Automated Crop Estimation
Measuring tension on the trellis wire

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Introduction

Accurate yield estimation is essential along all stages of the supply chain, from harvest intake logistics through to wine marketing and sales forecasting. The ramifications along the supply chain have meant that investigating new yield estimation methods is critical to the integrity of planning and business profitability for the Yalumba Wine Company. Furthermore, the economic benefits of improved crop estimation are substantial, with conservative estimates in the order of tens of millions of dollars annually (Clingeleffer, 2001). There are also indirect benefits in vineyard and winery waste reductions, improving vineyard management and operational efficiency, irrigation and intake scheduling, wine making and accurate demand and supply forecasts.

Yalumba's current crop estimation technique

After harvest, canes are collected and buds are dissected under a microscope to determine the number of fruiting structures per bud and bud viability; thus indicating potential bunch numbers. Yalumba's bud dissections are used as a tool for adjusting pruning levels in years showing poor fruitfulness.

After the vines have been pruned, the bud numbers remaining on the vine are counted to establish the average bud number per vine; thus indicating the potential number of shoots that will burst in spring. When the new flower (fruit) has emerged (~October) the fruiting structures are counted in order to identify any/the correlation between the bud dissection results with actual bunch numbers per shoot (Smith, 2003). Once bunch numbers have been defined, bunch weight measurements are used to provide the final crop estimate. Bunch weights represent the greatest source for error (Dunn et.al, 2003).

Approximately two weeks after veraison (~February), vines are stripped of all bunches, which are weighed to determine fruit weight per vine. However, in order to establish an acceptable sample size in any given block, a large number of vines need to be stripped. This destructive method is costly and time-consuming and the results do not provide sufficient accuracy, within 20%.

Current estimation costs

Bud Dissection: One person at $25 per hour to sample, conduct bud dissections and to collate data for a total vineyard area of 250 Ha costs
$2000

Bunch Counting at 8 leaf stage: One person at $25 per hour for 130 blocks (4 blocks/hr) over 250 Ha of vineyard costs
$1200

Bunch stripping between veraison and harvest: Two people at $25 per hour for 130 blocks over 250 Ha (10 vines per block = 1hr).
$6500

Total cost for a growing season (on 250Ha) is $9700

Yalumba grower's current crop estimation technique

Due to growers having limited time to invest in crop estimation, a less demanding approach is taken. When bunches are visible, around 8 leaf stage, bunches are counted as approximately 60% of crop estimation variation is due to bunch number per vine (Dokoozlian, N, 2008). The winery receives the first estimate in December and these are compared to the current season bunch counts.

Between veraison and harvest bunch weight records are taken to predict a trend. At the time of harvest a few rows are selected to harvest providing a final indication of crop level in which the winery is notified. However, by maintaining a database of bunch counts and weights and knowing your vineyard in combination of matching up estimates with historical climatic events, such as wet and dry years, some Yalumba growers tend to be reasonably close to their final crop estimates. However, there are also a number who are significantly out.

Issues and outcomes

The current estimation methods in our Yalumba vineyards are costly and time-consuming and the level of accuracy between estimated tonnages versus actual are often inadequate. The issues in estimating above or below actual include:

Under-estimates:

- Winery processing problems and inadequate tank allocation
- Increased labour cost
- Wine surplus creates more pressure on sales and marketing
- Reduced grape prices to growers and or grapes uncontracted to wineries
- Increased waste and what to do with excess (Environmental issues)

Over-estimates:

- Unfilled tanks at the winery, increasing the $/L in production costs
- Wineries require extra capital for wine production. e.g. oak barrels
- Putting casual labour off earlier during harvest
- Upsets market forecasting on a domestic and global scale
- Potential loss of overseas markets as demand has not been met

Trellis tension technology

Trellis tension is an automated form of yield estimation by measuring the tension on the trellis wire. It works through measuring the tension on the wire as the vine grows. As bunches increase in size and weight, the increase can then be related to the increase in wire tension (Figure 1).

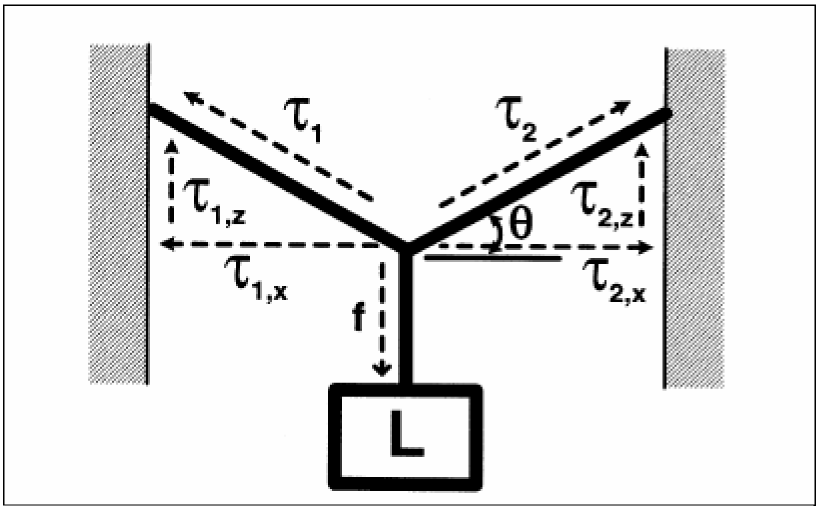

Figure 1. Free body diagram of an idealized trellis system where the vine is a load (L) hanging from a wire that is strung between two fixed end posts. The tension (τ) in the wire is resolved into horizontal (x) and vertical (z) components. The angle (θ) between the wire and the horizontal is a primary determinant of the sensitivity of the system to a change in load, resulting in the tensile force (f) applied by the load.

The system involves a continuous measurement of the tension in the trellis wire, with the conversion of the data output into a crop estimate. Other factors such as environmental effects on the wire including temperature and wind have been accounted for in the tension measurement process, which has resulted in acceptable accuracy on a single wire trellis system (Tarara et. al, 2004).

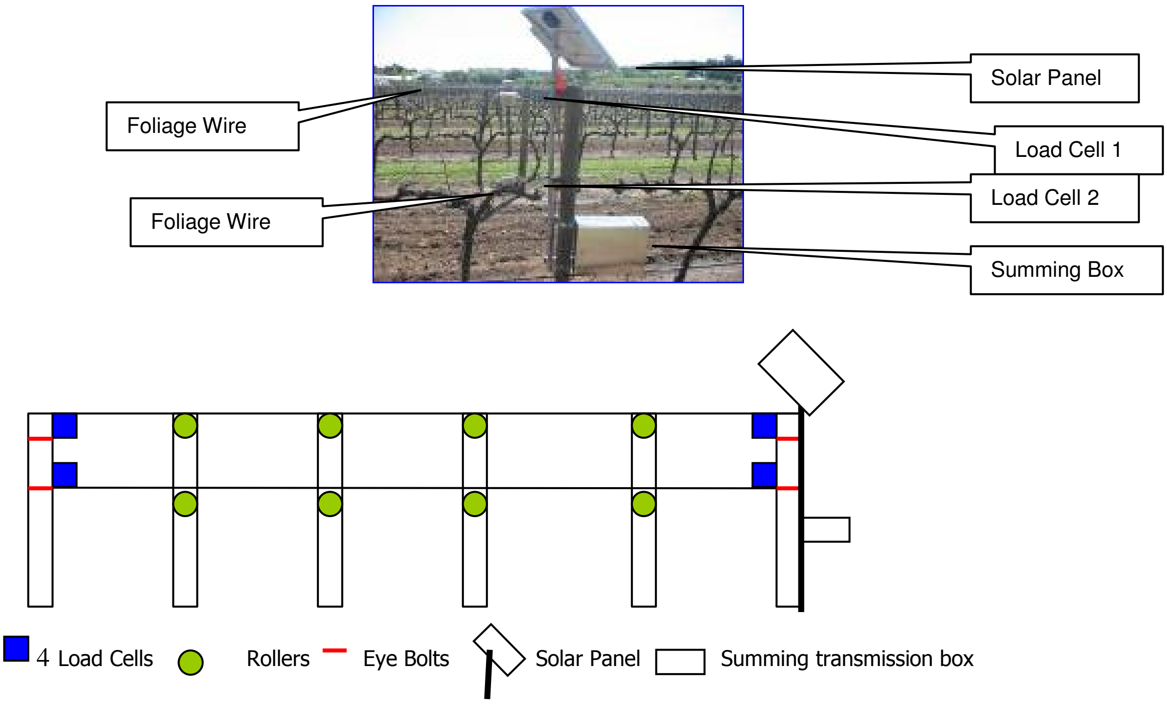

Figure 2: Four load cells, rollers, summing transmission box and solar panel are installed across five panels within the block.

How the system works

The tension on the load cells creates a small voltage which is transmitted to a weight transmitter (Figure 2). A signal from the weight transmitter is sent to the DT50 Data taker. By using the data taker program the milliamps were scaled to the weight of the load cells to express the reading in kilograms.

Two thermocouples are installed which take temperature readings for the top and bottom trellis wires. The whole setup is powered by a solar panel that charges a 12VDC sealed lead acid battery. All components are housed within a rugged stainless steel box attached to a post. Every hour the program takes a reading and all the data was stored on a 1Meg memory card supplied with the DT50 Data taker. The data was obtained in a tabulated format for easy manipulation when exporting to Microsoft Excel spreadsheet.

Treatments were set up in areas representative of the block with the first treatment located in a low vigour section and the second in the high vigour area. Biomass maps were used for site selection of treatments

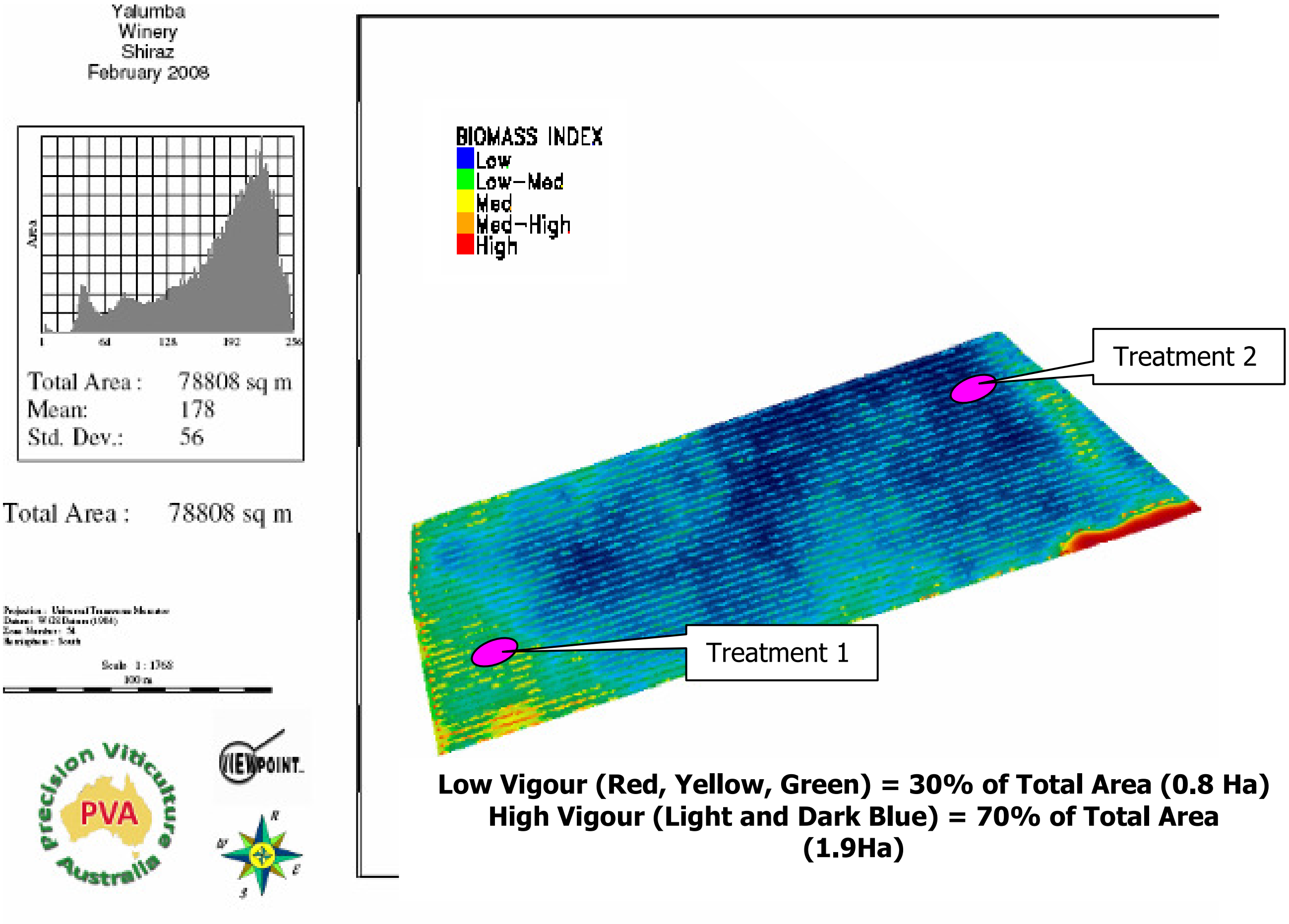

Figure 3: GIS View point program was used to separate vigour components with the 'fly over' occurring at veraison.

Data Collection

Data was downloaded on a weekly basis via a continuous measurement program and was set to take tension readings from top and bottom wires, expressed in newtons (N) together with temperature, °C from thermocouples for temperature adjustment on a continual hourly basis. Due to contraction and expansion of the wire via temperature influences, readings were temperature corrected.

Tension corrected = [tension uncorrected (N)] + [(Mean Monthly temperature °C – Average weekly wire temperature)] x slope

At berries pea size, veraison and just prior to harvest, fruit to foliage weight ratios were established.

Table 1: High Vigour Area 1.9Ha~ Canopy (kg) and bunch weight (kg) per vine breakdown

Stage	Foliage (kg)	%	Bunches (kg)	%
Pea size (5mm diameter) - EL-31	3.0	7.03	0.2	0.47
Veraison (50%) EL-36	4.3	8.97	4.2	8.76
Harvest	3.6	7.42	5.5	11.33

Table 2: Low Vigour Area 0.8Ha ~ Canopy (kg) and bunch weight (kg) per vine breakdown

Stage	Foliage (kg)	%	Bunches (kg)	%
Pea size (5mm diameter) - EL-31	5.2	9.59	2.0	3.69
Veraison (50%) EL-36	5.3	8.97	6.8	11.51
Harvest	5.5	8.70	10.7	16.93

Results

The following two tables represent crop estimation comparisons made between our current method adopted at Yalumba and trellis tension technology over the past two growing seasons with trellis tension showing significant accuracy improvement and potential. In the growing season of 2006-2007, the percentage difference between estimated versus actual picked tonnes was 4.85% for the trellis tension method and 19.9% for the current method adopted. A similar result occurred in the 2007-2008 growing season.

Table 3: Accuracy of Trellis tension versus the 'Yalumba Method'

Year	Crop Est Method	Estimated Tonnes	Actual picked tonnes	% Diff
2006/2007	Current Method	37.8	30.3	**19.9**
2006/2007	Trellis tension	28.84	30.3	**4.85**

Year	Crop Est Method	Estimated Tonnes	Actual picked tonnes	% Diff
2007/2008	Current Method	38.3	33.82	**11.7**
2007/2008	Trellis tension	36.07	33.82	**6.23**

Below are three figures representing load cell readings plotted against time in a growing season. There are responses of vine weight increases from irrigations and rainfall events which enabled us to use this data as another irrigation scheduling and water saving tool.

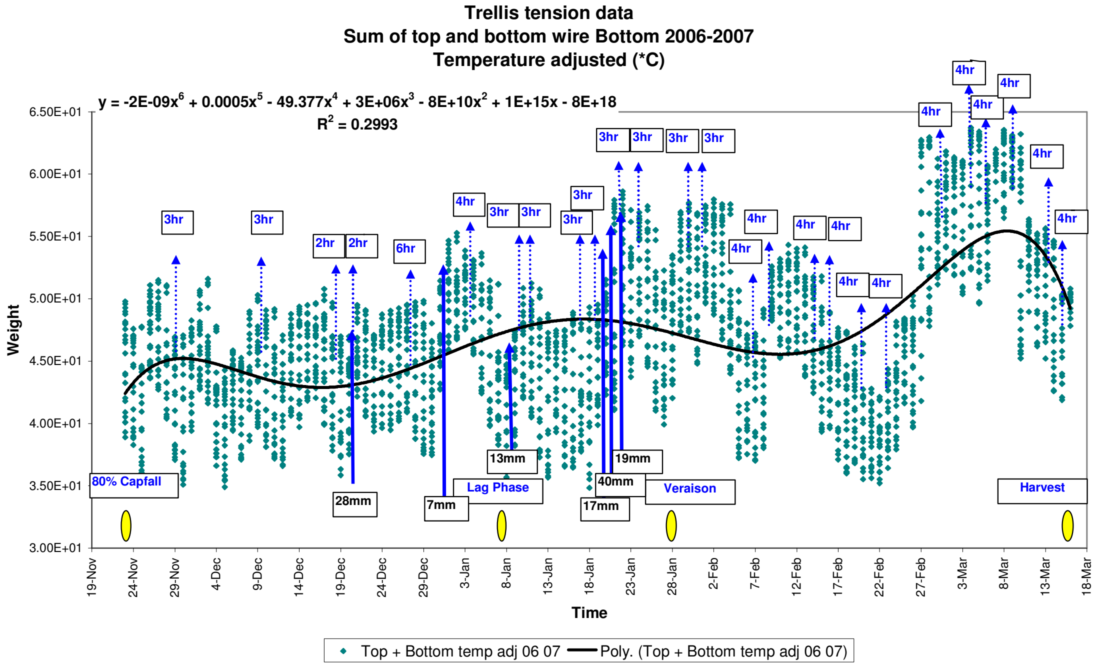

Figure 4: Response to rainfall, phenology and irrigation; load cell readings – response to 2, 3 and 4 hour irrigations and rainfall events occurring in growing season 2006-2007 with phenology stages. The bolded blue arrows represent rainfall events and the dotted blue arrows indicate when 26 irrigations were applied.

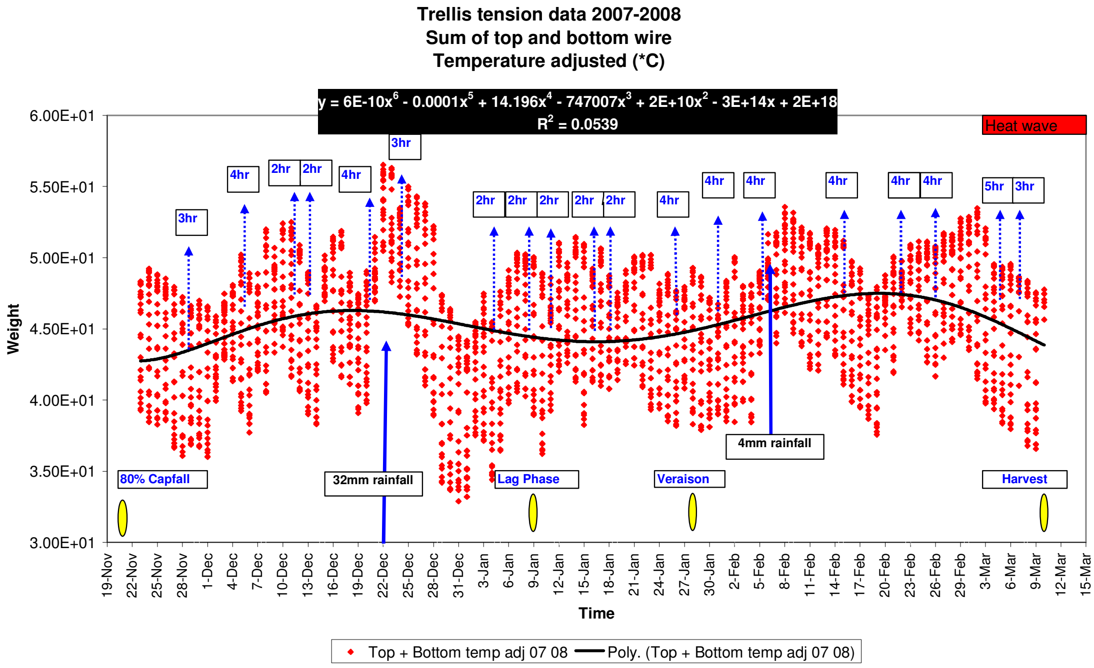

Figure 5: Note in 2007-2008, phenology stages were approximately 10 days early, reducing applied irrigations. Nineteen irrigations were applied, despite less rainfall events. However, winter 2007 rainfall was much greater than winter 2006 rainfall.

In growing season 2007-2008 we applied seven irrigations less than in the 2006-2007 growing season, saving water. The figure below represents how irrigations can be managed during a heat wave event by maintaining a uniform canopy and bunch weight right up until harvest.

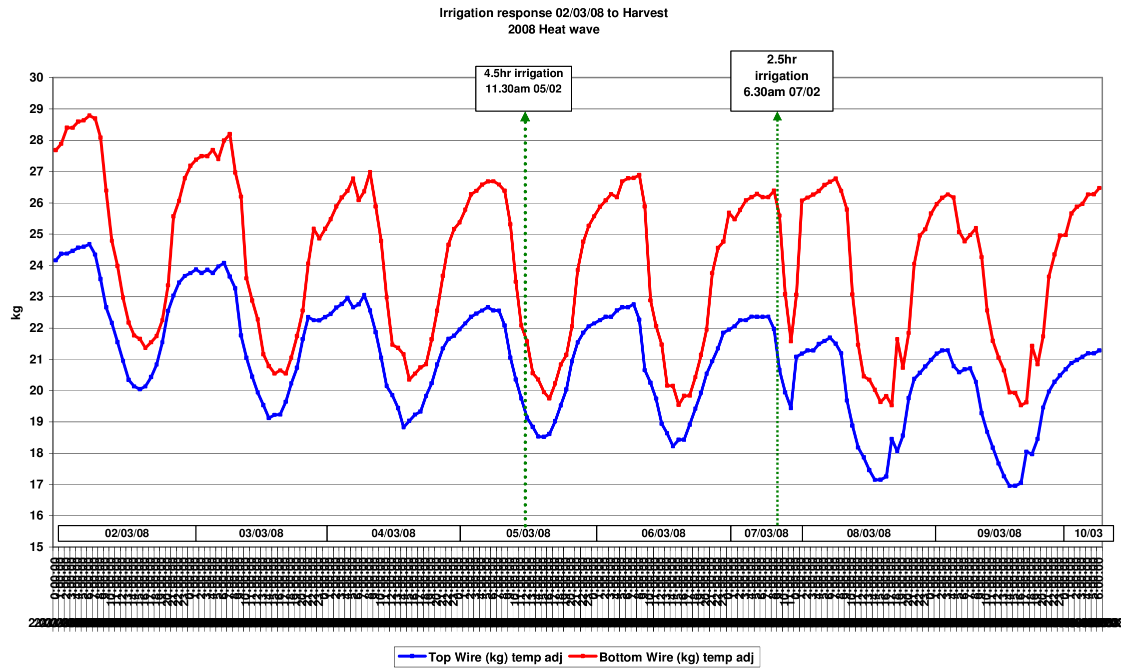

Figure 6: Irrigations that took place during the March 2008 heatwave (02/03/08 until harvest). The foliage and crop weight decline rapidly between 02/03/08 and 04/03/08. Four hour irrigations maintained vine canopy and bunch weight until harvest.

This graph represents load cell readings plotted against time of the day and the data is being used to provide understanding of diurnal variation and can be used to select harvest date by matching desired tonnage.

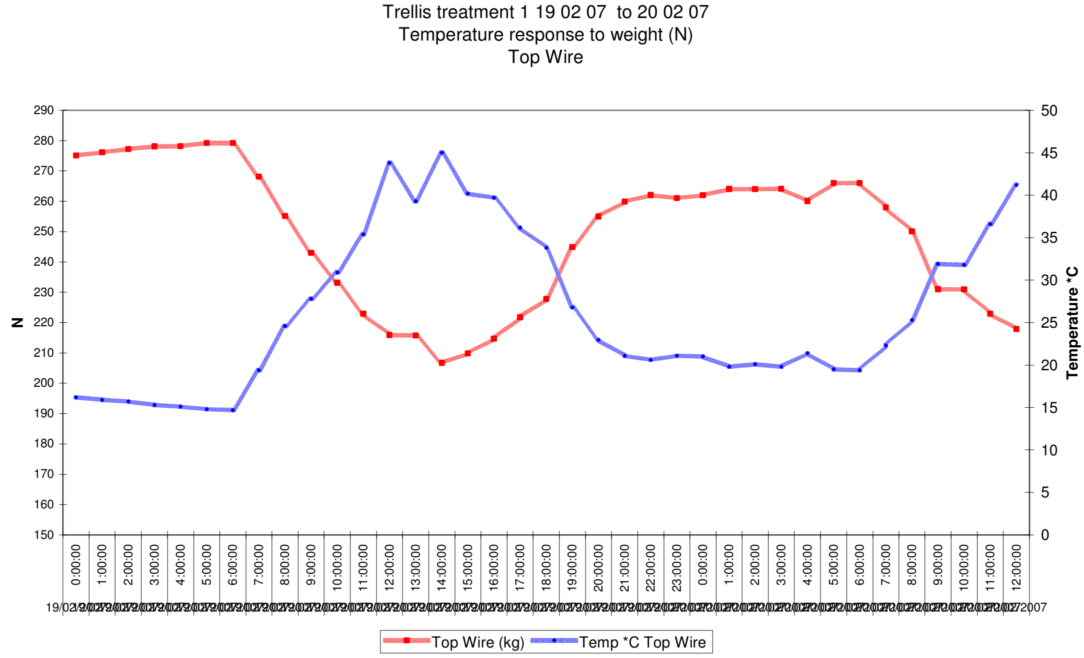

Figure 7: Weight change response over time of day; as temperature increases, weight decreases as moisture has left the plant via transpiration due to temperature increase.

Recommendation

The Yalumba crop estimation trellis tension trial has been successful for the past two seasons, with estimation accuracy within 10%.

Table 4: Cost for a single wire trellis system for a 7Ha block

Task/Item	Description	Cost ($)
Load Cells	Measuring Device	$1000
Solar Panel	Power Source	$400
Temperature Thermocouples	Measuring Device	$200
Load Cell brackets	Hold Load cells on wire	$210
Data Taker Program	Data collection	$650
Data logger	Data Logging	$3000
Battery		$200
Cable		$800
	TOTAL	**$6280**

Cost equates to around $1000/Ha

In regards to costing for a trellis tension system, it would be cost effective for corporate growers who could introduce these to indicator blocks to follow crop weight trends from budburst to harvest. However, for smaller growers this system is currently too expensive due to the high cost of data logger systems. We are currently investigating new ways of reducing the cost to make it more cost-effective for private growers to use in the future.

The system itself is very user-friendly and does not require any special training beyond that required for similar logging moisture monitoring programs. The data is easy to download and can be done once or twice a week.

This technology has much potential for use by growers; however it is still in its experimental phase and requires some further refinement before commercial production.

Future of trellis tension

We would like to see this technology become more cost effective for private growers and to be able to measure wire tension in any part of the vineyard at any time. Other potential applications for trellis tension have been a result of the irrigation and rainfall response detected by the increase in weight of the canopy and bunches in the data loggers. This may offer new opportunities for improving the efficiency of irrigation scheduling and other vineyard management practices. Furthermore, the optimal time of harvest may be detected using tension as an indicator for quality purposes and or desired tonnage. Similarly, the data we have found can be used to accurately predict crop loads from lag phase onwards and also be incorporating seasonal climatic variations/events with this data

Acknowledgements

The Yalumba Wine Company
Barossa Viticulture Technical Group
Barossa Young Viticulturist Fellowship
Barossa Vine Selection Society
Elders Limited
Department of Agriculture, Forestry and Fisheries
Grape and Wine Research Development Corporation

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