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Potential changes in the competitiveness of maize growers in Central Chile through the use of transgenic seed (Bt and RR)

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Abstract

A number of studies have shown that the use of transgenic seed increases productivity, reduces the quantities of pesticide required to protect crops, and cuts down the labour involved in cultivation. Besides saving time, this reduces manpower requirements and the use of farm machinery, and the use of such seed has had an important economic (and environmental) impact on the production of certain crops. These advantages translate into reduced production costs-particularly so for a number of crops whose international market price has fallen steadily over the last ten years. Current Chilean legislation, however, only allows the multiplication of genetically modified plants whose final product is destined for export. The aim of this work was to compare the production costs associated with conventional and transgenic Bt and RR maize, and therefore to highlight the potential economic benefits to Chile of opening the market to genetically modified seed.

Key words: biotechnology, transgenic crops, production costs, GMO.

Resumen

Cambio en la competitividad de los productores de maíz de grano en Chile Central mediante el uso de semilla transgénica (BT y RR)

Existen trabajos que han probado que los cultivos transgénicos aumentan la productividad, reducen el uso de pesticidas convencionales, disminuyen el número de labores culturales, con el consiguiente ahorro de tiempo, mano de obra y uso de maquinaria, en definitiva, han tenido un impacto económico —e incluso ambiental— sobre la producción de algunos cultivos. Lo anterior se traduce en una disminución de los costos de producción, especialmente aquellos cultivos cuyos precios internacionales en la última década han caído sistemáticamente. En Chile, la legislación sólo permite la multiplicación de especies vegetales modificadas genéticamente cuyo producto final sea para exportación. Dado este marco, el presente trabajo tuvo por objetivo comparar los costos de producción convencional de maíz para grano y con modificaciones Bt y RR, permitiéndonos construir un escenario para comparar los beneficios económicos potenciales que tendrían en Chile la liberación al mercado de semillas modificada genéticamente.

Palabras clave: biotecnología, cultivos transgénicos, costos de producción, OMG.

Introduction

Over the years, advances in technology have spurred the development of agriculture. The industrial revolution brought improved agricultural productivity through the intensive use of the soil and the incorporation of mechanical, chemical and biological inputs. Later, the «green revolution» led to the wholesale use of many kinds of technology. More recently (since the late 1980s) our growing knowledge of molecular biology and ever-improving biotechnological processes have generated new plant varieties that today are cultivated in most industrialised countries. One such product is genetically modified (GM) or transgenic maize (Dunwell, 2000). Two types of GM maize are available, one resistant to insect infestation, the other tolerant to herbicides.

Researchers working on genetic transformation projects foresee such crops bringing substantial improvements in terms of profitability. According to Ferber (1999), their potential economic impact is well known; transgenic crops have already been seen to increase production, to benefit the environment through the

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reduced use of conventional pesticides, and to reduce the number of cultivation procedures required (with consequent reductions in necessary manpower, the use of farm machinery and fuel, and the saving of time). Such benefits could have positive repercussions for the traditional agriculture of Chile, especially in the production of grain maize, a crop that has suffered from a sustained reduction in its market value. Reduced production costs would benefit Chilean growers and contribute towards the sector's improvement.

The present work was performed with the conviction that the solution to the controversy surrounding the use of GM organisms (GMOs) lies in research and in the publication of sound scientific arguments on the pros and cons of this new technology.

Aims of genetic manipulation

Transgenic plants and other biotechnological products fall into three main categories depending on the objectives of the genetic manipulation undertaken (Dunwell, 1999; Schaper, 2001). The first category concerns the incorporation of resistance to insects and tolerance to specific herbicides such as Roundup. In soybean this type of modification has reduced the labour involved in cultivation, increased the efficiency of weeding, reduced the use of herbicides, and has brought direct production costs down by 25% (Izquierdo, 2001). The second category concerns improvements in nutritional value through changes in protein, starch, fatty acid, vitamin and micronutrient composition. This has involved an area of major impact in biotechnology, for example, the production of rice crops containing provitamin A (Ye *et al.*, 2000), plants with greater lipid contents (Broun *et al.*, 1999), and plants containing xenogenic proteins (Hood and Jilka, 1999). The third category concerns plants and other products with medical or pharmaceutical applications, e.g., in the production of vaccines (Walmsley and Arentzen, 2000), antibodies (Zeitlin *et al.*, 1998; Verch *et al.*, 1998), enzymes or industrial proteins (Hood *et al.*, 1997).

Public controversy surrounding genetically modified crops

The controversy over genetic modification includes ethical, economic, environmental and social concerns (Kok and Kuiper, 2003; König, 2003).

A lack of information and poor dissemination of news regarding biotechnological advances in the field of transgenic plants and GM food are both to blame for the general public's low opinion of this technology (Aldhous, 2003; Kalaitzandonakes and Bijman, 2003). Its creators and defenders have failed to inform the public sufficiently well about the benefits of transgenic products while its opponents have successfully raised concerns and fears. Governments, meanwhile, have failed to provide a consistent framework of principles for discussion and public analysis. Nonetheless, reports are available that discuss the accumulated data of several years' worth of field trials (Andow, 2003; Wilkinson *et al.*, 2003).

Current Chilean legislation regarding genetically modified organisms

Current Chilean legislation regarding GMOs is covered by Resolution No. 1523 of the Agriculture and Livestock Department (SAG, 2001), which came into force in August 2001. The first article of the Resolution recognises a number of innovations in the field including biosafety, modern biotechnology, and the evaluation of the risks associated with releasing live GMOs into the environment.

All decisions regarding the introduction of GMOs to Chile and their release into the environment rest with the SAG. For such decisions to be taken, the SAG demands an analysis of the risks involved — whether the material involved be Chilean or foreign in origin. With respect to imported materials, the competent authorities of the country of origin must provide a favourable report stating that the release of the organism into the environment will have no adverse effects. For Chilean material, as well as a risk analysis, a report is required from the SAG indicating that tests performed prior to introduction suggest there to be no negative side effects. All cases are reviewed on an individual basis. A further requirement is that an abstract should be published in the *Diario Oficial* (State Bulletin) making public the request to release a GMO. A phase of public debate can them proceed. With respect to seeds, the multiplication of GM plants must follow the *Decreto Ley N° 1764* (DO, 1977) which states the norms for research, production and marketing. This *decreto* establishes that a seed species or variety may be imported as long as all conditions regarding plant health, as well as any imposed by the Ministry of Agriculture, are met. Currently, the trading of GMOs on the Chilean market is prohibited. The law permits, however, that GM plants can be raised as long as their final product —their seeds— are exported.

Current situation regarding genetically modified crops

The area given over to GM crops worldwide increased from 1.7 million ha at the time of their introduction in 1996, to 52.6 million ha in 2001.

A review of the distribution of GM crops in 2000 and 2001 shows that the USA, Argentina, Canada and China are the main producers, with 68%, 22%, 6% and 3% of the total planted area respectively. This distribution is the same as seen for the 1999/2000 season. In 2001, transgenic crops were also produced in ten other countries, including Mexico, Australia, Germany, France, Bulgaria and Rumania (James, 2001), although the planted areas were much smaller.

The 52.6 million ha planted with GM crops represented about 19% of the total area used to raise related conventional crops in 2001. Among the most important GM crops are transgenic soybean (*Glycine max* L.), which occupies about 46% of all soybean-planted land, transgenic cotton (*Gossypium spp.)*, which occupies about 20% of cotton-planted land, transgenic canola (*Brassica napus* L. *emend.* Metzger) var. napus, 11%, and transgenic maize (*Zea mays* L., 7% (James, 2001). In global terms, the main products of 2000 and 2001 were soybean (which occupied 63% of all land planted with transgenic crops), maize (19%), cotton (13%) and finally canola (5%). On a global scale, and in terms of the genetic modification induced, herbicide-resistant soybean was the mostly widely raised GM crop (covering 63% of all GM-planted land, i.e., 33.3 million ha), followed Bt maize (11%, 5.9 million ha), herbicide-tolerant canola (5%, 2.7 million ha), herbicide-tolerant cotton (5%, 2.7 million ha), Bt cotton with herbicide tolerance (5%, 2.7 million ha), and finally herbicide-tolerant maize, Bt cotton, and Bt maize with herbicide tolerance (4%, 4%, and 3% respectively) (James, 2001). Independent of crop type, herbicide tolerance was the most important genetic modification (40.6 million ha –77% of GM-planted land in 2001), followed by resistance to insects (7.8 million ha –15%). The combination of insect resistance and herbicide tolerance represented only 4.2 million ha or 8% of total GM-planted land.

Impact on crop production costs

Transgenic crops that are resistant to herbicides, insects and disease allows growers to increase their profits; such crops require fewer agrochemical agents and potential yield per ha is improved since losses to insects are reduced and the ability to compete with weeds is increased (Riley *et al*., 1998; James, 1997; Hillyer, 1999). Crop management is also made easier, the use of herbicides and pesticides is simplified, the amounts that have to be used are less, and less time has to be spent inspecting for pests (Krattiger, 1998; Riley *et al*., 1998; Carpenter and Gianessi, 1999). The potential of genetic modification in agriculture is well known (Ferber, 1999). The mean profitability of GM crops is greater than that of conventional varieties (James, 1997; Riley *et al*., 1998) due to the cost of the seed, the quantities of agrochemicals required, the level of pest and weed infestation, and the market price that can be demanded. Any advantages provided by non-transgenic plants are usually compensated by the reduced outlay in agrochemicals and the yield associated with GM varieties. This difference varies directly depending on the pests and weeds affecting productivity (Schaper, 2001).

Transgenic soybean

Studies performed in Argentina with soybean resistant to glyphosate (a systemic herbicide with a wide action spectrum) have allowed growers to reduce production costs by 15-20% compared to crops raised form non-GM seed. GM crop yields were up by 2.4 t ha^{-1} in the 1997/8 season, and by 2.6 t ha^{-1} in 2000/2001; costs were also reduced (Arentsen, 2002). In 1998, the cost of treating conventional soybean with herbicides was approximately 62 US$ ha^{-1} compared to only 41 US$ for glyphosate treatments of GM crops. Therefore, if weed control can be achieved with a single application of glyphosate, the savings associated with transgenic soybean can be considerable (OECD, 2000).

Also in Argentina, Ablin *et al*. (2000) compared the costs and gross profits associated with soybean and maize raised from conventional seed and from RR and Bt transgenic seed. Analysis of the total direct costs for soybean showed a slight advantage of 0.2 U$S ha^{-1} in favour of the transgenic seed. However, the authors suggest that a series of non-quantifiable advantages should also be taken into account, such as the reduction in the number of applications of herbicide, the effectiveness of weed control, the simplification of tasks, and the time saved by the use of the GM crop. This translates into better performance — a product of the reduced care and labour required.

The difference in gross profits between conventional and transgenic soybean for Argentinean farmers was calculated considering a 50% better yield obtained from American farmers (USDA, 1999). According to the data considered a favourable differences up to 42 US$ and 44 US$ per ha was calculated, which largely explains the preference of Argentine growers for RR soybean.

Transgenic maize

The cost of transgenic maize cultivation, as for any crop, is of absolute importance since it has a major effect on profits. A synthesis of the changes in the cost of seed and agrochemical agents in the US$ corn belt was presented by Benbrook (1999). An increase in the price of seed between 1980 and 1996 was observed, related to the incorporation of Bt maize and the research and development costs incurred by seed companies. It is interesting to note the increase in the cost of seed and agrochemicals as a proportion of gross profit.

Comparisons between conventional and Bt transgenic maize made by Ablin *et al*. (2000) consider the latter to have a 5% better yield [as shown by studies performed by the OECD (2000)]. Under similar agricultural management, the gross profit obtained with Bt maize is higher, the greater yield obtained through effective control of the army cutworm being responsible.

Tomas (2001) (cited by Arentsen, 2002) compared the total costs and gross profits associated with RR soybean and Bt maize and their corresponding conventional crops. The results were clearly in favour of the transgenic soybean but only a rather moderate advantage was provided by the transgenic maize.

Several studies report increases in the mean yield of Bt maize over conventional maize to the order of 0.73 t ha^{-1} in 1997 and 0.26 t ha^{-1} in 1998, i.e., an improvement of between 3% and 9% in favour of the GM crop. These studies also estimate figures of between 7-40 US$ per ha in additional economic benefits (considering a mean maize price of 86.6 US$ t^{-1}) (OECD, 2000).

Studies performed by the OECD in 2000 indicate an additional cost for Bt seed over conventional seed of approximately 25 US$ ha^{-1} in 1997 and 20 US$ ha^{-1} in 1998. Bt maize, however, offers resistance to lepidopteron insects, especially the European corn weevil (*Ostrinia nubilalis*), which causes worldwide harvest losses of 15-20% (OECD, 2000).

The sugarcane borer (*Diatraea saccharalis*) annually causes serious damage to sugar cane, rice, sorghum and maize crops. The damage inflicted depends on the size of the pest population and the phenological stage of the plant when the attack occurs. In maize, losses of between 10-25% have been recorded - even 50% in some extreme cases. This damage usually worsens as sowing date is delayed (Vallone *et al*., 2000). The latter authors compared the performance of non-transgenic and transgenic (Bt) maize seeds under similar agricultural management but sown at different times, and recorded greater profits with the transgenic maize. The gross profits were calculated by multiplying the mean yield obtained with each treatment by the price of maize, and then subtracting the operating costs. The results gave no apparent reason for abandoning the use of Bt maize since the profitability of even the latest-sown crop was 8.5 times that of the gross labour capital invested (Vallone *et al*., 2000).

Aims

The aims of the present work were to:

— Produce and compare technical profiles for maize grown from conventional seed, from seed containing a gene from *Bacillus thuringiensis* (Bt) providing resistance to insects, and from transgenic Roundup Ready (RR) seed with herbicide tolerance.

— Construct potential economic scenarios for Chile if the market were open to such modified maize.

Material and Methods

Data for comparing the production costs associated with cultivating transgenic and conventional maize were collected in a questionnaire completed by the main maize seed companies from Central Chile. All belonged to the *Asociación Nacional de Productores de Semillas* (ANPROS, 2003) (National Seed Producers' Association). Ten out of 17 possible companies provided the requested information. These data provided real production costs per company; from them, technical profiles on transgenic and conventional seed production were created. Data were processed using a Microsoft Excel spreadsheet.

The following activities were undertaken:

— *Determination of the study area.* A general questionnaire revealed the area in which the main Chilean seed companies produce their seed.

— *Selection of companies and completion of the questionnaire*. Companies were contacted and presented with two questionnaires. The first covered general questions about the company while the second focused on agricultural topics such as the preparation of the soil, the workforce required, the different activities performed during cultivation, inputs, etc.

The data obtained were gathered under the following headings:

— Soil preparation.
— Sowing.
— Cultivation activities involving machinery.
— Cultivation activities involving manpower.
— Products and inputs.

Cultivation costs

Technical profiles were produced for each company using the information provided and by employing the equation:

$$VC = \Sigma(Q_i * Pr_i) + ... + (Q_n * Pr_n) \qquad [1]$$

where

VC = variable costs associated with the crop ($ * ha^{-1})
Qi = quantity or number of items (labour, input dose, etc.) (unit * ha^{-1})
Pr = price of labour or input ($ * labour^{-1})

The costs of mechanised labour, manual labour and inputs, etc., were provided by the different companies. However, if not properly provided, the values used were the market prices published in the October 2002 issue of the journal *Revista del Campo* (ODEPA, 2003).

Gross income from the crop

The gross income is the difference between the yield per ha and the price of exportable seed for each variety:

$$GI = YIELD * Pr \qquad [2]$$

where

GI = gross income from the crop ($ * ha^{-1})
YIELD = Yield per ha processed (qqm * ha^{-1}) (1qqm = 100 kg)
Pr = Seed price according to variety ($ * qqm)

Determination of the gross profit for the crop

The gross profit is the difference between the gross income and the variable costs associated with the crops:

$$GP = GI - VC \qquad [3]$$

where

GP = gross profit ($ * ha^{-1})
GI = gross income for the crop ($ * ha^{-1})
VC = variable costs associated with the crop ($ * ha^{-1}).

Sensitivity analysis

The gross profits of the companies were compared to see whether there were any economic differences between raising transgenic and conventional crops. A technical profile was then produced based on international experience data concerning the production of grain maize using transgenic seed, which is not used by Chilean growers. These data were compared with those of a similar profile for high technology growers using conventional maize seed. This provided a means of examining the potential economic benefits offered by transgenic seed in a hypothetical scenario in which growers could buy seed with the Bt and RR modifications on the Chilean market.

Results and Discussion

General background

Currently, the *VII Región Del Maule* is the area of Chile with the highest concentration of maize seed producers - greater than the *Región Metropolitana* and even greater than the *VI Región*, traditionally the area of greatest maize production. Some companies produce seed in both the *VI* and *VII Región*.

These companies face the problem of isolating their crops from other commercial or traditional seed crops, but also from crops whose parentals have undergone genetic modification (i.e., GM plants). The most important companies raising GM plants in Chile are located in the *VI Región* (where there are six), the *VII Región* (with 5) and the *Región Metropolitana* (with 1). But more or less the same distribution is seen for GMO-free seed, with seven companies in the *VI Región*, six in the *VII Región* and one in the *Región Metropolitana*.

The questionnaire showed that the majority of companies working with GM maize take precautions to reduce the possibility of contamination, and that they comply with the norms imposed by the SAG and the Biosafety Protocol, and meet the demands of their foreign clients in terms of genetic and varietal purity. The main differences in production concern the greater isolation of GM plants, the separation of GM from GMO-free crops, the recording of global positioning system (GPS) data where cultivation occurs, compliance with SAG resolutions, separate harvesting and processing, and the cleansing required of sowing, harvesting and processing machinery.

Most of the companies surveyed do not take full advantage of the genetic modifications of the maizes they produce. Despite these crops being resistant to insects and herbicides, these companies still use pre- and post-emergence insecticides and herbicides. This is mainly because the males and females of the varieties multiplied do not always show the same genetic modifications. This is more important with respect to herbicide resistance since no machinery exists that can apply herbicides without damaging the line lacking the resistance modification. Only two companies have developed a way to make such applications to their seed reserves and thus take advantage of the genetic modifications made; in so doing, they have considerably reduced their costs.

Production costs associated with modified and conventional maize seed

To honour confidentiality, and given the strong rivalry in the seed business, the names of the responding companies are not mentioned. Two companies whose costs represented the mean of national companies operating in the sector were then compared, one producing GM maize, the other traditional maize. Table 1 shows the production costs per ha for these two companies.

The main differences between them were:

a) **Soil preparation:** The costs of the company dealing with GM maize showed costs in this area 8.75% below those of the company dealing with conventional maize. The latter company undertook more activities in this area, which increased its costs. This might have been due to location and grower technological level.

b) **Sowing:** The company dealing with transgenic seed had greater sowing costs (11.7% higher), since, inexplicably, very expensive furrowing was performed.

c) **Other activities:** Great differences were found between the two growers, but not because of the seed. Rather, these were the result of company practices and cultivation costs. For example, as well as banking up the crop, the company using traditional seed undertook two additional harrowings, applied of an acaricide, and employed harvest practices costing around twice as much those used by the transgenic seed company. This resulted in mechanical costs some 62.2% higher.

d) **Manpower:** The costs for the GM-seed company were 12.4% lower than those of the traditional seed company, mainly because the former undertook no hand-hoeing; glyphosate herbicide adequately controlled all weeds.

e) **Inputs:** The difference here was some 252.25 US$, the GM-seed company showing 51.5% lower costs. However, although the outlay for post-emergence insecticides and herbicides was lower for the GM crop company, the bulk of this difference was actually due to the company's policy of not applying acaricides or fungicides and its use of lower doses of maize mix and urea (see Table 1). It is important to note that these differences do not, therefore, have anything to do with the transgenic nature of the seed; they are all due to cultivation practices.

Hypothetical scenarios involving market access for GM crops in Chile

Using data from international experience in transgenic maize seed production, a technical profile was produced for comparison with a similar profile prepared for traditional seed maize grown in the Talca region (using mean national data). The following assumptions were made:

1. That the grain yield corresponded to the mean national yield for 2001-2002 (SAGA, 2003), and that this reached 102 qqm ha^{-1}. In agreement with that described by Tomas (2001), it was assumed that the use of Bt transgenic seed would increase total income by 5%. Therefore if the price per qqm (100 kg) do not vary, then the variation in price can be attributed to the yield.

2. That GM seed has a 24% higher cost than traditional seed (Tomas, 2001).

3. That the cost of maize corresponded to the mean wholesale price for the months of January 2001-June 2003 as published by the ODEPA (2003).

Table 1. Costs (Chilean pesos $) per hectare associated with conventional and transgenic maize seed

Item	Conventional maize seed			GM maize seed		
	Quantity ha^{-1}	**Price $ unit^{-1}**	**Value ($)**	**Quantity ha^{-1}**	**Price $ unit^{-1}**	**Value ($)**
Soil preparation						
Chisel plough	2	13,000	26,000	1	13,000	13,000
Mouldboard plough	1	30,000	30,000	1	18,000	18,000
Rotary cultivator				1	18,000	18,000
Disk harrowing	2	12,000	24,000	2	12,000	24,000
Subtotal			80,000			73,000
Sowing						
Preplanting herbicide application	1	6,500	6,500	1	6,500	6,500
Sowing	1	38,000	38,000	1	40,000	40,000
Furrowing	1	2,500	2,500	1	6,000	6,000
Subtotal			47,000			52,500
Other practices						
Cultivate	1	14,000	14,000	1	16,000	16,000
Banking up + N	1	16,000	16,000			
Flame weeding	3	5,000	15,000	1	1,000	1,000
Aeroplane application	3	6,800	20,400	3	6,500	19,500
Cutting male	1	5,500	5,500	1	8,000	8,000
Herbicide application	1	6,500	6,500			
Insecticide application	1	6,500	6,500	1	6,000	6,000
Acaricide application	1	12,000	12,000			
Strike out irrigation	1	2,500	2,500			
Harvest	1	115,000	115,000	1	50,000	50,000
Harvest transport (mean locality)	1	47,000	47,000	1	60,000	60,000
Subtotal			260,400			160,500
Manpower						
Spreading of fertilizer	1	800	800	1	800	800
Maintenance of irrigation system	1	10,000	10,000	1	10,000	10,000
Manual hoeing	1	40,000	40,000			
Preplanting irrigation	1	5,000	5,000	1	5,000	5,000
Irrigation	10	6,000	60,000	12	5,000	60,000
Plant elimination	1	5,000	5,000			
Roguing	10	6,500	65,000	4	6,000	24,000
Male flower elimination	24	6,500	156,000	28.5	7,000	199,500
Subtotal			341,800			299,300
Input						
Maize mix (17-20-20)	500	142	71,000	450	142	63,900
Granulated urea (banking up)	400	125	50,000	300	125	37,500
Alachlor	5	5,612	28,060			
Atrazine	3	2,245	6,735	2.5	1,992	4,980
Atrazine + mineral oil	3	4,080	12,240			
Gramoxone	2	4,490	8,980			
Chlorpyriphos	5	3,819	19,095	5	3,819	19,095
Pyrethrine	0.75	30,287	22,715	0.75	30,287	22,715
Methamidophos	1	5,859	5,859	1	5,859	5,859
Pyrethrine	0.25	30,287	7,572			
Kelthane	2	13,096	26,192			
Wettable sulphur	6	998	5,988			
Atout	13	4,094	53,222			
Subtotal			317,658			154,049
Total costs + VAT in Ch$			1,046,858			739,349
Total costs + VAT in US$			1,614			1,140

VAT: value added tax (18%). *Source:* produced by authors (2003).

Table 2. Costs per hectare for conventional and transgenic maize

	GMO free ($)	GMO RR ($)	GMO Bt ($)
Technological level		National mean	
Price US$ (in Chilean $)	648.60	648.60	648.60
Yield (qqm ha^{-1})	102[1]	102[1]	107.1[3]
Unit price[2] ($ qqm^{-1})	8,857	8,857	8,857

[1] Mean yield for 2001-2002. (Source: SAGA, 2003). [2] Unit price corresponds to mean prices for 2001–2003 ($ qqm-[1]) (Source: El Mercurio, 2003). [3] Performance of GMO Bt maize 5% greater.

Table 2 shows the costs per ha for conventional and transgenic maize seed in a scenario where GM seed has free access to the Chilean market.

In such a scenario for Bt and RR seed, some factors would not change such as soil leasing and soil preparation, banking up, and the application of herbicides and insecticides. With respect to total manpower costs, those associated with transgenic maize would be 32% lower than those associated with conventional seed. This is because glyphosate removes the need of hoeing by hand.

The use of inputs might be thought to have a major influence on production costs, but these would be higher for conventional maize by only 2% (7.23 US$ per ha). Although the transgenic crops would cost less in insecticides and herbicides, the greater cost of the seed (24% extra) would make the final difference of little importance.

The harvest costs for the transgenic maize would be 3% higher (5.03 US$ per ha) than the conventional crop: the greater yield of the transgenic crop would increase the cost of transporting and drying. In general, the total production costs for GM maize would be 1,149.40 US$ per ha, while for conventional grain the figure would be 1,216.45 US$ per ha. Therefore, switching to GM maize would reduce costs by 63.87 US$ per ha (6%) and would have a strong impact on final gross income.

Total income —the product of the maize price multiplied by the yield obtained— would be 3% higher with GM maize. This would mainly be due to the greater yield obtained with transgenic crops. This is surely a reflection of the better pest and weed control achieved.

Economic analysis shows that because of these greater returns and lower production costs, the gross profit associated with GM maize would 77% or 136.70 US$ per ha higher than with conventional crops.

Analysis of the above scenario

The only GM seed allowed into Chile is that whose product is destined for export. Table 3 shows hypothetical scenarios in which transgenic seed is allowed access to the market, and reveals the benefits that such technology could bring to traditional agriculture. The use of RR maize throughout the country (Scenario

Table 3. Costs (Chilean pesos $) and consumption comparison of herbicides and insecticides for scenarios with conventional and transgenic maize

Mean national area (1993-2003)	90,056 ha
Mean national yield (2001-02)	102 qqm ha^{-1}

Source: SAGA, 2003.

Scenario 1		Dose (L ha^{-1})	Unit cost ($)	$ ha^{-1}	Consumption Chile (L)	Cost Chile ($)
Maize RR	Glyphosate	3	3,450	10,350	270,169	932,081,670
Maize Bt	Methamidophos	1	3,057	3,057	90,056	275,301,803

Scenario 2		Dose (L ha^{-1})	Unit cost ($)	$ ha^{-1}	Total $ ha^{-1}	Consumption Chile (L)	Cost Chile ($)
Traditional maize	Bentazon	2	8,765	17,530	22,510	180,112	1,578,685,186
	Atrazine	2.5	1,992	4,980		225,140	448,479,876
	Methamidophos	1	3,057	3,057	10,651	90,056	275,301,8036
	Pyrethroid	0.25	30,375	7,594		22,514	683,864,269

1 US$ = 648.60 Chilean pesos. *Source:* produced by authors (2003).

Annex 1) would generate an use of glyphosate of more than 270,000 L, and an income for the companies marketing this product of some thousand million Chilean pesos. With respect to Bt maize, the differences with respect to insecticide use would lie in the non-use of pyrethroids: some 22,514 L would no longer be needed for maize cultivation. If Scenario 2 (Annex 2) were to disappear, the national demand for glyphosate would increase but there would be a corresponding fall in the sale of post-emergence herbicides such as atrazine and bentazon to the order of some two thousand million pesos.

The marketing of transgenic seed in Chile will certainly give rise to much debate. Until now controversy has only been centred on ecological and environmental issues, but much remains to be discussed with regard to its effects on the marketing of inputs.

Conclusions

— The total direct cost of multiplying GM maize seed is 8.75% lower than that associated with conventional seed. This is owed to a reduction in the number of cultivation practices required. With respect to input costs, these may fall by 72% of those associated with raising conventional maize seed, mainly because of the reduced use of agrochemical agents. The use of herbicides with transgenic RR crops would reduce labour costs by 14.2%.

— The use of GM seed maize would increase the competitiveness of the sector due to reduced production costs and increased income through higher yields. If RR maize were used, production costs would fall by 5.11% if weeding were manual - a 27.61% increase in gross profit per ha. If Bt seed were used, the increased yield obtained would greatly outweigh the 0.37% increase in production costs; gross profit would rise by 30.1% above that obtained with conventional seed.

— The gross profit from maize production with GM seed would be further increased if manual weeding were replaced by the use of a post-emergence herbicide (atrazine plus mineral oil). Bt seed would give the best results, the gross profit reaching 47.9% above that obtained with conventional seed. However, this would not be wise if RR maize were used; gross profit would fall from 27.61% extra to 12.98% extra.

— Owing to its particular agroecological characteristics, the area that would experience the greatest positive impact of freely available GMO seed would be from Maule river towards the south. Rainfall increases towards the south of Chile and sowing is delayed until around the second half of October or thereafter. This exposes the crop to severe attack from army cutworm and corn earworm (*Heliothis zea*). The use of Bt seed would lead to a strong reduction in the use of insecticides, reducing the associated costs and therefore increasing gross profit.

— Free production of grain maize based on the use of GM seed could be detrimental to the seed-producing industry since it would pose a contamination problem. Seed multipliers must isolate their lands to avoid contamination and ensure genetic homogeneity. It is clear that these companies would oppose the free commercial use of GMO in Chile. This should be taken into account by the agricultural authorities. National producers of maize grain would also have to compete with imported maize strongly supported by large subsidies in its different countries of origin.

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Annex 1. Costs (Chilean pesos $) per hectare for conventional and transgenic maize (RR and Bt). Scenario with manual weeding and no use of post-emergence herbicide

	Quant ha^{-1}	$ unit^{-1}	GMO-free ($)	GMO RR ($)	Difference RR	GMO Bt ($)	Difference Bt
Soil leasing			**150,000**	**150,000**		**150,000**	
Soil leasing			150,000	150,000		150,000	
Soil preparation			**84,000**	**84,000**		**84,000**	
Chisel plough	1	13,000	13,000	13,000		13,000	
Mouldboard plough	1	30,000	30,000	30,000		30,000	
Preplanting irrigation	1	5,000	5,000	5,000		5,000	
Disk Harrowing or field cultivator	3	12,000	36,000	36,000		36,000	
Sowing			**32,000**	**32,000**		**32,000**	
Preplanting herbicide application	1	6,000	6,000	6,000		6,000	
Sowing	1	20,000	20,000	20,000		20,000	
Furrowing	1	6,000	6,000	6,000		6,000	
Other practices			26,000	26,000		26,000	
Cultivate + banking up + N	1	14,000	14,000	14,000		14,000	
Herbicide application	1	6,000	6,000	6,000		6,000	
Insecticide application	1	6,000	6,000	6,000		6,000	
Labour manpower			**125,000**	**85,000**	**–32.00%**	**125,000**	
Maintenance of irrigation system	1	10,000	10,000	10,000		10,000	
Manual hoeing	*1*	*40,000*	*40,000*		*–100.00%*	*40,000*	
Irrigation	15	5,000	75,000	75,000		75,000	
Inputs			**224,775**	**227,683**	**1.29%**	**224,212**	**–0.25%**
Seed[1]	1	Bag	42,029	52,116	24.00%	52,116	24.00%
Maize mix (20-14-12)	400	142	56,800	56,800		56,800	
Granulated urea (banking up)	500	125	62,500	62,500		62,500	
Atrazine	3	2,246	5,615	5,615		5,615	
Surpass	3	6,150	15,375	15,375		15,375	
Chlorpyriphos	5	2,855	14,275	14,276		14,276	
Glyphosate	*3*	*3,450*		*10,350*	*100.00%*		
Methamidophos	*1*	*3,057*	*3,057*	*3,057*			*–100,00%*
Karate	*0.25*	*30,375*	*7,594*	*7,94*			*–100,00%*
Basagran	2	8,765	17,530		–100.00%	17,530	
Harvest			**110,280**	**110,280**		**113,544**	**2.96%**
Harvest	1	45,000	45,000	45,000		45,000	
Drying	1	$60/qqm*grade	21,420	21,420		22,491	5.00%
Harvest transport (50 Km)	1	$4,3/qqm*Km	43,860	43,860		46,053	5.00%
Subtotal costs			**726,055**	**688,963**	**–5.11%**	**728,756**	**0.37%**
Unforeseen costs (5%)			36,303	34,448	–5.11%	36,438	0.37%
Total costs		**($ ha^{-1})**	**762,357**	**723,411**	**–5.11%**	**765,194**	**0.37%**
Final yield[1]			102	102		107	5.00%
Total income			903,414	903,414		948,585	5.00%
Gross profit		**($ ha^{-1})**	**141,057**	**180,003**	**27.61%**	**183,391**	**30.01%**

[1] GM seed is 24% more expensive than GMO-free seed. 1 US$ = 648.60 Chilean pesos. *Source:* produced by authors (2003).

Annex 2. Scenario with post-emergence herbicide application (2) and no manual hoeing

	Quant ha^{-1}	\$ unit^{-1}	GMO-free (\$)	GMO RR (\$)	Difference RR	GMO Bt (\$)	Difference Bt
Soil leasing			150,000	150,000		150,000	
Soil preparation			**91,000**	**91,000**		**91,000**	
Chisel plough	2	14,000	28,000	28,000		28,000	
Mouldboard plough	1	30,000	30,000	30,000		30,000	
Preplanting irrigation	1	5,000	5,000	5,000		5,000	
Disk harrowing or field cultivator	2	14,000	28,000	28,000		28,000	
Sowing			**29,000**	**29,000**		**29,000**	
Preplanting herbicide application	1	6,000	6,000	6,000		6,000	
Sowing	1	20,000	20,000	20,000		20,000	
Furrowing	1	3,000	3,000	3,000		3,000	
Other practices			**46,000**	**40,000**	**–13.04%**	**46,000**	
Corn grower contract costs	1	12,000	12,000	12,000		12,000	
Cultivate + banking up + N	1	16,000	16,000	16,000		16,000	
Herbicide application	*2*	*6,000*	*12,000*	*6,000*	*–50.00%*	*12,000*	
Insecticide application	1	6,000	6,000	6,000		6,000	
Manpower			**75,000**	**75,000**		**75,000**	
Maintenance of irrigation system	1	10,000	10,000	10,000		10,000	
Irrigation	13	5,000	65,000	65,000		65,000	
Inputs			**252,768**	**244,968**	**–3.09%**	**241,588**	**–4.42%**
Seed[1]	1	Bag	45,000	47,250	5.00%	47,250	5.00%
Maize mixture (20-14-12)	600	142	85,200	85,200		85,200	
Granulated urea (banking up)	400	125	50,000	50,000		50,000	
Pre-sowing atrazine	2,5	2,245	5,613	5,613		5,613	
Post-emergence atrazine (2)	*5*	*4,080*	*20,400*		*–100.00%*	*20,400*	
Surpass	2,5	5,612	14,030	14,030		14,030	
Chlorpyriphos at sowing	5	3,819	19,095	19,095		19,095	
Glyphosate	*3*	*3,450*		*10,350*	*100.00%*		
Methamidophos	*1*	*5,859*	*5,859*	*5,859*			*–100.00%*
Karate	*0,25*	*30,287*	*7,572*	*7,572*			*–100.00%*
Harvest			**110,280**	**110,280**		**113,544**	**2.96%**
Harvest	1	45,000	45,000	45,000		45,000	
Drying (\$ qqm^{-1} * grade)	1	60	21,420	21,420		22,491	5.00%
Harvest transport (50 km, \$ qqm^{-1} km^{-1})	1	4.3	43,860	43,860		46,053	5.00%
Subtotal costs			**754,048**	**740,248**	**–1.83%**	**746,132**	**–1.05%**
Unforeseen costs (5%)			37,702	37,012	–1.83%	37,307	–1.05%
Total costs		**(\$ ha^{-1})**	**791,751**	**777,261**	**–1.83%**	**783,438**	**–1.05%**
Final yield[1]			102	102		107	5.00%
Total income			**903,407**	**903,407**		**948,577**	**5.00%**
Gross profit		**(\$ ha^{-1})**	**111,656**	**126,146**	**12.98%**	**165,139**	**47.90%**

[1] GM seed is 24% more expensive than GMO-free seed. 1 US\$ = 648.60 Chilean pesos. *Source:* produced by authors (2003).