Economic assessment of hydrogen cyanamide use in New Zealand

Report to the Environmental Protection Authority

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Executive summary

We have estimated the economic value of Hydrogen Cyanamide (HC) use to New Zealand. By implication, this estimated value is equivalent to the value that would be foregone if HC was no longer available.

Over a ten-year study period, the present value impact on growers of removing HC (labelled OGR-orchard gate return in the table below) is between $1.9 billion and $2.5 billion, or $191 million to $253 million in year one. These revenue estimates convert to present value GDP impacts of $858 million to $1.1 billion across ten years, or $85 million to $113 million in year one. Based on current annual GDP of around $308 billion, the estimated effects represent an impact of less than half of one per cent of annual national GDP.

A substantial majority (around 97 per cent) of the estimated impacts are for kiwifruit. Given the importance of kiwifruit to particular regions, the regional economic impact may be felt more acutely than the national figures convey. However, lack of information prevents more detailed analysis of regional economic effects.

	OGR (10 years, $million)	GDP (10 years, $million)	OGR (year 1, $million)	GDP (1 year, $million)
Low	$1,922	$858	$191	$85
Central	$2,190	$977	$224	$100
High	$2,494	$1,113	$253	$113

The main driver of the estimated costs is the reduced efficacy of alternative chemicals currently available. In simple terms, relative to the alternatives, HC reduces the risk of lower yields and also contributes to better fruit quality in a cost-effective manner. We also include additional costs to growers due to alternatives being more expensive than HC.

Our estimates of potential harm are reasonably closely aligned with economic analysis prepared by NZIER for New Zealand Kiwifruit Growers in response to the call for information by the Environmental Protection Agency. The broad similarity in cost/harm estimates is not surprising given essentially the same process was used in both studies.

We discuss the possibility of a price response from the estimated reduction in kiwifruit supply due to the unavailability of HC in New Zealand. Using economic theory and previous events, we are able to demonstrate the potential for a large off-setting effect for growers due to prices rising. Such a price rise would reduce considerably the estimated impact of HC being unavailable. However, given the inherent uncertainty in estimating the key response parameter, we do not include it in the central result.

We have not looked to estimate the value of any potential benefits from removal of HC, as these are not strictly in the realm of economic analysis. The analysis has limitations, but in our view represents a reasonable estimate of likely economic importance of HC use, notwithstanding a range of factors that influence relevant behaviour and outcomes in horticultural markets.

1. Introduction

The Environmental Protection Authority (EPA) has commenced a reassessment of the use of hydrogen cyanamide (HC) in New Zealand. HC is primarily used by orchardists to promote bud formation, principally in kiwifruit crops.

As part of the reassessment, the EPA has commissioned a report estimating the potential costs of HC use in New Zealand, the subject of this report. We have not looked to estimate the value of any potential benefit from removal of HC, as these are not strictly in the realm of economic analysis.

This report focusses on economic aspects associated with HC use, particularly the benefits to the New Zealand economy from HC use. Human health impacts and environmental effects of HC use are covered elsewhere.

The starting point for the analysis is the status quo, or 'business as usual' situation pertaining to HC use. We then consider an alternative scenario where HC is no longer available. A third scenario is possible, where some restrictions are put in place around the use of HC, but this scenario is not yet developed, so is much less prominent.

The results of this analysis are contained in section 3 below, which follows a section containing relevant context and describes the nature of costs and benefits under study. More detailed explanations of key inputs and parameters used in the modelling work are contained in an appendix.

2. Economic benefits of hydrogen cyanamide use

This section describes the main elements used in the analysis. We outline the ways in which HC is used and by implication the benefits from such use. We begin by presenting some context on the volume and nature of use in New Zealand.

2.1 Uses and users of HC

There are currently six commercially available products using HC in New Zealand:

- Hi-Cane
- Treestart
- Hortcare Hi-break
- Synergy HC
- Gro-Chem HC-50
- Cyan

Exact figures on the volume of HC used in New Zealand are not available. While we have received some sales data from agrichemical companies, such figures are commercially sensitive and unable to be reported here. Nevertheless, we are able to glean some insights from the EPA call-for-information process and the lack of volume data is not material to this analysis.

Table 1 shows that the major use is in kiwifruit and of this use, the vast majority is in the Bay of Plenty. HC is also used on other fruit. Precise data on product use across regions and varieties of fruit are not readily available.

Table 1 Overview of HC use

	Commercial production (Ha)	Share of planted area using HC	Main regions
Kiwifruit	14,000	86%	Bay of Plenty, Northland, Gisborne
Apples	10,417	13%	Hawkes Bay, Nelson, Gisborne,[1]
Summerfruit	1,940	10%	Hawkes Bay, Marlborough

[1] There is noteworthy regional variation in HC use. Hawkes Bay accounts for just over 60 per cent of total production (in hectares), only 15 per cent of the regional planted area is estimated to use HC. On the other hand, Gisborne accounts for slightly less than three per cent of total production (in hectares) but around 36 per cent of the regional planted area uses HC.

Kiwiberry	22	±100%	Bay of Plenty

Source: EPA Call-for-information material

2.2 Impacts of HC

The beneficial impacts of HC have been summarised in an economic report submitted by New Zealand Kiwifruit Growers Incorporated (NZKGI) as part of their response to the call-for-information. The impacts relating to growers are contained in Table 2 below. In our view, these are the major effects that need to be considered, as they are more direct.

Table 2 Beneficial effects of HC use for growers

Impact area	Description
Bud breaking uniformity, volume and timing	Maximises the chances of a predictable and optimal crop, including quality, timeliness and cost
Number of 'king' flowers	HC increases the number of 'king' flowers, which correlate to higher numbers of fruit
Timing of flowering and leaf canopy	Encourages fruit consistency (quality) and more compressed flowering time (reducing labour costs)
Pest control	Removes pests after flowering
Pollination	Compresses the flowering period which means bees are in the orchard for a shorter time and artificial pollen is more effective. An increase in the flowering time would also delay sprays that deal with insect infestations.
Pruning and thinning requirements	Reduced need for pruning and thinning (lower labour costs)

Source: NZIER (2020)

2.3 Importance of HC

From an economic perspective, two dimensions of importance are key. The major dimension is efficacy - how well HC works. The second dimension of importance is cost - the outlay of users on agrichemicals.

2.3.1 Efficacy includes reliability, consistency and timing

The value of any agrichemical (or alternative process) comes from the property that it works:

- every time it is required to;

- in the way it is required to; and
- at the point in time it is required to.

The implication of the three conditions above being met is a yield that is higher in volume and better in quality, relative to a situation where the treatment fails on one or all of the conditions.

2.3.2 Availability and efficacy of alternatives

The importance of HC is effectively defined by the presence of alternatives. There are essentially two categories of alternative: chemical and non-chemical. The latter refers to organic production, which is reported to account for around four per cent of the kiwifruit crop.

Other pack house and cool store data suggests that for some regions and varieties, the share of land in kiwifruit production accounted for by organic production and use of alternative chemical products is up to around 14 per cent. Trend data and more specific data on the breakdown between organic and alternative chemical use is not available.

At present, we understand that only two chemical alternatives are registered under the Agricultural Compounds and Veterinary Medicines (ACVM) Act, which is required for use in New Zealand. Waiken is a trademarked product promoted by SST New Zealand as a plant growth regulator for use on pipfruit, stonefruit and kiwifruit. Advance Gold is promoted by Zelam to improve bud break and flowering in the Gold 3 kiwifruit variety.

In addition, non-ACVM-registered agrichemical products are thought to be in use currently, sold as fertiliser or fertiliser adjuvants which claim to have dormancy breaking properties. These alternatives incorporate ingredients such as ammonium nitrate, calcium nitrate, and various surfactants.[2]

It is clear from demonstrated use patterns that HC is hugely important, especially in the case of kiwifruit and we now turn to why that is the case.

[2] Response to Call for Information on hydrogen cyanamide substances, Agrinova NZ Ltd.

3. Economic impact of HC use

In common with previous assessments of this nature, we take a 'value-at-risk' approach. We consider the economic value that is supported by use of HC. By definition, such value could be foregone if HC is not available and it is this potential foregone vale that is the focus of this report.

3.1 Available report suggests impact to kiwifruit growers of $2.2 billion-$2.8 billion over ten years

As part of the response to the call-for-information, NZKGI included a report commissioned by the New Zealand Institute of Economic Research (NZIER) on the economic costs and benefits to the kiwifruit industry of withdrawing HC from use in New Zealand. The key reported results relate to direct costs faced by growers in the export market if HC is not available (see Table 3). That is, these impacts relate to the 'orchard gate revenue' (OGR) to growers.

The first-year impact of HC no longer being available for use by kiwifruit growers is between $234 million and $301 million, depending on the assumed efficacy of available alternative agrichemicals. Over a ten-year period, the present value of impacts using a six per cent discount rate is between $2.2 billion and $2.8 billion.

Table 3 Key results of NZIER economic analysis for NZKGI

	Value ($m)
Grower return from export crop (2019) year	$1,165
Effect of HC withdrawal with no use of alternatives (2019 year)	$334
Effect of HC withdrawal with use of alternatives with efficacy of 10% and 30% (2019 year)	$234-$301
Effect of HC withdrawal with use of alternatives with efficacy of 10% and 30% (10 year period)	$2,187-$2,811

3.1.1 Key components of NZIER analysis

The underlying estimating equation used by NZIER can be characterised as:

$$V = \sum_{r=1}^{8} A_r * B$$

Where:

V is economic value of HC to kiwifruit growers relative to alternative agrichemicals

A is the value of kiwifruit treated with HC versus the value of untreated kiwifruit, which is indexed to a particular region (of which there are eight)

B is the efficacy of alternative agrichemicals relative to the efficacy of HC, which is assumed constant across regions

Thus, there are essentially three steps used by NZIER. The first step involves estimating the production difference between the kiwifruit treated with HC and untreated kiwifruit. This is called yield improvement and is measured as the percentage increase in extra trays per hectare of treated versus untreated kiwifruit. This yield improvement comes from trial data and ranges from a low of around 26 per cent in Bay of Plenty, Hawke's Bay and Poverty Bay for the Gold3 variety to a high of 58 per cent in Waikato for the Hayward variety.[3]

Table 4 NZIER yield improvement hydrogen cyanamide vs untreated

Region	Gold3	Hayward
Northland	41.9%	48.2%
Auckland	51.7%	58.3%
Waikato	51.7%	58.3%
Bay of Plenty	25.8%	28.9%
Hawke's Bay	25.8%	28.9%
Southern North Island	0.0%	0.0%
Poverty Bay	25.8%	28.9%
Nelson	0.0%	0.0%

Source: (Nixon, 2020)

The next step is to determine the current revenue by multiplying the (per hectare) value per tray by the number of hectares in each region and then multiply that current revenue figure by the proportion of yield that would be lost without HC use (i.e. the yield improvement that is foregone by HC not being available). Summing across varieties and regions results in the $334 million figure for the annual contribution of HC to production that would be lost if it were not available and kiwifruit were left untreated.

The final step looks to adjust the total impact relative to an untreated situation for the fact that alternative agrichemicals are available. NZIER does this by using available data on rainfall to estimate the likelihood of there being no rain over a three day period in July/August. The underlying rationale is that the efficacy of alternatives is reduced the more likely a three-day rain period is, due to the

[3] Hayward and Gold3 are the major kiwifruit varieties and were the only two varieties modelled.

shorter timing window within which alternatives are effective, relative to HC. The comparison used by NZIER is that of a three-day window for alternatives versus a three-week window for HC.

NZIER estimates that, based on rainfall data, alternatives are between 10 per cent and 30 per cent as effective as HC. Thus, the aforementioned annual impact on kiwifruit orchards of $234 million to $301 million.[4]

3.2 The core approach we take is similar to NZIER, but there are important differences…

The basic approach used by NZIER is sound. Using per-hectare, per-tray values to calculate the difference between HC use and HC non-use based on trial data is sensible and what we would expect most practitioners to adopt as the core calculation of interest. This approach forms the basis of our estimation method. However, we diverge in a number of areas, which we summarise below.

3.2.1 We use the same analysis period, forecast data and discount rate as NZIER

Our analysis uses a ten-year analysis period (from 2020-2030). While this is the same time period as NZIER, our first year is 2020, while NZIER's is 2019, meaning there is an expected slight difference in estimated numbers due to forecast volumes. We were also able to negotiate the use of the same production forecast from Zespri that NZIER used, which is not publicly available due to commercial sensitivity. Finally, we apply the same basic discount rate as NZIER of six per cent in order to translate future values into today's equivalents.

3.2.2 Our estimation extends past kiwifruit

The NZIER analysis focussed solely on kiwifruit alone. This focus is understandable, given the client commissioning the analysis represents kiwifruit growers and the fact that kiwifruit accounts for the majority of HC use (see Table 1 above).

Notwithstanding their relatively minor share of total HC use, our analysis includes consideration of the situation for kiwiberry, pipfruit and summerfruit as well as kiwifruit. Thus, all else equal, we would expect our estimate of the economic harm from potential removal of HC from use would be higher than NZIER's.

[4] The calculations are $334 million multiplied by one minus the relevant effectiveness percentage (i.e. $334m*0.9=$301m and $334m*0.7=$234m).

3.2.3 Main difference relates to how efficacy of alternatives is determined; we derive a narrower band when all derived results are compared

The sole estimator of yield reduction in the NZIER analysis is rainfall. In particular, the range of relative efficacy of alternatives to HC of 10 per cent to 30 per cent reported as central results by NZIER is determined by rainfall alone. The underlying premise of their approach was that significant rain within three days of application would greatly reduce the efficacy of alternative chemicals. In the July to August period historically, NZIER calculates that the chances of a three day clear spell in July and August are between 10–35 per cent in target areas and that is the basis of the 10 per cent to 30 per cent figures.

In sensitivity analysis, NZIER consider, but give little credence to the results of using 50 per cent as the relative efficacy figure. While data from trials exists that shows the efficacy of alternatives most likely lies outside the central band, that data was not used in NZIER's central analysis.

Our approach was to give more weight to trial results, but we also used the rain data (and regional production as a weighting) as inputs into our determining the efficacy band we believe is best supported by the relevant available evidence. In addition, given available trial evidence, we delineate efficacy by kiwifruit variety (Hayward versus Gold3) rather than apply a blanket figure. The resulting efficacy figures we derived are shown in Table 5 alongside those used by NZIER.

We note the following point of relevance to our estimation process. Efficacy of alternatives is higher for Gold3 than Hayward and the difference in efficacy is less material in areas where the majority of kiwifruit are grown. Hence, weighting by regional production tends to lower the expected effect of withdrawing HC from use. That is, measured yield improvements from HC use relative to alternatives is noticeably lower in major growing areas, principally the Bay of Plenty (based on application of trials data for Te Puke).

In terms of the actual numbers, the high figure of 50 per cent is a pragmatic choice. There is trial evidence suggesting that alternatives could be as much as three-quarters effective as HC. Our assessment of those results are they are overly influenced by some outlier results for Hayward in particular. In order to be conservative, we chose to put those results to one side, consistent with the NZIER treatment and essentially land on the same high relative efficacy figure as NZIER's sensitivity analysis for the Gold3 variety.[5]

The medium figures were derived from averages of available trials data. In the case of Gold3 variety, the two alternatives produced a similar range of results, while for Hayward we use the average of results for one alternative only, which represents the best available evidence in our view.

The low figures were derived by comparing our replication of the NZIER rain data and combining with regional production to get weighted average effects, with available trials data. The former resulted in

[5] Though in essence, we differ as NZIER treated the 50 per cent figure in sensitivity analysis (i.e. there was no support for its inclusion in the central results), whereas we support the inclusion of the figure in our central results for the Gold3 variety.

figures of 23.4 per cent efficacy for Gold3 and 23.5 per cent efficacy for Hayward variety. The lowest reported trials data was 25 per cent and 24 per cent respectively, which we used. Further detail is not able to provided for reasons of confidentiality.

Table 5 Efficacy of alternatives comparison

Efficacy relative to HC	NZIER	Sapere
High	50% (effectively for both varieties)	39% (Hayward) 50% (Gold3)
Medium	30%	27% (Hayward) 36.5% (Gold3)
Low	10%	24% (Hayward) 25% (Gold3)

3.2.4 We expect a price response to the potential reduction in kiwifruit volume, which would substantially lower estimated harms/costs[6]

We also differ from the NZIER analysis in the extent to which potential price responses to reduced kiwifruit production are likely to arise. Our preference is to include such responses, which have the effect of lowering the potential harms/costs to growers but as the level of price response is highly uncertain, we illustrate the impact of a price response rather than include it in the core results.

The material we reviewed from the call-for information and other sources, including the NZIER analysis, suggests a marked reduction in the total production of kiwifruit if HC is not available. Our estimate of the reduced production volume were HC not available to be 22 per cent for Hayward and 17.5 per cent for Gold3 varieties respectively.

Accepted economic orthodoxy is that, for normal goods a reduction in availability tends to result in an increase in price, all else equal. While we accept that in general, New Zealand is a price-taker on world markets (i.e. it cannot dictate prices through its transactions), we suggest that this is not necessarily the case for kiwifruit. New Zealand enjoys an almost 50 per cent market share of the global kiwifruit export market.

That is, we would expect a change in price as a result of the reduction in kiwifruit available for consumption if HC is not available due to the relatively large market share held by New Zealand. Moreover, in the timeframe used for this study, we would not expect there to be sufficient time for

[6] Given its importance to calculations, further information relevant to the potential for price change to result from a significant drop in kiwifruit volumes is contained in an appendix.

additional supply from other countries (or from development of a substitute chemical) to fully come on stream.

The possible price change can be expressed through the well-used concept of elasticity (i.e. the response of demand/supply to a change in price and vice versa). Unfortunately, very few estimates of such elasticities are available. We essentially invert the price elasticity of demand relationship and apply the findings to supply responses. While inherently speculative, the approach has intuitive appeal and some empirical support from supply shocks in Chile relatively recently (see the appendix for further detail).

We model elasticities in the range of -0.74 to -5. An elasticity of -5 means that for a given reduction in volume of 22 per cent, we would expect to see an increase in price of around four per cent (i.e. -0.22/-5). For an elasticity value of -0.74 a given reduction in volume of 22 per cent would result in a price increase that outweighs the reduction in revenue from the volume drop (i.e. 22 per cent volume drop versus a 30 per cent price increase). The effective midpoint elasticity value of -3 would result in price rises of around seven per cent for Hayward and around six per cent for Gold3 varieties.

Given the uncertainty around actual price responses and the array of market dynamics at play, we present results in a range and do not include the offsetting price effect in our core results.

3.2.4.1 Other assumption changes largely insignificant

We utilise spray diaries to determine the total land area of conventional growth (i.e. non-organic) where HC is used. The relevant figure used is 86 per cent. As far as we can tell this land area differed somewhat from NZIER as they appeared to use a higher land area due to not netting out the use of alternatives but they did exclude parts of the South Island which reduced the relevant land area somewhat. We were not able to accurately determine the precise difference but it is in the region of about 10 percentage points.

3.3 …which results in our orchard gate revenue impact estimate of $1.8 billion-$2.35 billion over ten years for kiwifruit

Table 6 shows the result of utilising available trial data on efficacy of alternative chemicals is around $2 billion (range of $1.8 billion-$2.35 billion), in present value terms over a ten-year period. The table also shows the year one impact on growers of around $212 million (range of $180 million-$238 million). For completeness and comparative purposes, we also include the equivalent estimates derived by NZIER. While we present results in the low-mid-upper range in reality the upper range is not strictly comparable as the NZIER “upper bound” is really a scenario rather than part of the core results. Hence, it is largely illustrative rather than instructive here.

Table 6 Comparison with NZIER results ($ millions, present value)

Alternative effectiveness	Sapere (10 years)	NZIER (10 years)	Sapere (year 1)	NZIER (year 1)
Lower bound	$2,350	$2,811	$238	$301

Mid	$2,063	$2,187	$212	$234
Upper bound	$1,812	$1,562	$180	$167

Source: Sapere analysis, (Nixon, 2020)

3.3.1 Difference potentially much larger when price response is considered

Table 7 shows the effect of including a price response with a range of elasticity values (-0.74 to -5). The difference between the NZIER estimates and those of this analysis is much larger when both factors are included, meaning that the price response effect essentially dominates the alternative efficacy effect, which is not unusual in economic studies of this kind; prices and volumes are the essential components of demand and microeconomic theory. See Appendix A for details.

Table 7 Including price responses in calculations ($ millions, present value)

Alternative effectiveness	Sapere (10 years)	NZIER (10 years)	Sapere (year 1)	NZIER (year 1)
Lower bound	-$366 to $1,948	$2,811	-$34 to $198	$301
Mid	-$198 to $1,728	$2,187	-$19 to $178	$234
Upper bound	-$234 to $1,509	$1,562	-$24 to $150	$167

Source: Sapere analysis, (Nixon, 2020)

3.3.2 Chemical costs $45 million - $63 million higher due to prices of alternatives

Part of the existing grower preference for HC is that the cost per hectare is much lower than that of alternatives. We were provided estimates of the cost differential per hectare for the most likely alternatives and combined this with the expected number of hectares treated to estimate the increase in chemical costs to growers (see Table 8). These costs did not feature in the NZIER analysis but we feel are important to consider. They result in additional costs as a result of HC not being available of $45 million to $63 million over ten years.

Table 8: Increased chemical costs for Kiwifruit growers ($ million, present value)

Chemical costs	Outlay 10 years	GDP lost 10 years	Outlay year 1	GDP lost year 1
Low	$44.6	$18.2	$4.5	$1.8
Midpoint	$53.9	$21.9	$5.4	$2.2
High	$63.1	$25.7	$6.3	$2.6

3.4 Other fruits could see losses of $61million-$75 million across ten years

While HC is used as a bud break enhancer on other crops our view is that it is used more as an orchard management tool. HC would bring forward and condense production in certain blocks and varieties to increase the early season premium for fruit, as well as assist with harvest logistics and pruning requirements.

There is considerably less detailed information available on use of HC and efficacy of alternatives for other fruit. As a result, the method applied is coarser than is the case for kiwifruit. We are not able to estimate ranges for all of the other fruit-specific effects and some require simplifying assumptions that have a speculative element. Nonetheless, we calculate estimates of potential harms for these other fruits that total between $61 million and $75 million, across the ten-year study period.

3.4.1 Kiwiberry ($9.64 million)

Use

The effect of HC on kiwiberries is consistent to that shown by the Hayward and Gold3 varieties of kiwifruit commonly grown in New Zealand. Under ideal conditions, the benefits include earlier, enhanced and uniform budbreak, increased flower numbers, condensing of flowering resulting in improved pollination, and a reduction in the number of unwanted lateral flowers (NZKGI, 2020).

Alternatives

Alternatives are considered to be the same as modelled in the kiwifruit section.

Modelled impacts

We used the most recent data which shows average revenue of $4.15 million in the two seasons for the base year (Fresh Facts, 2018; Fresh Facts, 2019). This was forecast to grow by 6.2 per cent, the average Compounding Annual Growth Rate (CAGR) of Gold3, Hayward and organic varieties derived from the Zespri 5 year outlook (Zespri, 2019).

Reduction in value same as modelled for kiwifruit

We use the average reduction in value seen across the Gold3 and Hayward varieties of kiwifruit.

Chemical cost increase small due to low number of hectares

Table 9: Increased chemical costs to kiwiberry growers ($ millions, present value)

Chemical costs	Outlay 10 years	GDP 10 years	Outlay year 1	GDP year 1
Low	$0.12	$0.048	$0.013	$0.005
Midpoint	$0.14	$0.058	$0.015	$0.006

High	$0.17	$0.068	$0.018	$0.007

3.4.2 Pipfruit ($24 million-$37 million)

The effects of HC becoming unavailable are uncertain and not straightforward to quantify for pipfruit. There are alternatives available, but while we understand generally that they are less effective and/or less consistent than HC we are not able to confirm the extent of uses and users HC is used as a management tool on specific blocks for targeted/niche use so has a range of values specific to individual growers.

Use

HC is considered the most effective of the budbreak chemicals available. It has shown to be reliable to advance and synchronize bud break in apples, particularly in regions with low or marginal chill units. The controlled termination of dormancy is an important tool for growers to manage the timing and duration of flowering and to advance the maturity date and profile of apple crops at harvest.

The use of HC is varied to meet individualised grower management strategies depending on growing climate, varietal mix and market opportunities. From spray diary data about 13 per cent of national apple area uses HC. However, industry suggests HC use could be over 20 per cent of the national planted area (New Zealand Apples & Pears Inc., 2020).

Alternatives

Spray diaries show alternative products are used on approximately nine per cent of apple blocks nationally. Again, industry suggests spray diary records may underestimate use. Growers report alternative products can be unreliable, inconsistent or ineffective at times (New Zealand Apples & Pears Inc., 2020).

Modelled Impacts

Impacts suggested by New Zealand Apple and Pears were modelled across 13 per cent of hectares:

- Without a reliable tool for bloom compaction, approximately three additional chemical thinning applications would be needed. Hand thinning costs would increase by $1500 - $2600/ha.
- Loss of the ability to secure a premium in terms of price or access to market from earlier availability of fruit (New Zealand Apples & Pears Inc., 2020).

The increase in thinning costs was modelled as the change in costs per hectare across the number of hectares impacted. Total hectare growth for New Zealand apples over the last decade (2009 to 2019) was used to forecast a compound annual growth rate of 0.5 per cent per year (Stats NZ, 2020).

Thinning costs

Additional thinning costs range between $2 million to $3.4 million in the first year and a total of $18 to $31 million over the ten-year period. This does not account for the ability of alternatives to reduce these costs so likely overstates the impact.

$$Thinning\ cost = Cost\ per\ hectare\ \times Hectares\ HC\ used$$

Loss of early season premium

The estimate of the potential loss of early season fruit used the aggregate monthly data for apple sales over the last five years. There is evidence of a premium per tonne for February fruit when compared to the average price per tonne for the March to April peak season. This price difference was applied to a percentage of the February volume. Assuming a 50 per cent volume suggests losses of around $630,000 in the first year and $5.7 million over ten years (Stats NZ, 2020).

$$Early\ season\ fruit\ loss = 5\ year\ average\ Feb\ premium\ \times tonnes\ impacted$$

Total impact over ten years $24 to $37 million

$$Total\ impact = Thinning\ costs + Early\ season\ fruit\ loss$$

Chemical costs of $3 million to $4 million increase over ten years

Table 10: Increased chemical costs to pipfruit growers ($ millions, present value)

Chemical costs	Outlay 10 years	GDP 10 years	Outlay year 1	GDP year 1
Low	$3.05	$1.24	$0.34	$0.14
Midpoint	$3.66	$1.49	$0.41	$0.17
High	$4.27	$1.74	$0.47	$0.19

Impacts not modelled

Due to uncertainty we did not model the following potential impacts:

- **Increased pressure on harvest labour supply and costs** – while this is a likely outcome the contribution to the already well-known issue of orchard labour makes attribution uncertain
- **Challenges with alternatives such as variable results, and greater uncertainty** – qualitative impact only as alternative efficacy not available or amenable to modelling
- **Fruit quality impacts** – more detailed data is required to model this as impacts are uncertain.

- **The increased risk to fire blight infection, the impacts of fire blight and response** – attribution was not possible with the data and timeframe available. Longer term, it looks like orchards would transition away from susceptible varieties.

3.4.3 Summerfruit $27.6 million

Use

HC is used by summerfruit growers as a flower synchroniser/bud breaker in Hawkes Bay and Marlborough on around 200 hectares out of a total of 1,800 hectares.

- Apricot growers use HC to bring forward flowering and harvest times, to meet early local market demand and to help with bud break of high chill varieties.[7]
- Cherry growers use HC to assist with fruit set in lower chill years.

Alternatives

An alternative exists but it is three to four times the price and has poor efficacy compared to HC.

Modelled impacts

Assumptions and sources follow those of pipfruit. We use Fresh facts 2018 and 2019 figures as a base and CAGR of hectares over the last ten years to predict future production. As we have little information to convert the value at risk based on percentage of hectares sprayed with HC we test a loss of 25 per cent of the production value associated with HC use.

Table 11: Summer fruit value at risk ($m, present value)

	Base value at risk	10 year value at risk (25% impact)
Apricots	$0.9	$1.9
Cherries	$9.6	$25.7
Total	**$10.5**	**$27.6**

Chemical costs of $0.5 million to $1 million over ten years

Table 12: Increased chemical costs to summerfruit growers ($ millions, present value)

Chemical costs	Outlay 10 years	GDP 10 years	Outlay year 1	GDP year 1

[7] Refers to the number of chill hours that fruit trees require for flowering and fruit production each year. The number of hours over the dormancy period that are below a certain temperature.

Low	$0.55	$0.22	$0.055	$0.022
Central	$0.79	$0.32	$0.080	$0.032
High	$1.03	$0.42	$0.10	$0.042

3.5 Total costs/harms to growers are $1.9 billion to $2.5 billion, representing $858 million to $1.1 billion in GDP over ten years

Combining the OGR costs/harms with the additional costs of alternatives for growers results in a range of $1.92 billion to $2.49 billion across ten years. These costs/harms translate to a potential cost to the country of $0.858 billion-$1.113 billion in GDP impact (see Table 13).

Of these GDP impacts, around 97 per cent pertain to kiwifruit, with apples the next biggest contributor, at around 1.4 per cent of the GDP impact. National GDP is estimated to be $308 billion (as at the June 2020 quarter), meaning the estimated impact on yearly GDP is a fraction of one per cent (i.e. around 0.03-0.04 per cent).

Given the importance of kiwifruit to particular regions, the regional economic impact may be felt more acutely than the national figures convey. However, lack of information prevents more detailed analysis of regional economic effects.

Table 13 Total combined grower cost and national GDP impacts ($ millions, present value)

	OGR (10 years)	GDP (10 years)	OGR (year 1)	GDP (1 year)
Low	$1,922	$858	$191	$85
Central	$2,190	$977	$224	$100
High	$2,494	$1,113	$253	$113

Source: Sapere analysis

3.5.1 OGR costs/harms to growers of $1,873 million to$2,425 million, which translates to GDP impacts of $838 million to$1,085 million, across ten years

Summing up OGR potential costs/harms for growers gives a range of $1.87 billion to $2.4 billion, with kiwifruit accounting for the vast majority of this total.

Consistent with previous economic contributions to EPA reassessments we express impacts in Gross Domestic Product (GDP) terms. GDP is a well-utilised and reasonably well-understood measure of national income, as represented by the total value of goods and services produced in a country, usually in the period of a year. In other words, lower levels of GDP represent a nation being poorer, while higher levels of GDP indicate a nation is richer.

We use simple calculations based on the relationship between the value of exports and GDP (for kiwifruit) and the farmgate production for the remaining fruit affected. These relationships were examined for various plant species in the last five years and the ratio of farmgate production to GDP is 0.37, while the corresponding ratio for kiwifruit exports is 0.45 (NZIER, 2016). Output/export values converted to GDP equivalents are contained in Table 14, showing that GDP could be reduced by $838 million to $1,085 million as a result of the removal of HC

Table 14 Total OGR cost and national GDP impacts ($ millions, present value)

	OGR (10 years)	GDP (10 years)	PV (year 1)	GDP (1 year)
Low	$1,873	$838	$186	$83
Central	$2,131	$954	$219	$98
High	$2,425	$1,085	$246	$110

Source: Sapere analysis

3.5.2 Additional chemical costs to growers $48 million to $68 million which translates to GDP impacts of $20 million to $28 million over ten years

Over 90 per cent of the estimated total increase in chemical cost is for kiwifruit growers. To convert chemical cost to GDP impact we use the GDP agrichemical ratio calculated in Nixon & Morel, (2019).

Table 15: Increased chemical costs to all growers ($ million, present value)

Chemical costs	Outlay10 years	GDP 10 years	Outlay year 1	GDP year 1
Low	$48.3	$19.7	$4.9	$2.0
Central	$58.5	$23.8	$5.9	$2.4
High	$68.6	$27.9	$6.9	$2.8

3.6 Data and other limitations affect analysis

Like previous exercises of this nature, the analysis has been limited by availability of:

- specific and detailed data in a range of areas, including efficacy and use of alternatives, organic practices, market responses and dynamics and relevant prices, meaning we needed to rely on assumptions more than we otherwise would
- official regional GDP statistics which would allow a better picture of the magnitude of impacts in particular regions as opposed to national aggregates (we acknowledged that estimated costs/harms for key regions such as Bay of Plenty would be more magnified than might seem the case nationally)

- insights around HC use as part of integrated pest management – other than some general references in relation to apples we do not have information on which to assess HC's role, restricting our ability to make much by way of comment in this area

4. Conclusions

We find that there are likely costs to growers and the national economy (expressed in GDP terms) if HC is not available. The vast majority (around 97 per cent) of the costs relate to kiwifruit.

The main driver of the estimated costs is the reduced efficacy of alternative chemicals currently available. In simple terms, relative to the alternatives, HC reduces the risk of lower yields and also contributes to better fruit quality in a cost-effective manner. We also include additional costs to growers due to alternatives being more expensive than HC.

Our estimates of potential harm are reasonably closely aligned with economic analysis prepared as part of the call for information. The broad similarity in cost/harm estimates is not surprising given essentially the same process was used in both studies.

We discuss the possibility of a price response from the estimated reduction is supply from the lack of availability of HC. Using economic theory and past experiences, we are able to demonstrate the potential for a large off-setting effect for growers due to prices rising, which would reduce considerably the estimated impact of HC being unavailable. However, given the inherent uncertainty in estimating the key response parameter, we do not include it in the central result.

We have not looked to estimate the value of any potential benefit from removal of HC, as these are not strictly in the realm of economic analysis.

The analysis has limitations, but in our view represents a reasonable estimate of likely economic importance of HC use, notwithstanding a range of factors that influence relevant behaviour and outcomes in horticultural markets.

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Appendix A Approach taken to including a price response to falling volumes

For most primary agricultural products New Zealand activities are not able to influence prevailing international prices (i.e. New Zealand is a price taker in export markets). However, New Zealand has an approximately 50 per cent share of the global export market for kiwifruit. As a result, we expect some price response from a large reduction in yield as expected from the unavailability of HC. Due to the nature of the industry there is substantial uncertainty associated with elasticity parameters and a large range is presented in seasonal data and the literature.[8]

Sales of top and premium quality produce at the international markets is usually accompanied by sales of secondary class product at lower prices at the local market. For several commodities, these market segments are closely interlinked. Recent research suggests a reduction in post-harvest losses will effectively increase total market supply and thus eventually leads to lower farm-gate prices. (Gogh, Boerrigter, Noordam, & Ruben, 2017). We suggest the removal of HC will have the opposite effect, decreasing supply and leading to a higher price per tray.

Recent export demand elasticities are unavailable as data requirements for robust assessment are extensive. Export elasticities measure the responsiveness of demand for a country's exports to a change in the world price. The greater the elasticity, the greater the change in export demand following a price shift. Our suggestion represents the inverse, measuring the price response to a shift in supply. An NZIER review of export elasticities suggested the old kiwifruit elasticity of -2.45 could be halved in a synthesized model update to -1.225 (Allen & Ballingall, 2011).

A review of studies on the price elasticity of demand for major food categories found price elasticities for fruit ranged from -0.16 to -3.02 across twenty studies with an average of -0.70 (Andreyeva, Long, & Brownell, 2011).

A recent quantitative kiwifruit-specific modelling exercise used a NZ supply elasticity of -0.40, and demand -1.7 (Anker-Kofoed, 2015). While two decades ago U.S. analysis found elastic demand for kiwifruit, and used -1.81 as the lower limit of the actual elasticity with the short-run and long-run flexibilities of monthly price estimated to be -0.55 and -0.79, respectively (Peterson & Willett, 2000).

History of volume and price volatility for Hayward variety

Supply is subject to 'natural' production volatility with high yield volatility over recent seasons reported for Hayward variety. Notably the reduction from a record crop of 90 million trays in the 2016/17 season, to 65 million trays in the 2017/18 season we match this with reported price per tray

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[8] Agricultural and food prices are not easily explained by conventional market models, due in part to food price rigidity,farmgate price volatility, and low correlation between prices at different stages of the supply chain (Russo & Goodhue, 2017).

and use the percentage change year on year to calculate an implied elasticity. Also of note is the impact of a frost event in Chile on the price per tray in the 2014/15 season.[9]

Table 16: Seasonal supply volatility (Hayward)

Season	Trays (millions)	Price per tray	Seasonal quantity change	Seasonal price change	Implied elasticity
2013/14	69	$5.23			
2014/15	69	$6.01	0%	15%	-
2015/16	80	$5.13	16%	-15%	-1.09
2016/17	91	$4.36	14%	-15%	-0.92
2017/18	65	$6.71	-29%	54%	-0.53
2018/19	81	$5.36	25%	-20%	-1.22
2019/20	70	$6.46	-14%	21%	-0.66
Average	75	$5.61	-		-0.74

Source: Sapere analysis

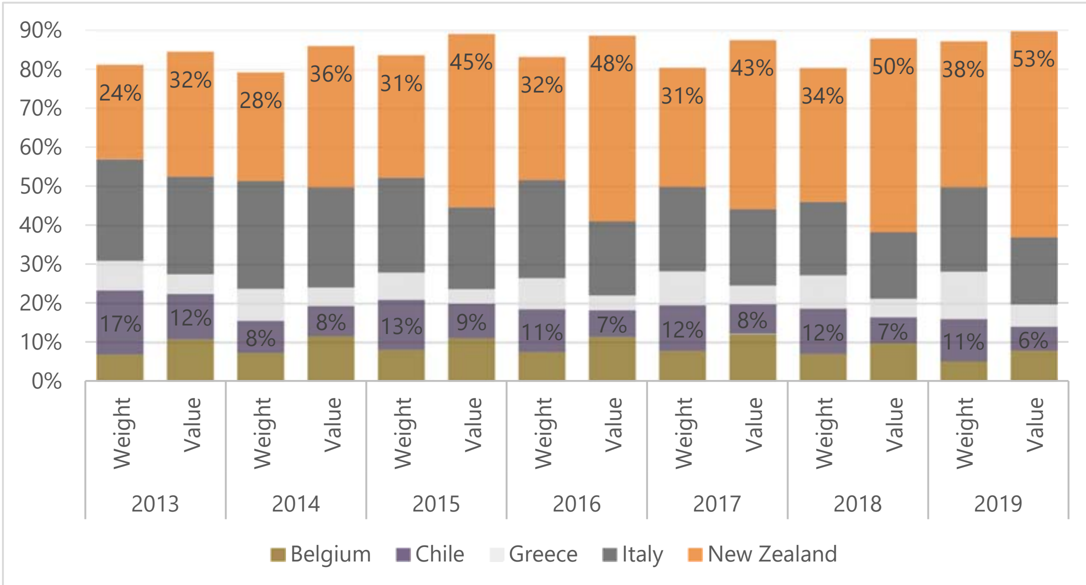
Impact on world market

Traditionally New Zealand primary producers are price takers on world markets. However, there appears to be a correlation between price per tray and the number of trays produced. This indicates the New Zealand production share of the world export market is significant enough to influence world prices. Comtrade data over the last seven seasons for the top five kiwifruit exporting countries shows that New Zealand production commands a higher share of value than quantity.

The recent increase in the differential is likely attributable to the shift to Gold3 variety that commands higher prices. The impact of the 2014 Chilean frost event is seen in the change from 2013 to 2014 figures. At the time it was reported that an estimated reduction in Chilean supply of 50 per cent created scarcity of green kiwifruit globally and contributed to New Zealand growers receiving higher prices (Hutching, 2014).

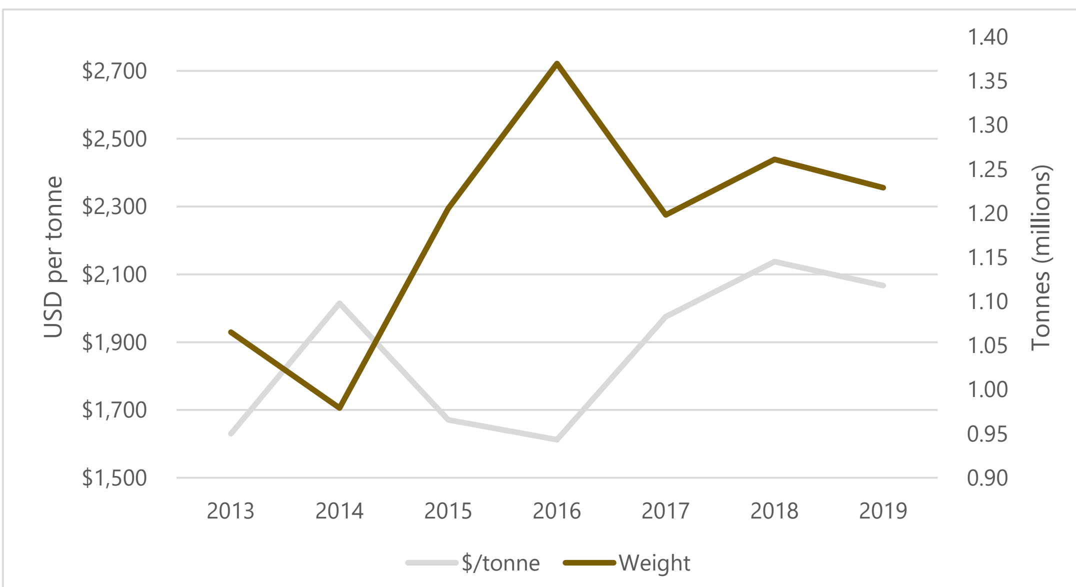
[9] "The 2014/15 season was extraordinary due to the shortage of Chilean kiwifruit in the market, following a severe frost event in Chile. This shortage – together with strong end-of-season sales and great work from growers, the post-harvest sector, the Zespri team onshore and in the markets, and our retail and trade partners – meant a strong season for Zespri Kiwifruit. Zespri sold 69 million trays of Zespri Green Kiwifruit earning record per-hectare returns" (Zespri, 2015, p. 6)

Figure 1: Top five exporters market share by weight and value



Source: Comtrade, Sapere analysis

Figure 2: Top five exporters tonnes and price per tonne



Source: Comtrade, Sapere analysis

Impact of range of elasticities investigated

The supply of different varieties of kiwifruit are a key determinant of orchard-gate pricing. Supply influences the marketing mix, in-market price tension, and the volume for which costs (i.e. marketing) can be spread. With many dynamics in play and a variety of elasticities in the literature suggests reporting the results of a range of elasticities. We investigate and report the impact of elasticities in the range -0.74 to -5, which represents a useful range, for our purposes.

Table 17: Elasticity impact with chosen alternative efficacy ($ million, present value)

Elasticity	Supply reduction Hayward (Gold3)	Price increase	OGR costs (10 years)	GDP at risk (10 years)	OGR cost (year 1)	GDP at risk (year 1)
-0.74	22% (17.5%)	30% (23.6%)	-$198	$89	-$19	-$9
-1.5	22% (17.5%)	14.8% (11.7%)	$948	$426	$98	$44
-3	22% (17.5%)	7.4% (5.8%)	$1,505	$677	$155	$70
-5	22% (17.5%)	4.4% (3.5%)	$1,728	$778	$178	$80
No price response	22% (17.5%)	-	$2,063	$928	$212	$95

Source: Sapere analysis

To calculate the potential reduction in supply we use our preferred central estimate of alternative efficacy (27 percent Hayward and 36.5 per cent Gold3). We compare the expected tray yield with and without HC, to calculate the expected reduction in supply.

$$Supply\ reduction = \frac{(Yield_{HC} - Yield_{Alt})}{Yield_{HC}}$$

We note that the actual elasticity is likely different for Gold3 and Hayward but given the uncertainty around this parameter and the lack of empirical evidence we have not attempted to account for this elasticity differential.

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