The socio-economic and environmental impacts from using corn hybrids with biotech trait/technologies in Vietnam

Graham Brookes
PG Economics Ltd, UK
And
Tran Xuan Dinh
Former Deputy Director General
Crop Production Department, Ministry of Agriculture and Rural Development (CPD MARD), Vietnam

Dorchester, UK
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Foreword

The authors of this paper would like to thank staff in the Crop Production Department of the Ministry of Agriculture and Rural Development (CPD MARD) and technical staff in the Provincial Departments of Crops and Plant Production for undertaking the survey of farmers in Vietnam. Thanks' are also extended to the farmers for providing responses to the survey.

Graham Brookes and Tran Xuan Dinh
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Executive summary and conclusions

This paper provides an independent assessment of the farm level economic and environmental impact[1] associated with the adoption of biotech corn technology in Vietnam.

Context of current production systems

The 2019 area planted to corn was about 0.9 million hectares (ha), of which biotech corn seed was planted on 92,000 ha (10.2% of the total crop).

The biotech corn technology represents an alternative to existing conventional corn crop technology. It offers weed control through seed that is tolerant to the broad-spectrum herbicide glyphosate commonly used as both a pre-plant or post-emergent herbicide. In addition, the technology offers resistance against the important lepidopteran pest of corn, the Asian Corn Borer (ACB), allowing farmers to reduce the loss to yield that this pest causes. It also provides protection against the Corn Earworm (CEW), Common Cut Worm (CCW) and Fall Armyworm (FAW) pests. This technology was first made available to farmers in nine corn varieties in 2015, and in 2019 continued to be available in these nine stacked[2] varieties. The technology was/is not available in some of the latest developed varieties, nor is it available in specialty corn (eg, waxy corn, sweetcorn) varieties.

Research methodology

The primary source of information has come from a survey of farmers in corn growing regions of the country in 2018-2019, conducted by staff from the Crop Production Department of the Ministry of Agriculture and Rural Development (CPD MARD) and technical staff in the Provincial Departments of Crops and Plant Production. The survey aimed to be reasonably representative of corn production by region, with a focus on regions where biotech seed was widely grown. A total of 735 farms were interviewed.

Survey findings

The average size of farm was 0.865 ha, and on each farm, the average area devoted to corn was 0.63 ha. The remaining area was used for other farm enterprises such as growing rice or keeping livestock. The farms using biotech seed were, on average, marginally larger than the conventional corn growers.

The main survey findings and impacts of using biotech corn were (see Table 1 for a summary):

Yield performance, production and farm income impacts

- The biotech varieties out-performed conventional varieties in terms of yield by +30.4% (+2.03 tonnes/ha or about 1.27 tonnes/ha de-husked and dried). In relation to a yield comparison between the nearest performing equivalent conventional varieties to the biotech-traited varieties, the biotech varieties outperformed the conventional equivalents by +15.2% (+1.15 tonnes/ha or 0.72 tonnes/ha de-husked and dried). In revenue terms this amounted to an increase of between 3.75 million Vnd/ha and 6.65 million Vnd/ha;
- Weed control practices have changed, with changes in the type and nature of herbicides applied (more use of the broad-spectrum herbicide glyphosate and less use of pre-

[1] Environmental impact arising from changes in herbicide and insecticide use

[2] Stacked refers to the two traits of herbicide tolerance and insect resistance

emergent herbicides like atrazine and acetochlor). There has also been a reduction in the use of hand weeding. Whilst average expenditure on herbicides and their application has increased, this has been more than offset by savings from less use of hand weeding. Overall, the average cost of weed control has fallen by 1,172,300 Vnd/ha;

- Pest control practices have changed. There has been a reduction in use of insecticides, with the control of the main lepidopteran pests of corn now provided via the seed, leaving residual use of insecticides for the control of pests not controlled by the biotech traits. These savings amounted to 328,040 Vnd/ha. In addition, farmers using biotech varieties spent less time walking/scouting their crops checking pest levels. This resulted in an additional cost saving equal to about 510,000 Vnd/ha;
- The higher yields derived from biotech corn have required additional use of labour for harvesting. This extra cost has been an average of nearly 677,660 Vnd/ha;
- The cost of seed has increased, with the seed premium for biotech corn seed being an average of between 636,060 Vnd/ha (average to all conventional varieties used) and 743,620 Vnd/ha (average to equivalent performing varieties to the biotech varieties);
- Overall, the net impact on farm income associated with using biotech corn has been an increase in the average level of farm income of between 4.34 million Vnd/ha (relative to equivalent conventional varieties) and 7.34 million Vnd/ha. In US dollar terms, this equates to an income gain of between +$195/ha (equivalent conventional varieties) and +$330/ha (average of all conventional varieties);
- Examining the cost farmers pay for accessing the biotech seed technology, the average additional cost of seed (seed premium) relative to conventional seed, was between 636,060 Vnd/ha (US $28.6/ha) and 742,620 Vnd/ha (US$33.43/ha). These cost of technology values are equal to between 8% and 15% of the total (gross) technology gains (before deduction of the additional cost of the technology payable to the seed supply chain - the cost of the technology accrues to the seed supply chain including sellers of seed to farmers, seed multipliers, plant breeders, distributors and the GM technology providers). In terms of investment, this means that for each extra dollar invested in biotech corn seed, farmers gained an average of between US $6.84 and US $12.55;
- An important production impact highlighted by 60% of biotech corn users was improvements in the quality of the grain. Through reduced levels of pest damage, the aflatoxin levels in the grain have typically been lower than for conventional corn, leading to reduced levels of wastage and/or rejection by purchasers (of the grain), notably in the food using sector.

Table 1: Summary of farm level income impact of using biotech corn (Vnd/ha)

	Biotech	**Conventional: all**	**Conventional: nearest equivalent varieties to biotech**
Crop yield (tonnes/ha)	8.72	6.69	7.57
Crop yield de-husked/dried (tonnes/ha)	5.45	4.18	4.73
Price 2019	5,227,340	5,227,340	5,227,340
Revenue	28,498,522	21,850,354	24,747,448
Yield difference (tonnes/ha)		**1.27**	**0.72**
Revenue change		**+6,648,168**	**+3,751,074**

Cost of seed	2,909,690	2,273,630	2,166,070
Seed premium		**- 636,060**	**- 743,620**
Weed control costs: weighted average			
Herbicides	833,900	531,100	531,100
Hand weeding	60,100	1,517,300	1,517,300
Mechanical	12,000	29,900	29,900
total cost	906,000	2,078,300	2,078,300
Change in weed control costs		**1,172,300**	**1,172,300**
Pest control costs			
Insecticides	235,000	563,040	563,040
Change in insecticide costs		**328,040**	**328,040**
Crop walking/scouting	181,200	691,200	691,200
Change in crop walking/scouting costs		**510,000**	**510,000**
Harvesting costs	2,778,160	2,100,500	2,100,500
Change in harvesting costs		**- 677,660**	**- 677,660**
Total change in costs of production		696,620	589,060
Total change in income including yield gain		**+7,344,788**	**+4,340,134**
Total change in income in US $ terms		**+330.19**	**+195.11**

Exchange rate $1 = 22,244 (2019 average)
Note: - ve sign = increase in costs

Labour use changes
The main changes in labour use associated with the adoption of biotech corn were:

- A reduction in the total amount of labour used per ha of about 71 hours/ha (-8.9 days). This derives from less use of labour for weeding (largely hand weeding), application of insecticides and crop walking/scouting. Some of these labour reductions were offset by an increase in the labour requirement for harvesting;
- The majority of the labour use changes and especially the requirements for less labour use have affected family labour. For hired labour, the adoption of biotech corn has resulted in a small net increase in labour requirement because of the increased requirement for labour for harvesting. Whilst the requirement for hired labour to undertake weed control (and to a lesser extent pest control) has decreased, this has been more than offset by an increase in hired labour use for harvesting. Overall, the hired labour requirement has increased by about 10 hours/ha (1.25 days/ha);
- The overall reduction in labour use on biotech corn growing farms, which has mostly impacted on the use of family labour was acknowledged by many of these farmers as a positive aspect of change because it had freed up more time for farmers and their family to spend on other income-generating activities and leisure.

Environmental impact associated with herbicide use for weed control
Whilst biotech corn farmers have increased their use of herbicides as the primary form of weed control relative to the weed control practices of conventional corn producers, the average amount of herbicide active ingredient used and its associated environmental impact, as measured by the EIQ indicator, is lower for biotech corn than conventional corn. The average amount of herbicide active ingredient applied on the biotech crop area was 26% lower (1.66 kg/ha) than the average value for the conventional corn area (2.26 kg/ai per ha).

In terms of the associated environmental impact of the herbicide use, as measured by the EIQ indicator, the average eiq/ha value for herbicides applied to the biotech crop area was also lower by 36% (30.26/ha) than the average value applicable to the conventional corn area (46.95/ha).

Environmental impact associated with insecticide use for pest control
The adoption of biotech corn has led to insecticides being used on a significantly lower crop area and, where used, in smaller amounts. Insecticides were applied to only 19% of the biotech crop area (for the control of pests not controlled by the biotech trait) compared to 72% of the conventional corn area (for the control of all corn pests). When this insecticide usage is averaged across the respective total areas planted to biotech and conventional corn, the average amount of insecticide applied to the biotech corn crop was significantly lower by 78% (0.08 kg/ai per ha) than the average value for the conventional corn area (0.36 kg/ai per ha).

In terms of the associated environmental impact of the insecticide use, as measured by the EIQ indicator, the average eiq/ha value for insecticides applied to the biotech crop area was also lower by 77% (3.23/ha) than the average value for conventional corn (14.06/ha).

Views, experiences and perceptions of biotech corn
The vast majority of farmers who had grown biotech corn expressed high levels of satisfaction with the technology, with 99.5% of adopters stating that they would be using the technology in the 2020 crop year. The high levels of satisfaction were linked to the benefits; of better pest and weed control, higher yields, higher incomes and better grain quality. In addition, higher income provided more money for on-farm investment and household expenditure. The reduced need for family members to work on farms was also viewed positively.

The main reason cited by conventional corn growers for not trying the new technology was the (perceived high) price of the seed and/or the view that any benefit (of adoption) would be less than the extra cost of the seed.

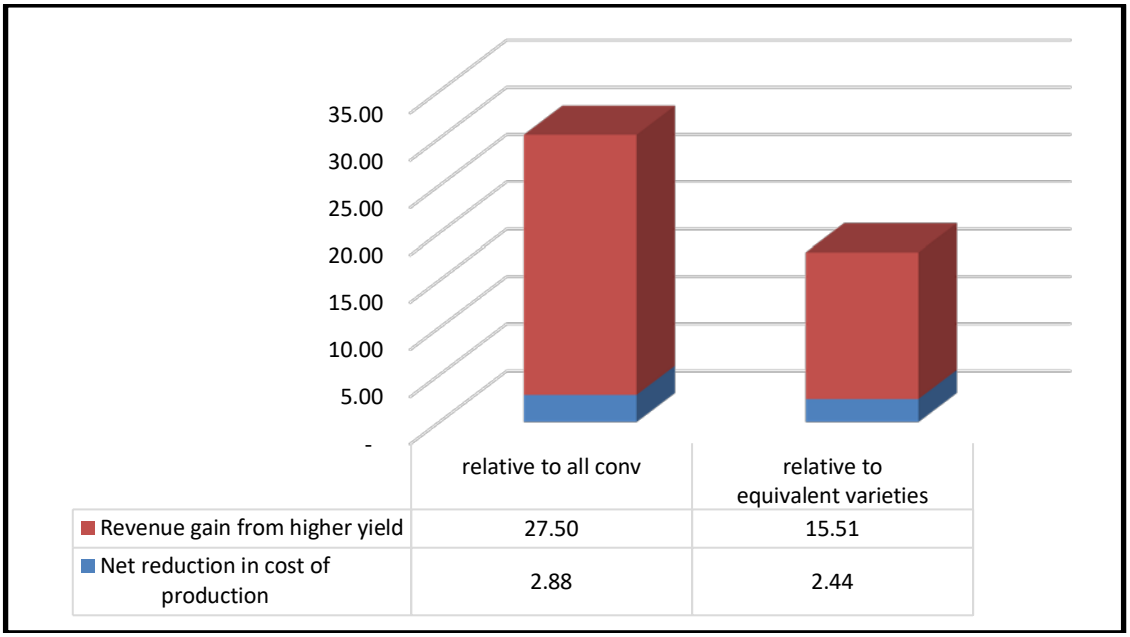
Aggregated (national level) impacts

Farm income, production and labour change impacts
The aggregated farm level income impact of using biotech corn in 2019 (on 92,000 ha or about 10.2% of the national crop) was a net income gain of between $17.95 million (based on the yield gain relative to the nearest equivalent varieties to the biotech varieties) and $30.38 million (based on the yield gain relative to all conventional varieties: Figure 1). The vast majority of these income gains (more than 90%) came from yield gains.

If these farm income gains are applied to the cumulative biotech crop area planted since the technology was first used in 2015 (a total of 224,500 ha), the total farm income gain has been

between US $43.8 million (based on the yield gains relative to the nearest equivalent conventional varieties) and $74.1 million (based on the yield gains relative to all conventional varieties).

Figure 1: National farm income benefits associated with adoption of biotech corn (US $ million) in 2019



	relative to all conv	relative to equivalent varieties
Revenue gain from higher yield	27.50	15.51
Net reduction in cost of production	2.88	2.44

Based on the yield gains identified in the survey, the biotech corn technology added between 66,000 tonnes and 117,000 tonnes of corn in 2019 and cumulatively since 2015 has added between 157,900 tonnes (based on the yield gains relative to the nearest equivalent conventional varieties) and 315,400 tonnes (based on yield gains relative to all conventional varieties). This extra production has made a small contribution to reducing pressure on farmers to use additional land for crop production. If biotech corn technology had not been available to farmers in 2019, maintaining production levels for this year using conventional technology would have required the planting of an additional 13,930-24,680 ha of agricultural land to corn. This equates to between 1.5% and 2.7% of the total area planted to corn in 2019.

At the national level, the aggregate labour impact in 2019 is small and equal to a net reduction in labour use of about 6.52 million hours or 815,000 days (or 3,400 full-time equivalents - FTEs). Most of this reduction in labour use has affected family labour. In terms of hired farm labour, the impact has been a net increase of about 0.92 million hours (115,000 days), or 480 FTEs, primarily for additional crop harvesting work.

Environmental impacts associated with changes in weed and pest control practices

The use of biotech corn (on the equivalent of 10.2% of the total corn crop) resulted in a reduction in the amount of herbicide active ingredient used on the 2019 total corn crop (0.9 million ha) of 2.7% (-55,220 kg) and a net reduction in the associated EIQ value of 3.6%. Cumulatively, since 2015, there has been a net decrease in the amount of herbicide active ingredient used of 134,760 kg (-1.2% of total crop use over this period) and a net reduction in the environmental load associated with herbicide use, as measured by the EIQ indicator of 1.5%.

In terms of the pest control changes, the use of biotech corn has led to a reduction in the amount of insecticide active ingredient used on the whole crop of 25,440 kg (-7.95%) and a net reduction in the associated EIQ value of 7.87%. Cumulatively, since 2015, there has been a net decrease in the amount of insecticide active ingredient used of 62,075 kg (-3.4% of total crop use over this period) and a net reduction in the environmental load associated with insecticide use, as measured by the EIQ indicator of 3.3%.

Concluding comments

The performance of biotech corn in Vietnam has been very positive, delivering significant socio-economic benefits to the farms that have used the technology. There have also been wider (to society) environmental benefits associated with changes to weed and pest control practices.

Comparing the performance of the biotech seed technology in 2019 at the farm level with the expected (ex-ante) performance[3], the benefits realised have significantly exceeded expectation:

- The yield gains, at more than +15% (and up to +30%) are higher than the expected +5% to +12%. This suggests that historic estimates of yield losses associated with pest damage and weed competition in the conventional crop may have been conservative. Equally with the incidence of a relatively new corn pest in Vietnam in 2019 (the Fall Armyworm), the positive yield impacts identified in the study may have begun to include a contribution from the effective control to this pest in the regions where this pest has become established, whilst conventional corn growers have suffered additional yield losses and incurred additional costs for extra insecticide applications;
- Largely due to the high yield benefits derived, the farm income gains derived by farmers (+$195/ha to +$330/ha) also exceeded expectation;
- The average return on investment (relative to every extra $1 cost of biotech seed) of between US $6.84 and US $12.55 is one of the highest rates of return earned by any biotech crop-adopting farmers in the world. It is broadly equivalent to the level of returns earned by biotech cotton farmers in India and China and is higher than the returns biotech corn farmers in the Philippines have achieved (of about $6.2);
- The small net decrease in employment requirements on-farm, is consistent with the estimates made in the ex-ante paper of 2017;
- The environmental gains of reduced use of herbicides, a switch to more environmentally benign herbicides and a reduction in insecticide use are larger than the levels suggested in the ex-ante report.

It should also be noted that the insecticide use savings identified in the study may understate the likely level of savings (in terms of both expenditure on insecticides and environmental benefits associated with reduced insecticide use) because some biotech farmers (about 20%) were still using some insecticide in early 2019 targeted at control of the FAW pest. At that time, this was a relatively new corn pest in Vietnam and farmers had no experience of the levels of efficacy of biotech seed in controlling it and therefore were probably undertaking some 'insurance' use of insecticides.

[3] See Brookes G. The potential socio-economic and environmental impacts from adoption of corn hybrids with biotech trait/technologies in Vietnam. 2017. PG Economics, UK. www.pgeconomics.co.uk

Whilst these farm level benefits have provided national level gains in terms of higher farm/rural household income levels, additional production of corn and wider societal environmental benefits, these have, to date, been limited due to the relatively low levels of adoption of the technology. A significant increase in the national level of both socio-economic and environmental benefits are likely to arise if levels of adoption can be increased.

The evidence identified in this research may contribute to increased adoption if effectively communicated to more corn farmers in Vietnam. However, for higher levels of adoption to be realised, the biotech (seed) technology needs to be available in more of the leading varieties of corn.

Lastly, an additional factor that is likely to impact on future adoption levels is the introduction of the ban on the use of the herbicide glyphosate effectively from mid-2021 when the phase out for use ends. This will reduce the scope for obtaining some of gains identified in this study and is therefore likely discourage adoption.

1 Introduction

Corn crops that have been genetically modified (GM/biotech) to be tolerant to herbicides and resistant to some of the main corn pests became available to farmers in Vietnam in 2015. In 2019, 92,000 ha (about 10.2% of the total crop) were planted to seed containing biotech traits in Vietnam (source: CPD MARD).

This relatively new corn seed technology offers greater flexibility to Vietnam corn farmers for managing and minimising the development of weeds through seed that is tolerant to the herbicide glyphosate. In addition, the biotech corn offers resistance against the Asian Corn Borer (ACB) pest and other pests such as earworms, common worms and the Fall Armyworm.

This new bio-technology (seed) is available to farmers in a limited number of hybrid varieties that have been approved for use in Vietnam, notably NK66 BT/GT, NK 67 BT/GT, NK4300 BT/GT, NK7328 BT/GT, DK9955S, DK6919S, DK8868S, DK6818S and CP 501S. The technology is not available in some of the latest developed hybrid varieties and is not available in specialty varieties (eg, waxy corn used in the starch manufacturing sector) or in sweetcorn.

In 2017, a baseline quantification of the potential socio-economic and environmental impacts of this technology at the farm and national levels in the Vietnamese corn crop was undertaken. This utilised experience of other (similar) countries using this corn technology and the findings of farm scale trials from 2015 in Vietnam as the basis for estimating potential impacts in Vietnam (Brookes, 2017). Now that Vietnamese farmers have been able to use this seed technology for four years and have had time adapt to this new technology in years of differing climatic and pest pressures, the same authors[4], in association with CPD MARD have undertaken this analysis to identify and compare actual performance of the seed technology.

1.1 Objectives

This paper reports the findings of analysis to identify the economic and environmental impacts/benefits that have arisen from the commercial adoption of corn hybrid seed with insect protection and herbicide tolerant trait technology in Vietnam. It examined both the farm level and the national (aggregated) level impacts. The main environmental impact examined related to changes in pesticide use.

1.2 Methodology

The primary source of information has come from a survey of corn growers in Vietnam. Personal interviews with farmers in all corn growing regions of the country were conducted in 2018-2019 by staff from the Crop Production Department of the Ministry of Agriculture and Rural Development (CPD MARD) and technical staff in the Provincial Departments of Crops and Plant Production.

The survey aimed to be reasonably representative of corn production by region, with a focus on regions where biotech seed was widely grown (Table 2). As a result, there was a higher

[4] The authors acknowledge a funding contribution towards this study made by Croplife Asia

concentration of interviews undertaken in the regions of the Mekong Delta, Red River Delta and South East relative to their respective regional importance to national corn production. Within each region, the aim was to divide the interviews equally between farmers growing biotech corn and farmers of conventional corn. The final outturn was a total of 395 farms using biotech seed were interviewed, of which 56 of these farmers planted both biotech and conventional corn seed varieties. The balance of 340 farmers interviewed planted only conventional corn.

The interviews were conducted mostly in the second half of 2018 and the first half of 2019, with completion by the end of October 2019.

Table 2: Interview sample

Region	% of crop area	Target number of interviews	Number of interviews	% of interviews
Mekong Delta	3	140	140	19
Red River Delta	8	140	138	19
North Mid-lands/Mountains	44	210	199	27
North Central	11	35	88	12
South Central	7	35	30	4
Highlands	20	70	50	7
South East	7	70	90	12
Total	100	**700**	**735**	**100**

Note: 740 interviews were undertaken but five questionnaires were discarded due to inconsistent and/or incorrectly recorded data

1.3 Structure of paper

The paper is structured as follows:

- Section one: introduction, objective and methodology;
- Section two: Survey findings: production base of the corn crop in Vietnam: current weed and pest control practices, environmental impacts, problems and issues;
- Section three: aggregated (national level) impacts.

2 The farm survey findings

2.1 General features of farms surveyed

The average size of farm was 0.865 hectares (ha), within a range of 0.024 ha to 11 ha. These farms were a mix of owned and rented farms, with average size of owned farms being 0.76 ha and the average size of rented farms being 0.6 ha.

The average age of those interviewed was 48, within a range of 21 to 72. 73% of those interviewed were in the age range of 40 to 65 years old.

On each farm (all grew corn), the average area devoted to corn was 0.63 ha. In addition, 44% of the farms also grew rice (an average area of 0.31 ha), which was typically the second most important farming activity. Many also kept farm animals, with 39% keeping chickens (an average of 273 per farm), 25% kept pigs (an average of 10 per farm) and 19% kept cattle (an average of 4 per farm).

In relation to the corn production, just under three-quarters of the farms sold all or some of their production, with 41% consuming some or all of their production. This contrasted with rice production, where 90% grew all or some of the crop for own consumption, with only 35% selling some of their rice production.

2.2 Corn varieties planted and yield performance

A summary of the main corn varieties planted by farmers is shown in Table 3. The main features are:

- The main biotech varieties planted were DK 6919S and NK 4300 BT/GT, which were planted by more than two-thirds of the farmers planting varieties with biotech traits. In terms of the area planted to each variety, the main varieties planted were DK 6919S, NK 7328 BT/GT, NK 4300 BT/GT and DK 9955S which together accounted for over 90% of the total planted area of biotech corn;
- The main conventional varieties planted were NK 7328, HN 88 (waxy variety), CP 511 and NK 4300.

Table 3: Main categories of varieties planted

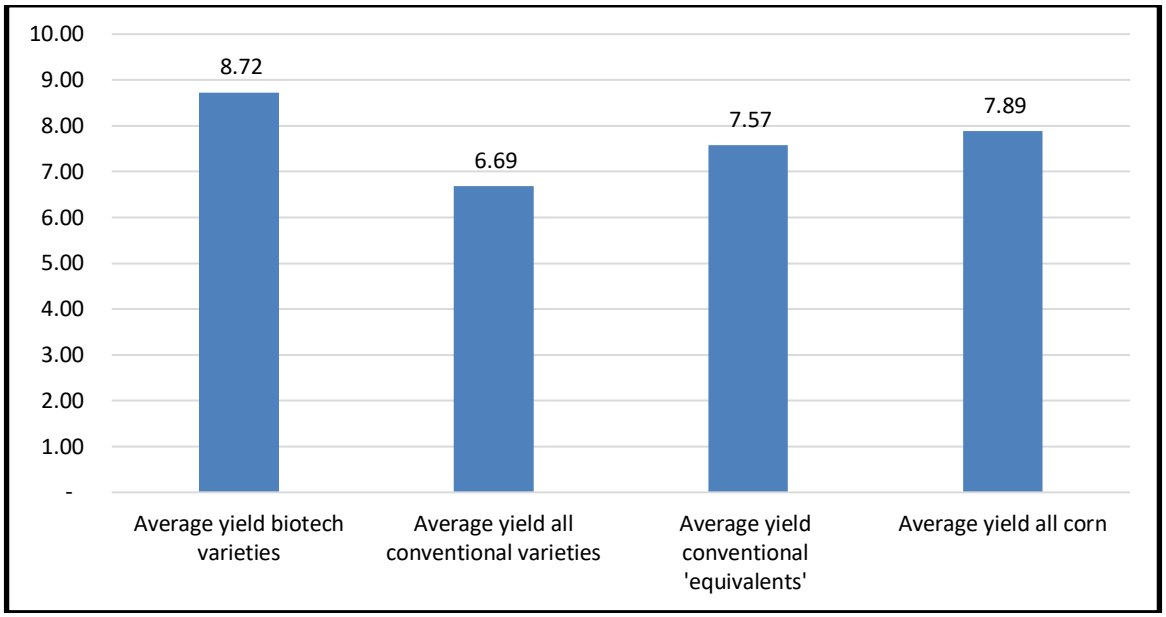
Variety	Number of farmers planting	Total area planted (ha)
Biotech varieties	395	251.8
Conventional varieties	396	211.2
Of which nearest performing varieties to biotech varieties	152	90
Total	**735**	**463**

Note: The total number of farms planting conventional varieties included 56 of the farms planting biotech varieties who also planted one or more conventional variety

The yield performance of the different varietal categories of corn grown is shown in Figure 2.

The biotech varieties, with an average yield of 8.72 tonnes/ha (5.45 tonnes/ha de-husked and dried), out-performed the average of all of the conventional varieties grown by +30.4% (+2.03 tonnes/ha or about 1.27 tonnes/ha de-husked and dried). In terms of a yield comparison between the nearest performing equivalent conventional varieties to the biotech-traited varieties, the biotech varieties outperformed the conventional equivalents by +15.2% (+1.15 tonnes/ha or 0.72 tonnes/ha de-husked and dried).

Figure 2: Average yield performance of different corn variety types (tonnes/ha)



Note: Yield figures are before de-husking and drying

2.3 Reasons for choice of variety

The main reasons for choice of conventional varieties were ease of selling the variety, familiarity with the variety and satisfaction with the yield level achieved (Table 4). In relation to the biotech varieties, the most important reason cited for choice was (expectation or experience of) high yield, followed by pest resistance, the value of requiring minimal care (in terms of needing to monitor for pest attack) and ease of weed control.

Table 4: Reasons for choice of variety

Reason	% of farmers in each category
Conventional varieties (396 farmers)	
High yield	19.2
Familiar with variety	17.7
Easy to sell	25.2
Soil suitability	5.3
Prefer this variety	4.1
Recommended by retailer or extension service	6.4
Good abiotic stress tolerance	4.9
High quality crop	3.0

Biotech varieties (395 farmers)	
High yield	30.5
Requires minimal care	14.0
Pest resistant	21.4
Ease of weed control	11.7
Overcomes weed resistance to paraquat	5.7
Recommended by extension service or farmer co-operative	9.4
Stable yield	4.0
High quality crop	6.3

Note: respondents were able to provide more than one reason for choice of variety

2.4 Cost of seed

For farmers using biotech corn seed, the average cost paid per hectare was 2,909,690 Vnd. For conventional 'nearest equivalent corn varieties', the average cost was 2,166,070 Vnd/ha and the average cost for all conventional seed varieties was 2,273,630 Vnd/ha. The (seed) premium paid by farmers for the biotech traits relative to the 'nearest equivalent conventional seed varieties' was therefore equal to +743,620 Vnd/ha (equal to about +$US 33.4/ha). Relative to the average of all conventional varieties planted (excluding specialty waxy corn and sweetcorn varieties), the seed premium was +636,060 Vnd/ha (equal to about +$US 28.6/ha).

2.5 Weed control: biotech corn

Of the 395 farmers using biotech corn seed, 82% used herbicides as the main form of weed control. Eighteen per cent stated that they did not use herbicides but (continued) to use hand weeding as their main form of weed control. A small proportion of farmers (who used herbicides as their main form of weed control) also undertook some hand weeding (less than 20% of the total) or some mechanical weeding (less than 5% of the total).

The main herbicides used were glyphosate, atrazine, ametryn/atrazine, S metolachlor, sulcotrione, acetochlor, paraquat and topramezone. Glyphosate accounted for about half of the volume of herbicide active ingredient used, followed by atrazine and ametryn/atrazine which both accounted for about 15% each of the total amount of herbicide active ingredient used. Average usage of glyphosate was about 2.5 litres (about 1.2 kg of active ingredient per ha), average usage of atrazine and ametryn/atrazine were 1.75 litres and 2 litres respectively (about (1.4 kgs ai/ha and 1.6 kgs ai/ha respectively).

The average cost of weed control where herbicides were used was 1,017,000 Vnd/ha (comprising 489,000 on herbicides (48%) and 528,000 Vnd (52%) for labour application. Where supplemented with other forms of weed control, these costs were an average of 286,000 Vnd/ha for hand weeding (an average of 10 hours/ha) and an average of 300,000 Vnd/ha for mechanical weeding (3 hrs: Table 5).

Based on the proportion of the biotech corn crop using each form of weed control, the weighted average cost of weed control was 906,000 Vnd/ha (Table 5).

Table 5: Weighted average cost of weed control: biotech corn (Vnd/ha)

Form of weed control	Average cost per ha	% of crop using each form of weed control	Weighted average cost of weed control
Herbicides	1,017,000	82	833,900
Hand weeding	286,000	21	60,100
Mechanical	300,000	4	12,000
Total			**906,000**

Note: values subject to rounding

2.6 Weed control: conventional corn

All of the 396 growers of conventional corn provided responses to weed control questions (inclusive of the 56 farms that planted both biotech and conventional corn varieties on their farms).

Thirty-two per cent of these farmers indicated that they did not use herbicides for weed control, relying on hand weeding only. A small number (under 5%) supplemented their use of herbicides with some mechanical weeding.

The main herbicides used were atrazine, acetochlor, ametryn/atrazine, S metolachlor, glufosinate and paraquat. Atrazine accounted for about 55% of the volume of herbicide active ingredient used, followed by acetochlor and ametryn/atrazine which accounted for about 15% and 7% respectively of the total amount of herbicide active ingredient used. S metolachlor and glufosinate both accounted for about 5% each of total herbicide active ingredient use. Average usage of atrazine was about 1.6 litres (1.28 kg of active ingredient per ha), average usage of acetochlor and ametryn/atrazine were 2.5 litres and 1.6 litres respectively (about (1.25 kgs ai/ha and 1.28 kgs ai/ha respectively).

The average cost of weed control where herbicides were used was 781,000 Vnd/ha (comprising 358,000 on herbicides (46%) and 423,000 Vnd (54%) for labour application. Where supplemented with other forms of weed control, these costs were an average of 2,616,000 Vnd/ha for hand weeding (an average of 126 hours/ha) and an average of 748,000 Vnd/ha for mechanical weeding (17 hrs: Table 6).

Based on the proportion of the conventional corn crop using each form of weed control, the weighted average cost of weed control was 2,078,300 Vnd/ha (Table 6).

Table 6: Weighted average cost of weed control: conventional corn (Vnd/ha)

Form of weed control	Average cost per ha	% of crop using each form of weed control	Weighted average cost of weed control
Herbicides	781,000	68	531,100
Hand weeding	2,616,000	58	1,517,300
Mechanical	748,000	4	29,900
Total			**2,078,300**

Note: values subject to rounding

2.7 Pest control: biotech corn

19% of biotech corn farmers used insecticides. These farms were located mostly in Thai Nguyen (North Mid-lands and Mountainous region) and Ha Noi (Red River region).

Where applied, the main insecticides used were emamectin benzoate, diazinon, permethrin, cypermethrin and abamectin.

The average expenditure on insecticide control, where used was 1,238,000 Vnd/ha, of which 662,000 Vnd/ha (54%) was for insecticide and 576,000 Vnd/ha (46%) was for labour application.

Given that the biotech seed technology provides control for the main lepidopteran corn pests, we examined further the circumstances relating to the biotech farmers who were still making some use of insecticides. The main features were as follows:

- In 2019, FAW pest incidence was reported to be affecting between 35% and 75% of the corn area in most regions (source: industry), with the highest levels of incidence in the regions of North Mid-lands/Mountainous, Red River and North Central. Experience of (controlling) this pest[5] was relatively limited among Vietnamese corn farmers and consequently, it is likely that some of the insecticide (notably use of emamectin benzoate which was the most commonly used insecticide by biotech corn farmers) targeted control of the FAW pest, even though biotech seed offers control of this pest. As such, some of the farmers may have not been aware that the seed offered this control and/or had no experience of how effective the seed was in controlling the pest. It is interesting to note, for example, that in the Son La district of the Northern Mid-land and Mountainous region, where interviews did not take place until late 2019 (when farmers had experienced performance of the biotech seed in controlling the FAW pest in early 2019 crops), there was no recorded use of insecticides by biotech farmers at all. Also, it is likely that some farmers experienced different levels of FAW control according to the traits present in the seed varieties used - where the traits provided effective control, no additional insecticide was used compared to using one additional insecticide application where the trait provided only partial suppression;
- Sixty per cent of the biotech farmers using insecticides were first time users of the seed. Therefore, it is possible that the lack of experience of using this technology and its efficacy levels in controlling pests may have contributed to some farmers making 'insurance' applications of insecticide;
- Some of the insecticide use may have been used to control pests such as aphids, thrips and the stored nut moth, which are not controlled by the biotech traits.

In addition, 60% of the biotech corn farmers also said they devoted some time (an average 6 hours/ha) to scouting/crop walking for pest presence, at an average cost of 302,000 Vnd/ha.

Based on the proportion of the biotech corn crop using insecticides and undertaking crop walking, the weighted average cost of pest control was 416,200 Vnd/ha (Table 7).

[5] Relative to the other main corn pests, incidence of the FAW was new to Vietnam

Table 7: Weighted average cost of pest control: biotech corn (Vnd/ha)

Form of weed control	Average cost per ha	% of crop using each form of pest control	Weighted average cost of pest control
Insecticides	1,238,000	19	235,000
Crop walking	302,000	60	181,200
Total			**416,200**

Note: values subject to rounding

2.8 Pest control: conventional corn

72% of conventional corn farmers used insecticides for pest control (of all corn pests including the lepidopteran pests (Asian Corn Borer (ACB) – *Ostrinia furnacalis*), Corn Earworm (CEW), Common Cut Worm (CCW), Fall Armyworm (FAW)), as well as aphids, thrips and the stored nut moth.

The average expenditure on insecticide control was 782,000 Vnd/ha, of which 358,000 Vnd/ha (46%) was for insecticide and 424,000 Vnd/ha (54%) was for labour application.

Where applied, the main insecticides used were chlorfenapyr, chlorantraniliple, abamectin, emamectin benzoate and spinetoram.

80% of the conventional farmers also spent time (an average 17 hours/ha) scouting/crop walking for pest presence, at an average cost of 864,000 Vnd/ha. Given the proportions of the conventional corn crop using insecticides and undertaking crop walking, the weighted average cost of pest control was 1,254,240 Vnd/ha (Table 8).

Table 8: Weighted average cost of pest control: conventional corn (Vnd/ha)

Form of weed control	Average cost per ha	% of crop using each form of weed control	Weighted average cost of weed control
Insecticides	782,000	72	563,040
Crop walking	864,000	80	691,200
Total			**1,254,240**

Note: values subject to rounding

2.9 Harvesting: biotech corn

A summary of costs and labour use for harvesting the biotech corn crop is shown in Table 9. The average amount of labour time spent on harvesting was 92.5 hours/ha at a (weighted average) cost of 2,778,160 Vnd/ha. A large majority of the farms used adult family members (more than 80% of the total) to do harvesting, with just under 50% using some hired labour.

Table 9: Biotech corn harvesting costs and labour use (per ha)

Type of labour	Hours – where used	Cost/ha (Vnd)	% of crop using each form of harvesting labour	Weighted average cost of harvest labour

Adult family	40.9	1,228,000	81	994,680
Family – children	5.5	110,000	2	2,200
Hired	123.7	3,711,000	48	1,781,280
Average all forms of labour	**92.5**			**2,778,160**

Note: values subject to rounding

2.10 Harvesting: conventional corn

Table 10 shows the costs and labour use for harvesting the conventional corn crop, with the average amount of labour time spent on harvesting being 72 hours/ha at a (weighted average) cost of 2,100,500 Vnd/ha. Whilst a large majority of the farms used adult family members (90% of the total) to do harvesting and 42% made some use of hired labour, the relative importance of family labour was greater than amongst the farmers growing biotech corn.

Table 10: Conventional corn harvesting costs and labour use (per ha)

Type of labour	Average hours spent/ha – where used	Cost/ha (Vnd)	% of crop using each form of harvesting labour	Weighted average cost of harvest labour
Adult family	50	1,497,000	90	1,347,300
Family – children	17	364,000	2	7,280
Hired	64	1,776,000	42	745,920
Average all forms of labour	**72**			**2,100,500**

Note: values subject to rounding

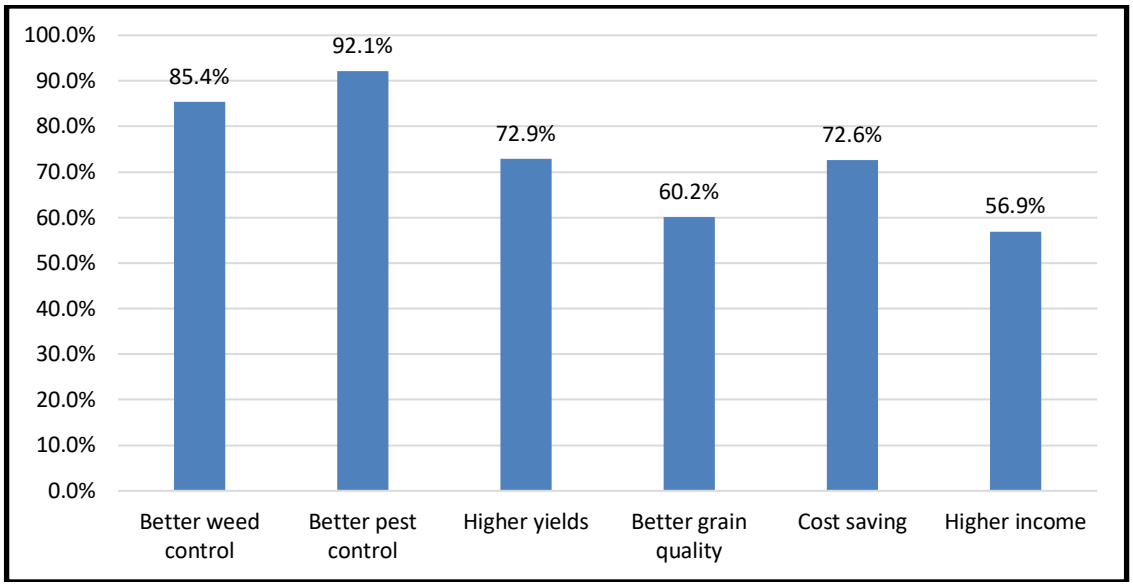
2.11 Changes to farming practices

Farmers who were growing biotech corn were asked what, if any, changes they had been made to farming practices, as a result of the switch from conventional to biotech corn. A third of these farmers indicated that they had reduced the frequency of application and/or amount of insecticides used and a quarter stated they had reduced the frequency of application of herbicides. In addition, about a quarter of the farmers stated that they were now making reduced use of hand weeding. Lastly, just under 30% of the farmers indicated that they had made little significant change to their farming practices.

2.12 Biotech corn: likes and dislikes

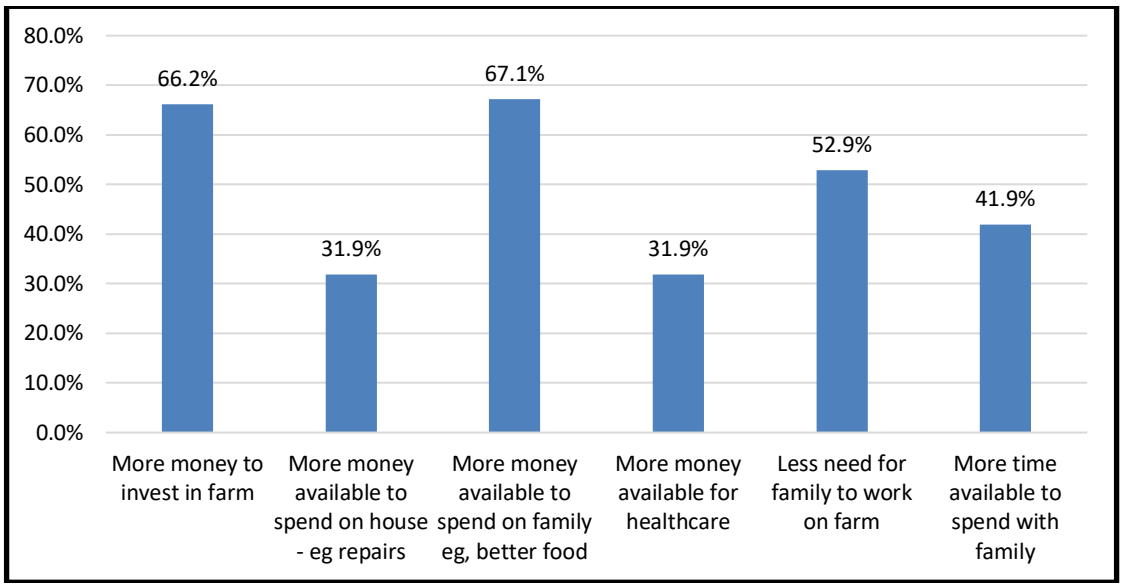
The farmers who had grown biotech corn were asked about any likes or benefits they perceived had occurred from using this type of corn. The main impacts are shown in Figure 3. Improved pest and weed control were cited most frequently by the farmers, with higher yields, higher incomes, improved yields and better grain quality all registered as positive impacts by a majority of the farmers.

Figure 3: Main perceived impacts of using biotech corn



The 225 farmers (57% of the biotech corn farmers) who actively stated that the use of biotech corn had resulted in higher incomes also provided further information about the impact of having higher levels of income. The main impacts were having more money for on-farm investment and/or to spend on their families. In addition, a majority highlighted less need for family members to work on the farm (Figure 4).

Figure 4: Main effects of having higher incomes levels from use of biotech corn



Note: % values relate to a total of 225 respondents

In relation to perceived dislikes or negative aspects of using biotech corn, 158 farmers (40% of users) provided responses to this question. The main complaint, registered by 134 farms (34% of all biotech farmers or 85% of this sub-set of responding farmers) was about the (high) price of seed. There were very few other complaints; less than 4% of farmers (15 farmers) said they

perceived there might be 'negative health' issues associated with use of the technology (based on information they had read in the media) and 2% (8 farmers) said they were disappointed with the yield performance.

Lastly, in relation to next season and the likelihood of farmers choosing to grow biotech corn again, only 2 farms (0.5% of the total) said they would not plant biotech corn next season.

2.13 Conventional farmers: reasons why they had not tried using biotech corn

One hundred and sixteen conventional corn growers offered responses to this question. The main reason cited (by 57% of the respondents: 66 farmers) was the high price of the seed. In addition, twenty-nine per cent of these farmers (34 farmers) indicated that they perceived that the benefit would be less than the expected higher cost of the seed[6]. Lastly, ten farmers (9% of this group) were growing specialty varieties of waxy corn and said if they switched to using biotech seed (the biotech traits are not available in any waxy corn varieties), they would expect to see income levels fall because any agronomic gains would be offset by the higher cost of seed and lower value of the (non-waxy) corn.

2.14 Summary of survey finding and comparisons

2.14.1 Yield, cost of production and income impacts

The main impacts of using biotech corn have been (Table 11):

- The biotech varieties out-performed conventional varieties in terms of yield by +30.4% (+2.03 tonnes/ha or about 1.27 tonnes/ha de-husked and dried). In relation to a yield comparison between the nearest performing equivalent conventional varieties to the biotech-traited varieties, the biotech varieties outperformed the conventional equivalents by +15.2% (+1.15 tonnes/ha or 0.72 tonnes/ha de-husked and dried). In revenue terms this amounted to an increase of between 3.75 million Vnd/ha and 6.65 million Vnd/ha;
- Weed control practices have changed, with changes in the type and nature of herbicides applied (more use of the broad-spectrum herbicide glyphosate and less use of pre-emergent herbicides like atrazine and acetochlor). There has also been a reduction in the use of hand weeding; less use of hand weeding on farms that had previously used a mix of hand weeding and herbicides and a switch from using only hand weeding to a mix of hand weeding and herbicides. Whilst average expenditure on herbicides and their application has increased, this has been more than offset by savings from less use of hand weeding. Overall, the average cost of weed control has fallen by 1,172,300 Vnd/ha;
- Pest control practices have changed. There have been reductions in the use of insecticides for the control of pests, with the control of the main lepidopteran pests now provided via the seed, leaving residual use of insecticides for the control of pests not controlled by the biotech traits. These savings amounted to 328,040 Vnd/ha. In addition,

[6] This included some farmers who perceive that the level of crop damage caused by the target pests of the technology was limited

farmers using biotech varieties spent less time on crop walking/scouting checking pest levels. This resulted in an additional cost saving equal to 510,000 Vnd/ha;

- The higher yields derived from biotech corn have required additional use of labour for harvesting. This extra cost has been an average of nearly 677,660 Vnd/ha;
- The cost of seed has increased, with the seed premium for biotech corn seed being an average of between 636,060 Vnd/ha (average to all conventional varieties used) and 743,620 Vnd/ha (average to equivalent performing varieties to the biotech varieties);
- Overall, the net impact on farm income associated with using biotech corn has been an increase in the average level of farm income of between 4.34 million Vnd/ha (relative to equivalent conventional varieties) and 7.34 million Vnd/ha. In US dollar terms, this equates to an income gain of between +$195/ha (equivalent conventional varieties) and +$330/ha (average of all conventional varieties);
- It is interesting to note that 18% of the farmers using biotech corn, did not use herbicides for weed control even though the seed contained tolerance to the herbicide glyphosate. In effect, these farmers used the seed specifically for its pest control capability rather than its potential for improving weed control. Whilst these farms will have foregone potential weed control cost savings (as derived by other users of the technology), the savings associated with lower pest control costs and higher yields were still significant.

Table 11: Summary of farm level income impact of using biotech corn (Vnd/ha)

	Biotech	**Conventional: all**	**Conventional: nearest equivalent varieties to biotech**
Crop yield (tonnes/ha)	8.72	6.69	7.57
Crop yield de-husked/dried (tonnes/ha)	5.45	4.18	4.73
Price 2019	5,227,340	5,227,340	5,227,340
Revenue	28,498,522	21,850,354	24,747,448
Yield difference (tonnes/ha)		**1.27**	**0.72**
Revenue change		**+6,648,168**	**+3,751,074**
Cost of seed	2,909,690	2,273,630	2,166,070
Seed premium		**- 636,060**	**- 743,620**
Weed control costs: weighted average			
Herbicides	833,900	531,100	531,100
Hand weeding	60,100	1,517,300	1,517,300
Mechanical	12,000	29,900	29,900
total cost	906,000	2,078,300	2,078,300
Change in weed control costs		**1,172,300**	**1,172,300**
Pest control costs			
Insecticides	235,000	563,040	563,040
Change in insecticide costs		**328,040**	**328,040**
Crop walking/scouting	181,200	691,200	691,200
Change in crop walking/scouting costs		**510,000**	**510,000**

Harvesting costs	2,778,160	2,100,500	2,100,500
Change in harvesting costs		**- 677,660**	**- 677,660**
Total change in costs of production		696,620	589,060
Total change in income including yield gain		**+7,344,788**	**+4,340,134**
Total change in income in US $ terms		**+330.19**	**+195.11**

Exchange rate $1 = 22,244 (2019 average)
Note: - ve sign = increase in costs

Examining the cost farmers pay for accessing the biotech seed technology, the average additional cost of seed (seed premium) relative to conventional seed, over the period of adoption was between 636,060 Vnd/ha (US $28.6/ha) and 743,620 Vnd/ha (US$33.43/ha). These cost of technology values are equal to between 8% and 15% of the total (gross) technology gains (before deduction of the additional cost of the technology payable to the seed supply chain - the cost of the technology accrues to the seed supply chain including sellers of seed to farmers, seed multipliers, plant breeders, distributors and the GM technology providers). In terms of investment, this means that for each extra dollar invested in biotech corn seed, farmers gained an average of between US $6.84 and US $ 12.55. Given these very high levels of return on (seed) investment, it is therefore not surprising that the farmers who had used the technology expressed widespread satisfaction with the technology and 99.5% of them planned to continue using the technology in 2020.

2.14.2 Labour use changes

The main changes in labour use associated with the adoption of biotech corn are summarised in Table 12. These are:

- A reduction in the total amount of labour used per ha of about 71 hours/ha (-8.9 days). This derives from less use of labour for weeding (largely hand weeding), application of insecticides and crop walking/scouting. Some of these labour reductions were offset by an increase in the labour requirement for harvesting;
- As the majority of the labour used on farms has been family labour, the labour requirement changes have mostly impacted on this category of labour. For hired labour, the adoption of biotech corn has resulted in a small net increase in labour requirement because of the increased requirement for harvesting. Whilst the requirement for hired labour to undertake weed control (and to a lesser extent pest control) has decreased, this has been more than offset by an increase in hired labour use for harvesting. Overall, the hired labour requirement has increased by about 10 hours/ha (1.25 days/ha);
- The overall reduction in labour use on biotech corn growing farms, which has mostly impacted on the use of family labour was acknowledged by many of these farmers as a positive aspect of change because it had freed up more time for farmers and their family to spend on other income-generating activities and leisure.

Table 12: Summary of labour use impacts of using biotech corn (hours or days per ha)

Labour use (hours)	**Biotech corn**	**Conventional corn**
Weed control: all forms	5.34	81.77
Pest control inc scouting	3.75	18.7
Harvesting	92.5	72.0
Total labour use	*101.59*	*172.47*
Difference: decrease in labour use		**70.88**
Decrease in days		**8.86**
Of which hired labour		
Weed control: all forms	1.48	18.94
Pest control inc scouting	0.03	1.6
Harvesting	59.3	30.29
Total hired labour use	*60.81*	*50.83*
Difference: decrease in labour use		**- 9.98**
Decrease in day equivalents		**- 1.25**

Note: -ve signs = increase in labour use

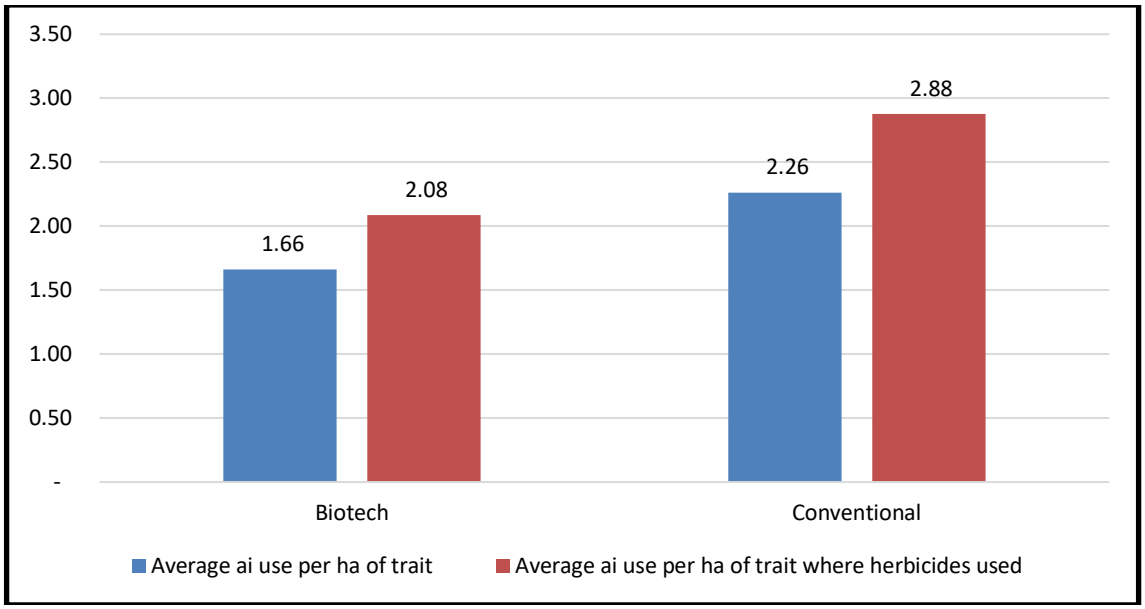
2.14.3 Environmental impact associated with herbicide use for weed control

The adoption of biotech corn has resulted in changes to weed control practices. Biotech farmers have increased their use of herbicides as the primary form of weed control relative to the weed control practices of conventional corn producers. However, the profile and volume of the herbicides used has changed, with the average amount of herbicide active ingredient used and its associated environmental impact, as measured by the EIQ indicator, being lower for biotech corn adopters than conventional corn growers (Figure 5 and Figure 6). The average amount of herbicide active ingredient applied on the 82% of the biotech crop area that used herbicides for weed control was 2.08 kg/ai per ha, compared to 2.88 kg/ai per ha on the 68% of the conventional corn crop area that used herbicides for weed control. When this herbicide usage is averaged across the respective total areas planted to biotech and conventional corn, the average amount of herbicide applied to the biotech corn crop was 26% lower (1.66 kg/ha) than the average value for the conventional corn area (2.26 kg/ai per ha: Figure 5).

In terms of the associated environmental impact of the herbicide use, as measured by the EIQ indicator, the average eiq/ha of herbicide active ingredient applied on the 82% of the biotech crop area that used herbicides, was 37.95/ha, compared to 59.74/ha on the 68% of the conventional corn crop area that used herbicides. When this herbicide usage is averaged across the respective

total areas planted to biotech and conventional corn, the average eiq/ha was also lower by 36% (30.26/ha) than the average value applicable to the conventional corn area (46.95/ha: Figure 6).

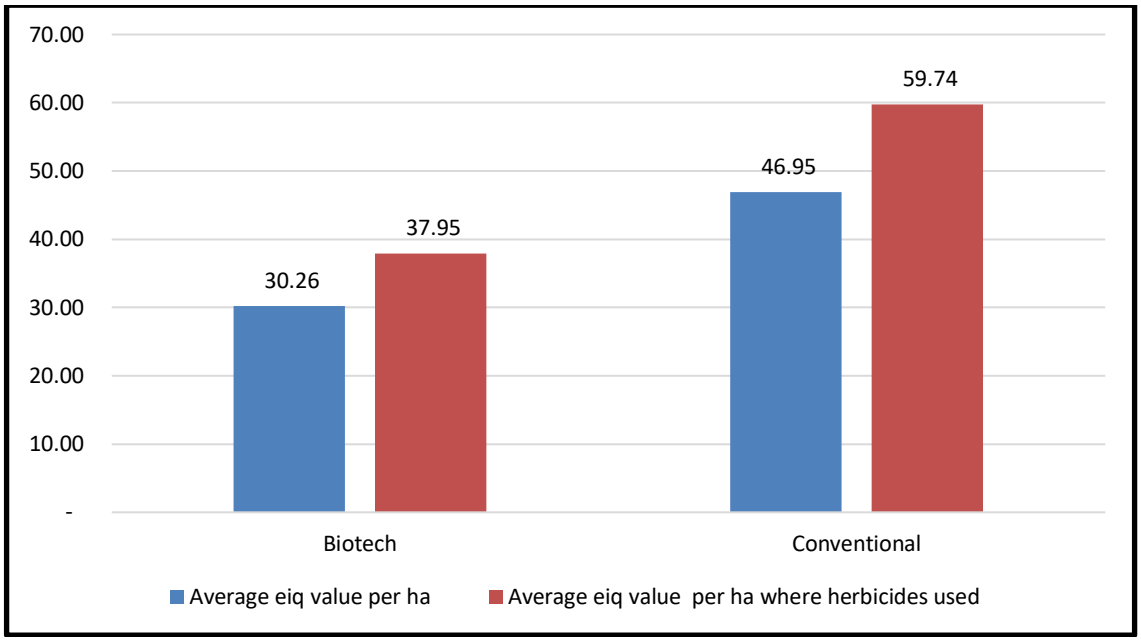
Figure 5: Average herbicide use (active ingredient in kg/ha): biotech and conventional corn



Notes:

1. Average use per ha where herbicides are used relates to 82% of the biotech crop area and 68% of the conventional crop. The total usage on these areas was then divided by the total area recorded as planted to either biotech or conventional corn to derive the average usage across the total areas planted to each type of production

Figure 6: Average herbicide use (field eiq/ha value): biotech and conventional corn



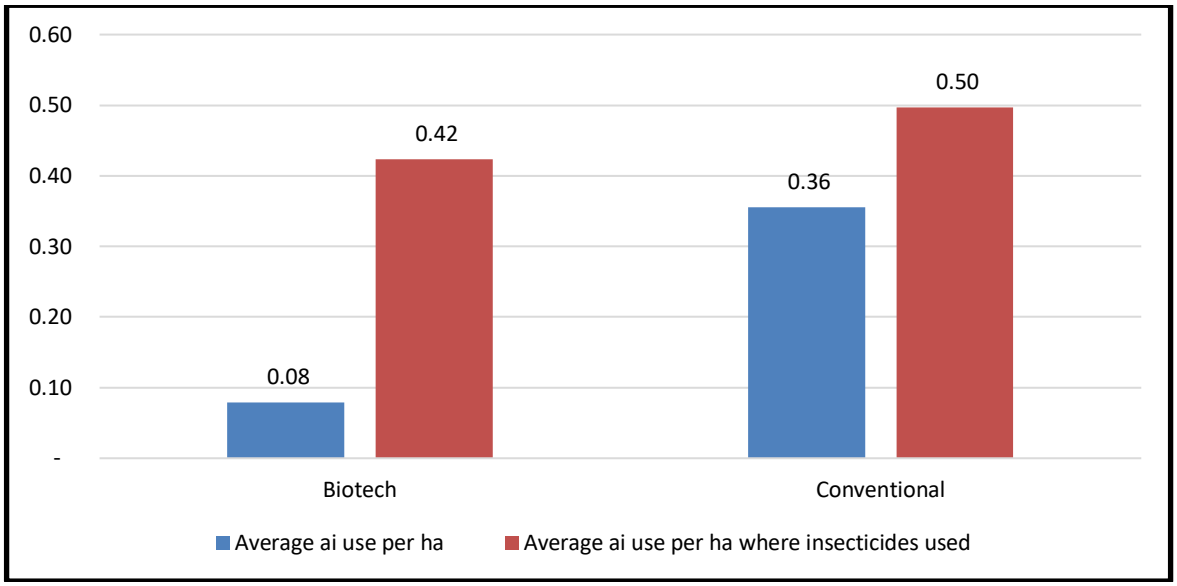
2.14.4 Environmental impact associated with insecticide use for pest control

As indicated in sections 2.7 and 2.8, the adoption of biotech corn has led to changes in pest control practices, with biotech farmers applying insecticide to a significantly lower crop area and, where used, in smaller amounts.

Figure 7 shows that on the 19% of the biotech crop area that used insecticides, the average amount of insecticide applied was 0.42 kg/ai per ha, compared to an average of 0.5 kg/ai per ha on the 72% of the conventional corn crop area that used insecticides. When this insecticide usage is averaged across the respective total areas planted to biotech and conventional corn, the average amount of insecticide applied to the biotech corn crop was significantly lower by 78% (0.08 kg/ai per ha) than the average value for the conventional corn area (0.36 kg/ai per ha: Figure 7).

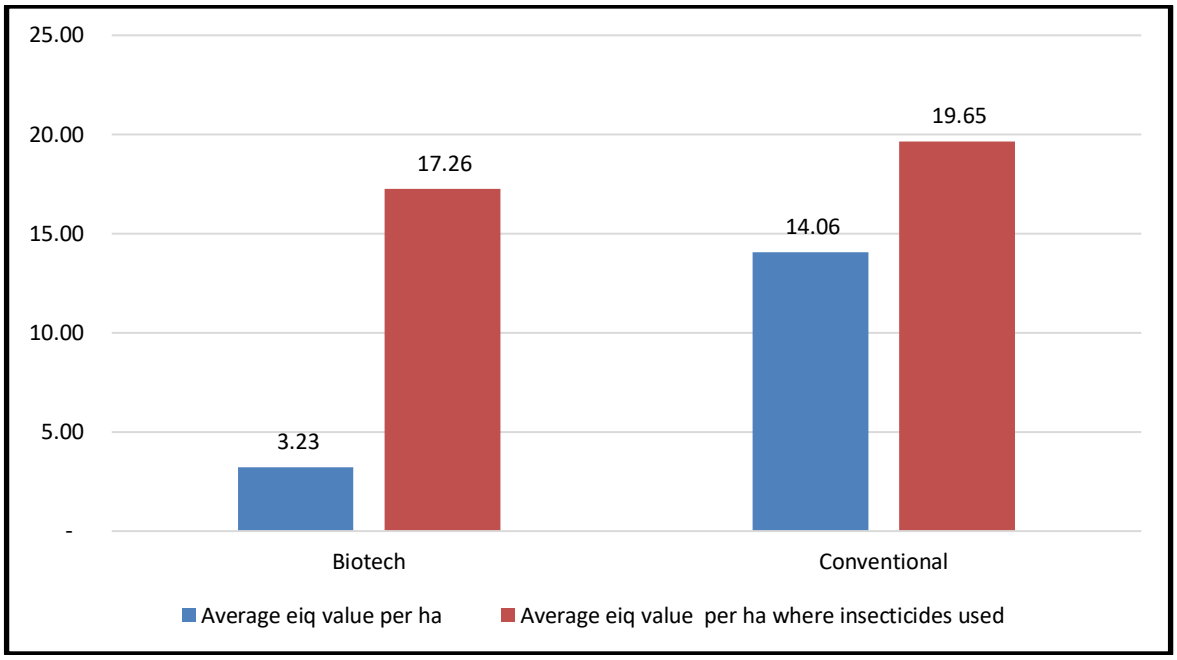
In terms of the associated environmental impact of the insecticide use, as measured by the EIQ indicator, the average insecticide eiq/ha value on the 19% of the biotech crop area that used insecticides was 17.26/ha, compared to an average of 19.65/ha on the 72% of the conventional corn crop area that used insecticides (Figure 8). When this insecticide usage is averaged across the respective total areas planted to biotech and conventional corn, the average eiq/ha was significantly lower by 77% (3.23/ha) than the average value for conventional corn (14.06/ha: Figure 8).

Figure 7: Average insecticide use (active ingredient in kg/ha): biotech and conventional corn



Note: Average use per ha where insecticides are used relates to 19% of the biotech crop area and 72% of the conventional crop. The total usage on these areas was then divided by the total area recorded as planted to each of biotech or conventional corn to derive the average usage across the total areas planted to each type of production

Figure 8: Average insecticide use (field eiq/ha value): biotech and conventional corn



2.14.5 Views, experiences and perceptions of biotech corn

The vast majority of farmers who had grown biotech corn expressed high levels of satisfaction with the technology, with 99.5% of adopters stating that they would be using the technology in the 2020 crop year. The high levels of satisfaction were linked to the benefits associated with adoption, of improved levels of pest and weed control, higher yields, higher incomes and better grain quality[7]. In addition, the higher levels of income had resulted in farmers having more money for on-farm investment and household expenditure. In addition, there has been reduced need for family members to work on farms, allowing more time for leisure activities.

In relation to conventional corn growers the main reasons cited for not trying the new technology was the (perceived) high price of the seed relative to conventional seed and/or the view that the benefit (of adoption) would be less than the extra cost of the seed. In addition, growers of specialty varieties of waxy corn said if they switched to using biotech seed (the biotech traits are not available in any waxy corn varieties), they would expect to see income levels fall because any agronomic gains would be offset by the higher cost of seed and lower value of the non-specialty corn.

[7] Which is reflected in lower aflatoxin levels and reduced wastage or rejection of crops when sold, especially for human food use

3 Aggregated impacts

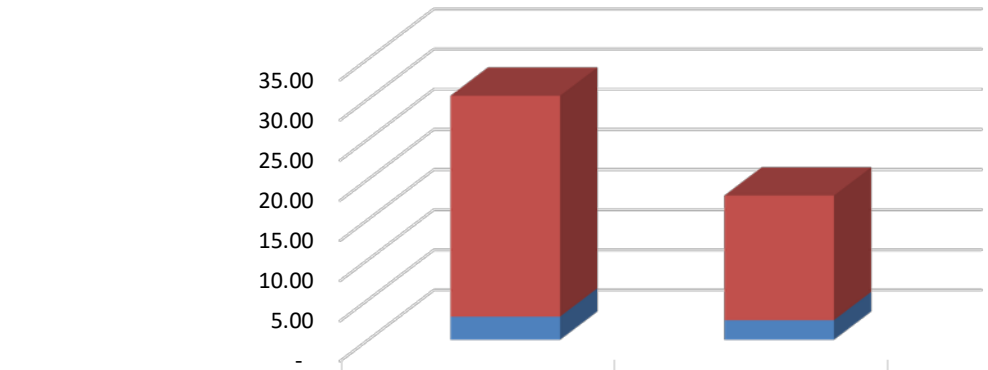
Building on the farm level data collected in the survey and presented in section 2, this section aggregates the impacts to the national level.

3.1 Farm income, production and labour change impacts

The aggregated farm level income impact of using biotech corn based on the survey findings and applied to the national level of biotech corn seed adoption in 2019, (92,000 ha or 10.2% of the national crop) was a net income gain of between $17.95 million (based on the yield gain relative to the nearest equivalent varieties to the biotech varieties) and $30.38 million (based on the yield gain relative to all conventional varieties: Figure 9). The vast majority of the income gains (more than 90%) came from yield gains, with some small additional benefits associated with lower net costs of production.

If these farm income gains are applied to the cumulative biotech crop area since the technology was first used in 2015 (a total of 224,500 ha 2015-2019), the total farm income gain has been between US $43.8 million (based on the yield gains relative to the nearest equivalent conventional varieties) and $74.1 million (based on yield gains relative to all conventional varieties).

Figure 9: National farm income benefits associated with adoption of biotech corn (US $ million) in 2019



	relative to all conv	relative to equivalent varieties
Revenue gain from higher yield	27.50	15.51
Net reduction in cost of production	2.88	2.44

Based on the yield gains referred to in Table 11 , the biotech corn technology added between 66,000 tonnes and 117,000 tonnes of corn in 2019 and cumulatively since 2015 has added between 157,900 tonnes (based on the yield gains relative to the nearest equivalent conventional varieties) and 315,400 tonnes (based on yield gains relative all conventional varieties).

This extra production has made a small contribution to reducing pressure on farmers to use additional land for crop production. Thus, if biotech corn technology had not been available to farmers in 2019, maintaining production levels for this year using conventional technology would

have required the planting of an additional 13,930-24,680 ha of agricultural land to corn. This equates to between 1.5% and 2.7% of the total area planted to corn in 2019.

At the national level, the aggregate labour impact in 2019 is small and equal to a net reduction in labour use of about 6.52 million hours or 815,000 days (or 3,400 full-time equivalents - FTEs). Most of this reduction in labour use has affected family labour. In terms of hired farm labour, the impact has been a net increase of about 0.92 million hours (115,000 days), or 480 FTEs, primarily for additional crop harvesting work.

3.2 Environmental impacts associated with changes in weed and pest control practices

Based on the weed control changes identified in section 2.14.3, in 2019, the use of biotech corn (on the equivalent of 10.2% of the total corn crop) resulted in a reduction in the amount of herbicide active ingredient used on the whole crop of 2.7% (-55,220 kg) and a net reduction in the associated EIQ value of 3.6% (Table 13). Cumulatively, since 2015, there has been a net decrease in the amount of herbicide active ingredient used of 134,760 kg (-1.2% of total crop use over this period) and a net reduction in the environmental load associated with herbicide use, as measured by the EIQ indicator of 1.5%.

In terms of the pest control changes identified in section 2.14.4, the use of biotech corn has led to a reduction in the amount of insecticide active ingredient used on the whole crop of 25,440 kg (-7.95% in terms of all insecticide used on the crop) and a net reduction in the associated EIQ value of 7.87%. Cumulatively, since 2015, there has been a net decrease in the amount of insecticide active ingredient used of 62,075 kg (-3.4% of total crop use over this period) and a net reduction in the environmental load associated with insecticide use, as measured by the EIQ indicator of 3.3%.

Table 13: Insecticide and herbicide use changes with biotech corn: 2019 and cumulative 2015-2019

	Area of trait (ha)	Average reduction in ai use (kg/ha)	Average reduction in field EIQ/ha	Aggregate change in ai use ('000 kg)	Aggregate change in field EIQ/ha units ('000s)
Insecticides 2019	92,000	0.28	10.83	25,440	996
Herbicides 2019	92,000	0.60	16.69	55,220	1,536
Insecticides cumulative	224,500	0.28	10.83	62,075	2,431
Herbicides cumulative	224,500	0.60	16.69	134,760	3,747