

Mapping Apple Quality Using Supply Chain Information

By

Matthew Dolan

Prepared for

KELLOGG RURAL LEADERS PROGRAMME

Lincoln University, New Zealand

2009

Contents

1. Introduction

2. Methodology

2.1 Research Method

2.2 Block Description

2.3 Harvest method

2.4 Postharvest process

2.5 Packing and Data Collection

2.6 Data Analysis

2.7 Considerations

3. Results

3.1 Fruit Size

3.2 Bitterpit and Lentical Blotch

4. Discussion of Results

4.1 Fruit Quality

4.2 Fruit Value

5. Conclusion

Acknowledgements

Appendices

Executive Summary

The Fresh Produce industry is by nature competitive, and the demand for high quality consistent products requires technologies and methods to describe and manage the high degree of variability which is inherent in Horticultural crops.

An opportunity exists to use Supply Chain Information to measure the quality and value of fruit, and a range of exploratory and Precision Horticulture methods may be used to create a higher level of understanding for growers than the existing reporting method.

In this study an orchard block was divided into sectors, and the position of harvest was noted for a sample of harvested field bins. At the time of packing, data collected from the fruit sizer, and quality control records, was analysed using exploratory statistical methods (e.g. residual analysis), and spatial maps. This provided information with a high level of meaning on which the grower could base his orchard practices in order to manage the factors underlying variation.

The real value of this information was realized when it was presented to the grower, and with his technical consultant further analysis of the block was undertaken. Specific recommendations were made to control a problem with tree vigour (branch growth) in the block and remedial actions were taken with a successful outcome.

1. Introduction

The use of simple statistics and spatial maps to describe patterns of variability in Pipfruit, provides an opportunity to display and explore complex quality data in simple and meaningful ways. The objective of this project is to explore the process of gathering and managing fruit quality data from the postharvest process, and producing simple analysis and maps which describe patterns of variation within the orchard. The information can be used as part of a simplified approach to Precision Horticulture.

The demand for high quality and consistent products in horticulture provides a unique set of challenges in managing the inherently high levels of biological variation. Consignments of export fruit are sourced from a range of growing and harvest conditions. However, the quality of packed fruit is required to fall within a narrow range, in order to meet the customer's expectations and specifications. Where high levels of variability are present in the harvested fruit, greater effort is required in the postharvest and sorting process. There is therefore a need to manage variation at its source - on the orchard.

Much of the effort and investment expended in the pipfruit supply chain is committed to managing variation, consequently, there is a large amount of data (Supply Chain Information) available to growers which describes this variability. However, little effort is currently made to utilise this information and describe variation back to growers.

Precision Horticulture principles have a role to play in managing crop variability. The approach of breaking large production areas down into smaller management units, enables growers to more accurately manage crop variability. There a valuable source of data for this type of approach from postharvest grading and quality control processes.

Pipfruit is biologically active and perishable, making the need for technologies and approaches and methods to measure and control variability compelling. The performance of horticultural supply chains can be measured to a large extent in terms of their ability to manage variability and deliver consistent products to its customers. Hewett (2003) describes 3 factors in relation to this, and which support greater efforts in gathering and sharing supply chain information;

- 1) Strategic alliances and transparency between partners, including sharing high quality information.
- 2) Human resource partnerships based on a common vision and commitment to excellence at all levels.
- 3) The availability and utilization of Information Technology systems to collect, order, and transfer information between partners. This includes sophisticated inventory systems, GPS, and tracking systems such as barcoding and RFID. (p.39).

In addition to this, there are a number of areas where information technology is advancing rapidly, which is changing the nature of information. As more technology is introduced into the supply chain, the amount and complexity of the information captured increases, creating greater opportunities for improvement, but requiring better processes and techniques to manage it. Praat et al, (2003) identified this technology as;

- Smarter inventory and tracking systems.
- GPS tracking, mapping, and RFID (radio frequency identification)
- Mobile, and real time data management devices
- More accurate postharvest handling and sorting systems.
- Technologies (including packaging) to reduce postharvest deterioration.
- Advanced sensing equipment linked to environmental controls

The challenge for any organization wishing to participate in successful large scale, or large distance supply chains in the fresh produce industry, is to understand these technologies and to continually assess and integrate them. It is also important to manage the complex nature of supply chain information, and provide appropriate solutions to ensure that supply partners are not left behind. The rate at which these technologies have been adopted into the horticulture supply chain has been slow. This is possibly due to the nature of the industry in which products are of often marginal value, the relatively small scale of growers and post harvest operators, and the complexity of multiple steps in the supply chain.

Currently the standard format for reporting post harvest quality information to a grower is a tabulated report including averages reported for key attributes such as fruit size, reject rate, and a summary of key defects identified at packing. (appendix 2) The increasing use of RF tagging systems, Geographic Information Systems (G.I.S.), and Near Infra Red (N.I.R.) technology enables rapid and precise tracking and measurements of fruit, and provides the spatial aspect to the information. Added to this, the use of ever more sophisticated and integrated Information Technology systems provides enormous potential to collate and transfer data in meaningful ways.

The transfer of supply chain information requires systems and techniques which are able to collect and collate information in challenging conditions in the field, industrial (post harvest) facilities, and retail environments. Much of this data already exists as a result of a range of quality tests, inventory transactions, sorting processes, and environmental sensor systems. Often the key driver for the collection of this data is to support phytosanitary, food safety, and traceability requirements from customers and regulators. (Praat J-P, et al, 2003) But the value of information is frequently diminished by poor transfer to producers. A real opportunity exists in relating data to the spatial area in which the product originated, and by presenting the information in a relevant and easy to interpret format (Praat, 2000).

2. Methodology

2.1. Research Method

This project explores techniques for measuring and describing variation in pipfruit quality and value using data generated during the packing process. By relating postharvest data back to its point of origin within the orchard block, the patterns of variation can be described in the form of spatial maps and exploratory graphs. It is hoped that in presenting data in this way it will provide greater meaning to the grower, and provide a starting point from which the patterns and sources of variation can be explored within the orchard. The existing method of reporting packing data in the form of tabulated average values for some key quality characteristics, masks the pattern of variation within the block (*appendix 1*). This approach has been reported in a number of research papers relating to Supply Chain Information (S.C.I) and Precision Horticulture. Of particular relevance is the work undertaken in 2003 by Lincoln Ventures Research engineer John Paul Praat et al, regarding spatial mapping of orchard profitability. The desired outcome is for a simple method of applying Precision Horticulture principles using Supply Chain Information and which is easily understood, and works with existing processes and equipment.

This approach to managing supply chain information is similar to Precision Horticulture (P.H.), in that it provides for large datasets from continuous, usually automated, sampling processes. In the case of Precision Agriculture, sampling is done directly in the orchard, using G.P.S technology to mark the position of a datapoint made by some form of sensing or sampling equipment. This discipline has been gaining recognition for a number of years, and is useful for measuring, primarily crop yield, but also static factors such as soil, environmental, or plant characteristics. In contrast, the Supply Chain Information approach provides a means of measuring harvested fruit, in which quality is continuing to change. This includes measurement of postharvest disorders which develop in storage. With the industrial nature of postharvest facilities, many types of measurements can be made at once, and under controlled conditions, e.g. defects, size, and

colour, utilising continuous, (batch or lot) sampling processes, as well as automated grading equipment capable of singulating and measuring individual fruit.

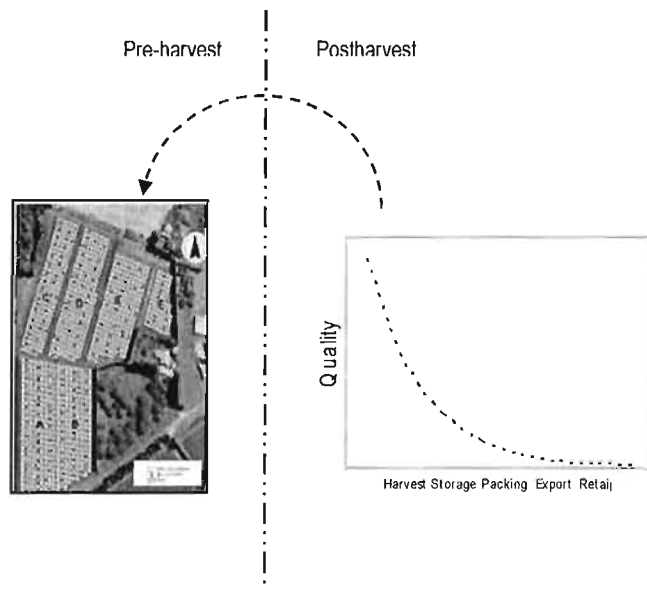


Fig 1. Data collected at packing includes measurement of disorders which have developed after harvest. These may be related spatially back to the production area and considered in relation to preharvest factors.

2.2. Block description:

The spatial mapping exercise presented here was undertaken at ENZAPak Ltd, in the Hawkes Bay. The block from which fruit was measured was from a local orchard and was selected due to its relatively large area, general appearance of consistent trees, and consistent topography and soil type (appendix 2). The production area had been severely affected by frost in the previous (2008) harvest season, and it was considered that this would result in some reduction in cropload and increase in fruit size in the current season.

Location: Napier, Hawkes Bay

Variety: Jazz™

Rootstock : M9 (semi-dwarfing)

Area: 3.85 Ha

Tree Spacing: 1.5m tree spacing x 3.5m row width (semi-intensive)

Planted: 2005

Harvest period: x 3 picks between

.

2.3 Harvesting process

The orchard block was divided into 3 sections identified as North, Middle and South. These areas are not equal in size, but are divided clearly by orchard tracks. Each section comprised 35 tree rows of unequal length. These were divided into 8 groups of 5 rows each, creating 24 sectors as follows;

| Rows Section | 1-5 (east) | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 |
|-----------------|---------------|------|-------|-------|-------|-------|-------|
| North | NA | NB | NC | ND | NE | NF | NG |
| Middle | MA | MB | MC | MD | ME | MF | MG |
| South | SA | SB | SC | SD | SE | SF | SG |

Fruit was harvested at commercial maturity, in 3 harvest events (picks) between 03. March – 23 March 2009. The harvesting operation utilised the orchards own staff and following standard harvest practice for the orchard. Only bins from the 2nd pick were included in the trial. As field bins (400kg) were harvested, the sector in which the fruit was picked was manually written on the bin card. Bins were harvested by a gang of 15 – 20 pickers, working (roughly) in a direction from South to North, and across from rows 1 to 35. Orchard Supervisors were

requested to move bins between rows in the same sector to minimise mixing of fruit between sectors, and where this was not achieved, the mixed bin was removed from the trial.

2.4. Post harvest Process

Harvested bins were transferred directly to a marshalling area in the orchard, where they were counted, carded and loaded onto a truck for delivery to the postharvest facility. The bins were allowed to move and mix through the submission and storage process in a normal manner.

At the point of submission at the postharvest site, a barcode label with details of the orchard identification number (Rpin), Block, Variety, and Harvest date, were attached to the bin.

After cooling to a storage temperature of 0.5C, (using a stepwise cooling method), bins were placed into storage lanes, and were physically segregated into their harvest sectors (e.g. NA, NB etc). A unique code (9 digit batch reference number) was assigned to each group of bins from the same orchard sector, and this batch identification number was physically attached to each group of bins. The segregated bins were held together in the same storage location until they were scheduled for packing.

2.5 Packing and Data Collection

At packing, the bins were placed into the water dump in order from NA – SG, with marker fruit (20 green Granny Smith apples) used to mark the point at which fruit from each new sector entered the packhouse. The time at which the last green marker apple entered the sizer was recorded, and this became the start time for which the size data was taken for a new sector. There was a natural degree of mixing of fruit between the end of packing of from one sector & the beginning of

the subsequent sector, and this was taken into account when defining the packing time for each sector.

Fruit were graded by hand over grading tables, rejecting any fruit with defects exceeding the export grade standard. Rejected fruit were sampled (n = 50 fruit) to provide a profile of the types and portions of each defect in the rejected fruit. The data for bitterpit was derived from this process by recording the level, and origin (orchard sector) of the disorder.

The average fruit size was continuously measured from individual fruit weights which were recorded on the packhouse Compac fruit sizer. A data point for average fruit size was taken at 2 minute intervals throughout packing, and the data was assigned to the orchard sector being packed at the time. For example, the fruit from sector 'North A' was packed over 18 minutes, achieving 9 data points for fruit size.



Figure 3: Compac Fruit sizer showing singulation of fruit and measurement of fruit size (grams) and colour area and type.

2.6. Data analysis

A sample of size and quality data was taken for each orchard sector, excluding data associated with the zones in which fruit from adjacent sectors mixed during packing, and to avoid data for the marker fruit. This data was associated back to the relevant orchard sector for statistical analysis and mapping.

Datapoints for average fruit size, and percent bitterpit were calculated for each orchard sector, and exploratory analysis was performed to measure variation within the orchard area, including distribution of the averages, residuals (% difference from the mean), and spatial, maps using ArcGIS.

The estimated value of fruit from each orchard sector was also calculated based on the yield, (number of export cartons / Ha), and the distribution of fruit size within each sector multiplied by the export \$ return per carton in the 2009 season.

2.7. Considerations

In order to identify the limitations of the existing process, fruit was allowed to move through the standard harvest and postharvest processes, with as little intervention as possible. The continuous movement of bins around the orchard block during the harvest process provided a challenge in ensuring that fruit was harvested within the same orchard sector. In addition to this, the extent to which bins are mixed as they are moved through the coolstorage process is great, and provides a challenge for ongoing development of this process. Identifying the location of harvest of bins was achieved using markings on bin cards, and tracking fruit in the post harvest was achieved using the standard inventory process in the coolstore. It is envisioned that technology such as RFID tags, and sensors could track the movement and location of bins in both the orchard and coolstores in the future.

A significant problem with bitterpit, a physiological postharvest disorder associated with fruit mineral levels during fruit development, emerged weeks after harvest. The incidence of bitterpit in the orchard block in the study was significant, and an opportunity arose to include this in the mapping process. This illustrates a valuable feature of supply chain information versus the P.H. approach, in that disorders which exhibit in the weeks after harvest can be measured and tracked back to the production area.

3. Results

3.1. Fruit Size

Fruit size data was summarized as the average size for each sector from raw data obtained from the Compac sizer. Each piece of fruit is singulated and weighed (grams) as it passes over an electronic scale micro cell. A weight range is defined to enable a certain number of fruit (count) to fill an 18.6 kg carton, and fruit is sorted into the appropriate carton filling lane for the assigned count. The average fruit size statistic is calculated continuously by the sizer's microprocessor as the portion of fruit of each count / by the total number of fruit. This data is displayed on the sizer screen, and also as a line graph with each point representing the average size for the previous minute of packing. The average size recorded for each orchard sector is the average size for the period in which fruit from the sector was being packed.

The 'average fruit size' statistic is used by growers to compare the sizes, and therefore value, of fruit between blocks, regions, or seasons. It is used in conjunction with a distribution curve (or size curve) of carton counts, ie the number, or portion, of cartons of each count, to calculate the value of fruit from a block. The average fruit size statistic reported to the grower and exporter represents an average for a packing run. Whilst this is adequate for small, or even blocks, it does not describe the variation in size often seen during a packing event.

Table 1: Size data shows that all sectors produced fruit the high value bands for fruit size (i.e. greater than size 100). An average fruit size of 96.4 was recorded for the block, and this is substantially higher than the Hawkes Bay average of Size 105.3 reported for Jazz™ in 2009.

| | A | B | C | D | E | F | G | Ave % |
|---------------|--------------|--------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <i>North</i> | 101.0 | 98.5 | 96.7 | 99.0 | 94.0 | 94.0 | 95.7 | 97.5 |
| <i>Middle</i> | 102.3 | 100.3 | 100.3 | 94.3 | 93.8 | 93.3 | 94.8 | 95.5 |
| <i>South</i> | 102.2 | 101.3 | 97.9 | 95.0 | 92.8 | 91.0 | 95.4 | 96.1 |
| Ave % | 101.8 | 100.0 | 98.3 | 96.1 | 93.5 | 92.8 | 95.3 | 96.4 |

Fruit size data indicates a high level of variation within the block. Differences between the sectors running north to south show a range of 5 size units, but without a clear pattern. However fruit size increases progressively from east to west with a range of 8 size units. Differences in fruit size, and the general pattern of variation was understood well by the grower prior to harvest. However, the extent of this variability is far greater than was expected, and is not signaled in the average data reported in the packhouse run reports.

Further exploration of the packing data for fruit size within each sector provides a better understanding of the level and pattern of variation within the orchard block. As the automated sorting process provides a large dataset, it is possible to explore the data further with the use of descriptive statistics and boxplots. This is not appropriate for data generated using acceptance or batch sampling procedures as the data set is normally small.

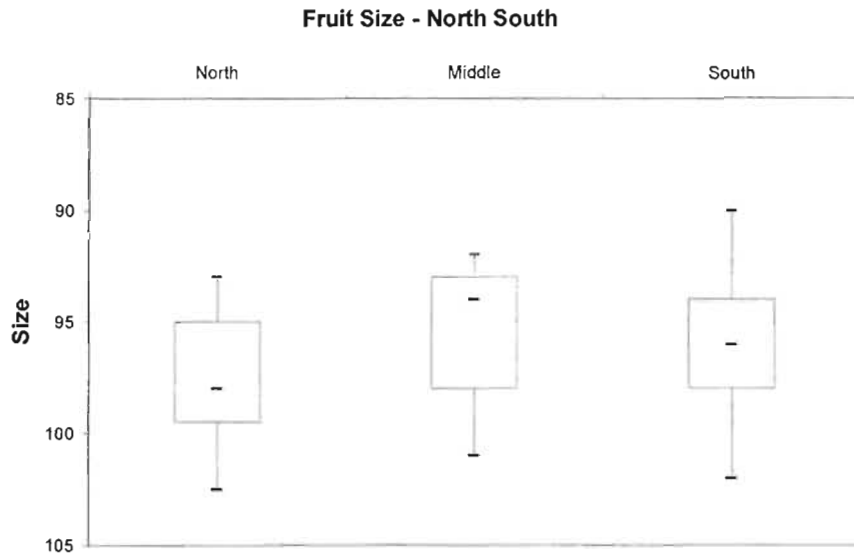


Figure 1: Boxplot display for fruit size in the North, Middle and South areas indicates that fruit size is relatively consistent despite larger differences in the mean fruit size.

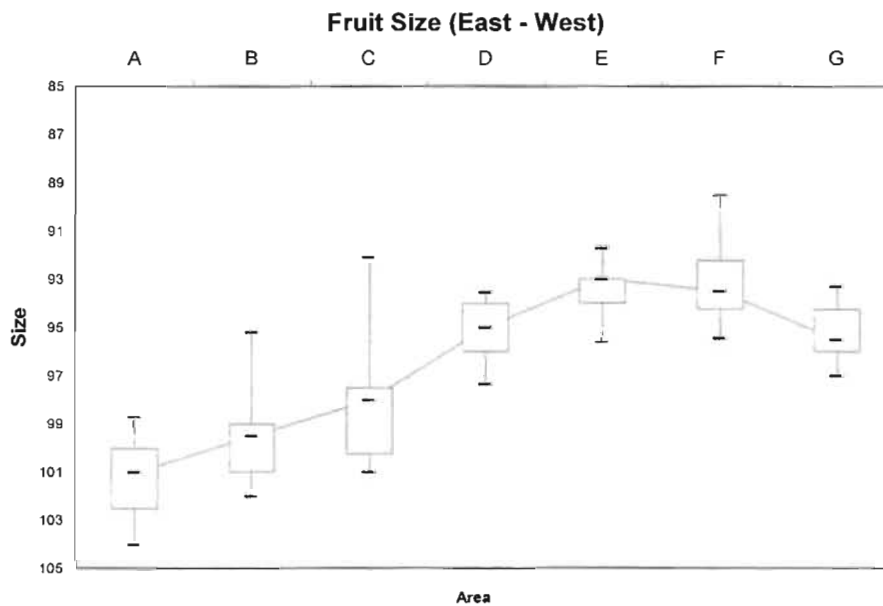


Figure 2: Fruit size from east to west across the block shows a greater amount of variation than North to South. In addition to this, the areas with the smallest

fruit (A – C) appear to show a greater amount of variation than those sectors with larger fruit (D – G).

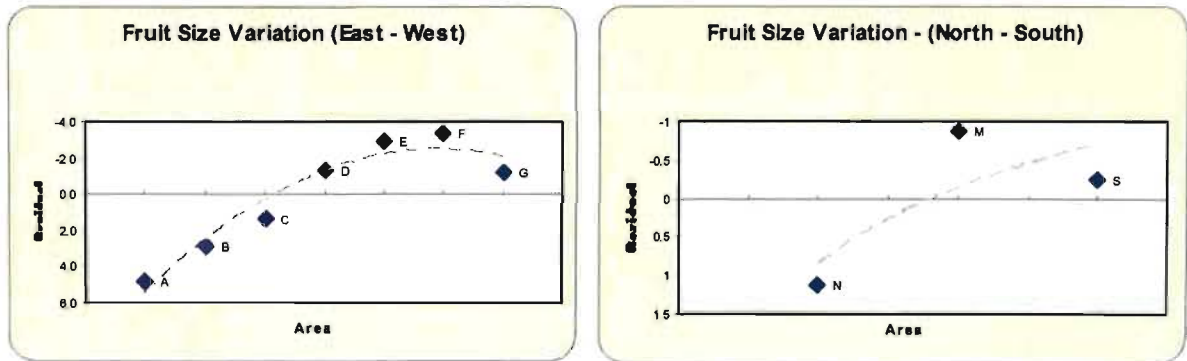


Figure 3: By grouping datapoints from the North – South, and then East – West directions, exploratory analysis can be undertaken for fruit size based on the difference from the mean, (i.e. the residuals). This method may highlight or emphasise patterns in size variation that exist. In this case the analysis confirms that there is greater variation in fruit size in the east to west direction than in the north to south direction.

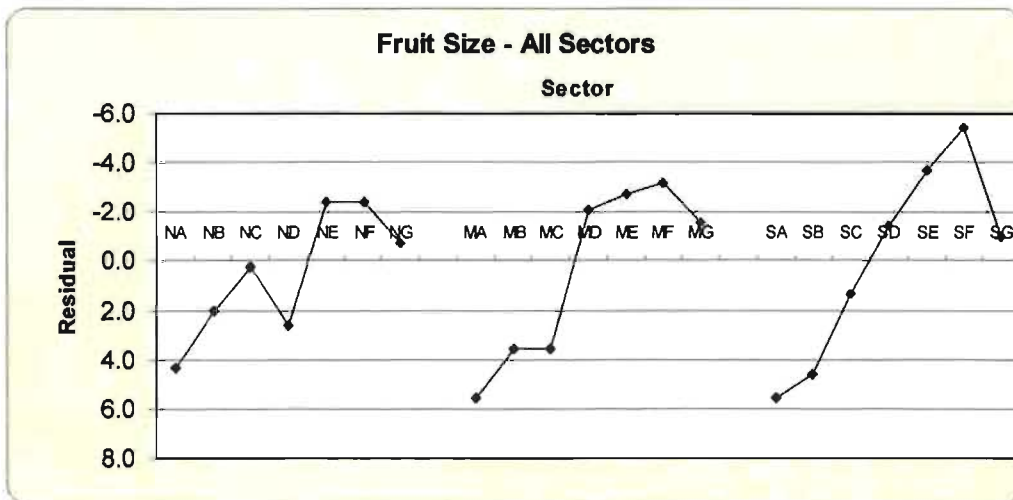


Figure 4: Exploring the residuals across each of the sectors in order provides the most informative analysis, as it shows the pattern of variation in all directions within the block. From this we can see that the north area of the block not only

produced the largest, and most even sized fruit, but also showed the lowest amount of size variation in the direction East – West. Sectors in the South end of the block had an average fruit size of 96.1, which is close to the average for the block, but shows the highest amount of variation within the area, indicating the possibility that orchard factors are affecting fruit size in that area.

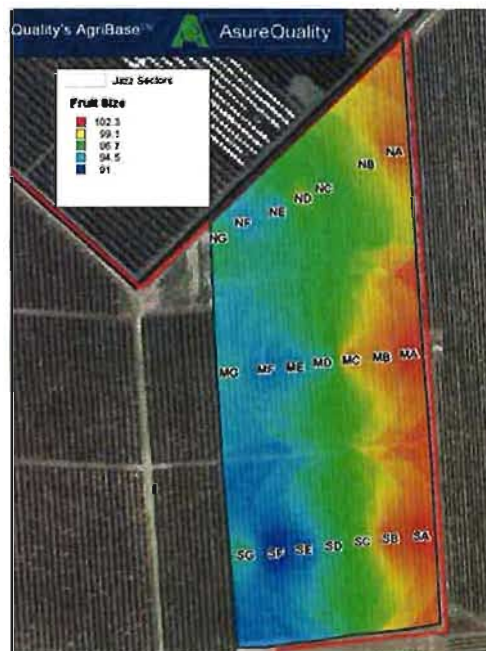


Figure 5: The Spatial Map for fruit size provides a clear means of visualizing the pattern of this variability. The patterns of fruit size are in line with the exploratory analysis of residuals above, but in addition to this, it provides more clearly defined pattern of fruit size within the block. Using this information the grower may elect to explore the factors which are contributing to this variation in fruit size, and concentrate any remedial efforts variably across the block in an east / west direction, while minimizing differences in management from North to South. The area in the South West of the block is of particular interest as it represents an isolated area of unusually large fruit.

3.2. Bitterpit and Lentical Blotch

Bitterpit and the associated disorder Lentical blotch (pit /blotch), are severe post harvest disorders in pipfruit. Localised breakdown of the flesh results in dark and sunken patches on the skin. The disorder normally develops after harvest, and there is often little sign of it before, or at the time of harvest.

The combination of factors underlying the causes of bitterpit are poorly understood, and the incidence of the disorder is erratic and difficult to predict. The extent and frequency in which the disorder appears in individual apple block varies within individual trees in a block, between trees within a block, and between seasons. It is widely understood that the incidence of pit – blotch is associated with mineral levels in the fruit flesh, and in particular the level of calcium. Measurement of bitterpit in the current study is of interest as the levels of the disorder in the Jazz™ variety in the 2009 season were exceptionally high in the Hawkes Bay region, including in the block under study. This provides an opportunity to consider a quality factor for which data is obtained via a manual inspection process, rather than from automated equipment. There are many other quality defects in pipfruit which could be reported using this process in conjunction with spatial mapping methods.

The data for pit /blotch was obtained from an inspection of rejected fruit. This is a standard packhouse operation in which fruit defects are categorised from samples of 50 rejected fruit. The % Pit Blotch is expressed as the portion of affected fruit in the field bin. The dataset for this type of sampling process is typically small. Therefore only simple analysis of this data can be undertaken.

Table 2: The levels of bitterpit across the orchard area are high relative to other similar blocks of Jazz™, and represent a significant loss in value for the crop. In a normal growing season, losses to bitterpit in Jazz™ would be expected to be

lower than 2%. However, the average levels in each sector ranged from 10.3% to 22.3% with an average of 16.4% for all sectors.

| | A | B | C | D | E | F | G | Ave % |
|---------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <i>North</i> | 14.0 | 10.3 | 14.4 | 20.9 | 16.0 | 17.5 | 12.2 | 14.9 |
| <i>Middle</i> | 15.0 | 16.0 | 19.9 | 22.3 | 17.8 | 21.0 | 19.8 | 18.5 |
| <i>South</i> | 13.0 | 14.3 | 13.0 | 14.3 | 18.9 | 19.5 | 17.8 | 15.8 |
| Ave % | 14.0 | 13.5 | 15.4 | 18.8 | 17.2 | 19.2 | 16.6 | 16.4 |

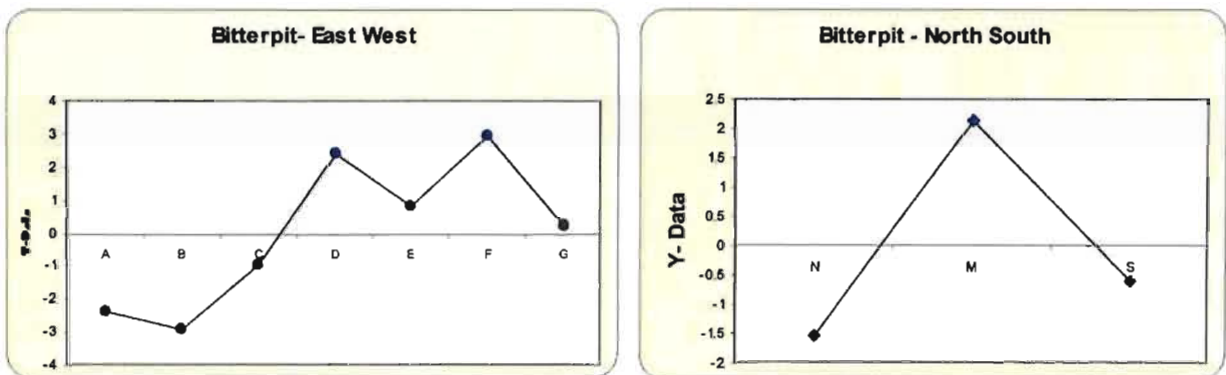
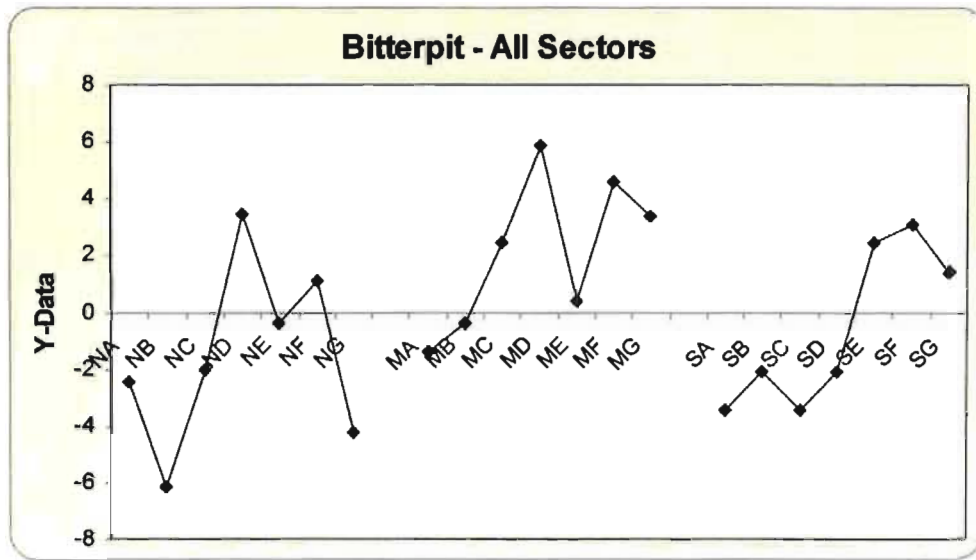


Figure 3: The incidence of bitterpit increases across the block from east to west, with the eastern blocks (A,B, and C) having similar and lower levels than the western side of the block (D, E, F and G). The middle area of the block has significantly higher levels than the North and South areas.



Analysis of the residuals all sectors in order also shows the pattern of increasing bitterpit levels from East to West, but also confirms the higher levels in the Middle areas (MA – MG).

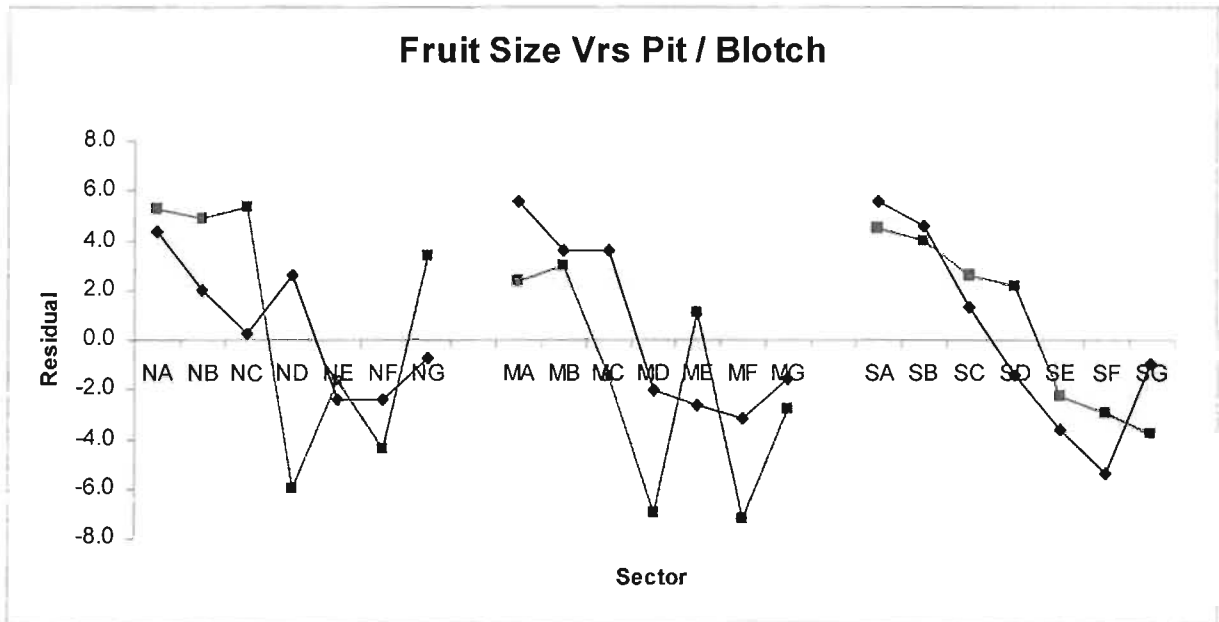


Figure 4. Comparison of the pattern of fruit size and Bitterpit incidence can be undertaken by overlaying the residuals for both factors. In this case the scale for fruit size has been reversed to show how large fruit size relates to high bitterpit incidence. This relationship is in line with the long held understanding that smaller fruit has lower incidence of bitterpit than larger fruit. This relationship is particularly strong in the sectors in the south area of the block. The factors underlying this could be explored by looking at factors known to contribute to both size and bitterpit incidence on the orchard.

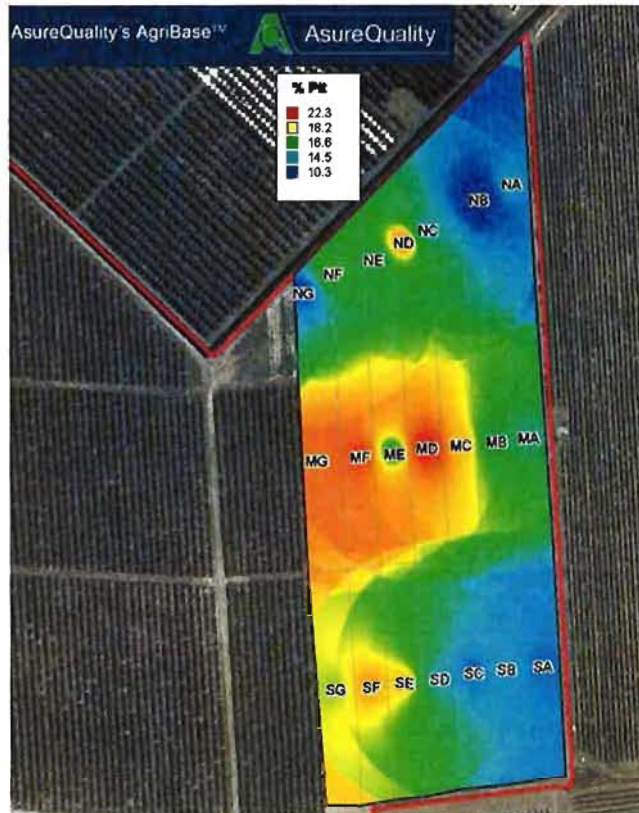


Figure 5. The Spatial Map shows the pattern for bitterpit incidence within the orchard block. The pattern follows a gradient increasing from 13% - 16% the eastern (A) sectors through to 19% – 22% the middle and south western areas of the block. The grower reported that the pattern of bitterpit matched closely to the pattern of damage from a significant frost event in the previous (2007) season.

4. Discussion of Results

Increasingly, supply chain data is being used in horticulture. Applying a spatial dimension to this data allows growers to identify variation in crop performance on the orchard, and the ability to apply more precise management practices in response to these patterns. This study explores a simple method of collecting and managing data in this way, and provides an example of how the data can be analysed using simple statistical methods, and visual maps, in order to present it in meaningful ways to growers.

The use of boxplots enables us to display the range and variation in fruit size and bitterpit damage across the blocks, and within sectors of the block. These reveal a large amount of variation both between and within the individual sectors, which would be of immediate interest to the grower. The boxplots also displays a degree of autocorrelation, meaning that areas in close proximity are more similar than those far apart. This is common in horticultural crops as the environmental factors affecting the plant tend to change gradually across an area.

The use of residual analysis, expressed as % difference from the mean, provides the starting point to explore relationships and patterns in pipfruit quality data. This method enables the reader to simply look for the patterns in the data without having to consider the units of measurement or the scale of the axis. This is useful as it allows easy comparison of unrelated, or unequal, factors.

Both the boxplot and residual analysis are exploratory, and where a pattern or trend appears to be of interest it can be explored further. In addition to this, surface response charts of the data presents these patterns visually, which adds to the ease in which the information can be understood by growers.

4.1 Fruit Quality

The spatial data from this work was passed onto the Grower and his Technical Consultant, John Wilton (Agfirst Ltd) and was used in a subsequent study of the factors underlying the incidence of Pit/blotch within the block. In this work, annual shoot growth (tree vigour) was measured within each of the block sectors, and compared to the level of Pit/Blotch from that sector. The length of branch extension growth (cm) was measured from the largest branches within the tree. From this the number of new shoots with length greater than 30cm were counted. The results show a particularly strong relationship ($R^2 = 94.7\%$) in which the level of Pit/Blotch is explained by the number of shoots per branch greater than 30 cm. (Wilton .J. 2009)

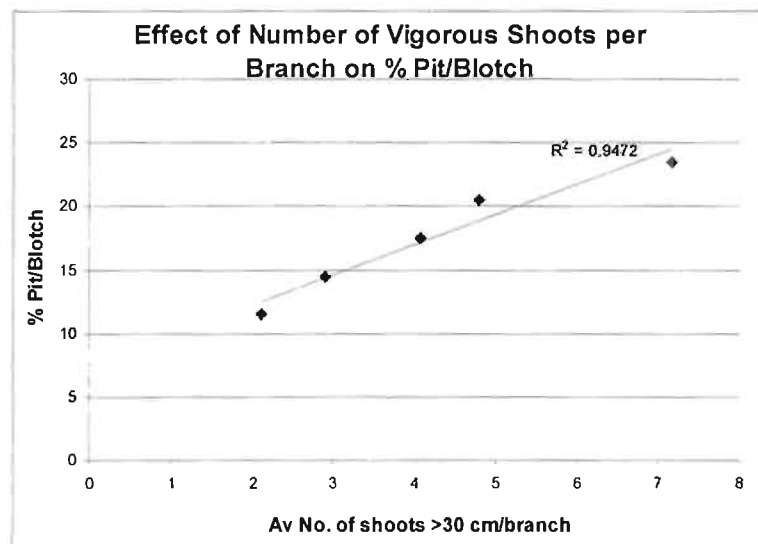


Figure 6: The effect of shoot growth on the incidence of pit/Blotch showing the average number of shoots with extension growth greater than 30cm.

Recommendations were made to the grower that average shoot extension should not exceed 20cm per branch, in order to maintain Pit/Blotch levels below 5%. To achieve this, it was recommended that vigorous branches be identified and treated as follows:

- Removed by pruning
- Training into a pendant position
- Summer pruned to devigorate
- Increase crop load to soak up surplus photosynthate reserves.

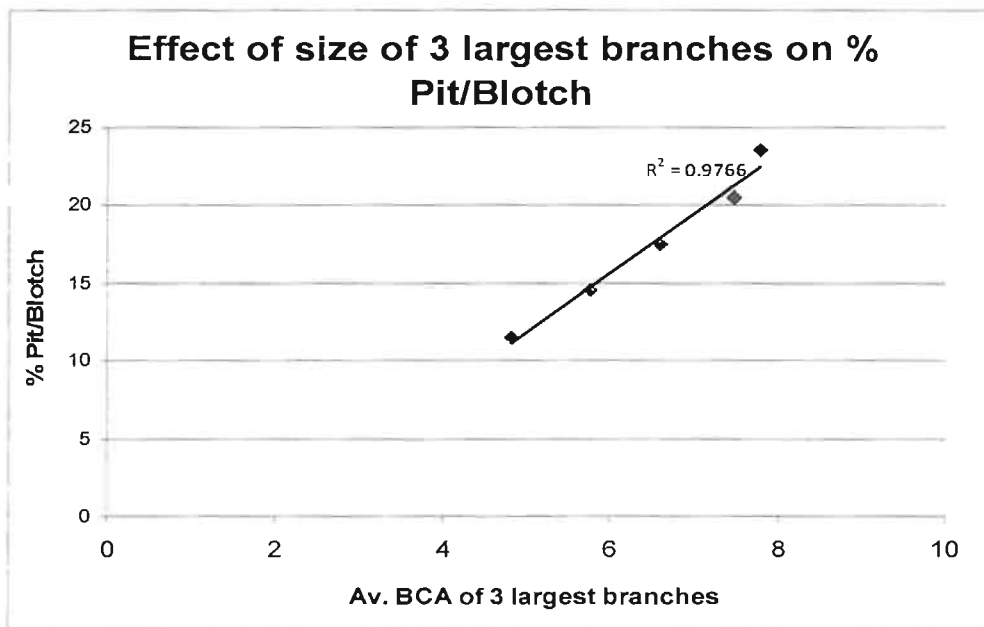


Figure 5: Measurement of the branch cross sectional area (BCA cm^2) of the 5 largest branches in relation to Pit/Blotch incidence (Wilton J, 2009)

The incidence of Pit/ Blotch in relation to branch size also shows a strong relationship ($R^2 = 97.7\%$) with the highest levels of damage occurring in trees with larger branches. Branch size is measured as Branch Cross section Area (BCA cm^2) as a ratio of branch length (m). From this relationship a recommendation

was made to remove all branches within the tree with ratio of 1.75 cm² BCA per meter of branch length.

The spatial pattern for Pit/Blotch and tree vigour corresponds closely with the pattern of frost damage in the 2007 growing season. It is likely that fruit affected by Pit / Blotch was from large and vigorous branches within trees. It is believed that root cause of this vigour was de-cropping of the trees through frost damage in the previous season resulting in a buildup of carbohydrate reserves in the tree. It is expected that this affect, and the resulting high levels of Pit/ Blotch would continue in subsequent seasons unless remedial actions are taken to control vigour. With this, recommendations were made to the grower, including;

- Root pruning
- Trunk girdling
- Regulated deficit irrigation (RDI)
- Use of growth regulators



Figure 6: Excessive tree vigour (left), a situation in which mineral and photosynthate resources are sacrificed from fruit to support new tree growth. Low vigour trees (right) in which the fruit can be easily seen.

4.2 Fruit value

The three most important orchard factors determining fruit value for Jazz™ are 1) Yield, 2) Size, and 3) Pack out. (nb: Jazz™ is not graded into colour bands). Fruit yield within each sector is difficult to measure, due to the movement of partially filled bins between sectors during harvest. Therefore, the yield for the entire block (39 tonnes / ha), has been applied to each sector for the calculation of a theoretical fruit value.

Fruit size is described in terms of 'count'. This is the number of fruit required to fill a standard sized carton to 18.3kg. For the majority of varieties, including Jazz™, larger counts relate to higher value. For this analysis, a size distribution curve showing the number of cartons of each count, has been calculated from the average fruit size data for each sectors. Gross return was then be calculated based on the number of cartons in each count, multiplied by the \$ export return

for that count. Finally, production costs were deducted using rates based on an industry model to provide an estimate for net return / hectare.

Table 3 shows the estimated value of fruit from each sector as net return (\$) / hectare. This calculation of value is based on the number of cartons of each size (count), multiplied by the export return for each of the sizes, less the costs of production. (Orchardnet; 2009)

| | A | B | C | D | E | F | G | Ave % |
|---------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| <i>North</i> | \$21,081 | \$21,703 | \$23,101 | \$15,775 | \$20,770 | \$18,947 | \$19,250 | \$20,090 |
| <i>Middle</i> | \$18,839 | \$20,434 | \$17,935 | \$17,479 | \$22,133 | \$18,094 | \$19,421 | \$19,191 |
| <i>South</i> | \$19,098 | \$20,042 | \$20,075 | \$22,224 | \$21,018 | \$20,840 | \$18,826 | \$20,430 |
| Ave % | \$19,967 | \$20,726 | \$20,370 | \$18,493 | \$21,307 | \$19,294 | \$19,166 | |

There is a well accepted relationship between fruit size and yield in which lower yields result in larger fruit, and vice versa. This is due largely to competition between fruit which draw on finite resources within the tree. The relationship shown between fruit size and the incidence of quality disorders shown in figure 4 is also well understood. The main effects between these factors is complex, and management of any one of the factors results in a trade off in terms of either fruit value, yield, or production costs. It is therefore valuable to have a means of quantifying and expressing the outcome of these orchard factors using visual techniques.

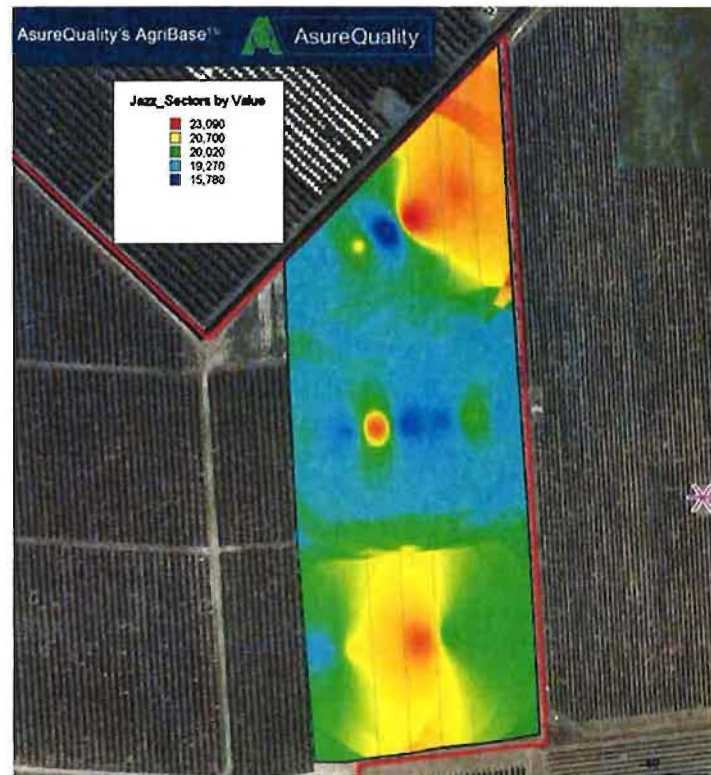


Figure 7 shows the pattern of fruit value from the export \$ return achieved at packing. The areas in the south of the block are shown to have the highest value. These areas produced the largest fruit, but with the lowest pack outs due to higher levels of bitterpit. It appears that the advantage of greater fruit size in this part of the block outweighed the negative impact of the higher incidence of the disorder.

The mapping technique is successful in showing the pattern and level of variation in fruit value within the block. This relationship is complex and difficult to describe and understand using the basic average data available to growers in the existing reporting system. This type of information could provide the basis for further analysis of the optimum cropload to achieve the yield and size combination which maximizes net return, whilst taking into account the effects of potential losses due to postharvest quality. This cost – benefit approach would enable the grower to consider a range of remedial actions within the block and

over time, and compare the outcome of their actions relating to the management of the crop.

5. Conclusion

Producing exploratory graphs and spatial maps of fruit quality and value from packing data, can improve its meaning and provide valuable information to growers. By adding a spatial dimension to postharvest data growers can easily visualise patterns of variability in their orchard blocks. Although the uptake of precision horticulture techniques has advanced only slowly in recent years, the amount of information available to growers about the performance and profitability of their crops is increasing. With this, techniques are now needed to make this information available to growers in simple and meaningful ways.

The techniques described here have potential as a tool for calculating and describing variation within orchard blocks, using Supply Chain Data which is currently not used. The ongoing development of such techniques has a number of limitations including the cost and effort required in sorting and segregating bins from areas of the orchard, and the time required in obtaining and analysing the packing data. It is possible the solutions to these issues may be available in the future through software development and the implementation of RFID technology, however the current cost of these is prohibitive for any individual orchard or packhouse.

This type of information is intended to provide only part of the information a grower might obtain in order to make production decisions on the orchard. It can only supplement the growers own knowledge of their orchards and the effects of one action over another. In this case, the greatest value from the data was derived when it was provided to the orchardist and his regular consultant.

It is important that changes in husbandry practices are based on the consistent relationships which may be found over a number of seasons, and by measuring the effects of different practices and approaches to crop management. In this case the main influence on the value of the crop appears to be from the ongoing effects of a frost event in 2007. There is however, greater value in the ongoing monitoring of the block to find the consistent and underlying patterns of variation over a number of seasons, and to be able to measure improvements in the overall performance of the block as new techniques and practices are applied.

Acknowledgements

My thanks to ENZA Ltd for supporting me throughout the year in the Kelloggs Rural Leaders Programme. Carl Fariey from Waimea Orchards, for providing me with his time, and access to his orchard block. James Ellis, ENZAPak Packhouse Manager, for his patients and allowing me to run my trial during his production time. Ben Rimmer, ENZA Account Manager, for logistical assistance. Quentin Huggins, ASUREQuality Ltd, for his excellent work mapping the quality data in Arc GIS. John Wilton & Ross Wilson, Agfirst Ltd, for their valuable information on tree vigour and bitterpit, and the use of the 'Orchardnet' online software for calculating fruit value. But mostly, I thank my wife Melanie for her incredible patience during the completion of this project.

References

- Abbott J.A. Quality measurement of fruit and vegetables. *Postharvest Biology and Technology* 15 (1999) 207 – 225
- Agfirst Hawkes Bay Ltd. (2009). *Improving Jazz™ Productivity*. Wilton, J.; Author.
- Hewett, E. 2003 Perceptions of Supply Chain management for Perishable Horticultural Crops: *Acta Hort* 604, ISHS 2003.
- Praat, J.P., et al. 2003 Using Supply Chain Information: Mapping Pipfruit and Kiwifruit Quality. *Acta Hort*. 604.
- Praat, J.L., Bollen, F. & Whigham, P.A. (Eds.). (2000). Proceedings of the 12th Annual Colloquium of the Spatial Information Research Centre: *Integration of data sources and visualization for Apple Production*. Retrieved from <http://www.business.otago.ac.nz/SIRC/conferences/index2000.html>
- Schuster E.W. 2009. Agricultural Supply Chains: Track and Trace for Improved Food Safety. *Acta Hort*. 824.
- Whigham, P.A. (ed.). (2001). Proceedings: Sircumnavigation: Where have we been? Where are we going?, Thirteenth Annual Colloquium of the Spatial Information Research Centre. *Spatial Variabilty of Fruit Quality*. Praat, J.P., Mowat, A. & Amos, N. pp.23-30. Retrieved from <http://www.business.otago.ac.nz/SIRC/conferences/index2001.html>

Appendices

Appendix 1

Packing report, summarising key statistics for fruit value and defects, generated from a packing event.

Quality Summary

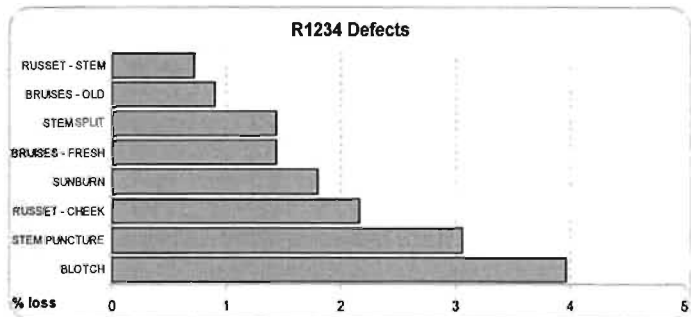
R1234

| Variety | Block | Area | Bins | TCE | PO% | Size |
|---------|-------|------|------|------|-----|------|
| Jazz™ | A | B | 108 | 2112 | 84% | 105 |

Note; Defects are calculated as a % of the field bin rejected at the point of grading.

Defect Analysis

| | |
|-----------------|-----|
| BLOTCH | 4.0 |
| STEM PUNCTURE | 3.1 |
| RUSSET - CHEEK | 2.2 |
| SUNBURN | 1.8 |
| BRUISES - FRESH | 1.4 |
| STEM SPLIT | 1.4 |
| BRUISES - OLD | 0.9 |
| RUSSET - STEM | 0.7 |
| BLEMISH | 0.5 |



Appendix 2:

Orchard block aerial map with sectors.

