, so we know where they are and where they’re stored. And then from there, depending on the customer’s priority, when he needs that seed in the northern hemisphere, we work back from there – saying well this line doesn’t need to be cleaned until May, so it can sit in the boxes until then; this line has to be on the water by 10th April, so therefore we’ve got to start on it now. So we have a computer system that tells us all those sort of things, and splits it all off saying: we need to do this and this.

Production companies are very experienced at tracing seed, meaning that they do not consider this to be a significant point of risk:

You know, this whole tracking thing with regard to food quality is not hard for the seed industry to accomplish because the nature of its trade is to track the life of the plant and the seeds right through until it goes into a pouch. And that’s kind of a protocol of the trade. Mistakes happen, but they’re very infrequent because of the tracking. For example when we receive the mother seed, the stock seed, from the customer there’s only one person in the company who’s responsible for receiving it, giving it an identifier number and putting it in a special storage area, and it’s got a special tag on. He’s the only one that touches it. We don’t touch it until he re-weighs it, tests ins and out – a test to see if it’s viable, and what the quality of the seed is. And he puts it in pails with a ear tag on it that you use on stock, with a number, and gives it to the crop manager, who runs out to the farmer and says: ‘here’s your stock seed.’ Takes the tag off it, puts it on the front gate along with a big sign that says ‘here’s the number of the seed’. When the farmer harvests the seed, he
must come in with a special identification form and the tag off the gate and present it to the seed store and say: here’s this seed. Now it’s possible that he could get it mixed up, or his truck was filthy, or the organ that he used was dirty. But these are part of our contract terms…and seed growers know better than to…. Anyway the trackability of that seed line is part of that industry. Unlike, say, sheep. Keeping track, although I think they’ve made great progress there.

5.1.8. Farm Ownership and Farm Labour

The ownership structure of farms, and on-farm labour organisation, potentially presents risks, and also are significant for imagining possible biopharming trajectories. Growers did not consider that ownership and labour practices presented sites of risk in and of themselves. Most arable farms, we were told, are owner-operated farms:

The majority of arable production will still be run within the family probably, [though this will depend on the size and cycle of the farm]. I think the average size is something like 240 odd hectares, 260 even. Yet there’s still a lot of farmers that are farming 150-200 hectares which are clearly economic. But they obviously have no debt and they do everything themselves.

On these family farms the grower has involvement in and control over all aspects of on-farm production. On larger farms labour is employed. One grower explained the changing situation on his farm:

I guess ours when we started was about 600 hectares in a partnership. We were doing most of it ourselves. We normally had one or two employees as well. Now I do very little on the farm, with everything else I’m involved in, so the two guys here sort of run the farm. We have another two or three come at harvest time. And most family farms will normally have someone else in there helping there as well.

There are also some extremely large corporate farms:

So at the extreme there are semi-corporate farms, particularly the potato growers in Canterbury. They’re all originally family farms too, but instead of our 400 hectares, I don't know what the biggest might be – 4000 hectares or something. …So they obviously rely a lot on labour, for that they have good managers managing the individual farms.

Like many agricultural sectors, the arable sector is experiencing difficulties in attracting and maintaining good workers. Dairy farmers interviewed for the animal biopharming project (Goven et al. 2008) suggested that farm workers might be loathe to report any violations of the protocols that would be established around biopharm cows to their employers, which, they said, would present a risk. Arable farmers did not raise this issue, but a similar potential exists.
5.2. Risk Management Practices

5.2.1. SCID system
Risks to crop purity presented by cross pollination, whether from other crops or from wilding or domestic plants, is managed primarily through establishing isolation zones between crops:

Vegetable seed crops require at least a 2-3km isolation from another radish. So you have one radish, so you can’t have another one right next door because they will cross.

Some of these [brassica] seed crops require up to 2km or even up to 5km isolation because of the cross-pollination.

The method that has been developed for managing the isolation zones necessary for dealing with cross-pollination is the Seed Crop Isolation Distance (SCID) system. SCID is operated by AssureQuality on behalf of the industry. The SCID system was developed as an industry initiative to deal with problems emerging from the substantial increase in specialty vegetable seed production in the Canterbury region in the 1990s, particularly brassicas. This is an industry-run system and was set up because of the need for self-regulation in the absence of state regulation:

In fact the seed industry in New Zealand is, there’s absolutely no legislation around it at all, other than biosecurity. So most countries around the world have pretty strict rules about what you can sell, what you can’t sell, what you can do and what you can’t do. But we’re really laissez faire here, other than for biosecurity.

AssureQuality became involved because they also manage the crop certification system. Initially the system was manual:

Originally it was a map, a hard copy map based system that they just put sticky dots on. And the sticky dots, it was colour coded. So each company that was involved had a set of these maps and they had two different sized sticky dots, stuck them on the map and then they’d send them into us over a period of time in the spring and the autumn. And we would then overlay each map and see if there was an overlap of the sticky dot. And that was a potential contamination issue.

If there was a contamination issue AgriQuality would fax the details of the overlap to the production companies involved and “then they’d have to go and have a talk about whether there’s a potential issue for contamination”.

In 2002 AgriQuality, in conjunction with FAR (the Foundation for Arable Research) began to work together to set up a web-based system, financed by a MAF Sustainable Farming Fund grant:

It’s now been going, I think we’re into the fourth year now. And we’re probably averaging over 1000 crops put into the system each year.
The system is based on a number of farm databases, including the seed certification database which records the exact location and crop histories of farms and individual paddocks. Under the web-based system production companies log in and register the details of the paddock in which they intend to plant a particular crop. The database checks for overlaps, and generates email messages to the companies involved in the overlap, if there is one:

There could be more than one merchant; it could be four or five merchants. And all those five merchants will get an email. And what they get on their email is they’ll get that number, they’ll get the species that is put in there, they’ll get the isolation distance put in, and what the status is. And then it’s up to the person that creates the conflict to then get in touch with those other merchants.

The SCID system is a voluntary system involving “15 or 16 different companies”. It works because of mutual self interest and a logic of deterrence:

It’s a voluntary system, and to me at this stage for what it’s used for, the main self policing process if you like, is the ability for, if a merchant is being stroppy and being a bit bolshie and basically not giving anything away, then another merchant can just turn around and say: fine, I’ll stop using the system, which then is going to impact on everybody. Because then it’s the potential that they will just put a crop in, not tell anybody, and you won’t know until suddenly it’s up and growing, and you find out it’s actually going to ruin your crop, but it might not be a worry for them.

Though a cooperative system would seem to contradict the individuality that characterises arable farming, growers cooperate because it is in their interest to do so:

It was a matter of getting everybody’s thinking in the right place, and that took some time because they’re so used to being able to go and do what you want on someone else’s farm – I don’t care what happens over here, that’s not my problem. And I suppose even I, from the traditional trade, going back all those years ago, would probably say ‘you can’t tell us what we can do and what we can’t do. We’re all free trade, we can do whatever we like.’ So everybody’s learnt very quickly: let the industry decide, we all have to work together.

The SCID system has resulted in a system of informal zones, whereby particular companies are known to grow particular crops in particular areas:

But it’s now a voluntary scheme that’s got a bit of teeth, because it’s now sort of saying: well we’ve been growing on this particular farm for the last 14 years, go away, that’s our isolation. And that’s pretty much how it works – if you have the isolation, it’s yours. ...I mean carrot’s a good example. [Company] have their area for carrot and we have our area for carrot. You know, we sometimes get in each other’s way, in fact we try very hard to stay out of each other’s way because it’s in everybody’s best interests that we don’t do silly buggers about it.
It is possible that new growers or production companies entering the seed industry might not participate in the SCID system:

The big danger is you get some of the newer – oilseed rapes I suppose. And we’re actually growing a crop this year but we’ve entered it voluntary into the system because we don’t want to upset anyone else. But the issue is that farmers can just grow it, put a crop in, and don’t enter it. And therefore they can stuff up another crop somewhere.

As noted above, canola plantings for biofuel are perceived as a potential threat to the seed industry. However, this problem is being dealt with as Solid Energy, the company behind biofuel development, has joined the SCID system. This does not deal with the problem of independent canola growers though. It seems likely that a biopharming enterprise would participate in SCID, as it would be important to such a company to avoid the legal and economic costs of contaminating other crops and the negative publicity that such an event would generate.

Generally, production companies consider that the SCID system works well, though occasionally a problem occurs:

It has worked reasonably well, and there’s a fair bit of to-ing and fro-ing between farmers as well. You know: ‘I’ve always grown a crop of beet so please don’t do it yourself, and if you are going to do it, do it in the far corner where it won’t affect mine.’ So it does rely on a fair bit of cooperation, both at the merchant level and farmer to farmer level. But you get the odd snag now and again. But mostly it works.

AssureQuality does not police isolation zones, but facilitates a system through which potential crop overlaps can be identified and worked out before crops are actually planted and actual problems occur. Solutions to potential isolation zone overlaps are worked out by the merchants themselves and rely on good communication:

The one thing we do stress is that this isn’t to stop growers talking to each other. The growers should still be talking to each other. Neighbours should be talking to each other, merchants should still be talking to each other, and so it’s not there to replace that process.

Participant: We have problems with other farmers growing crops.
Interviewer: What happens?
Participant: Well, we talk to each other. One of our neighbours grows carrots. There’s a bad patch, an area where he grows it there’s a lot of wild carrots on the roadsides and what have you…been there for years. And he comes and sprays. He tells us what he’s doing. And we co-exist. We have trouble with some of our grass seeds, with annuals and perennials growing close by neighbours. We just co-exist…. And some farmers just don’t bother talking to their neighbours and they go and plant this crop, and then all of a sudden they have found that there’s hundreds of hectares in a neighbouring paddock, the merchants get pretty upset, and everybody gets pretty upset about it.
We were told of a case where the SCID system did not work and contamination occurred. In this case the problem was discovered and rectified before the crop was harvested:

Participant: We had a case, a whole chapter of errors led to a crop being placed that nobody knew about, right between two of ours. And the only way we knew was when it started to flower we started thinking: what’s that? And what happened there, as I say, because of a whole set of errors, it wasn’t picked up. At the end of the day that crop has been taken out, it has been completely destroyed. All the companies involved have had to chip in quite a bit of money to the farmer to say ‘well, we’ve all mucked up. This is the only way out of it.’

Interviewer: How did it happen?

Participant: Pretty much a difference between an autumn sown crop and a spring sown crop. And I think the firm that placed the crop there were looking at it as an autumn crop. We were probably looking at the isolation as a spring crop, and the two didn’t quite gel I think, more human error than computer error. I think the computer was telling us the right things, but I don’t think either party was sort of recognising it as being the right thing.

Growers consider the SCID system to be very effective in organising isolation zones and enabling growers, and production companies, to produce uncontaminated crops:

Interviewer: What would happen if your neighbour put in a crop while you were thinking about one?

Participant: Well I probably wouldn’t get a contract, because they’d say ‘no, you’re too close to another crop.’

Interviewer: So the seed companies kind of manage it.

Participant: Yes, between themselves and farmers. It works quite well.

Interviewer: Has there been trouble with that?

Participant: I guess so, but not that I’m aware of.

Knowledge of local arable history is also an aspect of achieving successful isolation:

They get to know you. We were growing radish up until about four or five years ago, they just didn’t grow in a sort of 10km radius round here because we’ve got farms spread around, so they said: well, the Xs are growing radish, so we just can’t go there.

However, there appears to be no consensus that standard industry isolation zones are realistic. The discussion regarding bees’ travelling distances in section 5.1.1 illustrates this, as does the following exchange regarding wind pollination:

Interviewer: Is [the isolation distance for] carrots the same, is it 2km?

Participant: Most crops, these out-crossing crops, we go one to two kms. Wind pollination.
Interviewer: So it won’t go any further than that. (He smiles – I say for the
tape recorder!). In your experience is that enough?
Participant: That’s the industry standard, yes.

Another strategy, apart from the SCID system, for avoiding cross-pollination and for
dealing with it if it occurs is temporal zoning, achieved through staggered plantings:

This one flowers in November, and this one doesn’t flower until the end of
December – no problems.

However, there are limitations to this strategy because of seasonality.

5.2.2. Crop rotation and paddock history

Crop rotation, and recording crop rotation, is the central strategy for dealing with seed
burden in the soil:

Any of those oil crops, you’ve got to have a pretty good sound rotation to
make sure you clean them up. [After] about five years [the paddock will be
very clean]. If you’ve done a good rotation you’ve got most of the seeds
grown. I wouldn’t say you’ve got every one.

They will have a rotation of crops that they will go through because you can’t
just keep growing the same thing year after year for disease and all those sorts
of issues. So they will grow grass one year and then clover after that. And then
they might go to a cereal crop and then into peas, and maybe a vegetable seed
crop, and then back into grass.

Different crops require different lengths of time between plantings before a paddock
is considered to be ‘clean’:

That’s exactly the question I was asked by one of our Japanese customers this
morning: ‘How long before you can go back to fields?’ We were saying:
‘We’re up to 12 years now, and we haven’t gone back to one yet. But the next
couple of years, probably the next 3 or 4 years will be tricky’. And then we
should be right - because we should have gone far enough then to be out of the
lie of it. Maybe the next 3 years might be a little bit tricky.

For example, a grower explained the complexity of growing high endophyte grasses
where purity of kind is critical:

We need to be careful when we’re planting that the history’s right. [The
paddock] can’t have grown a different perennial ryegrass with a different
endophyte for five years before that. We plant it in wide rows so it can be
inspected to make sure that there’s no rogue grass coming up.

To ensure that the rye grass seed is pure, such crops are certified independently. As
such growers, and AssureQuality, keep detailed records of the histories of each
paddock on the farm. A grower explained the system:
Every registered grower has a certification number, and each field has a number. So I have a map and my number here is [X] on this farm. You buy another farm you get another number. And this paddock out here is called Paddock [X]. So when I grow my crop of rye grass seed in the first week of October, I fill in a form and it says: this is the paddock where I’m growing it, history of how many years before so they can say it needs to be clean for 3 years previous. And then I have to send the tickets of the seed – so when I buy the seed it has a little label, a registered label with a number on it, a tracking procedure. So I send the tickets away and tell them what field it’s going to be in, and then when it’s flowering an inspector will come and walk that field and look for off types and look for weeds that are prohibited. If it’s legitimate and it’s clean, he’ll sign that off and MAF will send me labels to say that I’m alright. And the labels stay with the seed, so it’s a paper trail again. They go off to the seed dressing plant and those labels are stitched on. So it’s a quality control. And if it has weeds that are prohibited you won’t get your labels, you won’t get certified for that. You can’t sell it. You couldn’t sell it as certified seed.

Likewise, having clean fields is the first method for achieving a good seed potato crop:

You want a clean paddock for a start. In the US, some of the areas where they grow potatoes there, they get huge frosts, thermo frost – frost goes down through the soil and it will destroy any potatoes that are left behind. But in New Zealand we have what is called self-sets – if we leave a few potatoes behind they can keep growing year after year after year. But you can put sheep in to eat them, that’s one way of getting rid of them. They do well on potatoes. You cultivate. And then we’ll put the sheep in. And they’ll scratch sometimes if they can smell a potato. You have wheat and barley and break crop, and then hopefully when you go back to the next crop of potatoes, you’re not going to have these foreign ones coming up again.

As with grass seed, detailed records of crop rotations are kept:

Because for seed potatoes we’re not allowed to grow any closer than one year in six, one harvest in six.

More record keeping. And our computer’s helped that a bit, too. But we’ve still got things on the wall like that [points to crop rotation chart on the wall] which you can easily look at and: that’s the crop rotation. You ask me about a paddock and we can go back further than that. I can tell you what was in it five or six years ago.

Brassicas, however, are not so easily dealt with by rotation practices:

It’s not like the brassica seeds. Some of the brassica seeds can last for years and years. They’re a hard seed which means it can survive in the soil. But the grass seeds – that’s why there’s a two year break between one variety of rye grass and another one.
5.2.3. Monitoring and Rogueing

Crops can be contaminated from a variety of sources: cross pollination, plants in the wild, old seed in the soil, the dispersal of seed by birds and other animals, and through the spread of seed during and after harvesting. To deal with what seems to be the inevitability of some contamination, crops are monitored very closely. Seed production companies employ field staff to do this:

We have 14 field reps, they’re basically agronomists who have their own growers that they’re allocated to, therefore their own crops they’re allocated to. And that’s their job, to produce the 30 or 40 crops we’re doing. Their backgrounds would just about always be Bachelor of Science, Bachelor of Ag Science, whichever, …an agronomic scientific type background, interested in chemicals and sprays, and all these sorts of things that go on – that’s the sort of guys we look for.

We asked how often field staff would visit growers:

Maybe twice a week. At this time of the year it might be three or four times, because they’re working in relatively confined areas, they’ve going round the crops certainly once a week, sometimes three or four times a week.

We have a system where we visit every two weeks, every 14 days we walk the crop and take our photos and do a report on it. And take note of any weeds or diseases or insects.

Production companies said that in general growers follow the guidelines stipulated:

Interviewer: Do the farmers mostly follow your direction, or do they have their own kind of ideas about what should be happening?
Participant: A little bit. I would say that 90% of our farmers would, dare I say it, ‘obey our orders’. I mean if we need chemicals sprayed on, they’ll get a written instruction that we want this, this, this done. And, yeah, they’ll go and do it. A lot of them rely on us totally, some of them are a bit more forward than that and get on and do a bit more themselves.

Growers, it was said, did not resist this involvement, because production companies and growers have common interests:

Interviewer: Is there farmer resistance to people like you turning up and going ‘spray now.’?
Participant 1: ‘Spray now’! It’s slightly more diplomatic!
Interviewer: Because dairy farmers, I know some of them are very resistant to being told by anyone what to do.
Participant 2: No, not at all. The farmers I deal with are very, very recipient to the advice, and, as you say, it’s the way you approach the subject. They know that you’re there protecting both your investments, so, yeah, they’re recipient to what you’re saying.
Interviewer: So they regard you as pretty much on their side?

Participant 2: Yes, yes, they do.

Participant 1: If they thought for a moment that we weren’t on the side with them, well, they’d go elsewhere.

Furthermore, if growers do not follow guidelines, they will not get further contracts:

Those who aren’t diligent in their farm husbandry, you don’t go back there next year. But there’s not many of those fellows now. The growers we deal with, they’re all well aware of the risks, and, let’s face it, no money at the end of the day. The quickest way to learn is through your own cheque book.

When weeds or undesirable plants (called volunteers) are found, various steps are taken to remove them. One way is by rogueing, where people walk through crops and rogue plants are pulled out by hand:

At this time of the year we have all our rogueing gangs on for off types, when the crops are nice and short, so we get in there and look for things that shouldn’t be there.

With the garden peas they rogue them, which is go through and take any off types out, so they’ll walk the paddocks. With our peas [company] have a team of people to do that. …It’s not actually that big a job and it’s quite easy to do once you know what you’re doing. They usually go through just on flowering and the ones they don’t want quite often have a different coloured flower. So you’re walking through a paddock full of white flowers, and there’s a purple one, you pull it out.

Participant: We don’t have contamination problems really with potatoes. Very seldom, in today’s crops. But we go through the crop, walk through it two or three times in the season, looking for any foreign variety and any virus that we can identify. And you dig it up and take it away.

Interviewer: So how long does it take to walk around?

Participant: We usually only go in the mornings, when it’s good light and no wind. And same with a grass seed crop, we might walk through that crop, and if we can see, later on, a foreign grass, we’ll pull it out.

Interviewer: And is it quite obvious?

Participant: Some. And we have an inspector to come through and he walks through that paddock. …We’ve gone through and taken anything out before the inspector arrives. And the inspector looks at grasses. He looks at all crops – brassica crops too. When you’re doing it all the time, you get a good eye, and you walk into the paddock and look around. They will pick anything very quickly. That’s the only way. Once you’ve harvested the paddock you won’t see the difference….

In some cases the international customer even comes out to New Zealand to check the progress of their crop:
Well this morning we had three lots of customers here, and...they’ve been out here walking the crops, again while they’re nice and small so they can see things, and say ‘well, you’ve got to look for this one,’ and we’ll get a diagram drawn for us saying that. Yeah, [plants that] don’t look right. …Different colour, or slightly different green, or one’s tall, the other one’s short. Or different leaf or something like that. We just pull that now while we’ve got a chance.

Volunteers are also dealt with through spraying:

There are weeds, you do get weeds, but the herbicide’s pretty good that we use.

Things get in – wheat and borage seed can be about the same size, and they’re about the same density so when they’re trying to separate the two it can be quite problematic. But you can spray one or the other. So there’s all these things about contaminants – so if you’ve got wheat in borage, it’s easy to spray. There’s a grass killing herbicide that kills grasses and not other things, so I can kill grasses out of phacelia, out of brassica, but I can’t kill a grass out of another grass. So to kill a grass out of wheat’s quite difficult, it can be done. To kill wheat out of grass is the same.

As well as rogueing the crops, production companies search for other sources of contamination:

We have to go round where all our carrot crops are grown, up and down all the driveways and roadsides and spraying these things out because we don’t want them cross pollinating with our good carrot seed.

On the side of the road, where you get the stuff growing along the side of the road, we actually go round the roadsides here on the odd occasion with a bit of spray and knock out any volunteers that we see. And we walk the fence lines and spray them every year.

Companies work with adjacent farmers to reduce possible contamination:

That’s part of the diligence. [The rep] would walk the paddock and look for fence rows, hedge lines, anything that has contaminate weeds that are going to cross pollinate. So it’s not just an adjacent crop, very often it’s – let’s say that someone grew Swedes, and they stayed resident in the soil, the next thing the bastards are all taking to seed and the guy’s crop is yellow – we can’t have that. So [the rep] and the farmer would spot this, go over to the neighbour and say: ‘Can I mow this for you?’; ‘Can we spray this off?’ . So, yeah, the answer is we can get pretty pure.

Companies also work to educate local people about the risks to the industry posed by their garden plants:
I mean there’s increasing awareness all the time. And the companies that are involved are always telling people: look out for it, be aware of it.

We were told that companies would go to houses and talk to people about their gardens:

If we really think there’s something there [or if] somebody new moved into the neighbourhood.

5.3. Industry Evaluation of Risk

Achieving crop purity requires managing a number of sources of potential contamination: cross-pollination by wind or insect, seed burden in the soil, contamination by domestic or wilding plants, and spread or mixing of seed during harvesting and post-harvest transport, storage and processing. These are some of the vectors through which a biopharm crop might contaminate other crops. What is clear is that it would be extremely difficult to eliminate such risks entirely. “You can never be 100% sure -- which has some implications with what you’re talking about, obviously”, one production company representative said. However, while it may not be possible to eliminate these risks completely, as described above, there are procedures in place to manage and reduce those risks.

We asked participants whether they thought it would be possible to contain a biopharm crop in open field growing conditions. Growers told us that they could manage risks to a significant extent under current management practices:

Participant: I think that there are systems, and I mean growing a genetically modified crop that requires an isolation, that requires all the care and attention, I don't think is a hell of a lot different to what we’re doing with a particular radish variety that requires 5k isolation and requires all the things done to it. I’m not sure that there’s any difference in the practices to get them grown.

Interviewer: So do you think you could probably safely contain one of these crops?

Participant: Safely contain…I think the protocols and the systems that are in place, even now, might need to be tweaked a bit. But probably strong enough, or getting to the strong enough stage now to be able to handle that.

Interviewer: Do you think it would be possible to fully contain a crop?

Participant: Yeah, the likes of [company] have a pretty good reputation internationally for doing just that. So what will happen, say if they’re growing a radish crop 2km over there somewhere, they’ll drive round the area and if they see that we’ve got some rogue radishes growing in this wheat crop because we had radish there 10 years ago and there’s still a few seeds left in the ground, they’ll actually ring us up and they’ll say ‘look can we come out and rogue your crop, get them out of the ground?’ Or they’ll say, if it’s bad enough, in fact there is quite a bad one in the farm we used to own just down
the road, they’ll probably say to that guy: look, next time you’re going over it can we give you some chemical to put in there to take those out because they’re going to give us problems. And it’s because their buyers will come out from Asia two or three times a season, and they’ll be driving round and they’ll be inspecting their crops, and if they see those other things, they’ll say: no, we don’t want it.

However, they say, in the final analysis it is never possible to 100% guarantee containment in the open:

At the end of the day it’s the same, that the biggest risk is probably pollen escape. And in the Canterbury Plains, I don't know how you ever restrict that. Because I mean if you’re growing a GE crop for instance is grown here, it’s probably likely that the outcross is going to be not just 10 yards down the road, but probably 10k or 15k down the road. So 3k or 5k isolation’s probably a waste of time. …I think that’s the scary thing, because as I say we’re no different to some areas of the States that have a prevailing wind. I mean when our wind blows it blows big time, and it doesn’t matter how good your isolation is, and it doesn’t matter how good the tree lines are. We count on all those kind of things trying to help us, but we’ve had experience.

What this participant is saying is that it would be impossible to fully guarantee containment in an open field environment:

Interviewer: So are you saying with some of these brassica and pollinator crops, you couldn’t possibly keep the pollen and genetic material contained?
Participant 1: Not 100%.
Interviewer: Not in a field.
Participant 2: No, not at all.

Likewise, production companies say that it is impossible to guarantee one hundred percent containment, but, as they point out, nothing can be one hundred percent guaranteed. The sense that emerges from talking to production companies is that while risk cannot be eliminated it can be mitigated to a considerable extent. Further, as the following chapter will illustrate, neither growers nor production companies consider that genetically modified plants present risks in and of themselves. As such, their statements concerning the inevitability of risk must be interpreted in light of the fact that they do not consider that risk to be very great at all.

5.4. Discussion

Growers identified a number of sites at which biopharm seeds could escape into the environment and potentially contaminate other crops and perhaps enter the food chain. They also pointed to a number of ways in which a biopharm crop could be contaminated. However, growers also noted that there were already systems in place to deal with many of these risks. The risk of cross-pollination was dealt with through the SCID system, and the emergence of volunteers through seed burden in the soil
was dealt with through processes of crop rotation, spraying and rogueing. Machinery could be cleaned, or designated machinery could be used, and there were kinds of trucks available that would reduce the risk of escape at this point in the process. Seed cleaning plants already have systems in place to limit the chances of different seeds being mixed. In fact, growers claimed, the most common source of crop contamination was from contaminated source seed, and this was to do with the practices of the breeding companies themselves. Moreover, the botanical particularities of different crops could be put to use to reduce risk – it appears that using brassicas for biopharming would be particularly risky.

Growers said that they could produce largely uncontaminated crops, if not 100% pure. They achieved this through the agronomic practices discussed above, along with well established traceability and certification systems. And this whole range of practices is backed up with multiple inspection regimes which ensure practices are carried out correctly, and testing procedures that assess the inspection regimes. Growers experience successfully growing crops where containment and contamination are significant problems, and it is on this experiential basis that their claims that they could grow a biopharm crop with a high degree of safety are based.

However, it is important to note, as growers and production companies do themselves, the impossibility of guaranteeing 100% containment when growing an open-field crop. What this indicates is that the harm that would be caused by a seemingly inevitable escape would need to be considered carefully when developing protocols.
Chapter 6: Biopharming Scenarios in the Arable Sector

This chapter discusses the biopharming futures imagined by participants. The scenarios they outlined and their understandings of the desirability of biopharming development and its likelihood were based on their experience of growing a wide variety of crops with a high degree of success.

6.1. Desirability: Would the industry turn to biopharming?

We asked growers whether they would be willing to grow a biopharm crop. All said that they would consider it under particular circumstances, namely changed public attitudes to genetic modification and economic returns:

Oh, I’d grow it…it would have to be safe and what have you.

If the crop was available and it was, and GE was allowed in New Zealand, we would certainly be interested in doing it, especially if it was financially viable, a good pay out.

I’d be very interested to have a look at it. Those sort of crops would be a break between the grains. I guess there’s a fair bit of expertise and attention required to those crops too. They’re probably not grown on a large scale, I imagine. But I would hope that there’s potential there for a good income. And the continuity, if you get a contract to grow some each year. But it would be a new crop for me. We’d have to give a lot of thought to security and isolation, I guess. Because I imagine there’s a lobby that don’t like even those sort of crops.

It’s got to be financially viable. It’s got to be financially worthwhile especially if there’s going to be an extra effort involved in growing and isolation. And by the time we start thinking about growing I would hope that the problems perceived by the general public will have been addressed. …I wouldn’t be daunted by it, I’d like to go through the exercise.

I think it would be quite exciting. It’s nice to think that arable farmers of the future have got possible potentials of another choice. Because all doing the same old thing over and over and over. But in recent years it’s become quite exciting because we’ve got new techniques and new knowledge. And although we’re not getting paid as much as we hoped, we’re being able to produce more per hectare.

I think I’d be reasonably up to do it. I suppose there is a risk that, for a start, it would have to be financially rewarding. Because it’s something not the normal, and there would be a lot of hassle factors. Depending on the area, I suspect it wouldn’t be a big area, and I think it would be that – depending on what type of crop it is – whether there would be issues with volunteers or seed contamination or whether we could grow something else in that crop. If it’s
genetically modified, it may cause issues in the future if the seeds are still in the ground. …We’d want a long term commitment from the company or they may have to pay a bond or some security for the future.

We were told by farmers that other growers would be prepared to grow either biopharm crops or genetically modified crops, if the money was right. Growers constantly said that “somebody” would do it; “somebody always seems to”.

Interviewer: Do you think farmers would?
Participant: At the end of the day it all comes down to dollars. So if it’s the best farming crop in the district, you will have no trouble.

There’s farmers out there that would say ‘oh, there’s nothing wrong with it, let’s just get into it’ without considering what effect that might have on their neighbouring farmers.

People need to survive, farmers, we want to be as wealthy as doctors, that’s our dream, we all want to be as wealthy as the doctor, and it purely comes down to economics. So if these crops are economical to grow and we’re allowed to grow them, people will grow them with no issues.

One grower said he would not grow a biopharm crop in practice, though he would in theory. His reasoning was similar to the growers above, but his conclusion differed. This was for practical reasons to do with his farming system, not because he had negative views of genetic modification or biopharming:

Interviewer: So under current practice – would you do it?
Participant: Oh yeah.

Interviewer: Do you think you could contain it enough?
Participant: What is ‘enough’? Would I do it? No, I probably wouldn’t because I’ve got this ‘keep it simple’ thing, and I would think that it’s going to be 3 hectares of crop, not 33. So it’s all this what we’re talking about of contaminating. And saying ‘right, we’d need to clean this dryer out and clean the floor out before you do the next crop’ and that’s not the business I’m in. I used to do that…But there are a number of farmers that quite enjoy that attention to detail aspects of that. So it’s not for me, but I think for a number of people, and it’s the economics basically: ‘A small block, but I can make as much off this as three other fields. So I’m quite happy to go through what it takes’.

Interviewer: And like you say some farmers might actually enjoy that.
Participant: There are a lot of them out there that really enjoy that. …I used to enjoy growing these different crops as a conversation thing. People who knew nothing about arable farming, it was quite interesting as opposed to ‘oh, yes, I’m spraying my wheat at Stage 32, with 2.4 litres of…’ . Nobody wants to have a conversation about that, they just want to go home.
Production company representatives also indicated that there would be little resistance within the industry to biopharming:

There’s not really a particularly strong farmer to say no. Individually they’d probably say, oh, if the price was right. Yeah, of course they’d grow it. So I think it’s at that stage. But there doesn’t seem to be, certainly from where we sit, there doesn’t seem to be any great pressure being applied on our side of things for genetically modified vegetable seed to come through.

Growers were quite prepared to consider growing a biopharm crop because, as is illustrated above, they have a high level of confidence in their ability to grow such a crop safely. If there are any risks, they say, science can sort it:

Interviewer: What would be the major risks for growing a crop that would face a farmer?

Participant: The risk would be if you grew a crop and there was the issues that it could, cross contamination and also – but a lot of those issues aren’t that bad. And also getting mixed with something else that it wasn’t supposed to be mixed with.

Interviewer: Do you think the science could sort that?

Participant: Yeah.

And, if science did not sort it they would not grow it:

Either we completely understand the science or somebody else takes the risks really, I guess that’s probably where it’s at.

Growers, it seems, have no doubt that science can provide the answers, and that they will be able to evaluate them. Linked to this confidence in science is the general situation that growers did not perceive that genetic modification presented extra risks in and of itself:

Participant: I guess that would depend very much on your attitude on the ability of genetic modification and whether the technology can actually jump from one. I don’t believe that there’s a high risk there at all so I wouldn’t see that as a big problem. Really the only ways that things can jump is through the pollination process or whatever the reproductive process is.

Interviewer: And how would you control that?

Participant: That comes down to isolation from other crops, that’s really the only way of controlling that and that’s no different to our other seed crops, and the likes of Asian brassica seeds that we might grow.

However, growers also noted that it would not be likely to be in any individual growers’ interest to be the first to grow a biopharm crop:

Well, there’s the old Chinese adage: never be the first upon whom the first is tried, nor the last to see the old goat. So do we want to be number one off the
block, or you can say, well, we’ve got two farmers that have done this already, this is the problem, this is the possible returns.

Likewise, production company representatives considered that while biopharming technology was available, it would not be prudent to be the first to grow such crops:

The technology is there, and I think that’s acknowledged by probably everybody, certainly the major players in the vegetable seed industry. Because of the links back to Monsanto and these sorts of people, that technology is there. They spent huge amounts of money on that technology, and they all got to a point of saying ‘we’ve got it, we know it works, we can do anything you want us to do, now what do you want us to do with it?’ They said: well, can’t do it in New Zealand, and Aussie doesn’t want it. Nobody in the world wants to step forward and say we’ll be the first ones, at this stage. So pretty much it’s parked, and I think that’s where it stays. I mean we do not grow genetically modified vegetables, we have to ask the question every time of our customers, and they all say the same thing: we’re not going to be first.

6.1.1. Risks: Contamination of food supply/other crops

We discussed with growers two potential risks presented by biopharming: contamination of the food supply chain and contamination of farm land. What the following discussions highlight is grower belief that these risks are technical rather than moral or ethical and can be dealt with, and, that the most significant risk for them is not environmental but economic. The discussion also illustrates that the risks posed by biopharming, and potential solutions, would depend very much on the plant modified, and that growers were well aware of this. The most significant risk a biopharm crop poses is its potential to escape and to contaminate other crops, and possibly enter the food chain. We asked growers to think through the issues in growing a biopharm crop or replicating genetically modified biopharm seed, and to consider the risks. The issues are somewhat different for each scenario.

Growers said that containing a biopharm crop (as opposed to replicating biopharm seed) would present few problems. Crops that produced a biopharmaceutical substance would be easy to contain because they would never be allowed to seed. This could be done through existing breeding processes:

A lot of those hybrid maizes that they grow, up in north Island, even the seed won’t grow again.

Terminator genes were another clear option (provided GM was allowed).

The seed might have a terminator gene in it as well. It would only have one lifecycle, then it falls on the ground, it won’t grow anyway. Like, in the hybrid maize, you can’t keep the maize seed and grow it next year because it just doesn’t grow. And it hasn’t got a terminator gene, that’s just how it is.

Another grower cited the example of opium growing in Australia to show that there are no serious issues with growing a pharmaceutical crop and as a model of how biopharming might work:
When I worked in Tasmania one of the people over there was growing opium, because all the pharmaceutical grade opium in the world is produced in Tasmania. It’s specifically grown as a crop on sheep and dairy farms. Only when it’s in the husk, in the head, is there a problem. I mean sheep quite happily eat the green plant that’s growing, there’s no issues there, and those heads, they’ve got their own specific harvesting machines that have that stuff, and then it’s taken to specific processing plants that handle it. And that’s where I see a specialised crop growing. That they would be producing it and it would go to their own plant.

It was noted that the risk would depend on the toxicity of the modified plant. Though this grower did note that there were potentially serious risks if the plant was highly toxic, he downplayed them:

Say you were growing a bio crop that they then took the seed away and extracted something from it, well that type of crop’s going to have very few issues because it’s just a crop and it’s what they’re extracting from it once they’ve got the crop. Unless it’s growing to spread, which realistically, with a seed crop, isn’t really that much of an issue. The birds might eat it, but I mean if it’s only going to grow as a wheat plant in another paddock then that’s not really going to matter. Unless that wheat plant’s going to be toxic and it’s going to kill animals or people. …But unless that, if it’s something they’re extracting from the plant and it’s just a normal plant, well, it’s not an issue. But if there was something on the plant that you had to keep within a refined area because it had issues with humans or if it got into the water it contaminated it, or what have you.

It depends very much on whether that technology was to move to a cabbage or something like that, whether there’s actually any risk associated with that, whether that means that the person that ate the cabbage in China in two years time actually dropped dead, or whether they got some free benefits or something.

As such, risks, and solutions, would depend very much on what crop was grown. Growers said that you would choose what crop you modified carefully:

Yeah, a wheat crop for example potentially would travel five or ten metres or something like that. You get the pollen crossover. But brassicas are different that are carried by bees, so if you’re selective in your crop…. The other extreme is a potato or an onion where it’s clearly not going to flower anyway, so if you’re involved in that kind of production it’s quite simple”.

6.1.2. Risks: Contamination of land

Another issue presented by biopharming is the potential contamination of land, and the inability to grow other crops on that paddock if a biopharm crop had been grown there. The risk though, for growers, is the risk to the farm business, an economic rather than a health or environmental risk. The risks this grower is weighing up are the comparative risks between growing a biopharm crop and a different crop:
I guess right at the start I’d have to say well the seed’s obviously got to be sourced from somewhere, we need to know that the seed is pure, if it’s come in from say, UK for example, they’ve got some bad weeds over there that we don’t have and we don’t want. So we need to be comfortable with that. So there’s those biosecurity risks that aren’t necessarily related to the GM side of it…There’s a lot of seed that’s impounded and forced to be cleaned as well. So it’s no riskier, it wouldn’t be any riskier than anything else, but it’s just something we’d need to consider.

The risk is that of a poor economic return:

What it really comes down to is: is it going to perform both in yield and quality so you end up getting your expected return on the crop. If it doesn’t yield because you haven’t been able to use certain fungicide technology or whatever and you end up with a lower proportion of the end product within your wheat crop because you’ve used some insecticide or whatever, you need to know that you’re not facing that risk as well.

We grew oil seed rape probably twenty years ago and some of it’s still coming up now. So I guess we made the decision at the time that that crop was valuable enough that it meant that we probably wouldn’t grow any high value brassicas there for at least ten years. Some of the management techniques are better now…. So you can manage around it a little bit, but I guess when you put a crop in that’s one of the decisions you make: is this valuable enough.

The solution to this risk is financial guarantees:

Yeah. I mean if you were going to tie up a paddock so you couldn’t use animals on it for a certain number of years, you’d want to be financially compensated accordingly.

If you got paid enough and you just kept Rounduping it out. Because basically there’ll be a chemical that’ll kill it, you just keep the paddock sprayed out so it wouldn’t be an issue.

The decision for growers, then, appears to be driven primarily by economic considerations:

I think it could be handled, depending on the financial arrangements, and that would certainly have to be – that is certainly a major consideration or why would you do it? I think we’d like to have some sort of commitment, or a bond or something. Or something like that. I guess, I would imagine it’s pretty lucrative for the people involved. We’d have to weigh all that up.

Growers did not discuss potential environmental and health risks (as might have been expected) because they consider that those risks can be largely controlled. This position is supported by beliefs that growing a biopharm crop would not be significantly different than growing any specialised crop:
It’s not dissimilar to these endophytes, novel entophytes that we’re using – we’re actually contracted to produce a level, I think, of 80% of an endophyte. Now we need to make sure that the crop that actually comes in, that we’re planting, or the seed that we’re planting is at least 80, preferably 90 or 95, and there is nothing that we know that we will do in the growing that will actually force the level down to 60%. It’s really no different to that.

A more relevant risk for growers is from anti-GM protesters:

Participant: I imagine there’s a lobby that don’t like even those sort of crops …Well we’ve had potatoes ripped out of the ground at Lincoln College that students have done two or three years of research on – the whole thing just pulled out of the ground. …If you poured a lot of money in, there would be more good reason why you don’t want anyone to destroy it.

Interviewer: How could you deal with the potential protester?

Participant: Well I think we could grow it and we wouldn’t be telling anyone. But of course there’s a few people always looking over the fence. I’m not sure of the issues on that.

Generally, then, there is little resistance to the idea of biopharming in the seed industry, with many participants stating they would be interested in growing such a crop. The primary risk of biopharming for participants was economic, at both industry and individual farm levels. Risks of contamination of the food supply chain or of the land were considered to be primarily economic risks, rather than environmental or health risks, and participants were confident that risks could be managed successfully under current management regimes. Despite this attitude, there was widespread agreement that biopharming was not likely to develop in New Zealand.

6.2. Likelihood of Biopharming

Having discussed the desirability of biopharming, we then asked participants to consider the likelihood of biopharming developing. Industry participants noted that the impetus for such a development was likely to come from outside of New Zealand:

Participant: If it’s one of the big fellows and we’re doing a significant amount of business with them, you’d have to weigh that up. And saying, well, no, we’re not going to do that one, but we’ll do all the others, they might just turn round and say: either you’re doing that one and those ones, or you’re not doing any of them.

Interviewer: So you think that could happen?

Participant: It could. Some of those companies would be that way inclined. If push came to shove. A lot of these customers aren’t exclusive necessarily with us. A significant number deal with each of us. …As we do with our growers, yes. We growl at them saying: the best approach would be to be exclusive with us, we’d get all the good growers and everything else. I mean, put yourself in their shoes, they’re not going to do it. And I can understand that too I suppose. I suppose if this type of push was coming from the Monsanto type companies,
it’s going to be hitting us, it’s going to be hitting others as well at the same
time. I’m sure we’re all going to get pinged at the same time.

A couple of growers suggested that New Zealand might be a good place for
biopharming development because of its isolation and the relatively small size of the
arable industry:

New Zealand might have some advantages because of its isolation. And South
Island. We’re surrounded by sea, aren’t we? So does that help us keep purity
and stopping cross pollination – vehicles, people, wind…you could have a
specialist pharmaceutical enterprise there. If farmers got together and
protected themselves from contamination and whatever. …Even North Otago,
there’s only about 3 arable farmers there. They could have a unique industry
there.

Maybe it’s [a good idea] because we’re not commodity producers. We’re not
large scale operators. We’ve got a very stable climate. And probably one of
the best growing mediums you can find for conventional plants, not, say, for
warm climate plants. So, if it meant that we had to import some barley for the
pork and poultry industries, I guess it’s no big deal. We already import a lot of
our flour requirements. We’re not self sufficient. So it’s not like a food
security issue, that we’ll have to import food.

Moreover, replicating biopharm seed may well be a small industry in terms of land
area needed, because small crops produce enormous amounts of seed. As such
biopharming could be integrated into the existing industry.

If you’re replicating the seed. But you don’t need very much seed. For
example a brassica crop might be sown at 5 kilos per hectare, and it might
yield 4000. So you don’t need a lot of base stock.

The way the seed crop system operates, say we’ll grow 10 hectares of turnip
seed and we’ll get two tonnes of seed [per hectare], that’s 2000 kilos. So we’re
going to get 20 000 kilos of seed. When you go and sow a crop, you’ll sow 4
kilos to the hectare, there’s enough for 5000 hectares, which is about the New
Zealand market. So the seed brassicas, there’s not that many grown if you
know what I mean …One or two paddocks might be grown in New Zealand of
each different variety, so there’s not a lot grown.

6.2.1. Barriers
Growers identified New Zealand’s GM-free status, and public resistance to the
introduction of GM (GE), as the most significant barrier to the development of
biopharming:

Yeah the GE. Biopharming itself’s not a problem. But the GE.

If consumers said ‘we don’t want it’ we’ve got to listen to them. Whether
they’re right or wrong. I’d be banging my head up against a wall if it’s ‘oh no,
you’re all wrong, I want to carry on growing it’ because if they go against me,
and I upset them – we get contamination we can’t control, there’s always that fear I suppose.

It’s only ever going to be an issue once we’ve got [to] a point where there’s general acceptance in the community that we can grow these things. I mean it’s all very well talking about them but I assume we all know that we’re actually not going to grow anything GM for at least ten years.

Similar sentiments were expressed by production companies:

I think at the moment because of the public stance we wouldn’t. Except that we’re not that naïve as a business that if there were opportunities, with all the right controls in place, maybe we wouldn’t. I mean our directors aren’t completely blind to what is happening worldwide.

Yes, if there was financial benefit…. It’s the sort of thing that [the company] would do if all the other issues were sorted out … [if] that [public resistance] waned, yeah, and if there was a strong feeling that we could do it, manage it properly.

As a result of public resistance to GM, there was no pressure from within the industry for the introduction of biopharm crops:

I don’t see it happening to be honest. I don't think there’s a will. I don’t think there’s a farmer will to have it happen.

Some in the industry considered that they benefited from being GM-free, and stated that biopharming would pose a risk to their livelihoods:

The one thing that New Zealand is known for is our purity and quality of our food. We’re getting multiplications for the various things.

My attitude still is, that I’m quite keen to see New Zealand stay GM free because it appears that we’re now getting some margin by being GM free, so we’re getting a premium. A friend of mine is involved in German oilseed rape production, and he’s saying that there’s a premium on GM free. So it’s a genie in a bottle, we can’t just grow a little bit. We’re either in the GM market or we’re not.

At this stage we’re probably one of the few places in the world that has this non-GE where you do grow a lot of these vegetable crops. In the southern hemisphere probably the next one you’d look at would be Chile and they’re flat out growing GE stuff there. They’re totally open.

Participants noted the consequences of something going wrong in the context of widespread anti-GM sentiment:

Participant: There is a lot at stake if we get it wrong. …Contamination. If we got it wrong, we’d destroy our industry.
Interviewer: So if there was one that got out…
Participant: And did something nasty. And our customers said ‘that’s it’ – we’re history. So whatever we do, we have to be very careful. And with these crops, a lot of these crops we’re dealing with, as we’ve just been talking about, the contamination is potentially a big issue. From where we sit it’s much more likely to happen than it is perhaps with a dairy cow. Because of the seed in the ground or the bee flying the pollen off somewhere else. So, it’s be very careful. We wouldn’t rule it out, but we’d want to be very careful.

Growers tended to consider that public resistance to GM will diminish over time, particularly in relation to pharmaceuticals:

[Its] back to how the public perceive it. You know, insulin’s genetically modified, that’s reasonably well accepted. So I think there will be an acceptance by the public.

I believe in a couple of years time, just like bio fuels – growing ethanol and bio diesel is the change for climate change, the politicians will say GE crops are going to be the saviour of the world.

I don't think just at the moment we’re quite ready to accept the GM. I think we probably will in the future when there’s better knowledge and better information coming out. And when they accept the demand, especially for the pharmaceutical type plants.

There is, however, also a sense that the introduction of GM into New Zealand is inevitable and that there are risks in continuing to resist the technology.

It is inevitable that there will be growing crops that are genetically modified. So, given that inevitability, as a nation, what’s our stake, what’s our position? Are we going to hold off the inevitable for ever and use steam engines, or are we going to go to internal combustion? Because it’s inevitable.

One cost would be the loss of scientific expertise, presenting a risk to the future of the industry, to science and to the economy; “the science will stop and it will go someplace else”. Another cost is economic:

On one side, we’d say ‘we don’t want [GE]’. On the other side, if you look through the logic of production and the amount of production and how it’s going to be done, and where it’s going to be done – are we being bloody stupid in saying we’re better than anybody in the world, we’re just sitting here growing all these things. Because maybe that production would then, you know, if they come to us and say: we’ve got this new thing, can you do it? We say ‘oh no, we can’t.’ ‘Well, fine, we’ll go and find someone else to do it.’ And then five years time it’s gone anyway, you never get it back.

In the current political climate then, participants consider that biopharming development is unlikely.
6.2.2. Who Benefits?

A further potential barrier to biopharming development was the general grower view that the economic benefits of biopharming (their primary motivation for considering it) would be unlikely to accrue to the growers of biopharm crops:

It only benefits industry on the supply side really.

This position was based on experience of the returns from growing specialty seeds:

We would be sceptical about it if we hadn’t been involved in some of these things. It’s generally priced to the next best commodity alternative. So unless we’ve actually got a stake in the technology that I would like to think we could have, as an industry. So unless we’ve got that stake, there’s no real obligation on the owner of the technology to pay a reasonable proportion of the value of that. So if wheat’s worth $300, there’s a bit of extra hassle involved, and a few risks, you might have to pay us $350 to get it grown, but somebody would do it.

As this grower notes, the major beneficiaries of GM technology are multinational companies, and this was considered to be likely to be the case with biopharming:

My opinion is that it benefits the companies – I’ve seen it in America, what they’re doing with soya beans, and corn and I think there’s a small benefit to the farmer, but the big benefit’s to the company because they get to sell their seeds and they get to sell their sprays to match the seeds. So it’s multinationals....

Growers considered that any economic benefits would accrue to those who owned the intellectual property, and that for New Zealand to benefit from such developments the scientific developments would have to happen here:

But the problem will be if we’re not well up there with the capability – our scientists aren’t doing – we’ll never be first and we therefore won’t be able to actually get any value out of it.

Moreover, any benefits to growers were not likely to benefit all growers but only a few:

It would be a sort of the haves and have nots, I suppose. There would be some that are into it and some that aren’t. And there may be a bit of tall poppy type stuff, I don't know.

6.3. Biopharm Scenarios

Having discussed the desirability and the likelihood of biopharming developing in New Zealand, we asked participants to consider how, if it were to be done, plant biopharming would be done in New Zealand.
6.3.1. Mixed Biopharm/Food Cropping

Many growers said that if a biopharming industry was to develop, it would likely happen within the existing industry structures:

I think if it was going to happen it would have to be in a smaller part of a large farm, and it would have to be isolation surrounding it somehow.

Interviewer: So do you think people would do it as a crop, or would you get specialist biopharmers?

Participant: I mean it would depend on the crop. But as long as it was financially viable and the restrictions weren’t too great you’d have no problem growing it.

Growers cited the organisation of specialist vegetable seed growing as the most pertinent model for potential future development:

I would see that coming in through a firm, or the people who were wanting the product would have to have that sort of knowledge themselves. Like the stuff we’re doing, if you look at the bio diesel that is coming through Solid Energy at the moment, they are actually setting up their own agronomy side. They’re setting up their own side of the company that’s going to do that. So they’re going to have men out there doing the paddock work. Farmers are going to put the crops in. But they’re going to have people out there doing the brokering and the agronomy side. So I would see that if these bio crops were going to come, they would either be done by a firm that sets up their own agronomy side and puts their own reps out on the road, or else the firm would go to someone like Wrightsons. Probably the Asian brassicas are the best ones to look at because basically there’s firms set up specifically to grow those Asian brassicas for Asian companies.

We asked a grower whether not growing other food crops in close proximity to biopharm crops would be one way to control the risk. One grower’s response indicates that he considers that the potential risks in growing a biopharm crops within a wider arable farm were manageable:

Well, not really. Because I mean it’s not going to transfer. I mean I don't know. I can’t think of any examples, I’ve seen a little bit of the ideas that people have got. But if you use wheat as an example that could be a little bit more difficult than a brassica crop because you’re going to have wheat each year grown on your farm, but you wouldn’t necessarily have a brassica crop and you certainly wouldn’t have a brassica crop in the same paddock each year. So if it was some completely different type of crop, say cotton for seed, you could bring that in and put it in that one paddock then next year go to another paddock, and that one might not go back for 10 or 15 years into that same crop. So I guess the more diverse the crops are that you actually biopharm, that the easier it would be to control, rather than just go for the straight commodity crops.
A grower told us that GE crops had been trialled in the past, and as such there were established models and practices for dealing with potential risks. The grower told us that he did not think you could guarantee containment 100% in open field growing:

I would think there’s no way of it not getting out. Outside of full containment, laboratory type conditions.

He went on to describe how the GE crop was grown:

Participant: We’ve grown GM crops in this district before…. Before the moratorium came on.

Interviewer: What was grown?

Participation: GM rape. In tents. And hand harvested. …It was a trial. Completely covered with tents and they came and hand cut it all, took it away. And then they came back and checked for the next two years, in theory. So I’ve seen it. That was just literally next door.

6.3.2. Specialist Companies

Some growers, considered that the most likely trajectory would be for the seed breeding company to own and operate the entire production chain:

I think if they were going to do it, they’d specialise in it.

I think, to be honest, if a company was serious about doing it, I think it’s probably so lucrative they could just go and buy the farm themselves and manage it…. The other thing is they could lease some land off an enlisted farmer. …Depending on how you want to do the corporate thing, I don't know. I think that the two have got their advantages. The thing about the corporate buying the farm [is that] they control everything. Then, as long as people are rewarded well, they’ll stay around. And it’s reasonably transportable, the management. I mean there is a lot of expertise.

They own the whole supply chain. And rather than contractual basis work with lay people, commercial growers, they say ‘this is it, we’ll go out there and we’ll purchase x amount, we’ll have all of our own self-containment, and we can order that. …So you keep it in-house, and the pharmaceutical company does that. Or it has some really tight contractual arrangement that it has some farmers, and that’s all they do for them.

Production company representatives tended to concur:

At the level of intellectual content, the breeding, the transgenics, whatever goes into the seed, it becomes so valuable that it may come to the point where production companies that are contracted become less and less acceptable to someone who’s got $10 million in the variety. Instead they’ll put their own production people on the ground.
Are they going to have a use for [us] when they have a $12 million research budget? And are they going to entrust it to a couple of yokels who are used to putting ear tags on gates? Probably not. They’re going to open an office in Christchurch and they’re going to hire us for our local knowledge, but basically control it.

There were models in New Zealand and Australia of an international company bypassing production companies:

   Syngenta has a man on the ground here, Seminis has some people on the ground in Masterton but largely they don’t go off and visit farmers like [we] do. They supervise the likes of [us]. They supervise their contracts within the country.

In this case Syngenta undertakes the role currently undertaken by seed production companies, contracting growers to produce crops. According to one participant:

   [This places us in] exactly the same status as we are where they’re doing the cleaning and everything else as well.

This model, he said, exists in Chile and in South Africa, but

   New Zealand is probably a little bit unique in that they haven’t really pushed that far yet, and probably won’t.

The reason that so few companies operate in this way is because of the way the New Zealand industry is organised:

   I think because they’re getting good service out of the existing companies that are doing the work for them. And probably there’s no need for them to have to put staff down there, they’re quite happy relying on us, coming to us around Canterbury to do the job.

One of the barriers to a seed breeding company setting up their own operation was the potential difficulty for a company in acquiring enough land to have their own farms:

   Depending on the scale of course. I mean an international company could come in and buy a farm and do it, but it might take them ten years if they wanted to buy 4000 hectares of something like that, they’d have to compete with everyone else, the dairy farmers or the dairy farmers that have sold their dairy farms and the English think it’s a good place to live, and the Dutch have got so much money from selling their land. So it’s pretty competitive out there.

Another reason that international breeding companies would use existing industry structures is because of the economics of land ownership. This participant noted that growers, like many farmers, were getting very poor returns relative to their investment, and that it was ideologies of family farming that meant that they continued in the industry. As such, it would make sense for a breeder company to
draw not only on the expertise of the grower, but also his willingness to exploit himself in the name of family farming:

We realise that farmers accept shockingly poor returns on investment. And if you confront them with this fact they get all stiff and brittle. But, you know, they own a $2 million asset and they clear $42,500 working six and a half days a week. Mr Farmer, if you put the $2 million in the bank, and it only does 6%, you’d be way ahead. You wouldn’t even have to get off the lounge couch. Call it lifestyle, call it quality of life, this is the family farm, this is what we’re doing. Well, if you get [an international company] you’re going to say ‘let me see now, then the real estate is $2 million, and it will return nothing after we pay a manager.’ ‘Well you’ve got it.’ So, why are you in your right mind, if you are selling this, would you want to own the real estate? You’d probably come all the way down to the point where you did what [we] did, which took away from [us], and you dealt with the farmer quite directly. You know, the farmer could become a serf of anybody. Because he’ll sell his soul. He’ll say, ‘Ok, I’ll do it for $59 a kilo’, or he does it on a leased crop basis, where they pay him so much per hectare, he essentially drives the tractor and does what they tell him to do, and then he gets out the way. And he’s happy with his paltry return.

Because of the ultimate impossibility of 100% guaranteeing containment in open field situations, production companies considered that agronomic practices different from those currently used in seed production might need to be employed. What is suggested is that the best solution to issues of containment would be to grow the crops in fully contained glass houses and to have a siloed production and processing chain. What system would be used would depend very much on the quantity of seed needed, and how many plants were required to produce that seed:

Five kilos of seed, or two kilos of seed, it can be done in tunnel houses and all that sort of thing.

A small crop of carrots, for instance, produces a vast quantity of seed. The same is not true of potatoes. One possibility was that the crops would be grown in enclosed and secure greenhouse systems, and then processed through designated channels:

I would suspect that whoever’s going to set themselves up doing that will probably have that whole supply chain dedicated to that. …There wouldn’t be huge volumes, and so it might be a bit like the canola process where firms that are setting themselves up are also setting their own equipment up for processing and stuff, and they’re not relying on outside contractors. I suspect that, from a biopharming perspective, the value will be such that they’ll want to make sure that there’s no contamination. Because they’ll need it as pure as they can, and the only way to guarantee that’s probably setting up your own little dressing plant, your own little cartage process that only deals with that, yeah. Or setting it up so that when it’s harvested it goes into completely sealed bags, and then put into public transport, so it’s completely sealed and there’s no chance of contamination. And then taken to the processing site. But I suspect the processing site will be owned by whoever sets the system in place for the crop itself.
However, there was doubt that this would happen as such production systems are so expensive:

It’s unlikely that that’s even...we don’t want to go there because, it’s just too expensive. Like Crop and Food over here, they’ve inoculated Bt genes into the species, and Mary Christie’s got them in a glasshouse. Well, there has to be negative pressure and heavy filter, and 24 hour guards. It’s not commercially feasible.

Moreover, if biopharm crops were to be grown in glass houses, there would be no advantage for international companies to growing in New Zealand (and as noted above it is likely that biopharming technologies will not be developed in New Zealand).

6.3.3. The Best Crop

We asked participants what the best crop to modify for biopharming would be:

You’d want to grow something that didn’t have a pollination issue. They are things like peas and barley because they are self-pollinating crops. You can plant them that far apart, they pollinate their own plant not the one next [to it]. ...So you’d certainly start looking at those sorts of crops that aren’t going to cross pollinate. You’d look at crops that are less likely to create residual problems in the soil, and they’re generally the same sort of crops. Clover’s a bad news one because it can stay in 20 years. Rye grass, probably 10 years. Brassicas – forever, from my observation. ...The peas and the cereals, other than maize. They’re probably the safest, the self pollinating crops generally.

As this participant noted, not only do peas and cereals not pollinate, they do not create the soil residue problems that oily seeds do because their seeds do not last in the soil:

Participant: You can usually get rid of them within a year or two.
Interviewer: And how do you get rid of them?
Participant: Sprays.
Interviewer: And do they rot more quickly?
Participant: Some seeds will sit in the soil for years, like clover for instance – 20 plus years it will sit in the soil. And the moment it gets into a place where it can germinate, it probably will. It remains viable for an extremely long time. Whereas these other ones won’t, they’ll rot, and lose their germinability very quickly. In the soil they’d probably be gone within 2 years.

Furthermore, from a transport and harvesting perspective, the size of seeds would be important:

The bigger the seed the less likely you are to have problems because you can see it, you can manage it and it’s easier to clean equipment. Peas and cereals again. And small seeds – it’s very hard to be sure that you’ve cleaned
everything up. Your combine harvester, or your tractor or seed cleaning machine. The bigger the seed, the better the chance. …You’d have to do it like that. Have a totally closed system so it didn’t get involved with anything else. Your own transport, your own harvest, your own cleaner. Just so that the whole thing was a closed system.

Under these circumstances, with a large-seed, non-cross-pollinating crop, we were told, it would be possible to contain a biopharm crop:

With those sorts of seeds, I’d be pretty comfortable you can do it. But as you say it only needs that one escape, you’re in trouble.

6.4. The Inevitability of Risk

What became clear from talking to industry participants is that while they consider that they can control the risks to a considerable extent, they also believe that it is impossible to grow an open crop with no risk at all – risk along the seed chain can be mitigated, but not erased:

But this is one of the problems with helping the public to understand about science. There is no such thing as 100%. It may be good marketing to say 100% pure, but as a practical matter, that’s not what happens.

The discussion by the grower below sums up general grower thinking about how to grow a biopharm crop, and the ways in which they assess potential risks. We asked this grower whether it would be possible to guarantee that an open-field biopharm crop could be contained:

No, I don’t think you can do. You can just do some risk mitigation. You’d net it, so you’d take birds out of the equation. And then you’d need to have soil follow ups, sterilisation. That’s like herbicide. So what you can do is grow other crops and spray, and have an inspection regime, so MAF Quality or whoever, comes in, on certain times and inspects that crop for volunteers. …Brassicas are quite easy to kill. So if you grew a brassica crop and then grew a wheat and two barley crops, you could be very confident that you’re going to remove all those brassicas in those years. …There’s enough differentiation between sprays so that you could selectively remove them. So that’s not the issue. …If somebody’s developing a biopharm crop, perhaps they have a terminator gene that has a very quick drop off in germination so that after four years…I’m working just on historical knowledge of growing these things. So let’s say: these are our issues, we can’t have volunteers in it. Maybe it’s all terminator gene, so all the seed are sterile.

The risks that this grower saw (as is illustrated at length above) was not in the production process itself, but in the longer term:

They would also have to have some quite strict control protocols, because the farmer might say ‘no, I’m not going to spray that.’ ‘I just bought the farm.’ You can see there’s going need to be a contractual arrangement, because
A brassica crop could come up in 20 years. So if a farmer deep ploughs it, buries the seed very deep, and then leaves it there and 10 years later ploughs it up again, it will come to life because it’s got the warmth and light. …A long time. So someone could say they’d check for two years, and there’s no volunteers, no contaminants. Now, that would be a really stupid thing to do.

This grower went on to point out the problems of predicting the long term consequences of growing a biopharm crop, and the difficulties of regulating the future, given New Zealand’s current regulatory environment:

So if you said: we’re going to grow a genetically modified crop that can’t enter the food chain, so we’re going to designate this area to be a non-food producing area and a buffer zone around that. Now, how that would be legislated and worked through in a consenting [RMA] environment, I’m not too sure. Very difficult. But, say that happened, and then, time goes on and technology moves along and we’re not doing this anymore, but there’s a legacy for the next 200 years that that area – it’s the Chernobyl of the growing medium. Where do you go with that? That’s the argument that’s been put up – whether it’s realistic or not, who knows?

6.5. Discussion

This chapter illustrates the complexity of the arable/seed industry, and demonstrates the extent of participant knowledge both about the workings of the industry and about the practicalities of growing crops. This knowledge is the base from which participants imagined biopharm futures and from which they considered the potential risks presented by such a development and means of mitigating those risks. Participants were able to identify and discuss a variety of risks, and also to consider existing, and potential, solutions to those problems. Growers concentrated on on-farm risks, as might be expected from their location in the arable/seed network. What is significant is their willingness to consider growing a biopharm crop, and their confidence in their ability to do so with a considerable degree of safety. All growers said that they would be willing to grow a crop in certain circumstances: none were against the possibility per se – it would depend on the price versus the effort and the risk, understood largely as an economic risk either to the industry or to their own business. Growers who said that they would not grow a biopharm crop, did so because growing such a crop (a small crop) did not fit in with their current farming system.

Production company representatives identified a number of potential risks with regards to growing a biopharm crop. The most significant risk was cross-pollination. However, there were procedures and practices already in place, such as the SCID system, that would reduce these risks. Further, production companies noted this risk could be avoided in the case of biopharming altogether simply by modifying a crop that was neither wind nor insect pollinated.

Another risk site is the potential for the mixing of seed, either though machinery that had not been cleaned properly, during transport, in the cleaning process or during storage. Again, there were procedures in place by which this risk was reduced, and producer company experience of these procedures working assured them that the risks
were not great. Farm machinery was well cleaned, and production companies supervised this process. At the company premises well established systems of traceability meant that there was little chance, they thought, of serious mix-ups. These problems could be avoided, as production company participants indicated, by having a specially designated system.

Companies were willing to consider growing biopharm crops in certain circumstances, namely a reduction in public resistance to GM and worthwhile economic returns. What emerges from the interviews of production company representatives is a strong sense of confidence in their ability to manage risks. This confidence is generated by the technologies and practices they use; their experience tells them that while it is not possible to guarantee 100% that a crop is contained and not contaminated, it is a relatively straightforward matter to achieve this to a high degree. This confidence is bolstered by the tightly integrated structure of the industry, so that there are considered to be no weak links in the human chain either, as production companies constitute themselves and growers as having similar interests and working together to achieve common goals.

Production companies have developed a range of highly effective procedures and practices to deal with the potential contamination of crops, which also work as containment, providing a model for protocols for biopharm crops. Production companies also note how existing practices could be strengthened to deal with the extra security issues presented by biopharm crops.

Growers say it is impossible to guarantee that you could contain a crop 100%, with no escape and no contamination in an open field growing situation:

…especially if we’re talking very low margins – if a seed is important as opposed to some seed.

So if you said ‘how would you keep the situation contained?’. There couldn’t be any guarantees. It would be a numbers game of 400 million seeds, ten are going to get out.

It is the significance of the risk presented by “a seed” or “ten” escaping that is the question. Growers tend to consider that this is a minimal risk, and that there is not such thing as totally guaranteed freedom from risk. They say, as a general rule, that, depending on the crop, it would be possible to grow a GM biopharm crop in an open field with a considerable degree of security.

What drives this grower willingness to consider undertaking biopharming and their certainty that they could stop crops spreading and produce pure crops? This confidence comes from their experience of being able to successfully produce crops with high levels of purity over long periods of time within complex farming systems. What growers have learnt from this is that technologies and procedures they currently use to deal with the potential contamination of crops work. And, if existing practices and technologies allow the production of first generation hybrid radish seed, then they would also allow the production of pure and uncontaminated biopharm seed. Growers experience nature as controllable. Good arable farmers are those who are able to produce high yielding, uncontaminated crops. Achieving this gives them a strong
sense of being able to control their world, and thus, what appears to outsiders as a risky process (i.e. growing GM) seems to them to be controllable.

This sense of control is strengthened by their experiences of the structure of the industry. Arable farmers make a living through the successful weighing up a of variety of factors, balancing expected returns (based on current market prices and assessments of future prices) with management and labour requirements, and agronomic constraints (to do with the particular cropping history of the farm). They organise multiple contracts with, potentially, multiple production companies, as well as growing crops which they market themselves. As such, they have a strong sense of their own abilities as strategic operators with the ability to assess the costs and benefits of potential courses of action and to extract maximum benefit for themselves from the system.
Chapter 7: Conclusions

The aim of this research was to explore whether imagined commodity chain analysis would provide knowledge that would be useful in assessing new agricultural biotechnologies. The Canterbury seed sector was chosen as a likely context of biopharming development because the industry specialises in the production of crops in which the avoidance of contamination is critical. Actors in the industry – growers, production companies, scientists and research managers and others – were interviewed about potential risks, and possible solutions to those risks. Participants were also asked about likely developmental trajectories for biopharming in New Zealand, and to identify what they saw as the drivers for and barriers to biopharming development.

Internationally the impetus behind plant biopharming development is the search for by pharmaceutical companies for a cheaper and more flexible platform for the production of a class of drugs known as biologics. No plant based pharmaceuticals have yet reached the market, but a significant number are in the trial stage. However, the international literature reveals considerable uncertainty and significant unknowns around the efficacy and claimed benefits of plant biopharming.

In New Zealand, promoters of biopharming claim the same benefits as do their international counterparts, though there is a greater emphasis on potential benefits for the agricultural sector and for farmers.

Scientists and managers working in the crop sector consider that there is little likelihood of plant biopharming being developed in New Zealand because of the capacity, funding and organisation of the science sector, and because of public resistance to GM. Instead, they argue, research effort is (and should) be directed to more traditional forms of agricultural science and nutriceuticals.

Likewise, both production company representatives and farmers consider that it is not likely that biopharming science would be developed in New Zealand, largely because of public resistance to GM. They considered it much more likely that biopharming would enter New Zealand via the established seed replication industry, as some international seed breeding companies are also involved in the development of biopharm plants. However, this would require a change in public attitudes.

The risk posed by growing biopharm crops, or replicating biopharm seed, is that the plants will not be contained, and will spread to other crops or into the wild, potentially entering the human food chain. Production companies and growers identified a wide range of points and processes through which containment could fail. What the risks were depended heavily on the crop in question. Brassicas were considered to be the most difficult crops to contain as they are pollinated by wind and insects, and are also vulnerable to cross-pollination. Another problem identified was the build-up of seed in the soil, producing volunteer plants in subsequent years. Farmers note cases where brassica plants have appeared in paddocks up to 20 years after the crop was planted. Machinery, particularly combine harvesters, were identified as sites where seed from
different crops could be mixed, and, along with trucks used to transport seed, were potential sources of the spread of seed into the wild. Similarly, post-harvest processing at seed cleaning plants was recognised as another potential place in which containment could be compromised.

However, they also identified the solutions that have been developed by the industry to combat these problems. The risk of cross-pollination is dealt with by isolation zones, managed cooperatively at industry level through the SCID system, and by searching for, and destroying rogues, i.e. plants that have escaped into the wild. Volunteers are dealt with by crop rotations, spray regimes, tillage techniques, and by rogueing, or manually weeding crops. Machinery is cleaned thoroughly to avoid the mixing of seed, and cleaning is monitored by production companies to make sure protocols are being followed. Furthermore, for very high value seed production companies use specially designated machinery. Post-harvest there are sophisticated traceability and testing procedures to reduce the possibility of contamination. These practices and procedures are highly effective and allow growers and production companies to consistently produce uncontaminated crops. It is this experience of success that underlies grower and production company willingness to consider growing biopharm crops and their confidence in their ability to grow such crops with as great a degree of safety as is possible.

What the research shows is that a great deal of information that would be very useful for assessing a new agricultural biotechnology could be gained through the process of imaginary commodity chain analysis. This includes technical knowledge, such as the length of time a brassica seed can last in the soil, which has implications for how long a paddock would need to be monitored and treated after a biopharm crop was grown. Grower and production company knowledge also encompasses an understanding of the structures and relationships within the industry and gives insight into potential trajectories of development. The extent of unknowns reported in the international literature suggests that a very cautious approach to biopharming should be adopted, as the benefits are not clear. Likewise, the experience of participants in the seed industry suggests that there are likely to be few benefits to New Zealand agriculture or New Zealand farmers from biopharming, and the costs of the loss of GM-free status (though its benefits are disputed among participants) may be significant. Results also suggest that there are significant barriers to the development of biopharming in New Zealand.
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