SeasonReview2023

Stuart Dykes

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Preface

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1 Introduction

2 Cyclone Gabrielle and resilience

Author: Stuart Dykes and Matt Saunders

2.1 Introduction

2.1.1 Hawkes Bay regional context

On 14th February 2023 Cyclone Gabrielle hit New Zealand with record rainfall and flooding. Hawke's Bay was one of the hardest hit regions leaving many communities and businesses damaged or destroyed.

16% of the Hastings District was flooded. Initial estimates (Selvaraj, Sadhvi (2023)) suggest approximately 1,600 homes were flooded across Hawke's Bay, some with up to seven metres of water. Across the region over 1,000 properties were stickered (i.e. unable to be either temporarily or permanently inhabited). Homeowners in severely impacted areas had to wait several months for central and local government to make decisions around the future use of their land.

28 days after Cyclone Gabrielle, the State of Emergency was lifted in Hawke's Bay. The region then entered a phase of recovery and rebuilding, which required a significant investment from industry, iwi, central and local government. Estimates put the final expected national rebuild cost in excess of NZD13 billion. Fundamental to the recovery is the need for regionally-led leadership and direction. Local leaders have worked together to develop a Hawke's Bay Cyclone Gabrielle Regional Recovery Framework to provide a structure for recovery efforts. Cyclone Gabrielle has exposed the fragility of the region's critical infrastructure, so underpinning the recovery activities will be the need to ensure future resilience against catastrophic events at every level.

2.1.2 Environment

Cyclone Gabrielle is the most significant weather event on record with between 250 – 400mm rainfall recorded across the region. Slash, debris and soil slowed the flow of rivers which in turn breached stop banks, inundating surrounding areas with flood waters. It is only the third time in New Zealand's history a national state of emergency has been declared. Climate change and the resulting warming oceans intensified the cyclone and increase the likelihood of future catastrophic weather events. As a region, a better understanding of the environmental impacts of climate change and what skills are needed to deliver sustainable solutions and risk mitigations need to be explored. Environmental resilience will be a key focus of the recovery.

2.1.3 Horticulture

Horticulture remains vital to the Hawke's Bay economy. Initial estimates put orchard losses from the cyclone at approximately 30% for all apple orchards and other crops, but with other organisms and disorders latently affecting non-damaged trees, this number has risen beyond those trees directly impacted. The supply of replacement trees is estimated to be below the required numbers, with commercial nurseries predicting it may take up to five years to meet demand caused by damage due to cyclone.

2.2 Cyclone Gabrielle impact on Rockit^{TM} apple orchards

In January 2023 the total canopy hectares of productive (i.e. producing) Rockit^{TM} orchards was xxxx hectares with an additional yyyy hectares of new orchards yet to produce a commercial crop. When cyclone Gabrielle arrived on the 13th February the flood and consequential silt inundation caused extensive damage to a number of orchards that were close to rivers and low lying areas. Figure 2.1 shows a map of Hawke's Bay immediately after cyclone Gabrielle with areas of flooding and silt inundation; overlaid is all the productive Prem A96 orchards at the time of the cyclone.

Figure 2.1 shows a map of Hawkes Bay including the post cyclone Gabrielle distribution of silt and flooding. Overlaid are the locations of all producing Rockit™ apple orchards. The most striking feature of the map is the silt inundation between between the Ngaruroro and Tutaekuri rivers. This was a result of the northern and southern stop banks failing for the Ngaruroro and Tutaekuri rivers respectively, affecting a large area between those two rivers, most significantly: Pakowhai, Waiohiki and Korokipo. There are four large Rockit^{TM} apple orchards in the Korokipo catchment.

The Tutaekuri river stop banks also failed further upstream in the Puketapu and Moteo Pa areas causing extensive damage to four Rockit^{TM} apple orchards. A subsequent decision was made not to replant one of hose orchards which was catastrophically damaged.

Extensive damage also occurred in the Omahu sector where flooding destroyed more than 60% of a single block with less than 34% remaining from the pre-cyclone canopy area. In total

As can be seen from Figure 2.1, apart from the aforementioned damage the block standing, however production was affected as only apple 30cm above the flood line were harvested to avoid any ongoing issues with food safety (predominantly Listeria).

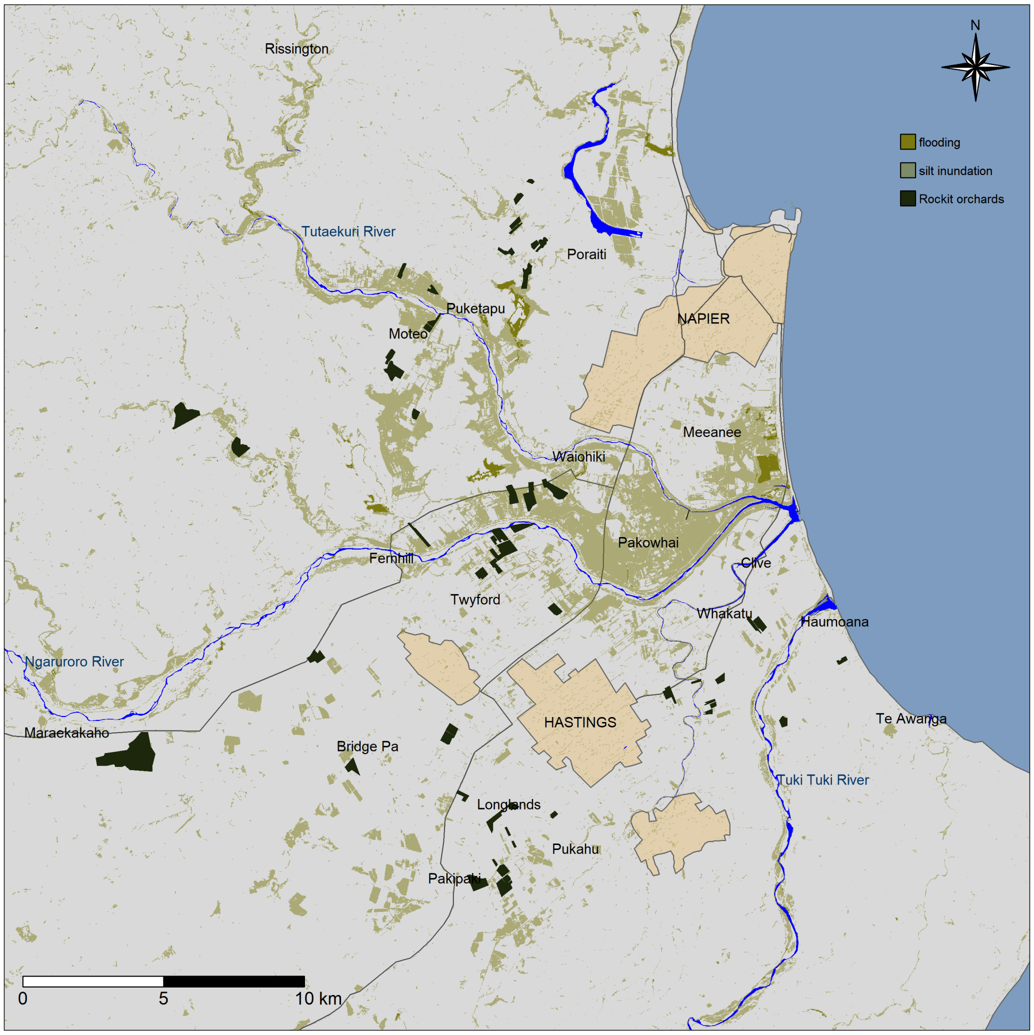


Figure 2.1: Post cyclone Gabrielle map showing: flooding, silt inundation and all productive Prem A96 orchards overlaid

2.2.1 Weather

To give the cyclone some perspective the rainfall and wind data is reviewed below for the weather stations that are installed on Rockit^{TM} apple orchards. The exception being the Puketapu data which was sourced from the Met Services weather station available through the NZ Apple and Pears database. The cumulative and hourly rainfall are shown graphically for Rockit™ apple orchard sectors in Figure 2.2 and Table 2.1. Over the duration of the cyclone the most rain fell in the Pukehamoamoa, Puketapu and Omahu in-land areas (refer to Figure 2.1) with cumulative rainfalls of 269, 248 and 226mm respectively. South of Hastings the rainfall was less in volume with Ngatarawa, Bridge Pa and Whakatu delivering 145, 118 and 117mm of rain respectively over the same period. Gisborne saw 184mm of rain fall over the same cyclone duration which was above the Hawke's Bay mean cumulative rainfall of 178mm.

Table 2.1: Maximum cumulative and amximum hourly rainfall for 11 regional Rockit™ apple growing sites during cyclone Gabrielle

	rainfall / mm	
weather station site	cumulative	hourly
Pukehamoamoa	268.6	34.2
Puketapu	248.3	21.7
Omahu	226.8	33.2
Gisborne	184.6	20.4
Maraekakho	170.2	16.4
Mangatere	163.0	18.2
Paki Paki	159.6	17.4
Haumoana	159.2	19.8
Ngatarawa	145.0	16.6
Bridge Pa	117.8	10.4
Whakatu	116.6	16.8

Wind is typically measured by looking at both wind speed and the azimuthal direction. A convenient way to visualise the distribution of windspeed and direction over a period is through a windrose diagram. This is presented in Figure 2.3 for the five weather stations with wind sensors installed. The prevailing wind direction was easterly for Gisborne and south-east easterly for the Hawke's Bay region. The rose indicates that there was very little variation in the wind direction over the cyclone duration.

Figure 2.4 shows that the wind sensor in Gisborne failed just after 22:00 on the evening of 13th February. Winds were blowing around 60 and gusting above 100 km/hr. At the peak of the cyclone (estimated to be around 22:00 on Monday 13th February), wind-speeds of 80 gusting to 132 km/hr were recorded at the Mangatere station. In all cases the wind gusts were approximately double the measured wind speeds.

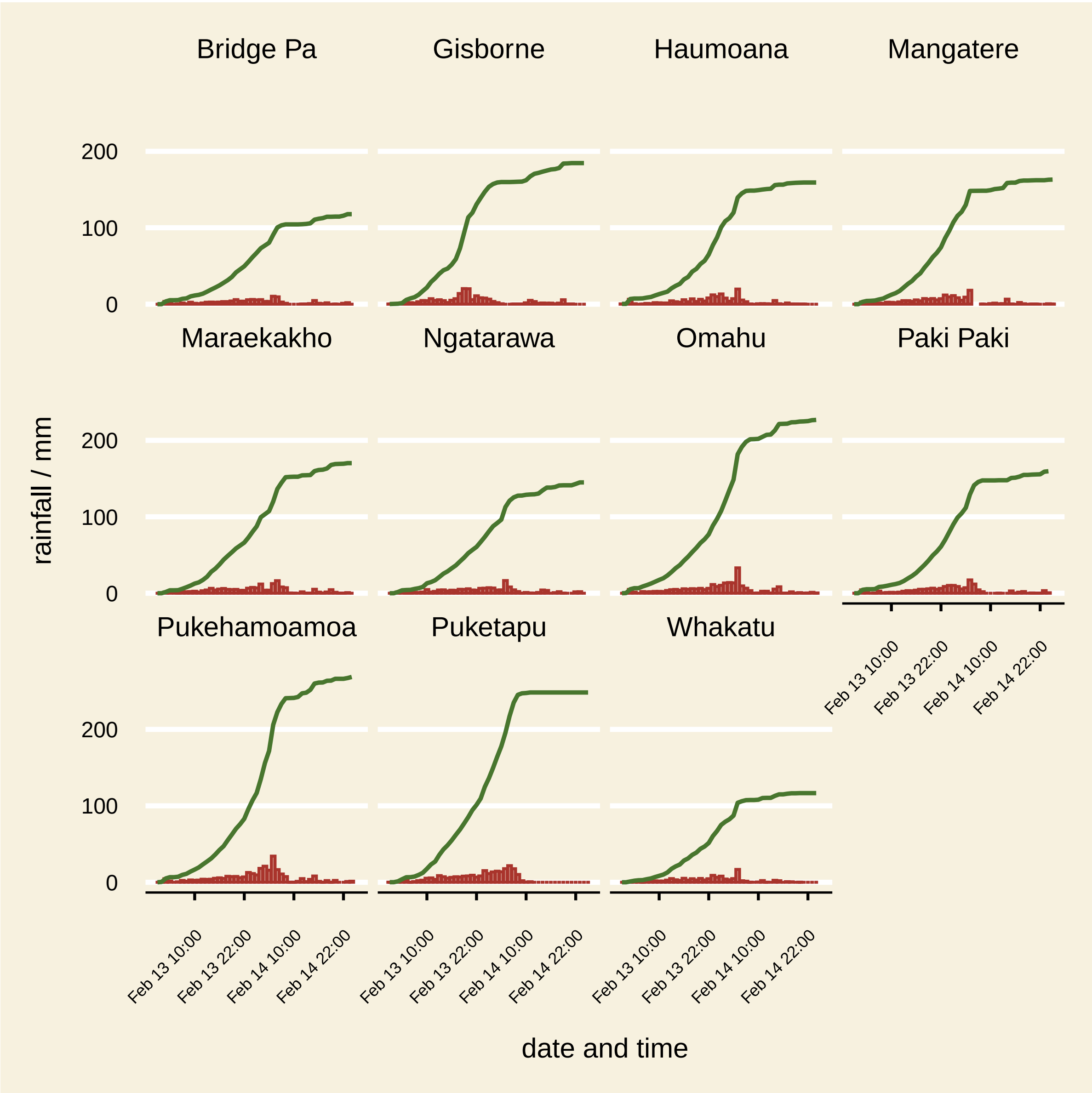


Figure 2.2: Cumulative and hourly rainfall over the 36 hours of cyclone Gabrielle for 10 weather stations located on Rockit™ apple orchards. The Puketapu site data is obtained from an independent MetService site accessed through NZAPI website

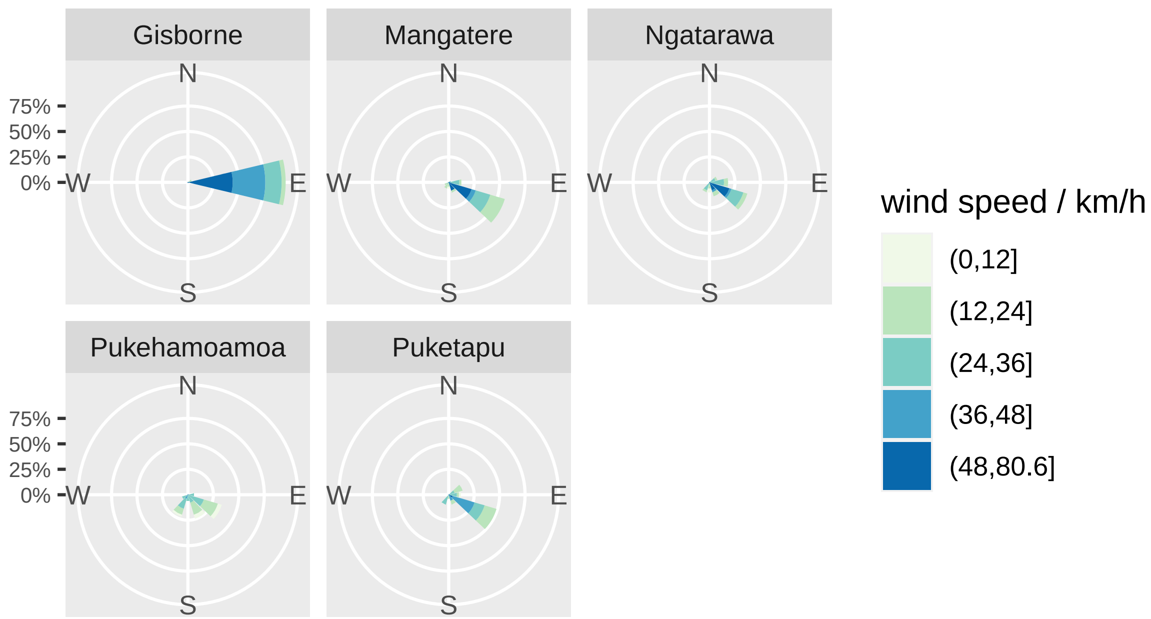


Figure 2.3: Windrose showing the distribution of wind-speed and direction over the duration of cyclone Gabrielle. The wind-speed is given in km/h units

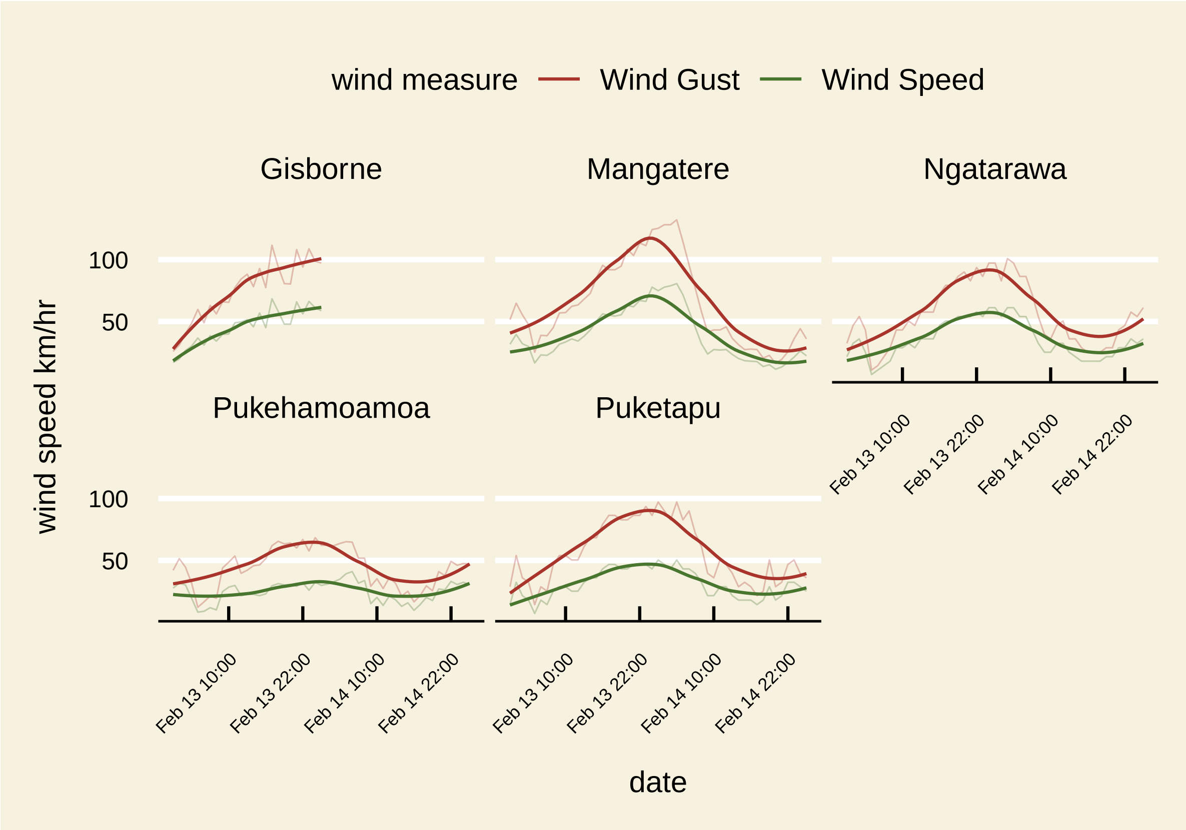


Figure 2.4: Wind and gust speeds as a function of time over the duration of cyclone Gabrielle. The wind-speed is given in km/hr units

2.2.2 Immediate actions post cyclone

The initial triage began on the afternoon of 14th February by contacting all staff and verifying access to orchards. Initially no access was available for a number of blocks predominantly around the Moteo Pa, Swamp Road, Puketapu and Puketitiri Road areas. A number of bridges had been destroyed including main bridge between Moteo Pa and Puketapu, restricting all access between these sites that were, hitherto, part of the same sector.

Where river stop banks had failed (this happened on both the Ngaruroro and Tutaekuri rivers), the water flowed into adjacent land areas with considerable momentum carrying silt and debris through orchards and vineyards. The effect was to knock over the infrastructure (posts and wires) and trees. Moreover equipment such as filed bins and reflective mulch were picked up and taken down stream. Rockit™ apple bins were collected more than four kilometres from the nearest orchard. What remained after the flood waters subsided was a thick layer of silt (more than one metre in some cases), debris brought from upstream (often termed slash) and debris from the orchard (posts, wires, reflective mulch field bins and also orchard mobile plant).

For affected orchards where access was possible the immediate and urgent remediation was to remove the flood water where

3 seasonal climate summary

Authors: Stuart Dykes & Tim Channing Pearce

3.1 Introduction

Rainfall, temperature, and solar radiation are the major climatic factors affecting apple growth and yield (Li et al. 2018; Fujisawa and Kobayashi 2011). As stated in Chapter 1 the 2022/2023 growing season has been challenging in terms of the effects of the climate, culminating in the devastating effects of cyclone Gabrielle.

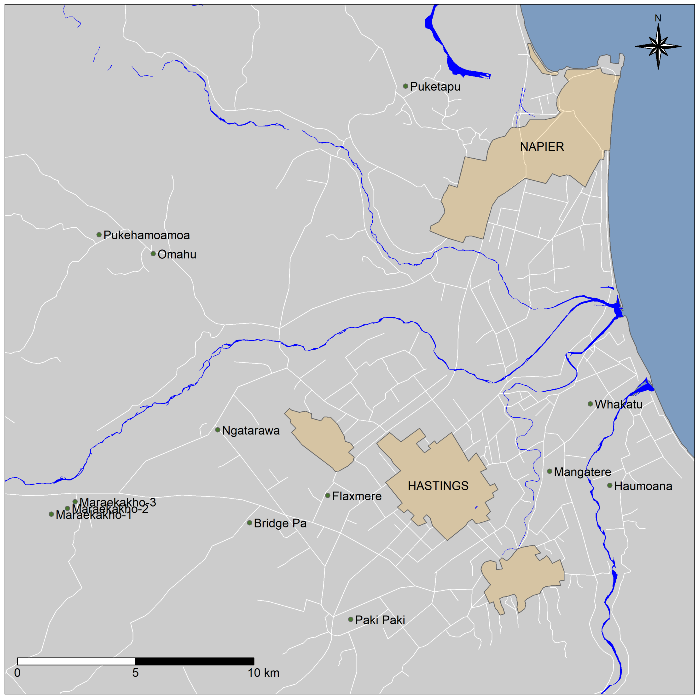
In general, seasonal performance can be attributed to a number of factors such as:

- climate (e.g. rainfall, temperature, wind)
- management decisions (e.g. pruning, spray programme, thinning philosophy/execution and harvest manipulations)
- disease pressure (e.g. black spot, ALCM)
- Fruit maturity at harvest
- post-harvest conditions (storage) and management decisions

In terms of the climate, the effects can be categorised in two ways: long term trends and major events. The first part of this chapter will review some of the long term trends and the second part, which focuses on cyclone Gabrielle, is covered in Chapter 2.

3.2 Sources of climate data

In 2020 Rockit began a project to place climate station in close proximity to orchards. To date 13 stations have been deployed and are active (one station was destoryed with the orchard), which gives RGL unique and local insight into the micro-climates and their influence on the growth of Rockit™ apple trees. The oldest stations have only been in place for three years at the time of this report in some cases it is difficult to compare the 2022/2023 with prior seasons and assess trends. To anonymise the exact location of the weather stations, the geographic region will be stated rather than the orchard name.



(a) Hawkes Bay

(b) Gisborne

Figure 3.1: Active Metris weather station locations providing data for the following analysis

Figure 3.1 shows the location of the Rockit™ apple Metris weather stations which are used for analyses in this chapter.

A number of key climate metrics are ubiquitous in the literature (Logan, McLeod, and Guikema 2016; Li et al. 2018) these include:
- rain - air temperature (minimum, maximum and mean) - ground temperature (minimum, maximum and mean) - growing degree days - sunshine hours

The above parameters will be evaluated for the growing areas where PremA96 is currently commercially harvested. Comparison with previous seasons is useful in understanding the trends and potential cause and effects with respect to yield and fruit quality.

3.3 Rainfall

the 2022/2023 growing season saw high precipitation even compared to 2021/2022. The extent of rainfall can be measured in two ways: total cumulative and number of days with significant rain (arbitrarily defined as 25mm). Table 3.1 and Figure 3.2 displays the daily evolution and total rainfall for each sector and Figure 3.3 the number of days where the rainfall is greater than 25mm respectively. The analysis covers the growing season defined as the period from 1st September through 1st May.

As can be seen from @Figure 3.2 and Table 3.1 The total rainfall over the growing season was consistently greater than

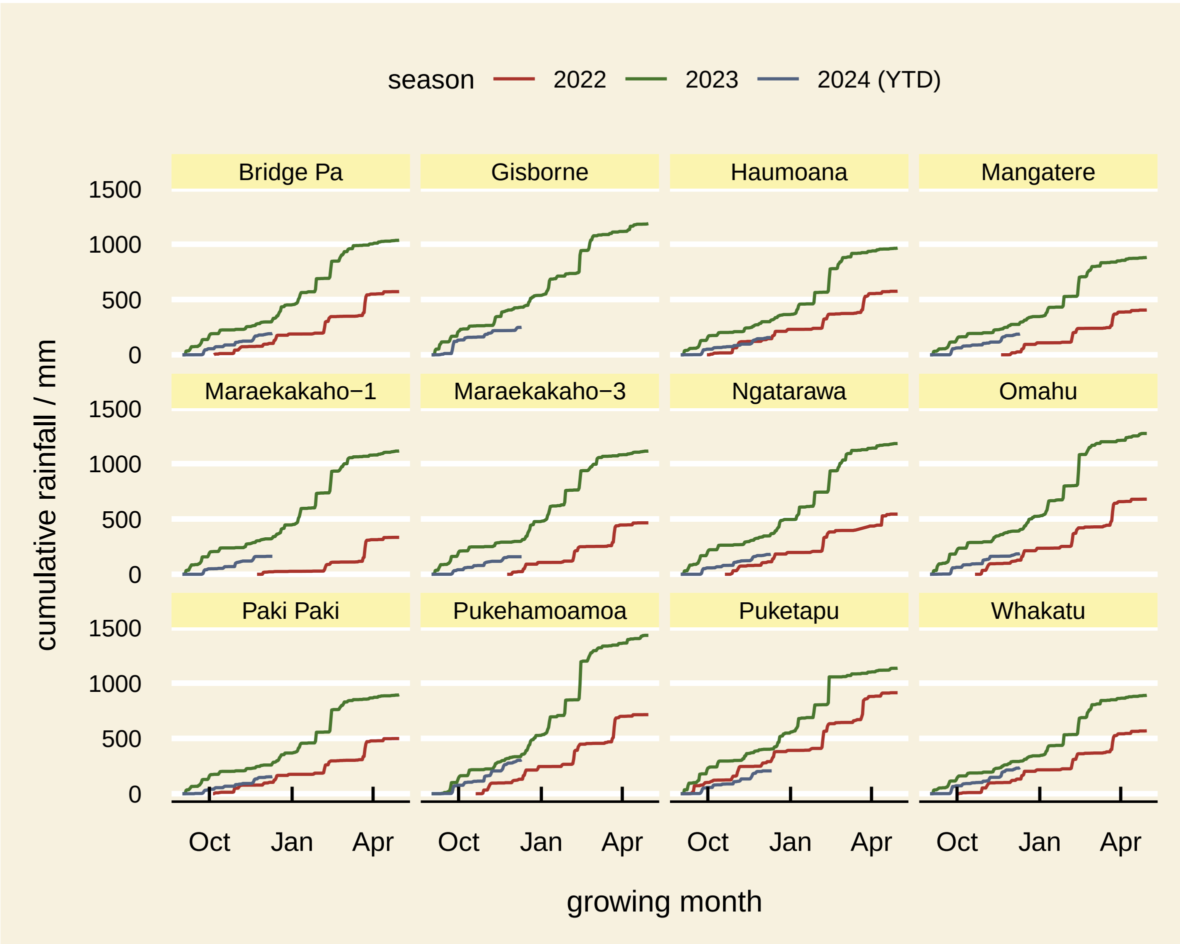


Figure 3.2: Annual rainfall for the growing season (1-September through 1-May) on Rockit™ apple orchard based weather stations. The rainfall is plotted as cumulative daily rain

Table 3.1: Annual rainfall for the growing season (1-September through 1-May) Rockit™ apple orchard based weather stations

	annual rainfall / mm		
season	2022	2023	2024 YTD[1]
Bridge Pa	571.2	1036.0	193.8
Gisborne[2]	NA	1186.0	249.0
Haumoana	575.0	965.6	158.4
Mangatere	405.2	880.6	189.0
Maraekakaho-1	333.8	1115.0	162.2
Maraekakaho-3	465.0	1114.2	158.2
Ngatarawa	544.0	1182.0	181.8
Omahu	679.0	1273.2	187.2
Paki Paki	499.0	895.2	155.0
Pukehamoamoa	715.0	1432.2	306.8
Puketapu	913.4	1135.7	206.6
Whakatu	568.8	890.4	236.8

[1] the last reading were taken on 13th December 2023
[2] the weather station in Gisborne was only established in 2023

3.4 Growing degree days

A common measure of heat accumulation in agriculture (and particularly horticulture) is growing degree days (GDD).

Plants generate biomass through photosynthesis. Photosynthetic activity depends to a large extent on sunlight which is typically measured in terms of radiative exposure through sunshine hours. Temperature is another important factor as it triggers and sustains changes in the apple through phyto-hormone regulation (Karami and Asadi 2017). While all stages are important to the development of the fruit the first 42 days after full-bloom (DAFB) appears to be a particularly important measure (Beaudry, Schwallir, and Lennington 1993; Bergh 1990). Temperature over this period is a major predictor final fruit size and yield (Bergh 1990). Productive heat, in horticulture, is measured through growing degree days. This is a simple measure, which subtracts a base temperature (in Rockit™ apple's case 10°C) from the average daily temperature, the difference being the number of GDD accumulated in that day. Generally the daily GDDs are summed to give a cumulative GDD over a period (The convention is to begin the accumulation at June 1st through to May 30th the following year). The mathematical calculation of GDD is given in Appendix 19.1.

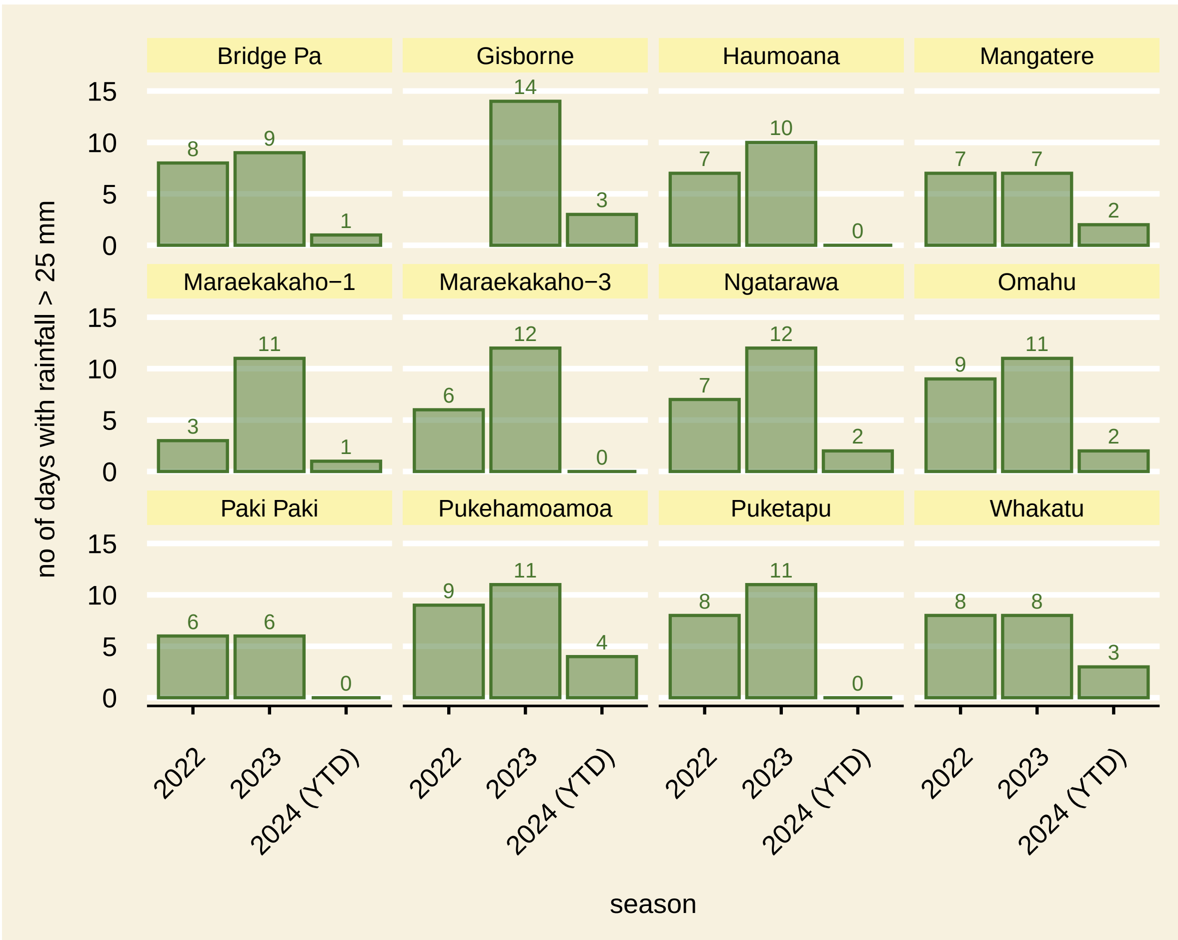


Figure 3.3: Number of days with rainfall greater than 25mm 2022, 2023 and 2024 (YTD). Data taken from weather station on Rockit™ apple orchards

As can be seen in Figure 3.4 the accumulation of GDD over the 2022/2023 growing season was relatively consistent across the Hawke's Bay and Gisborne with annual totals given in Table 3.2. Annual totals range from 1,621°C at the Maraekakaho sector to 1,904°C at Puketapu. The 2023/2024 YTD accumulated GDDs are tracking a very similar trajectory to 2022/2023 with the exception of Gisborne which is tracking slightly lower.

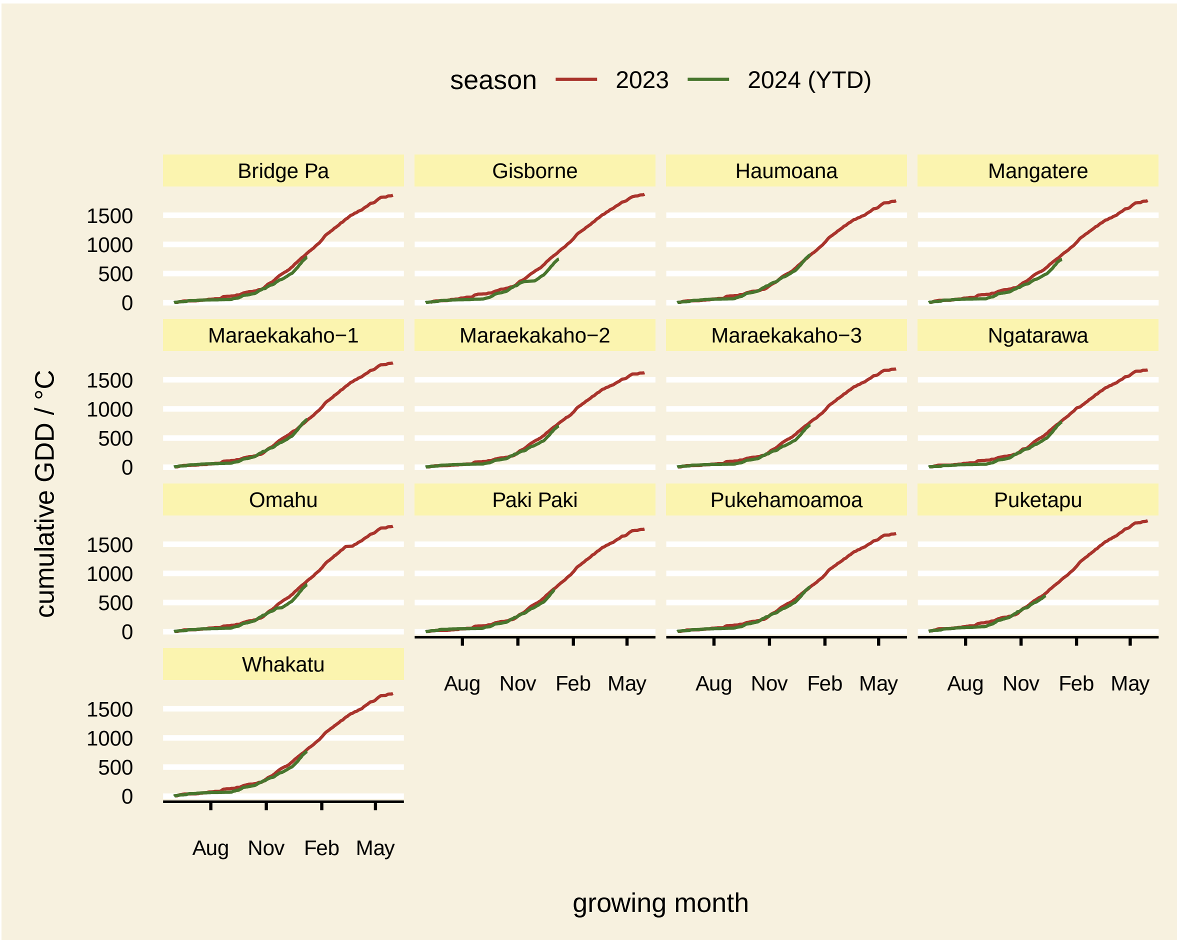


Figure 3.4: GDD for 2022/2023 and 2024 YTD growing season

Table 3.2: Regional distribution of annual GDD across Rockit™ apple growing sites

	annual GDD / °C	
sector	2023	2024 (YTD)[1]
Bridge Pa	1,843.8	776.0
Gisborne	1,861.0	748.5
Haumoana	1,750.0	819.5
Mangatere	1,753.4	740.0
Maraekakaho-1	1,790.1	817.8
Maraekakaho-2	1,621.2	705.7
Maraekakaho-3	1,686.9	724.4
Ngatarawa	1,670.4	775.5
Omahu	1,809.4	806.0
Paki Paki	1,761.4	723.8
Pukehamoamoa	1,684.3	768.5
Puketapu	1,904.3	618.1
Whakatu	1,763.0	766.8
mean GGDs	**1,761.5**	**753.1**

[1] the last reading were taken on 13th December 2023

Table 3.3: mean annual increase in GDD for Hawkes Bay and Gisborne regions

		95% confidence interval	
	growth rate	lower	upper
region	°C/year	°C/year	°C/year
hawke's Bay	4.1	2.8	5.3
Gisborne	5.1	3.9	6.3

The long term trend is increasing GDD for both the Hawke's Bay and Gisborne regions. Figure 3.5 shows the annual GDD values for Gisborne and Hawke's Bay from 1940 through 2022 (Stats NZ 2023). Linear trend lines are modeled and overlaid which give an estimate of the mean growth in GDD per year since 1940. The growth rates and associated confidence intervals are presented in Table 3.3. The Hawke's Bay and Gisborne's long term trend mean growth rates are 4.1°C/year and 5.1°C/year respectively. As can be see from the spread of the historical data, however, there is considerable year-to-year variability. the mean annual GDDs for the last 10 years (2012 through 2022) are 1,908°C and 1,865.4°C for Hawke's Bay and Gisborne respectively. This compares with a mean annual GDD for the two regions of 1,761.5°C for 2023 (Table 3.2) which is almost 8% lower that the 10 year average.

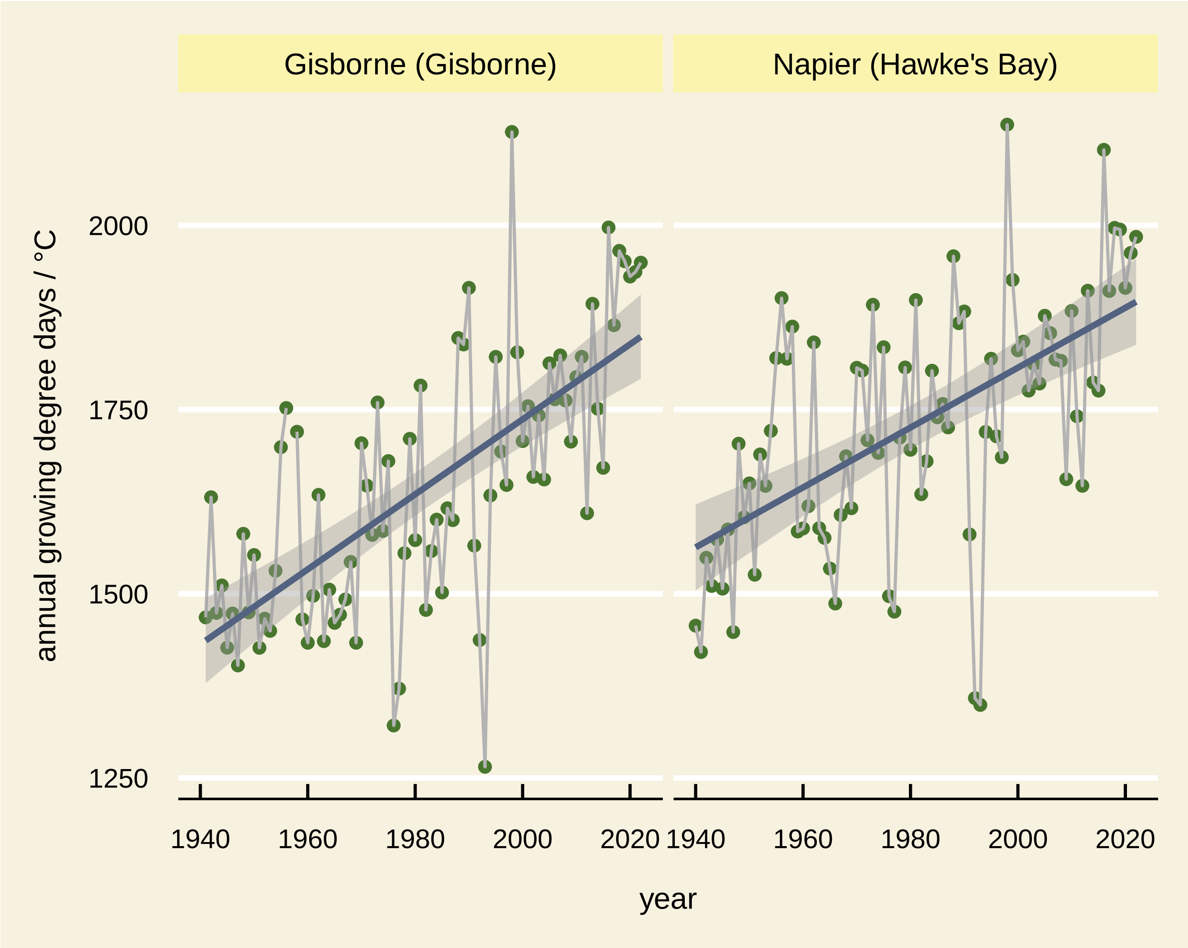


Figure 3.5: Historical annual GDD for Gisborne and Hawkes Bay from 1940 to 2022

3.5 Chill units

Dormancy is a phase of the annual cycle of the apple tree that allows it to survive unfavourably cold winter conditions. Three stages of dormancy have been defined based on the source of dormancy control: paradormancy (controlled by conditions within the tree but external to the bud, such as apical dominance), endodormancy (controlled by conditions within the bud itself) and ecodormancy (controlled by environmental conditions external to the tree such as temperature) (Parkes, Darbyshire, and White 2020). Progression through these phases is dependent on seasonal temperatures, and the length and depth of bud dormancy phases for a particular cultivar can vary between seasons and locations. The minimum accumulation of winter chill needed to break bud endodormancy and enable the shift into ecodormancy is defined as the chilling requirement (CR) (Luedeling and Brown 2011). Chilling requirements for particular cultivars are poorly understood and the range for apples has been loosely defined and is given in table Table 3.4 and is adapted from (Luedeling and Brown 2011). In terms of apple physiology recent studies have identified specific genes that play a direct role in the up- and down- regulation of phytohormones in the dormant bud such as: abscisic acid, gibberellic acid, ethylene, auxin and cytokinin (Kumar et al. 2017).

Table 3.4: Chill requirement range from Luedeling and Brown (2011)

	RCU range	
safe winter chill	min	max
high	2000	NA
intermediate	700	2000
low	-1000	700

Insufficient chilling over the dormant months (i.e. the chilling requirements are not met) delays the onset of flowering and subsequent irregular breaking of bud dormancy is often observed; this can eventually effect the fruit yield and quality. Monitoring chill units is, therefore, an important tool in predicting bud break and flowering and establishing the optimum management strategy through the growing season.

3.5.1 Winter chill models

Two winter chill model are widely used throughout the pip fruit industry: chilling hours and richardson chill units (also known as the Utah model). The chill units are accumulated from 1st June through 1st October. The individual models are formally defined in the glossary below and mathematically in Appendix 19.2. Both are presented in Figure 3.6

and figure Figure 3.7. A summary for the 2023 and 2024 seasons for each sector is given in Table 3.5.

The accumulation of chilling hours for 2023 (i.e. the winter of 2022) was, for most sectors lower than what was observed for the 2024 harvest season. The exception being two stations at Maraekakaho. The divergence between 2023 and 2024 season is most pronounced at: Mangatere, Whakatu and Haumoana (Figure 3.6). The comparison of RCU and chilling hours highlight the difference between the two models. RCU gives the ability to accumulate negative chill units (refer to Equation 19.3) when temperature get above 15.9°C. Mid august 2022 saw a particularly warm period which saw a decrease in accumulated RCUs. the second half of September 2023 (i.e. affecting the 2024 season) was also relatively warm also and a decrease in RCU was observed in several of the blocks. The effect of the later warm weather in 2023 (i.e. 2024 harvest season) was that late September is very close to the end of dormancy and hence the warm conditions aided in compressing the bloom **(reference the phenology)**.

The mean difference between the 2023 and 2024 season was 73.6 (12.1%) chill hours and 57 (5.6%) RCUs; the reason for the relative difference between the two units being due to the warm months in August and September for 2023 and 2024 respectively. Based on the aforementioned guidelines (Table 3.4) the amount of chilling was at the lower end of the intermediate level of the safe winter chill.

Table 3.5: total accumulated chilling hours and RCU for the 2023 and 2024 seasons. Note the chilling period was in the year before the harvest date (i.e. the chilling for 2023 season occured in 2022)

	chilling hours		RCU	
sector	2023	2024	2023	2024
Bridge Pa	632.0	751.0	1,043.5	1,116.0
Flaxmere	NA	722.0	NA	1,004.5
Gisborne	537.0	598.0	892.5	1,144.5
Haumoana	606.0	757.0	1,023.0	1,090.0
Mangatere	538.0	656.0	900.5	1,099.0
Maraekakaho-1	686.0	763.0	1,141.0	1,119.5
Maraekakaho-2	672.0	653.0	1,123.0	1,151.0
Maraekakaho-3	670.0	619.0	1,161.5	1,044.0
Ngatarawa	579.0	645.0	1,005.5	1,006.0
Omahu	615.0	680.0	971.0	1,015.5
Paki Paki	645.0	727.0	1,007.0	1,060.0
Pukehamoamoa	643.0	670.0	1,068.5	1,107.5
Puketapu	500.0	557.0	874.0	956.0
Whakatu	572.0	734.0	942.0	1,049.0
mean	**607.3**	**680.9**	**1,011.8**	**1,068.8**

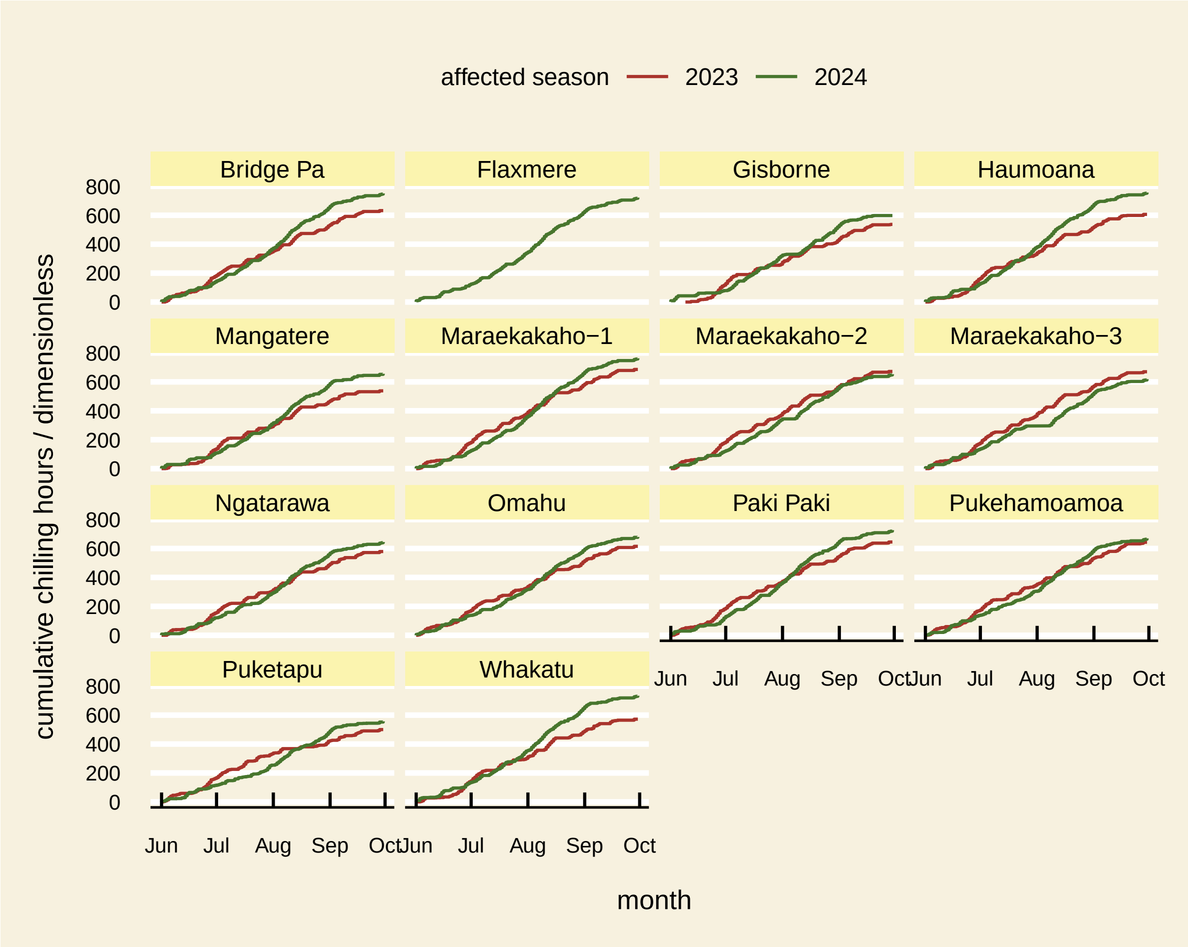


Figure 3.6: winter chill hours between the period from 1st June through 31st October

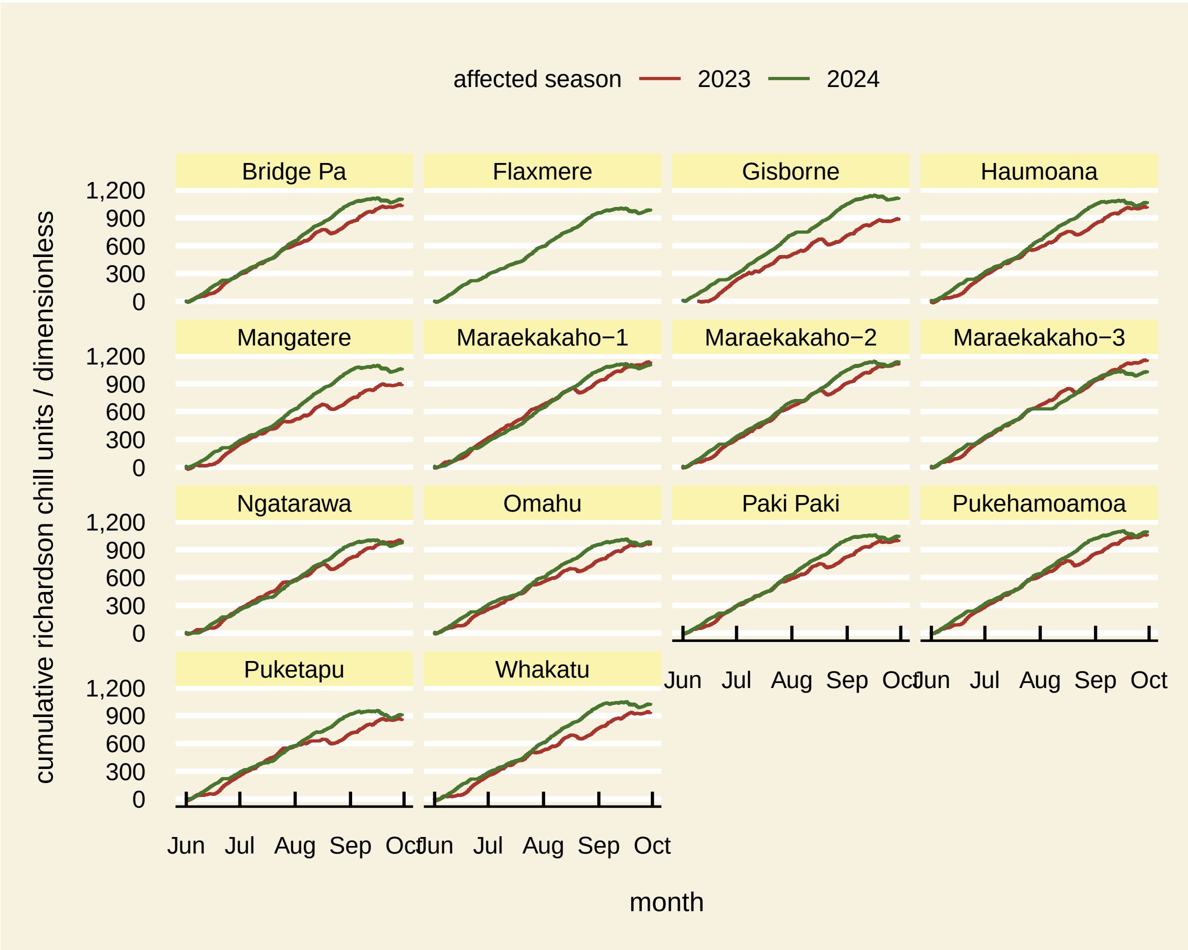


Figure 3.7: Richardson chill units between the period from 1st June through 31st October

3.6 Frost days in 2023

Frost is a significant risk in the Hawke's Bay region and

3.7 Glossary

DAFB days after full bloom - The number of days after the "full bloom" phenological stage of apple development

GDD growing degree days - GDD are the total number of degrees Celsius above a base threshold temperature for each day. The base threshold used is 10°C. GDD are calculated on a daily basis and typically reported on an annual cumulative measure (referred to as annual GDDs). GDD are defined mathematically in Appendix 19.1

Chilling hours model The Chilling Hours Model is the oldest method to quantify winter chill (Chandler, 1942). According to this model, temperatures between 0°C and 7.2°C are assumed to have a chilling effect, with each hour at temperatures between these thresholds contributing one chilling hour. Chilling hours are thus accumulated throughout the dormant season and then summed up. Chilling hours are defined mathematically in Appendix 19.2.

RCU Richardson chill units - also known as the "Utah model". It contains a weight function assigning different chilling efficiencies to different temperature ranges, including negative contributions by high temperatures. This model of chill units (CU) defines a CU as the permanence of the buds for a period of 1 hour in a temperature range considered optimum (2.5-12.5°C) to accumulate chill. The Utah model is more complex because it introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation). According to Richardson et al. (1974) temperatures between 0 and 16 °C promote the breaking of rest, whereas temperatures > 16°C negate such effects. Maximum promotion occurs at 7 °C (1 h at 7 °C = 1 chill unit); higher and lower temperatures within the 0-16 °C range are less effective. RCU are defined mathematically in Appendix 19.2

4 Prem A96 seasonal phenology

5 pest and disease monitoring (pre-season)

Author: Svetlana Drinnan - Fruition Technical Services Manager

5.1 Introduction

This report aims to look at presence of major market access pests and diseases (P&D) in RMS orchards in Season 2022-23 by sector as well as trends in the last five years.

This analysis may assist in: - understanding differences between management areas - tracking blocks season to season - reviewing controls and understanding how effective they have been - planning P&D management for future growing seasons.

This report will cover spring/summer field assessments, trapping and harvest assessments with the focus on the following P&D's: Black Spot (BS), Codling Moth (CM), Light Brown Apple Moth (LBAM), Apple Leaf Curling Midge (ALCM), Woolly Apple Aphid (WAA) and Mealybug (MB).

5.2 Season 2022-2023 pest and disease summary

5.2.1 Black spot

BS control in 2022-23 has been a challenge because of persistent rain throughout the season. BS incidence across all blocks has almost doubled in 2023 harvest assessments compared to the previous season but this result needs to be seen in context of extremely high disease pressure. The establishment of early season infection was a problem at some orchards.

A number of suggestions for improved control are made including 1) maintaining a tighter protectant cover programme over ascospore release, 2) using the Integrated Disease Model to assist in identifying high risk infection periods, 3) considering combination of protectants to cover resistance risk and 4) hygiene measures during wintertime.

5.2.2 Codling Moth

Almost no actionable thresholds throughout the trapping season and nil CM damage on fruit during the harvest confirms the company's very successful CM management approach which results in maintained low CM pressure status for all managing areas.

5.2.3 Light Brown Apple Moth

This season recorded the lowest level of old LBAM damage (4.4%) on fruit at harvest, in the last 5 years. However, slight increase in fresh damage and live larvae, 1.5% and 2.9% respectively, is not something to ignore. An insecticide application 3-5 weeks before harvest may be considered to eliminate the risk of larval presence in fruit at harvest.

5.2.4 Apple Leaf Curling Midge

ALCM appear to be well controlled across the company in Season 2022-23 with nil interception during harvest assessments in the last 4 consecutive years, all while expanding in producing hectares with many new plantings.

5.2.5 Woolly Apple Aphid

For the first time in the last 5 years pre-harvest monitoring recorded WAA colonies on Rockit orchards. However, biocontrol of WAA appears to be assertive, as no unparasitized WAA was found at harvest. The incidence of A.Mali has also dropped across all blocks by 28%, but increased by 0.1% within affected blocks. It is important to remember that parasitised WAA is also considered a quarantine pest in sensitive markets.

5.2.6 Mealy bug & scale

Both presence and incidence of mealy bug increased in 2023 harvest, by 6% and 0.1% respectively. Combined 0.5% of San Jose scale was also observed across all bin assessments. Both mealy bug and scale have the potential for rapid spread in the absence of appropriate control measures.

5.2.7 Mites

Fruition observed pest mites on quite a few Prem A96 orchards during spring/summer monitoring this season. Although, there were a couple of blow-outs of European Red mite, they did not translate into infestation of this pest on fruit at harvest. A combination of a good pest management and effective bio-control can take credit for it.

5.2.8 Other Pests

This season Rockit orchards have seen a decrease in % incidence of 'non-critical' pests like Bronze Beetle, Fullers and Noctuid damage. This is a pleasing reversal of the trend over the previous seasons where these pests were on the increase.

5.3 Season 2022-23 Sectors Summary

5.3.1 Napier Sector

- There was an increased incidence of Blackspot this season with most blocks in the sector showing the combined highest percentage, 7.6%, found at harvest. Blackspot was sighted at newly planted blocks during Nov-Dec monitoring, predominantly around the edges of the blocks. This may point to boundary coverage of helicopter applied sprays. Reviewing the impact of 'on the ground' issues such as equipment, spray application timing, methods may help determine the cause.
- Codling moth control has been effective this season with no incidence during harvest assessments and no actionable CM thresholds. It was a slightly different picture with LBAM though. Despite low average trap catches per week, Napier sector was the only sector that recorded all types of LBAM damage during harvest assessments including a live larva at Lawn F. However, the combined percentage was still very low at 0.3%.
- ALCM does not appear to be a critical pest for Napier sector this season. Percentage of damaged shoots increased from G2 to G3 monitoring by 20%, but no ALCM pupae was found at harvest.
- There has been some detection across most of analysed P&D this season, but it is worth mentioning that Mealybug incidence was the highest at Napier sector at 2.2%. This % does not include sooty mould which is indicative of internal mealy bug.

5.3.2 Havelock North Sector

- Black spot was sighted at only one orchard during spring monitoring. This, unfortunately, resulted into 0.5% incidence during the harvest, which is a minimum pest limit for China.
- Codling Moth and LBAM controls have been effective this season with no CM thresholds throughout the entire season or CM interceptions at harvest. Only one orchard exhibited LBAM pressure this season. One Block in particular had a several blowouts in Feb-March.
- Spring/summer ALCM scouting recorded 8.1% of damaged shoots post G2, and that number jumped to 34.8% post-G3, which is the highest increase across the company. Movento applications review is recommended.
- Unparasitised WAA colonies were detected for the first time this season. As a result, the affected blocks fell into high and medium export risk for WAA sensitive markets.
- Combined ranking for sensitive market access, which includes risk factors from all assessed P&D's, placed one orchard into a high-risk level; the rest of the blocks fell into medium risk.

5.3.3 Bridge Pa Sector

- Season 2022-23 has been a good season for the Bridge Pa sector with relatively low P&D pressure. Longlands orchard was the only site with actionable CM and LBAM thresholds this season.

- Similarly to Havelock Nth sector, WAA colonies were detected during field monitoring. Both affected blocks also saw a small percentage of A.Mali in their bins; the fruit was considered a high-risk line for sensitive markets based on all combined risk factors.

5.3.4 Puketapu Sector

- Black spot control was very effective in Puketapu orchards this season with no detection both during the season walks and at harvest.
- Puketapu sector continues to show low pressure for CM and LBAM, recording lowest average weekly moth catch per trap, and no actionable thresholds as well as nil moths' damage interception at harvest.
- Even though Puketapu sector saw more damaged shoots with ALCM, namely 15.1% post-G2 and 27.9% post-G3, compared to last season, it was the sector with the highest % of low-risk blocks for ALCM sensitive markets.

- Puketapu sector recorded the highest interception of parasitised WAA during harvest assessments at 2.1%. Unparasitised colonies of WAA during field assessments were also recorded.

5.3.5 Omahu Sector

- Black spot has been an issue this season. The disease was detected late season only with a high 10.5% and 1.2% at two adjacent blocks. Unavoidably, BS showed up at harvest assessments too. Spray programme review during the critical period (the beginning of bud growth until small fruitlet stage) is recommended.
- Omahu sector saw a reasonable LBAM pressure this season with the highest average trap catch per week, several actionable thresholds and a live larva at 9B in bin assessment.
- The sector recorded the highest percentage of ALCM damaged shoots (new infestation and old damage) both post G2 and G3, 18% and 36% respectively. Midge infestation at two blocks were high enough in combination with vigour to place these blocks into high-risk post G3.
- WAA control was very effective – it was the only sector that was completely clean of any type of WAA.

5.3.6 Valley Sector

- Valley Rd sector is a new Rockit sector this season with only one year of obtained P&D data.
- Sector has showed a very good Blackspot and CM management. However, there have been some LBAM pressure with 2nd highest average trap catches per week, several thresholds and one fresh interception at harvest.
- The sector also recorded some detection of WAA during field monitoring, and combined 1.4% of A.Mali during bin assessments, however, it was below allowed maximum pest limit and did not entail any export risk.
- Bin assessments at Valley Rd and Pioneer also saw small % of other critical and non-critical P&D.

5.4 Black spot

Black spot (BS) is a quarantine disease for Chinese market with Maximum Pest Limit (MPL) 0.5%.

It has been a very wet spring and summer in Hawke's Bay with moderate to heavy rains every month which has created a lot of disease pressure this season. Black spot infection

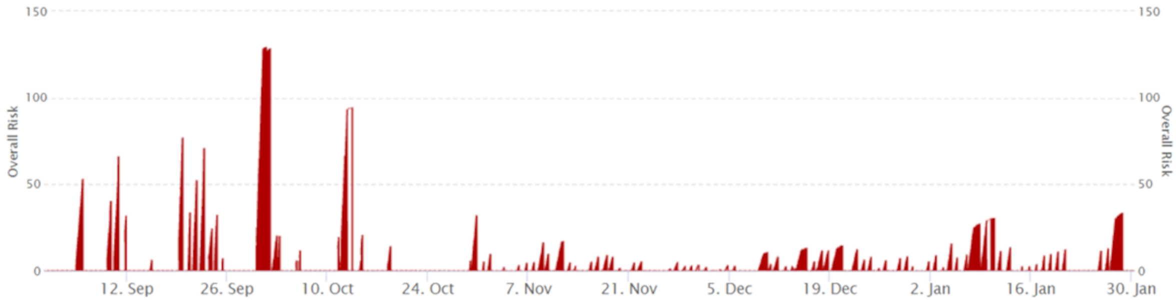
Figure 5.1: example of an apple with a black spot lesion

period risk graph below shows a number of high-risk events that occurred over the period of ascospore release (Sept-Nov) (Figure 5.2). Early spring infection period is determined by the number of ascospore available when it rains. Risk continues while wetness continues and accumulates each hour as more ascospores are released. It is critical to control this primary inoculum to minimise secondary infections as the magnitude of risk is many times greater over the primary spore release period until ascospore reaches its maturity (usually early November).

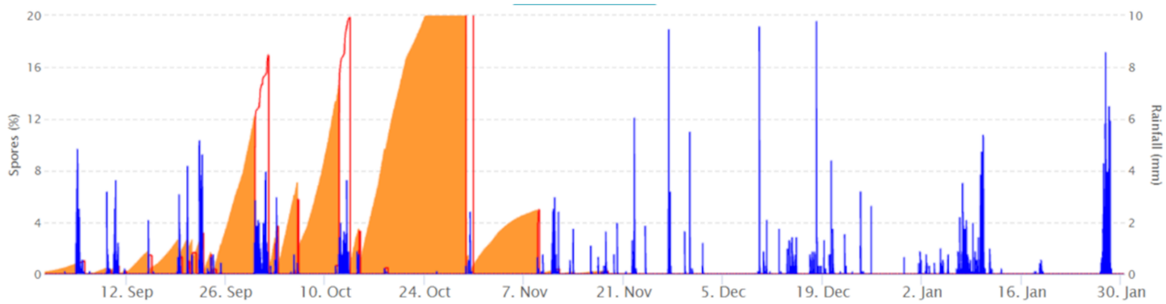
Overall, black spot control in 2022-23 appears to have been a challenge. The establishment of early season infection was a problem in blocks at the following sectors shown in Table 5.1.

Table 5.1: blocks with sighted black spot during November - December monitoring

sector	average leaves per shoot	black spot				
		leaves	fruit tops (250)	fruit bottoms (750)	overal (%)	risk level
Puketapu	11.0	0.00%	NA	0.10%	0.10%	Medium
Havelock	12.0	0.00%	0.40%	NA	0.10%	Medium
Twyford	15.1	0.70%	1.20%	2.80%	2.40%	High
Twyford	13.7	0.00%	2.80%	1.20%	1.60%	High
Whakatu	12.9	0.00%	0.80%	NA	0.20%	Medium



(a) Summary of primary infection periods for black spot



(b) Summary of secondary infection periods for black spot

Figure 5.2: Black spot infection summary for 2022-2023 spring and summer in Hawke's Bay

The following blocks are a good example of how a secondary infection can occur during the right conditions later in the season. Even though black spot was not observed there during spring assessments (primary infections may be very few in number and therefore escape detection), these blocks were reassessed in February on manager's request, the resulting observations (Table 5.2) show quite prolific spread of black spot.

Table 5.2: two blocks with observed secondary black spot infection during February monitoring. No primary infectcion was detected during the November and December monitoring

	black spot				
average leaves per shoot	leaves	fruit tops (250)	fruit bottoms (750)	overal (%)	risk level
11.2	2.00%	12.70%	4.00%	10.50%	High
11.6	NA	1.50%	0.40%	1.20%	High

Disease levels in November was a good indicator of incidence at harvest. Black spot incidence across all blocks during harvest assessments increased by 11.4% compared to the last season. Black spot incidence within affected blocks jumped to 0.7%, which is a 0.4% increase from last season (Table 5.3 and Graph 3).

Table 5.3: two blocks with observed secondary black spot infection during February monitoring. No primary infectcion was detected during the November and December monitoring

year	monitoring		
	across all blocks	within affected blocks	spring monitoring
2019	11.10%	0.60%	0.03%
2020	14.90%	0.20%	0.00%
2021	8.80%	0.10%	0.00%
2022	1.36%	0.30%	0.00%
2023	2.50%	0.70%	0.10%

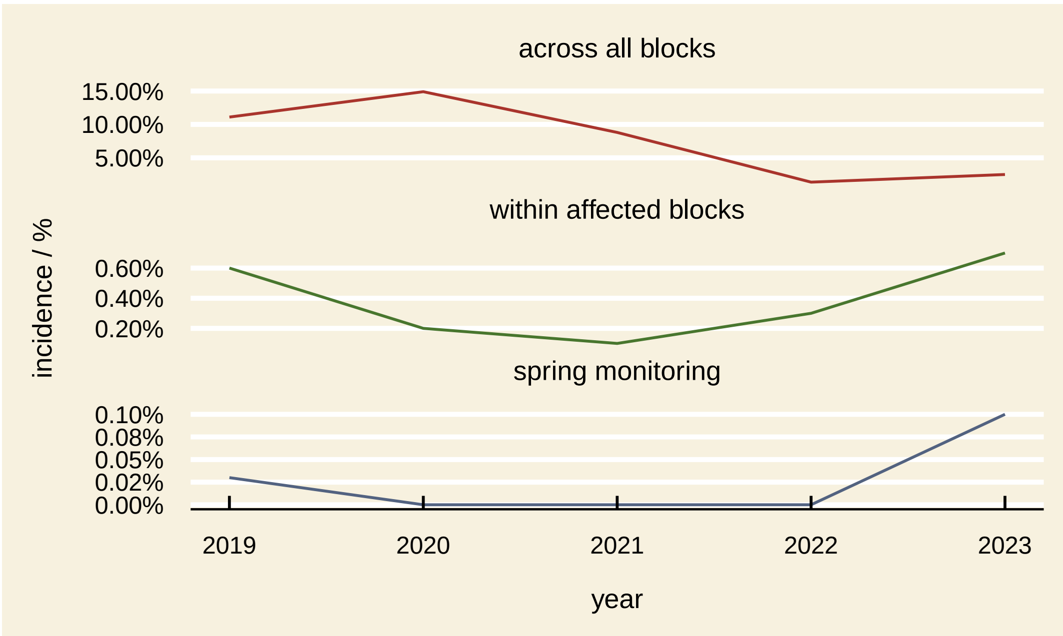


Figure 5.3: historical mean incidence of black spot across different monitoring scenarios from 2019 through 2023

The Naier sector has recorded the highest combined percentage of black spot, 7.6%, found at harvest (Table 5.4), followed by Omahu, 4.1%, and Havelock Nth, 0.5%.

Table 5.4: black spot percentage incidence detected at harvest 2023 by sector

sector	black spot percent
Napier	7.60%
Omahu	4.10%
Havelock North	0.50%

5.4.1 Conclusion/Recommendations

- Rockit's black spot incidence across all blocks has almost doubled in 2023 harvest assessments compared to the previous season, mainly due to increased numbers of bin assessments at orchards with known disease presence from spring assessments. Assessing risk factors against spray programme is recommended for these blocks to see where errors might have happened, i.e. equipment (rates and calibration), timing with respect to weather conditions (coverage and drying times), product (resistance possibilities) etc.
- Maintain a tight protectant cover programme over ascospore release. A few uncontrolled primary infections can set up an orchard for a major blackspot problem later if other favourable factors fall in place.
- Use the Integrated Disease Model which may assist in identifying high-risk infection periods especially if these events are not readily recognized.
- Regardless of amount of BS found during spring assessments, it may still be advisable to apply a BS protectant fungicide throughout the season if an extended (>48 hours) wet period is forecasted to prevent conidial risk mid- to late-season.
- Winter is the perfect time to control the disease with hygiene measures, as often this disease originates from the last season's spores. Overwintering spores are looking to infect, and more spores in the orchard means higher chance they will during the right conditions. Successful black spot management involves keeping the primary innoculum levels to a minimum.

5.5 Codling moth

5.5.1 Overview

Codling Moth (CM) is quarantine pest for Taiwan, China and Japan markets with Maximum Pest Limit (MPL) 0%.

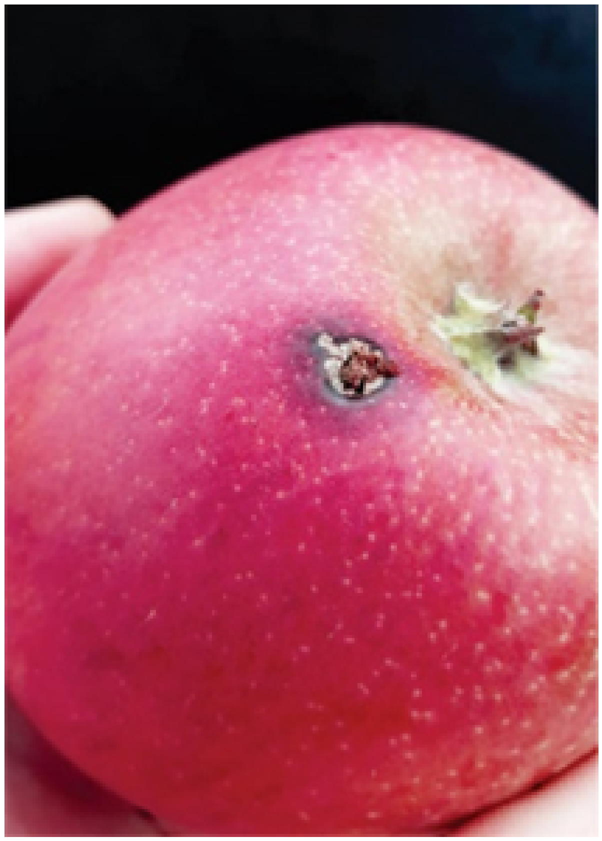


Figure 5.4: example of an apple with a black spot lesion

During harvest assessments we look for three types of codling moth damage on fruit: Old damage, New/fresh damage, and codling moth larvae. Historically, Rockit™ apple's harvest assessments have been free from any fresh codling moth damage or live larvae. This season CM control has improved even further with no codling moth damage to fruit being found at all, not even old chews or stings (Table 5.5, Figure 5.5).

Table 5.5: two blocks with observed secondary black spot infection during February monitoring. No primary infectcion was detected during the November and December monitoring

	codling moth incidence	
year	across blocks	within affected blocks
2019	0.00%	0.00%
2020	4.30%	0.20%
2021	29.40%	0.10%
2022	11.40%	0.10%
2023	0.00%	0.00%

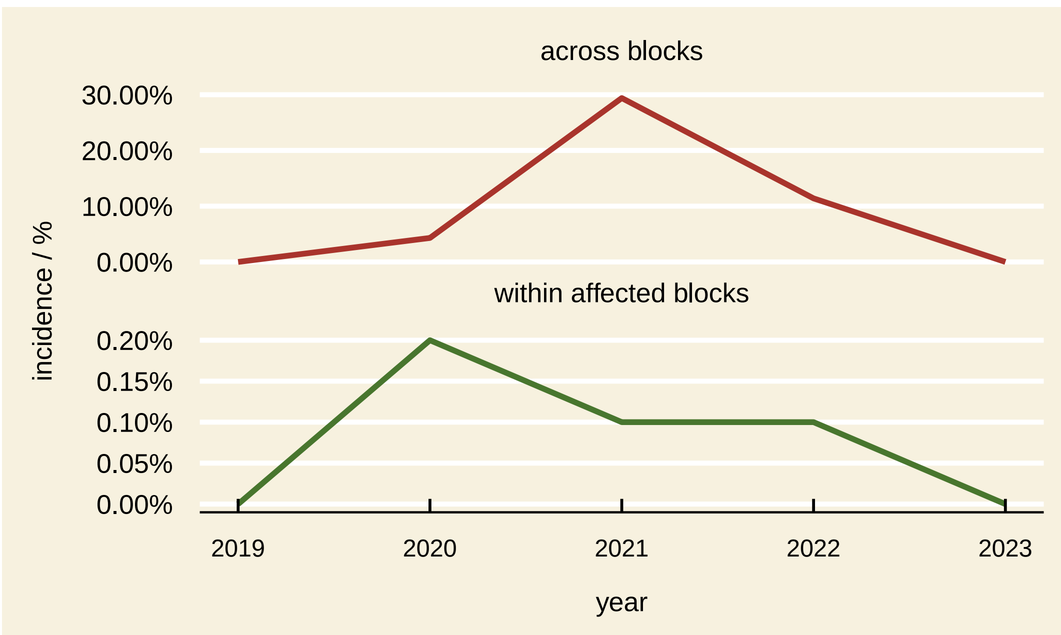


Figure 5.5: historical mean incidence of codling across different monitoring scenarios from 2019 through 2023

5.5.2 By Sector 2022-23

Seasonal trapping records also indicate that codling moth pressure was very low (below 0.5 moths per trap per week on average) and well controlled through spraying programme and use of mating disruption across all management areas (Figure 5.7). There was only one actionable threshold at a non-CMSM orchard throughout the entire season.

Statistical analysis of trapping data showed that Bridge Pa sector has caught more moths per week on average this season followed by Havelock North, Omahu and Valley. Puketapu and Hastings sectors had the lowest codling moth pressure this season (Figure 5.6).

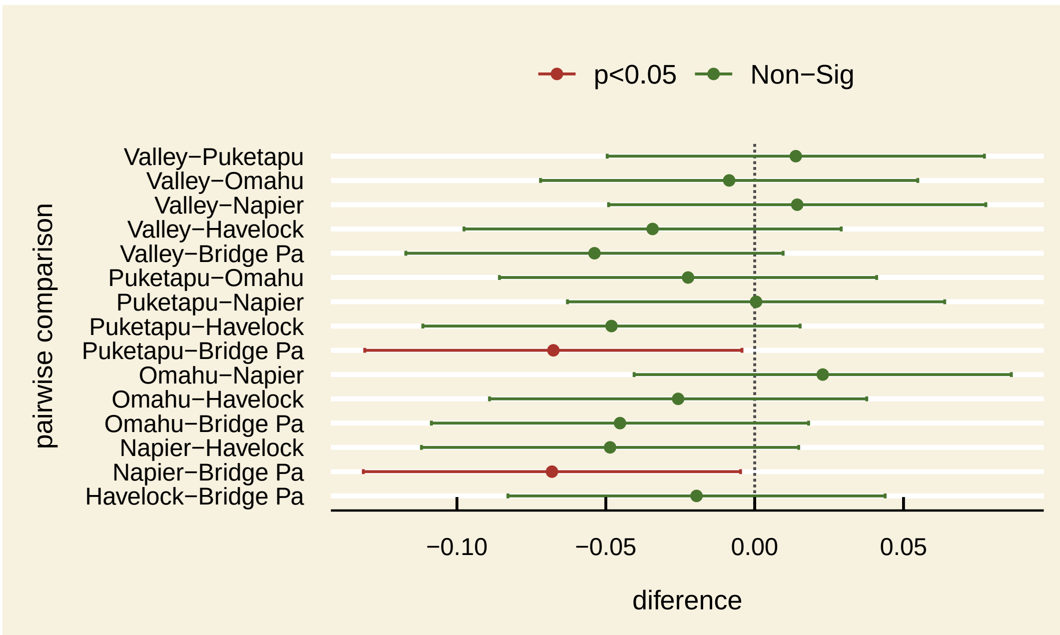


Figure 5.6: pairwise comparison of sectors using Tukey HSD post hoc test

5.5.3 Recommendations

Follow the same controls and spray programme next season as almost no actionable threshold throughout the trapping season and nil CM damage on fruit during the harvest confirms the company's successful CM management approach which results in maintained low CM pressure status for all managing areas.

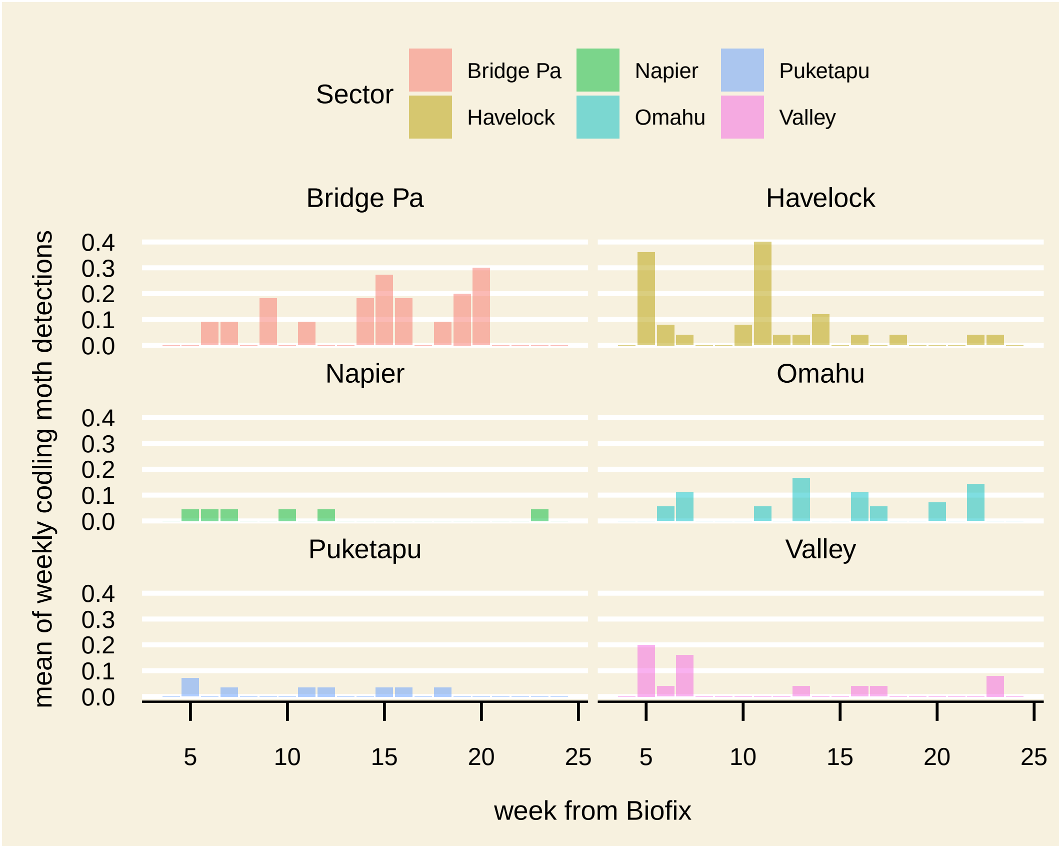


Figure 5.7: Average CM catch per trap/week in 2022-23

Figure 5.8: example of damage to fruit caused by light brown apple moth

5.6 Light brown apple moth

Light brown apple moth (LBAM) is a quarantine pest for some key markets: Japan, USA with maximum pest limit (MPL) 0%, and Taiwan, China with MPL 0.5%.

Same as with codling moth, during harvest assessments we look for three types of leaf roller damage on fruit: old damage, new damage, and codling moth larvae.

Season 2022-23 has seen a slight drop in old light brown apple moth damage incidence during harvest assessments both across all blocks and within affected blocks. However, there was a small increase in both fresh damage and live larvae compared to last season (Figure 5.9, Figure 5.10, Table 5.6, Table 5.7).

Light brown apple moth flying activity generally picks up again in February, around the time when Prem A96 fruit matures. So, it is highly recommended that an insecticide is applied 3-5 weeks before harvest to eliminate the risk of larval presence in fruit at harvest.

Table 5.6: Average incidence of light brown apple moth across all blocks between 2019-23

	LBAM incidence		
year	old	fresh	larvae
2019	11.10%	0.00%	0.00%
2020	25.50%	0.00%	0.00%
2021	55.90%	2.90%	2.90%
2022	11.40%	0.00%	0.00%
2023	4.40%	1.50%	2.90%

Table 5.7: Average incidence of LBAM within affected blocks between 2019-23

	LBAM incidence		
year	old	fresh	larvae
2019	0.10%	0.00%	0.00%
2020	0.60%	0.00%	0.00%
2021	0.20%	0.10%	0.10%
2022	0.20%	0.00%	0.00%
2023	0.10%	0.10%	0.10%

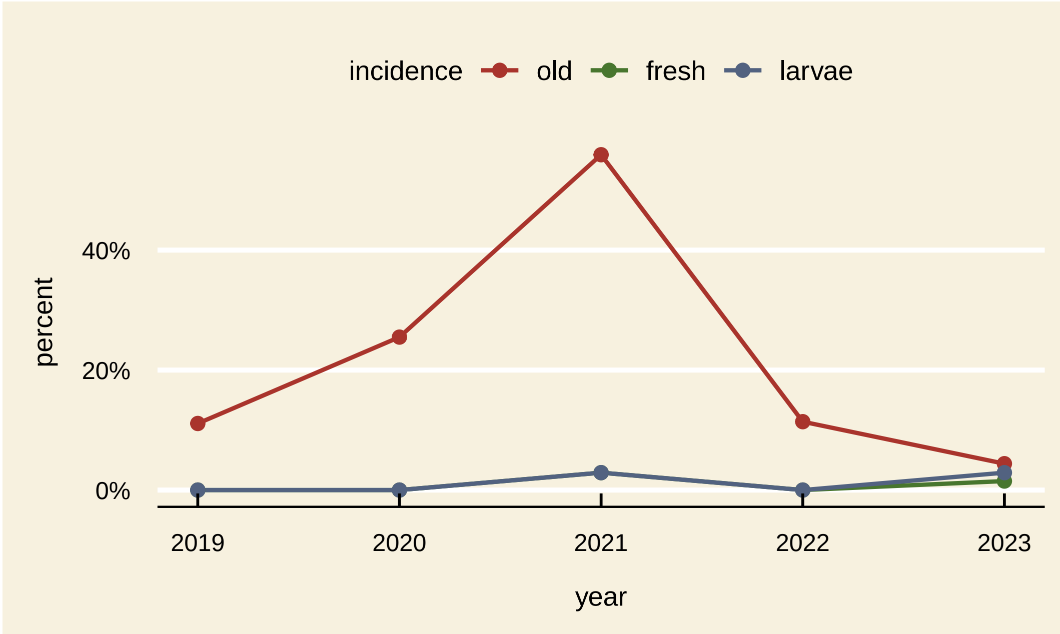


Figure 5.9: Average incidence of LBAM across all blocks between 2019-23

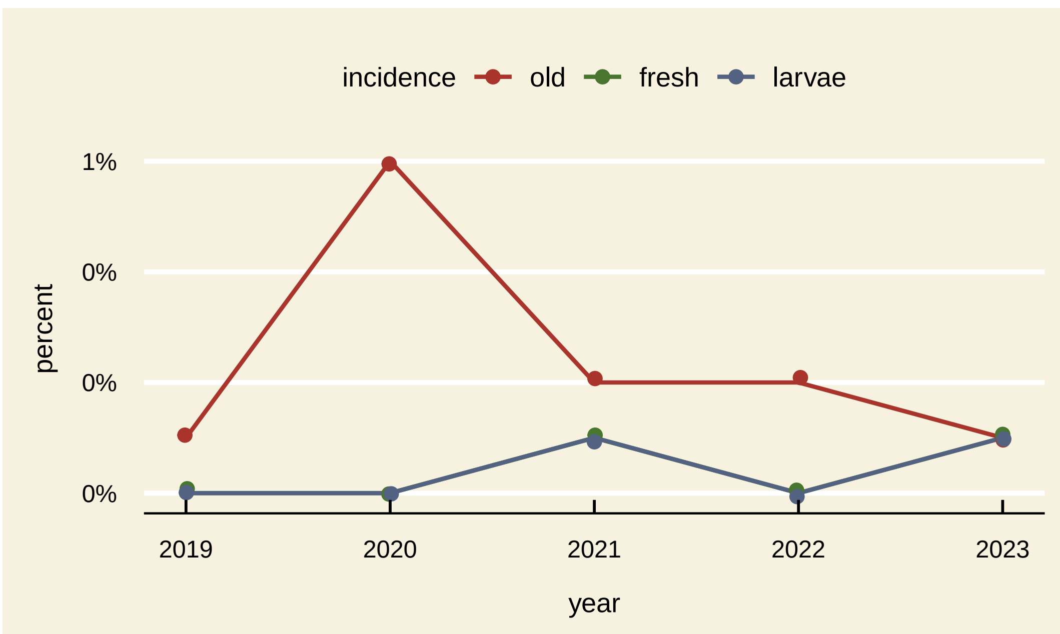


Figure 5.10: Average incidence of LBAM within affected blocks between 2019-23

5.6.1 By Sector 2022-23

Napier sector was the only sector that recorded all types of LBAM damage during harvest assessments, however, the combined percentage was still very low at 0.3% (Table 5.8).

Trapping data analysis placed Omahu sector at most pressure with the highest average moth catch per week (Table 5.8, Figure 5.11). Overall LBAM pressure on Rockit orchards was relatively low and mainly built up towards the end of the season with several blocks being the only management areas with actionable LBAM thresholds.

Table 5.8: Light brown apple moth percentage incidence detected at harvest 2023 by sector

	LBAM, incidence %		
sector	old	fresh	larvae
Havelock North	0.10%	0.00%	0.00%
Omahu	0.00%	0.00%	0.10%
Valley	0.00%	0.10%	0.00%
Napier	0.20%	0.00%	0.10%

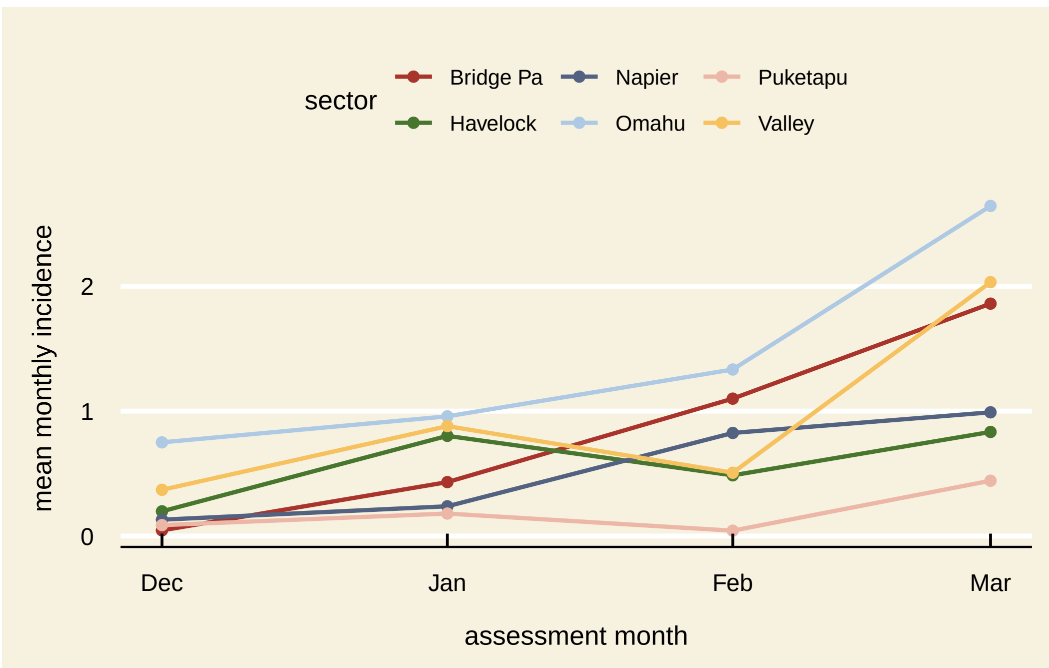


Figure 5.11: Average LBAM catch per trap/week in 2022-23

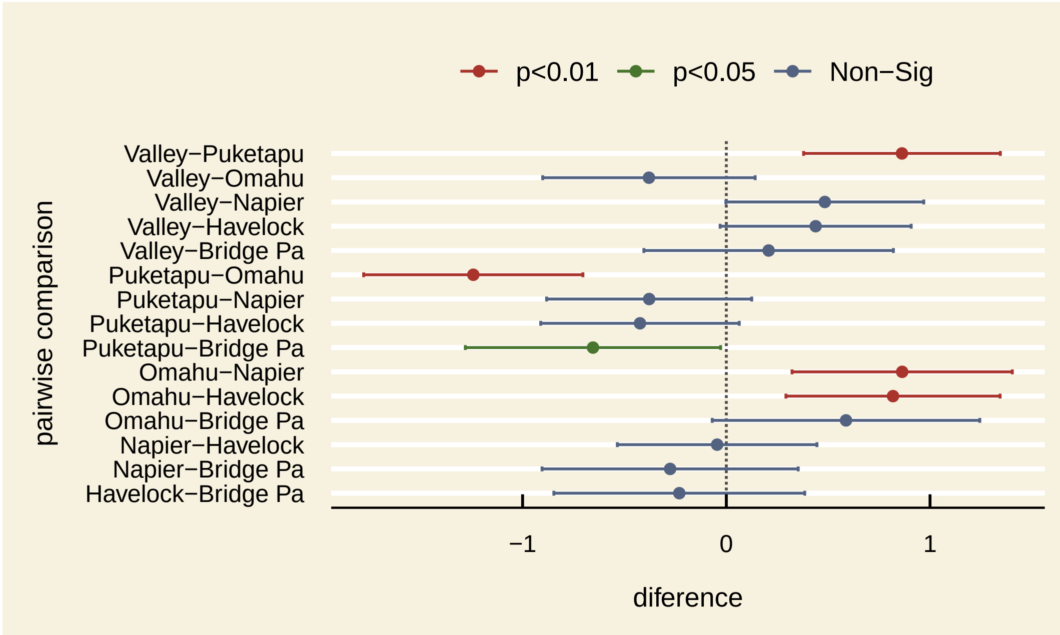


Figure 5.12: pairwise comparison of sectors using Tukey HSD post hoc test

5.6.2 Conclusion/recommendation

- Overall LBAM control in 2022-23 was similar to the previous season.
- Fresh damage and larval finds during harvest as well as an increase in moths catches towards the end of the season, once again confirms that LBAM are most active in autumn. A cover around mid-February on blocks with known LBAM pressure could be beneficial to keep moths' numbers and fresh damage minimal before harvest.

5.7 Apple leaf curling midge

Apple Leaf Curling Midge (ALCM) is quarantine pest for China, Japan with Maximum Pest Limit (MPL) 0.5%. Access to Taiwan relies on nil detected apple leaf curling midge.

ALCM is a difficult pest to control. Effective control can only be achieved when several strategies are used in combination with each other: on orchard monitoring for tree vigour and new shoots damage, Movento^{TM} applications and fruit assessments for ALCM pupae presence. Although, traditionally monitoring for ALCM is done in summer (post 3rd midge generation, G3), knowing ALCM presence on orchards from generations 1 (G1) and 2 (G2) can assist in control strategies with focus on G3 to minimise export risk.

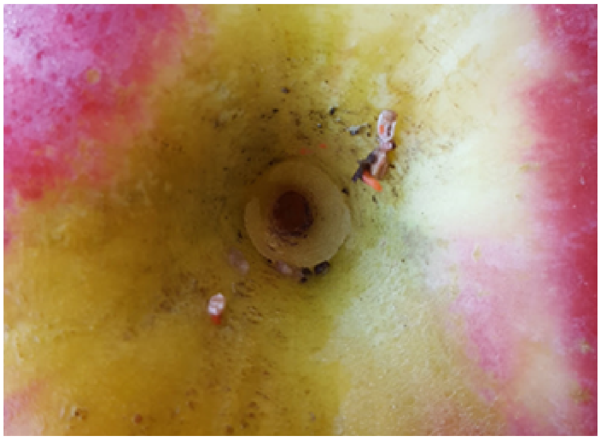


Figure 5.13: example of damage to fruit caused by apple leaf curling midge

On orchard monitoring post G2 and G3 returned the following average results shown in Table 5.9 :

Table 5.9: mean results for post G2 and G3 assessments for 2023 harvest season

		midge damage %		
generation	vigour[1,2]	old[1]	fresh[1]	overall risk
G2	62%	0.6%	0.7%	high
G3	45%	0.6%	2.8%	medium

[1] Average % is calculated across all assessed blocks, individual results vary;
[2] actively growing shoots %

Overall risk calculations are based on tree's active growth and new midge damage. Tree growth is obviously important in young orchards and a high risk ALCM rating has to be taken in context with canopy development objectives. Quite often a block falls into a high risk due to high vigour while midge infestation stays relatively low. These results are useful as a guidance in "on the ground" decision making and in planning for lower risk lines of fruit. However, they are not a complete and final ruling on export risk for ALCM sensitive markets, finds at harvest bin assessment are.

The following data analysis shows that despite a 22% increase in infected shoots post G3 (new, old or broken leaves), ALCM presence on orchards did not translate into an export risk during harvest as there was nil % of ALCM detection in bin assessments (Table 5.10, Figure 5.14).

Table 5.10: Average incidence of ALCM between 2019-23

	ALCM incidence %		
year	across all blocks	within affected block	summer infected shoots
2019	11.0%	0.1%	12.1%
2020	0.0%	0.0%	21.1%
2021	0.0%	0.0%	7.9%
2022	0.0%	0.0%	7.3%
2023	0.0%	0.0%	29.7%

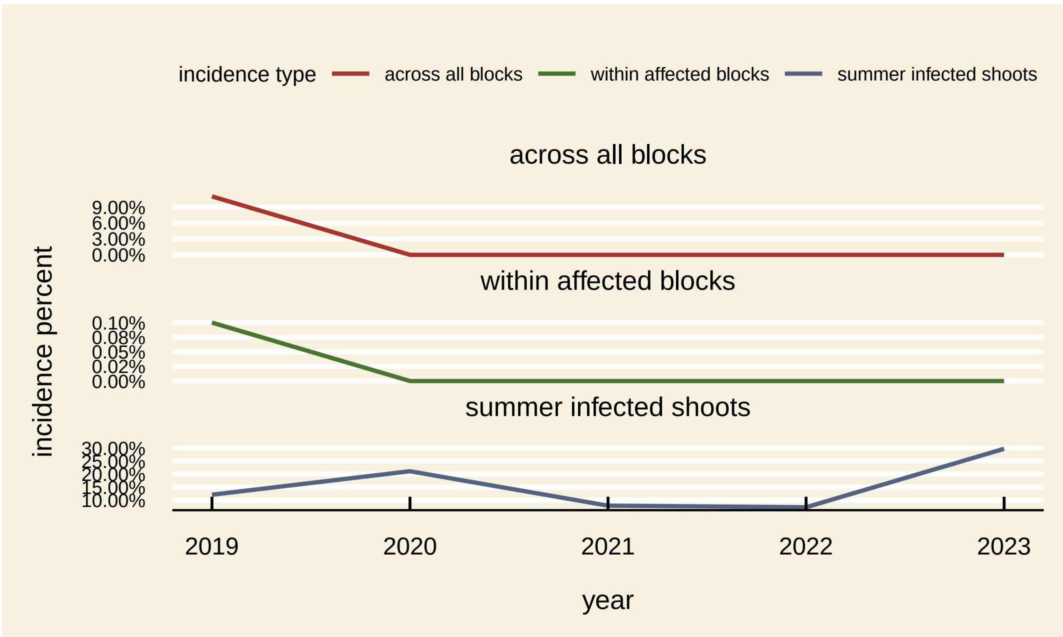


Figure 5.14: incidence of ALCM taken at harvest assessment from 2019 through 2023

5.7.1 By sector 2022-2023

Below charts show how number of damaged shoots increased across all sectors during post G3 assessments. Omahu sector recorded the highest percentage of damaged shoots (new infestation and old damage) both post G2 and G3, 18% and 36% respectively (Figure 5.15). It was also the only sector with midge infestation high enough to place some blocks into high-risk post G3 (Figure 5.16).

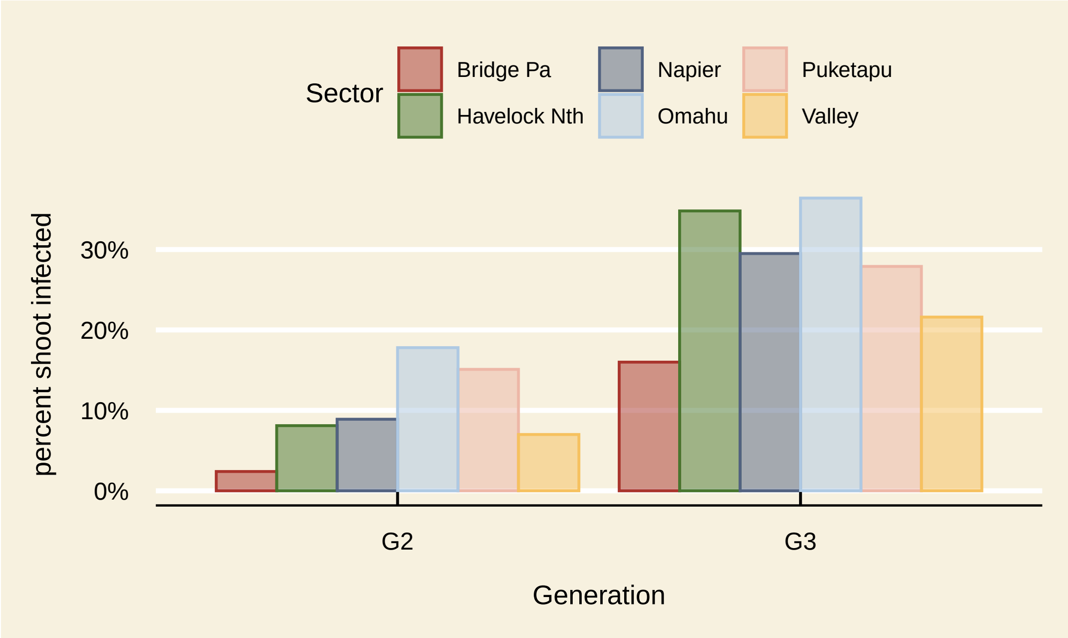


Figure 5.15: Damaged shoots post G2 and G3 by Sector for 2023 harvest

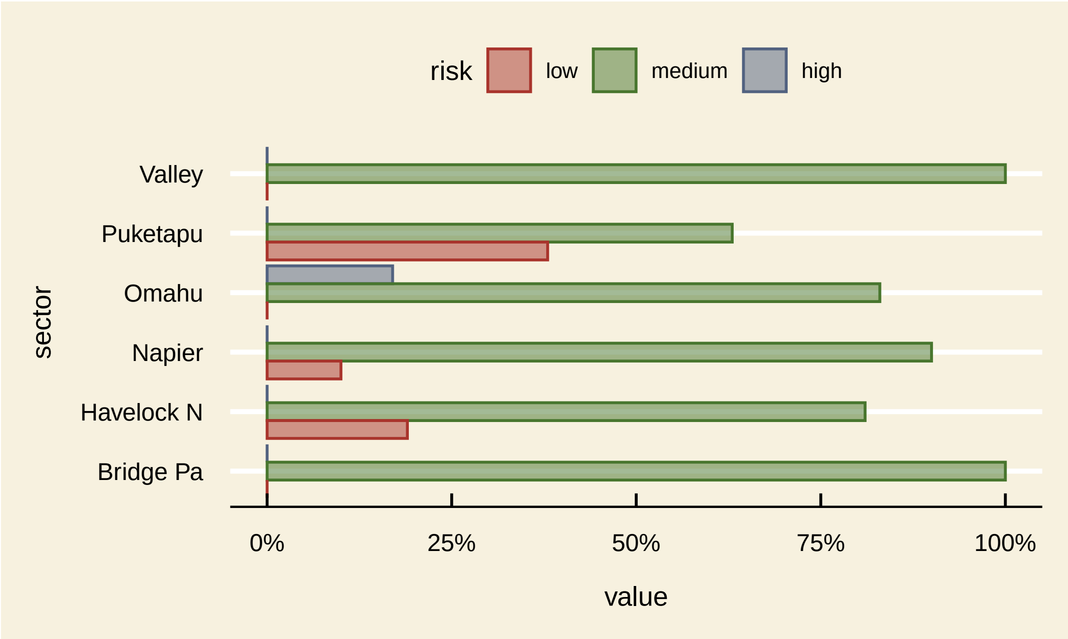


Figure 5.16: ALCM risk factor for 2023 summer shoots assessments

5.7.2 Conclusion / recommendations

- ALCM appears to be well controlled across the company with nil interception during harvest assessments in the last 4 consecutive years, all while continue expanding in producing hectares with many new plantings.
- ALCM is a hard pest to tackle, and there is not a silver bullet for its control. A combination of strategies including tree vigour control, on orchard monitoring, Movento^{TM} applications at right timing is recommended as the most efficient way for ALCM management.
- The NZAPI ALCM population regional graphs is the best available guide to go off for Movento^{TM} applications' timing for better ALCM control.

5.8 Wooly apple aphid

Woolly Apple Aphid (WAA) is quarantine pest for markets such as China and Taiwan with Maximum Pest Limit (MPL) 0.5%.

Figure 5.17: example of damage to fruit caused by wooly apple aphid

Successful control of WAA is achieved by maintaining high populations of its natural predator, parasitoid wasp Aphelinus mali (A.Mali). During both on orchard monitoring and harvest assessments we distinguish the two. We look for unparasitized WAA (WAA) and WAA parasitised with the wasp (A.Mali). If incidence of A.Mali prevails, this indicates effective bio-control. However, both types are recognised as quarantine pests.

For the first time in the last 5 years pre-harvest monitoring recorded WAA colonies on Rockit^{TM} apple orchards. Below is the list of blocks that were placed in either medium or high risk during on orchard assessments:

Table 5.11: medium and high risk blocks from the 2023 harvest season

		woolly apple aphid				
date	sector	% infested shoots	live	parasitised	% parasitised	risk
27-Feb-23	Puketapu	5%	13	8	38%	Medium
23-Jan-23	Bridge Pa	12%	27	2	7%	High
31-Jan-23	Havelock	10%	153	20	12%	High
20-Feb-23	Havelock	5%	69	23	25%	Medium
31-Jan-23	Havelock	3%	22	24	52%	Medium
31-Jan-23	Valley	20%	448	940	68%	Medium

Table 5.12: Definition of WAA risk parameters

	WAA risk			
key	low	medium	high	timing
% infested shoots	<2%	2-5%	>5%	mid-season & pre-harvest
% parasitism	>25% (effective control)		<25%	mid-season

More than 5% shoot infestation of WAA means that a block is higher risk for fruit infestation at harvest (live WAA or parasitised), and therefore, is a higher risk in export market. Pre-harvest assessments certainly were a good indicator of what to expect at harvest. Same orchards recorded parasitised WAA during harvest assessments. Overall, the incidence of unparasitised WAA both across all blocks and within affected blocks was non-existent this season, which suggests that the parasitoid wasp caught up with the WAA population towards the end of the season despite the cooler spring/summer. The incidence of A.Mali has dropped across all blocks by 28%, but increased by 0.1% within affected blocks (Table 5.13, Figure 5.18).

Table 5.13: Average incidence of WAA and A.Mali in Rockit harvest assessment between 2019-23

	across all blocks		within affected blocks	
year	WAA	A.Mali	WAA	A.Mali
2019	11.1%	27.8%	0.1%	0.1%
2020	2.1%	8.5%	0.1%	0.3%
2021	8.8%	20.6%	0.1%	0.1%
2022	4.5%	54.5%	0.1%	0.2%
2023	0.0%	26.0%	0.0%	0.3%

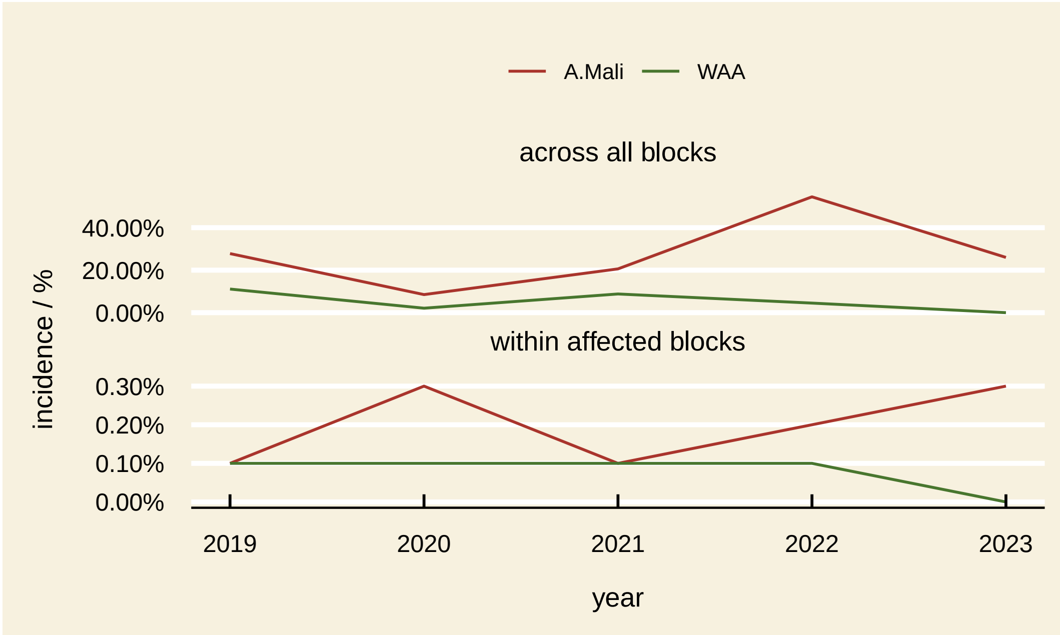


Figure 5.18: Average incidence of WAA and A.Mali in Rockit harvest assessment between 2019-23

5.8.1 By Sector 2022-23

Puketapu sector recorded the highest interception of parasitised WAA during harvest assessments at 2.1%, followed by Valley, Havelock Nth, Napier and Bridge PA. Omahu was the only sector that was completely clean of any type of WAA.

Table 5.14: A.Mali finds at harvest by Sector

sector	A.Mali incidence
Puketapu	2.1%
Valley	1.4%
Havelock Nth	0.7%
Napier	0.4%
Bridge Pa	0.3%

5.8.2 Conclusion/Recommendations

- A. Mali wasp is still the best (and free) control of WAA but emerges later than WAA crawlers and is also conditional on spring temperatures.

- Early seasons cover sprays are best as colonies are small and crawlers are more vulnerable, as well as a good way to protect the overwintering wasp.
- To archive "zero" fruit infestation, there needs to be close to zero shoot infestation from mid-January onwards.
- Continue with mid-season WAA and A.Mali population monitoring to assess the level of risk for market access at harvest. Pre-harvest monitoring for WAA infestation can either reassure or confirm the problem.
- To lower the risk of WAA, tree structure management is recommended, i.e. open canopy, removal of suckers, summer prune and thinned fruit bunches to singles or doubles.

5.9 Mealy bug

Mealy bug (MB) is quarantine pest for Taiwan, Thailand, Japan USA markets with Maximum Pest Limit (MPL) 0.5%, and Australia with 0% tolerance.

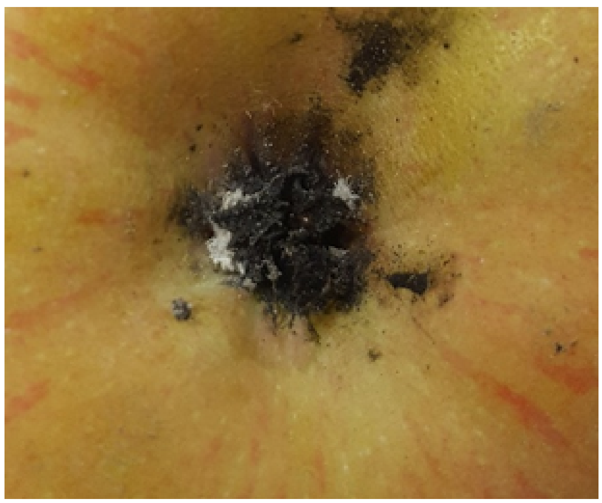


Figure 5.19: example of damage to fruit caused mealybug

Season 2022-23 continued a trend of increased percentage of blocks recording MB and the severity of the incidences during harvest assessment. There were 6% increase in incidence across all blocks compared to last season, and 0.1% increase in incidences within affected blocks (Table 5.15, Figure 5.20). Below data analysis does not include sooty mould, though it is indicative of internal MB.

Table 5.15: Average incidence of Mealy bug in Rockit harvest assessment between 2019-23

	mealy bug incidence	
year	across all blocks	within affected blocks
2019	38.9%	0.1%
2020	2.1%	0.1%
2021	2.9%	0.1%
2022	20.5%	0.1%
2023	26.0%	0.2%

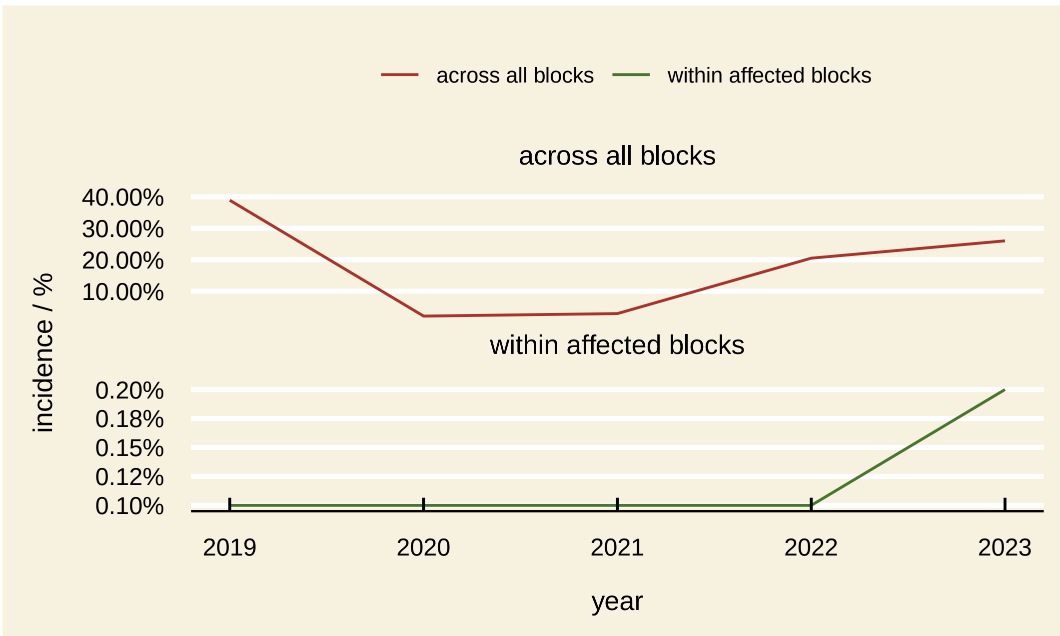


Figure 5.20: Average incidence of Mealy Bug in Rockit harvest assessment between 2019-23

5.9.1 By Sector 2022-23

Napier sector recorded the highest combined incidence of MB, 2.2% followed by Havelock Nth, 0.6%, Valley, 0.3% and Omahu at 0.1% (Table 5.16). Puketapu and Bridge Pa were two sectors with nil MB interceptions during harvest assessments.

Table 5.16: Mealy bug finds at harvest by Sector

sector	mealy bug incidence
Napier	2.2%
Havelock Nth	0.6%
Valley	0.3%
Omahu	0.1%

5.10 Scale

Scale monitoring is carried out in summer (early February) over 500 fruit per block. Pre-harvest on-fruit scale assessments on Rockit blocks did not record any pest's sighting this season. On fruit inspection can be difficult: fruit should be checked with paying special attention to the calyx at the same time as a great care is taken not to knock it off the branch.

Despite the clean pre-harvest results, the following blocks recorded non-zero levels of San Jose scale during harvest assessments:

Table 5.17: blocks (anonymised) with San Jose scale observations during the harvest assessment 2023

sector	San Jose scale
Valley	0.1%
Valley	0.1%
Havelock Nth	0.1%
Havelock Nth	0.1%
Havelock Nth	0.1%

Both Mealy bug and scales have the potential for rapid spread in the absence of appropriate control measures.

5.11 Mites

Mites' monitoring is recommended to carry out at least twice during a growing season: in late spring and late summer. At each assessment Fruition team checks 50 leaves per blocks for two pest mites: European red mite (ERM) and two-spotted spider mite, as well as any predator (beneficial) mites. Season 2022-23 saw quite a lot of ERM on Rockit orchards, however, only one block in the Puketapu sector reached a threshold set at 30%

during spring assessment, and a block in the Omahu sector was near a threshold set at 75% during summer assessment. Many predator mites were also observed, which speaks of a good bio-control on Rockit orchards.

5.12 Other pests

In recent years we have noticed a worrying trend of increased incidence of several 'non-critical pests' during harvest assessments: Bronze Beetle, Fuller's Rose Weevil and Noctuid moth. Even though these pests are considered 'non-critical', their damage on fruit still causes rejects on a packing line and are worth of keeping an eye on.

It is pleasing to see that these pests' numbers have declined in 2022-23 compared to last two season. However, incidence of Fullers' and Noctuid's presence on Rockit orchards has not yet reached lower levels observed in 2020.

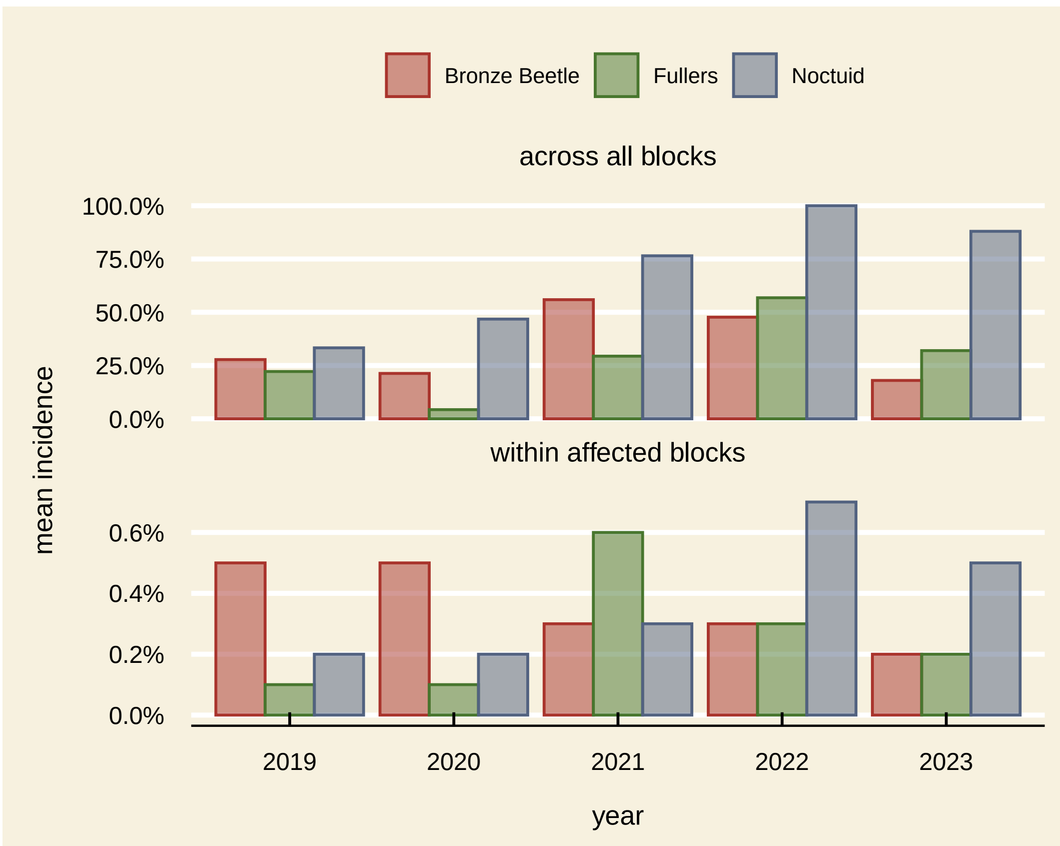


Figure 5.21: Average incidence of Bronze Beetle, Fuller's Rose Weevil and Noctuid moth in Rockit harvest assessment between 2019-23

5.13 Glossary

incidence a measure of presence or absence of a pest and disease

% Incidence % Incidence - the percentage of blocks having a known P&D in their bin assessments

P&D Pest and disease

P&D incidence within affected blocks a measure of how bad P&D presence was within affected blocks

average Incidence across all blocks a measure of how widespread P&D presence was across all assessed blocks

NZAPI New Zealand apple and pears institute

Movento Chemical solution for controlling a range of sucking pests including ALCM, WAA and scale.

6 yield and fruit size prediction

7 Maturity management

Authors: Stuart Dykes, Dharini Marinkovich and Tim Channing Pearce

7.1 Introduction

Traditionally, the maturity of apples have been measured using a suite of tests that measure the chemistry and physiology of the fruit. The principal measurements being starch pattern index (SPI), flesh firmness (FF) and total soluble solids (TSS) or brix (Lysiak, Grzegorz 2011; Skic et al. 2016).

Starch accumulates in the apple during the growing season and is enzymatically hydrolysed into sugar (predominantly glucose and fructose) in the later stages of development (Smith et al. 1979). The starch-to-sugar conversion is measured in the field by cutting the apple along its equator and applying potassium iodide solution to one of the cut faces. The solution complexes with the starch staining it dark blue. The mono- and di-saccharide sugars are left un-stained, hence the stained area is approximately proportional to proportion of starch remaining. As the starch conversion progresses, a smaller area of the cut surface is stained. An empirically derived index is applied to the SPI with the value zero being given to 100% staining (i.e. no conversion) through to seven given to a face where none of the area is stained.

Flesh firmness, or pressure, is traditionally measured using a device called a penetrometer. This plunges a rod of fixed diameter a pre-defined depth into the apple and measures the maximum compressive force required to drive the rod into the apple flesh. The force measurement (divided by the cross-sectional area of the rod tip) give the FF of the fruit generally in units of kgf (Harker, Maindonald, and Jackson 1996).

The TSS is defined as the concentration of sugars and other soluble minerals present in fruits. TSS is generally measured using a refractometer device which measures the refractive index of the juice of the apple. It is an important measure for fruit maturity however tends to be second order in terms of its importance in determining the harvest window. The rate of change of brix is generally slow and the effect is very linear and for PremA96 is not a good predictor of maturity.

For PremA96 maturity is currently determined using the criteria detailed in Table 7.1

Table 7.1: RSP classification for submission samples

RSP	SPI[1]	pressure kgf	soluble solids °brix	colour foreground	colour background
A	2.0-4.0	≥8.0	≥12.0°	≥ 50% red	light green/ white
B	2.0-5.0	≥7.5	≥12.0°	≥ 50% red	light green/ white
C	3.0-5.5	≥7.0	≥12.0°	≥ 50% red	white
D	>5.5	≥7.0	≥12.0°	≥ 50% red	white
I	<5.5	<7.0	≥12.0°	≥ 50% red	white
X	>5.5	<7.0	≥12.0°	≥ 50% red	white
N	<2.0	>15	<12.0°	<50% red	NA

[1] for China eligibility all submissions samples must have a non-zero reading

The submission profile classification for 2023 was considerably different from previous years and was designed to better reflect the maturity of PremA96. The most obvious changes is the name, going from the industry standard ENZA submission profile (ESP) to the more specific Rockit submission profile (RSP). The thresholds for the main maturity criteria remain unchanged (e.g. SPI, Firmness and TSS), however there are now seven classifications (A, B, C, D, I, X and N) instead of three (A, B, C). The C classification in the ESP system included fruit that was out of specification (i.e. SPI > 5.5 and/or firmness < 7.0). With the RSP classification, out-of-specification fruit are given the designation D, I and X which indicate respectively, out-of-specification SPI, firmness and both measurements simultaneously. Additionally and N classification (for "not ready") has been introduced for completeness. The RSP classification allow storage and packing decisions to be made more precisely than with the ESP classification.

7.2 Starch Pattern Index

The Starch pattern index directly measures the enzymatic hydrolysis of starch in the apple to simple sugars (glucose, fructose and sucrose). The rate or kinetics of this transformation can be understood using a logistic growth model characterised by a lag, growth and saturation phase (Peirs et al. 2002). This type of model is applied to many constrained biological systems and can be described mathematically using the same equation used to describe yield refer to Section 19.3.

An example of the SPI progression is given in Figure 7.1 for a Rockit™ apple production site in 2023. Overlaid is the modeled (continuous) SPI progression and the harvest window for this particular sample. The points represent SPI assessments from individual fruit and the vertical lines represent the dates when the block was harvested. The background plot colours represents the RSP classification (based on SPI). Figure 7.1 shows clearly the first pick on the 10th February was in the middle of the A and B RSP profile. The first pick was significant (69% of the total bins harvested for the block). The remaining harvest dates all occurred when the SPI was out of specification (31% of the total bins harvested). In mitigation it should be realised that the initial pick took place before Cyclone Gabrielle. Logistical difficulties meant that this particular orchard could not be accessed for picking until

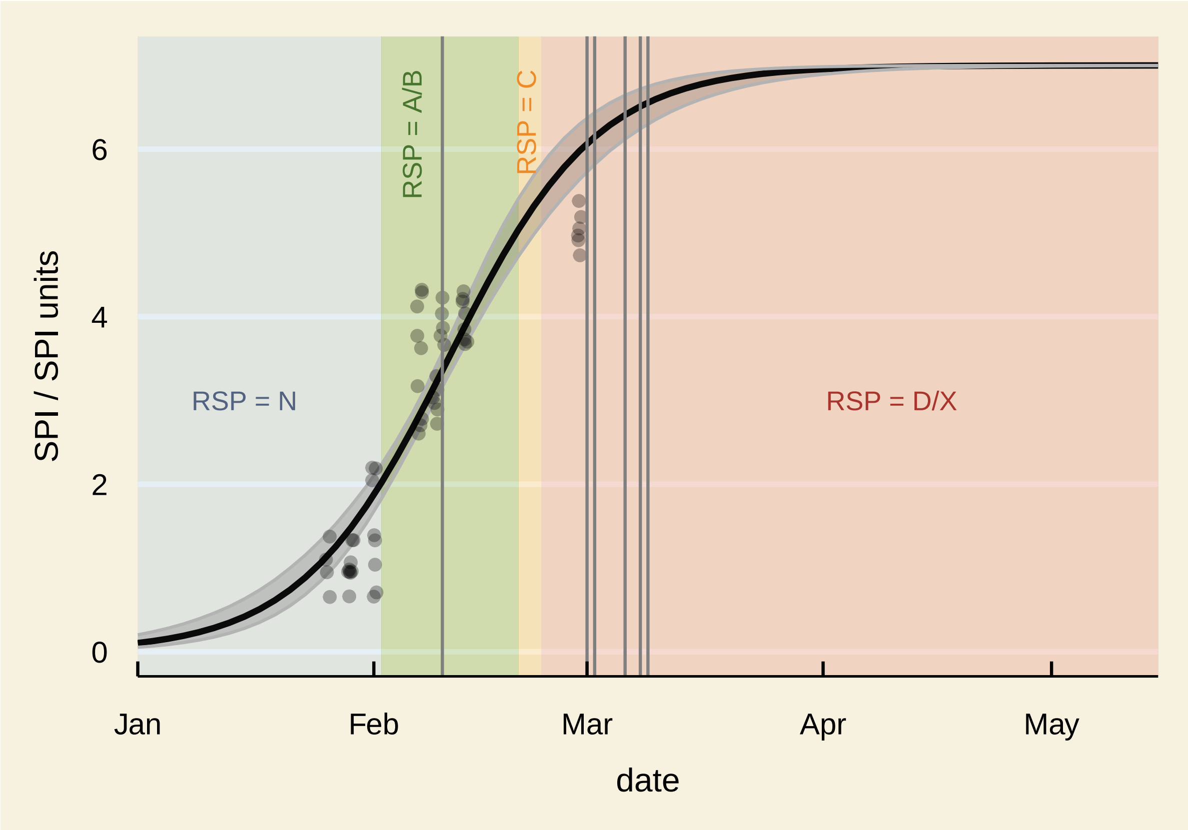


Figure 7.1: An example of the evolution of SPI for a single production site of PremA96 from the 2023 harvest season

7.3 Flesh Firmness

Flesh firmness (FF) or pressure as it is alternatively known, is measured at the same time as SPI measurements are taken. Two measurements are taken on the cheek of the apple, one sample diametrically opposed to the other. In preparation the skin is sliced leaving a flat surface approximately 25mm in diameter. The penetrometer measurement is taken by displacing the tip of the device into the centre of the flat section. The apple is rotated and the measurement repeated on the other side. Flesh firmness is defined as the maximum force required to traverse a rod a pre-determined distance into the apple. The probe moves the cortical cells either rupture or slip aside relative to each other (Mowatt 1997). As the fruit continues to senesce the inter-cellular bond strength decreases and the cell-walls become weaker, reducing the overall force requires to penetrate the flesh of the apple.

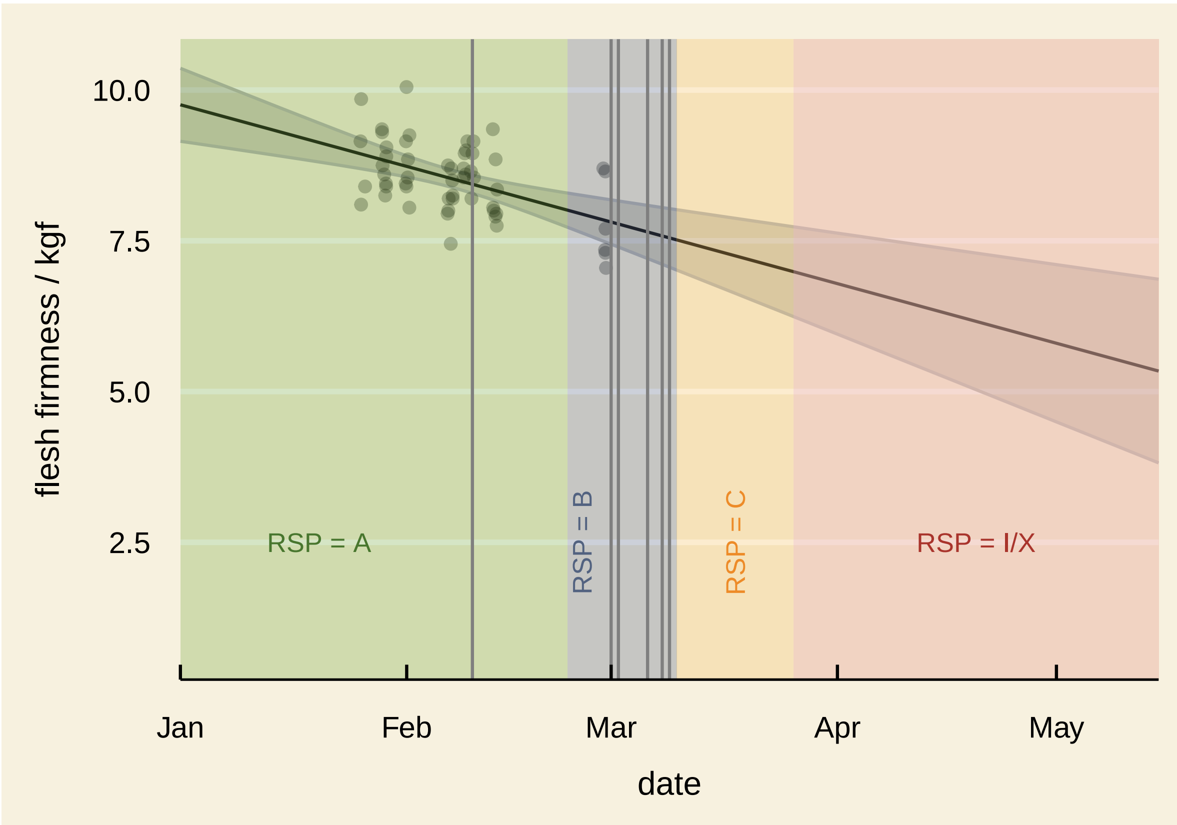


Figure 7.2: An example of the evolution of firmness for a single production site of PremA96 from the 2023 harvest season

Flesh firmness tends to reduce as a linear function of time (as compared to the non-linear behaviour of SPI). Figure 7.2 presents the same block as in Figure 7.1 plotting flesh firmness as a function of assessment date. Note that the predicted firmness does not intersect with the minimum threshold of 7.0 kgf until 2023-03-26. This is typical of most blocks and firmness is a second order predictor for maturity compared to SPI. While this is the case firmness remains an important measurement in fruit quality. As discussed in chapter 13 the relatively strong and stable inter-cellular bonding observed in PremA96 means that firmness does not deteriorate as rapidly as other apples (Segonne et al. 2014).

Comparing the RSP threshold dates for SPI and firmness shown in Figure 7.1 and Figure 7.2 the behaviour is typical of most production sites and for most seasons. Table 7.2 presents the dates and by every measure the RSP classification is driven by the changes in SPI which are more dynamic than firmness over the ripening period. The exception being for classification I and X which are driven by pressure and both pressure and SPI by definition.

Table 7.2: comparison of maturity drivers SPI and firmness using a PremA96 single block example from the 2023 growing season

	threshold date		
RSP	SPI upper	firmness lower	decsion driver
N	2023-02-02	NA	SPI
A	2023-02-20	2023-02-23	SPI
B	2023-02-20	2023-03-10	SPI
C	2023-02-23	2023-03-26	SPI
D	NA	2023-03-26	SPI
I	2023-02-23	NA	firmness
X	NA	NA	both

7.4 Total Soluable solids

For completeness the evolution of total soluble solids (TSS) is shown for the same block that was presented in Figure 7.1 and Figure 7.2 is shown in Figure 7.3. If the three charts are compared, there are fewer data points. This is because TSS is measured by taking the combined (blended) juice fraction from all of the 20 sample apples. While a linear model is applied the relationship between assessment day and TSS may not be linear.

7.5 Maturity performance

Maturity management performance can be measured a number of ways. One way is to plot each consignment by RSP classification and measure the proportion of each class. As a very broad measure, the bins (or consignments) that were harvested within specification as a proportion of the total bins (or consignments). This is visualised in Figure 7.4 and Figure 7.5

Table 7.3: comparison of fruit submission samples based on different RSP classifications for 2022 and 2023 growing seasons

	RSP classification						specification	
season	A	B	C	D	I	X	in	out
2022	8.1%	55.1%	20.8%	11.9%	2.1%	2.1%	84.0%	16.0%
2023	13.4%	52.4%	22.8%	9.0%	1.1%	1.3%	88.6%	11.4%

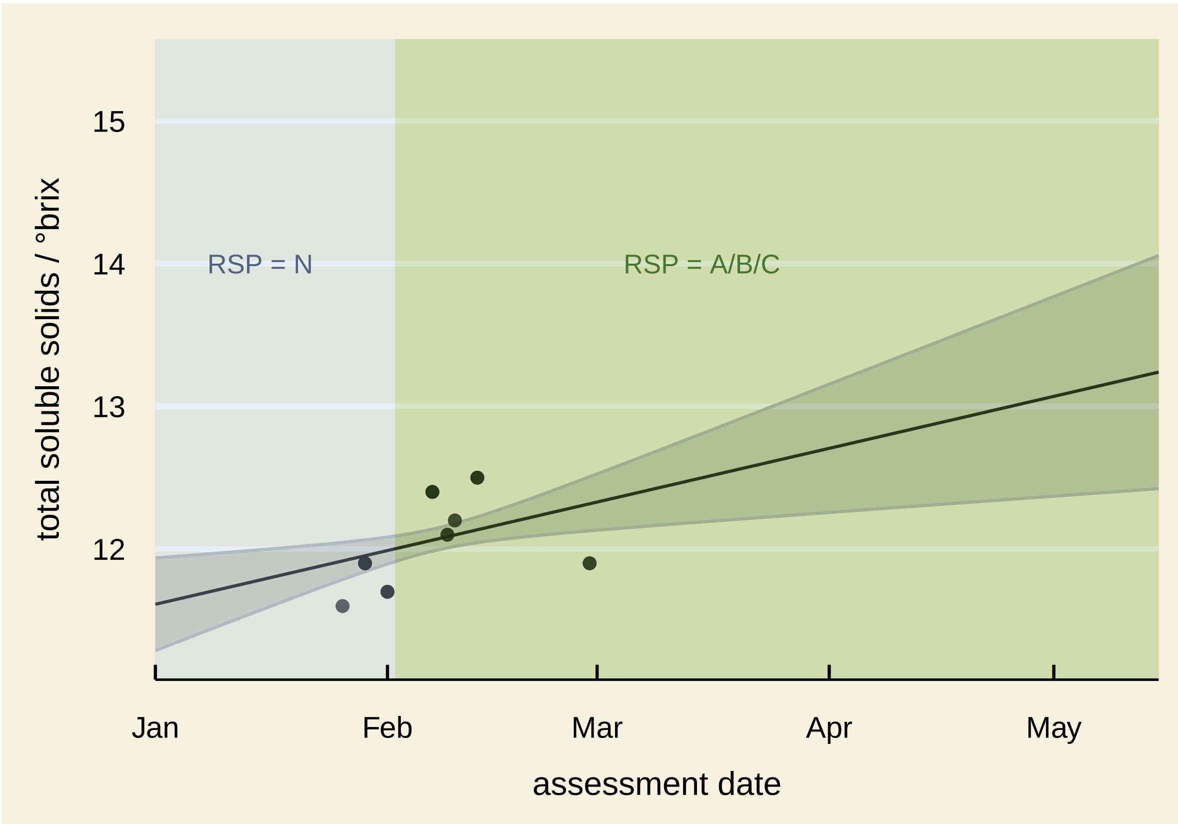


Figure 7.3: An example of the evolution of TSS for a single production site of PremA96 from the 2023 harvest season

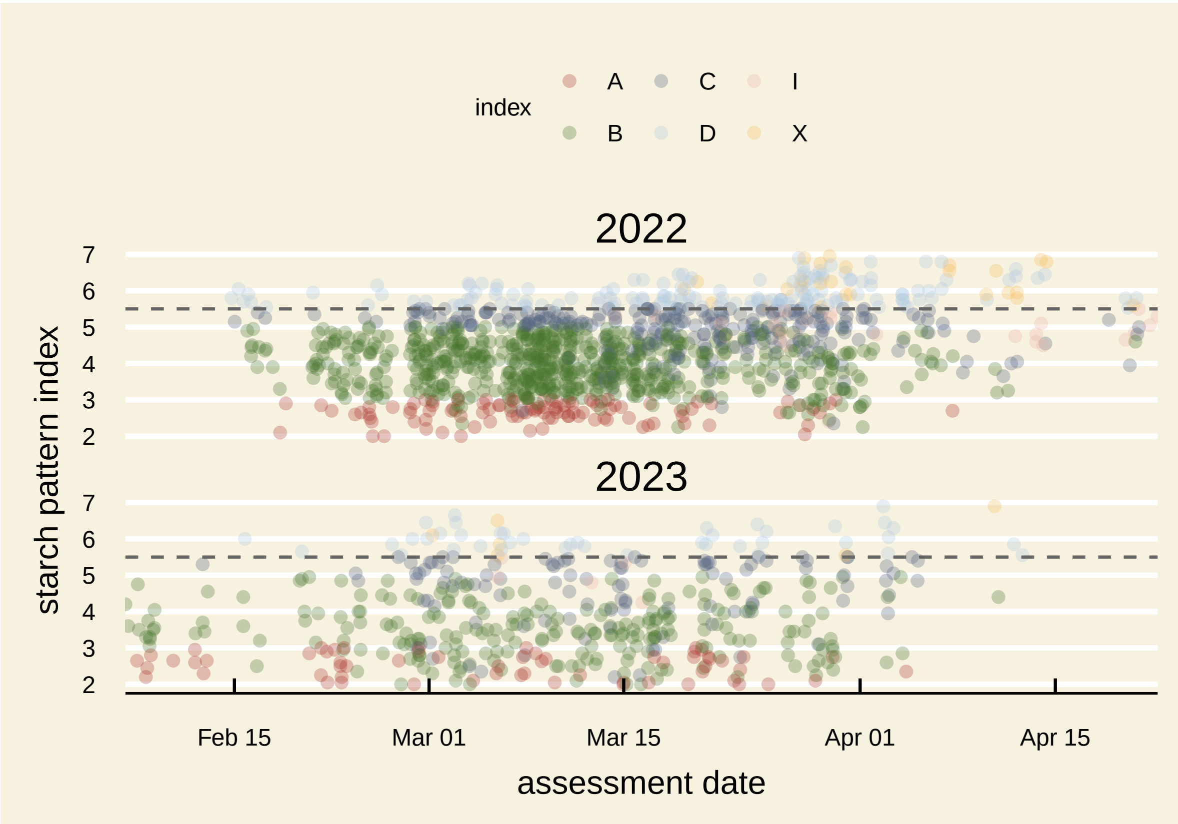


Figure 7.4: SPI measurements at bin submission as a function of assessment date. The RSP classifications are overlaid on the plot

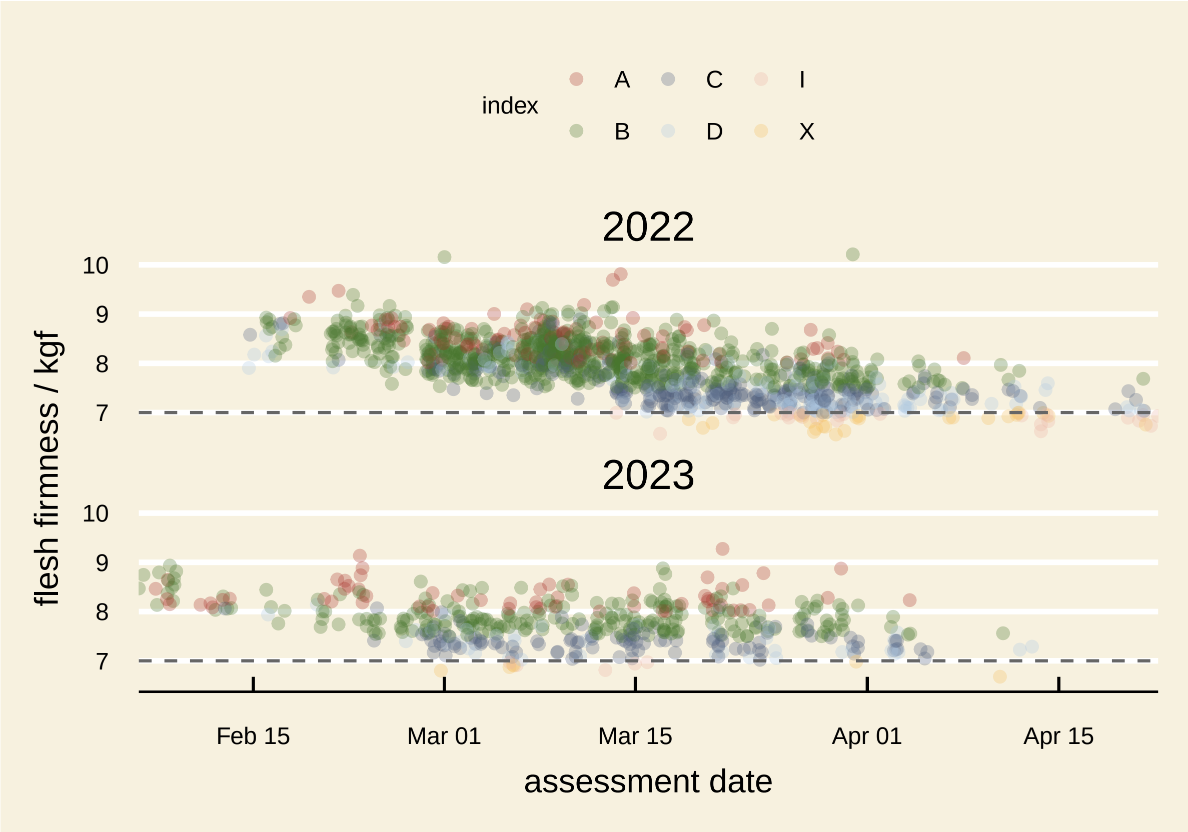


Figure 7.5: Firmness measurements at bin submission as a function of assessment date. The RSP classifications are overlaid on the plot

7.6 Application of growth regulators

One of the principal tools for managing harvest timing is the application of growth regulators to either delay or accelerate maturity. Three chemicals are currently widely used in the New Zealand pip fruit sector. Rockit^{TM} apple orchards typically utilise Ethrel^{TM} (as a maturity accelerator) and Harvista^{TM} (as a maturity retarder).

Ethrel^{TM} produces ethylene and acts to accelerate maturity by triggering the ethylene auto-catalysis (Busatto et al. 2017). Harvista^{TM} inhibits the effect of ethylene on the fruit by blocking the ethylene receptor sites on the surface of the apple.

Table 7.4 gives a summary of the extent of Harvista^{TM} and Ethrel^{TM} use on RMS blocks (independent grower information was not available). High rate Ethrel^{TM} treatment refers to two successive treatments of 500ml/ha which is the rate used to accelerate maturity. Low rate Ethrel^{TM} is defined as 200ml/ha and is primarily used for colour development, and does not appear to have any effect on rate of maturity. Table 7.5 shows the number of blocks with one, two or three applications of Harvista^{TM}. Repeated doses of Harvista^{TM} have acted to delay maturity, and therefore, allow labour to be spread further.

Because of the strategic importance of growth regulators for PermA96 harvest management, RGL commissioned Plant and Food Research to study the effect of both Ethrel^{TM} and Harvista^{TM} applications (including rate, timing and number of application) on the maturity of PremA96. While the Harvista^{TM} study was covered extensively in the 2022 Season Review (Dykes, Stuart 2023). The complete Ethrel^{TM} is presented in chapter 9.

Table 7.4: Extent of Harvista and Ethrel usage 2023 season

Treatment	Rate	No Of Blocks	Hectares sprayed
Ethrel	high rate	52	84.81
Ethrel	low rate	134	260.01
Harvista	various	57	95.65

Table 7.5: Blocks and hecatres by number of Harvista applications 2023 season

No of applications	blocks	hectares sprayed
1	33	54.65
2	22	40.37
4	1	0.38
6	1	0.26

Harvista^{TM} is a relatively new product and its effects on PremA96 are not understood in great detail. In 2022, RGL engaged with Plant and Food Research (PFR) to assist with a trial to measure the efficacy of multiple Harvista^{TM} applications. The trial involved measuring the internal ethylene levels at set times after the Harvista^{TM} applications. Three treatments were applied initially when the SPIs were 1.3, 1.8 and 3 for Omahu AB, Omahu F and TRS respectively. Figure @ref(fig:harvestTrial1) shows the rate of increase of internal ethylene for all four treatments. The Harvista^{TM} treatment show a very clear inhibition of ethylene production relative to the control. Successive applications of Harvista^{TM} also show a positive effect however the etheylene levels are not reduced, the rate of increase is merely slowed. By 21st April, the internal ethylene of all treatments are close to the control.

8 Harvest

Authors: Stuart Dykes

8.1 Introduction

Harvest commenced on 10th February 2023 and continued through to the 14th April spanning 63 days. A comparison of the of the 2022 and the 2023 season is given in Table 8.1. The major difference between the 2022 and 2023 season is the impact of cyclone Gabrielle which occurred over the 13 - 14th February 2023. Three days of apple picking were achieved before the cyclone struck and 414 bins were harvested. Harvesting resumed six days after the cyclone on 18th February. The gap can be seen clearly in Figure 8.1.

One (albeit crude) measure of harvest performance is the rate the fruit is harvested from the orchard. The curve follows a logistic shape where rate of bins delivered to the cool store begins slowly, accelerates and then declines when most of the fruit has been picked.

The harvest rate curves for the Rockit™ apple pool for 2019 through 2023 are shown in Figure 8.2. This shows clearly that the harvest performance in 2023 was better than previous years in terms of rate of fruit picked and consistency over the harvest period

Table 8.1: Summary statistics for 2022 and 2023 harvest timing

	harvest date			bins			
season	start	finish	length[1]	total	peak daily	days to peak	days with > 1,000
2019	2019-02-26	2019-04-18	51 days	11,866	751	14	0
2020	2020-02-24	2020-04-17	53 days	16,648	845	24	0
2021	2021-02-17	2021-04-14	56 days	21,932	926	13	0
2022	2022-02-15	2022-04-22	66 days	24,507	1,049	22	2
2023	2023-02-10	2023-04-14	63 days	28,734	1,118	27	4

[1] This also includes the six day gap in harvest cause by cyclone Gabrielle in 2023

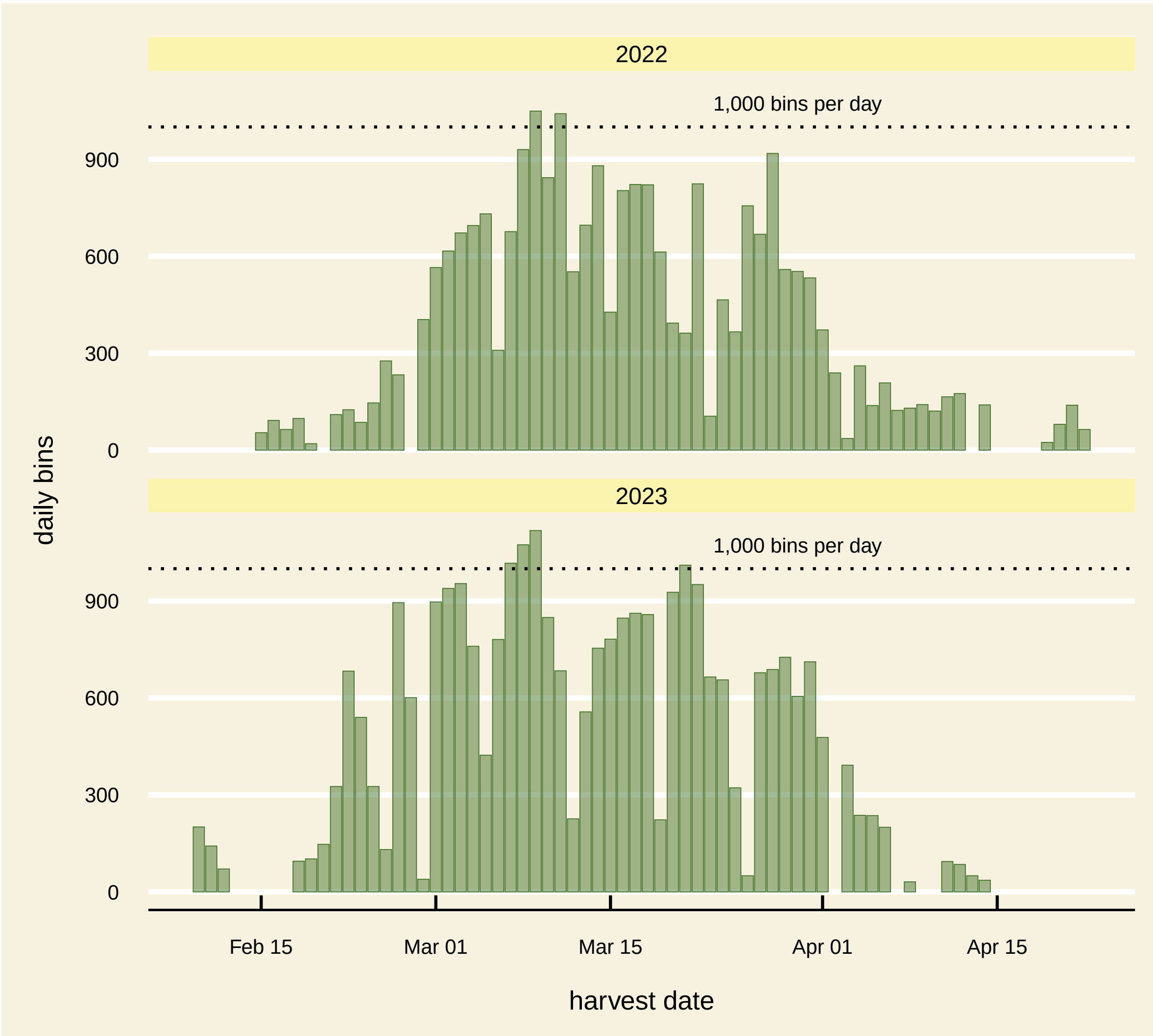


Figure 8.1: histogram of daily bins through the 2022 and 2023 harvest

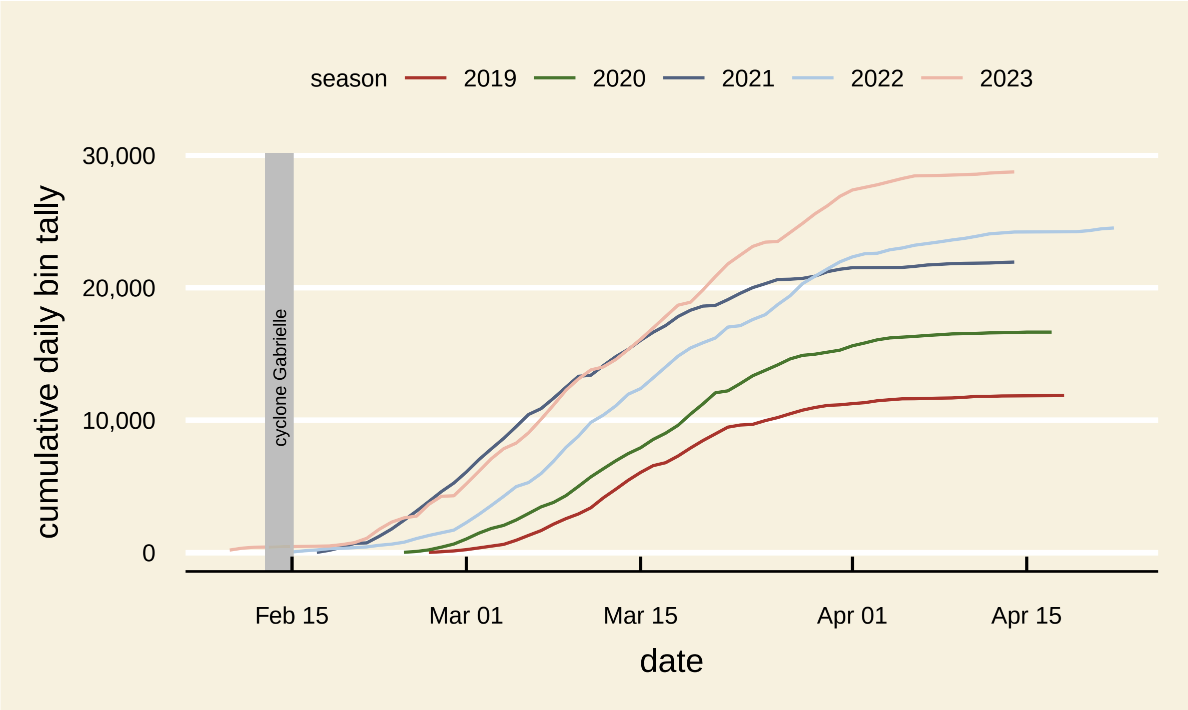


Figure 8.2: Comparison of cumulative daily bins since 2019

8.2 Number of picks

Historically, Rockit™ apple orchards have been harvested multiple times during a season and multiple picks of an orchard is a relatively common practice, particularly with the 3D spindle growing system due to maturity differences within the tree. Reducing orchard picks A secondary reason was to allow the future estimation of pick numbers and to allow the optimisation of orchard picks to maximise productivity and quality.

Table Table 8.2 shows the number of blocks harvested in one, two or three picks. The same table also lists the bins harvested for each pick, depending on how many picks were required for the given block. Only 50 (of 313) blocks were harvested once. This is likely due to orchard age and the small crop load. 123 and 140 blocks were harvested two and three (or more) times respectively. In terms of the number of bins per pick, these are given in absolute and relative terms in table Table 8.3.

INSIGHT:

44% of orchard blocks are harvested more than three times (24% in terms of bins harvested on the third or greater pick). Only 16% of blocks are harvested in only one pick (3% in terms of bins). This is only marginally better than 2022 and needs to be a focus to lift harvest productivity in 2024.

Each time a block is picked, resources (labour, platforms, trucking) need to be deployed to take in the crop. An obvious way of improving productivity is to minimise the number of times a block is harvested. The focus in 2024 is to identify three-pick blocks that could be reduced to two-pick blocks by removing more fruit in the first pick. As the proportion of trees shifts from 3D to 2D canopy the within-tree maturity variance should reduce allowing a reduced number of picks. 2D growing systems make up 43.2% of planted canopy area (refer to **?@sec-yieldPerf** for further discussion on the mix of growing systems).

Table 8.2: Summary of blocks by number of picks, 2023 Harvest

		No. of bins in each pick		
No. of picks[1]	No. of blocks	1st Pick	2nd Pick	3rd Pick
1	50	3,958	0	0
2	123	10,233	5,304	0
3	140	15,306	11,587	6,853

[1] 3rd pick actually denotes 3 picks or greater. This will be changed in 2024

Table 8.3: Summary of bins by pick number, 2022 and 2023 Harvest

	1st Pick		2nd Pick		3rd Pick[1]		
season	bins	% total bins	bins	% total bins	bins	% total bins	total bins
2022	13,057	53.3%	8,164	33.3%	3,286	13.4%	24,507
2023	16,440	57.2%	8,727	30.4%	3,567	12.4%	28,734

[1] 3rd pick actually denotes 3 picks or greater. This will be changed in 2024

8.3 Labour and orchard productivity

Check with Chris when he gets back from leave on the labour data

8.4 Conclusion

Despite the challenges of Cyclone Gabrielle, at the start of the harvest period, performance was considerably better than 2022 on a number of metrics. In 2023, a total 28,734 bins were picked over 63 days giving an average bins per day of 456, despite a six day delay due to the cyclone. This contrasts with a mean daily bins of just 371 in 2022. The improvement in the harvest productivity can be largely attributed to:

- Better maturity management and timely communication to growers
- For RMS, more centralised decision making around the allocation of resources
- Better use of ethylene regulating sprays (Harvista™ and Ethrel™)
- More focused use of platforms and bins trailers, improving harvest productivity
- Less labour pressure due to availability of contract seasonal labour

8.5 Recommendations

Tow factors: centralised decision making and maturity management, arguably, contributed most significantly to the improved harvest performance (relative to 2022), i.e. resources were allocated to the most appropriate blocks ensuring the fruit was harvested at optimum maturity profile. This approach is being repeated in 2024 with several refinements, namely:

- Improved maturity progression sampling
- Modeling of maturity to better predict the optimum harvest window
- Better planning and allocation of resources with the RMS managed blocks
- Improved, daily communication with growers both RMS and independent

Chapter 7 cover maturity management in some detail, in terms of insights from 2023, lessons learned and recommendations. 2024 brings the prospect of more than 60,000 bins. This represents a bin increase of more than 110%. This represents a significant challenge in getting the fruit picked with optimal maturity as well as storage and packing capacity.

8.6 Glossary

9 Ethephon spray applications on PremA96 apples 2023

Authors: Niemann N1, Marinkovich D2, Julian A1, Palmer G1, Mair S1, Johnston J1

9.1 Summary

Remarkable growth in Malus domestica 'PremA96' plantings in New Zealand is leading to logistics pressures at storage facilities and the packhouse. Multiple actions can be brought into practice to streamline and ease these pressures, including using growth regulators such as the ethylene-producing compound ethephon (which triggers maturation, ripening and senescence in fruit) and the compound that inhibits ethylene's action, 1-methylcyclopropene (1-MCP). Both these compounds can be applied in the orchard as spray treatments, and both have physiological effects on the fruit that may continue into storage. Ethephon spray treatments (Ethin™, containing 480 g/L chlorethephon) may bring the start of harvesting forward by a few weeks, while the research last year on the spray application of 1-MCP-containing Harvista™ 1.3 SC proved it could delay the end of the harvest period by up to 4 weeks.

Ethephon treatments at two doses (applied at 200 and 500 mL/ha) were applied two or three times in test blocks on 'PremA96' trees in January 2023. Fruit maturity was tracked on a weekly basis to determine optimum harvest windows and to follow how fruit quality changed. One 200 mL/ha block furthermore received two Harvista spray treatments to determine how 1-MCP treatment can influence Ethephon treatment. Apples were harvested weekly from 11 January to 4 April 2023 and placed in regular air (RA) or controlled atmosphere (CA) storage after a SmartFresh™ treatment for 3 and 6 months to determine how these growth regulators affect storage performance of the apples.

The key findings of this trial were:

- Ethephon treatment brought the recommended harvest date forward from 21 February to as early as 30 January, depending on application number and dose. The harvest window (when average starch pattern index (SPI) was 3–4) was longer for Ethephon-treated fruit compared with unsprayed fruit. The timing of application may be more important than the number of spray applications, since little difference could be measured between blocks that received two and three applications.

- The lower, label-recommended dose of 200 g/ha Ethin moved the recommended start date of harvest forward by only a week relative to untreated controls, and there was considerable overlap with the time when unsprayed fruit could be picked. It is unclear whether this dose can have a stronger effect if applied earlier.
- Following Ethephon treatments with Harvista sprays can slow ripening down again, therefore fruit could be picked from the same time and up to 2 weeks later than the control fruit (21 February to 14 March). These fruit stored better than just Ethephon-treated fruit.
- Ethephon treatments resulted in fruit with different traits than unsprayed fruit when their SPI was 3–4. Fruit firmness was higher than control fruit during their recommended harvest times. Dry matter content was lower in Ethephon-treated fruit, but soluble solids concentration (SSC) was similar. The implication is that earlier harvests deprive fruit of the opportunity to accumulate structural carbon, although SSC is similar between control and Ethephon-treated fruit.
- Fruit permeance decreased as the fruit matured. Picking any fruit earlier (Ethephon-treated at correct maturity, or immature unsprayed fruit) increase the risk of shrivel symptom development in storage.
- Storage tests revealed that Ethephon does have a negative effect on the times fruit can be stored. The most important quality parameter affected was shrivel symptom development. Up to 30% more Ethephon-treated fruit would develop shrivel compared with unsprayed fruit in the same storage environment.
- Internal ethylene concentration (IEC) and SPI changes correlated with each other, proving that SPI alone can be used to judge when fruit are ready for picking.

9.2 Introduction

Ethephon (2-chloroethylphosphonic acid) is one of the most commonly used plant growth regulators that can promote pre- and postharvest ripening. After being absorbed by the plant, the molecule is metabolised and ethylene is released. In addition to ripening, ethylene can induce abscission, flower induction and leaf senescence (Wang and Dilley 2001). In order to limit these effects, Ethephon is often applied in conjunction with the synthetic auxin plant hormone naphthalene acetic acid (NAA). NAA is known to prevent premature fruit dropping by inhibiting abscission. It can help to limit leaf drop as ethylene concentrations increase in and around the trees after Ethephon application, but likewise accelerates ripening in apples (Ozturk et al. 2019). Additionally, it may exacerbate russet in susceptible apple cultivars (Jones et al. 1991).

The benefits of exposing apples (Malus domestica) to ethylene during the later stages of their development include improved colour development and being ready for harvest earlier. This could help to ease picking pressures during the harvest window. But once ripening has sped up, senescence will follow. The implications of this include the fact that the apples may not be stored as long as otherwise could be expected, with storage and aging disorders more likely to develop. 1-Methylcyclopropene (1-MCP) technologies such as SmartFresh™ and Harvista™ could help to slow senescence again, but since the processes have already started in the orchard, these mitigations will have limited effects (Mair, S. and Niemann, N. 2021).

The aim of this project was to track fruit ripening in the orchard for a period after Ethephon spray applications, and to determine how well the fruit stored after the various treatments. Multiple application regimes were tracked, with two dosage concentrations applied to different blocks in the same orchard. In addition, one block received a Harvista spray treatment after conventional Ethephon treatment to investigate how 1-MCP can block the cascade of effects that Ethephon may have on 'PremA96' apples.

9.3 Materials & methods

9.3.1 Spray application

A Rockit™ apple orchard was selected for this trial, with several blocks receiving different spray treatments to address the questions in this trial. The spray treatments and dates are recorded in Table 1. All blocks received Erger (Valagro®) treatment to stimulate bud break in August 2022, but different doses were applied to some blocks since the experimental plans for this trial were not in place yet.

The block reserved for control fruit sampling was accidentally picked by orchard staff towards the end of January, necessitating the use of a second block (designated new control) to sample fruit for the remainder of the trial.

Table 9.1: Details about the spray treatments of 'PremA96' blocks in an orchard in Hawke's Bay before harvest in 2023. Trees in a block received one of the following spray strategies: two applications of 200 mL/ha Ethin™ with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista™ 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples for comparisons

block	date	days after first Ethephon spray	spray details
E500 × 3 E500 × 2 E200 × 2 Control	8th August 2022	NA	5 L/100 L Erger (Valagro)
New Control E200 + Harvista	21st August 2022	NA	2.5 L/100 L Erger (Valagro)
E500 × 3	11th January 2023	-1	500 mL Ethin/ha, NAA 100 (10%), Spray Aid
E500 × 3 E500 × 2	21st January 2023	9	500 mL Ethin/ha, NAA 100 (10%), Spray Aid
E200 × 2 E200 + Harvista	27th January 2023	15	Captan 80 WG, 200 mL Ethin/ha, NAA 100 (10%), Spray Aid
E200 + Harvista	2nd february 2023	21	200 mL Ethin/ha, Regulaid, NAA 100 (10%), Spray Aid
E500 × 3	2nd February 2023	21	500 mL Ethin/ha, NAA 100 (10%), Spray Aid
E500 × 2	9th February 2023	28	Captan 80 WG, 200 mL Ethin/ha, NAA 100 (10%), Spray Aid
E200 + Harvista	10th February 2023	29	Harvista (150 g/ha)
E200 + Harvista	22nd February 2023	41	Harvista (150 g/ha)

9.3.2 Fruit ripening assessments after spray treatments

Every effort was made to pick 20 fruit from each test block once a week from 11 January to 4 April 2023. One assessment was missed on 15 February 2023, after Cyclone Gabrielle hit the region.

To evaluate fruit ripening and how Ethin™ and Harvista treatments could affect it, we concentrated on starch breakdown trends and tracked how internal ethylene was produced. Starch pattern index (SPI) is a quick and easily performed assessment method that can be completed by growers in the field, and immediate decisions can be made based on the results.

- SPI — Apples were assessed at time of harvest by staining a cut half of each apple

with iodine solution and recording the amount of staining according to the ENZA SPI chart for apples, a 0–7 scale where 0 = fully stained and 7 = no staining.
- Internal ethylene concentration (IEC) — Assessments were conducted 1 and 14 days after harvest on fruit held at 20°C. IEC was measured by extracting a 1-mL gas sample from the core of an apple and injecting it into an Agilent 6890N gas chromatograph equipped with an activated alumina grade F–1 80/100 column at 130°C. Nitrogen was the carrier gas (flow rate of 35 mL/min), with hydrogen (35 mL/min) and air (350 mL/min) as makeup gas. Ethylene was detected with a flame ionising detector at 150°C. Ethylene was calibrated using a gas standard.

9.3.3 Fruit permeance after spray treatments

Permeance was assessed for apples picked weekly after the spray applications by Rockit packhouse staff.

Because of its small size, 'PremA96' has a high surface area to volume ratio and therefore is susceptible to shrivel via water loss from the fruit. Water vapour permeance is a measurement used to determine the ease with which water vapour can depart the fruit via the apple skin barrier.

In a constant environment, the effective permeance of the fruit surface to water vapour under prevailing conditions can be calculated from the rate of water loss ($r^{'}_{H_2O}$ in $nmols^{-1}$), provided Δp_{H_2O} (the difference in partial pressure of water vapour between the environment and inside the fruit in Pa) and A (the surface area of the fruit in m^2) are known, using the steady state solution of Fick's first law of diffusion (Equation 9.1):

$$r^{'}_{H_2O} = \Delta p_{H_2O} A P^{'}_{H_2O} \tag{9.1}$$

Where:
$r^{'}_{H_2O} =$ rate of water loss from the apple in ($nmols^{-1}$)
$\Delta p_{H_2O} =$ difference in partial pressure of the water vapour between the environment and inside the fruit (Pa)
$A =$ surface area of the fruit (m^2)
$P^{'}_{H_2O} =$ the effective permeance of the fruit surface to movement of water vapour under prevailing conditions ($nmols^{-1}m^{-2}Pa^{-1}$)

Weekly samples of 20 fruit were taken from the same trial areas as the fruit for the SPI and IEC tests.

Each weekly sample of fruit was stored in a coolstore overnight. The following morning the fruit were acclimated by placing them in the water vapour permeance 'stack' in the Rockit lab and running the fan at the top and bottom of the stack for 1.5 h (Figure 1).

This removed any condensation from the apples' surfaces. The lab was kept at 19.5°C throughout the experiment with the room fan speed on high.

The apples were then weighed with a microscale (Wedderburn microscale AB623RCE serial 190016676) and placed back on the trays in the 'stack'.

The fans were turned back on for 3 h and a dehumidifier was run on a dry setting during this time. A TinyTag datalogger was started at the beginning of the 3 h to record temperature, dew point and humidity.

The apples were reweighed with the microscale at the end of the 3 h and the weight loss was calculated. Permeance (nmol/s/m2/Pa) was calculated using the following formula:

$$permeance = \frac{m}{18At\Delta_p H_2O * 10^{11}} \tag{9.2}$$

Where: m = mass loss (kg) A = surface area of the fruit (m^2) t = experimental time (s)

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The experimental setup at the Rockit packhouse to determine permeance in 'PremA96' apples

9.3.4 2.4 Fruit quality at-harvest and after storage

Apples from each test block were stored by Rockit Global for up to 6 months after harvest and assessed for fruit firmness, soluble solids concentration (SSC), weight loss and shrivel symptom development by Rockit packhouse staff.

- Fruit Firmness — A thin slice (1 mm) of peel on opposite sides of each fruit was removed and the firmness of each side was measured using a fruit texture analyser (FTA, model GS, Güss Manufacturing Ltd, South Africa) fitted with an 11.1-mm diameter probe. The probe was driven into the flesh at 10 mm/s to a depth of 8.9 mm, and the maximum force recorded as the firmness value. Data were calculated as the average of the two measurements from each fruit sample and expressed in kilograms force (kgf).
- SSC — Juice was squeezed by hand from each firmness puncture hole to extract juice from each apple. A droplet of juice from each puncture hole was placed in the well of a temperature compensated digital refractometer (HI96802 Digital Fructose Refractometer, Hannah Instruments, USA) for measurement.
- Weight loss – Fruit was weighed on the day of removal from storage and again after the shelf-life period. Percentage weight loss was calculated.
- Storage defects – Each fruit was checked on the day of removal from storage and again after the shelf-life period for defects and shrivel symptoms.

9.4 Results

9.4.1 Weather during the trial

The La Nina weather during the summer of 2022–23 resulted in higher rainfall during January and February 2023 than normal (Figure 9.1). Usually the average rainfall for these 2 months is 50–60 mm. In 1 day (14 February) 139 mm of rain fell, totalling almost 180 mm over 4 days. Other noteworthy rain events happened on 7–11 January (92 mm), 27–28 January (92 mm) and 22–28 February (120 mm). The total rainfall for January and February this year was 502 mm, five times as much as the average. The rain was accompanied by overcast days, resulting in decreased irradiance on leaves. This could affect photosynthesis, placing even more strain on trees to produce the carbohydrates that needed to be transported to the fruit. The temperatures this season were slightly cooler when compared with other years, average maximum temperatures usually vary from 24 to 22°C and minimum from 15 to 13.5°C. This year the average maximum hovered just above 20°C while the minimum varied from 15 to 10°C.

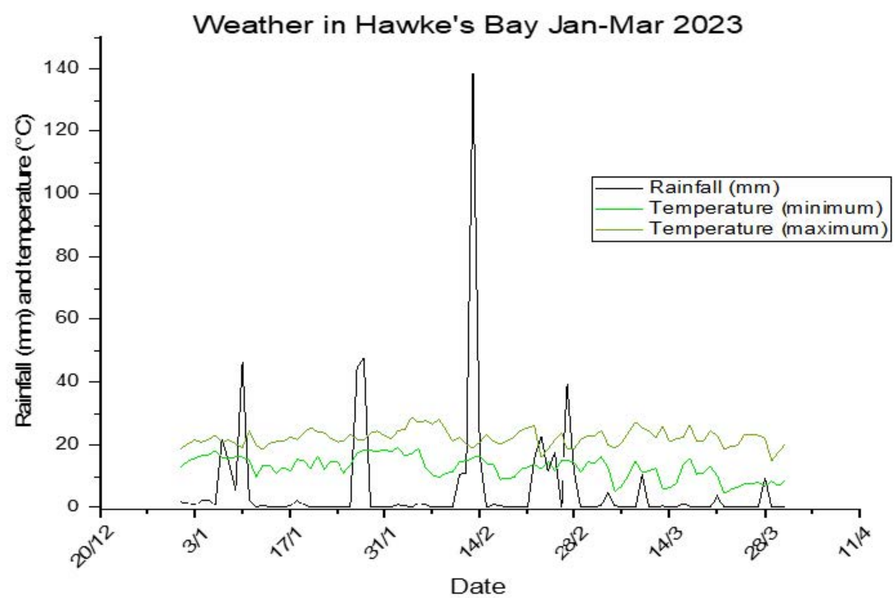


Figure 9.1: Rainfall, maximum and minimum temperatures in Hastings during the treatment and harvest windows of 'PremA96' apples in 2023. Data were collected from the MetService Te Aute Rd, Havelock North weather station (www.hortplus.metwatch.nz).

9.4.2 How apples matured in response to growth regulator applications

9.4.2.1 Effects of different Erger spray applications on blocks

Erger (active ingredient: 20–25% Oxirane, 2-methyl-, polymer with oxirane, mono(2-propylheptyl) ether) can be used to move flowering earlier and to compress the flowering window. The blocks that received a full dose of Erger (E200 × 2, E500 × 2, E500 × 3 and Control) recorded 5% buds at greentip on 30 August 2022 with full bloom on 1 October 2022, while the blocks that received a half dose of Erger (E200 + Harvista and New Control) had greentip on 5 September 2022 and were in full bloom on 11 October 2022. The full dose of Erger applied a week earlier than the half dose brought flowering forward by 10 days.

This treatment could have contributed to the earlier ripening that we may observe in E500- and E200-treated apples. It is important to remember this treatment was likewise used on the Control fruit, but not on the New Control and E200 + Harvista-treated fruit.

9.4.2.2 Starch breakdown over time

According to Figure 9.2, unsprayed (New Control) apples from the test orchard reached SPI = 3 around 21 February, indicating the start date of harvesting for this block. In contrast, apples that were sprayed with the higher dose of Ethephon (E500 × 2 and E500 × 3) were ready for picking between 28 and 31 January, bringing the harvest date forward by just over 3 weeks. The Erger treatment could have contributed up to a week towards this movement in the harvest date. The difference between double and triple applications were so small that it could be negligible (E500 × 3 reached SPI = 3 a day or two before E500 × 2 fruit). In both cases the last Ethephon treatment was applied after the fruit had reached picking ripeness, but sharp increases in SPI changes could still be detected after each application.

A lower dose of Ethephon applied twice (E200 × 2) in a full dose Erger block could bring harvesting forward by almost a week (just after 15 February). This result could indicate that the effects of the full dose Erger were not as effective as suspected for the E500-treated blocks, or that 200 mL/ha Ethin did not have a strong effect at bringing the harvest window forward. Harvista spray applications on E200 × 2-sprayed trees delayed ripening back by a week, therefore the start of harvest for these apples coincided with that of the New Control apples (both blocks received half dose Erger in August 2022). A big difference between apples from these two blocks is that Harvista treatment slowed fruit ripening up to 3 weeks during the harvest window and it would be possible to pick these apples into the week of 14 March 2023 if decisions were made purely on SPI of the fruit. Using the different spray strategies tested in this trial could spread the harvest window for this orchard over 7 weeks (from 28 January to 14 March 2023). Taking the results from last

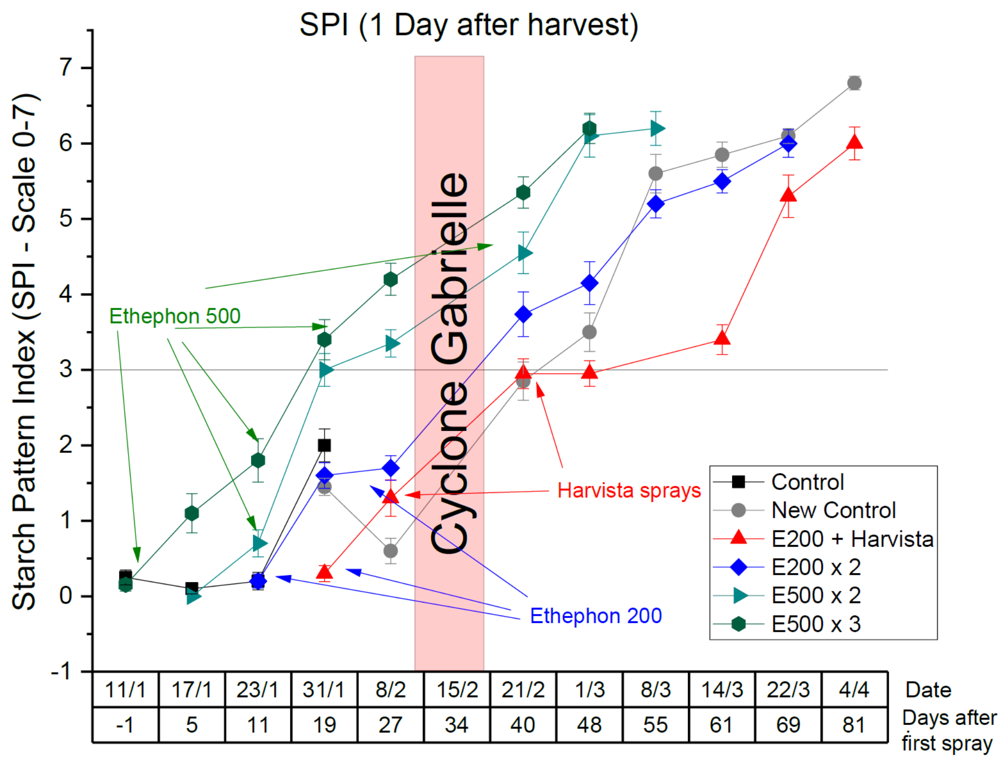


Figure 9.2: Starch pattern index (SPI) of 'PremA96' apples as measured within 24 h of picking in 2023 from blocks in one orchard in Hastings, Hawke's Bay after receiving various growth regulator spray treatments. Trees in a block received one of the following spray strategies: two applications of 200 mL/ha Ethin™ with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista™ 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples for comparisons. Apples were picked and assessed once a week from 11 January to 4 April 2023, covering fruit maturities from SPI = 0 to SPI = 7. SPI was determined based on the ENZAFRUIT SPI chart guidelines for apples. n=20 per pick date.

year into consideration (Niemann et al. 2022), an additional 3 weeks at the tail end could be possible if the trees only receive Harvista spray treatments without any Ethephon exposure.

9.5 Recommended harvest-windows and fruit quality while SPI = 3–4

We used the SPI data illustrated in Figure 3 to determine the dates that fruit would have SPI between 3 and 4 and drew up Table 2 to indicate recommended harvest windows for the different treatments applied during this trial:

- Fruit that received no growth regulators (New Control) were ready for harvest between 21 February and 1 March, a window of 9 days.

- Fruit that received high doses of Ethephon (E500 × 3 and E500 × 2) ripened considerably faster, with picking windows from 29 and 30 January, respectively. E500 × 3 fruit could be picked for 11 days and E500 × 2 fruit for 16 days.

- A lower dose of Ethephon (E200 × 2) brought the picking window forward by a little more than a week (starting on 13 February) and the fruit could be picked for 15 days, resulting in a large overlap with the control fruit.

- The longest picking window was observed for E200 + Harvista-treated fruit. These apples were ready for picking on 21 February, and could be picked until 14 March, a window of 22 days.

The question arose whether other fruit quality parameters such as firmness, dry matter content and SSC would be altered and become unsynchronised with normal ripening traits. To answer this, we drew box plots of those traits for fruit assessed in the harvest windows based on when SPI for apples in each treatment were between 3 and 4. Fruit firmness for all the apples ranged between 8 and 10 kgf (Figure 4). Control fruit were the softest during their picking window, with fruit that received high doses of Ethephon recording the firmest values. Harvista-treated fruit had the biggest variation in fruit firmness measurements, ranging from 12 to 7 kgf. This is not surprising if we consider that the picking window is 22 days, revealing that fruit softening still proceeds even if SPI remains more stable.

Apples that received high doses of Ethephon (E500 × 2 and E500 × 3) recorded the lowest dry matter content during their recommended harvest windows (13.5–14%), while control fruit had 14–16% (Figure 5). Harvista-treated and E200 apples had similar dry matter content as the control fruit.

Ethephon treatment resulted in average SSC measurements dropping to or slightly below 12°Brix during their harvest windows (Figure 6). The control fruit samples picked during their harvest window had a greater range in SSC measurements of all the treatments assessed, with a mean SSC of just above 12°Brix.

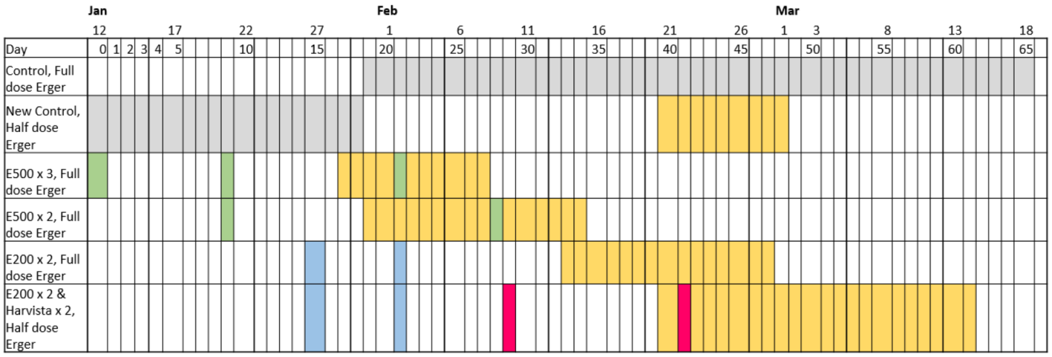


Figure 9.3: Dates when 'PremA96' apples from different test blocks in an orchard in Hawke's Bay had an average starch pattern index (SPI) between 3 and 4 (coloured yellow), indicating optimal harvest windows after different Ethephon (Ethin™) and Harvista™ 1.3 SC spray strategies. Trees in a block received one of the following spray strategies: Half dose Erger™ and two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista (E200 × 2+ Harvista x 2); Full dose Erger and two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); Full dose Erger and two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and full dose Erger and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply control (Full dose Erger) and New Control (half dose Erger) apples for comparisons. Apples were picked and assessed once a week from 11 January to 4 April 2023. Dates that Ethephon treatments were applied at either 500 mL/ha or 200 mL/ha with 10% NAA 100 are indicated in green (E500) or blue (E200). Harvista was applied at 150 g/ha on the days highlighted in red. Fruit were monitored on a weekly basis for starch pattern index based on the ENZA SPI chart for apples, on a 0–7 scale where 0 = fully stained and 7 = no staining. n=20 per pick date.

9.5.1 Changes in IEC in response to growth regulator applications

Apples that received Ethephon treatment immediately developed increases in IEC (Figure 7). Apples that received the earlier, higher doses (E500) revealed a stronger response than fruit that received lower, later doses (E200). The SPI trends seen in (Figure 3) reflected the IEC trends, again indicating that monitoring SPI is a useful substitute for the costly IEC test. 'PremA96' apples are low ethylene producers, and it took until after 1 March before any of the fruit started producing more than 1 L/L ethylene. It seems that IEC measured 1 day after harvest cannot be used to recommend pick times, but it can reveal a physiological response to hormone spray treatments, indicating whether treatments were effective or not.

An interesting phenomenon was observed just after the cyclone. IEC did not increase as quickly in the E500 and Harvista-sprayed fruit, but it increased at similar rates as before the cyclone for E200 and New Control fruit. At that stage, the average IEC was still only around 0.02–0.07 L/L, but the trend is noticeable (Figure 7).

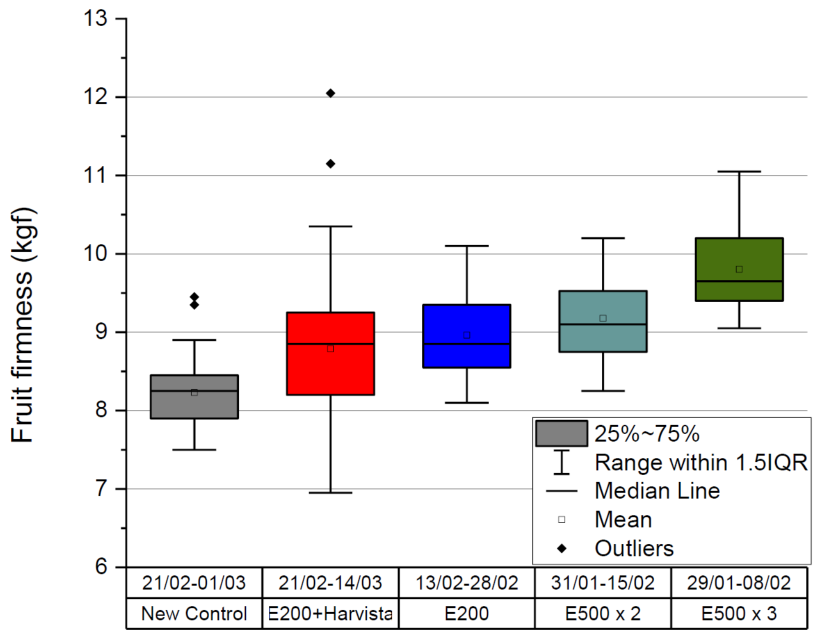


Figure 9.4: Fruit firmness (reported as kgf) measured by a Güss penetrometer of 'PremA96' apples as recorded during their recommended harvest windows after various Ethephon (Ethin™) and 1-MCP (Harvista™ 1.3 SC) treatment strategies. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23. Trees received one of the following spray strategies: Two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista (E200+Harvista); Two applications of 200 mL/ha Ethin with 10% NAA (E200); Two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and Three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). An unsprayed block was used to supply control apples for comparisons (New Control). Apples were picked and assessed once a week from 11 January to 4 April 2023. n=20 per pick date, with one to three picks represented in each treatment.

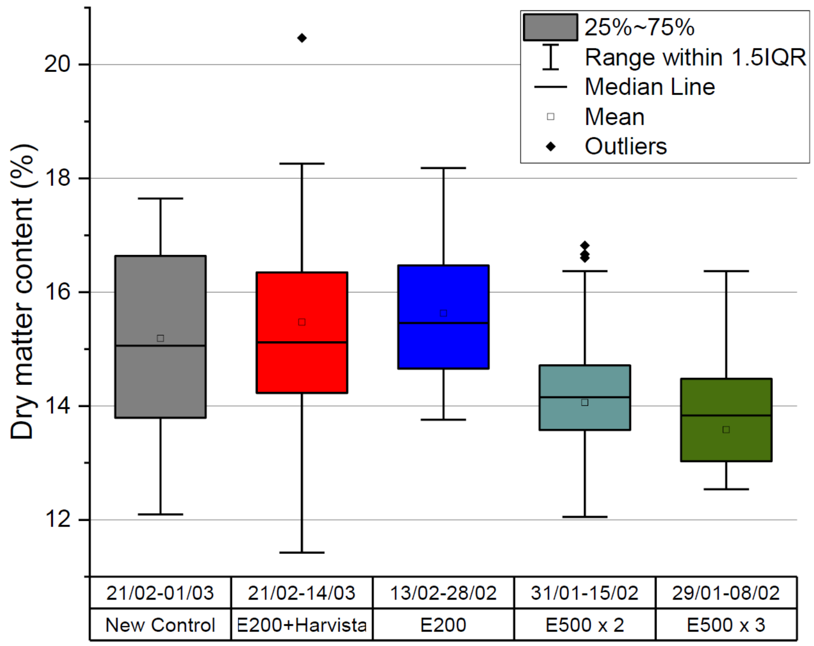


Figure 9.5: Dry matter content (% of total mass) of 'PremA96' apples as recorded during their recommended harvest windows after various Ethephon (Ethin™) and 1–MCP (Harvista™ 1.3 SC) treatment strategies. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23. Trees received one of the following spray strategies Two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista (E200+Harvista); Two applications of 200 mL/ha Ethin with 10% NAA (E200); Two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and Three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). An unsprayed block was used to supply control apples for comparisons (New Control). n=20 per pick date, with one to three picks represented in each treatment.

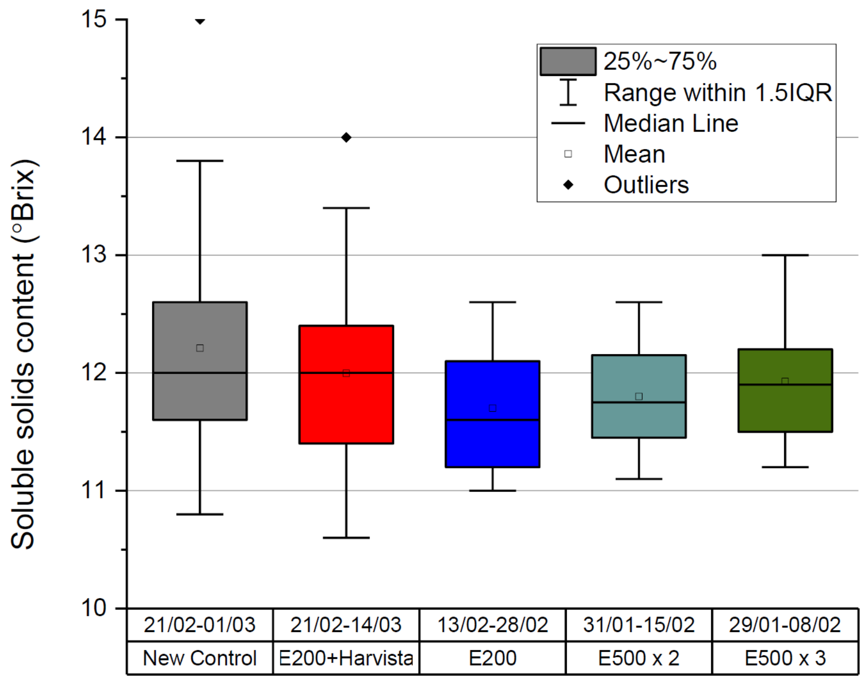
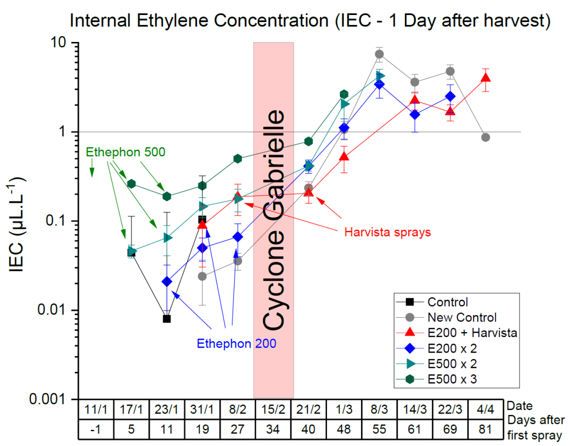


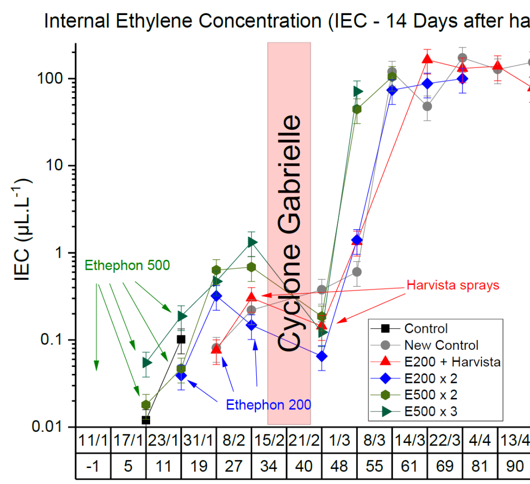
Figure 9.6: Soluble solids content of 'PremA96' apples as recorded during their recommended harvest windows after various Ethephon (Ethin™) and 1-MCP (Harvista™ 1.3 SC) treatment strategies. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23. Trees received one of the following spray strategies: Two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista (E200+Harvista); Two applications of 200 mL/ha Ethin with 10% NAA (E200); Two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and Three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). An unsprayed block was used to supply control apples for comparisons (New Control). n=20 per pick date, with one to three picks represented in each treatment.

The increased ethylene production in response to Ethephon exposure that was evident 1 day after harvest were still observed 14 days later. E500 treated fruit had higher IEC than all other treatments throughout January and February 2023. Fruit sprayed with E200 likewise displayed increases in IEC, but not as high as E500-treated fruit.

The effects of the cyclone were even more pronounced in IEC 14 days after picking (Figure 8). All fruit picked just after the cyclone (control, Ethephon-treated and Harvista-treated) had less IEC than what was measured in fruit picked just days before the cyclone. But within 2 weeks IEC had increased in all apples to around 100   L/L. There was a small delay in this increase in E200, New Control and Harvista-sprayed fruit compared with E500 fruit.



(a) Internal ethylene concentrations (IEC) of 'PremA96' apples as measured within 24 h of picking in 2023. Blocks of trees in an orchard in Hawke's Bay received one of the following Ethephon (Ethin™) and 1-MCP (Harvista™ 1.3 SC) treatment strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply control (and new control) apples for comparisons. IEC was measured from a core gas sample with a gas chromatograph. n=20 per pick date.



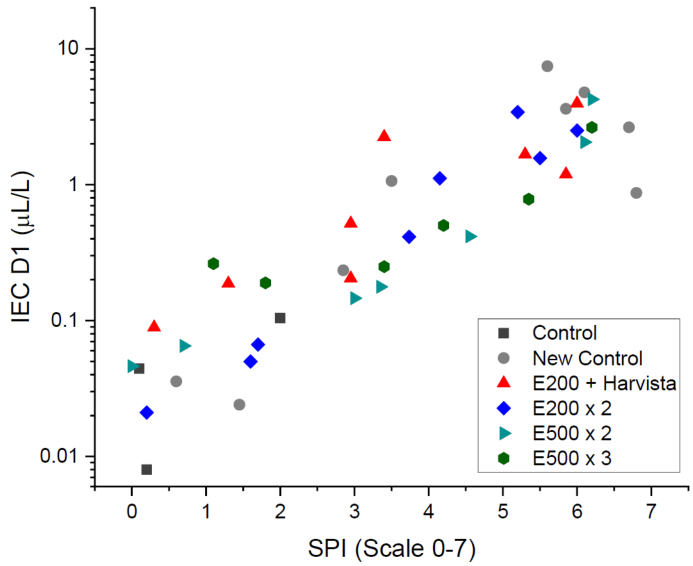
(b) Internal ethylene concentrations (IEC) of 'PremA96' apples as measured after being held at 20°C for 14 days after harvest in 2023. Blocks of trees in an orchard in Hawke's Bay received one of the following Ethephon (Ethin™) and 1-MCP (Harvista™ 1.3 SC) treatment strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply control (and new control) apples for comparisons. IEC was measured from a core gas sample with a gas chromatograph. n=20 per pick date.

Figure 9.7: Internal ethylene concentrations at one and 14 days after harvest

9.6 The correlation between IEC and SPI

The correlation between SPI and IEC is stronger with Ethephon-sprayed fruit than what it was with Harvista-sprayed fruit as measured in 2022 (Figure 9; Niemann et al. 2022). The correlation is constant throughout fruit maturation, where the Harvista-treated fruit demonstrated improved correlation as the fruit matured. We can be more confident that

SPI alone can be used to track fruit maturations, and that we do not have to rely on IEC data.

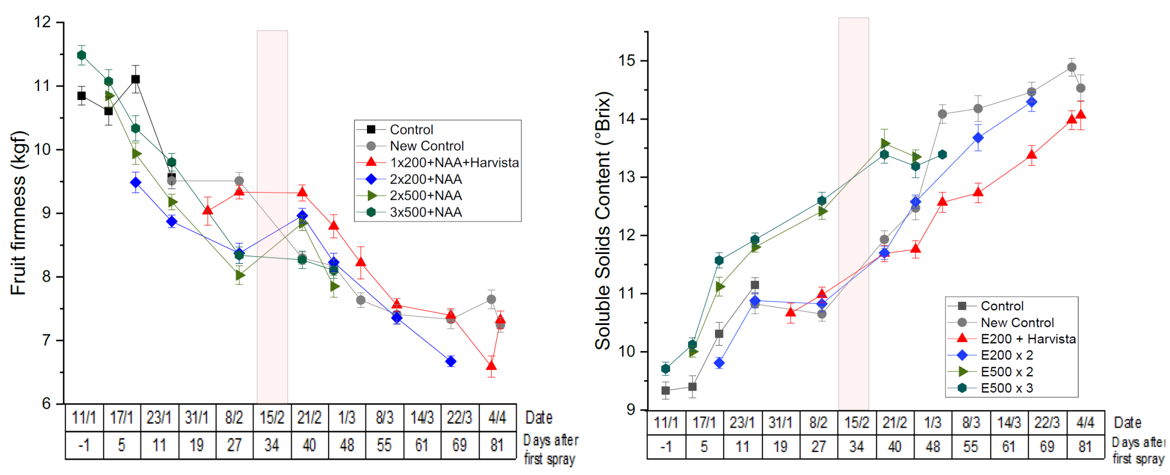


Fruit softening and SSC changes on the trees

Fruit firmness measurements of 'PremA96' apples indicate that the Ethephon-treated fruit softened faster than the control fruit. On average, the Harvista-sprayed fruit were firmer than the control fruit at most assessment times (Figure 10). This seems to contradict the observations in Figure 4, but taking into consideration that the Harvista-treated fruit included in the data illustrated in Figure 10 were sampled between 21 February and 14 March 2023, it is clear that the New Control fruit had softened to 7.5 kgf by 14 March.

Fruit that received higher doses of Ethephon developed higher concentrations of soluble solids during early February, but SSC in unsprayed fruit caught up with those concentrations by early March (Figure 11). Fruit sprayed with lower doses of Ethephon developed soluble solids at similar rates as the control fruit. Harvista-treated fruit had the slowest increase in SSC over the trial period, which aligns with other quality assessment results. Interestingly, when looking back at Figure 6, SSC for treated fruit during their harvest windows was lower than what was measured in control fruit when their SPI was between 3 and 4.

More detailed graphs illustrating the spread of measurements at each pick date are in the Appendix (Figure A1, Figure A2 and Figure A3).



(a) Fruit firmness of 'PremA96' apples as measured within 24 h of picking in 2023. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2023 after receiving one of the following Ethephon (Ethin™) and 1-MCP (Harvista™ 1.3 SC) treatment strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples. n=20.

(b) Soluble solids content of 'PremA96' apples as measured within 24 h of picking in 2023. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2023 after receiving one of the following Ethephon (Ethin™) and 1-MCP (Harvista™ 1.3 SC) treatment strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples. n=20.

Figure 9.8: firmness and soluble solids measured within 24 hours of the time of picking

9.7 Permeance changes on the trees

Permeance in all treatments was remarkably similar before the cyclone, especially in January 2023 (Figure 12). It was only on 31 January 2023 that Harvista-treated fruit developed lower permeance than the other fruit picked and assessed on that date. Permeance results fluctuated from week to week, dropping as January progressed, but increasing and decreasing sharply during the first 2 weeks in February. This could have been in response to the high rainfall events that were experienced during that month. After the cyclone, permeance values differentiated more, with E500 fruit having up to 20 nmol/m2/Pa higher permeance than the control fruit. Permeance in E200 + Harvista-treated fruit was similar to that of the control fruit throughout the trial into April. Again fluctuations were observed from week to week, but the trend of decreasing permeance as the fruit mature can be distinguished.

9.8 How to store ethephon-treated fruit

Apples were picked throughout the trial and were placed in storage for 3 or 6 months to see how fruit quality changed during storage. Apples were placed in either controlled

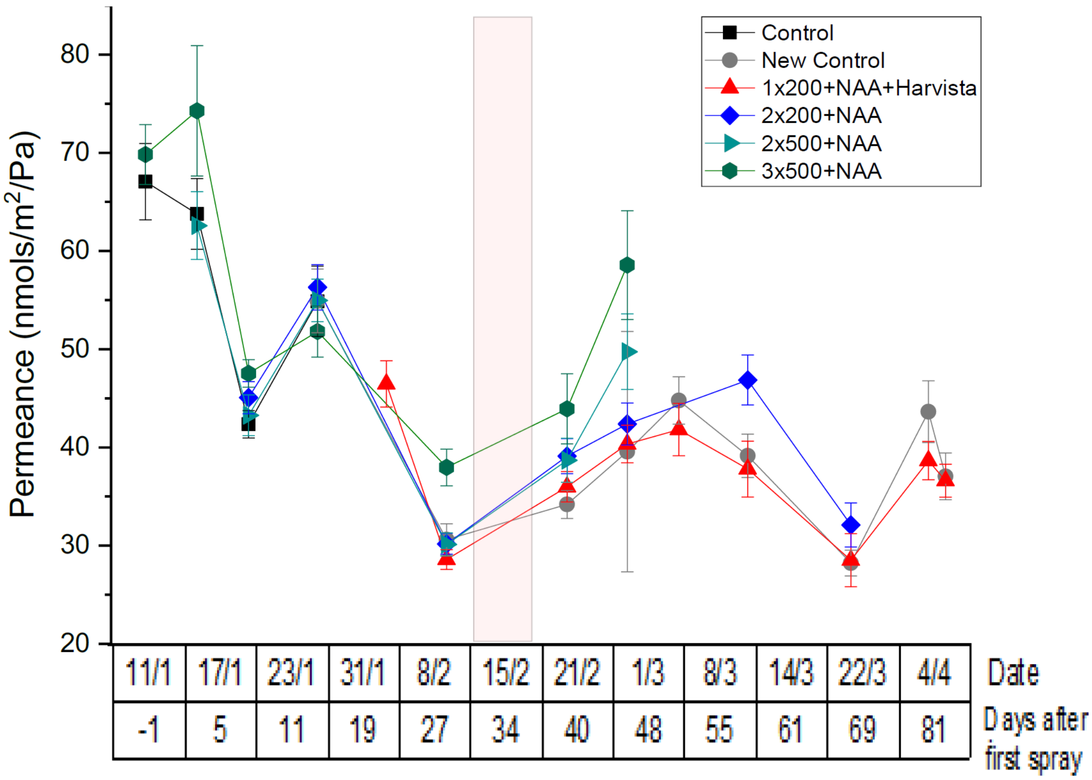


Figure 9.9: Permeance of 'PremA96' apples as measured within 24 h of picking in 2023. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23 after various Ethephon (Ethin™) and Harvista™ 1.3 SC spray treatments. Trees in a block received one of the following spray strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples. n=20.

atmosphere or regular atmosphere storage, with all fruit receiving a SmartFresh treatment within 12 h of being picked.

Unfortunately the storage trials started after the high dosage Ethephon-treated apples (E500 × 2 and E500 × 3) had ripened beyond SPI = 4 (the recommended picking window), therefore precise storage recommendations cannot be made for less mature fruit that received high doses of Ethephon (Figure 13).

- After 3 months in storage: fruit firmness of control, E200 and E200 + Harvista apples picked with SPI = 3–4 had fruit firmness around 8 kgf. The mean fruit firmness in E200 apples was the lowest of the three treatments at 7.7 kgf.
    - More mature fruit at time of harvest softened to around 7.5 kgf after 3 months in storage. E200 fruit again had the softest fruit (7.3 kgf). E500 fruit recorded the highest mean firmness values at 7.7 and 7.8 kgf.

- After 6 months in storage: The trends observed for fruit picked at SPI = 3–4 after 3 months in RA storage were more pronounced. By then fruit had softened to between 7.3 and 7.8 kgf. E200 fruit was again the softest, but E200 + Harvista fruit were the firmest.
    - More mature fruit all recorded close to 7.5 kgf. E500 × 2 fruit were the firmest at 7.6 kgf.
    - CA storage did not help the fruit to maintain firmness better than RA storage. Fruit firmness ranged from 7.8 to 7.2 kgf, with E500 × 2 and E500 × 3 developing the softest fruit.

Weight loss:

- After 3 months in RA storage: Control and E200 + Harvista-treated fruit could lose 1.5–2% of their weight during the shelf-life period (Figure 14). Ethephon-treated fruit lost more weight, ranging from just over 2% in E200-treated fruit up to more than 3.5% in E500 × 3 fruit.

- After 6 months: After RA storage, fruit that received three high doses of Ethephon (E500 × 3) lost more weight than control fruit and fruit that had a subsequent Harvista treatment. E200 recorded similar weight loss as the control and Harvista-treated fruit when picked on 1 and 8 March (while their SPI was 3-4), but E200 fruit picked later than that lost more weight during their shelf-life. Fruit picked after 21 March demonstrated increased weight loss, irrespective of pre-harvest treatment. Mean weight losses ranged from 3.5% to more than 5%.

- All fruit stored in CA storage lost on average between 3 and 4.5% weight during their shelf life after 6 months in storage. E200 and E500 × 3 fruit lost most weight.

When keeping the observations from Section 3.6 in mind, Ethephon-treated fruit tended to have higher permeance from February onwards, while a decrease in permeance could be observed as the control fruit matured. This could explain the lower weight loss in more mature control fruit, while Ethephon-treated fruit demonstrated decidedly higher weight loss.

Shrivel symptom development (Figure 15):

- After 3 months in storage: a few apples developed shrivel symptoms, notably in more than 20% of E500 × 3 apples that were picked at SPI>4.
- After 6 months in storage: The percentage of shrivel in that treatment increased to almost 60%. In addition, E200-treated apples developed high incidences of shrivel (50%), followed by E500 × 2 apples with 30%. Apples picked at SPI = 3–4 developed less shrivel (30% in E200 apples), while there were almost no differences between control and E200 + Harvista fruit (around 10%).
- After 6 months in CA storage, between 30% and 60% of E200-, E500 × 2- and E500 × 3-treated apples developed shrivel. Almost 30% of control apples developed shrivel symptoms in CA storage after 6 months, again irrespective of whether they were picked at SPI 3–4, or SPI > 4.

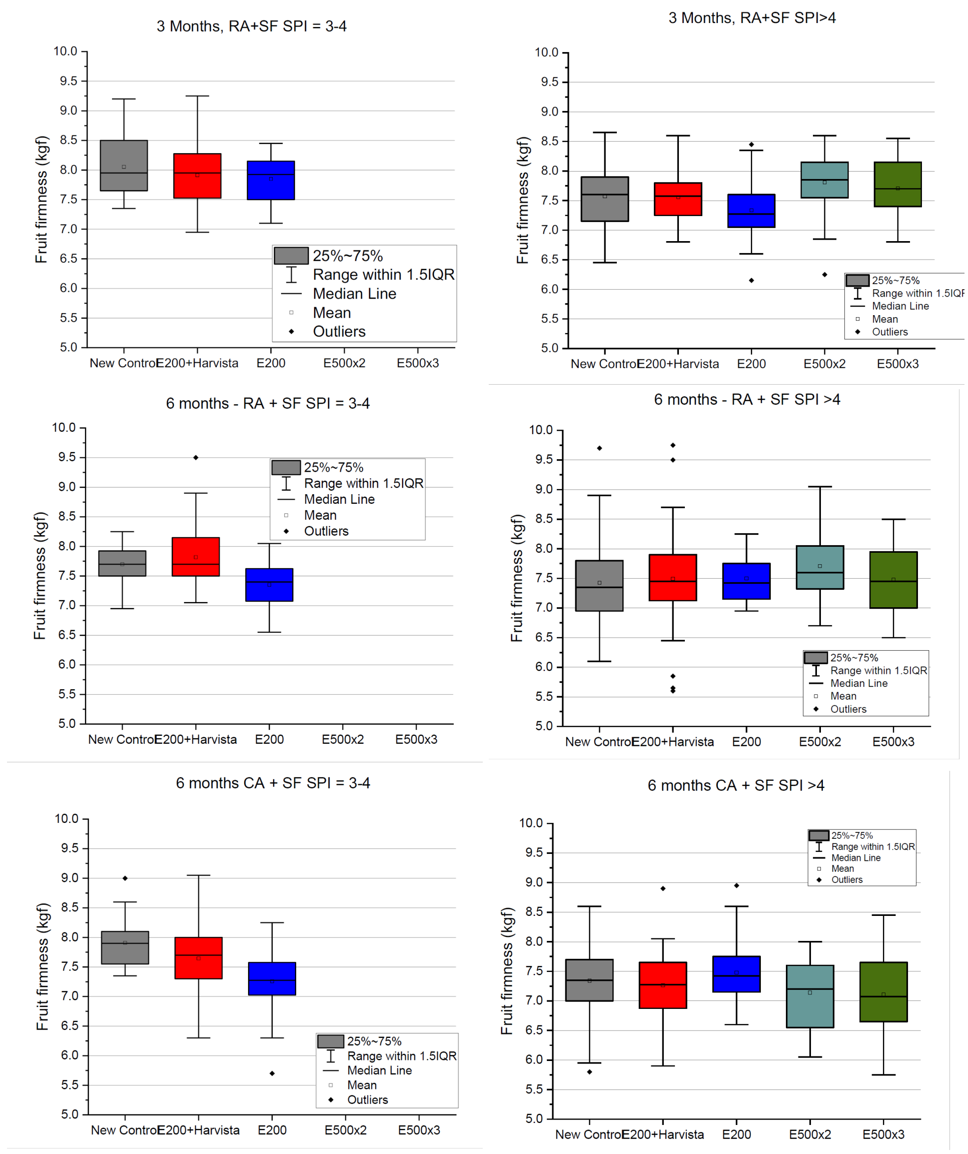


Figure 9.10: Fruit firmness of 'PremA96' apples after 3 and 6 months stored at 0.5°C and 7-day shelf life at 20°C. Fruit were stored in either regular atmosphere (RA+SF) or in controlled atmosphere (CA+SF) conditions. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23 after various Ethephon (Ethin™) and Harvista™ 1.3 SC spray treatments. Trees in a block received one of the following spray strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples. Apples were picked and once a week from 11 January to 4 April 2023. Values represent the mean of measurements, with standard error of mean. n=20–40.

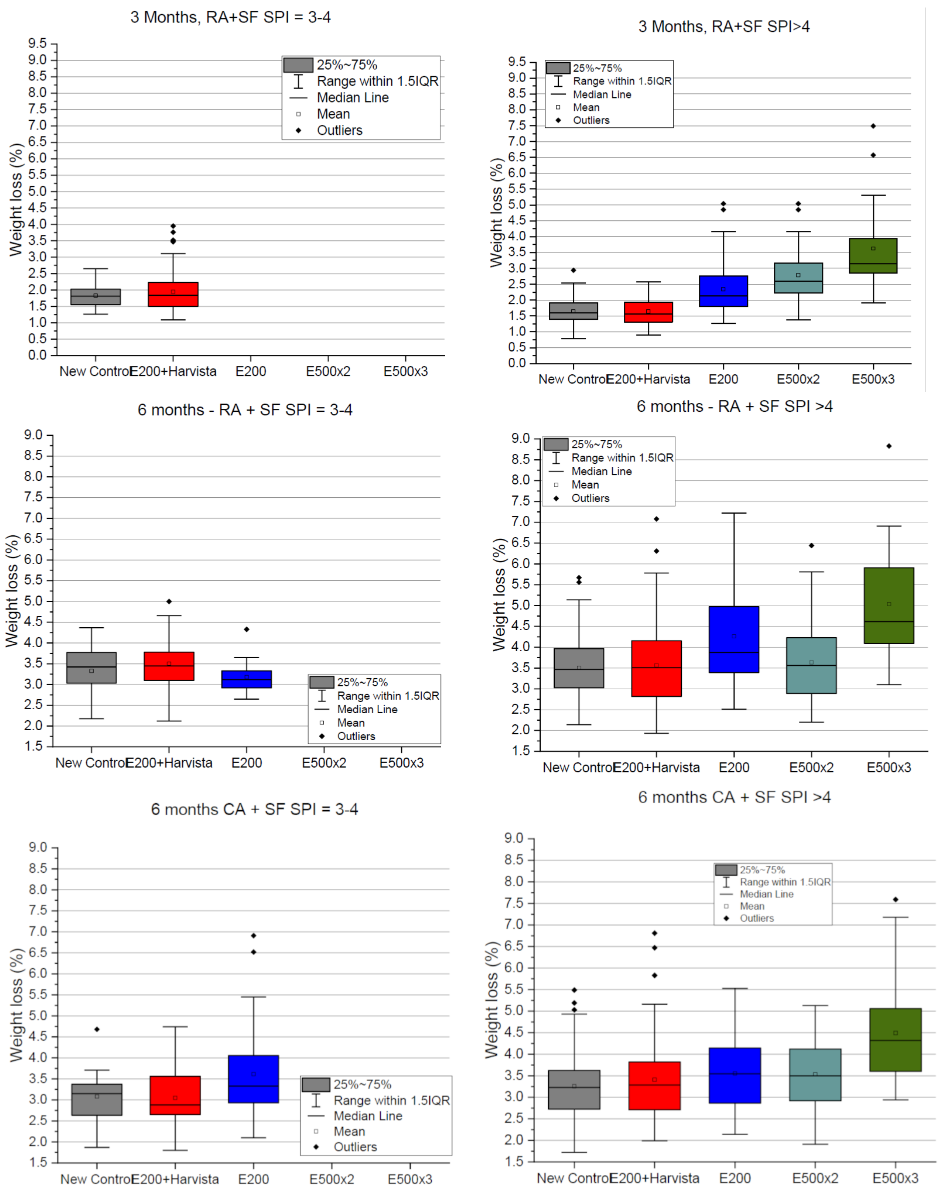


Figure 9.11: Weight loss of 'PremA96' apples after 3 or 6 months stored at 0.5°C. Fruit were weighed on the day of removal from storage, and again after 7 days of simulated shelf life at 20°C. Fruit were stored in regular atmosphere (RA+SF) or controlled atmosphere (CA+SF) after receiving SmartFresh™ treatment at harvest. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23 after various Ethephon (Ethin™) and Harvista™ 1.3 SC spray treatments. Trees in a block received one of the following spray strategies: two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples. Apples were picked and assessed once a week from 11 January to 4 April 2023. Results are presented for fruit that were ready for harvest (SPI = 3–4) of fruit that were overripe (SPI >4). Values represent the mean of measurements, n=20–40.

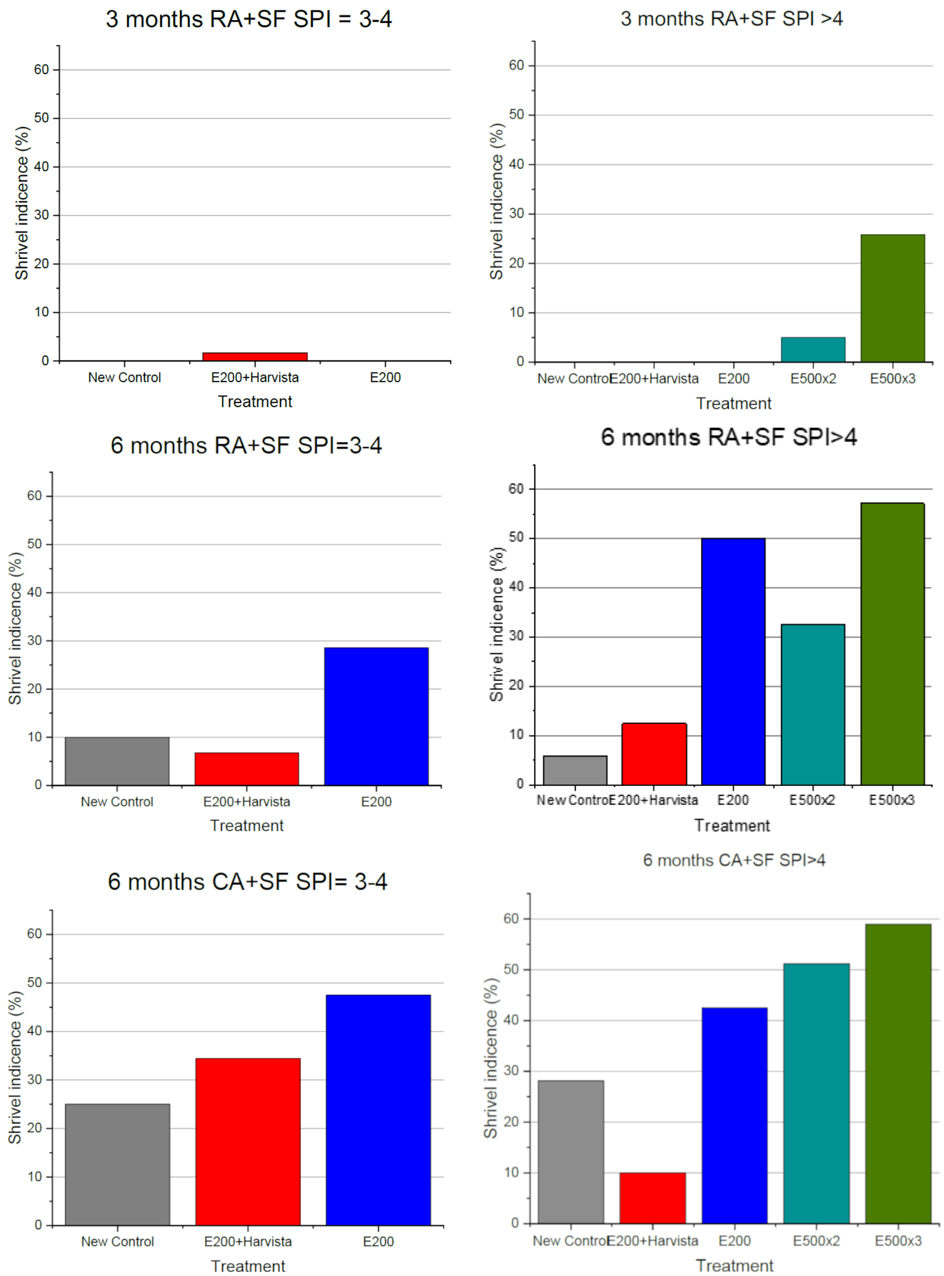


Figure 9.12: Shrivel incidences observed in 'PremA96' apples after 6 months stored at 0.5°C and 7-day shelf life at 20°C. Fruit were stored in regular atmosphere (RA) or controlled atmosphere (CA) conditions. All apples were grown and harvested from orchard blocks in one orchard in Hastings, Hawke's Bay, in 2022–23 after various Ethephon (Ethin™) and Harvista™ 1.3 SC spray treatments. Trees in a block received one of the following spray strategies two applications of 200 mL/ha Ethin with 10% naphthalene acetic acid (NAA), followed by two applications of Harvista 1.3 SC (E200 + Harvista); two applications of 200 mL/ha Ethin with 10% NAA (E200 × 2); two applications of 500 mL/ha Ethin with 10% NAA (E500 × 2) and three applications of 500 mL/ha Ethin with 10% NAA (E500 × 3). Unsprayed blocks were used to supply Control (and New Control) apples. Apples were picked and assessed once a week from 11 January to 4 April 2023. Fruit were stored at 0.5°C in either RA or CA coolstores. Values represent the mean of measurements, n=20–40.

10 Yield Performance

Author: Stuart Dykes and Lachlan MacKay

10.1 Introduction

An annual analysis is performed to calculate the orchard yield (excluding pick-out). This is done to compare one season to another but also to validate the yield versus orchard age assumption used to calculate commercial returns when evaluating potential new orchard investments.

In 2023 Rockit orchards are grown using four types of systems:

- 3D spindle (top grafted)
- 3D spindle (own planted)
- 2D planar canopy
- FOPS planar canopy
- Twin leader

The extent of each planting style is given in table Table 10.1 including the mean orchard age (weighted by planted canopy hectares). Approximately 40% of the planting are own-planted 3D spindle and a further 39% for 2D planar canopies. While the future orchard production system (FOPS) is only 4.5% of total (production hectares) in 2023, it represents considerable promise as a planar canopy that is well suited to PremA96. Depending on the performance of existing plantings, it is anticipated that additional PremA96 hectares will be planted using FOPS.

Table 10.2 gives the yields that are currently used for modeling orchard investments for 3D spindle, 2D planar and FOPS growing system. This table has been derived empirically based on historical data and/or theoretical estimates. This table can be directly compared to the observed yields achieved in 2023.

The yield analysis for 2023 has been complicated by the effects of cyclone Gabrielle. Extensive flooding across the region meant that many orchards could only be partially harvested. Some orchards lost 100% of their crop. In order to keep the analysis consistent, all flood affected orchards were removed from the data-set under analysis. This has affected, particularly the more mature 2D blocks .

10.1.1 Other exclusions

Hitherto the yield analysis has only looked for associations with a single predictor variable, namely orchard age. The analyses is then performed independently for each growing system. There are a number other co-variates that are likely to have a material impact on yield that have not bee factored, such as:

- soil type
- seasonal weather and climate
- root-stock
- orchard set-up (tree and row spacing)
- pruning and thinning - strategy and execution
- pest and disease pressure
- harvest management
- ...

Future analyses will begin to incorporate most or all of the variables using newly developed statistical and machine learning approaches to deliver a more accurate prediction of yield for a given set of parameters.

Table 10.1: Breakdown of New Zealand, producing PremA96 orchards by planting type and growing system

		mean orchard age	planted area	
growing system	planting type	years	Hectares	%
2Dim	planted	3.8	327.8	38.7%
3Dim	grafted	13.0	135.6	16.0%
3Dim	planted	7.1	342.7	40.5%
FOPS	planted	3.2	38.2	4.5%
twin	planted	3.0	1.7	0.2%

Table 10.2: Yield profiles for different growing systems currently used in investment models

	yield / tonnes/Ha		
orchard age	3D Spindle	FOPS	2D planar
0	0	0	0
1	0	0	0
2	0	9,000	9,000
3	21,658	18,900	18,900
4	40,936	37,800	33,300
5	56,406	56,700	56,700
6	64,022	76,500	76,500
7	66,878	85,500	85,500
8	66,878	90,000	90,000
9	66,878	90,000	90,000
10	66,878	90,000	90,000

10.2 3D spindle, own-planted

10.2.1 Introduction

The 3D spindle system is the traditional canopy that was adopted for PremA96. The management of this growing system is challenging due to the basitonic habits of PremA96 (Johnston, J, and Bryant, S. 2023) making the early development of the trees more labour intensive. From 2020 a decision was taken to only plant new PremA96 orchard developments in either 2D planar or FOPS canopy systems. The decision was made principally to facilitate the use of automation and orchard assist technology such as platforms.

Due to the relative ubiquity of the 3D spindle system for PremA96 there are several orchards that can be included in the analysis with a range of orchard ages. This allows a high quality curve to be modeled over the data. The details of the modeling are given in Section 19.3 and this approach is applied to all own-planted 3D spindle analysis. The model is based on fitting a logistic curve to the data using non linear least squares regression.

10.2.2 2023 by block

After removing all flood affected blocks, yields (mass of fruit harvested divided by canopy area) were calculated and plotted (Figure 10.1). A curve was then estimated using the methodology outlined in Section 19.3. The modeled result is overlaid as a curve in Figure 10.1.

Table 10.3: Regression parameters and confidence intervals for 2023 yield model, 3D spindle, planted by block

			confidence intervals	
coefficients	mean	median	lower 95%	upper 95%
L	42.9	42.8	38.5	48.0
α	1.4	1.3	0.7	2.4
x_0	3.9	3.9	3.4	4.3

10.2.3 2023 by orchard

Yield was also evaluated by aggregated to an orchard or RPIN level. This is believed to be a superior measure as the planted areas are more consistent and the overall yields more balanced that when comparing individual blocks within an orchard. Despite the "smoothing" effect of the orchard aggregation, there is still considerable valriability across the orchards. The large variability in the orchard yields (Figure 10.2) is a function of various factors, believed to be:

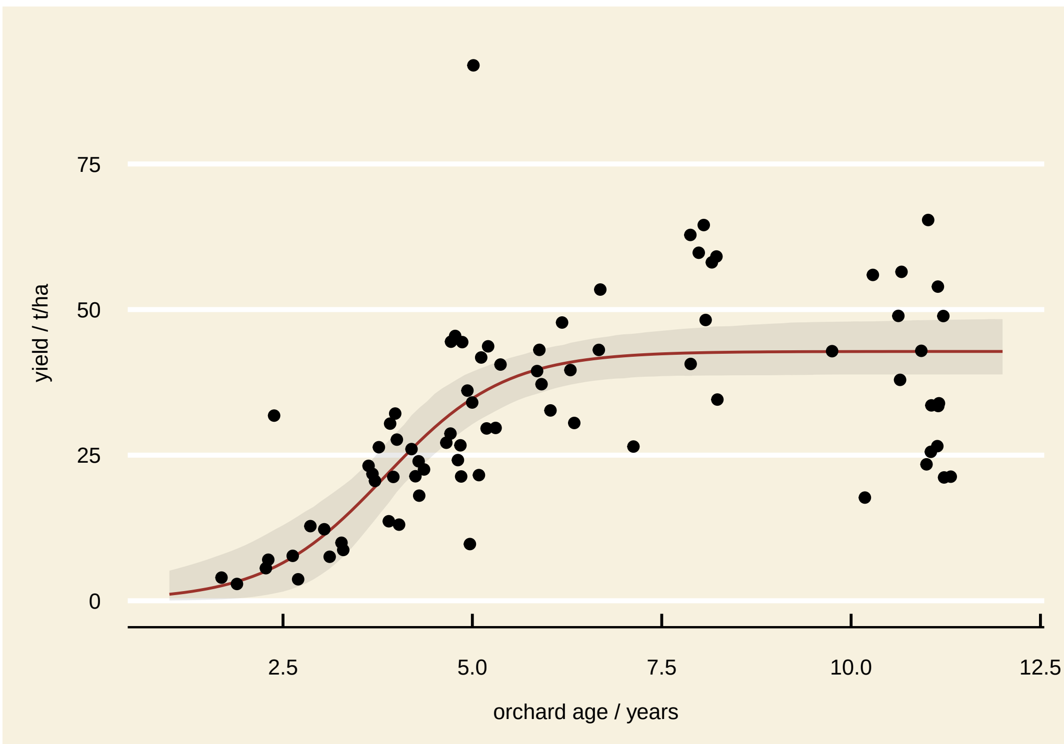


Figure 10.1: Yield as a function of orchard age for own planted spindle orchards in 2023 inclusive, grouped by block with individual block yields overlaid. The block names are not shown due to the number of data points but are given in the appendix

- the initial condition of the trees
- the choice of rootstock
- the soil type
- the early canopy management decisions

Unfortunately the respective effects of these variables not easily quantified.

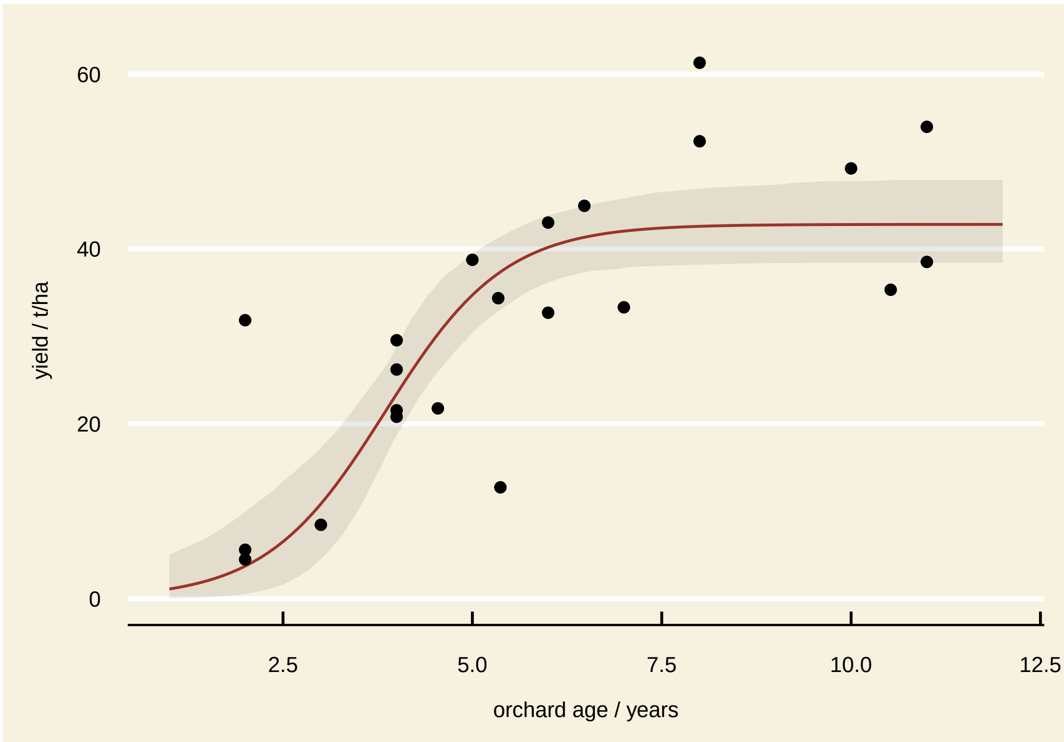


Figure 10.2: Yield as a function of orchard age for own planted spindle orchards in 2023 inclusive, grouped by RPIN with individual orchard yields overlaid

10.2.4 Three year summary by block

Table 10.4: Regression parameters and confidence intervals for 2023 yield model, 3D spindle, planted by RPIN

			confidence intervals	
coefficients	mean	median	lower 95%	upper 95%
L	52.0	49.2	40.2	72.6
α	0.7	0.6	0.3	1.3
x_0	4.4	4.2	3.1	6.8

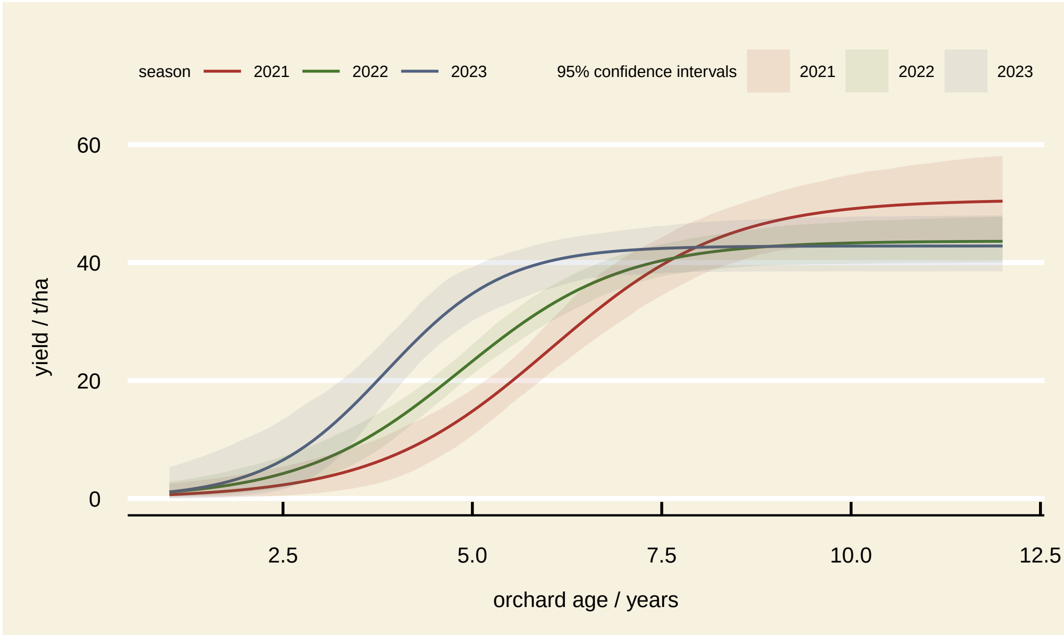


Figure 10.3: Yield as a function of orchard age for own planted spindle orchards 2021 to 2023 inclusive, grouped by block

Table 10.5: Regression parameters yield model applied to 3D spindle, planted by block, 2021 to 2023

coefficients	2021	2022	2023
L	50.70	43.66	42.81
α	0.86	0.95	1.27
x_0	6.03	4.86	3.85

10.2.5 Three year summary by RPIN

Table 10.6: Regression parameters yield model applied to 3D spindle, planted by RPIN, 2021 to 2023

coefficients	2021	2022	2023
L	49.04	48.94	48.76
α	0.93	0.69	0.61
x_0	5.91	5.49	4.16

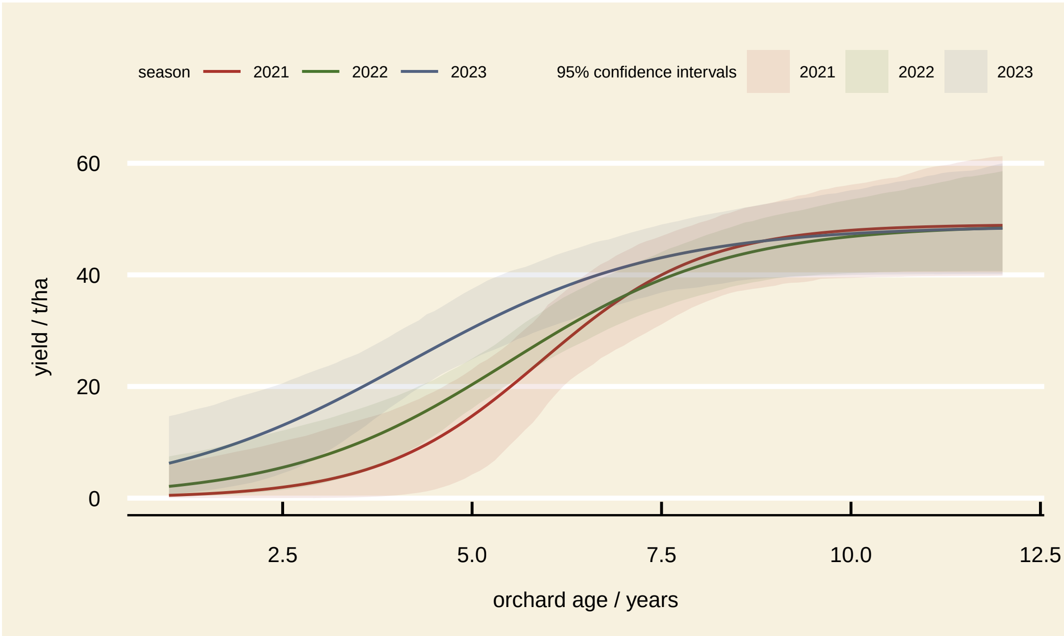


Figure 10.4: Yield as a function of orchard age for own planted spindle orchards 2021 to 2023 inclusive, grouped by RPIN (orchard)

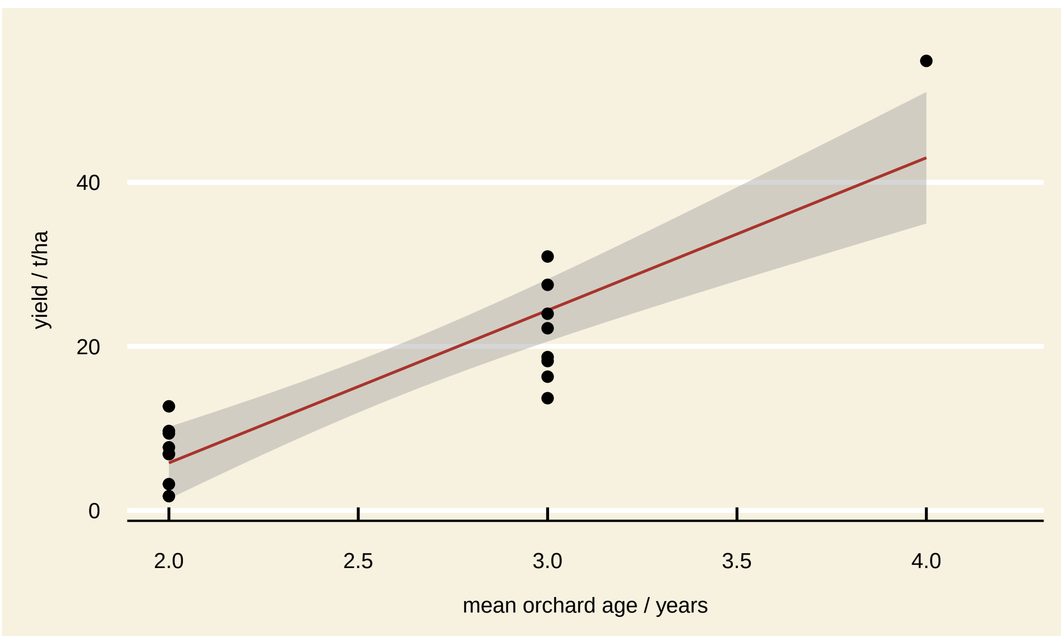


Figure 10.5: Yield as a function of orchard age for own planted 2D planar canopy orchards grouped by RPIN (orchard)

10.3 2D Planar Canopy

As shown in Table 10.1 2D canopies now make up almost 40% of the planted Hectares of PremA96. The principal motivation for planting planar canopies (FOPS and 2D) are for increased gross yield per canopy hectare compared to 3D spindle and to allow for future orchard automation. In terms of the increased yield, this is yet to be validated to maturity (the oldest producing PremA96 2D orchard is only four years old). The yield results for the 2023 harvest for 2D canopies are shown in Figure 10.5. Note that only a single orchard is shown at four years. The three 2D blocks that are one year older (Dartmoor, Korokipo and Korokipo Verries) were all significantly affected by Cyclone Gabrielle and have been excluded from the analysis.

A linear (least squares) regression was performed and overlaid on the orchard data in Figure 10.5. The regression summary is given in Table 10.7 and the modeled yield with orchard age is given in Table 10.8.

Table 10.7: Regression parameters yield model applied to 2023 2D planar, planted by RPIN

parameters	estimate	p.value
intercept	-31.40	2.26e-04
slope	18.60	1.66e-06

Table 10.8: Modeled yields for 2023 2D planar, planted by RPIN

orchard age	yield
years	tonnes/ha
2	5.80
3	24.39
4	42.99

10.4 FOPS

In 2023 only two producing orchards were using the FOPS system . The yields are given in table 9 and for both orchards exceed the estimated years for their respective orchard age. While this looks promising there are only two data points and no conclusions can be drawn about the mature yields that will be achieved.

Table 10.9: Yield as a function of orchard age for own planted FOPS planar canopy orchards grouped by RPIN (orchard)

	orchard age	planted area	yield
orchard	years	hectares	tonnes/ha
Home Block	3	11.2	26.08
Ormond Rd	2	11.7	8.73

10.5 3D Top grafted Canopies

The 3D top grafted canopies have become a legacy growing system but still represent 16% of total planting in 2023. The top grafts are of various types on various root- or inter-stocks. Figure 10.6 shows the relationship between yield and orchard age. There appears to be little association for these orchards and no attempt has been made to model one.

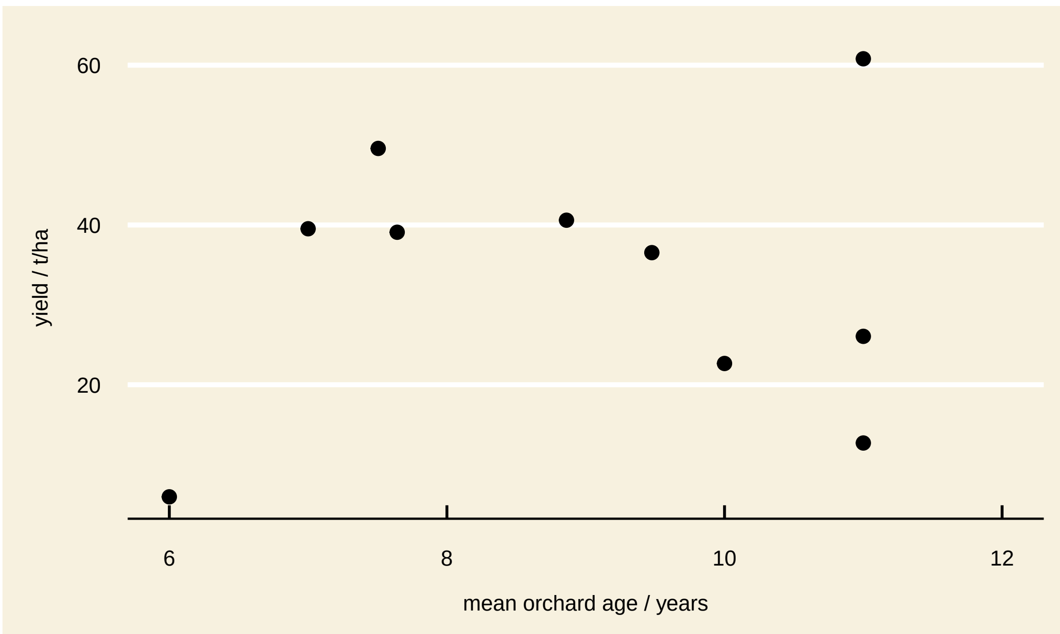


Figure 10.6: Yield as a function of orchard age for top grafted 3D canopy orchards grouped by RPIN (orchard)

10.6 Discussion

3D Spindle canopies have traditionally been the prevailing growing system for PremA96. Initially these were top grafted blocks and more recently own-planted. The 3D spindle top grafted blocks show very little association with orchard age (Figure 10.6). This is understandable when the large range of orchard configurations, ages and conditions that provided the root- and interstock for the top-grafted trees. In terms of own-planted 3D sindle trees, these are able top be successfully modeled on both a block and an orchard basis. The orchard (as opposed to block) analysis is recommended as this is less prone to outliers and gives more consistent results. The yield curve is modeled by a logistic curve and the regression parameters show a high quality fit to the data. The modeled, mature yield for 2023 is calculated as 49.15 tonnes/Ha. This is similar to the 2022 and 2021 result (48.94 and 49.04 T/Ha respectively), and considerably less that the mature yield used in investment models (Table 10.2).

2D Planar canopies have been in the ground since 2018 and theoretical estimates have calculated mature yields at greater than 100 T/Ha. The theoretical yield profile for both 2D and FOPS canopies are given in Table 10.2. The 2023 results (Table 10.8, Table 10.9) shows that in the case of both FOPS and 2D the yields achieved are exceeding the investment model. It should be noted that in the case of FOPS there are only two data points, and in the case of both planar canopies more season will need to be evaluated to build confidence in the model

10.7 Glossary

11 storage

12 quality and phytosanitary performance

Authors: Stuart Dykes & Anna Duly

12.1 Introduction

The 2022/2023 season was challenging not just because of cyclone Gabrielle in February but also the very warm and wet spring and early summer which led to high levels of pathogenic innoculum such as black spot (Venturia inaequalis) and botrytis (Botrytis cinerea). Conditions were also favourable for apple leaf curling midge (Dasineura mali) and various forms of mealy bug (with long tail mealy bug [Pseudococcus longispinus] being the most prevalent). The wet spring also facilitated the proliferation of russet (non-pathogenic) which contributed x% of all rejects.

Black Spot, ALCM and Mealy bug are a particular problem in that an entire batch can be excluded from a critical market (e.g. China, Taiwan, Japan) if a single incidence is detected.

The aim of this report is not to analyse and evaluate all observed defects and disorders, but only those that impact the ability of Rockit™ apples to enter key markets, most restrictive of all are Taiwan and China. Where possible, comparisons are made against previous years performance.

12.2 Phytosanitary regulation process

Rockit Trading Company (RTC) exports to jurisdictions that have Official Assurance Programmes (OAPs). These provide a prescriptive set of instructions to follow in order to be able to export to that particular jurisdiction. The OAPs include the grower requirements, Pack-house requirements (including registration), packing requirements (including detailed inspection regimens (Thomson, Peter 2015)), storage and export requirements (including active registration). A specific register of excluded pests, diseases and disorders and their respective threshold are listed. OAPs exist for the following jurisdictions:

- Australia
- West Australia

- China
- Japan
- Russia
- Thailand
- Taiwan

Of these seven areas, RTC actively exports to three (China, Japan and Taiwan). Of these three, Taiwan is the most restrictive and prescriptive and therefore is the OAP that is used to set the phytosanitary programme for Rockit Packing Company (RPC) (Olsen, Shane 2022).

12.2.1 Exclusion from OAP markets

given the proportion of the fruit volume that is sent to Taiwan and China by RTC, the requirement to comply with the OAPs is critical for the ongoing success of Rockit™ Apple. Market exclusion to China and/or Taiwan can occur for various reasons, most commonly is the interception of pests, diseases and disorders that appear on the pest register detailed in a document called the Importing Countries Phytosantiary Requirements (ICPR) which is specific for each jurisdiction and is referenced by the OAP. The identification of phytosanitary issues occurs during packing where a designated proportion of fruit is specifically inspected for the pests and diseases detailed in the ICPR (Ministry for Primary Industries 2000). The ICPR also states the rejection threshold for each (e.g. < 2%). If interceptions are encountered and the threshold is met, the batch will be excluded from the OAP market(s). The sampling programme and the acceptance sampling criteria are detailed in The Technical Standard: Phytosanitary Inspection (Thomson, Peter 2015)

12.2.2 Orchard and post harvest facility registration

OAP market access can also be excluded if the particular production site has failed to register for export to the specific market. Similarly the pack-house and cool-store also require official registration. There are a number of criteria (e.g. good agricultural practice certification - Global GAP) required to be able to register. Registration of orchards must be completed by the 1st September; pack-houses and cool-stores registration by 1st October. In the case of China, export is only allowed when the Chinese authorities verify and publish the approved register which may be after the start of packing. If the initial registration has only been the year before the fruit is harvested. For new orchards, it is therefore highly recommended to register the production sites the same year the block has been planted.

12.2.3 Rockit imposed exclusion criteria for 2023

In addition to the exclusion criteria mandated by the OAP, RTC has imposed additional rules to minimise the risk of a border interceptions in China and Taiwan, due to the increased sensitivity this year. These include:

- Remove the consignment from the market if more than three MPI lots are excluded for the same pest.
- ...

12.3 Review of the 2022/2023 growing season

The 2022 and 2023 growing seasons were characterised by relative cool wet weather. Figure 12.1 and Figure 12.2 show the cumulative rainfall, temperature profile for 2022, 2023 and the full bloom period of the 2024 season. As can be seen from fig-cumrain, the rainfall was persistent over the 2023 growing season, compared to 2022 where the rain came later in the season with an extreme rain event from the 20-24th March (mid-harvest). While there has been some rain in late 2023 it has not been as extensive as 2023 growing season. Note the extended full bloom window in 2022, which was driven by a very warm winter. contrast this with the relatively short full bloom window in 2023 on the back of 2785 additional Richardson chill units compared to 2022.

12.4 Post harvest pest interceptions

In terms of pest interceptions, the 2023 season was prolific compared previous seasons. Figure 12.4 shows the temporal distribution of pest interceptions through the packing seasons (2021 through 2023). The number of interception in 2023 was considerably greater than in either 2021 or 2022. The mix of pests and disorders was also quite different with three main disorders prevailing: ALCM, black spot and long tailed mealybug.

12.4.1 black spot

The incidence of black spot could be predicted from:

1. The weather, particularly the period from full bloom to the end of January.
2. The prior levels of innoculum in the respective orchard.
3. The visual incidence of disease during inspection in November/December (Drinnan, Svetlana (2023))

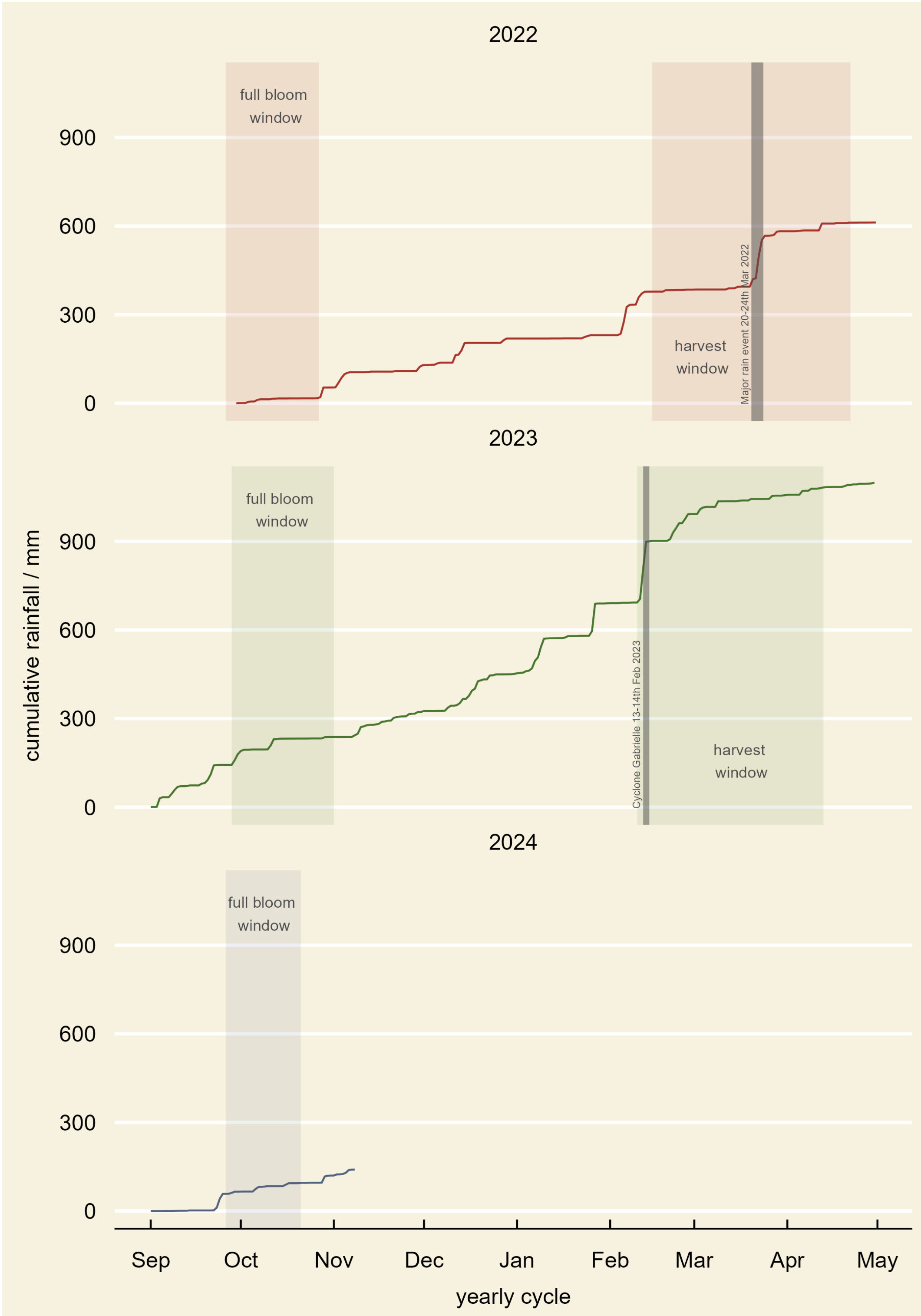


Figure 12.1: cumulative rainfall over the growing seasons 2022 through 2024 (YTD). Full bloom and harvest windows are overlaid for each season as well as the two extreme weather events in 2022 and 2023

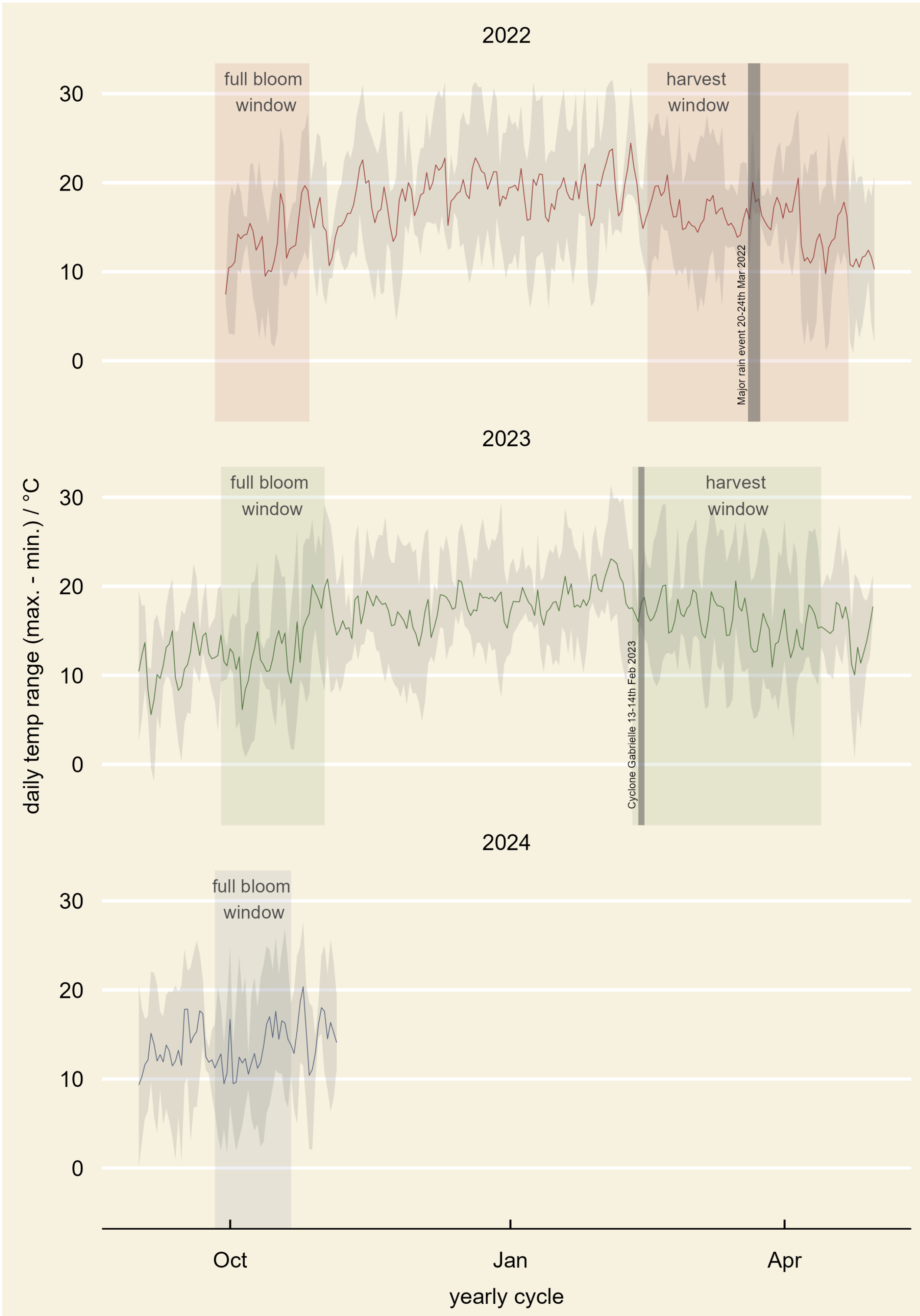


Figure 12.2: temperature profile over the 2022 - 2024(YTD) growing seasons. The solid line represents the mean daily temperature and the grey ribbon either side of the line is the diurnal variation. The full bloom and harvest windows are overlaid as well as the two extreme weather events the occurred in 2022 and 2023

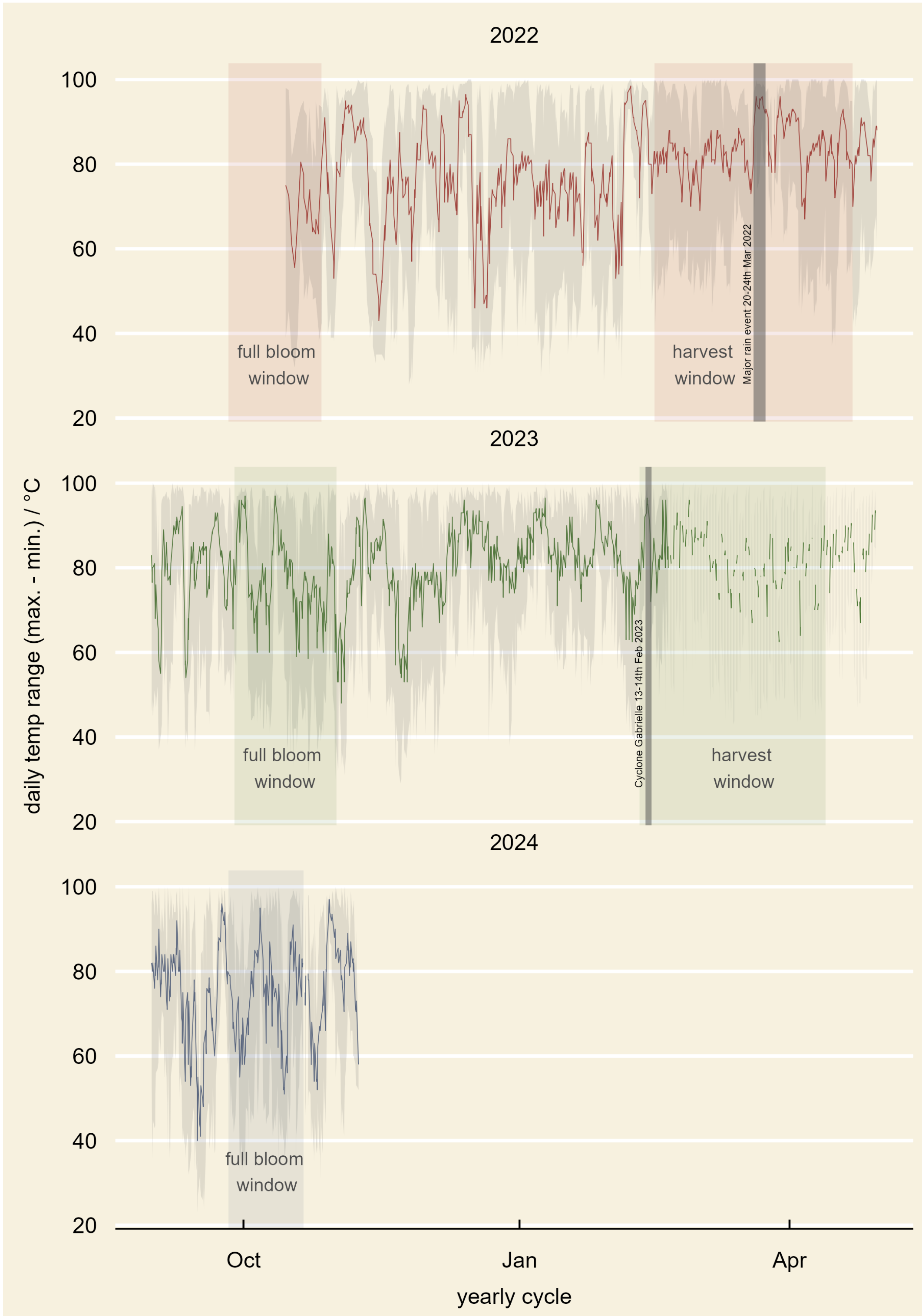


Figure 12.3: Daily relative humidity readings 2022 - 2024 (YTD) growing seasons. The solid line represents mean daily humidity and the grey ribbons to either side show the maximum and minimum humidity readings respectively. The full bloom and harvest windows are overlaid as well as the two extreme weather events in 2022 and 2023.

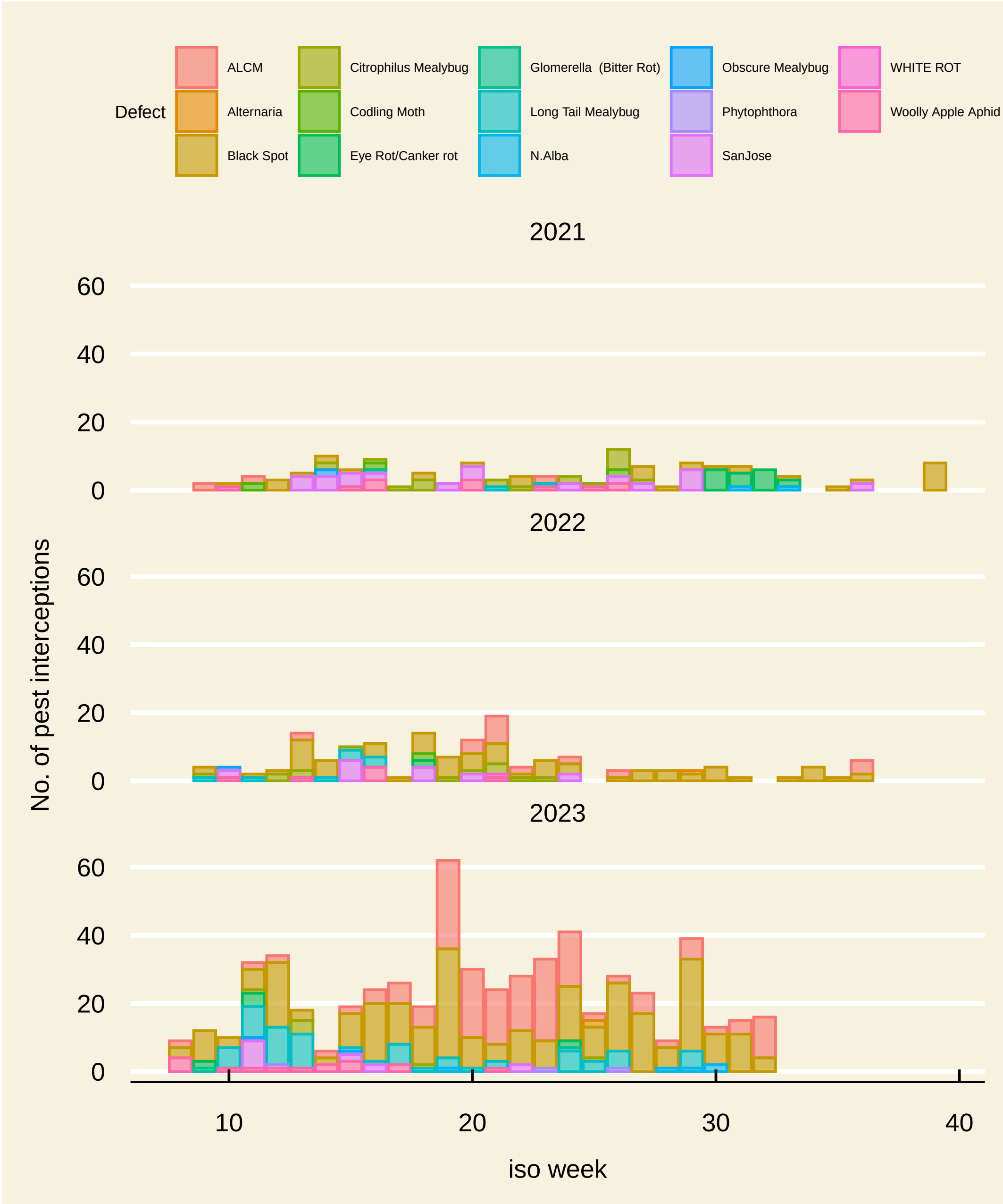


Figure 12.4: number of pest interceptions during the post-harvest packing, 2021 through 2023 inclusive

The visual incidence during the November and December inspections was considered elevated with up to almost 3% in one orchard. Rockit™ apple's black spot incidence across all blocks has almost doubled in 2023 harvest assessments compared to the previous season, mainly due to increased numbers of bin assessments at orchards with known disease presence from spring assessments. Assessing risk factors against spray programme is recommended for these blocks to see where errors might have happened, i.e. equipment (rates and calibration), timing with respect to weather conditions (coverage and drying times), product (resistance possibilities).

While the integrated disease models are available through the Metris application, it is unclear whether these are being used systematically across all orchards. This would give valuable assistance in identifying periods of high infection risk.

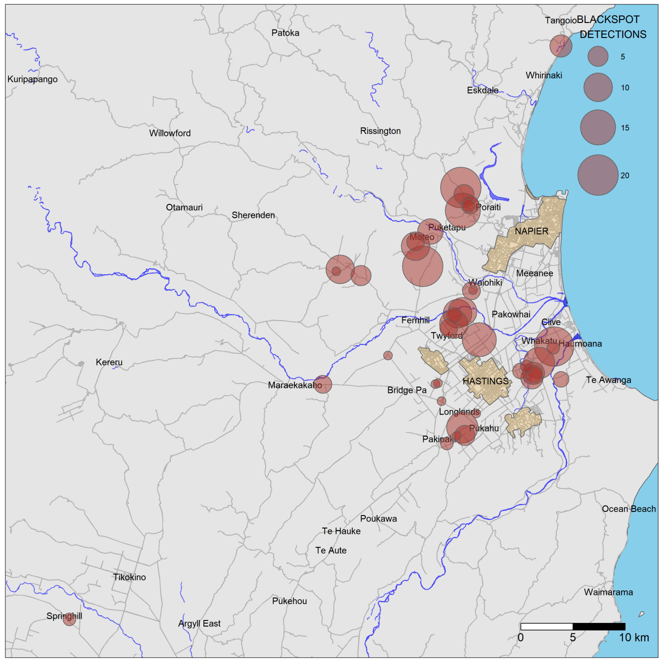
The spatial distribution of black spot in both Hawkes Bay and Gisborne region is shown in Figure 12.5. This shows the infection is wide spread in the Hawkes Bay and significant infections isolated to three orchards in Gisborne.

12.4.2 Blackspot infection modeling

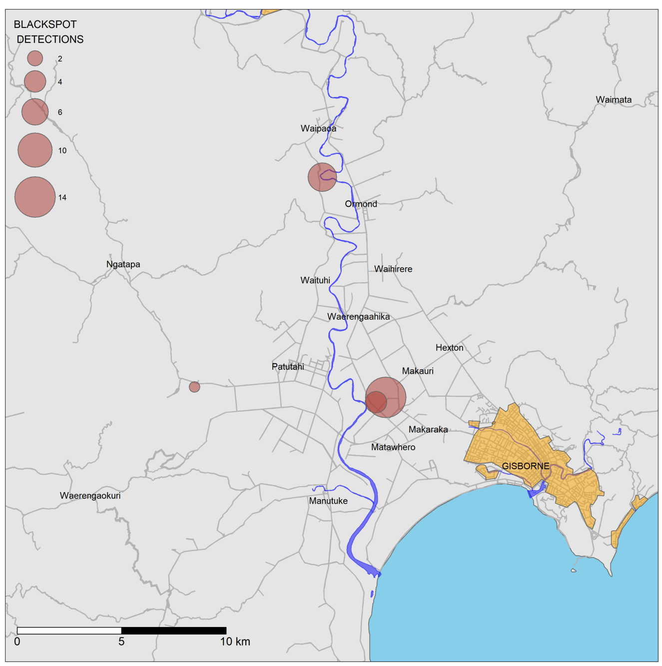
Given the prevalence of black spot (Venturia inaequalis), considerable research has been carried out in many apple growing areas around the world including extensive work that has been carried out in New Zealand (MacHardy (1996); R. M. Beresford and Spink (1992); R. M. Beresford and Manktelow (1994); R. M. Beresford, Henshall, and Palmer (2004); R. M. Beresford and Mackay (2012)). The fungi overwinters in the dead and infected leaves which gather on the orchard floor beneath the trees. In the spring the spores mature and there are three principal drivers:

1. the average temperature while the spores are maturing
2. the average temperature while the leaves are wet and
3. the length of the wetness period

The ascospores develop during the accumulation of the growing degree days. It is assumed that all ascospores have matured at 534 degree days (MacHardy (1996)). The release of the ascospores is dependent on weather (specifically daylight and leaf wetness). Once spores are released and move onto the secondary phase of the infection which involve canidia that germinate on the fruit or leaf surface causing black lesions. The duration of the infection period, and average temperature are inversely related; that is the higher the temperature the shorter the duration required for an infection. Infections are rated: marginal, light, moderate and severe based on the wetness duration and temperature. Figure 12.6 shows the significant infection events (i.e. greater than marginal) for 2022 and 2023 broken down by region in Hawkes Bay. It clearly shows that the black spot presure was greater in 2023 than 2022, in terms of the primary infection.



(a) Hawkes Bay



(b) Gisborne

Figure 12.5: regional spread of black spot detections in 2023

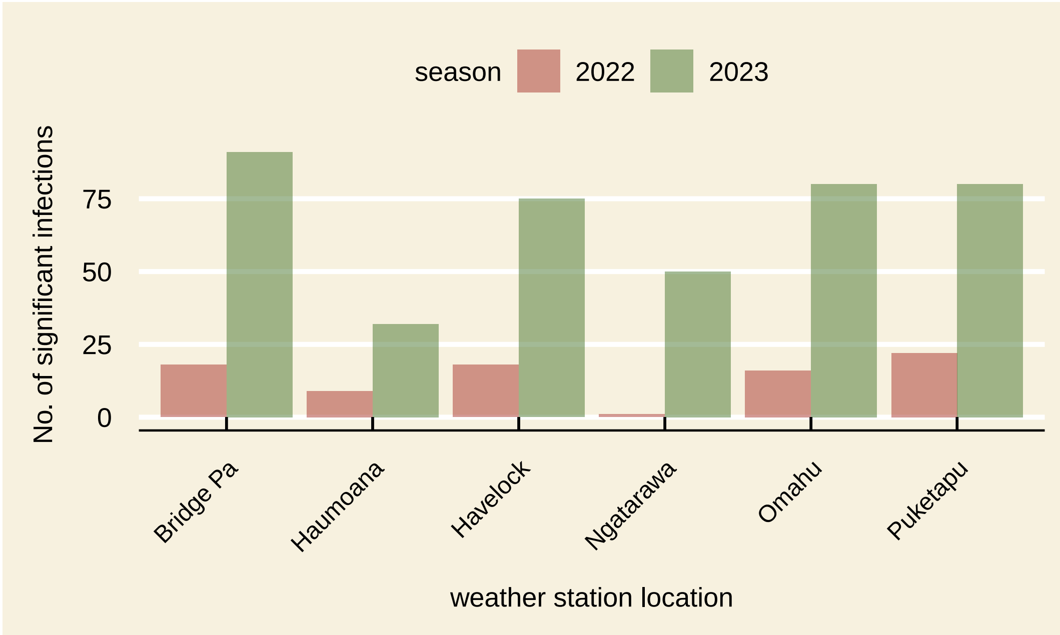


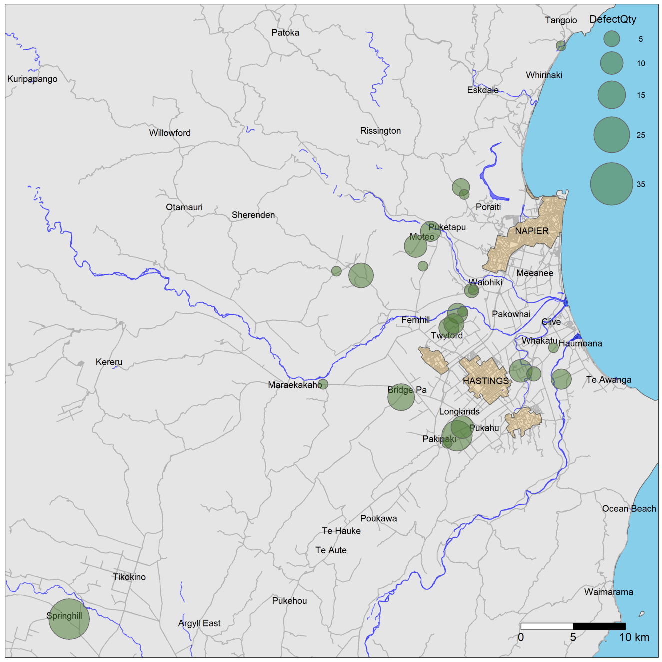
Figure 12.6: Comparison between 2022 and 2023 of the number of primary blackspot infections for the period between 1st Oct to 1st April

12.4.3 apple leaf curling midge (ALCM)

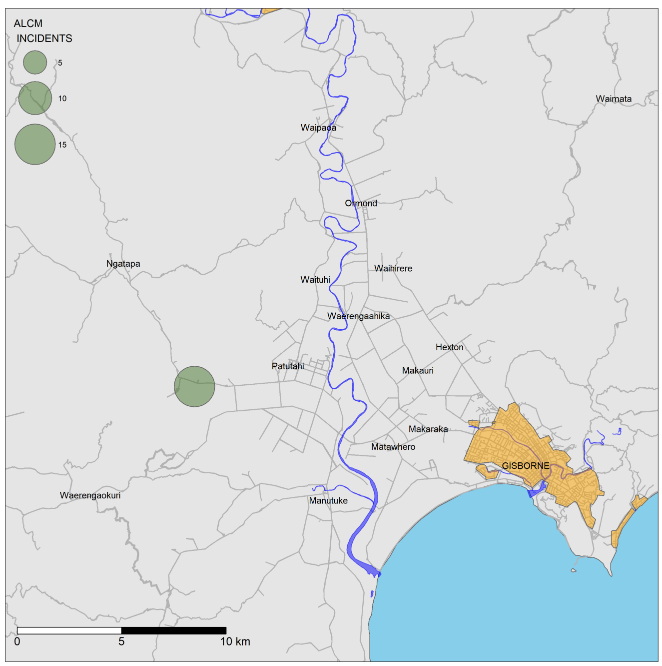
Apple Leaf Curling Midge (ALCM) is quarantine pest for China, Japan with Maximum Pest Limit (MPL) 0.5%. Access to Taiwan relies on nil detected ALCM.

ALCM is a difficult pest to control. Effective control can only be achieved when several strategies are used collectively with each other: on orchard monitoring for tree vigour and new shoot damage, Movento applications and fruit assessments for ALCM pupae presence. Although, traditionally monitoring for ALCM is done in summer (post 3rd midge generation, G3), knowing ALCM presence on orchards from generations 1 (G1) and 2 (G2) can assist in control strategies with focus on G3 to minimise export risk.

Pre-harvest ALCM assessments predicted that despite significant incidence of ALCM infection, the risk of a “bug-out” during packing was unlikely. despite the analysis, ALCM interceptions during packing were prolific in 2023 (compared to 2021 and 2022) as shown in Table 12.1. The regional distribution of ALCM in 2023 is shown for both Hawkes Bay and Gisborne regions in Figure 12.7.



(a) Hawkes Bay



(b) Gisborne

Figure 12.7: regional spread of ALCM detections in 2023

Table 12.1: Number of MPI lots facing market exclusion, by disorder, for 2021 through 2023

	harvest year		
disorder	2021	2022	2023
ALCM	3	12	81
Codling Moth	3	1	0
Black Spot	30	72	243
Woolly Apple Aphid	12	5	14
SanJose	16	6	3
Citrophilus Mealybug	20	11	5
Obscure Mealybug	2	1	1
Glomerella (Bitter Rot)	1	0	2
Long Tail Mealybug	2	6	52
Eye Rot/Canker rot	8	1	4
N.Alba	1	0	5
WHITE ROT	0	1	0
Alternaria	0	1	2
Phytophthora	0	0	3

12.5 Process change in the pack-house

In addition to the high pest pressure in the region, a change in process was applied in the pack-house that likely had an impact on the number of lots that were excluded from OAP markets. The change involved nominating MPI lot sizes prior to packing to comply with the OAP. These "MPI lots" were set nominally at 25 bins, hence the distribution of the number of MPI lots per batch has changed from 2022 to 2023 packing season. The change can be visualised by bar chart in Figure 12.8

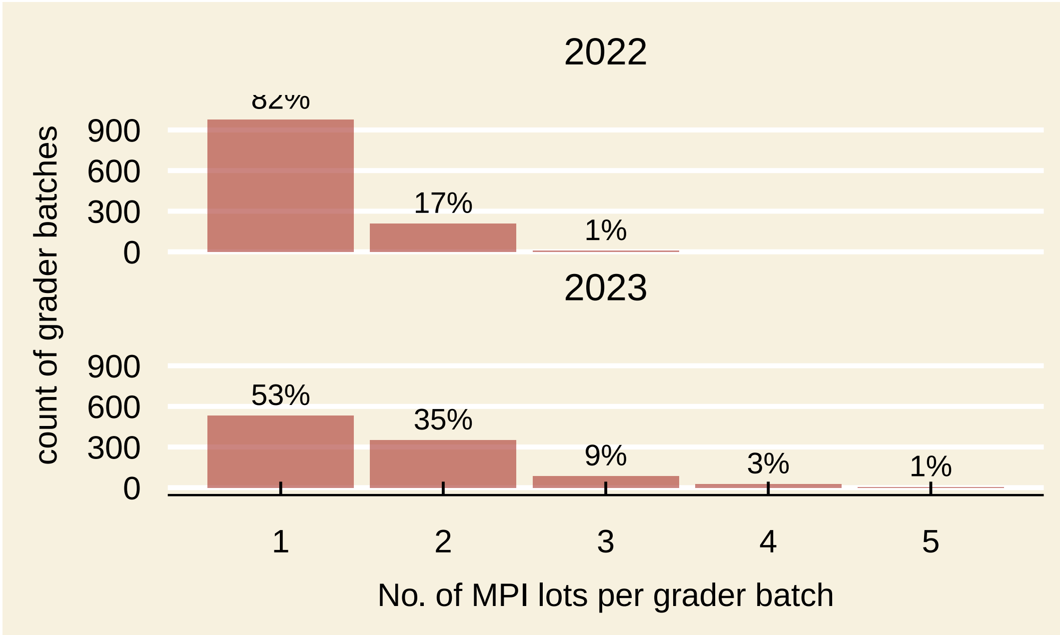


Figure 12.8: Comparison of number of MPI lots per grader batch for packing seasons 2022 and 2023

12.6 Conclusion

12.7 Glossary

13 defects and disorders

14 packhouse performance and the impact of automation

15 fruit size and SKU mix

16 stock on hand and inventory performance

17 in market quality

18 Summary

In summary, this book has no content whatsoever.

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19 Appendices

19.1 Growing degree days

$$GDD = \sum_{i}^{K} \frac{T_i^{max} + T_i^{min}}{2} - T^{base} \tag{19.1}$$

Where: $i =$ ith day
$K =$ total number of days summing over
$T_i^{max} =$ the maximum daily temperature on the ith days
$T_i^{min} =$ the minimum daily temperature on the ith day
$T^{base} =$ the base temperature for the model (in our case 10°C)

19.2 Chill units

The models used to predict chill requirement are empirically based and difficult to validate. Rockit tracks two models: Chilling hours and the Utah model (also known as Richardson Chill units). These are best described mathematically in equations Equation 19.2 and Equation 19.3 respectively.

$$CH_i = \sum_{i}^{t} T_{7.2} \text{ where } T_{7.2} = \begin{cases} 0^{\circ}C < T < 7.2^{\circ}C & : 1, \\ \text{else.} & : 0 \end{cases} \tag{19.2}$$

Where:
$i =$ ith hour
$t =$ total number of hours summing over

$$RCU_i = \sum_{i=1}^{t} T_U$$

$$\text{where } T_U = \begin{cases} T \leq 1.4^{\circ}C & : 0, \\ 1.4^{\circ}C < T \leq 2.4^{\circ}C & : 0.5, \\ 2.4^{\circ}C < T \leq 9.1^{\circ}C & : 1.0, \\ 9.1^{\circ}C < T \leq 12.4^{\circ}C & : 0.5, \\ 12.4^{\circ}C < T \leq 15.9^{\circ}C & : 0, \\ 15.9^{\circ}C < T \leq 18.0^{\circ}C & : -0.5, \\ T > 18.0^{\circ}C & : -1.0 \end{cases} \tag{19.3}$$

Where:
$i =$ ith hour
$t =$ total number of hours summing over

The chilling hours model takes the average temperature every hour and assigns an index of either one if the temperature is between $0^{\circ}C$ and $7.2^{\circ}C$ and zero if the temperature is outside that range. Daily totals are aggregated and the cumulative chill units over the dormant period are tallied. The Utah (Richardson) model uses a similar approach but provides weightings to various temperature ranges. These are detailed in equation Equation 19.3. Note that the weightings for the higher temperature ranges are negative which means that cumulative chill units can decrease as well increase; this reflects the reversible nature of the hormone accumulation in the apple buds (Sheard, Andrew G. 2001).

19.3 Yield modeling

19.3.1 Modeling of 3D Spindle yields

Yield for many biological systems can be described by a logistic growth model, slow to begin, a period of rapid growth then a period where the growth asymptotes to a steady state maximum value. A mathematical description of the logistic model is given in (Dykes, Stuart 2021). yield as a function of orchard age for planted, 3D spindle trees can be given Equation 19.4:

$$f(t) = \frac{L}{(1 + e^{-\alpha(x - x_0)})} \tag{19.4}$$

where:

$f(t)$ = yield as a function of orchard age
L = maximum asymptotic yield
α = rate constant
x = orchard age
x_0 = growth midpoint

Yield can be affected by a number of different influences, inter alia: the age of the trees, growing system, root-stock choice, seasonal effects and management decisions. In the analysis below yield is treated as a response, or outcome variable with orchard age as the principal predictor variable. The effects of growing system is accounted for by performing a separate analysis for the 2D and 3D canopies. The effect of top-grafted blocks has also been removed by only including planted orchards in the analysis.

19.3.2 Methodology

Yield is calculated simply by taking the total mass of fruit harvested (in tonnes) and dividing by the canopy hectares. No attempt has been made to correct for the effect of pick-out (the fruit that is left on the orchard floor or on the tree after harvest). Two analyses are carried out:

1. yield by individual block
2. yield by total orchard (RPIN)

The modeling was carried out using the non-linear least squares regression function as part or R's **stats** package (**R-base?**). The regression parameters and confidence intervals were calculated using non-parametric bootstraping through R's **nlsBoot** function from the **nlstools** package. All analysis code is contained within this markdown document.

The approach was to analyse the last three years of harvest data, 2020 through 2022. The first analysis was to examine block data (i.e. the sub-block of an orchard) which provide a greater data set but more variability, given block areas can be less that one hectare. The second analysis was to aggregate the blocks within an orchard together and calculate the orchard yield for the total orchard. This provides a more robust yield measurement as the orchard area will be larger than the block area, however, the inter-block variation is masked.

The final activity is an examination of the 2D canopy yield. There are currently four productive PremA96 orchards on a 2D canopy (planted in 2018 and 2019) and in 2021 only two data points were available making any prediction of terminal yield difficult.

The data used for all analysis was taken directly from the **ABCpacker** SQL Server tables using R's **odbc** and **DBI** packages. The data manipulation was carried out using the **tidyverse** package.