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Chapter xx

Collaborating with the enemy? A view from Down Under on GM research partnerships

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Introduction

The introduction of genetically-modified (GM) crops and food has generated long-running and often polarized public debate, and so recognizing that ethical tensions exist about GM agriculture is undeniable. Although many commentators have reflected on public concerns associated with "changing nature," possible risks from GM technologies, and the involvement of large multinational corporations (Thompson, 2007; Ankeny and Bray, 2018), there has been less attention in the scholarly literature on the role of public-private partnerships in GM research.

This chapter focuses on public-private funding patterns and partnerships in the development of GM crops and foods in the Australian context over the past two decades. GM research and development (R&D) processes have several ethical tensions associated with them: one key issue is who gains or profits from GM research and products. Many people who are not opposed to GM research in principle fear that when private entities are involved, particularly the large multinationals with which GM research is frequently associated, shortcuts will be taken in the name of profits, resulting in increased risks to human health and/or the environment associated with the work. Others question why such research is worth pursuing when the benefits are primarily associated with commercial needs and goals, rather than public benefits such as addressing global food security. More generally, there are concerns that the values traditionally associated with public research (such as openness, data sharing, transparency, and public benefit) are in fundamental conflict with those underlying privately-funded research (where commercial benefit and protection of intellectual property are critical).

Australia is an ideal locale for this exploration, given that industry-funded research has increased significantly in recent years. Australia also provides a useful case study as it does not have complete bans on GM crop growth or use in the food supply (as has been the case until recently in parts of the EU and other parts of the world) and GM products are not widespread (as is the case in the US). In addition, there have not been detailed studies about public-private collaborations in the Australian context. Furthermore, public opinions on and regulatory approaches to GM in Australia remain mixed, representing various tensions that exist in attitudes toward GM.

In order to shed light on the ethical tensions noted above, we use a quantitative data analysis of applications to the Australian regulatory authority for intentional release of a genetically-modified organism (GMO) to explore the actual distribution of public, private, and other forms of funding underlying the research, and patterns associated with types of crops and traits modified, in order to show that the typical patterns that have previously been found elsewhere are not the case in the Australian context. In addition, we develop short case studies based on publicly-available information, grey and published literature, and regulatory data in order to promote deeper reflection on the supposed public-private divide in research and to emphasize the need for scholars to explore the complex partnerships that often underlie GM research. Although a highly detailed analysis is not possible given the available data, we contend that the Australian setting provides a different perspective on the potential for various forms of public-private collaborations in GM research, as well as an excellent test bed for assessing effects of diverse types of funding and institutional arrangements. We use this analysis to illuminate some critical issues related to better understanding the tensions associated with this type of research and elucidate issues that require additional attention.

Background: GM and Public-Private Collaborations in Australia

Early development of GM food plants in Australia occurred in step with other regions, including Europe and the US, although Australia created one of the earliest oversight bodies focused on GM based on voluntary guidelines (AAS, 1980). In 1987, the first GMO was released outside the laboratory (a GM agrobacterium, later commercialized as "No Gall") and was the third recombinant DNA organism in the world to be field tested (Kerr, 2011; Hindmarsh, 2008). The first commercial release of a GM plant in Australia, a blue carnation for floriculture (Lu *et al.*, 1991), occurred in 1995 (GMAC, 1996). The first GM crop, released in 1996 (GMAC, 1997), was an insect-resistant cotton (Cousins *et al*., 1991) known as Bt or Ingard® cotton, and was developed by the Australian public agency Commonwealth Scientific and Industrial Research Organisation (CSIRO) using a gene owned by Monsanto and licensed by CSIRO, in partnership with Cotton Seed Distributors (Davidson, 2003).

The Commonwealth *Gene Technology Act 2000* came into effect on 21 June 2001 (Hain *et al*., 2002) due to increasing concern among the public and lack of adequate information to help people make informed decisions, perceptions that industry could not be relied upon to be sufficiently rigorous, and the need for transparency and a uniform regulatory system. The *Act's* aim is "to protect the health and safety of the people, and to protect the environment, by identifying risks posed by or as a result of gene technology and by managing those risks through regulating certain dealings with GMOs" (Commonwealth of Australia, 2001, section 3). Since the *Act*, the responsibility for regulating GMO dealings has rested with the Office of the Gene Technology Regulator (OGTR), which primarily relies on peer-review processes performed by professional scientists. The *Act* explicitly excludes economic and social arguments, despite calls from critics to revise the legislation to require their consideration during licensing (Wickson, 2007; Hindmarsh, 2008). Other scholars have criticized the required scientific assessment as too narrow in scope, arguing that the definition of the "environment" does not include ecosystem analysis (Lawson, 2002), and that the system facilitates approval of GM foods that is too rapid (Levidow and Carr, 2000) and thus is regulation *for* industry than regulation *of* industry (Lockie *et al.*, 2005).

Australia is currently ranked twelfth in the world in terms of the area of land sown with GM crops (ISAAA, 2016), particularly cotton and canola. However, as compared to other countries (such as the US), relatively few GM crops have been approved for commercial release; the total number of applications made to the OGTR for licenses on an annual basis is small. Nonetheless, GM crops remain a highly controversial issue in Australia. Shortly after OGTR approval of the commercial release of InVigor® canola in 2003, bans on growing GM food crops were established in canola-growing states. These moratoria have been attributed to various anti-GM campaigns and state-based political issues, including concerns about the potential economic impacts of GM canola on Australia's access to export markets where GMOs are not permitted or are greatly limited, such as Japan and the European Union (Hindmarsh, 2008; Tribe, 2012). By 2010, GM canola was permitted (with some restrictions) in most states. Currently, general bans only persist in Tasmania and South Australia (where the moratorium was recently extended to 2025).

Australians are generally considered to be less cautious about GM than Europeans and more hesitant than those in the USA. Yet, most studies of Australian consumers have found that attitudes to biotechnology in food production, including GM foods, tend to be more negative than positive (Bray and Ankeny, 2017) and the adequacy of GM food labelling in Australia is contested (Bray and Ankeny, 2015). Moreover, previous qualitative research has shown that the purpose for which GM is used and who will benefit from it are critical to Australian consumers' views on GMOs (Ankeny and Bray, 2016). Direct anti-GM activism has been far more limited in Australia compared to Europe or the USA; the 2011 destruction of a CSIRO field trial of GM wheat with altered nutritional value represents an extreme form of protest for Australia (described below in case study 2). Popular concern continues about the use of GM in crops destined for the food supply and the potential for drift between GM and non-GM crops (especially organics), highlighted in a recent court case in Western Australia (Neales, 2013).

GM research originally has occurred within an innovation system in Australia that was historically characterized as having a "low level of science and technology expenditure, a high level of government involvement in financing and undertaking research, a low level of private sector research and development and exceptionally high dependence on foreign technology" (Gregory, 1993, p. 324). Efforts were made in the 1990s and early 2000s to increase industry contributions to academic research, via tax and other incentives for collaborative research (Collier, 2007). For instance, the Australian Cooperative Research Centres (CRCs), which began in 1990, are multisite collaborative R&D ventures bringing together university and public-sector research and promoting the flow of knowledge and technical skills between private industry and public organizations (EOAS, 2011). The 2001 Commonwealth package *Backing Australia's Ability* provided significant support for the commercialization of research conducted in universities and publicly-funded research agencies. The National Competitive Grants Program of the Australian Research Council (ARC) instituted Linkage schemes in the early 2000s which are intended to encourage collaborative research especially with industry. Despite these efforts, Australia is still claimed to underperform based on most measures of collaboration (Commonwealth of Australia, 2010).

Conflicts Created by Public-Private Collaborations?

Traditionally, academic and industrial/commercial research has long been interdependent. However, recent commentators have decried the negative influences of industry on academic science, which they see as having increased in recent times. Indeed, contemporary critiques contend that partnerships between industry and universities have become more varied, aggressive, and publicly visible, and wider in scope in recent years (e.g., Lacy *et al.,* 2014).

Although considerable resources are necessary to pursue many forms of modern research, money from industry often is viewed with suspicion even by scientists themselves (Biscotti *et al.,* 2009). Criticisms range from potential to compromise the research problem choice and priority setting, to falsification or suppression of research results to suit commercial interests, particularly in the biomedical sector (e.g., Krimsky, 2003; Sismondo, 2008; Elliott, 2010). Some contend that the internal norms of academic science and commercial research are in principle incompatible (e.g., Blumenthal *et al.,* 1996; Slaughter and Leslie, 1997; Krimsky *et al*. 1999; Bok, 2003), as profit motivations necessarily run counter to traditional academic values associated with scientific inquiry and free flow of knowledge and information (e.g., Hackett, 2005). Others contend that these arguments require a blind adherence to existing systems without adequately considering that industry-academia-governmental, or so-called “triple helix” (Etzkowitz and Webster, 1998), collaborations may represent new modes of knowledge production (Gibbons *et al.,* 1994). More recently, scholars have noted that the boundaries between academic and commercial research are no longer fixed or rigid, as these domains are increasingly interwoven especially in medical and agricultural biotechnologies (Vallas and

Kleinman, 2008; Kleinman, 2010). Thoughtful scholarship has emerged about this interplay as well as potential regulatory and other forms of solutions (e.g., Radder ed., 2010).

Agricultural biotechnology is relevant for general debates on public-private collaborations in science, because agriculture was one of the earliest fields that attracted significant commercial investment (Busch *et al.,* 1991). Agricultural biotechnology has also traditionally received considerable public investment in the US, Australia, and elsewhere, with substantial efforts to attract industry funds for research collaborations (Mowery *et al.,* 2004). Our springboard for this chapter's analysis is Welsh and Glenna's (2006) study showing that US university research on transgenic crops has increasingly mirrored the research profile of for-profit firms during the period 1993-2002 and that private sector firms have dominated R&D and commercialization processes for GM. Welsh and Glenna conclude that these trends have led to a narrowing focus on a few commercially-important crops with plant-protection traits such as herbicide tolerance (HT) and insect resistance (IR). The reason is because these allow for substantial returns on R&D investments (Ervin *et al.,* 2001) and are linked to agricultural inputs produced and sold by the same companies (e.g., glyphosate-based herbicides). In contrast, critics note that staple food crops (FAO, 2004) and other traits, such as those with environmental or nutritional benefits, have been relatively neglected, especially during the early years of GM research. Some argue that to correct this situation, the public sector must pursue a greater share of transgenic crop development via direct funding or financial incentives, with emphasis on traits associated with publicly-valued benefits (e.g., Doering, 2004), or even less commercially-relevant or subsistence crops, sometimes termed "orphan" crops (e.g., Paarlberg, 2000).

In addition, Lacy and collaborators' recent survey (2014) of US university and industry-based scientists and others participating in agricultural biotechnological research collaborations identified concerns over their "distinct cultures" with different values and goals, understandings of their research environments, and criteria for research agenda choice. Although their one shared criterion for problem choice was the public good, it is noted that underlying this concept might be fundamentally different ideas, given that non-profit organizations such as universities have different responsibilities and goals than profit-making institutions (Mansbridge, 1998). In order to minimize conflicts and maximize the potential for complementary efforts in collaboratory work, the Lacy *et al*. recommend closer monitoring of the nature, goals, and outcomes of these relationships; stronger and more creative policies and practices to enhance university interactions with the private sector while protecting the autonomy and freedom of academic scientists; and adequate public agricultural research funding.

Data Analysis of GM Research in Australia

We use publicly-available data to elucidate general patterns over the past 15 years in GM research in Australia, in order to address questions about the dominance of private funding in GM research. Australia's OGTR's public website provides a constantly-updated table summarizing all applications and authorizations (licenses granted) for intentional release of GMOs into the environment, whether controlled (e.g., as part of a field trial) or released. Although the majority of applications and licenses have been for agricultural and horticultural crops, applications for viruses and vaccines are also listed in the OGTR's table (though excluded here as we focus on crops). While numerous organizations may have been involved in the R&D processes leading to the point of making an application, only the name of the license holder conducting the GMO dealings typically is supplied to the OGTR.

Our analysis of the GM research landscape focuses on key factors that have been discussed in the existing scholarship: the type of organization holding the license, the species or crop, and the trait(s) modified. From the time that OGTR licensing began in Australia in 2002 until 2017, 124 authorizations for Dealings involving Intentional Release (DIRs) for plants used in agriculture and floriculture have been granted to 25 different licensees. Applications for DIRs withdrawn prior to OGTR assessment or still pending, and applications for vaccines are excluded from our analysis. Table xx.1, which depicts the distribution of applications for DIRs by entity, shows that the division of private and public licensees is roughly equal. "Private" entities, including subsidiaries of international corporations such as Monsanto Australia Ltd., small, home-grown companies, university spin-offs, and industry-owned companies funded by statutory levies (e.g., Sugar Research Australia Ltd) hold or have held 63 out of 124 licenses (51%). "Public" entities, including universities and federal and state government agencies and research bodies, hold or have held the remaining 61 out of 124 licenses (49%).

Table xx.1: Applications for DIRs by Entity ('other public' and 'other private' are groupings with only one application per entity)

Public	**Private**

CSIRO	30	Monsanto Australia	22
Vic DPI/DEDJTR	8	Bayer CropScience	13
University of Queensland	7	Sugar Research Australia/BSES	5
Qld University of Technology	6	Florigene	5
University of Adelaide	4	Dow AgroSciences	3
WA Dept Ag	3	Hexima	3
Other 'public'	3	Pioneer Hi-Bred Australia	2
		Grain Biotech Australia Pty Ltd	2
		Nuseed Pty Ltd	2
		Other 'private'	6
Total	**61**	**Total**	**63**

Eighty-eight licenses have been granted for dealings with what are considered globally as major crops: cotton, canola, wheat (sometimes combined with barley in a license), rice, and maize (although rice and maize are not considered major crops in Australia). Of these licenses, 49 are currently or have been granted to private entities. As shown in Table xx.2, two are for wheat, 14 for canola, and the overwhelming majority for cotton (33). Public sector licenses for the major crops, differ in their distribution: of 39 granted, 19 are for wheat and wheat/barley together, 17 for cotton, and one each for canola, maize, and rice. Overall, cotton licenses far outnumber wheat/barley and canola combined, with a total of 50 public and private granted, constituting the greatest proportion of DIR license applications. One company, Monsanto Australia Ltd, has held 22 licenses for either cotton or canola. The only organization which has held a greater number of licenses during the period of study is the CSIRO, with 30. CSIRO’s licenses include 15 for cotton, but also cover a range of other crops such as wheat/barley, grapevine, poppy, maize, rice, and safflower.

Table xx.2: Crops in DIRs from Public and Private Entities

Public		**Private**	
Cotton	17	Cotton	33
Wheat	10	Canola*	14
Wheat and barley	9	Wheat	2
Canola	1		
Rice	1		
Maize	1		
Total “major crops”	*39*	*Total “major crops”*	*49*
Banana	5	Sugarcane	5
Sugarcane	4	Indian mustard (only)	2
Pineapple	2	Carnation	2

White clover	2	Rose	2
Papaya	1	Torenia (bluewings flower)	2
Oilseed poppy	1	Safflower	1
Poppy	1		
Narrow-leafed lupin	1		
Perennial rye and tall fescue grass	1		
Grapevine	1		
Potato	1		
Safflower	1		
Sorghum	1		
Total "minor crops"	*22*	*Total "minor crops"*	*14*
Total	**61**	**Total**	**63**

*two of the private Canola applications include Indian mustard

Comparison of these results with the breakdown for minor crops, which include "orphan" crops such as cassava, some legumes and course varieties of millet, and which are defined by Bender (2013) as those consumed by poorer populations for which there is little commercial market, shows a strong contrast: 17 different 'minor' crops are represented, including sugarcane, safflower, rice, lupin, and carnations. Of the 36 licenses granted for these crops, private entities hold 14, but for only six types of crops: three types of flowers modified for qualities such as color (6 licenses), sugarcane (5 licenses), Indian mustard (2 licenses, in addition to the 2 applications combined with canola), and safflower developed for industrial (i.e., non-food) purposes (1 license). Of the remaining minor crops, public entities have applied for 22 licenses for 13 crop and pasture species. This data provides evidence for the patterns observed elsewhere: private, commercial entities unsurprisingly tend to focus on commodities with significant potential for profit. Nevertheless, it also reveals that diverse crops with different purposes and of importance in diverse regions of Australia are represented in GM licensing.

Regarding the claim that private sector resources tend to be concentrated on plant protection traits, particularly insect resistance (IR) and herbicide tolerance (HT), licensing data shows this pattern also tends to hold in Australia, as shown in Table xx.3. Many licenses include multiple traits, some containing as many as six, and the majority containing two or three. The IR and HT traits are by far the most common inclusions in licenses held by the private commercial entities which far outnumber those held by the public entities for the same traits; 36 of 42 (86%) DIRs which include HT are (or have been) privately held and 27 of 35 (77%) for IR. The picture differs when considering other types of traits, including modifications related to yield, abiotic stress tolerance (e.g., drought or salinity tolerance, extremely important traits in the Australian context), human food composition (e.g., nutrition-related traits), animal nutrition, and disease resistance; licenses including these traits are held mostly by public entities.

Table xx.3: Traits in DIRs from Public and Private Entities. If a GMO contains more than one trait, it is listed in all relevant categories; selectable markers or reporter genes, promoters, and so on are not categorized here.

Public		**Private**	
Yield	14	Herbicide tolerance	36
Abiotic stress tolerance	13	Insect resistance	27
Composition - food (human nutrition)	13	Abiotic stress tolerance	6
Disease resistance	8	Hybrid breeding system	6
Insect resistance	8	Modified colour	5
Herbicide tolerance	6	Plant development	4
Composition - food (processing)	5	Composition - animal nutrition	2
Product quality - food	5	Composition - food (human nutrition)	2
Composition - non-food	4	Composition - non-food	2
Plant development	4	Disease resistance	2
Composition – animal nutrition	2	Yield	2
Product quality – non-food	1	Bioremediation	1
Total	**83**	**Total**	**95**

In summary, this analysis of OGTR publicly-available data shows active involvement of both the public and private sectors. Unlike the US situation (e.g., Walsh and Glenna 2006), private entities arguably do not “dominate” GM R&D in Australia, given the 49% public-51% private split. The general patterns of focus on certain types of crops and traits in DIRs granted to private versus public entities does appear to parallel those found elsewhere. Although commercially-important crops and traits have been prominent especially for private entities, we find evidence of minor and “orphan” crops and inclusion of non-plant protection traits in the public projects; however based solely on the quantitative assessment above, it is clear that staple food crops in fact have been relatively neglected.

However, this type of data obscures a range of complexities that must be considered when analyzing patterns in GM research. Some research entities are decidedly hybrid, since they are considered as commercial/private entities but they rely on statutory levies and hence have certain accountabilities to their stakeholders that mirror responsibilities held by public entities. Most importantly, the publicly-available data do not show the extent and nature of research partnerships and collaborations amongst and between the public and private sectors since (as noted above) only the name of the license holder conducting the GMO dealings typically is supplied to the OGTR. Additional organizations or companies, which may have been involved in the R&D processes leading to the point of making an application, are not available in the public summary data (or often not present explicitly in the licensing documentation). This apparent simplicity of origin obscures the fact that the processes of getting a GMO to where it can be assessed by a regulatory body such as the OGTR is extremely likely to have involved input—financial, technical, material, or otherwise—beyond that of the named applicant. We have no reason to assume that who is listed as the applicant is biased in any particular direction, but we note that to perform a full quantitative analysis of the balance and breadth of interests engaged in GM R&D in Australia would require additional source materials, many of which would be difficult to access given they are likely to be considered commercial-in-confidence.

Hence in the next section, we present three brief GM case studies from the Australian context to explore key issues arising and underlying complexities associated with this type of research: (1) drought-tolerant wheat, (2) high-amylose wheat; and (3) Vitamin A-enhanced "super banana." Not all of these cases were unmitigated successes in commercial terms or with reference to public benefits, but we contend that the mixture of outcomes represented is reflective of typical processes in this domain. We selected these cases because they all involve traits that arguably are associated with the public good in the broad sense, though of course there also is potential for commercial profits in some cases. We also do not intend our choice of these case studies to be construed as endorsement of them, particularly as they have not been without controversy (as we discussed below), but we use them as a springboard for discussion and reflections about future research questions that should be pursued to further illuminate various tensions that exist in this domain.

GM Case Study 1: Drought-Tolerant Wheat

Wheat is the dominant grain crop in Australia and one of its most valuable agricultural exports, second only to beef in 2015 (Xue *et al*., 2017). According to Wilson *et al*. (2015), there has been a recent resurgence in GM wheat research, especially in the US and Australia, following suspension of earlier attempts to commercialize GM wheat due to grower and consumer opposition in Canada and the USA (Eaton, 2011; Kinchy, 2012). In 2004, Monsanto withdrew applications for commercial release of its GM wheat in various countries, including Australia (Schurman and Munro, 2010; ISAAA, 2018).

Among the most common traits targeted for GM are those for tolerance to abiotic stressors such as drought, salinity, and frost; ten of the 21 (48%) of the wheat (or wheat/barley) DIRs issued by the OGTR since 2005 include drought-tolerance traits, with other traits being pursued including enhanced yield, improved nutrient use efficiency, improved grain quality, and altered grain composition (OGTR, 2018). The focus on drought tolerance is unsurprising, given that heat and drought stress are having considerable impacts and are considered to be the major challenges to future wheat production in Australia and many other grain-producing regions (Hopkins, 2009; Langridge, 2012). Although breeding for drought tolerance in wheat by conventional methods has been practiced for decades, only "modest gains" are said to have been achieved thus far (O'Neill, 2010).

In 2006, BASF Plant Science, a plant biotechnology subsidiary of the German chemical company BASF SE, announced an approximately A$28 million investment in a project to develop drought-tolerant wheat in Australia, spanning seven years and involving 25 scientists based at the publicly- and industry-funded Australian Molecular Plant Breeding Cooperative Research Centre (MPBCRC) (MPBCRC, n.d.; Hopkins, 2009). First established at the Waite Campus of the University of Adelaide in July 1997 as the Cooperative Research Centre for Molecular Plant Breeding, and intended to benefit the crop and pasture industries, the Centre received a further seven years' funding under the Commonwealth Government's CRC Program in July 2003, continuing in a new location in Victoria as the MPBCRC (which was disbanded in June 2010). A document produced by the MPBCRC (n.d.) during this period listed six core partners in the CRC (not just the wheat program), including the Victorian Government's Department of Primary Industries (now the Victorian Government Department of Environment and Primary Industries, and hereafter DPI Vic) and ten commercial and industry partners, including BASF, along with its federal government funding.

The gene candidates for the desired trait of drought tolerance were derived from plants (maize and thale cress), a moss, and a yeast (*Australian Grain*, 2007), and were provided by BASF Plant Science (along with genes related to yield increase and resistance to fungal diseases), with MPBCRC providing "expertise and a patented technique for developing highly effective genetic modifications of wheat" (MPBCRC, n.d., p. 9). Rights to commercialize any products resulting from the project were to be held by MPBCRC for Australia, New Zealand, and some countries in the developing world, namely those countries assisted by the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico, a non-profit research and training organization with over 500 partners in 100 countries and another core participant in MPBCRC (CIMMYT, 2016; MPBCRC, n.d.). BASF was to handle commercialization elsewhere (MPBCRC, n.d., p. 10).

Although the publicly-available information summarized above shows that the research processes prior to application were collaborative efforts between numerous public and private entities under the umbrella of MPBCRC, officially the DIRs were granted by the OGTR to the DPI Vic for the initial GM wheat trials of relevance in 2007 and 2008. DIR 071/2006 permitted trials of GM wheat with drought-tolerance genes, the first such trial in Australia, during the 2007 and 2008 growing season, with DIR 080/2007 covering trials from July 2008 to March 2010 involving new GM lines and continued research on previously approved lines (OGTR, 2016). Following "very promising" field trials over the two licensing periods, the MPBCRC's then-Chief Executive, Dr. Glenn Tong, stressed the need for a cautious approach to interpreting the preliminary results, with many field trials yet to come (Hopkins, 2009).

When MPBCRC ceased operating in in June 2010, DPI Vic was expected to continue with the GM wheat program (O'Neill, 2010); whether this research extended beyond the monitoring phase of the trials in question is unknown. Agriculture Victoria Services Pty Ltd—a private company wholly held by the Victorian Government—is responsible for the commercialization and protection (including intellectual property) of novel technologies created by the Agriculture Victoria Research Division, into which DPI Vic was recently rolled. Both licenses were surrendered in March 2016; drought-tolerant GM wheat has yet to be commercialized, with no DIRs pending.

GM Case Study 2: High-Amylose Wheat

Genetic modification for traits offering potential public health benefits is another area of crop research, which can fall in the realm of "public good." This case examines a wheat developed to be high in amylose, a type of resistant starch or functional form of dietary fiber, which is already present in wheat and other whole foods, but which is lacking in typical modern diets (Braidotti, 2016). Increasing the level of resistant starch in wheat, a staple grain, was pursued due to its potential contributions to promoting digestive health, fighting Type 2 diabetes, and reducing the risk of bowel cancer, without requiring behavioral changes (Regina *et al*., 2015; CSIRO, 2017).

High-amylose GM wheat was developed by Arista Cereal Technologies, an Australian-French, public-private joint venture announced in 2006 by the Australian research bodies CSIRO and the Grains Research and Development Corporation (GRDC), and the French-based company Limagrain Céréales Ingrédients (LCI) (CSIRO, 2017). LCI is a subsidiary of the French seed company Limagrain, an international farmer cooperative or grower-owned corporation (Limagrain, n.d.) which "develops and manufactures authentic and functional cereal ingredients for manufacturers in the food industry" (LCI, n.d.). Arista was created to allow research, development, and commercialization of a high-amylose wheat suitable for processing, utilizing genetic technologies developed by CSIRO's Plant Industry division and Biogemma UK Ltd, a European plant biotechnology company of which Limagrain is a shareholder. Biogemma was founded in 1997 by seed companies and French field crop producers, and shareholders include seed and agricultural finance companies and a French arable crops R&D institute (Biogemma, n.d.). The GRDC is a statutory corporation founded in 1990 to undertake research, development, and extension on behalf of Australian grain growers as well as for the benefit of industry and the public more widely. Primary financial support to the corporation comes from two sources: a grower levy based on the net farm gate value of the annual production of 25 grain, pulse, and oilseed crops, and an Australian government contribution, annually determined and based on the three-year rolling average of the gross value of production of the 25 leviable crops (GRDC, 2018).

A team composed of plant geneticists, agronomists, and human nutritionists including researchers affiliated with CSIRO's Food Futures National Research Flagship as well as Biogemma UK Ltd. used a combination of GM and conventional breeding techniques to create wheat with the desired qualities (Regina *et al.*, 2006; Braidotti, 2016). It was hoped that the use of some conventional techniques might make the wheat more acceptable to consumers; however despite early optimism (e.g., Patton, 2006), a clear pathway to regulatory and consumer acceptance of GM wheat has not readily emerged (see Salleh, 2006).

Following successful animal feeding trials, human nutritional studies of the high-amylose wheat were planned. However, activists from environmental organization Greenpeace destroyed the first outdoor trial of the CSIRO GM wheat near Canberra in July 2011; this crop was intended to be used in the first human studies (ABC, 2011). Greenpeace (2011, n.p.) claimed that CSIRO's involvement in the project represented a conflict of interest:

> The web of public-private partnerships that sits behind these research programs is misleading and makes it challenging for the public to know where and to whom their tax dollars are being spent. This lack of transparency makes it difficult for the public to exercise its right to hold the government to account. This difficulty is exacerbated by the secrecy surrounding government documents related to GM plants. Greenpeace's Freedom of Information request for documents about the commercial partnership between CSIRO and Limagrain was refused. The documents are "commercial in confidence". Australian taxpayers cannot properly exercise their rights to hold the government to account under these conditions.

Arista owns the intellectual property associated with this project and issued the first license for the high-amylose trait to an American milling company in 2016, with LCI as their partner in breeding the trait into locally-adapted wheat varieties (Bay State Milling, 2017). The first crop of enhanced (but non-GM) wheat, grown in Idaho, Oregon, and Washington, was harvested in 2017 and was to be milled into trademarked high-fiber wheat flour (CSIRO, 2017). Royalties would be paid per hectare of wheat grown, in principle providing a return on the funding originally allocated though funding of the GRDC by farmer levy and taxpayer funding of the CSIRO (Neales, 2017).

As for the potential future of high-amylose wheat in Australia, it was recently stated that Arista was partnering with a breeding company to develop high-amylose wheat varieties suitable for different regions, and working on ways to produce enough grain for product testing and seeds for initial commercialization. Lindsay Adler from CSIRO and an Arista Director stated that the company was keen to find an Australian licensee who would develop a new product for local and possibly Asian markets (CSIRO, 2017).

GM Case Study 3: Vitamin A-Enhanced Banana

Our third case also concerns the development of a crop with a modification that meets a public health need, a vitamin A-rich banana. One of the world's top ten food crops by production (Paul *et al*., 2017), various types of bananas are widely grown in wet tropical and subtropical regions for consuming fresh or cooking, with 85% of production worldwide consumed domestically. In many banana-growing regions, cooking bananas are principal staple foods (particularly in rural areas) as well as subsistence crops; in some regions of Africa and Asia, they also are the major source of dietary starch (Dale *et al.* 2017a).

Described by lead researcher James Dale as a "significant humanitarian project" (QUT, 2017), research on the biofortified banana has been underway since at least 2005. Biofortification is the process of increasing the levels of essential nutrients, especially in staple foods, by conventional plant breeding techniques or genetic modification (Dale *et al.*, 2017a; Bender, 2013). Similar to the widely-publicized (and highly controversial) GM Golden Rice, the enhanced banana, also orange-fleshed due to its provitamin A (beta carotene) content, is seen as a way to combat vitamin A deficiency, which despite various public health initiatives is still a major problem particularly in parts of Africa such as Uganda and in Southeast Asia. In addition to the public health aspect of the project, the banana will be engineered to be disease resistant and will be freely available if commercially approved: "No patents, breeders/variety rights, or commercial rights have been or will be claimed on the pro-vitamin A genes or trait. There will be no technology fees associated with applying the technology in Uganda or elsewhere, nor will there be any additional cost to farmers" (Banana21, 2016, n.p.).

Related GM research has focused on generating resistance to a virulent fungus commonly found in Cavendish bananas (known as Panama disease). Cavendish bananas constitute over 40% of world production and virtually all the export trade in bananas. Virus resistance research has been funded via the ARC Linkage program (LP110100186), in partnership with researchers in the USA, the Netherlands, and the Darwin Banana Farming Company, and an Australian banana wholesaler, LaManna (Dale *et al.,* 2017b). This project provides a good example of "open research," inasmuch as the researchers have communicated about and involved local banana growers in the research, particularly given the economic importance of bananas in Queensland, where the research institute is located and trials were to occur.

Prior to receiving support from the private Bill & Melinda Gates Foundation (BMGF) for the biofortified banana research, researchers at the Centre for Tropical Crops and Biocommodities at Queensland University of Technology (QUT) were working with Ugandan researchers from the National Agricultural Research Organization. They made a successful bid for their Vitamin A banana project in response to a 2004 call from BMGF for expressions of interest regarding solutions for the "Grand Challenges in Global Health" initiative, including the development of micronutrient-rich staple crops (Fresh Fruit Portal, 2013). In 2005, BMGF began supporting the project, now one of the genetic improvement projects under the umbrella of the "Banana21" collaboration between scientists at QUT and their Ugandan counterparts, and were joined by the UK Government Department for International Development in 2012 for Phase 3 (Banana21, 2016).

Following initial laboratory work, field trials began in Queensland in 2008 (which also was the first trial of GM bananas in Australia), with QUT obtaining licenses for controlled release. The intention was to transfer the resultant technologies to Uganda for incorporation into the local cultivars and for further field trials (which began there in 2010), and for selection and eventual release there and in other African countries with similar needs (QUT, 2014). However, when approval for human trials in the USA was announced in 2014, controversy arose with protests outside the BMGF headquarters in Seattle and elsewhere. Thus the trials were delayed, not only because of the protests but also because it was found that transporting the fruit was difficult, with no public announcement available about their completion. Uncertainty also has surrounded the process of approval for commercial release of the banana in Uganda: although there now is a regulatory framework for obtaining licenses for GM crop trials, a bill to expand the framework to include GMO release which was approved by Parliament in late 2017 is yet to be signed by the Ugandan president; no GM crops have been approved for commercial sale to date. Therefore, early predictions regarding the release date of the banana have been pushed back as the project continues.

Discussion

While these case studies are admittedly selective, combined with the quantitative analysis presented above they illustrate forms of collaborative research that have largely been overlooked in existing analyses of public-private partnerships, and they reveal different types of funding patterns than conventional collaborative partnerships, involving governmental entities and programs emphasizing both commercial and public benefits. In addition, they encourage us to consider less restricted definitions of "public benefit." These points taken together underscore that the potential sources of ethical tensions and conflicts about GM research typically discussed in popular and scholarly literature, notably the undue influence of industrial interests, may need to be reconsidered or at least situated in a much more complex context.

At least in Australia, the partnerships that underlie current GM research are complex webs that, ironically, have frequently been criticized by GM opponents (e.g., by Greenpeace). A key takeaway from our analysis is that many projects involve public entities and private companies and include not only large multinationals but also locally-based start-ups and transnational collaborations; the latter examples might not be surprising given that most Australian companies are relatively small (Dodgson, 2011). In addition, some of the projects involve non-governmental organizations (NGOs) as well as farmer-associated organizations. Importantly, current analyses of GM research tend to exclude these types of partners, because they have limited presence in the US, where most previous analysis has occurred, or because they have emerged more recently than the periods covered in previous scholarship. Overlooking projects involving these other types of partners and alignments could indicate an overemphasis on projects aimed at profits and other benefits not primarily aligned with the public good. They also may obscure the fact that some products that might appear to be primarily commercial or economic may contribute to the public good when defined more broadly. For instance, traits that provide environmental benefits also are likely to benefit farmers economically by making crops better adapted to the extreme conditions in Australia. In addition, many projects in this survey were funded not just via university-industry partnerships, but involved governmental funding schemes, such as the CRCs and ARC Linkage programs, as well as NGOs, all of which have mandates to create public goods, but in many cases also use commercial activities to partially fund ongoing and future research.

This analysis suggests the need to reconsider what counts as public benefit. Narrowly construed, "public benefit" is often taken to be equivalent with promoting global food security, parallel to the values promoted via the Green Revolution, in contrast with the "gene revolution" associated with GM (e.g., Parayil, 2003; FAO, 2004). However, the range of GM crop types pursued in the Australian research context is broad, with diverse goals within each project. Many of these are well-aligned with public needs and benefits, particularly associated with reducing environment impacts and growth of crops in extreme climatic conditions. It even may be contended that Australia has a distinct role to play in the pursuit of GM research aimed at public benefit given its unique qualities. For instance, Australia is the only "officially recognized Developed Countr[y]" with a tropical region area (Banana21, 2016), and therefore the only one with a tropical agriculture industry; hence it is well placed to develop various types of bananas that can have benefits in less developed regions and distributed in ways that are not commercialized (the question remains of course about whether these types of initiatives are appropriate in other terms, but this concern is not our primary focus in this chapter). The presence of projects including traits other than those associated with plant protection raises questions about fears that private agendas are swamping out other types of R&D priorities in GM research, which does not seem to be supported by the current Australian data.

Conclusions

It is clear that there are various types of tensions at work surrounding GM agriculture. A particularly important tension involves what role industry and other non-public entities should play in the development of GM technology and how the distribution of benefits should be decided. The examples presented here from the Australian context do not show or suggest that any or all GM research is good, or worth pursuing or supporting. There are numerous factors that need to be considered to develop a definitive analysis of the impact of GM research to date and future potential (or lack thereof). Instead, our contribution provides empirical information on the current state of play that allows us to widen our dialogue about these issues. Along with Vallas and Kleinman (2008), we contend that biotechnology (and GM research in particular) is a domain

> marked by an increasing commingling of normative codes and practices from two previously relatively distinct institutional domains, leading to the emergence of a knowledge regime that is fraught with tension, contradiction and inconsistency… Far from demanding resolution, such tensions can in fact serve as a source of creative dynamism, dialogue and reflexivity, compelling the various parties to justify their

> assumptions, to engage in dialogue with those whose orientation differs from their own and thus to make possible a deeper and more innovative understanding of the major tasks at hand. (p. 306)

As Vallas and Kleinman note, rather than viewing these complexities and tensions as difficulties, we should treat them as assets particularly because of their ambiguity (see also Stark, 2001).

Our study highlights future research topics to be pursued in order to enrich our understanding of the tensions underlying GM research and domains facing similar issues. First, due to the limitations of the existing quantitative data, more up-to-date, qualitative evidence should be gathered about how priorities are set, including the potential for increasing public engagement and participation in decision-making, and how research is structured, especially with regard to access to products, intellectual property arrangements, and so on. Admittedly, this type of approach may be limited due to commercial-in-confidence considerations, but this potential difficulty is not sufficient to warrant ignoring these issues. Second, more exploration is needed of scientists' views on how they fulfil their "social license" (Raman and Mohr, 2014) and assess and respond to public priorities and needs, particularly in the Australian case given the OGTR's lack of mandate in this regard. Finally, GM research has taken hold in numerous less high-profile locales, and collaborative practices in South America, Canada, Eastern Europe, and Asia are worthy of more scholarly analysis than has occurred to date.

Our analysis also shows that ignoring funding arrangements for the development of GM crops to a public-private binary obscures the complex networks and types of arrangements that are typical of contemporary science. It could be argued that the funding arrangements for the development of GMOs are less important to consider than evaluating how the GMO will be deployed within food production systems, neoliberal or otherwise, how these arrangements are regulated and monitored, and who in fact can benefit and how.

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