Current Contribution of Four Biotechnologies to New Zealand's Primary Sector

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1. Introduction

This paper presents an estimate the economic contribution of biotechnology to the primary sector in New Zealand. The primary sector is important to the New Zealand economy, and it employs biotechnology for production and processing. Biotechnology can be defined in a broad way, as technology applied to biological matter. More narrowly, modern biotechnology can refer specifically to techniques coming into commercial use after about 1980, when production processes could begin using the smallest parts of organisms, their cells and biological molecules. The present research focused on four specific modern biotechnologies and their impacts on primary production:

- Clonal propagation/cell manipulation: clonal propagation using meristem and shoot culture, doubling chromosome numbers of cells, embryo rescue, and similar techniques.
- Bio-control agents: bio-pesticides derived from organisms (classical biocontrol was not included).
- Enzyme manipulations: modified catalysts for improving feed quality, waste management, textile manufacture and bleaching of wood pulp.
- Marker-assisted selection: using genotypic information for selection, as opposed to older phenotypic selection based on physical traits.

2. Prior research

The impact of technological development on agricultural production has received much attention. One particular focus has been the contribution of improved germplasm to agricultural output. Agronomic research on staple crops led to important increases in production in the second half of the 20th century, and these increases have had economic impacts (Evenson and Gollin, 2003). Abeledo, Calderini, & Slafer (2002) summarize research on genetic gains in barley. Genetic yield gains in barley vary by study, but they are 0.3 per cent to 0.4 per cent per year for the whole 20th century. Abeledo, et al. (2002) further note that genetic gains from wheat have been slightly higher than those for barley, about 0.5 per cent per year. For maize, Duvick & Cooper (2004) demonstrate a clear linear trend in yields per hectare since 1930. Interestingly, potential yield per plant has not increased from 1930 to the mid-1990s. Instead, newer varieties perform better for harvest index and under stress and crop density, leading to increased yields per hectare over time. However, yield increases appear to have declined over time (Evenson and Gollin, 2003; Traxler et al., 1995). It appears that the 'easy gains' from traditional breeding techniques had already been achieved, so that further gains require more powerful technologies (Bajaj, 1990).

One technology that has received much attention is genetic engineering (GE) or genetic modification (GM). The current generation of GM crops tends to affects how the crops are produced, particularly with potential increases in yield and/or reductions in costs (Caswell et al., 1998; Fernandez-Cornejo and McBride, 2000, 2002; OECD, 2000). For example, university varietal trials of herbicide-tolerant (Ht) soybeans (Benbrook, 1999) and field trials (Marra et al., 2002) indicate lower yields in 1997 and 1998, while the USDA (Fernandez-Cornejo and McBride, 2002) found small yield increases. Ht soybeans are generally associated with higher use of glyphosate herbicide (Roundup), but lower use of other herbicides (European Commission, 2000; Duffy, 2001; Fernandez-Cornejo and McBride, 2000; Shoemaker et al., 2001). Management and labor effort are lower for Ht crops, because they make the job of weed management easier. Farmers can use fewer pesticides and have a wider window for their use than with other weed management programs (Benbrook, 2001; European Commission, 2000; Duffy, 2001; Fernandez-Cornejo and McBride, 2002; Gianessi et al., 2002). Overall, the impact of Ht soybeans on net returns is uncertain, as research has found reduced returns (Benbrook, 1999), increased returns (Shoemaker et al., 2001), and no effect (Duffy, 2001; Fernandez-Cornejo and McBride, 2002; 2001).

Other specific biotechnologies do not appear to have received the same attention as GM. There appears to be little indication in the literature of the impacts on agricultural production that may be ascribed to the four biotechnologies considered in this research. However, the GM research does suggest that a biotechnology may affect two different dimensions of agricultural production (Caswell et al., 1998; Shoemaker et al., 2001), as depicted in Figure 1. The first dimension is product quality, or the extent to which the primary product is altered by biotechnology. Changes to product quality may affect demand for the product. Furthermore, product differentiation in the market may result, possibly leading to a competitive advantage for adopters (Porter, 1991). The second dimension is production practices, which considers the similarity between the production systems with and without biotechnology. Some innovations are simply input substitutes: they replace non-biotech inputs. Other biotechnology applications may lead to more radical changes. Any change may be expected to affect the cost per unit of output through changes in inputs and yield. They may also affect the configuration of input factors (Barney, 1986) and/or the activity structure (Porter, 1991) of production.

[Figure 1]

3. Method

The method chosen for assessing the contribution of these four biotechnologies was a cost-benefit analysis (CBA). However, the data required are not available in official statistics or from other public sources. To obtain information for the CBA, the research included interviews with expert sources in biotechnology and primary production. These interviews provided important data for assessing economic impacts of biotechnology. This information was incorporated into the CBA to compare the costs and benefits of the biotechnologies. The present research focused on the economic impacts, but attempted to include other types of costs and benefits where feasible. The stages in the CBA were:

- Definition of impacts. This included market and non-market impacts. A key consideration was the counterfactual, the situation that would have prevailed in the absence of biotechnology, against which the impact of the biotechnology was estimated. In addition, the research focused mainly on production rather than processing impacts.
- Identification and estimation of impacts. Information regarding the physical impacts formed the basis for calculations of costs and benefits of the technology. The net impact was estimated from the gross impact by a calculation of the gross margin from production budgets (Burtt, 2004). The

research focused on currently commercial biotechnology innovations, so that estimates of future impacts were not considered.

- Consideration of relevant impacts. Relevance criteria include the size of the impacts on prices and quantities, as well as impacts on marketed and non-marketed goods and services.
- Discounting of cost and benefit flows. Costs and benefits over time were discounted to net present value.
- Application of the net present value test. For successful innovations, benefits would be expected to exceed costs.
- Review of study and assumptions. This study and its underlying assumptions have been extensively reviewed by the research team and biotechnology stakeholders in New Zealand.

For analysis, the primary sector was divided by commodity, as reported in Table 1. The dairy subsector is the largest for New Zealand, and is centrally organized around one firm (Fonterra). Horticulture, including floriculture, is the second largest and comprises a wide range of products and farm types. Sheep, beef and veal, and forestry subsectors are all largely based on extensive land use practices and tend to be export-focused. The arable subsector is small relative to the others. Finally, seafood is another export-driven area of primary production, and is based on both wild and farmed production.

[Table 1]

The interviews solicited information from a wide range of individuals, who were identified through the New Zealand Biosphere Website (http://www.biospherenz.com/) and discussions with Government agencies. This initial research identified 115 contacts with expertise in the primary sector, the physical impacts of biotechnology, or the commercial impacts of specific innovations. The interviews were semi-structured, and sought information on the impacts of biotechnology on the qualities of primary products and the methods of production. Informants were specifically asked about adoption patterns, characteristics of markets, upstream and downstream impacts, and the impacts of not having biotechnology. Fifty-nine interviews were conducted in person, by telephone, and via email in April, May, and June 2005.

4. Results

Through the interviews, the present research was able to identify virtually all innovations of commercial importance to New Zealand relying on the four biotechnologies. Using primary and secondary data sources, the analysis estimated the direct economic value of each innovation to each subsector of the primary sector.

The total estimated net benefit of these innovations to the primary sector is $266 million per year, assuming constant prices. Clonal propagation / cell manipulation represents the largest contributor, by virtue of its widespread and relatively long-term use. Biocontrol agents and enzyme manipulations had smaller economic impacts. The least-commercialized biotechnology was marker-assisted selection, contributing less than one million dollars.

The different contributions to the subsectors are also apparent. Dairy production benefited most, even without accounting for economic impacts of processing enzymes. This result is largely a function of the economic importance of dairy production. Other pastoral agriculture also benefited, with impacts on sheep production larger than those on beef production. The horticulture subsector showed significant benefits, with some crops benefiting significantly (e.g., potatoes, floriculture) and others barely affected. The value of impacts in arable crops was relatively small, a function of the size of the subsector. Impacts were relatively small for forestry and nil for seafood, due to lack of commercialized innovations.

In addition, non-marketed benefits appeared to have been measured only rarely. There were suggestions from the survey and the literature about possible non-marketed benefits, such as environmental improvements, but little information about the exact impacts. Without this information, measurement of the economic value was impossible. This appears to be a potential area for future research.

[Table 2]

The information from informants resulted in two types of calculations. Some calculations represent the values of specific innovations. Informants could provide data on the specific production impacts, which could then be used with secondary data to estimate an innovation's economic impact. The impacts of other innovations were not directly available in the same way. For example, informants identified increases in arable crop yields as a benefit of cellular biotechnology, but estimates of the size of the benefit relied on the literature on crop genetic gains (Abeledo et al., 2002; Bajaj, 1990; Evenson, 2003; Traxler et al., 1995).

The semi-structured nature of discussions with informants also yielded qualitative information on the impacts of biotechnology:

- Range of impacts. The identified technologies affected both the product qualities and production practices. For livestock, input-oriented innovations appeared to generate the greatest returns, whereas product quality innovations were more important for horticulture.

- Nil results. The 'nil' entries in Table 2 indicate subsectors where biotechnologies do not appear to be producing material commercial impacts. Significantly, marker-assisted selection appeared to be creating little commercial value.
- Extent of contributions of biotechnology. The survey did reveal the importance of other factors, such as natural resources, management effort, human labor, and machinery, in increasing returns from the primary sector.
- Awareness of the value of innovations. Commercial considerations seemed to be minor factors in the research and development of many innovations identified.
- Commercialization of biotechnology. Many informants distinguished between fundamental science and commercial application of science. Commercialization resulted from using fundamental science to produce usable, convenient innovations within the context of a production system. Furthermore, profiting from commercialization required business expertise in addition to technological proficiency.

Overall, these results point to uneven contributions of these biotechnologies across the primary sector. Some biotechnologies are so integrated into some subsectors as to be unremarkable. However, since they are so integrated, their impacts are quite significant. Other biotechnologies do not seem to be producing large commercial returns, e.g., marker assisted selection. Furthermore, some parts of the primary sector have been barely touched by these biotechnologies.

5. Conclusion

This research assessed the economic impact of the current commercial use in the primary sector of four biotechnologies. By choosing four specific biotechnologies and assessing only commercialized innovations, this research makes two contributions to previous studies. The first contribution is to calculate actual realized benefits, rather than to estimate potential future benefits. Secondly, the focus on commercially released technologies avoided potential issues regarding public perceptions and foreign market access.

Information on the contribution of these biotechnologies is not readily available. To obtain data for a CBA, an extensive survey of scientists and industry experts was undertaken. The survey revealed that successful products are making substantial contributions to the sector, while a number of commercialized products are having more modest impacts. However, much biotechnology research has yet to produce measurable economic value, and some parts of the primary sector are essentially unaffected by these biotechnologies.

A CBA was performed using information from this survey as well as secondary data sources. The annual direct impact of these biotechnologies to the New Zealand primary sector was estimated at $266 million. The sectors with the largest impacts were dairy, sheep, and horticulture. The biotechnology with the largest impact was clonal propagation / cellular manipulation, while marker assisted selection had the least impact.

The discussions with key informants yielded valuable qualitative insights. Informants emphasized that individual innovations are the products of long-term, fundamental research. The subsectors in which specific biotechnologies are not producing commercial returns can easily be viewed in this context: the fundamental science is being undertaken but has not yet been applied commercially.

The analysis reported in this paper did not account for changes in commodity prices as a result of increased productivity, but assumed that New Zealand is a price-taker for all commodities. This assumption is not likely to hold, so an extension of this research would account for the impacts of productivity gains on prices.

This economic analysis is also based on reports by informed persons of the impacts that biotechnology has had on primary production over the last 20 to 25 years. Where possible, these reported impacts have been confirmed with published sources. However, one weakness with this analysis is its reliance on perceptions rather than measurements of the contributions of biotechnology. Similarly, the counterfactual scenarios relied on reports of how production would be likely to happen in the absence of biotechnology. Relying on this information contributes some uncertainty to these calculations.

Nevertheless, the authors believe that reliance on industry experts is also a strength of this research. This analysis has attempted to decompose the impact of biotechnology on the primary sector into its constituent elements: what has been the economic impact of this specific technology on this crop or product? This decomposition was necessary in order to survey informants. As a result, the survey produced some unanticipated findings. One such finding was that the focus on economic impacts (as opposed to laboratory results) appeared foreign to many informants. A second unanticipated finding was that commercial gains are yet to be realized in some areas.

This research provides a baseline estimate of the contribution of specific biotechnologies to New Zealand's primary sector. Future research can use these results to compare them with other biotechnologies or to determine the value of subsequent technological developments.

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Figure 1. Biotechnology impacts in two dimensions

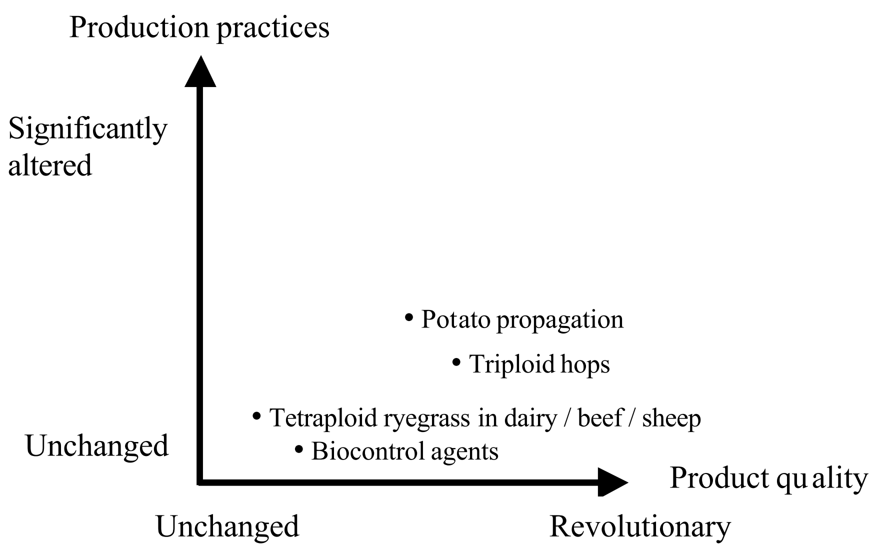

Table 1. New Zealand's primary sector*

Subsector	Physical measure of production	Value of production ($ million)	Value of exports** ($ million)
Dairy	5.11 million head, 1.2 billion kgs of milksolids	5,300	5,800
Beef and veal	4.64 million head	1,300	1,900
Sheep (meat & wool)	39.7 million head	2,800	3,000
Horticulture	110,000 hectares	4,500	2,100
Forestry	20,888,000 m^3	3,900	3,200
Arable	over 179,000 hectares	389	111
Seafood	750,000 tons	1,340	1,200

* Figures for each subsector are not directly comparable with each other, but are only representative. Sources: (Burtt, 2004; HortResearch, 2003; Ministry of Agriculture and Forestry, 2003, 2004a, b, c; Ministry of Fisheries, 2004; Statistics New Zealand, 2004, 2005a, b).

** Value of exports can exceed value of production due to processing of raw products.

Table 2. Summary of direct impacts of four biotechno logies

Subsector	Value of clonal propagation / cell manipulation ($000's)	Value of biocontrol agents ($000's)	Value of enzyme manipulations ($000's)	Value of marker assisted selection ($000's)	Total ($000's)
Dairy	74,914	19,893	3,791	nil	98,598
Beef and veal	20,890	772	nil	nil	21,662
Sheep (meat and wool)	35,287	41,353	nil	770	77,410
Forestry	16,976	nil	nil	nil	16,976
Horticulture and floriculture	32,995	small value	9,960	nil	42,955
Arable crops	8,220	nil	nil	nil	8,220
Seafood	nil	nil	nil	nil	0
Total	189,282	62,018	13,751	770	265,821