IDENTIFYING MANAGEABLE FACTORS DETERMINING CARBOHYDRATE ACCUMULATION IN RESERVES AND ROOT GROWTH OF GRAPEVINES AFTER HARVEST



Grape harvest in one of the experimental sites in the Hilltops region (Young/Harden) in 2002.

Final Report to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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Contents

Abstract 2

Executive Summary 2

Project Overview 5

Detailed project report 7

1 General Introduction 7

2 Research investigations 9

2.1 Productivity of Semillon vines in two districts 9

2.1.1 Introduction 9

2.1.2 Materials and methods 9

2.1.3 Results and discussion 9

2.2 Variation of vine productivity and reserves 16

2.2.1 Introduction 16

2.2.2 Material and methods 16

2.2.3 Results and discussion 16

2.3 Altering the post-harvest period 21

2.3.1 Introduction 21

2.3.2 Material and methods 21

2.3.3 Results and discussion 27

2.3.3.1 Effects on vine carbohydrate reserves 27

2.3.3.2 Effects on vine productivity 41

2.3.3.3 Relationship between reserves and vegetative and reproductive development 50

2.3.3.4 Effects on vine nutrient levels and the relationship to vine reserves 57

2.3.3.5 Root growth and portioning in the post-harvest period 62

3 General Discussion and future work 65

4 Summary 68

5 Acknowledgements 68

6 References 69

7 Outputs 71

ABSTRACT

Two surveys and four field trials were conducted across the Riverina and Hilltops regions in NSW to investigate the importance of the post-harvest period for vine productivity in Semillon. The surveys were used to gain an understanding of the level of variation in post-harvest reserve accumulation between and within vineyards. The four field sites were used to examine the impact of post-harvest treatments on reserve accumulation and productivity in following seasons. After two seasons, up to 60% yield increases were observed on the high reserve treatment, and 50% reductions in yield on the low reserve treatments. A similar effect was seen on pruning weights, but in both cases the treatments responses decreased in the lower yielding vineyards. Treatments designed to duplicate severe mechanical harvester damage to the canopy had a lesser impact on productivity. A key difference between regions was the greater accumulation of root reserves in the Riverina, which was probably related to post-harvest irrigation. The survey results showed that normal variation in reserve concentrations were not as great as that induced with the deliberate post-harvest treatments. However, the study suggests there is considerable potential for more targeted management of reserve levels to control vine vigour and productivity.

EXECUTIVE SUMMARY

The post-harvest period is important for the accumulation of non-structural carbohydrate reserves, since grapevines require stored energy to support early spring growth. Recent findings suggest that vine reserves are also important for inflorescence development and fruit-set. During the post-harvest period, a second root flush and major nutrient uptake also takes place. Vineyard management can alter the effectiveness and/or the length of the post-harvest period, and can therefore significantly impact on carbohydrate reserve accumulation and vine productivity. The project investigated this period by firstly looking at the normal level of variation in post-harvest reserve accumulation that exists within, and between vineyards with differing management and productivity. The second aspect of the project involved four field trials, in which treatments were applied to sites in the Riverina and Hilltops regions of NSW to alter the length and effectiveness of the post-harvest period.

The first part of the project was a survey conducted in two grape growing regions; Riverina (Griffith) and Hilltops (Harden/Young), which have different lengths of post-harvest periods. There was a range of vine productivity levels (yield, pruning weights) and berry maturity levels between vineyards in both regions, generally the higher yields resulted in lower berry sugar levels. The yields in the Riverina vineyards exceeded the vineyards in Hilltops grape growing region. The vine starch reserves levels in the wood differed between vineyards, the reduction in concentrations from harvest to leaf-fall was different between these vineyards ranging from nearly unchanged to around 30%. The Riverina vineyards with the longer post-harvest period also had higher reserves at leaf-fall, yield levels did not appear to correlate with reserve levels. The changes in soluble carbohydrates were the reverse compared to starch over the post-harvest period. The observed differences give an indication that vineyard management can alter reserve levels for next year's development.

A second survey was conducted in one vineyard in the Riverina to determine the level of within vineyard variability in reserve concentrations and post-harvest accumulation. An EM survey was used over the 4.2 ha vineyard, and five zones assigned based on the conductivity readings. Within each zone, four replicates of five vines were hand harvested, and reserve levels in the cordon and trunk determined at harvest and leaf-fall. Of the 100 vines harvested, individual yields ranged between 7.6 and 38.3 kg vine^{-1}. Between the lowest and highest yielding zones, average crop loads varied from 18

to 28 kg vine^{-1}. Using the area of each zone, the yield from the whole block was predicted within 5% of the final 40 t ha^{-1}. This indicated soil variation shown in the EM survey induced corresponding variation in vine yields across the vineyard. Despite the large differences in productivity, starch concentrations in the wood were the same across the whole vineyard. There was also no relationship between yield and the change in reserve levels in the post-harvest period. However, high yielding vines had a larger permanent structure, and would consequently have had higher total reserves.

The second part of the project consisted of two Semillon vineyards, which were selected in each of two grape growing regions. The vineyards in the Riverina region were furrow irrigated or, in the Hilltops region, dependant on rainfall and supplementary drip irrigation. The vineyards differed in their productivity level (yield, pruning weight) and length of the post-harvest period. Treatments were imposed at harvest (except for one) for two consecutive seasons to alter vine reserve accumulation (or length of the post harvest period) over two growing seasons. The six treatments were a control, leaf removal, early fruit removal, leaf damage, juice spray and a combination of juice spray and leaf damage. Treatments were applied after harvest in 2001 and 2002, and effects on vine productivity, vine carbohydrate and nutrient reserves (at selected dates) were followed until spring 2003.

The starch levels varied between years, vineyards, vine parts (cordon, trunk, roots) and time in the season (harvest, leaf-fall, bud-burst). The differences between years and vine parts was influenced by the vineyard, for instance the vines in the vineyards of the Riverina region had much higher starch reserves in the roots than vines growing in the Hilltops region. These differences were particularly pronounced at leaf-fall, but cordon and trunk starch levels were similar in all vineyards. Vine reserves were significantly lowered by the removal of leaves after harvest, while increased by the early crop removal. The impact was particularly strong in the high yielding Riverina vineyards. The leaf damage treatments caused a small reduction in yield, but otherwise suggested vines can tolerate significant canopy damage at harvest without greatly affecting productivity. Soluble sugar concentrations in the wood and roots showed the opposite response to the post-harvest treatments, such that leaf removal resulting in a high sugar:starch ratio, and early crop removal a low sugar:starch ratio. The impact of the treatments on the post-harvest period was more pronounced in the Riverina vineyard, as were the fluctuations in root reserve levels during the season. It appears that a key difference between the regions is the more effective post-harvest period in the Riverina, which allows a greater accumulation of root reserves than was observed at the Hilltops sites.

Vine productivity was affected by the treatments in all sites, although in the higher yielding Riverina vineyards, the impact on yields and pruning weights were more pronounced than in the Hilltops region. The later was at least partly due to the drought conditions encountered during the final seasons of the study, which had an overriding effect on the post-harvest treatments. Generally the productivity was increased if the crop was removed early the previous year, and was lowered by post-harvest leaf removal. There was a trend for juice spray to increase yield in the Riverina, possibly through effects on bunch size. Shoot growth rates in spring were also highest in the early crop removal treatment, while lowest in the leaf removal treatment. The effect on shoot numbers was less distinctive. Bud fruitfulness was often increased by early crop removal and lowered by leaf removal. Likewise flowers per inflorescence were altered and consequentially berries per bunch. Fruit-set was not significantly changed, but there was a trend for lower fruit-set on the leaf removal treatment. Berry sugar levels were altered by the treatment, with the highest yielding treatments have the lower sugar concentrations. These results indicate that the post-harvest period is more important in the higher yielding vineyards of the Riverina in regard to vine productivity.

The relationship between vine productivity (yield, pruning weight) and starch in the wood (trunk/cordon) at bud burst varied between vineyards. The strongest correlation between starch reserves and yield and pruning weights were observed in the Riverina vineyards. The differences in vine size is shown in the yield to pruning ratio, but was unrelated to starch levels in the wood. The relationship between shoot growth rates varied between vineyard and time, while the early shoot

growth rates were independent from the reserve levels (5 leaf stage), there was a strong correlation thereafter (6 to 16 leaf stage, bloom). Flower numbers per inflorescence, fruit set and berries per bunch all had relationships with the starch levels in the cordon. Both relationships were more pronounced in the Riverina vineyards, as for shoot growth. This shows that vine reserves in the higher yielding vineyards of the Riverina have an important role, since there was a smaller or no relationship between vine productivity and starch in the Hilltops region.

The nutrients in the spurs of the Semillon vines after two years of treatments were altered by the treatments which effected starch levels and vine productivity. The macronutrients N, P and S were increased by crop removal in the Riverina vineyards and in addition lowered by leaf removal in one of them. In the Hilltops vineyards K concentrations were altered, with the combination treatment (leaf damage + juice spray) leading to the strongest reduction in K levels. Ca levels were significantly higher in the leaf removal treatment compared to the control. The impact of the treatments on micro nutrients was restricted to B and Cu, the later was altered in both regions but differently, B concentrations were only changed in one Hilltops vineyard. The changes in the macro nutrients N, P, S in the Riverina vineyards and also K in the Hilltops vineyards would suggest that post-harvest leaf removal effects overall nutrient status of the vine, which could be due to reduced uptake by the roots or re-translocation from the leaves during the later part of the post-harvest period. The results also indicate that some of the effects on vegetative and generative development in the following season were not only altered by the starch but also by N or other nutrient reserves in the wood.

The experiment on potted Semillon vines showed changes in dry matter accumulation and allocation occurring during the post-harvest period under the three key treatments, which were also applied in the field trials. At harvest the total dry weight of the vines were already increased by the early crop removal treatment and there was a further increase during the post-harvest period. The latter was also present for the control, but virtually no increase took place in vines which received the leaf removal treatment. This indicates that the length of the post-harvest period effects total dry matter accumulation, which is particularly pronounced in the roots. This means at leaf fall, the leaf removal treatment had the lowest amount of dry matter partitioned to the roots, while the early crop removal had the highest portion of dry matter allocated to the roots. This further demonstrates the importance of the post-harvest period, not only for starch and nutrient accumulation as shown in the previous section, but also for the additional establishment of the vine roots during this period.

The findings indicate that the post-harvest period in Australia has a significant effect on vine reserve accumulation, and that this in turn has a dramatic effect on the following season's vegetative and reproductive development. For above ground parts of the vine, it was shown that post-harvest vine treatments could significantly reduce reserve concentrations. However, in normal situations it appears these reserves are largely replenished by harvest and do not change substantially in the post-harvest period. Instead, the post-harvest period appeared to be more critical for root reserve accumulation. Consequently, a key advantage of irrigated vineyards in warm/hot climates is the ability to accumulate greater amounts of root reserves for the following season. At the Riverina sites, the decline in root reserves between bud-break and harvest was greater under high crop load, suggesting at least one benefit of higher root reserves is a greater capacity for fruit ripening.

Further work should look at gaining a more detailed understanding of vine reserves on generative development, and the use of starch concentrations as factor for yield prediction models. The apparent use of root-reserves for ripening, and replenishment of cordon and trunk reserves prior to harvest, suggests there may also be a benefit in a greater understanding of factors that influence competition between fruit and storage sinks during the ripening period. Finally, treatment effects on vegetative growth were still evident at the Riverina sites in spring 2003, 18 months after the last post-harvest treatments were applied in early 2002. The longer term effectiveness of these treatments suggests that there may be the opportunity for a commercial adaptation of methods which could be used to deliberately decrease reserve accumulation and manage spring vigour. Effects on generative

development would need to be considered, but a yield reduction may be an acceptable trade-off in some situations for reduced input costs and improved fruit quality.

PROJECT OVERVIEW

Project code: CSU 99/2

Project Title: IDENTIFYING MANAGEABLE FACTORS DETERMINING CARBOHYDRATE ACCUMULATION IN RESERVES AND ROOT GROWTH OF GRAPEVINES AFTER HARVEST

Research Organisation: National & Wine Grape Industry Centre

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Project Site(s): Riverina, Hilltops

Commencement Date: August 1999

Completion Date: July 2002 (extended to June 2003, measurements were competed November 2003)

Project funding: Funds allocated by GWRDC

1999/00	$63,197
2000/01	$75,219
2001/02	$85,554
2002/03	$83,912

Remark: a significant amount of funds were returned from the 2001/02 allocation, due to the necessity to appoint a new Post-Doctoral Fellow in January 2001).

Project Objectives/Outcomes:

Objectives:

- Investigate the factors and mechanisms contributing to carbohydrate reserve accumulation and root growth after harvest.
- Specify how to manage vines to optimise carbohydrate accumulation after harvest until leaf fall and early shoot growth.
- Implement an industry strategy to optimise the post-harvest period for carbohydrate production, root growth and nutrient uptake.

Outcomes:

- Better understanding of the factors which impact on carbohydrate storage after harvest.
- Strategies to optimise starch and nutrient reserve accumulation and root growth.
- Industry training to widen knowledge of the effect of vineyard practises on carbohydrate storage and vine productivity.

Outputs and Performance Targets

Outputs	Performance Target
1999/2000 (year 1)	
1. Information on vegetative (shoots, roots) and generative production (yield, parameters) from vineyards in two grape growing regions	Survey of ten vineyards (Semillon) in two regions (hot, cold) by July 2000
2. Methods for measurements (root growth, nutrients, carbohydrates) and treatments (shoot/trunk-root interactions)	Optimal methods for root growth, nutrient and carbohydrate measurements as well as treatments by September 2000
2000/2001 (year 2)	
3. Publication in grower orientated journal of results from the first year	3. Article in grower orientated journal by February 2001
4. Information on vine productivity (vegetative, generative) and on nutrient and carbohydrate levels in the vegetative parts	4. Two trials in the two regions with treatments which alter the shoot/trunk-root interactions, samples analysed by September 2001
2001/2002 (year 3)	
5. Information on vine productivity (vegetative, generative) and on nutrient and carbohydrate levels in the vegetative parts.	5. Two trials in the regions for a second season, samples analysed by September 2002.
6. Seminars and publications in grower orientated and refereed journals.	6. Two seminars, three workshops conducted (50 growers each) and two publications in journal by December 2002
2002/2003 (year 4)	
7. Additional treatment season on all trial sites.	7. Treatments applied to all sites by early March 2003.
8. Airborne analysis of canopy development	8. Completed by Spring 2003.
9. Final workshop and field days conducted at Young and Griffith trial sites.	9. Conducted by Spring 2003.
10. Publication of results in industry and refereed journals.	10. Industry journal publication and 3 refereed journal publications by December 2003

The output and performance target 1 refers to the surveys (see section 2.1 and 2.2), the information from the vineyards was collected and the growers and industry informed (see section 7). Section 2.2 was additional work not stated in the original proposal and relates to within vineyard variation of vine reserves and productivity. Output and performance targets 2, 4, 5

and 7 refer to the field trial (see section 2.3), but four trials on vine reserves were conducted instead of only two as originally stated. A trial was conducted over three seasons, but in the last year 2002/03 the treatments were not applied, since responses were significant and reproductive data collection required the determinations of yields in all treatments (including crop removal). The output and performance targets 3, 6, 9 and 10 refer to the field trial (see section 7).

DETAILED PROJECT REPORT

1 GENERAL INTRODUCTION

The aim of the project was to study the importance of the vegetative post-harvest period for grape production in Australia. The growing period between harvest and leaf fall, particularly in warmer climates, is important for root growth and nutrient uptake. The production of carbohydrates during this period may also be important to fill grapevine starch reserves in shoots, cordon arms, cordons, trunk and roots. The availability of this stored energy is required for early growth in the following season until sufficient leaf area has been established. Further, root growth during autumn demands carbohydrates. A more developed root system will lead to better uptake of water and nutrients. This is an interactive effect since most nutrients are important for carbohydrate metabolism (production, transport, storage, remobilisation).

Optimal use of the period after harvest for carbohydrate production and nutrient uptake would ensure grapevine productivity, particularly in the first years of vine establishment. Lack of carbohydrates has been suggested as a major factor in Restricted Spring Growth (RSG) and is thought to be involved in other grapevine disorders such as bunchstem necrosis (BSN). Semillon decline might be due to reduced photosynthesis through indirect damage by mechanical harvesters. However, most of our knowledge of these effects is hypothetical, and have not been studied in detail. The impact of factors such as climate and vineyard management reducing leaf carbohydrate production, leading to less reserves, needs to be investigated more thoroughly.

There have been many studies on carbohydrate reserves in relation to grape/leaf interaction, rootstocks and irrigation. The importance of the availability of reserves for root growth and the production of carbohydrates after harvest in correlation or on its own is largely unknown. The most relevant work was conducted by Hunter *et al.* (1995), Scholefield *et al.* (1978) and Sommer *et al.* (1995). This research did not address the importance of reserves accumulated after harvest for root growth or early shoot growth, which are both important for vine productivity. The extensive work on carbohydrates in Northern Europe did not address a post harvest period, because the period is either very short or does not exist. In Australia the post-harvest period may extend up to four months. However, the influence of this period on vine productivity, and potential for more targeted management, has yet to be investigated.

Carbohydrate Metabolism and Reserves in Grapevines

The part of the growing season after harvest is important for the accumulation of carbohydrates (Williams, 1996), as well as nutrient uptake and root growth (Conradie, 1980). The root system is essential in determining the ultimate performance of the grapevine (Southey and Archer, 1988). Reserves are crucial for new shoot growth and development (Glad *et al.*, 1992a) until photosynthesis becomes the primary source of carbon.

Carbohydrate source-sink relationships are complex and alter during the growth season. Grapevine leaves reach about one third of their final size before they begin to export carbohydrates (Koblet 1977) but continue to import carbohydrates until half their final size. Retranslocation of carbon reserves begins with budburst, reaches a maximum at the 6 to 8 leaf stage and eases by the flowering stage (Yang and Hori, 1979). On the newly developed shoots, the basal leaves begin to export at the 5-leaf stage, and the export from leaves increases with age (Yang and Hori, 1980). Leaves between 30 and 50 days after leaf unfolding have the highest photosynthetic rate (Kriedemannn, 1968; Intrieri *et al., 1992*). Before flowering, translocation of photosynthates from the leaves is towards the shoot tips (Koblet, 1969; Hale and Weaver, 1962; Yang and Hori, 1980). The first flush of root growth peaks at anthesis, indicating its importance as a sink (McKenry, 1984; Van Zyl, 1984). After berry set the fruit starts to become a very large sink (Koblet, 1969). The carbohydrates in fruit originate mainly from leaf

photosynthesis. The mobilisation of reserves from the permanent structure only occurs if supply of photoassimilate to the fruit is insufficient due to stress situations (Candolfi-Vasconcelos *et al.*, 1994, Koblet *et al.*, 1996), or if the crop load is beyond the capacity of the vine (Balasubrahmanyam *et al.*, 1978). Although the fruit forms a major sink for assimilated carbon, it is clear that the vine has other major carbon-requiring processes or carbon stores to conserve assimilates for future requirements in the following seasons (Chaumont *et al.*, 1994; Miller *et al.*, 1997). These seem to become more important after mid berry ripening (Candolfi-Vasconcelos *et al.*, 1994; Koblet *et al.*, 1996; Keller 1993). Temperature is found to affect carbohydrate partitioning; at higher temperatures the movement of photosynthates is mainly acropetally (towards the shoot tip), at lower temperatures the movement is predominantly basipetally (towards the trunk, roots, clusters)(Sepúlveda *et al.*, 1986). It is important that photosynthesis after harvest continue for carbohydrate storage (Hunter *et al.*, 1994). However, the level of carbohydrate reserves in shoots, roots or trunk in the autumn to spring period was not significantly affected by defoliation (harvest pruning) in early autumn (Scholefield *et al.*, 1978). Root growth can be reduced by defoliation during berry ripening (Candolfi-Vasconcelos *et al.*, 1994) and carbohydrate concentrations in the wood are highest in winter (Sommer and Clingeleffer, 1995), indicating that the photosynthetic activity after harvest is important for the second major flush of roots and for storage (McKenry, 1984; Van Zyl, 1984). A large part of the reserves can be converted to soluble forms in connection with cold winter temperatures or support spring growth (Glad *et al.*, 1992a). The absolute amount of non-structural carbohydrates in vines differs according to cultivar, vine size, age, crop load, environmental conditions, presence of viral disease (Mullins et al. 1992), cultural practices, such as nutrition (Holzapfel and Treeby, 1998; Keller *et al.*, 1995; Keller and Koblet, 1995a; Korkas *et al.*, 1994a, b, 1996a, b), canopy management (Hunter *et al.*, 1995), vine spacing (Hunter, 1998) and irrigation (Ruhl and Alleweldt, 1990).

The period after harvest is certainly important for filling up carbon reserves, root growth and early shoot development. The accumulated reserves could be used to accelerate canopy development in the spring, to support larger crops and for coping better with stress periods. Restricted spring growth (Mattschoss, 1995), Semillon decline, coulure (Glad *et al.*, 1992b) and bunchstem necrosis (Keller and Koblet, 1995b) are discussed in connection with a lack of carbohydrate reserves, production or partitioning. This work will examine the effect of post-harvest photosynthesis on carbohydrate reserves and root growth as well as on early shoot development and fruit ripening.

2 RESEARCH INVESTIGATIONS

2.1 Productivity of Semillon vines in two districts

2.1.1 Introduction

Different grape growing regions vary in their climatic conditions and therefore in the length of the post-harvest period. Vineyard management can also impact on the length and effectiveness of this period. The harvest date can differ by several weeks in a region, and the canopy status can be influenced by irrigation and nutrient supply after harvest. Keeping the leaves free of pests and diseases in this period is also an important factor for sustaining a good photosynthetic activity. In the first season of the project (1999/2000) the vine productivity and vine wood reserves were determined in several vineyards. The study was conducted in two grape growing regions; Riverina (Griffith) and Hilltops (Harden/Young) both in NSW. The average yearly rainfall is 406mm and average temperature is 16.4^{o}C for the Riverina, while Hilltops region average rainfall is 653mm and average temperature 14.7^{o}C. The aim was to investigate the level of variability within a growing region and between regions.

2.1.2 Material and methods

The study was conducted on own rooted Semillon in the Riverina and Hilltops (Young/Harden) grape growing regions in NSW. Five vineyards in each region were selected, and in each vineyard, ten groups of five vine replicates were distributed randomly in an area of ten rows by 50 vines.

Bud burst and percent bud burst was determined, shoot and bunch numbers were recorded from the lateral cordon of the central vine. The rate of shoot elongation was measured (every second week) until flowering. The yields and pruning weights were determined from the vineyards by weighing the grapes and prunings from every five-vine plot. A 50 berry sample was taken in these vineyards at harvest for determining berry weight and measuring TSS in ^{o}Brix with a digital bench refractometer (PR-101 ATAGO, Tokyo, Japan). The growers or managers were asked to fill out a questionnaire with vineyard details and management.

Wood samples (cordon/trunk) were taken at harvest and leaf-fall and analysed for starch and soluble sugar concentrations. The samples were dried at 60°C and ground through a 0.12mm sieve. Soluble sugars were extracted from a 20 mg sample with three washes of 80% EtOH. Starch in the remaining sample was solubilized with dimethyl sulphoxide and digested enzymatically to glucose with a-amylase and amyloglucosidase. The glucose concentration of the digested sample was then determined colour metrically using the Megazyme glucose assay kit (MEGAZYME International Ireland Ltd, Bray, Ireland), with reagent volumes scaled down for use with 96 well micro plates. The plate is read at 510nm on a plate reader (µQuant, Bio-Tek Instruments Inc., Vermont, USA) as a glucose concentration, and the starch results presented are expressed as a percentage of wood dry weight. To 20µl of the soluble sugar extract, 80µl ultra pure water was added to each well on a deep-well microplate. The plate was placed into an ice bath and after a few minutes 200µl anthrone reagent was added to each well and the samples were mixed. Then the samples in the plate were placed for 15 minutes into a 98ºC water bath, and then again placed into an ice bath. From each sample in the deep well microplate 200µl was transferred into a standard microplate and read at 620nm on the plate reader. The soluble sugar content is the calculated to % DW basis.

The data were compiled and manipulated in the data base Excel 97 and further analysed using the graphic program Sigma plot (version 8.0).

2.1.3 Results and discussion

The vineyards were on a range of soils in the Riverina (loam, clay loam, clay) and Hilltops (sandy loam, loam, clay loam). The age of the Semillon vines ranged from only a couple of years to 25 years.

Planting density varied between vineyards, but all were trained to one trellis wire (Table 1.1). Most vineyards were machine harvested and pruned in both regions, harvest dates varied 10 days in the Riverina and 12 days in Hilltops region between vineyards, while between regions the difference could be more than one month. The management of vineyards varied in regard to irrigation (system, amount) and nitrogen application (amount, timing).

The vineyards differed in the number of retained buds per metre of cordon in both regions, although in the Hilltop region this range was greater (Table 1.2). Consequentially, the shoot numbers differed; generally the vineyards with lower bud numbers had the highest budburst. The fruitfulness of bunches varied in regions, but was higher overall in the Riverina. Shoot growth varied in the Riverina region, while vineyard S6 had the longest shoots a couple of weeks after flowering, vineyard S4 had one of the vineyards with the shortest shoots (Figure 1.1). Although budburst in the Hilltops region was only a week later than in the Riverina, the difference at flowering was much larger (approximately 1 month). Shoot growth fluctuated more in the Hilltops regions and appeared to stop at flowering. The vineyard S13 had one of the longest shoots shortly after flowering and S12 the shortest.

The variability between vineyards in shoot numbers and bunches per shoots resulted also in large differences of bunches per metre of cordon, the number of bunches per metre was higher in the Riverina region (Table 1.3). There was a range of bunch weights and berry weights in both regions. These yield components produced a range of yields (Figure 1.2), although the vines in the Riverina yielded more fruit than any of the vines in the Hilltop region. There were significant differences in TSS (^{o}Brix) in both regions; generally in vines with higher yields the grape sugar levels were lower. There were no distinct differences in pruning weights between regions (Figure1.2), but vineyard S6 (Riverina) and S10 (Hilltops) had much higher pruning weights than the other vineyards.

The vine starch reserves (Cordon/trunk) dropped in all vineyards in the Hilltops region (Figure 1.3), although the reduction varied between vineyards. In most vineyards starch levels were around 30% lower at leaf-fall compared to harvest. The vineyards S1, S12 and S14 reduction in starch was much less (4-16%). The soluble sugars increased over the post-harvest period, bringing the total sugars to similar levels at harvest and leaf fall. The level of starch reserves differed significantly between vineyards and was higher overall in the Riverina region. This indicates that there is not only a range of productivity levels between vineyards and regions, but also a range of vine reserves, and changes in reserve concentrations during the post-harvest period varied. This indicates the impact of management of both productivity and vine reserves and the likely connection between them. To investigate this relationship further, two vineyards in each region were selected for further investigations and will be described in section 2.3.

Table 1.1. Semillon vineyard characteristics of the Survey 1999/2000 conducted in the Riverina and Hilltops region.

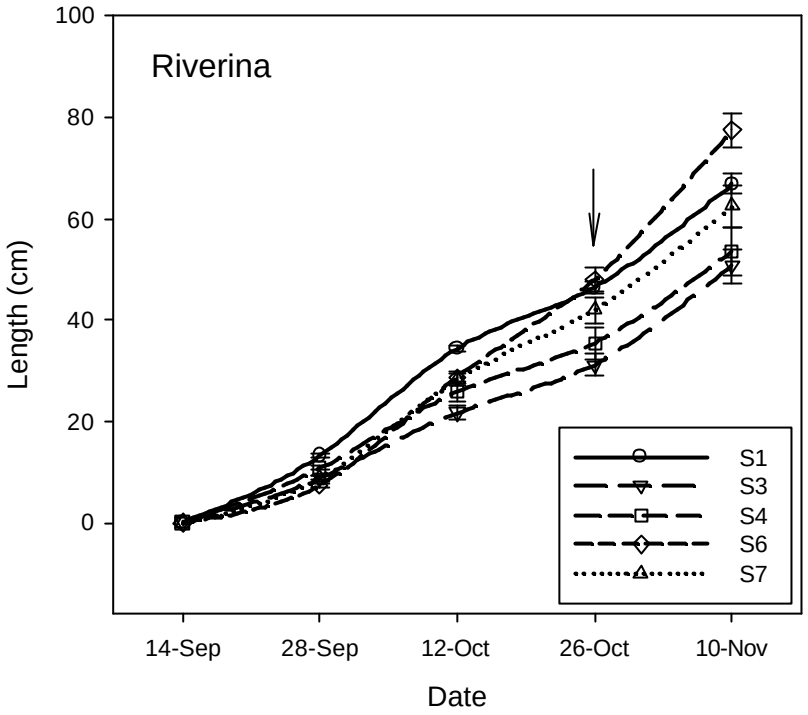
Region	Site	Soil Type	Age of Vines	Spacing (m) Vine x Row	Irrigation	ML	kg N/ha	Harvest Method	Harvest Date	Pruning Method
Riverina	S1	Clay	15	1.5 x 3.6	Drip	?	10	Mech.	27-Feb	Hand
	S3	Loam	4	1.5 x 3.6	Drip	3.0	35	Mech.	28-Feb	Hand
	S4	Clay	2	1.5 x 3.7	Furrow	6.0	164	Mech.	18-Feb	Mech.
	S6	Clay loam	4	1.6 x 3.9	Flood	4.0	95	Mech.	27-Feb	Hand
	S7	Clay	20	1.8 X 3.6	Flood	?	45	Hand	28-Feb	Hand
Hilltops	S10	Loam	9	2.0 x 3.0	Drip	?	85	Hand	9-Mar	Hand
	S12	Sandy loam	13	1.9 x 3.3	Drip	0.6	7	Mech.	9-Mar	Mech.
	S13	Loam	10	2.0 x 3.4	Drip	0.0	0	Mech.	11-Mar	Hand
	S14	Clay loam	25	1.8 x 3.0	Drip	0.1	0	Hand	21-Mar	Mech.
	S15	Clay loam	11	1.8 x 3.0	No	0.0	0	Mech.	21-Mar	Hand

Table 1.2. Buds and shoots per m cordon, bud burst and bunches per shoots (Riverina/Hilltops)(standard errors of the means are shown in small type, n=10).

Region	Site	Buds/m		Shoots/m		Budburst (%)		Bunches/shoot	
Riverina	S1	60.2	6.1	61.0	5.3	106.3	10.3	1.119	0.08
	S3	38.5	3.7	46.1	2.2	125.7	8.7	1.146	0.08
	S4	29.1	4.6	36.3	2.3	185.3	52.0	1.173	0.12
	S6	26.0	6.2	36.2	3.4	172.8	20.6	1.497	0.09
	S7	52.0	3.9	67.3	5.4	134.8	15.1	1.087	0.06
Hilltops	S10	18.8	1.0	33.0	1.9	177.9	11.1	0.86	0.06
	S12	58.3	7.6	67.2	7.9	120.0	8.3	0.78	0.06
	S13	25.7	1.9	39.9	2.4	158.5	8.0	0.81	0.08
	S14	29.3	4.1	43.7	5.4	153.9	9.7	0.65	0.09
	S15	16.2	2.2	25.1	3.5	162.7	18.8	0.96	0.18

Table 1.3. Bunches per metre cordon, bunch weight, berries per bunch and berry weight in two regions (Riverina/Hilltops)(standard errors of the means are shown in small type, n=10).

Region	Site	Bunches/m		Bunch wt. (g)		Berries/bunch		Berry wt. (g)	
Riverina	**S1**	68.2	7.4	136.4	18.2	106.9	13.3	1.27	0.02
	S3	52.4	3.9	242.2	16.0	152.6	11.3	1.59	0.03
	S4	40.5	3.9	225.9	35.8	145.3	19.6	1.52	0.06
	S6	53.8	5.2	406.5	41.9	206.2	19.4	1.97	0.05
	S7	72.4	6.7	118.3	12.0	72.0	6.4	1.63	0.03
Hilltops	**S10**	27.8	1.9	189.0	21.7	111.4	12.4	1.70	0.04
	S12	52.3	7.6	121.8	15.0	79.2	9.6	1.54	0.04
	S13	31.9	3.2	246.5	23.2				
	S14	29.7	6.9	210.0	46.4	114.8	25.4	1.82	0.06
	S15	19.8	1.7	119.2	14.3	78.3	9.6	1.52	0.05


Riverina
Length (cm)
100
80
60
40
20
0
14-Sep
28-Sep
12-Oct
26-Oct
10-Nov
Date
S1
S3
S4
S6
S7

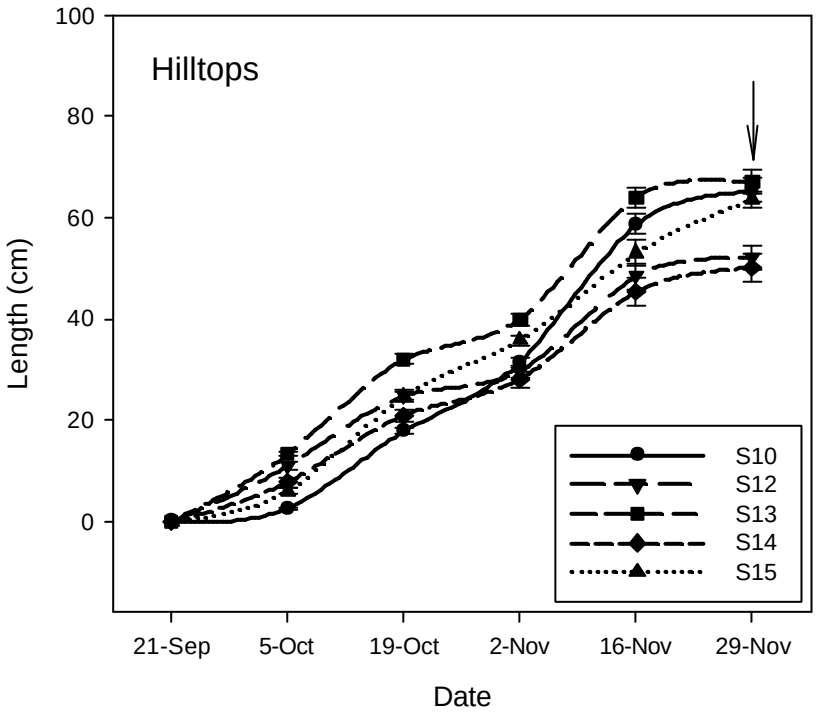

Hilltops
Length (cm)
100
80
60
40
20
0
21-Sep
5-Oct
19-Oct
2-Nov
16-Nov
29-Nov
Date
S10
S12
S13
S14
S15

Figure 1.1. Shoot growth in five Semillon vineyards in the Riverina and Hilltops region in spring 1999, arrows indicate flowering time (standard errors of the means are shown as bars, n=10).

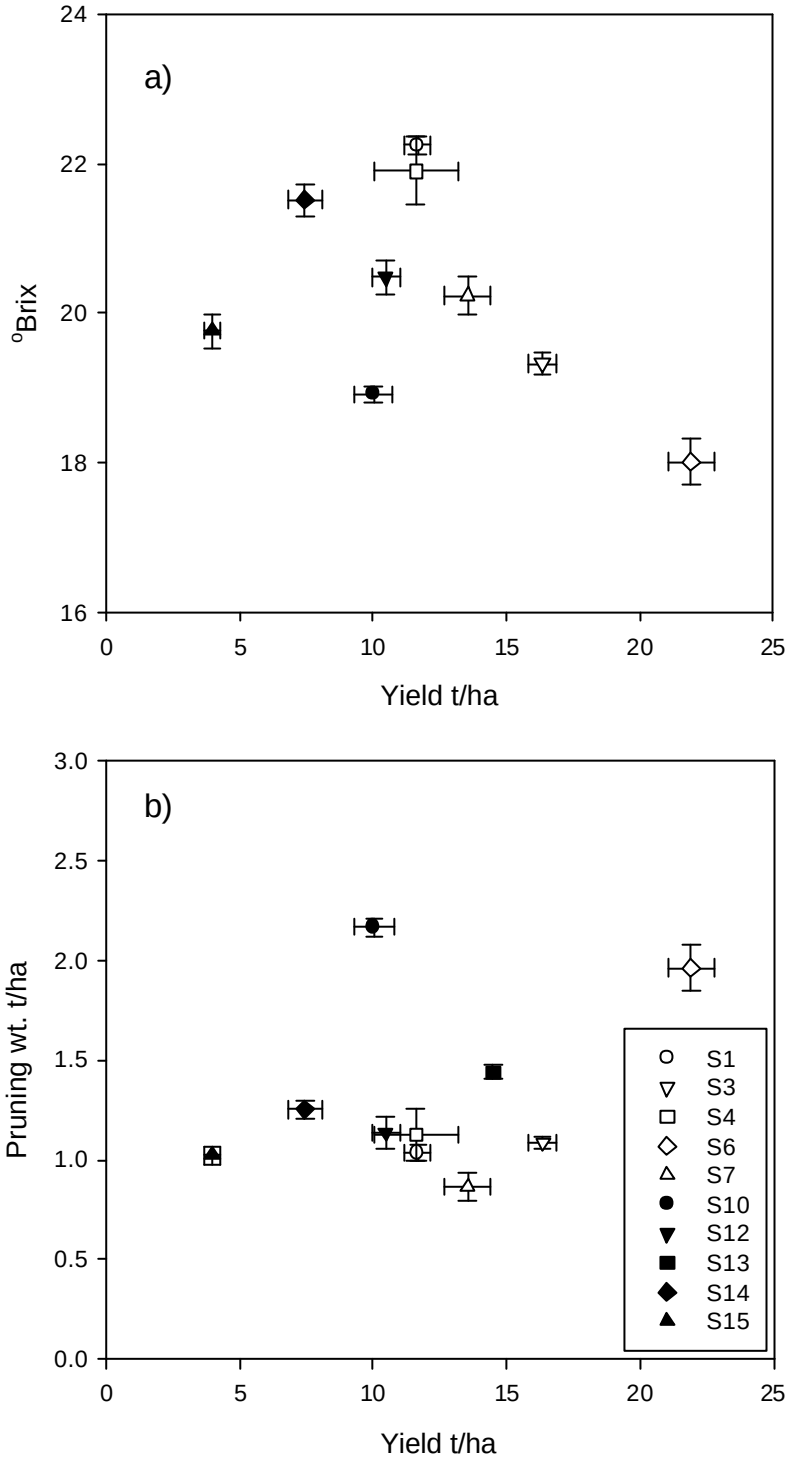
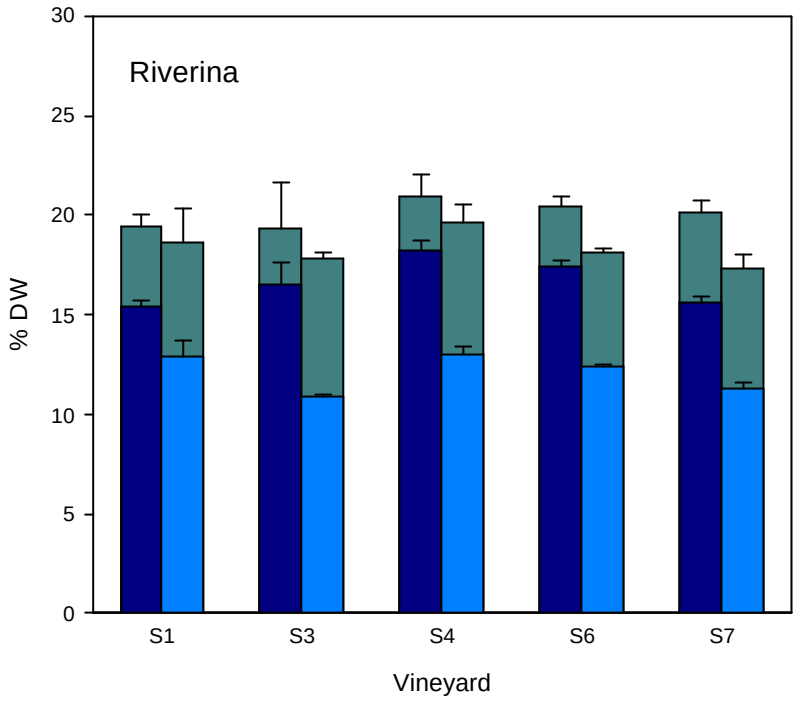


Figure 1.2. Relationship between (a) yield and TSS (°Brix) and (b) yield and pruning weight in the Riverina (S1 to S7) and Hilltops region (S10 to S15) in 2000 (bi-directional standard errors of the means are shown as bars, n=10).


Riverina
% DW
30
25
20
15
10
5
0
S1
S3
S4
S6
S7
Vineyard

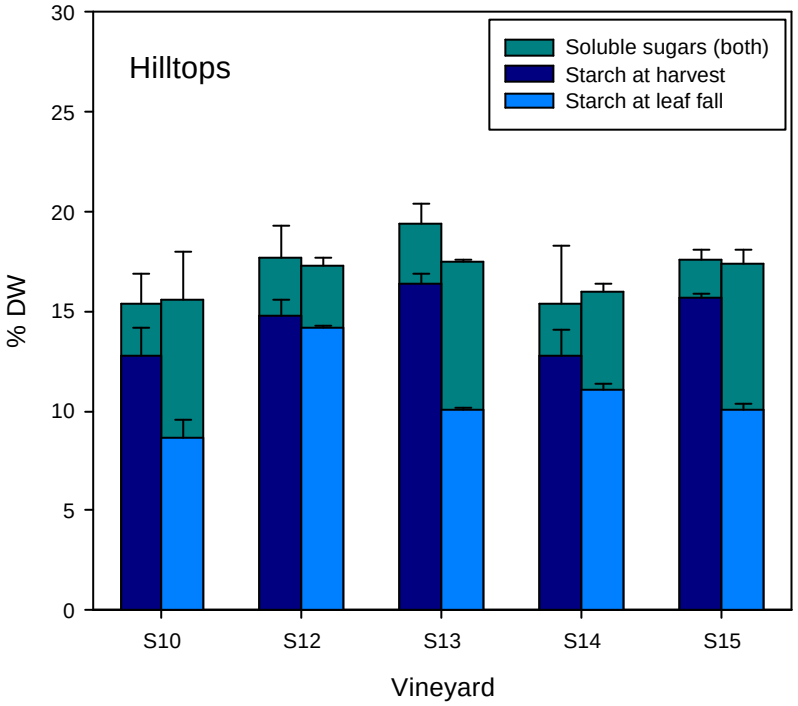

Hilltops
Soluble sugars (both)
Starch at harvest
Starch at leaf fall
% DW
30
25
20
15
10
5
0
S10
S12
S13
S14
S15
Vineyard

Figure 1.3. Starch and soluble sugar levels in the wood (cordon/starch) in Riverina vineyards (top) and Hilltops vineyards (bottom) at harvest and leaf-fall (2000) (standard errors of the means are shown as bars).

2.2 Variation of vine productivity and reserves in a vineyard

2.2.1 Introduction

Vine productivity can vary significantly in a vineyard, which is often related to differences in the soil characteristics (chemical and physical). Certain zones in a vineyard always have higher or lower yields and also differ in the grape composition attributes. The vine size is commonly related to the yields it produces. This work was carried out to look more specifically into within vineyard variation rather than between vineyards as described in section 2.1., determined by underlying soil conditions. This part of the project was conducted to determine the relationship, in a vineyard, between vine productivity (vigour, yield) and carbohydrate reserves.

2.2.2 Material and methods

The variation trial was conducted on a Semillon vineyard (McWilliams Wine's Hanwood). 20 lots of 5 vine panels were selected on the basis of EM survey (Figure 2.1) which was divided into 5 soil types. Every colour related to a specific EM 38 increasing conductivity range: red (27-50), orange (51-59), yellow (60-67), light green (68-83) and dark green (84-124), each of these colours were presented four times in the total vineyard of 5.4ha. Separate soil samples were taken down to 40cm from each of the five vine areas (0-10cm, 10-20cm, 20-30cm, 30-40cm) and electric conductivity (EC 1:5 soil water extraction) and soil pH (0.01M $CaCl_2$) was determined.

The vines were individually harvested (18 February 2002). Wood samples (cordon/trunk) at harvest (date) and leaf fall (24 June 2002) were collected from each individual vine from the five vine plot. Trunk and cordon circumference and height/length were measured to determine vine size and wood volume. The wood samples (mixture of cordon/trunk) were dried at 60^{o}C and ground through a 0.12mm sieve. The starch and soluble sugars were extracted, determined and calculated as described in section 2.1.2.

2.2.3 Results and discussion

The EM 38 survey shows sections of vines with low conductivity in red and high conductivity in dark green. There were also three ranges in between marked in orange, yellow and light green (Figure 2.1). The soil results show these increasing EC values from red to dark green in all depths. The values became particularly high in the 20-40cm soil layer in dark green zone. Soil pH was lowest in the yellow zone in all depths and generally slightly increasing with depth in all zones.

Vine yield and size was highest in the orange zone and lowest in the dark green zone (Table 2.2). Vines in other zones had similar yield, but there was some difference in vine size measured in trunk circumference. The vines in the yellow zone had the lowest TSS at harvest, but due to the larger yields were producing more sugar per vine than any vines in other zones. The dark green zone showed the lowest sugar per vine yield, despite relatively high berry sugar concentrations. Increasing yields resulted in lower TSS (Figure 2.2) and vine size was also positively correlated with yield.

The wood starch levels were similar in vines of every zone with about 14% at harvest and just over 10% at leaf fall (Figure 2.3). Due to increasing soluble sugar levels during the post-harvest period, the total sugar levels have remained similar at the two times (harvest, leaf-fall). This means there was no relationship between yield or trunk circumference to starch levels at harvest (Figure 2.4a). Similarly vine size did not correlate with starch levels at leaf fall (Figure 2.4b). Shoot growth in the following spring was lowest in the low production section, but highest in second highest producing vines (Table 2.2). These results indicate that the vine size is strongly related to yield, while wood reserves appear to have only a minor role in the vines yield produced. The differences in yield did not alter the vines reserve levels at harvest. Vine root reserves could be a potential factor in the observed differences as reported in the following sections.

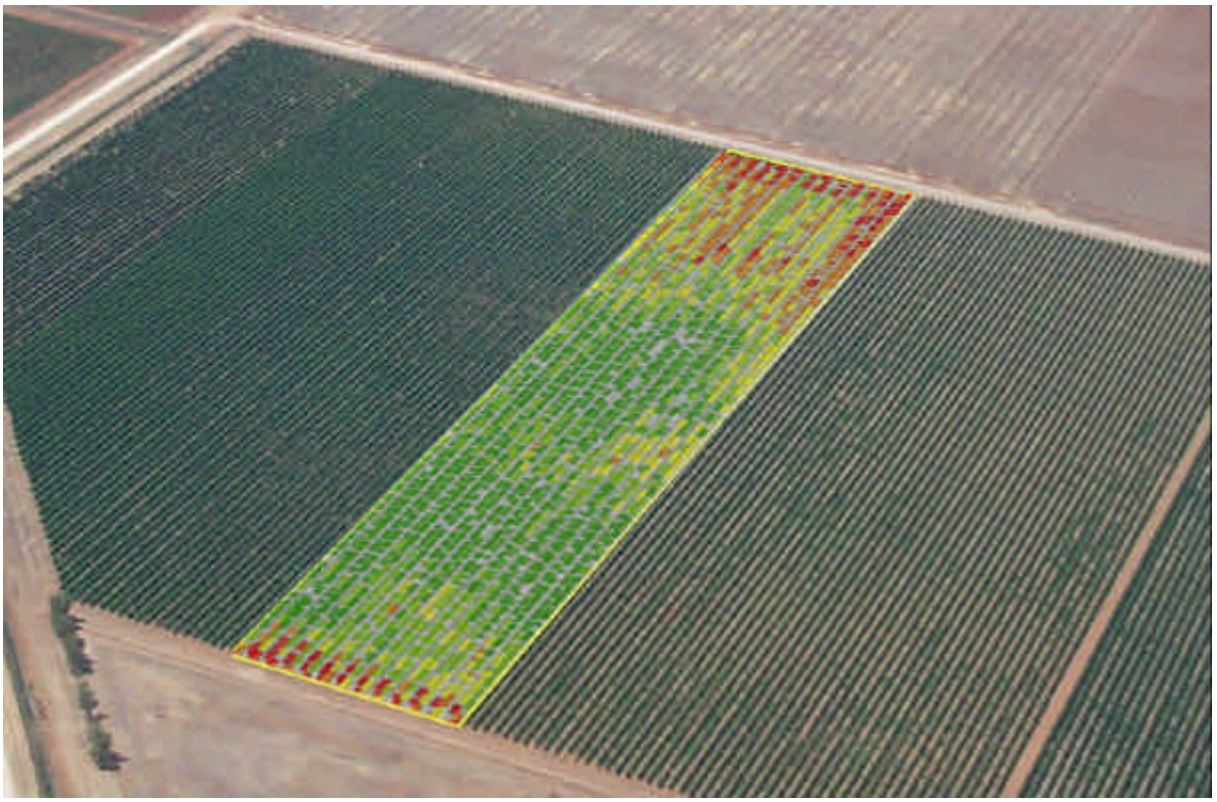


Figure 2.1. EM 38 survey overlay of the Semillon vineyard used to investigate within vineyard variation of carbohydrate reserve accumulation post-harvest. The block was divided into five zones (as indicated by colours), and yields and reserves within each area assessed. The dark green area had the highest soil conductivity, and was the lowest yielding. The orange areas towards the edge of the vineyard had the highest yields.

Table 2.1. Soil EC and soil pH (three depths) in the different categories in the vineyard identified by the EM survey (2002) (standard errors of the means are shown in small type, n=4).

Category from EM survey	Soil Depth 0-10cm EC (µS)		pH ($CaCl_2$)		10-20 cm EC (µS)		pH ($CaCl_2$)		20-40 cm EC (µS)		pH ($CaCl_2$)	
Red	62.3	8.98	6.1	0.29	51.3	3.17	6.6	0.16	57.3	9.91	7.0	0.21
Orange	67.5	10.37	6.0	0.15	54.3	3.66	6.2	0.15	89.8	20.03	7.0	0.14
Yellow	77.3	6.52	5.8	0.19	66.3	16.04	6.3	0.14	58.3	3.66	6.8	0.05
Light green	74.8	9.04	6.3	0.10	69.8	8.26	6.7	0.07	88.3	12.98	7.2	0.13
Dark green	81.0	4.71	6.1	0.17	77.5	9.39	6.7	0.07	169.8	48.96	7.2	0.05

Table 2.2. Yield, TSS, sugar per vine, trunk circumference and volume and shoot length (flowering) effected by soil differences (2002) (standard errors of the means are shown in small type, n=4).

Category from EM survey	yield kg/vine		TSS °Brix		Sugar/ vine kg		Trunk Circumference mm		Trunk volume L		Shoot Length cm	
Red	23.5	2.44	17.7	0.48	4.2	0.43	139.6	7.53	9.8	0.48	59.3	3.66
Orange	27.8	1.74	16.9	0.42	4.7	0.34	146.1	7.22	9.3	0.50	69.2	3.92
Yellow	24.6	2.76	18.4	0.78	4.5	0.40	143.3	4.64	7.8	0.19	72.2	4.23
Light green	23.6	3.32	17.5	0.80	4.1	0.50	132.4	5.79	9.6	0.31	69.3	3.8
Dark green	18.2	2.51	18.3	0.55	3.3	0.43	116.9	2.82	8.9	0.39	55.7	5.6

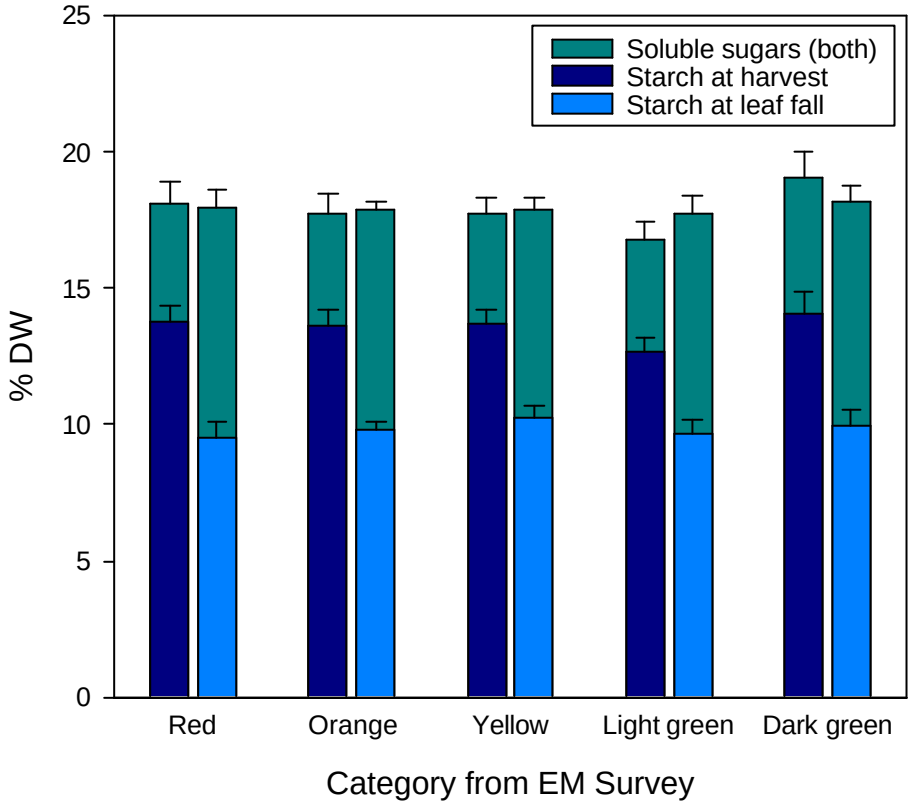
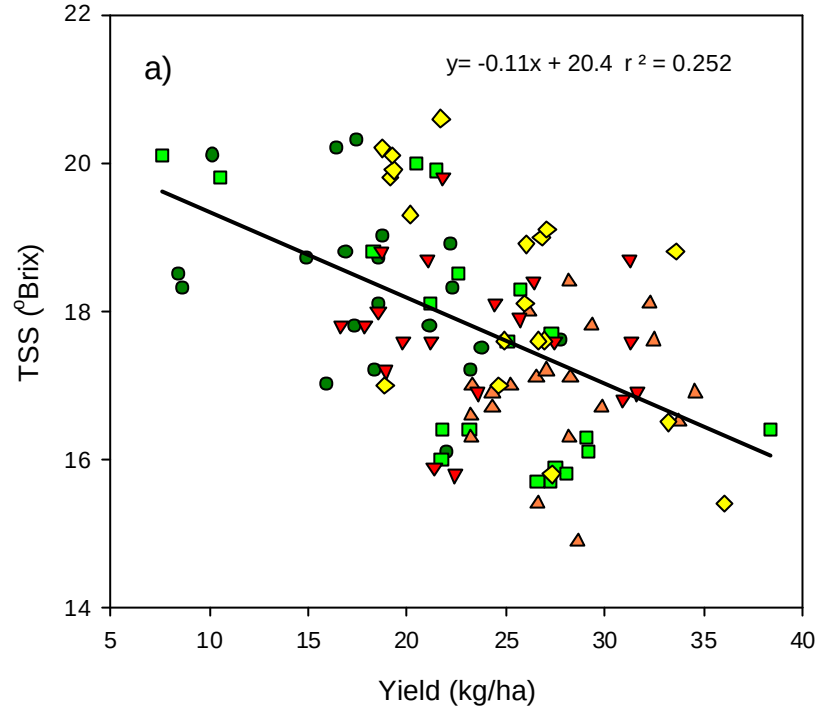


Figure 2.2. Changes in starch and soluble sugar concentrations of the cordon and trunk wood between harvest and leaf fall in Semillon variation trial. Categories represent

vineyard areas with low (red) to high conductivity (dark green) as indicated by EM 38 survey.



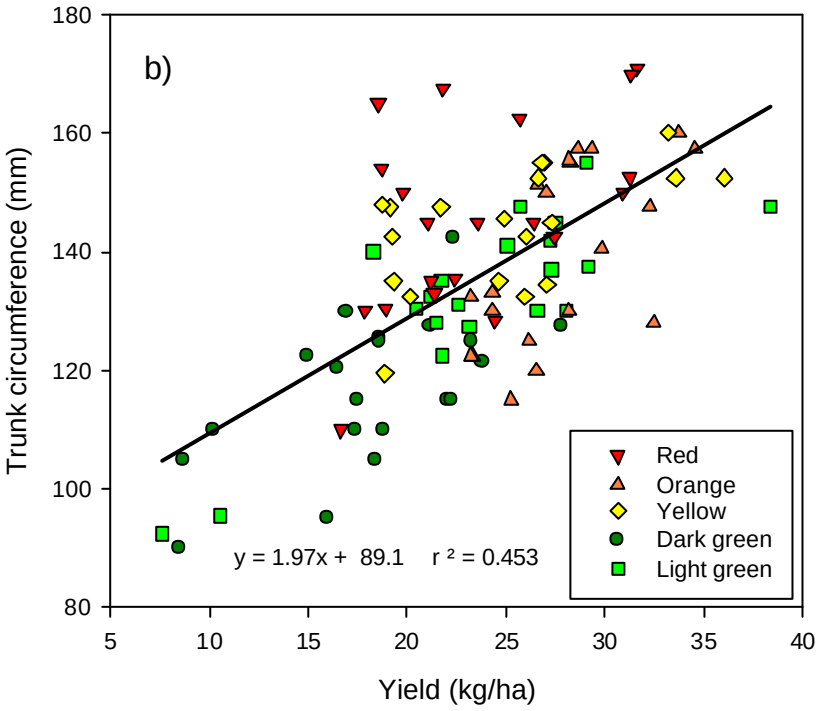


Figure 2.3. Relationship between (a) yield and TSS, (b) yield and trunk circum survey.

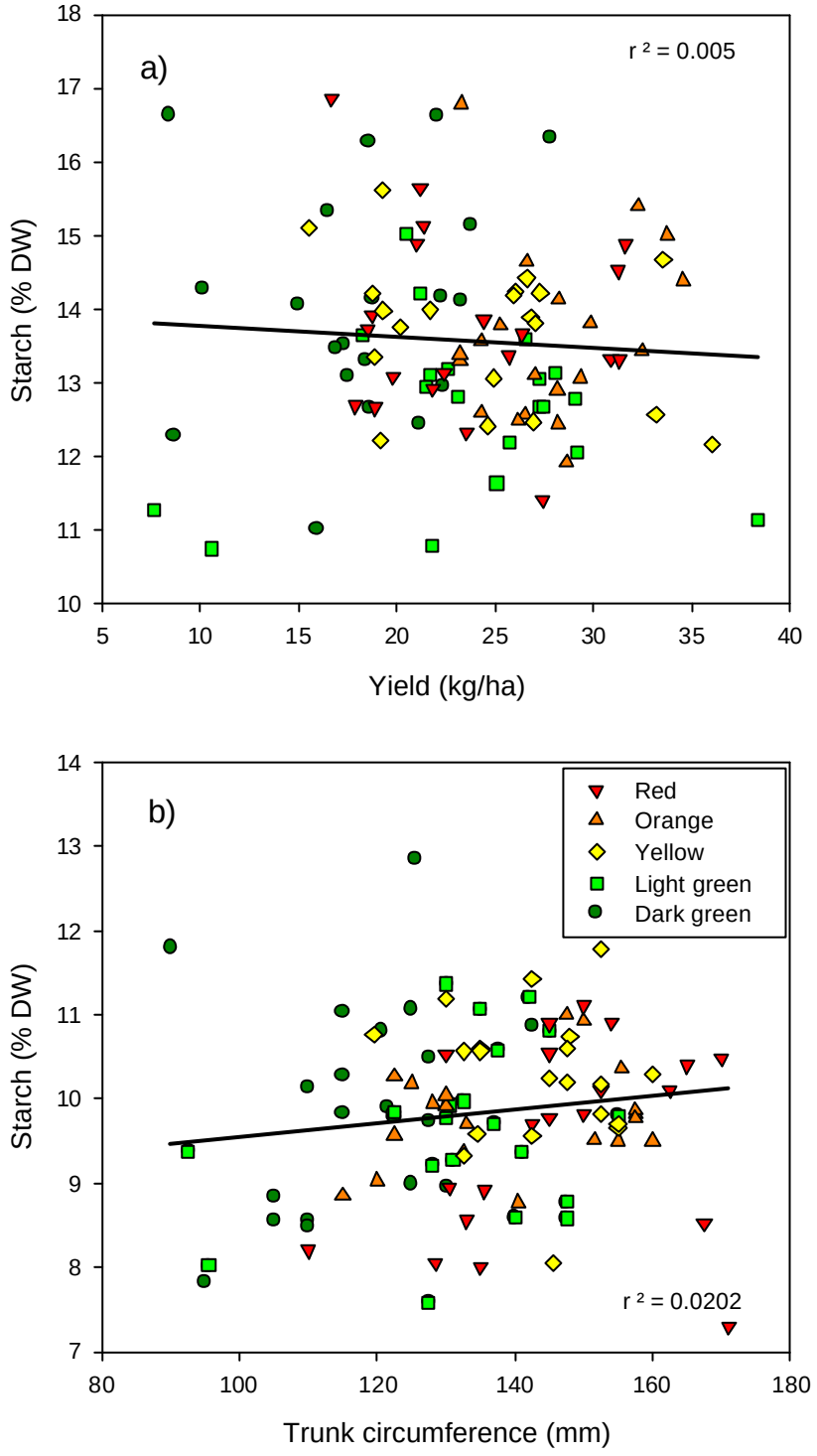


Figure 2.4. Relationship between (a) yield, (b) trunk circumference and starch in the wood (cordon/trunk) in the different categories in the vineyard identified by the EM survey (2002).

2.3 Altering the post-harvest period

2.3.1 Introduction

The survey has indicated differences in wood reserve levels in vineyards and also that changes in the starch concentrations from harvest to leaf fall varied between sites (section 2.1). Wood reserves appear to be similar over all productivity levels in a vineyard, as shown in the previous section (2.2). The following study was designed to provide a better understanding of the importance of the post-harvest period for vine productivity. Treatments were imposed to alter the length of the post-harvest period. This allowed manipulation of the carbohydrate reserve levels stored prior to leaf fall. Additional treatments were also included to simulate the damage done to the vine canopy by mechanical harvesting (leaf damage and juice spray) therefore reducing the effectiveness of the post-harvest period.

2.3.2 Material and methods

Two Semillon vineyards were selected in each of two NSW regions (Riverina and Hilltops) for this study. The vineyards in the Riverina region (Plate 3.1) were furrow irrigated and in the Hilltops region drip irrigated (Plate 3.2). Soil samples were taken down to 80cm in each vineyard and electric conductivity and soil pH was determined. All vineyards had had an increasing soil pH with depth, vineyard 3 had the highest and vineyard 4 the lowest soil pH (Table 3.1). The Riverina vineyards generally had the soil with higher soil EC and increasing with depth. The four vineyards differed in their productivity level (yield, pruning weight) and length of the post-harvest period (Table 3.2). Each trial in these vineyards was identical and six treatments were imposed at harvest (except one treatment) to alter vine reserves (or length of the post-harvest period)(Table 3.3, Plate 3.3). These treatments were replicated four times in a fully randomised block design and implemented over two growing seasons (2001/02, 2002/03), the areal image of vineyard 2 taken shortly after harvest 2002 (Plate 3.4) shows the treatments (leaf removal and damage) and effects (crop removal). The data and sample collection started at harvest 2001 and concluded shortly after flowering in 2003.

The effects of the treatments on shoot and bunch development and yield were determined. Shoots were measured fortnightly in the 2001/02 season and weekly in the 2002/03 season from budburst until shortly after bloom (10 shoots per 3 central vines in a treatment panel). Bunch and shoot numbers were assessed in early spring and harvest from the middle three vines of each plot, in 2003/04 only the key treatments were assessed. Yields and pruning weights were determined by hand harvesting and pruning these three vines in each treatment plot. Fruit set was assessed in three key treatments (control, leaf and fruit removal) in the 2002/03 season. For this purpose 10 bunches were bagged (meshed) and colour coded before flowering and removed after flowering to collect caps. The caps were counted later to determine flower numbers and berry numbers of the colour coded bunches were determined at harvest. This allowed the percentage fruit set to be calculated of each individual bunch. The starch and soluble sugars were extracted, determined and calculated as described in section 2.1.2. Wood and root samples were sent to a commercial laboratory for nutrient determination. Leaf nitrogen

was determined by using an N-analyser and other nutrients were analysed after an acid digestion on an inductively coupled plasma-optical emission spectrometer (ICP-OES).

A pot experiment was conducted with the two key treatments and a control in 2002/03 season (as imposed in the field experiments), which were applied on January 9 (early crop removal) and February 3 (leaf removal). The treatments were replicated six times and each replicate consisted of 6 vines. For each sampling date (harvest, leaf-fall) six vines from each replicate were destructively harvested. The roots were washed out and the vines were separated into roots, trunk, shoots and leaves and fresh weight was determined. The vine parts were dried at 60ºC and the dry weight was determined also. Statistical analysis was conducted using Genstat release 6.1 (Rothhamsted Experimental Station). An analysis of variance was applied to the results of the determinations to test for significant differences between the treatments. For locating the significant differences between means, least significant difference (LSD) was used (p=0.05).

Table 3.1. Soil EC and soil pH in the four vineyards of the reserve project.

Soil Depth (cm)	Soil pH and salinity	Vineyard 1	2	3	4
0-10	pH ($CaCl_2$)	5.3	5.4	6.8	4.5
	EC (µS)	220	110	97	128
10-20	pH ($CaCl_2$)	5.0	5.1	6.7	4.5
	EC (µS)	98	146	121	156
20-40	pH ($CaCl_2$)	6.2	6.6	6.5	5.1
	EC (µS)	188	229	142	168
40-60	pH ($CaCl_2$)	7.1	7.2	6.2	5.6
	EC (µS)	47	256	130	176
60-80	pH ($CaCl_2$)	7.5	7.5	6.2	5.9
	EC (µS)	486	265	97	128

Table 3.2. Site description and location of the four vineyards used in the study (2001-2003)

Region	Vineyard (Survey No)	Year of Planting	Soil Type	Average Yield[1)] kg/vine	Average Pruning wt.[1)] kg/vine	Post-harvest period[2)] weeks
Riverina						
Hilltops						

[1)] over 3 years (20







Plate 3.1. lanted in as planted rigated.



Plate 3.2. Hilltops vineyards in which the experiments were conducted. Site 1 (a) was planted in 1990, and had an average yield of 6.9 kg vine^{-1} during the study. Site 2 (b) was planted in 1987, and averaged 2.5 kg vine^{-1}. Both vineyards are dependant on rainfall and supplementary irrigation, but were affected by water shortages in the last two years of the study.

Plate 3.3.

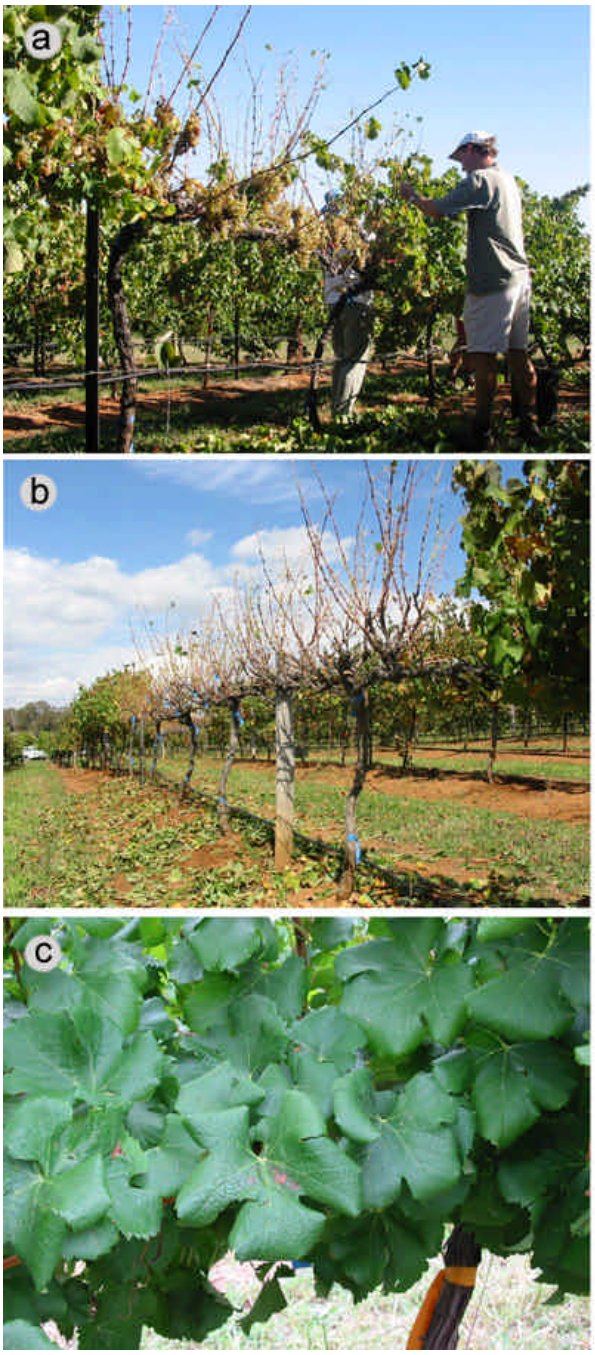






Table 3.3. Treatments applied to the vines over two consecutive seasons (2000/01, 2001/02)

Treatment	Decription	Intended effect
Control	Vine treated same as rest of vineyard	Control vines for comparison
Crop removal	All fruit removed 4-6 weeks prior to harvest	Increase reserve levels by removing fruit sink (↑ reserves)
Leaf removal	Remove all leaves after harvest, and any subsequent re-growth	Prevent any post harvest photosynthesis (↓ reserves)
Leaf damage	Simulate machine physical harvester damage without juice spray	Decrease available leaf area for photosynthesis (↓ reserves)
Juice spray	Spray leaves with juice	Induce leaf burning sometimes seen after harvest (↓reserves)
Leaf damage + juice spray	Simulate (severe) machine harvester damage to canopy + juice spray on leaves common in Semillon	Decrease available leaf area for photosynthesis + possible leaf burn by juice (↓ reserves)

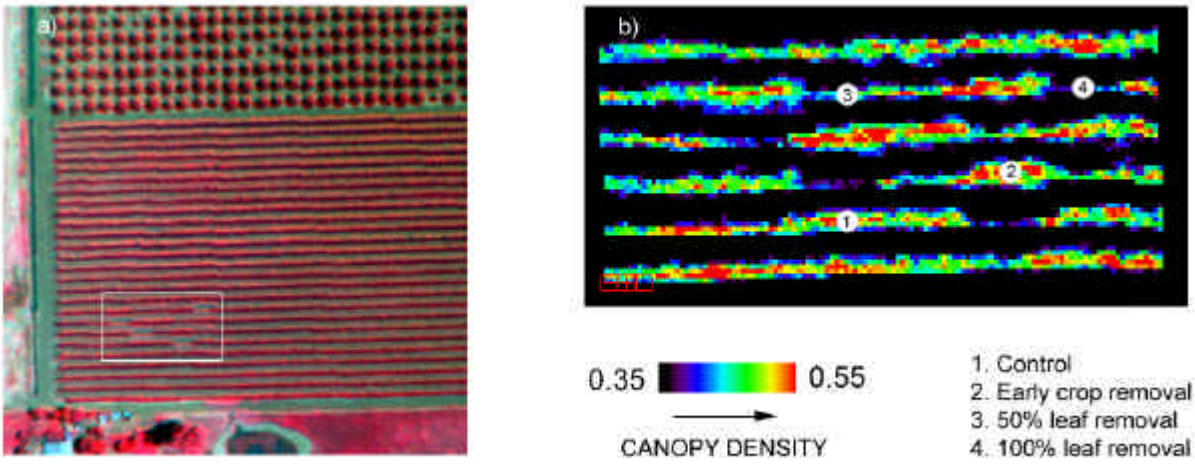


Plate 3.4. a) False colour image, and (b) normalised difference vegetation index (NDVI) of one of the Semillon trial sites taken just after post-harvest treatments were applied in 2002. NDVI values from each treatment panel indicate the reduction of canopy density was close to the 50% intended for the leaf damage treatments. The increase in canopy size as

a result of early fruit removal 7 weeks previously (b2) can be readily distinguished from the control treatment (b1).

2.3.3 Results and discussion

2.3.3.1 Effects on vine carbohydrate reserves

The starch levels varied between years, vineyards, vine parts (cordon, trunk, roots) and time in the season (harvest, leaf-fall, bud-burst). The differences between years and vine parts was influenced by the vineyard, for instance the vines in the vineyards of the Riverina region had much higher starch reserves in the roots than vines growing in the Hilltops region. While cordon and trunk starch levels were similar in all vineyards (Table 3.4, 3.5, 3.6). Soluble sugar concentrations were generally higher or unchanged at leaf-fall compared to the harvest values (Table 3.7, 3.8, 3.9).

The impact of the treatments on vine starch levels in the cordon was stronger in the Riverina region (Table 3.4), likely due to the higher yields produced in this region. In Vineyard 1 and 2 the removal of leaves after harvest reduced starch levels in the cordon determined at leaf-fall in 2001 and 2002, while early crop removal increased starch levels. Leaf damage had an intermediate effect, while juice spray had only a minor impact on the starch concentrations after harvest. Starch concentrations at harvest were also increased by early crop removal in the second year (2002); the leaf removal treatment now had similar levels to the control, which was likely due to the lower yields produced from the vines from this treatment. Vineyard 3 had only reduced starch levels in year 2 (2002) at leaf-fall implemented by the leaf removal treatment. In vineyard 4 cordon starch levels were not elevated by the crop removal measured at harvest, but were lowered if the leaves were removed after harvest in the last two years. These treatments also altered the leaf-fall starch concentrations.

The starch levels in the trunk changed similar to the cordon, increased reserves levels due to early crop removal and lowered levels by leaf removal or damage (Table 3.5). Treatment effects were still present in the third season in most vineyards and was particularly seen in the leaf removal treatment, suggesting that it takes a number of seasons for the vines to recover from leaf loss or damage after harvest. Interesting also is the elevation of starch in two Riverina vineyards effected by the juice spray.

Although there were large differences in vine root starch levels between treatments, they were only significant in the first year at leaf-fall in all vineyards (Table 3.6). The treatment effect differed between vineyards in that year, but not any treatment had significantly higher root starch levels than the control at leaf-fall. In the highest yielding vineyard 1 leaf removal after harvest produced lower starch levels at leaf fall in the first year, the level was unchanged in the second and increased in the third year (since one treatment was not applied). Early crop removal in year 2 increased root starch levels in the roots at harvest. This suggests that the lower yields diverted resources to the roots if the crop was removed early or if the vines have lower crop loads.

The soluble sugar concentrations changed in the opposite direction to the starch levels, meaning generally the levels were higher if the starch levels were low. For instance in the cordon (Table 3.7) soluble sugars are higher at leaf-fall in vineyard 1 in the first two years if the leaves were removed after harvest. This effect can also been seen in the trunk in this vineyard and in vineyard 2 and 3 (Table 3.8). The soluble sugar levels in the roots were significantly changed in vineyard 1 by all treatments at leaf-fall in year 2 and elevated by juice spray in year 3 (Table 3.9). The commonly opposing effects of the treatments on starch and sugar levels were reflected in the starch/soluble sugar ratio of the averaged trunk/cordon values (Table 3.10). Early crop removal often had the highest ratio, where leaf removal the lowest. This indicates that under low starch levels, more soluble sugar appears to be present.

There are significant changes in starch levels from harvest 2001 to leaf fall in 2003, these changes are more pronounced in the higher yielding Riverina vineyards and particularly in the roots of vines growing in this region. The starch levels in the trunk and cordon of these two vineyards were reduced by leaf

removal after harvest (Figure 3.1, 3.2) and slightly alleviated by early crop removal. The second season shows this clearly, since this treatment had been applied for two years. In the third season the starch levels reach similar values in all treatments, which is most likely due to altered crop levels induced by crop and leaf removal. The root starch levels appear to be more sensitive to the treatments, showing not only the direct effect of the treatment, but also the indirect effects implemented by the change in crop load. While starch levels at harvest for early crop removal and leaf removal were both much lower than the control, the starch levels of the vines without leaves after harvest remain the same at leaf fall, while the early crop removal treatments showed a 3 fold increase in the post-harvest period. In the third season the leaf removal treatment had the highest starch levels in the roots at harvest. Site 2 behaved similarly, although the leaf removal treatment has already increased over the control at harvest in year two, due to its effect on the crop load. The effect of the treatments on starch reserves at the two sites in Hilltop regions over the three years were less pronounced (Figure 3.3, 3.4) despite some variations between measuring points. Site 3 showed a decrease in starch in both wood and roots in both years when the leaf removal treatment was applied. There was a strong increase in root reserves if the crop was removed early in the second year. Site 4 showed only a small change implemented by the treatments, which could have been brought about by the low cropping level of this vineyard.

Vine size at the end of experiments in winter 2003 did not show any significant differences, but early crop removal vines appear to be bigger than the control, at least in vineyards 1 to 3 (Table 3.11). In vineyard 1 and 2 the vines appeared to be smaller if leaves were removed after harvest over two previous seasons. Photosynthesis or stomal conductance was not altered by crop removal, neither was the starch content of the leaves (Table 3.12). The leaves showed curling symptoms which suggested an increase in starch in the leaves. The results on starch reserves indicate that the length of the post-harvest period and, to some extent, the effectiveness can have a large impact on their concentration. The significance of the impact is largely influenced by the cropping level and can be overwritten by environmental conditions.

Table 3.4. Starch in the cordon affected by post-harvest treatments in Semillon (2001-2003) Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	Control	10.5	10.4 ^{c}	11.5 ^{a}	10.1 ^{c}	10.0	9.9
	Leaf Removal	11.0	7.9 ^{ab}	10.9 ^{a}	4.7 ^{a}	8.0	7.2
	Crop Removal	11.5	10.0 ^{bc}	14.5 ^{c}	11.4 ^{d}	8.5	9.2
	Leaf Damage	10.9	9.2 ^{bc}	11.7 ^{a}	8.4 ^{b}	9.0	10.4
	Juice spray	10.5	9.6 ^{b}	12.8 ^{b}	10.4 ^{c}	8.5	10.2
	Leaf damage + juice	11.9	9.0 ^{bc}	11.4 ^{a}	8.7 ^{b}	8.5	9.1
	Significance level (%)	ns	1.0	0.1	0.1	ns	ns
2	Control	9.8	10.1 ^{c}	9.5 ^{a}	9.0 ^{c}	12.0	12.9 ^{bc}
	Leaf Removal	10.2	8.2 ^{a}	8.9 ^{a}	4.1 ^{a}	8.5	10.9 ^{a}
	Crop Removal	10.5	11.3 ^{d}	11.2 ^{b}	9.4 ^{c}	10.2	13.2 ^{bc}
	Leaf Damage	9.2	8.8 ^{ab}	9.1 ^{a}	7.8 ^{bc}	10.5	12.2 ^{ab}
	Juice spray	9.5	10.6 ^{cd}	9.6 ^{a}	8.6 ^{c}	11.1	13.7 ^{c}
	Leaf damage + juice	9.5	9.1 ^{b}	10.0 ^{a}	7.3 ^{bc}	10.3	13.2 ^{bc}
	Significance level (%)	ns	0.1	5.0	0.1	ns	5.0
3	Control	9.4	6.7	10.1	8.0 ^{b}	9.9	5.9
	Leaf Removal	9.5	5.1	8.9	5.3 ^{a}	7.7	5.2
	Crop Removal	10.2	6.7	8.8	8.8 ^{b}	9.3	6.5
	Leaf Damage	10.5	5.6	8.7	7.8 ^{b}	9.2	6.1
	Juice spray	9.7	9.0	7.6	7.6 ^{b}	9.6	6.2
	Leaf damage + juice	10.4	6.3	9.7	8.0 ^{b}	9.3	5.6
	Significance level (%)	ns	ns	ns	5.0	ns	ns
4	Control	6.9	4.8 ^{a}	8.7 ^{bc}	8.5 ^{c}	11.7 ^{c}	8.8
	Leaf Removal	7.0	3.9 ^{a}	7.8 ^{a}	6.5 ^{a}	8.7 ^{ab}	6.6
	Crop Removal	6.5	6.3 ^{b}	9.5 ^{c}	8.7 ^{c}	10.1 ^{b}	7.5
	Leaf Damage	7.1	4.6 ^{a}	8.4 ^{ab}	7.3 ^{ab}	8.5 ^{a}	6.7
	Juice spray	7.0	6.0 ^{a}	8.9 ^{bc}	8.3 ^{bc}	10.0 ^{ab}	7.7
	Leaf damage + juice	7.8	4.3 ^{a}	8.2 ^{ab}	7.2 ^{ab}	9.7 ^{ab}	7.8
	Significance level (%)	ns	0.1	5.0	5.0	1.0	ns

Table 3.5. Starch in the trunk affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	Control	10.4	9.1 ^{b}	12.1 ^{a}	10.3 ^{c}	10.9 ^{c}	9.1 ^{ab}
	Leaf Removal	10.3	7.9 ^{a}	11.8 ^{a}	4.8 ^{a}	7.9 ^{a}	7.2 ^{a}
	Crop Removal	10.9	9.2 ^{b}	14.0 ^{b}	11.7 ^{d}	10.4 ^{c}	10.1 ^{bc}
	Leaf Damage	10.1	8.8 ^{b}	12.1 ^{a}	8.0 ^{b}	9.8 ^{bc}	10.1 ^{bc}
	Juice spray	10.4	9.0 ^{b}	12.2 ^{a}	9.9 ^{c}	9.7 ^{bc}	11.6 ^{c}
	Leaf damage + juice	10.5	8.7 ^{b}	11.1 ^{a}	8.2 ^{b}	9.5 ^{abc}	10.7 ^{bc}
	Significance level (%)	ns	5.0	1.0	0.1	5.0	5.0
2	Control	10.4 ^{ab}	10.1 ^{c}	10.9 ^{a}	9.0 ^{c}	9.9	11.9 ^{b}
	Leaf Removal	10.4 ^{ab}	9.1 ^{ab}	10.9 ^{a}	4.5 ^{a}	8.6	8.9 ^{a}
	Crop Removal	11.2 ^{b}	10.6 ^{c}	12.6 ^{b}	9.8 ^{d}	10.0	12.5 ^{bc}
	Leaf Damage	10.1 ^{a}	8.7 ^{a}	10.9 ^{bc}	7.7 ^{b}	9.7	11.5 ^{b}
	Juice spray	10.0 ^{a}	9.9 ^{bc}	11.4 ^{b}	8.6 ^{c}	10.0	12.8 ^{c}
	Leaf damage + juice	9.6 ^{a}	9.0 ^{ab}	10.4 ^{c}	6.3 ^{b}	9.6	11.3 ^{b}
	Significance level (%)	5.0	1.0	5.0	0.1	ns	0.1
3	Control	10.1	7.9 ^{bc}	9.9	5.4 ^{a}	10.1 ^{bc}	7.4 ^{b}
	Leaf Removal	10.0	5.7 ^{a}	9.6	7.7 ^{b}	8.3 ^{a}	5.5 ^{a}
	Crop Removal	10.6	8.4 ^{c}	11.0	8.1 ^{b}	10.7 ^{c}	7.2 ^{b}
	Leaf Damage	10.6	6.4 ^{ab}	9.3	8.3 ^{bc}	9.0 ^{ab}	5.6 ^{a}
	Juice spray	10.5	8.3 ^{c}	9.7	7.1 ^{b}	10.7 ^{c}	6.6 ^{ab}
	Leaf damage + juice	11.0	7.8 ^{bc}	9.7	9.8 ^{c}	9.5 ^{abc}	6.7 ^{ab}
	Significance level (%)	ns	5.0	ns	1.0	5.0	5.0
4	Control	7.4	5.9 ^{bc}	9.7	7.8 ^{d}	7.7	6.7
	Leaf Removal	6.9	4.6 ^{a}	8.9	5.9 ^{a}	6.4	5.7
	Crop Removal	7.4	6.6 ^{c}	9.8	7.8 ^{d}	8.2	5.7
	Leaf Damage	6.7	4.9 ^{a}	9.3	7.0 ^{bc}	8.1	6.5
	Juice spray	6.7	6.0 ^{bc}	9.5	7.6 ^{cd}	8.3	6.2
	Leaf damage + juice	7.0	5.1 ^{ab}	9.4	6.5 ^{ab}	7.4	5.6
	Significance level (%)	ns	1.0	ns	0.1	ns	ns

Table 3.6. Starch in the roots affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	Control	27.8	25.1 ^{c}	10.4 ^{a}	33.4 ^{b}	10.4 ^{a}	21.9
	Leaf Removal	30.8	11.2 ^{a}	12.8 ^{a}	12.4 ^{a}	17.8 ^{b}	24.0
	Crop Removal	33.0	22.1 ^{bc}	28.4 ^{b}	26.6 ^{b}	6.0 ^{a}	16.8
	Leaf Damage	24.6	16.8 ^{abc}	12.6 ^{a}	27.2 ^{b}	11.2 ^{a}	22.9
	Juice spray	26.9	23.8 ^{bc}	9.8 ^{a}	29.0 ^{b}	9.3 ^{a}	16.6
	Leaf damage + juice	22.9	15.3 ^{abc}	11.3 ^{a}	29.8 ^{b}	14.1 ^{ab}	20.4
	Significance level (%)	ns	5.0	0.1	1.0	1.0	ns
2	Control	13.7	28.2 ^{b}	17.8	22.4	10.9	22.5
	Leaf Removal	12.6	34.6 ^{b}	24.8	13.4	12.7	22.8
	Crop Removal	24.5	32.5 ^{b}	18.3	28.8	6.1	25.4
	Leaf Damage	12.9	18.4 ^{a}	17.1	25.2	12.4	20.3
	Juice spray	18.8	30.2 ^{b}	13.7	24.7	13.4	22.9
	Leaf damage + juice	16.5	31.3 ^{b}	17.9	25.3	14.3	23.3
	Significance level (%)	ns	1.0	ns	ns	ns	ns
3	Control	4.4	10.4 ^{c}	8.4	8.0	6.0	7.3
	Leaf Removal	4.2	4.1 ^{ab}	7.8	7.2	7.5	8.1
	Crop Removal	4.3	4.2 ^{ab}	17.0	10.6	6.8	9.2
	Leaf Damage	1.5	4.0 ^{ab}	9.0	9.4	5.6	8.2
	Juice spray	4.3	7.5 ^{bc}	6.2	11.7	6.0	6.9
	Leaf damage + juice	3.5	2.4 ^{a}	9.2	12.3	5.5	9.0
	Significance level (%)	ns	5.0	ns	ns	ns	ns
4	Control	9.9	7.7 ^{bc}	13.9	15.4	8.8	9.2
	Leaf Removal	13.7	3.2 ^{ab}	14.2	12.5	9.5	9.4
	Crop Removal	9.4	9.4 ^{c}	14.6	14.4	8.3	9.0
	Leaf Damage	6.0	3.6 ^{ab}	16.4	15.1	10.1	8.0
	Juice spray	5.8	8.3 ^{c}	9.7	12.3	8.9	8.3
	Leaf damage + juice	9.2	1.8 ^{a}	12.5	15.6	8.8	5.9
	Significance level (%)	ns	5.0	ns	ns	ns	ns

Table 3.7. Soluble sugars in the cordon affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	Control	2.49	3.40 ^{ab}	2.75 ^{ab}	5.81 ^{a}	2.61 ^{bc}	6.83
	Leaf Removal	1.89	4.99 ^{c}	2.55 ^{a}	8.14 ^{c}	2.71 ^{c}	7.44
	Crop Removal	1.96	2.75 ^{a}	2.96 ^{b}	5.83 ^{ab}	1.94 ^{a}	6.94
	Leaf Damage	1.97	4.12 ^{bc}	2.59 ^{a}	6.45 ^{b}	2.24 ^{ab}	7.00
	Juice spray	2.13	3.80 ^{bc}	2.60 ^{a}	5.84 ^{ab}	2.74 ^{c}	7.25
	Leaf damage + juice	1.91	4.46 ^{bc}	2.54 ^{a}	6.37 ^{b}	2.04 ^{a}	7.42
	Significance level (%)	ns	1.0	5.0	0.1	1.0	ns
2	Control	0.97	5.90 ^{a}	2.99	6.52 ^{b}	2.46	4.45
	Leaf Removal	0.77	6.39 ^{a}	2.86	9.26 ^{d}	2.66	4.23
	Crop Removal	0.82	4.56 ^{a}	2.55	5.02 ^{a}	2.39	4.11
	Leaf Damage	0.99	5.75 ^{a}	2.43	6.27 ^{b}	2.33	4.60
	Juice spray	0.88	4.70 ^{a}	2.46	5.95 ^{ab}	2.30	4.04
	Leaf damage + juice	0.47	9.65 ^{b}	2.56	7.49 ^{c}	2.50	4.41
	Significance level (%)	ns	5.0	ns	0.1	ns	ns
3	Control	1.88	2.63 ^{a}	3.02	5.80	2.87	7.49
	Leaf Removal	1.21	5.43 ^{b}	4.34	7.84	3.24	8.13
	Crop Removal	1.01	3.17 ^{a}	2.52	5.53	2.85	7.15
	Leaf Damage	1.67	5.50 ^{b}	2.74	5.93	3.46	7.28
	Juice spray	1.37	3.64 ^{ab}	5.04	6.36	2.89	8.15
	Leaf damage + juice	1.55	3.55 ^{ab}	3.02	5.84	3.03	7.26
	Significance level (%)	ns	5.0	ns	ns	ns	ns
4	Control	0.65	2.63	4.63	4.65	4.19	3.74
	Leaf Removal	0.54	3.73	4.87	5.14	4.03	4.08
	Crop Removal	0.49	2.20	5.10	4.65	4.25	3.66
	Leaf Damage	0.54	2.41	3.85	5.27	3.92	3.72
	Juice spray	0.64	3.13	6.26	4.70	3.60	4.01
	Leaf damage + juice	0.89	3.69	6.57	5.10	3.76	3.70
	Significance level (%)	ns	ns	ns	ns	ns	ns

Table 3.8. Soluble sugars in the trunk affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	**Control**	3.22	3.63 ^{ab}	2.82	6.43 ^{a}	2.37 ^{b}	5.08
	Leaf Removal	2.73	5.43 ^{c}	2.41	8.10 ^{b}	2.90 ^{c}	4.88
	Crop Removal	2.18	3.34 ^{a}	3.26	5.35 ^{a}	2.04 ^{ab}	5.47
	Leaf Damage	2.21	4.25 ^{ab}	2.51	5.89 ^{a}	1.69 ^{a}	5.50
	Juice spray	2.72	4.00 ^{ab}	2.18	5.73 ^{a}	2.27 ^{b}	5.35
	Leaf damage + juice	2.40	4.38 ^{b}	2.69	5.84 ^{a}	2.15 ^{b}	5.52
	Significance level (%)	ns	1.0	ns	1.0	0.1	ns
2	**Control**	1.04	8.47 ^{c}	3.19	5.99 ^{bc}	2.18	3.46 ^{a}
	Leaf Removal	1.52	8.86 ^{c}	2.65	9.00 ^{d}	2.28	3.51 ^{a}
	Crop Removal	0.66	3.90 ^{a}	2.75	4.45 ^{a}	1.80	4.46 ^{b}
	Leaf Damage	1.18	5.04 ^{b}	2.91	5.34 ^{b}	2.29	3.77 ^{ab}
	Juice spray	1.11	4.46 ^{b}	2.53	4.89 ^{b}	1.96	4.03 ^{ab}
	Leaf damage + juice	1.45	7.94 ^{c}	2.81	6.47 ^{c}	2.16	4.42 ^{b}
	Significance level (%)	ns	0.1	ns	0.1	ns	5.0
3	**Control**	1.79	2.64 ^{ab}	2.40	5.31 ^{bc}	2.46	5.93 ^{a}
	Leaf Removal	1.82	3.77 ^{c}	2.59	6.07 ^{c}	2.69	6.66 ^{b}
	Crop Removal	1.06	1.98 ^{ab}	2.55	4.57 ^{a}	2.61	5.63 ^{a}
	Leaf Damage	0.93	3.46 ^{bc}	2.52	5.49 ^{bc}	3.25	6.37 ^{ab}
	Juice spray	1.16	2.84 ^{ab}	2.53	5.20 ^{ab}	3.06	6.75 ^{b}
	Leaf damage + juice	1.54	3.05 ^{bc}	2.44	5.59 ^{bc}	3.20	6.15 ^{ab}
	Significance level (%)	ns	5.0	ns	1.0	ns	5.0
4	**Control**	0.50	2.70	4.73	4.85	3.27	3.12
	Leaf Removal	0.46	2.26	3.53	5.02	3.51	3.41
	Crop Removal	0.41	1.83	4.14	4.25	3.63	3.19
	Leaf Damage	0.48	2.65	4.32	4.56	3.60	2.85
	Juice spray	0.76	2.19	4.06	4.55	3.91	3.62
	Leaf damage + juice	0.49	2.86	3.60	4.68	3.58	2.94
	Significance level (%)	ns	ns	ns	ns	ns	ns

Table 3.9. Soluble sugars in the roots affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	Control	2.54	2.67	5.68	6.57 ^{c}	6.77 ^{a}	6.32
	Leaf Removal	2.57	3.37	6.99	8.01 ^{d}	6.62 ^{a}	6.91
	Crop Removal	2.00	3.92	4.44	4.34 ^{a}	6.58 ^{a}	6.08
	Leaf Damage	2.24	2.65	6.54	5.32 ^{ab}	6.94 ^{a}	6.42
	Juice spray	2.13	4.58	6.19	5.48 ^{b}	8.19 ^{b}	8.39
	Leaf damage + juice	2.49	3.18	6.94	5.07 ^{ab}	6.70 ^{a}	7.33
	Significance level (%)	ns	ns	ns	0.1	5.0	ns
2	Control	1.85	5.33 ^{ab}	4.74	4.46	4.59	4.10
	Leaf Removal	1.61	5.34 ^{ab}	4.31	5.63	5.20	4.81
	Crop Removal	1.23	4.12 ^{a}	3.76	4.06	4.67	5.49
	Leaf Damage	2.69	3.92 ^{a}	4.95	4.90	4.56	5.17
	Juice spray	2.16	4.92 ^{a}	4.87	4.84	4.55	5.05
	Leaf damage + juice	2.73	6.98 ^{b}	4.57	5.80	4.50	5.00
	Significance level (%)	ns	5.0	ns	ns	ns	ns
3	Control	2.28	4.91	5.69	7.52	5.76	8.00
	Leaf Removal	1.80	2.73	7.44	7.90	6.07	9.06
	Crop Removal	3.64	3.58	5.34	6.93	5.29	7.87
	Leaf Damage	2.20	3.64	6.40	7.87	6.59	9.14
	Juice spray	1.75	3.93	6.69	8.65	5.61	9.15
	Leaf damage + juice	2.35	3.64	6.98	8.54	5.99	8.33
	Significance level (%)	ns	ns	ns	ns	ns	ns
4	Control	2.99	5.11	9.02	5.73	6.94	4.03
	Leaf Removal	3.49	5.92	7.20	5.58	7.29	3.77
	Crop Removal	2.59	4.55	6.60	7.26	6.74	3.99
	Leaf Damage	2.17	4.62	7.91	6.02	6.23	4.30
	Juice spray	2.49	4.13	8.75	6.90	7.29	5.53
	Leaf damage + juice	3.05	4.55	8.21	5.39	7.18	3.10
	Significance level (%)	ns	ns	ns	ns	ns	ns

Table 3.10. Starch/soluble sugar ratio in wood affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Harvest	Leaf-fall	Harvest	Leaf-fall	Harvest	Leaf-fall
1	**Control**	3.74	2.85 ^{cd}	4.24	1.67 ^{c}	4.40 ^{bc}	1.61 ^{b}
	Leaf Removal	4.70	1.54 ^{a}	4.59	0.59 ^{a}	2.84 ^{a}	1.17 ^{a}
	Crop Removal	5.43	3.30 ^{d}	4.57	2.07 ^{d}	4.83 ^{c}	1.56 ^{b}
	Leaf Damage	5.06	2.23 ^{bc}	4.70	1.34 ^{b}	4.90 ^{c}	1.65 ^{b}
	Juice spray	4.33	2.41 ^{bc}	5.61	1.76 ^{c}	3.63 ^{ab}	1.73 ^{b}
	Leaf damage + juice	5.24	2.03 ^{ab}	4.31	1.39 ^{b}	4.40 ^{bc}	1.53 ^{b}
	Significance level (%)	ns	0.1	ns	0.1	1.0	5.0
2	**Control**	12.54	1.46 ^{abc}	3.32 ^{a}	1.44 ^{cd}	4.84	3.15 ^{bc}
	Leaf Removal	15.85	1.16 ^{ab}	3.60 ^{ab}	0.47 ^{a}	3.53	2.57 ^{a}
	Crop Removal	15.42	2.60 ^{c}	4.50 ^{b}	2.03 ^{e}	5.15	3.00 ^{bc}
	Leaf Damage	9.29	2.41 ^{c}	3.82 ^{ab}	1.34 ^{c}	4.47	2.85 ^{ab}
	Juice spray	11.31	2.29 ^{bc}	4.22 ^{b}	1.60 ^{d}	5.22	3.30 ^{c}
	Leaf damage + juice	10.99	1.10 ^{a}	3.79 ^{ab}	1.05 ^{b}	4.40	2.80 ^{ab}
	Significance level (%)	ns	5.0	5.0	0.1	ns	5.0
3	**Control**	5.44	2.85 ^{cd}	3.72 ^{bc}	1.21 ^{b}	3.76	0.99
	Leaf Removal	7.10	1.23 ^{a}	2.72 ^{a}	0.95 ^{a}	2.74	0.74
	Crop Removal	11.02	3.17 ^{d}	3.91 ^{c}	1.68 ^{d}	3.66	1.08
	Leaf Damage	9.38	1.74 ^{ab}	2.46 ^{a}	1.37 ^{bc}	3.05	0.86
	Juice spray	7.58	2.11 ^{abc}	3.31 ^{bc}	1.32 ^{bc}	3.15	0.86
	Leaf damage + juice	7.21	2.20 ^{bc}	3.57 ^{bc}	1.56 ^{cd}	3.07	0.93
	Significance level (%)	ns	1.0	0.1	0.1	ns	ns
4	**Control**	12.98	2.04 ^{ab}	1.98	1.72 ^{c}	2.61	2.27
	Leaf Removal	15.52	1.43 ^{ab}	2.03	1.23 ^{a}	2.00	1.64
	Crop Removal	15.11	3.37 ^{c}	2.33	1.86 ^{c}	2.33	1.95
	Leaf Damage	14.27	1.94 ^{ab}	2.16	1.46 ^{b}	2.24	2.04
	Juice spray	10.59	2.41 ^{b}	1.85	1.72 ^{c}	2.44	1.85
	Leaf damage + juice	11.10	1.47 ^{a}	2.72	1.40 ^{ab}	2.35	2.02
	Significance level (%)	ns	1.0	ns	0.1	ns	ns

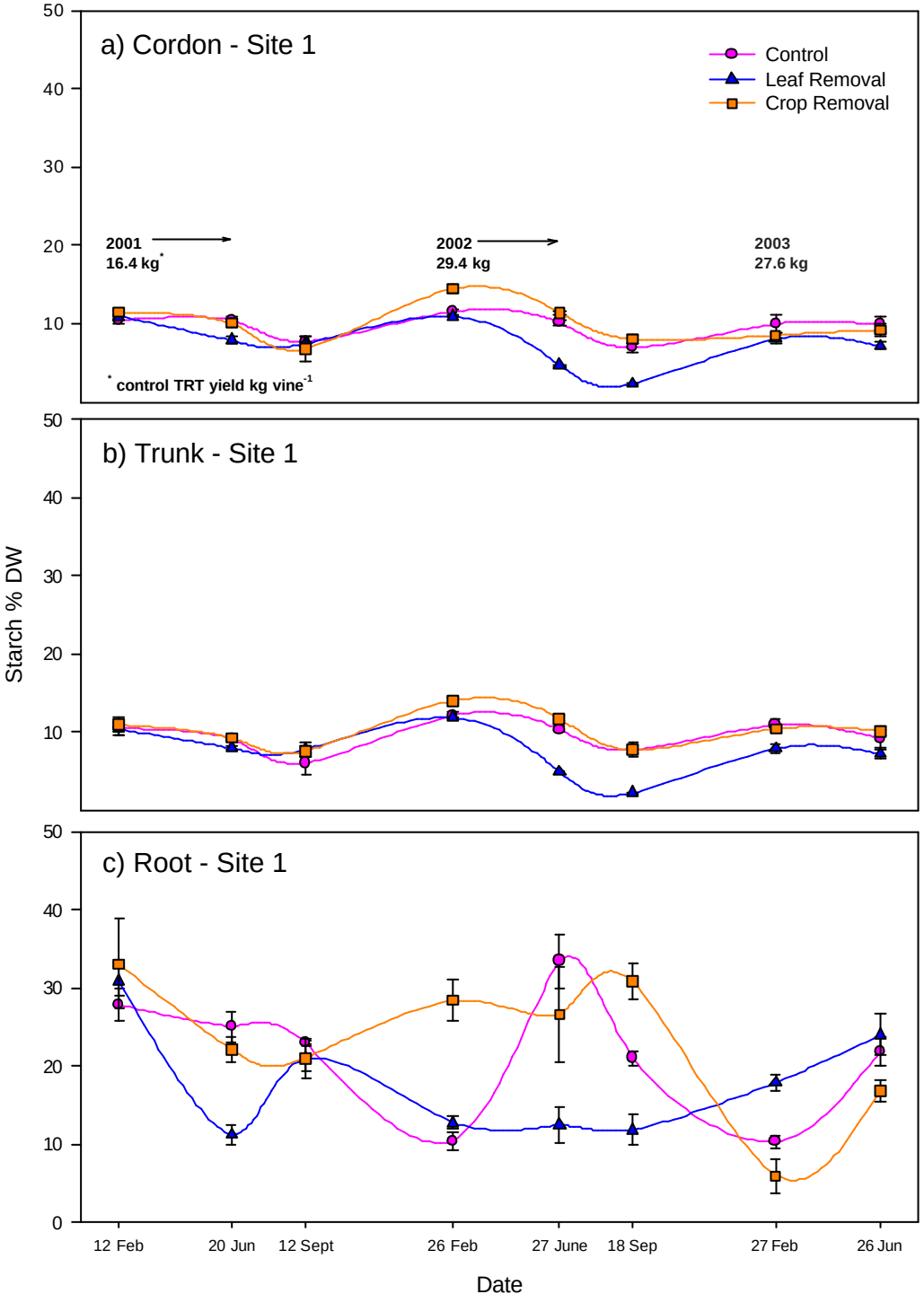

a) Cordon - Site 1
Control
Leaf Removal
Crop Removal
2001
16.4 kg*
2002
29.4 kg
2003
27.6 kg
* control TRT yield kg vine-1
b) Trunk - Site 1
c) Root - Site 1
Starch % DW
50
40
30
20
10
0
12 Feb
20 Jun
12 Sept
26 Feb
27 June
18 Sep
27 Feb
26 Jun
Date

Figure 3.1. The changes of starch reserve levels in cordon, trunk and roots (harvest 2001 to leaf-fall 2003) in vineyard 1 (Riverina region) (standard errors of the means are shown as bars, n=4).

Figure 3.2. The changes of starch reserve levels in cordon, trunk and roots (harvest 2001 to leaf-fall 2003) in vineyard 2 (Riverina region) (standard errors of the

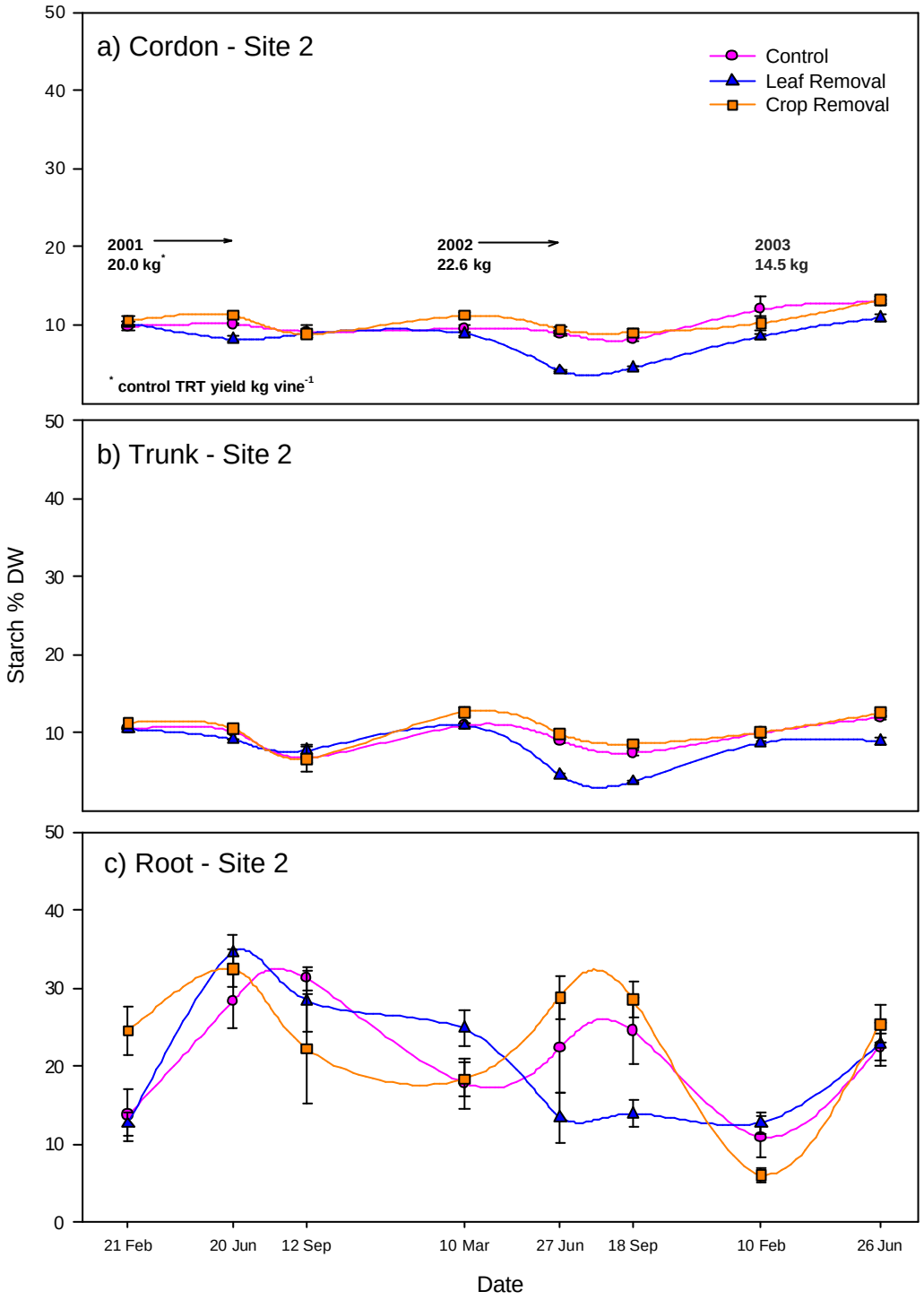


Figure 3.3. The changes of starch reserve levels in cordon, trunk and roots of the

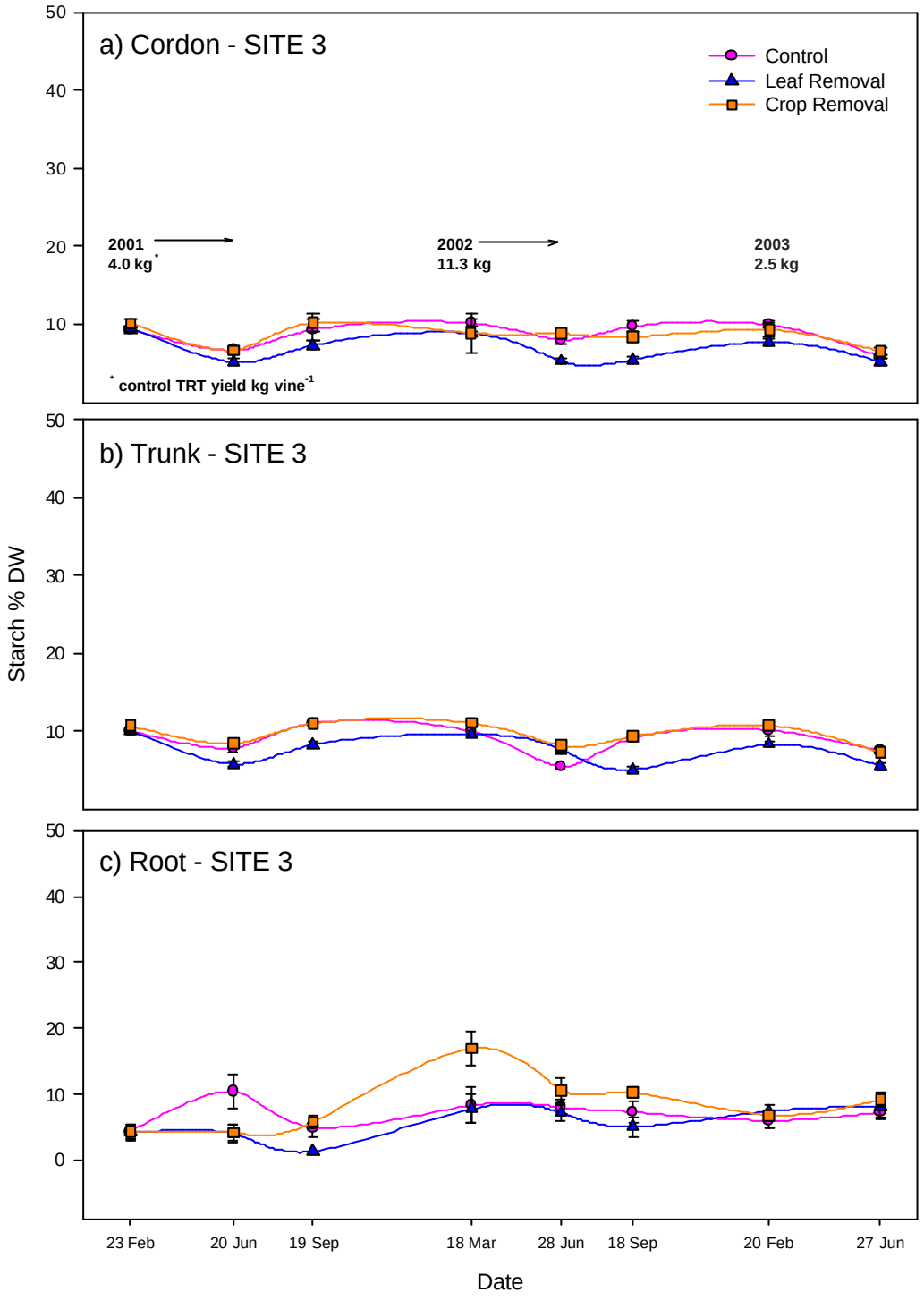


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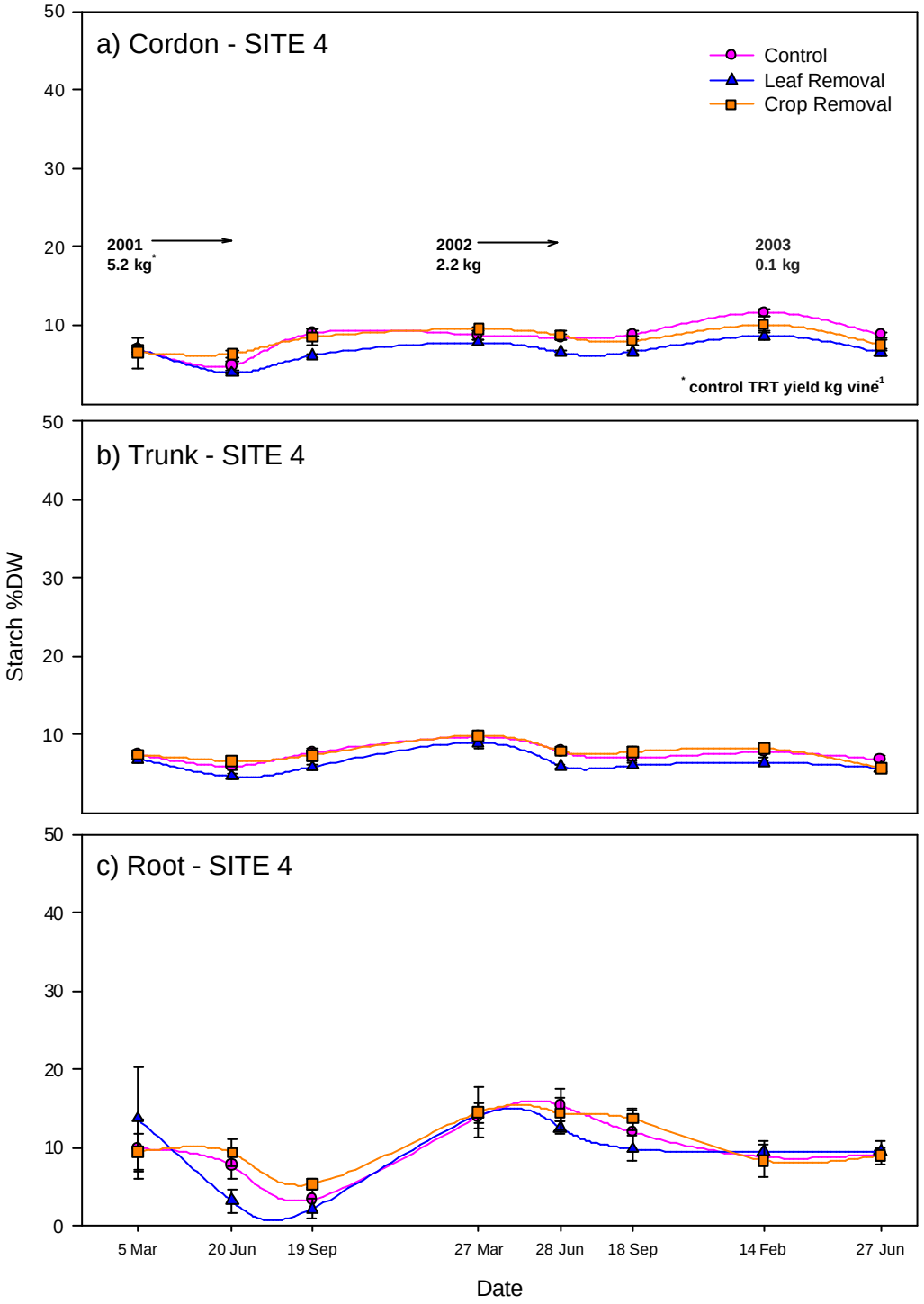


Table four

Table four
ined
lumn

Vineyard	Treatment	A $mmol \cdot m^{-2} \cdot s^{-1}$	E $mmol \cdot m^{-2} \cdot s^{-1}$	Gs $mol \cdot m^{-2} \cdot s^{-1}$	Leaf Temp. ^{o}C	Starch %DW	Sol. Sugars %DW
1	Control	13.02	7.18	0.41	35.9	0.79	7.77 [a]
	Crop Removal	12.38	6.75	0.50	34.8	0.85	9.73 [b]
		ns	ns	ns	ns	ns	1.0
2	Control	15.39	5.14	0.49	30.1	0.84	9.96
	Crop Removal	15.95	4.93	0.42	29.7	0.96	10.56
		ns	ns	ns	ns	ns	ns
3	Control	12.95	3.00	0.21	28.6	0.76	10.79
	Crop Removal	12.52	3.28	0.22	29.4	0.82	12.12
		ns	ns	ns	ns	ns	ns
4	Control	9.03	1.55	0.09	33.0	0.80	11.27
	Crop Removal	9.58	1.58	0.08	33.5	0.90	11.31
		ns	ns	ns	ns	ns	ns

2.3.3.2 Effects on vine productivity

The vine productivity was affected by the treatments in all sites, although severity varied between regions. In the higher yielding Riverina vineyards the impact on yields and pruning weights were massive, while in the Hilltops region the differences between treatments were small (Table 3.13). The latter would we be due to the drought conditions, overriding some of the treatment effects. Despite the low pruning weights in the Hilltops vineyards in year 3, vineyard 3 showed lowered yield and pruning weights, when the leaves were removed after harvest the previous season. The productivity was increased if the crop was removed early the year before. Vineyard 4 only showed a lowered pruning weight in year 2 if the leaves were removed after harvest in 2001. The vineyard 1 in the Riverina region was most responsive to the treatments, even showing an impact of the juice spray in year 3, by elevating the yields. Vineyard 2 was responsive to the leaf and crop removal treatment, particularly in year 3. These results indicate that the post-harvest period is more important in the higher yielding vineyards of the Riverina in regard to vine productivity.

Shoot number determined at the end of the season and shoot length shortly after flowering was affected in all vineyards, particularly in the second season (Figure 3.14). The Hilltops vineyard 4 had much higher shoot numbers than all the other vineyards, which was due to mechanical pruning. The shoot numbers were increased by early crop removal in 2001/02 and 2002/03, while a reduction in shoot numbers by leaf damage took place in the later year (spring 2002). The shorter shoots in this vineyard in the last two years were due to drought conditions. In vineyard 3, shoot length was increased by the early crop removal treatment in the first two years, and shoot length was also lowered by leaf removal after harvest in spring 2001. The Riverina vineyards were more responsive to the applied treatments in the shoot length in spring 2002 and 2003, the impact was still present two seasons after the treatments were applied. This suggests the importance of the post-harvest period in the high yielding vineyards of the Riverina on the following years shoot growth. The differences in the impact of altered post-harvest period of the different vineyards can been seen in Figure 3.6, shoots in vineyard 1 of the leaf removal treatments have only half the length than the shoots from the control vines. The differences between treatments become smaller from vineyard 2 to 3, while in vineyard 4 no differences between treatments were present. This poor response of the treatments in the Hilltop region could have been partly due to the drought conditions in that year. The difference between the treatments is already established between budburst and bloom (end of October), suggesting that the dependency of vine reserves is particularly important in the first 4-5 weeks until sufficient leaf area is established.

The number of shoots per vine and the number of bunches per shoots determines the bunches per vine and influences the overall yield. Therefore it is understandable that the Riverina vineyards bunch numbers were altered more by the applied treatments than in the Hilltops vineyards (Table 3.15), although there was a significant reduction in bunches per vine in vineyard 3 due to leaf removal after harvest in spring 2002. In vineyard 1 there was a significant reduction in bunches per shoot and per vine in spring 2002, while in vineyard 2 early crop removal increased these two parameters in spring 2001 and 2002. Bud burst was only altered in vineyard 3 (Table 1.16), where it was increased by post-harvest leaf removal. Flowers and berries per bunch were altered in all vineyards accept number 4, generally early crop removal increased and leaf removal lowered flower and berry numbers. Fruit set was not significantly affected by the treatments, which indicates that the treatments affecting the yield mainly by impacting on initiation (bunch numbers) and differentiation (flower numbers).

Bunch and berry weight was unchanged by the treatments at harvest 2002 in all vineyards, berries per bunch was increased by the juice spray in vineyard 1 (Table 3.17). Although leaf removal resulted in higher TSS, there were only significant differences in juice pH and TA in vineyard 2, this treatment had the highest pH and lowest TA. The measurements obtained at harvest 2003 showed significant differences in all bunch and berry parameters except berry size (Table 3.18). In vineyard 3 TSS were decreased by early crop removal and increased by juice spray at harvest. The crop removal treatment

also had the highest number of berries per bunch. In the Riverina vineyards the berry number per bunch and the bunch weight were increased by early crop removal and lowered by leaf removal after harvest. Berry TSS was higher in the leaf removal treatment and lower in the crop removal treatment compared to the control. Juice pH was lowest in the crop removal treatment, which had the highest TA. The differences in berries per bunch were mainly due to the flower numbers since differences in fruit set were not very strong. The impact on berry sugar would have been implemented by the different crop loads altered by the treatments. The effect on berry ripening was already present in the two Riverina vineyards at veraison and mid-ripening (Table 3.19). This suggests an indirect effect of the post-harvest period on berry composition in the following year, due to the impact on crop load.

Table 3.13. Yield and pruning weight affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Yield kg/vine			Pruning wt. kg/vine		
		2001	2002	2003	2001	2002	2003
1	Control	16.4	29.4 b	27.6 bc	2.7 bc	2.2 bc	2.0 cd
	Leaf Removal	15.5	22.9 a	13.9 a	2.4 ab	1.5 a	0.9 a
	Crop Removal[1]	-	-	35.2 d	2.9 c	2.5 c	2.4 d
	Leaf Damage	17.7	27.3 b	25.4 b	2.2 a	1.7 ab	1.5 bc
	Juice spray	18.1	29.2 b	30.6 c	2.2 a	2.1 bc	1.8 bc
	Leaf damage + juice	18.0	26.4 b	25.1 b	2.5 ab	1.8 ab	1.7 bc
	Significance level (%)	ns	1.0	0.1	5.0	0.1	0.1
2	Control	20.0	22.6	14.5 b	1.9	1.6 a	1.3 b
	Leaf Removal	19.0	17.7	9.4 a	1.8	1.5 a	0.9 a
	Crop Removal[1]	-	-	23.1 c	2.2	2.3 b	2.2 c
	Leaf Damage	18.9	19.7	13.5 b	1.8	1.5 a	1.3 b
	Juice spray	19.1	24.0	16.5 b	2.0	1.8 a	1.4 b
	Leaf damage + juice	20.2	19.9	13.6 b	1.7	1.5 a	1.2 ab
	Significance level (%)	ns	ns	0.1	ns	1.0	0.1
3	Control	4.0	11.3	2.5 bc	1.9	1.5	0.4 ab
	Leaf Removal	4.2	9.0	1.6 a	1.9	1.1	0.3 a
	Crop Removal[1]	-	-	3.4 d	2.0	1.6	0.6 c
	Leaf Damage	3.9	9.8	1.9 ab	1.6	1.2	0.4 ab
	Juice spray	3.6	10.6	1.9 ab	1.8	1.2	0.3 a
	Leaf damage + juice	4.5	11.8	2.8 cd	1.9	1.3	0.5 b
	Significance level (%)	ns	ns	1.0	ns	ns	0.1
4	Control	5.2	2.2	0.1	1.3	0.7 b	0.2
	Leaf Removal	5.0	2.5	0.3	1.1	0.4 a	0.2
	Crop Removal[1]	-	-	0.1	1.2	0.7 b	0.2
	Leaf Damage	5.7	2.0	0.4	1.0	0.6 ab	0.3
	Juice spray	4.6	2.8	0.4	1.1	0.6 ab	0.2
	Leaf damage + juice	5.4	2.5	0.3	1.0	0.6 ab	0.2
	Significance level (%)	ns	ns	ns	ns	ns	5.0

[1)]The crop was removed at mid ripening, therefore yield could not be determined

Table 3.14. Shoot number per vine and shoot length shortly after flowering affected by post-harvest treatments in Semillon (2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003	
		Shoot No[1)]	Shoot length (cm)	Shoot No[1)]	Shoot length (cm)	Shoot No[2)]	Shoot length (cm)
1	Control	51.6	69.2	51.4 ^{b}	90.1 ^{bc}	62.7	84.6 ^{b}
	Leaf Removal	51.4	61.3	49.1 ^{b}	54.2 ^{a}	66.3	68.9 ^{a}
	Crop Removal	50.8	71.0	48.8 ^{b}	97.3 ^{c}	70.2	94.6 ^{c}
	Leaf Damage	56.0	61.5	52.7 ^{b}	76.9 ^{b}	-	-
	Juice spray	46.2	69.7	42.9 ^{a}	94.5 ^{bc}	-	-
	Leaf damage + juice	52.1	63.3	50.2 ^{b}	91.3 ^{bc}	-	-
	Significance level (%)	ns	ns	1.0	1.0	ns	1.0
2	Control	48.7 ^{cd}	66.8	44.5	82.4 ^{b}	60.6	72.0 ^{a}
	Leaf Removal	42.0 ^{ab}	65.6	38.9	66.0 ^{a}	56.2	71.0 ^{a}
	Crop Removal	42.5 ^{ab}	72.4	41.4	99.3 ^{c}	59.9	89.1 ^{b}
	Leaf Damage	49.7 ^{d}	70.2	43.4	75.4 ^{ab}	-	-
	Juice spray	39.1 ^{ab}	67.7	39.6	80.8 ^{b}	-	-
	Leaf damage + juice	45.4 ^{bc}	69.2	40.8	80.7 ^{b}	-	-
	Significance level (%)	0.1	ns	ns	1.0	ns	1.0
3	Control	45.8	84.1 ^{bc}	54.3	57.0 ^{a}	49.6	56.3
	Leaf Removal	46.1	71.9 ^{a}	65.0	50.4 ^{a}	50.0	54.8
	Crop Removal	44.8	85.9 ^{c}	61.1	67.2 ^{b}	51.6	64.8
	Leaf Damage	47.5	81.2 ^{bc}	56.1	50.9 ^{a}	-	-
	Juice spray	46.8	76.7 ^{ab}	61.3	50.4 ^{a}	-	-
	Leaf damage + juice	46.8	76.2 ^{ab}	55.3	57.6 ^{a}	-	-
	Significance level (%)	ns	5.0	ns	1.0	ns	ns
4	Control	169.8 ^{ab}	69.2	243.3 ^{abc}	25.2	37.0	35.2
	Leaf Removal	163.8 ^{a}	56.6	249.5 ^{bc}	25.5	38.7	35.5
	Crop Removal	189.3 ^{b}	67.9	265.8 ^{d}	25.0	38.3	33.6
	Leaf Damage	160.3 ^{a}	62.9	216.8 ^{a}	29.7	-	-
	Juice spray	174.5 ^{ab}	62.3	260.8 ^{cd}	25.9	-	-
	Leaf damage + juice	156.8 ^{ab}	64.4	239.0 ^{abc}	26.5	-	-
	Significance level (%)	5.0	ns	5.0	ns	ns	ns

[1)]Shoot number determined in at the end of the growing season in autumn. [2)]The three key treatments were only assessed, both were determined in spring 2003.

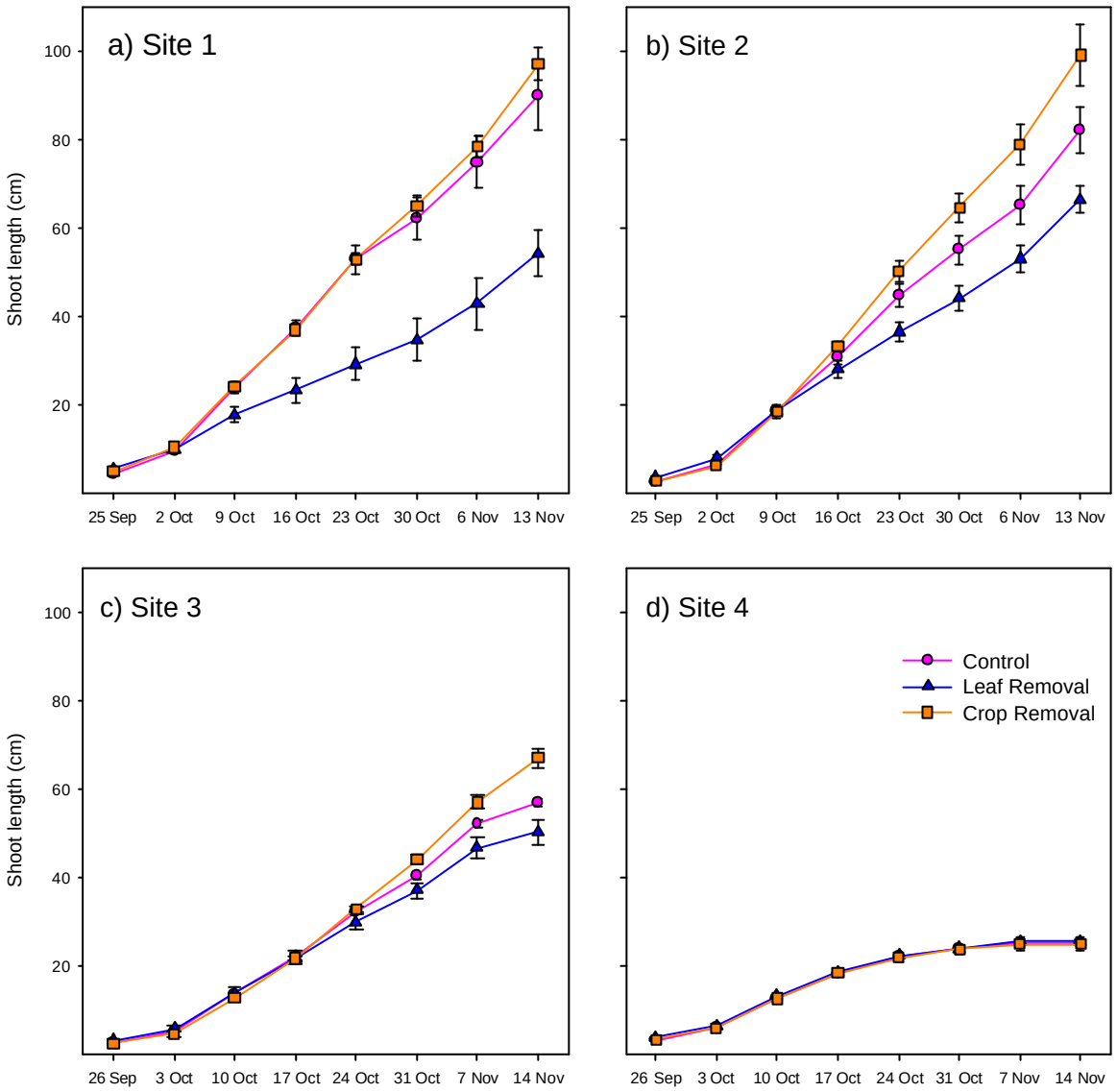


Figure 3.6. Shoot growth for the first 8 weeks following bud-break in spring 2002 as affected by post-harvest treatments applied after harvest in 2001 and 2002 (standard errors of the means are shown as bars, n=4).

Table 3.15. Bunches per shoot and per vine shortly after flowering affected by post-harvest treatments in Semillon (spring 2001-2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	2001		2002		2003[1)]	
		Bunches/ Shoot	Bunches/ Vine	Bunches/ Shoot	Bunches/ Vine	Bunches/ Shoot	Bunches/ Vine
1	**Control**	2.3	117.5	2.0 ^{bc}	103.3 ^{bc}	2.0	124.5
	Leaf Removal	1.9	98.6	1.4 ^{a}	66.6 ^{a}	1.9	122.7
	Crop Removal	2.4	120.3	2.2 ^{c}	107.2 ^{c}	2.0	139.4
	Leaf Damage	1.9	106.9	1.7 ^{ab}	90.8 ^{b}	-	-
	Juice spray	2.1	95.6	2.2 ^{c}	93.7 ^{bc}	-	-
	Leaf damage + juice	2.1	110.0	2.0 ^{bc}	98.8 ^{bc}	-	-
	Significance level (%)	ns	ns	1.0	0.1	ns	ns
2	**Control**	2.0 ^{ab}	97.5 ^{a}	1.8 ^{ab}	81.1 ^{a}	2.0	121.4
	Leaf Removal	2.1 ^{bc}	88.5 ^{a}	1.9 ^{ab}	73.3 ^{a}	2.0	109.4
	Crop Removal	3.0 ^{d}	126.3 ^{b}	2.3 ^{c}	93.8 ^{b}	2.1	123.0
	Leaf Damage	1.7 ^{a}	86.4 ^{a}	1.7 ^{a}	72.1 ^{a}	-	-
	Juice spray	2.4 ^{c}	95.1 ^{a}	2.1 ^{bc}	81.7 ^{a}	-	-
	Leaf damage + juice	1.9 ^{ab}	84.5 ^{a}	1.8 ^{ab}	73.9 ^{a}	-	-
	Significance level (%)	0.1	0.1	5.0	1.0	ns	ns
3	**Control**	1.5	70.7	0.9 ^{bc}	50.9	1.0	49.5
	Leaf Removal	1.4	66.4	0.7 ^{a}	48.1	0.9	44.9
	Crop Removal	1.8	82.8	0.9 ^{abc}	53.9	1.0	51.7
	Leaf Damage	1.5	73.2	0.9 ^{bc}	52.6	-	-
	Juice spray	1.5	71.3	0.8 ^{ab}	51.5	-	-
	Leaf damage + juice	1.6	74.1	1.0 ^{c}	56.3	-	-
	Significance level (%)	ns	ns	5.0	ns	ns	ns
4	**Control**	0.4	73.1	0.3	64.8	0.6	23.0
	Leaf Removal	0.5	77.3	0.2	60.3	0.6	24.0
	Crop Removal	0.4	75.0	0.2	66.3	0.7	25.8
	Leaf Damage	0.4	58.8	0.2	53.3	-	-
	Juice spray	0.5	80.3	0.2	58.8	-	-
	Leaf damage + juice	0.4	64.5	0.2	54.5	-	-
	Significance level (%)	ns	ns	ns	ns	ns	ns

[1)]The three key treatments were only assessed.

Table 3.16. Effect of post-harvest treatments on bud-break, inflorescence flower numbers and fruit-set in spring 2002. Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Retainded buds	Shoot No	Bud burst %	Flowers/ bunch	Berries/ bunch[1]	Fruit set %
1	**Control**	64	61	95	280 ^{ab}	152 ^{bc}	55
	Leaf removal	58	59	101	221 ^{a}	105 ^{a}	50
	Crop removal	61	63	103	323 ^{bc}	186 ^{c}	56
	Significance level (%)	ns	ns	ns	5.0	1.0	ns
2	**Control**	55	52	95	247 ^{a}	156 ^{b}	62
	Leaf removal	51	51	101	246 ^{a}	125 ^{a}	52
	Crop removal	59	56	95	311 ^{b}	193 ^{c}	63
	Significance level (%)	ns	ns	ns	0.1	1.0	ns
3	**Control**	51	52 ^{a}	102	255 ^{b}	79 ^{b}	34
	Leaf removal	50	59 ^{b}	117	187 ^{ab}	55 ^{a}	30
	Crop removal	46	48 ^{a}	106	230 ^{ab}	88 ^{b}	42
	Significance level (%)	ns	1.0	ns	5.0	5.0	ns
4	**Control**	115	111	97	224	39	18
	Leaf removal	109	109	101	197	32	16
	Crop removal	112	109	98	214	28	13
	Significance level (%)	ns	ns	ns	ns	ns	ns

[1)]All measurements were conducted in spring except berry numbers per bunch at harvest.

Table 3.17. Bunch and berry parameters affected by post-harvest treatments in Semillon (2002). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Bunch wt. (g)	Berry/ bunch	Berry wt. (g)	TSS °Brix	pH	TA (g/L)
1	**Control**	251	109 ^{ab}	2.3	18.2	3.46	5.77
	Leaf Removal	232	102 ^{a}	2.3	19.5	3.53	5.18
	Crop Removal[1]	-	-	-	-	-	-
	Leaf Damage	258	114 ^{ab}	2.3	18.5	3.51	5.34
	Juice spray	311	131 ^{c}	2.4	18.4	3.50	5.23
	Leaf damage + juice	244	107 ^{a}	2.3	18.7	3.53	5.08
	Significance level (%)	ns	5.0	ns	ns	ns	ns
2	**Control**	233	132	1.8	22.6	3.60 ^{a}	4.83 ^{bc}
	Leaf Removal	202	112	1.8	23.7	3.67 ^{c}	4.49 ^{a}
	Crop Removal[1]	-	-	-	-	-	-
	Leaf Damage	228	130	1.7	23.1	3.63 ^{ab}	4.63 ^{ab}
	Juice spray	253	136	1.9	22.4	3.62 ^{a}	4.91 ^{c}
	Leaf damage + juice	237	125	1.9	23.1	3.67 ^{bc}	4.51 ^{ab}
	Significance level (%)	ns	ns	ns	ns	1.0	5.0
3	**Control**	159	119	1.3	22.4	3.81	3.49
	Leaf Removal	134	98	1.4	24.1	3.82	3.33
	Crop Removal[1]	-	-	-	-	-	-
	Leaf Damage	135	105	1.3	23.3	3.77	3.48
	Juice spray	148	119	1.2	22.5	3.77	3.56
	Leaf damage + juice	159	121	1.3	22.7	3.75	3.46
	Significance level (%)	ns	ns	ns	ns	ns	ns
4	**Control**	30	30	1.0	25.5	3.73	4.32
	Leaf Removal	32	32	1.0	26.2	3.70	4.31
	Crop Removal[1]	-	-	-	-	-	-
	Leaf Damage	33	32	1.0	25.8	3.72	4.25
	Juice spray	35	35	1.0	25.7	3.71	4.32
	Leaf damage + juice	38	36	1.0	25.9	3.70	4.30
	Significance level (%)	ns	ns	ns	ns	ns	ns

[1)] The crop was removed at mid ripening, therefore bunch weight and berry paramteres could not be determined.

Table 3.18. Bunch and berry parameters affected by post-harvest treatments in Semillon (2003). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Bunch wt. (g)	Berry/ bunch	Berry wt. (g)	TSS °Brix	pH	TA (g/L)
1	**Control**	268 ^{b}	119 ^{ab}	2.3	19.3 ^{b}	4.06 ^{b}	4.15 ^{bc}
	Leaf Removal	209 ^{a}	108 ^{a}	2.0	21.7 ^{c}	4.18 ^{d}	3.80 ^{a}
	Crop Removal	328 ^{c}	147 ^{c}	2.2	17.1 ^{a}	3.98 ^{a}	4.24 ^{c}
	Leaf Damage	282 ^{b}	129 ^{bc}	2.2	20.8 ^{bc}	4.11 ^{c}	3.77 ^{a}
	Juice spray	328 ^{c}	140 ^{bc}	2.4	19.8 ^{b}	4.04 ^{b}	4.00 ^{ab}
	Leaf damage + juice	264 ^{b}	125 ^{ab}	2.1	19.7 ^{b}	4.08 ^{bc}	3.97 ^{ab}
	Significance level (%)	0.1	5.0	ns	0.1	0.1	1.0
2	**Control**	181 ^{b}	128 ^{b}	1.4	22.4 ^{bc}	4.01 ^{b}	3.75 ^{ab}
	Leaf Removal	128 ^{a}	105 ^{a}	1.2	25.5 ^{d}	4.07 ^{b}	3.58 ^{ab}
	Crop Removal	248 ^{c}	163 ^{c}	1.5	19.2 ^{a}	3.91 ^{a}	4.53 ^{c}
	Leaf Damage	190 ^{b}	127 ^{b}	1.5	22.7 ^{bc}	4.03 ^{b}	3.83 ^{ab}
	Juice spray	205 ^{b}	134 ^{b}	1.5	22.0 ^{bc}	3.98 ^{ab}	4.02 ^{b}
	Leaf damage + juice	188 ^{b}	132 ^{b}	1.4	23.6 ^{c}	4.02 ^{b}	3.67 ^{ab}
	Significance level (%)	0.1	0.1	ns	0.1	5.0	1.0
3	**Control**	48	76 ^{ab}	0.6	22.6 ^{ab}	4.09	3.46
	Leaf Removal	33	55 ^{a}	0.6	22.0 ^{ab}	4.17	3.35
	Crop Removal	65	98 ^{b}	0.6	21.6 ^{a}	4.10	3.73
	Leaf Damage	36	70 ^{a}	0.5	23.3 ^{bc}	4.19	3.62
	Juice spray	37	67 ^{a}	0.6	23.8 ^{c}	4.16	3.62
	Leaf damage + juice	50	77 ^{ab}	0.7	23.5 ^{c}	4.07	3.57
	Significance level (%)	ns	5.0	ns	5.0	ns	ns
4	**Control**	3	24	0.1	29.0	3.81	5.42
	Leaf Removal	6	31	0.2	28.2	3.85	5.39
	Crop Removal	3	25	0.1	28.3	3.79	5.40
	Leaf Damage	6	37	0.2	28.5	3.73	5.86
	Juice spray	10	42	0.2	28.1	3.85	4.63
	Leaf damage + juice	7	31	0.2	28.4	3.81	4.85
	Significance level (%)	ns	ns	ns	ns	ns	ns

Table 3.19. Berry size and berry ripening affected by post-harvest treatments in Semillon (spring 2002). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Veraison		Mid-ripening		Harvest	
		Berry wt. (g)	TSS (^{o}Brix)	Berry wt. (g)	TSS (^{o}Brix)	Berry wt. (g)	TSS (^{o}Brix)
1	Control	1.12	6.75 ^{a}	1.85	16.18 ^{a}	2.25	19.25 ^{a}
	Leaf removal	1.15	8.73 ^{b}	1.73	20.28 ^{b}	1.96	21.70 ^{b}
	Crop removal	1.17	6.50 ^{a}	1.90	15.05 ^{a}	2.23	17.13 ^{a}
	Significance level (%)	ns	0.1	ns	0.1	ns	1.0
2	Control	0.97	8.55 ^{b}	1.33 ^{b}	21.75 ^{b}	1.42	22.38 ^{b}
	Leaf removal	0.94	10.13 ^{c}	1.17 ^{a}	24.05 ^{c}	1.22	25.53 ^{c}
	Crop removal	1.00	7.23 ^{a}	1.43 ^{b}	18.15 ^{a}	1.53	19.20 ^{a}
	Significance level (%)	ns	1.0	5.0	0.1	ns	0.1
3	Control	-	-	0.47	17.15	0.64	22.58
	Leaf removal	-	-	0.49	17.45	0.59	22.03
	Crop removal	-	-	0.57	17.30	0.65	21.55
	Significance level (%)			ns	ns	ns	ns
4	Control	-	-	0.10	15.75	0.15	28.95
	Leaf removal	-	-	0.13	16.20	0.19	28.23
	Crop removal	-	-	0.10	15.63	0.14	28.33
	Significance level (%)			ns	ns	ns	ns

2.3.3.3 Relationship between reserves and vegetative and reproductive development

The relationship between vine productivity and starch in the wood (trunk/cordon) at bud burst varies between vineyards (Figure 3.7), but vines with the highest starch concentrations in the wood produced higher yields and pruning weights. Vineyard 1 showed the strongest correlation with yield and wood starch, while vineyard 4 showed no relationship with the other two vineyards in between (Figure 3.7a, d, g, j). The same ranking in this relationship is present between pruning weight and wood starch (Figure (b, f, i, l). This shows that vine reserves in the higher yielding vineyards of the Riverina have an important role, the smaller or non-relationship between vine productivity and starch in the lower yielding Hilltops region would have been further influenced by the drought conditions in the 2002/03 season. The yield to pruning ratio shows that yield and pruning weights (kg fruit is produced per kg canes) would increase similarly (Figure c, e, h, k) and that the ratio is not related to increasing starch levels in the wood. This means that the vine balance has not been changed by the treatments which altered the wood starch levels, only the overall productivity.

The shoot growth has been altered by the treatments which changed vine reserve levels; in vineyard 1 early crop removal produced double the shoot length than the leaf removal treatment (Plate 3.5) this difference in development was also visible in the shoot tips (Plate 3.6). The relationship between shoot growth and vine reserves at bud burst varies between vineyards and time in spring (Figure 3.8). The Riverina vineyards have much higher shoot growth rates after the 5 leaf stage than the Hilltops vineyards. In early spring (bud break to 5 leaf stage) there was only a weak relationship between shoot growth and wood starch levels in all vineyards (Figure 3.8a, d, g, j). The strongest relationship was between shoot growth rates and vine starch levels at the 6 to 16 leaf stage (Figure 3.8b, e, h, k). This can be seen particularly in the Riverina vineyards and to a lesser extent in vineyard 3 with no relationship in the severely drought effected Vineyard 4. The growth rates around full bloom were less related to wood starch levels (Figure 3.8c, f, i, l), this suggests the higher dependency of vine reserves on shoot growth between the 6 and 16 leaf stage.

The inflorescence size was increased by early crop removal and reduced by post-harvest leaf removal as shown for vineyard 1 (Plate 3.6). Flower numbers were lowered by the later treatment, while increased by early crop removal. The relationships between flower numbers per inflorescence, fruit set and berry number per bunch to cordon starch levels were similar, although the correlation between berries per bunch and starch was the strongest (Figure 3.9). The relationship between flower numbers and cordon starch was most pronounced in vineyard 1, with no relationship in vineyard 4 (Figure3.9a, d, g, j). The relationship between fruit set and starch was strongest in vineyard 2, again with no relationship in vineyard 4 (Figure 3.9b, e, h, k). Berry numbers per bunch and cordon wood reserves correlations were similar in the two Riverina vineyards, followed by vineyard 3 and in vineyard 4 vine reserves did not effect berries per bunch (Figure 3.9c, f, I, l). These relationships suggest the high dependency of the more productive vineyards on vine reserves, effecting flower numbers and fruit set and consequentially berries per bunch. Further, it demonstrates the overall impact of vine reserves on yield levels and also canopy size.

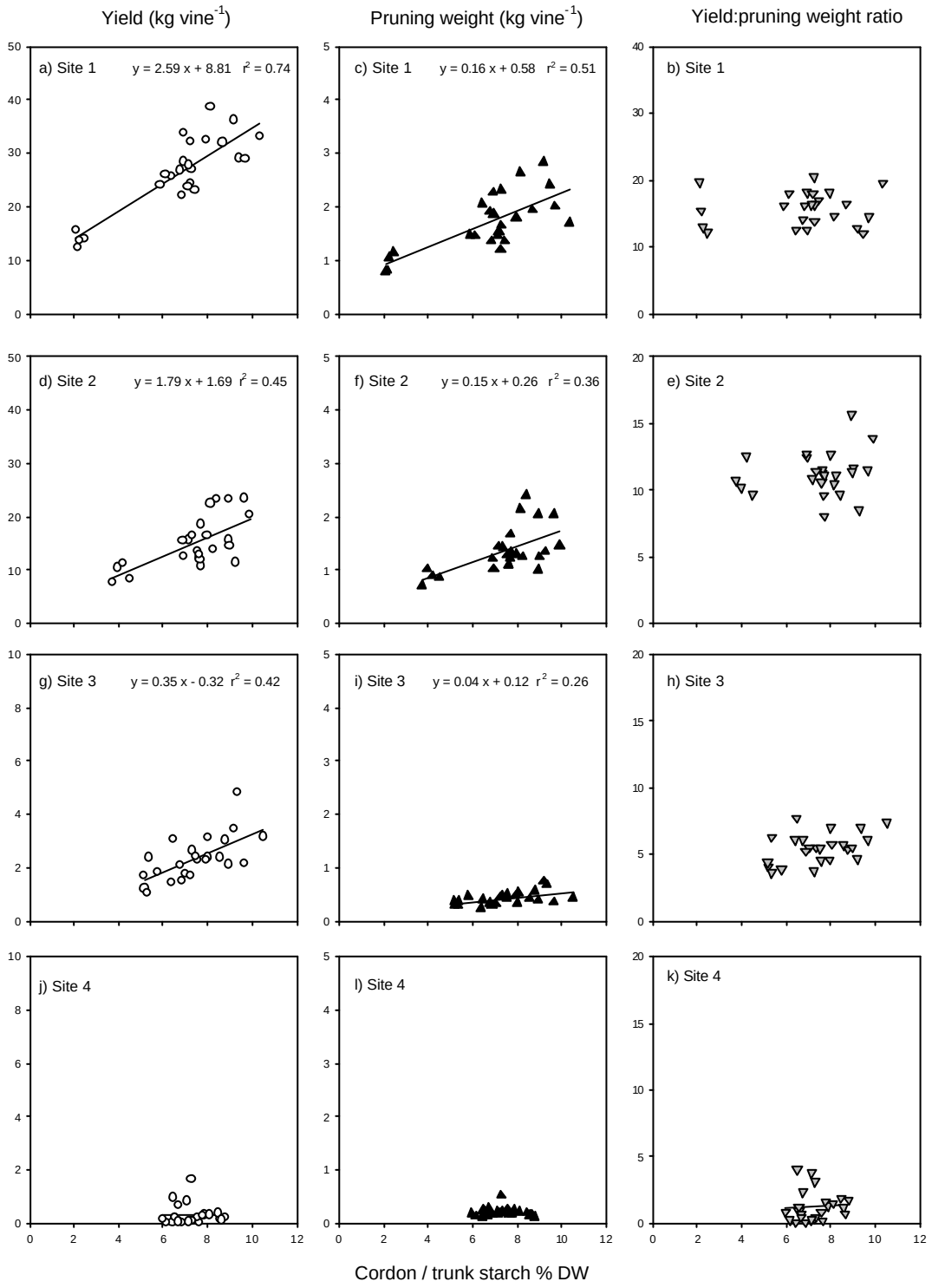

Yield (kg vine-1)
Pruning weight (kg vine-1)
Yield:pruning weight ratio
a) Site 1 y = 2.59 x + 8.81 r2 = 0.74
c) Site 1 y = 0.16 x + 0.58 r2 = 0.51
b) Site 1
d) Site 2 y = 1.79 x + 1.69 r2 = 0.45
f) Site 2 y = 0.15 x + 0.26 r2 = 0.36
e) Site 2
g) Site 3 y = 0.35 x - 0.32 r2 = 0.42
i) Site 3 y = 0.04 x + 0.12 r2 = 0.26
h) Site 3
j) Site 4
l) Site 4
k) Site 4
Cordon / trunk starch % DW

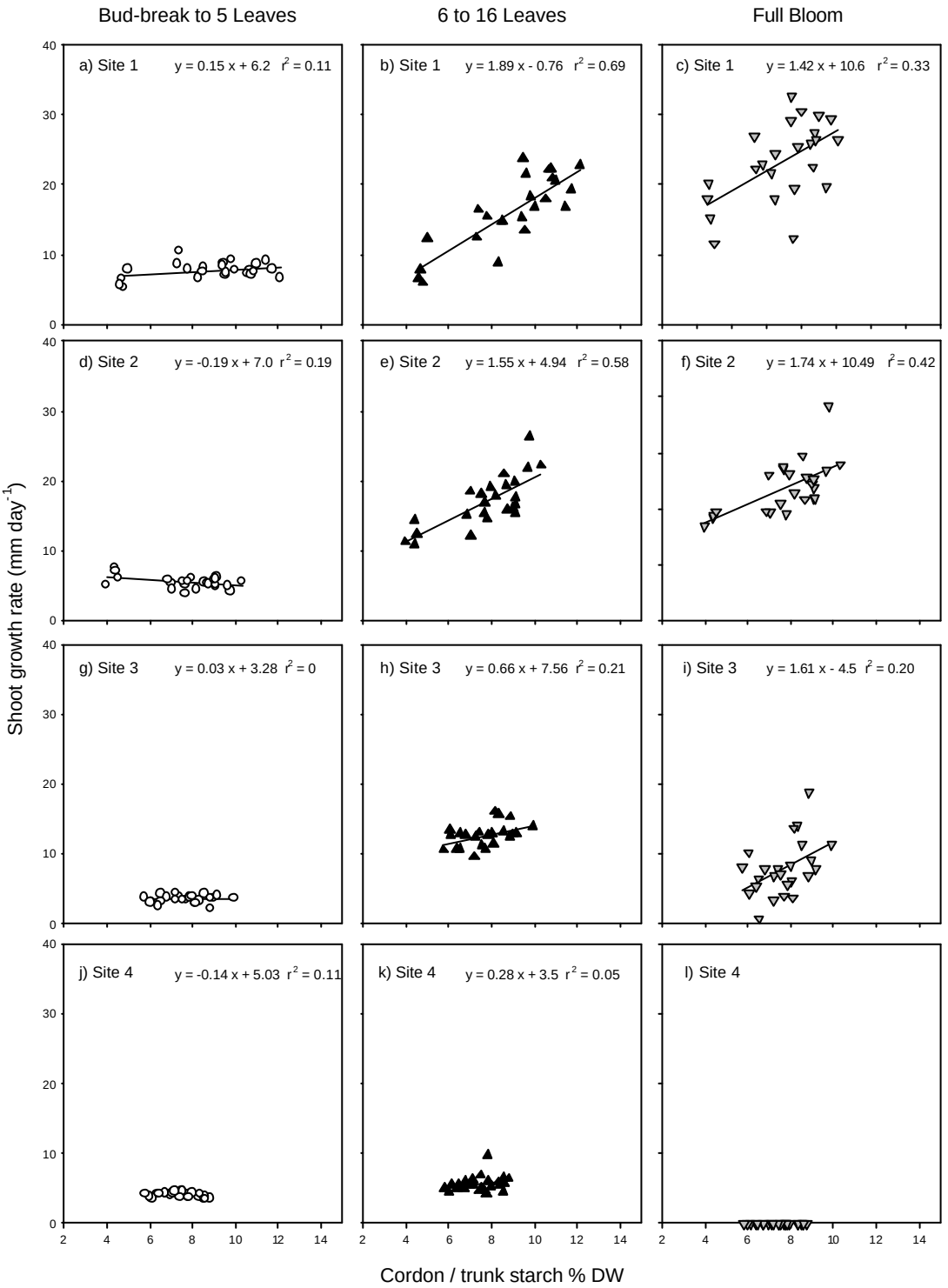
Figure 3.7. Relationship between starch reserves and (a, d, g, j) yield (b, f, i, l) pruning weights and (c, e, h, k) yield to pruning ratio in four vineyards (2002/03).





Plate 3.5. Effect of treatments on canopy size shortly after bloom at Vineyard 1 in the Riverina after bloom in spring 2002. Selected vines show the largest differences generated by the early crop removal and leaf removal treatments.

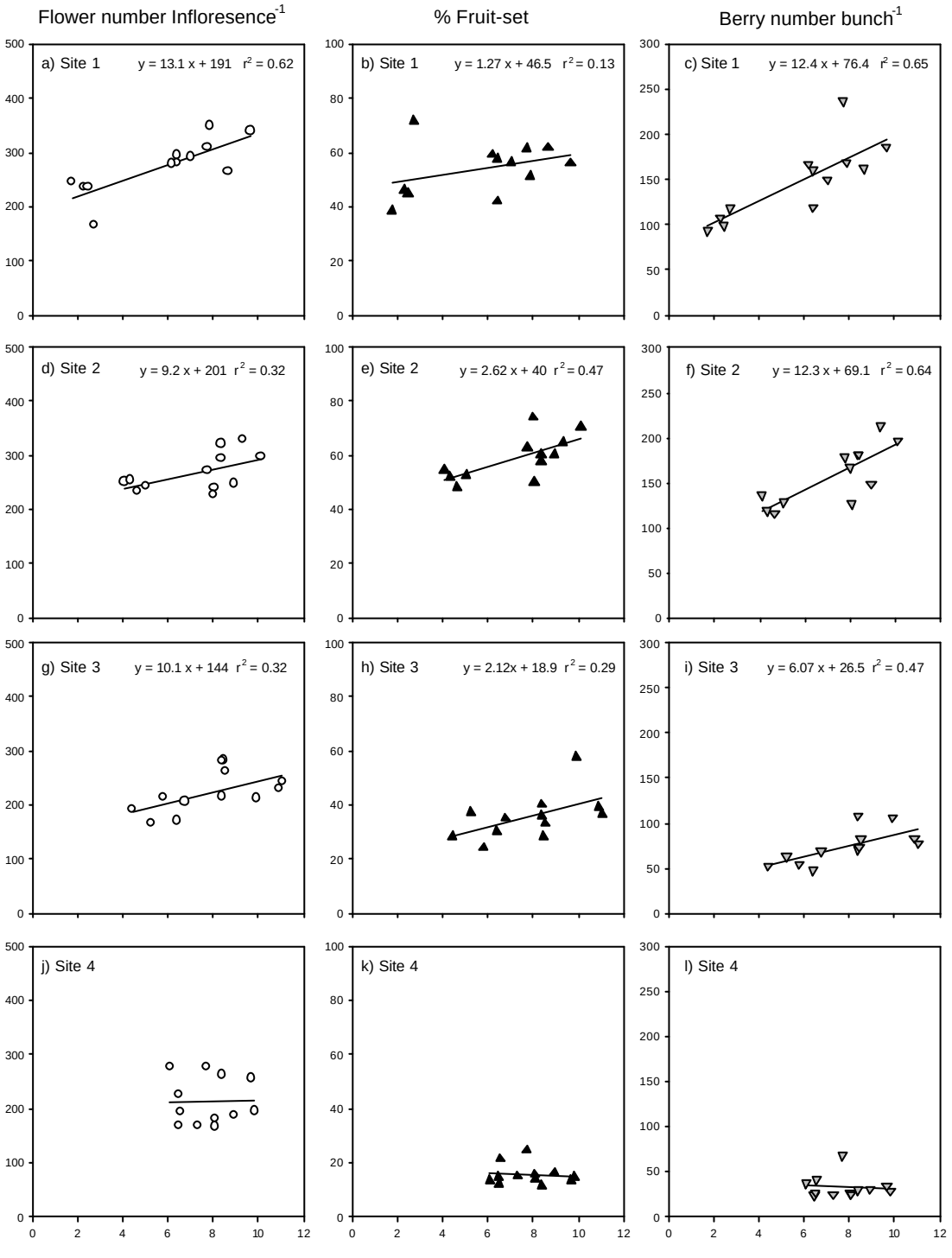
Figur


Bud-break to 5 Leaves
6 to 16 Leaves
Full Bloom
a) Site 1 y = 0.15 x + 6.2 r² = 0.11
b) Site 1 y = 1.89 x - 0.76 r² = 0.69
c) Site 1 y = 1.42 x + 10.6 r² = 0.33
d) Site 2 y = -0.19 x + 7.0 r² = 0.19
e) Site 2 y = 1.55 x + 4.94 r² = 0.58
f) Site 2 y = 1.74 x + 10.49 r² = 0.42
g) Site 3 y = 0.03 x + 3.28 r² = 0
h) Site 3 y = 0.66 x + 7.56 r² = 0.21
i) Site 3 y = 1.61 x - 4.5 r² = 0.20
j) Site 4 y = -0.14 x + 5.03 r² = 0.11
k) Site 4 y = 0.28 x + 3.5 r² = 0.05
l) Site 4
Shoot growth rate (mm day-1)
Cordon / trunk starch % DW


Crop Removal
Control
Leaf Removal

Plate 3.6. Effect of treatments on shoot tips and inflorescence development at Vineyard 1 in the Riverina in spring 2002.

Figure 3


Flower number Infloresence-1
% Fruit-set
Berry number bunch-1
a) Site 1 y = 13.1 x + 191 r2 = 0.62
b) Site 1 y = 1.27 x + 46.5 r2 = 0.13
c) Site 1 y = 12.4 x + 76.4 r2 = 0.65
d) Site 2 y = 9.2 x + 201 r2 = 0.32
e) Site 2 y = 2.62 x + 40 r2 = 0.47
f) Site 2 y = 12.3 x + 69.1 r2 = 0.64
g) Site 3 y = 10.1 x + 144 r2 = 0.32
h) Site 3 y = 2.12x + 18.9 r2 = 0.29
i) Site 3 y = 6.07 x + 26.5 r2 = 0.47
j) Site 4
k) Site 4
l) Site 4


a) Crop removal

Plate 3.7. Comparison of canopy size on crop removal (a), and leaf removal (b), vines in spring 2003. Post-harvest treatments were last applied after harvest 2002, approximately 18 months previously.

2.3.3.4 Effects on vine nutrient levels and the relationship to vine reserves

The nutrients in the spurs of the Semillon vines were also altered by the treatments which effected starch nutrient levels and vine productivity. These levels were determined from samples taken at pruning after two years of treatments were applied in winter 2002. Some macronutrients were altered in all vineyards (Table 3.20), in vineyard 1 the nutrients N, P and S were increased by crop removal, while in vineyard 2 these nutrients were also lowered by leaf removal. In the Hilltops vineyards K concentrations are altered in the spurs, where the combined treatment of leaf damage and juice spray lead to the strongest reduction in K levels. Ca levels were significantly higher in the leaf removal treatment compared to the control. The impact of the treatments on micro nutrients was less pronounced, although Cu was altered in every vineyard (Table 3.21). In the Riverina vineyards this nutrient was increased by the early crop removal, while leaf removal increased it in the Hilltops vineyards. B concentrations in the spurs were lowered by the combination treatment of leaf damage and juice spray and increased by the early crop removal treatment in vineyard 4. The changes in the macro nutrients N, P, S in the Riverina vineyards and also K in the Hilltops vineyards suggests that post-harvest leaf removal effects overall nutrient status of the vines, which could be due to reduced uptake by the roots or re-translocation from the leaves during the post-harvest period.

The starch levels in the spurs were significantly different in all vineyards and therefore also important as an indicator of the vine reserve levels. The response differed between vineyards (Figure 3.10), while in vineyard 1 only the leaf removal treatment lowered starch in the spurs, in vineyard 2 leaf damage also reduced it but to a lesser extent. In vineyard 3, early crop removal increased starch levels in the spurs and in vineyard 4 this was also achieved with the juice spray. Figure 3.10 shows that increasing N content in the spurs also related to increasing starch content in the spurs in the Riverina vineyards,

while this was not the case in Hilltops vineyards. This indicates that some of the effects on vegetative and generative development was not only altered by the starch but also by N reserves in the wood.

The changes of wood and root macro nutrient reserves during the post-harvest period differed between the vineyards, parts of the vine and particular nutrients (Table 3.22). All elements increased during the period (control) in the wood except Ca in vineyards 1 to 3. The increases during the post-harvest period were similar if the crop was removed early, but nutrient levels were already higher at harvest (data not presented). The leaf removal treatment lead to the reduction of most nutrients, although N was either similar to the control or even elevated. The response to root nutrients were inconsistent between vineyards, there was decline in all macro nutrients other than K and Mg in vineyard 1, while vineyard 2 showed a strong increase in N, P and S and a decline in the other three macro nutrient. Vineyard 3 had only a reduction in P levels in the roots and increases in the other elements, and in vineyard 4 less Mg was found in the roots at leaf-fall than at harvest. The leaf removal after harvest did generally increase the concentrations of nutrients in all vineyards (except vineyard 4), while the crop removal lead either to minimal changes or a reduction in most vineyards. The wood and the roots showed similarity to the spur nutrient concentration differences implemented by the treatments at leaf-fall for the nutrients N, P, and S in the Riverina vineyards (data not presented). The changes in the nutrient concentrations in the wood over the post-harvest period was similar between vineyards except the severely drought stressed vineyard 4. While the changes in root nutrients over the period was quite different between all vineyards, which could be due to differences in root growth over this period. Overall the changes suggest that the post-harvest period is important for nutrient uptake since some nutrients (eg. Mg) are mainly taken up by young roots.

Table 3.20. Macronutrients in one year old wood (spurs) affected by post-harvest treatments in Semillon (2002). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Nutrient in %					
		N	P	S	K	Ca	Mg
1	Control	0.590 ab	0.077 a	0.046 a	0.570	0.480	0.107
	Leaf Removal	0.547 a	0.074 a	0.044 a	0.585	0.460	0.105
	Crop Removal	0.771 c	0.091 b	0.058 b	0.558	0.448	0.128
	Leaf Damage	0.590 ab	0.082 ab	0.049 a	0.595	0.518	0.116
	Juice spray	0.635 b	0.078 a	0.048 a	0.580	0.508	0.115
	Leaf damage + juice	0.595 ab	0.079 a	0.046 a	0.605	0.493	0.107
	Significance level (%)	1.0	5.0	0.1	ns	ns	ns
2	Control	0.659 b	0.075 b	0.051 bc	0.600	0.485	0.112
	Leaf Removal	0.531 a	0.066 a	0.045 a	0.570	0.468	0.103
	Crop Removal	0.764 c	0.085 c	0.055 c	0.568	0.448	0.119
	Leaf Damage	0.622 b	0.071 ab	0.049 ab	0.603	0.445	0.096
	Juice spray	0.666 b	0.076 b	0.050 bc	0.598	0.493	0.107
	Leaf damage + juice	0.629 b	0.076 b	0.052 bc	0.605	0.493	0.106
	Significance level (%)	0.1	0.1	1.0	ns	ns	ns
3	Control	0.548	0.062	0.047	0.730 b	0.393	0.117
	Leaf Removal	0.557	0.056	0.045	0.703 ab	0.420	0.145
	Crop Removal	0.591	0.066	0.049	0.725 b	0.348	0.131
	Leaf Damage	0.575	0.062	0.050	0.715 b	0.430	0.138
	Juice spray	0.584	0.063	0.048	0.700 ab	0.373	0.131
	Leaf damage + juice	0.567	0.060	0.048	0.665 a	0.390	0.129
	Significance level (%)	ns	ns	ns	5.0	ns	ns
4	Control	0.710	0.076	0.058	0.883 cd	0.480 ab	0.123
	Leaf Removal	0.693	0.077	0.057	0.813 ab	0.570 c	0.148
	Crop Removal	0.743	0.081	0.061	0.908 cd	0.528 bc	0.131
	Leaf Damage	0.739	0.081	0.061	0.835 b	0.515 bc	0.143
	Juice spray	0.721	0.079	0.060	0.873 bc	0.505 b	0.141
	Leaf damage + juice	0.683	0.077	0.058	0.788 a	0.460 a	0.130
	Significance level (%)	ns	ns	ns	0.1	5.0	ns

Table 3.21. Micronutrients in one year old wood (spurs) affected by post-harvest treatments in Semillon (2002). Different superscripts within a table column indicate a significant difference (p=0.05).

Vineyard	Treatment	Nutrient in ppm					
		Fe	Mn	Cu	Zn	B	Ni
1	Control	35.4	37.9	8.4 [a]	16.6	10.8	3.5
	Leaf Removal	35.8	47.4	9.2 [ab]	20.8	10.8	4.6
	Crop Removal	45.5	43.3	10.5 [b]	18.8	11.4	2.7
	Leaf Damage	40.4	51.0	9.1 [a]	19.2	12.0	4.5
	Juice spray	38.8	46.2	8.5 [a]	16.3	11.5	3.5
	Leaf damage + juice	45.2	47.4	8.6 [a]	20.1	11.3	3.6
	Significance level (%)	ns	ns	5.0	ns	ns	ns
2	Control	24.7	62.3	10.9 [a]	25.0	12.0	4.5
	Leaf Removal	26.2	54.2	11.5 [a]	25.7	10.1	5.8
	Crop Removal	27.0	68.7	14.7 [b]	28.0	12.1	4.9
	Leaf Damage	24.7	58.6	10.7 [a]	24.0	10.7	4.6
	Juice spray	27.8	57.2	12.0 [a]	26.0	12.1	2.9
	Leaf damage + juice	29.5	73.6	11.6 [a]	26.8	11.3	9.1
	Significance level (%)	ns	ns	0.1	ns	ns	ns
3	Control	24.6	35.7	33.9 [ab]	14.5	10.2	3.5
	Leaf Removal	30.5	40.3	54.2 [c]	14.5	10.0	1.2
	Crop Removal	24.3	36.0	33.5 [a]	14.6	10.2	2.2
	Leaf Damage	27.8	40.7	50.6 [bc]	15.3	10.3	1.2
	Juice spray	22.0	34.2	41.9 [abc]	14.6	9.7	1.4
	Leaf damage + juice	25.5	39.6	41.9 [abc]	15.2	9.6	1.4
	Significance level (%)	ns	ns	5.0	ns	ns	ns
4	Control	18.0	89.6	17.8 [a]	17.3	13.5 [b]	7.8
	Leaf Removal	23.1	107.1	24.9 [b]	21.5	14.0 [bc]	1.7
	Crop Removal	20.8	95.4	20.1 [a]	20.7	15.2 [c]	2.6
	Leaf Damage	20.6	125.3	20.2 [a]	21.0	13.4 [ab]	1.5
	Juice spray	20.7	161.2	19.1 [a]	21.0	13.0 [ab]	1.7
	Leaf damage + juice	19.5	115.2	18.5 [a]	22.8	11.9 [a]	1.7
	Significance level (%)	ns	ns	0.1	ns	1.0	ns

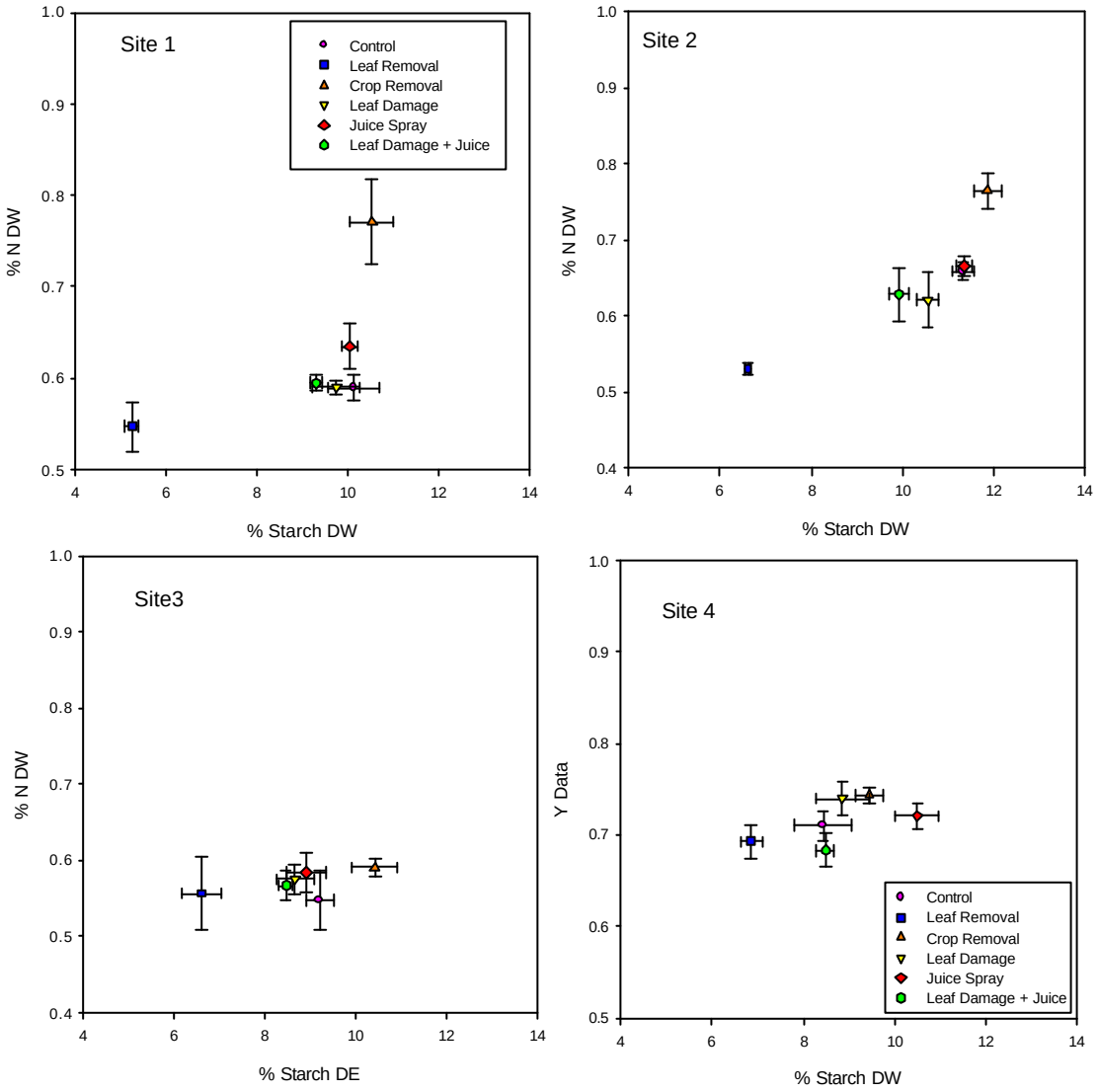


Figure 3.10. Relationship between starch reserves and nitrogen content in the spurs (2002) at leaf-fall (bi-directional standard errors of the means are shown as bars, n=6).

Table 3.22. Changes in macronutrients levels in wood (cordon/trunk) and roots from harvest to leaf-fall affected by post-harvest treatments in Semillon (2002).

Vineyard	Treatment	Vine Part	Change in % N	P	S	K	Ca	Mg
1	Control	Wood	28.7	13.3	20.1	24.0	-3.8	23.3
		Roots	-0.6	-23.3	-17.2	4.3	-17.9	25.3
	Leaf Removal	Wood	46.9	-9.1	2.5	-3.4	-11.4	-3.2
		Roots	-7.1	0.0	5.9	32.8	23.3	18.1
	Crop Removal	Wood	18.5	9.7	17.1	-5.1	35.7	36.4
		Roots	35.7	8.6	17.9	0.0	0.0	20.0
2	Control	Wood	42.1	16.1	17.0	25.9	-13.4	5.1
		Roots	70.1	62.8	29.3	-27.5	-6.9	-4.5
	Leaf Removal	Wood	46.4	-8.8	3.1	-6.3	0.7	-5.6
		Roots	5.9	39.1	48.1	8.7	20.0	45.6
	Crop Removal	Wood	45.1	15.8	16.7	6.5	-18.6	-2.1
		Roots	1.3	-21.2	-10.9	-11.1	-27.2	-19.2
3	Control	Wood	27.5	20.0	12.1	22.6	-20.5	10.8
		Roots	14.2	-1.4	19.7	25.0	4.4	0.5
	Leaf Removal	Wood	25.6	8.0	0.1	14.3	-12.5	7.7
		Roots	26.5	54.8	29.6	18.0	0.0	4.2
	Crop Removal	Wood	18.7	18.5	9.4	23.5	-8.5	20.0
		Roots	12.5	-1.0	23.4	-1.7	-1.2	18.9
4	Control	Wood	2.9	-3.1	-5.8	0.0	-16.9	-2.4
		Roots	23.0	39.3	13.0	0.0	11.4	-8.8
	Leaf Removal	Wood	7.7	-9.7	-18.5	-2.2	-40.0	-16.3
		Roots	13.0	6.7	-6.8	-13.4	17.4	-20.0
	Crop Removal	Wood	2.4	-3.0	-4.8	7.1	-29.3	-4.9
		Roots	9.8	-5.0	5.1	-3.3	11.4	3.6

2.3.3.5 Root growth and partitioning in the post-harvest period

Three field treatments (control, leaf removal after harvest and early crop removal) were also applied on potted Semillon vines, to investigate the vines development and portioning in the post-harvest period. At harvest the total dry weight of the vines were already increased by the early crop removal treatment and there was a further increase during the post harvest period (Figure 3.11). The latter was also present to lesser extent in the control vines, but virtually no dry matter increase occurred in vines receiving the leaf removal treatment after harvest. The early crop removal treatment, which means also a longer post-harvest period, had already much more root mass than the other treatments at harvest. This was more pronounced at leaf fall, there was also root mass increase in the control vines and to a lesser extent in vines which received the leaf removal treatment. Trunk dry weight was also the highest in the early crop removal treatment at harvest, but lowest at leaf fall, while the control had the highest value at leaf fall. The shoot mass was slightly lower in the early crop removal treatment at harvest but exceeded the control at leaf fall. The vines which had the leaves removed after harvest had the biggest shoot mass at leaf fall. This was due to some additional shoot growth during the post-harvest period for the establishment of new leaves.

In addition to the changes in dry matter accumulation between the treatments from harvest to leaf-fall, there is also an effect on vine portioning (Figure 3.12). At harvest the vines which received the early crop removal treatment already had the largest part of the total dry matter partitioned to the roots (Figure 3.12a). The removal of fruit diverted the resources to further root growth and reserve accumulation. At leaf fall the dry matter proportions of roots has increased further in the crop removal treatment and to a lesser extent in the control, while the leaf removal treatment root proportion of the vine stayed basically unchanged (Figure 3.12b). The dry mass proportion of the trunk is reduced by the early crop removal treatment and, in the vines of the leaf removal treatment, the shoots make up a larger part of the total dry matter than in the vines of the other treatments. This further shows the importance of the post-harvest period, not only for starch and nutrient accumulation as shown in the previous section, but also for the further establishment of the vine roots.

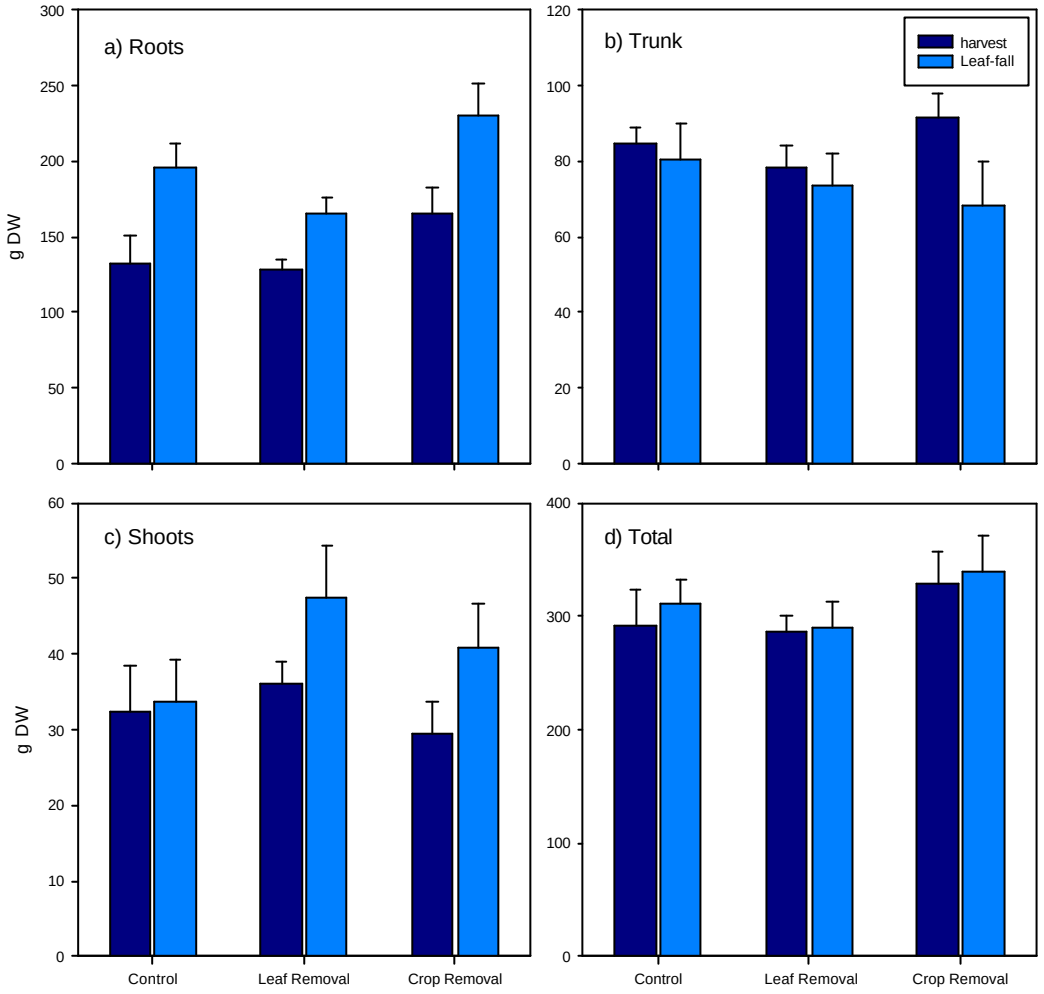
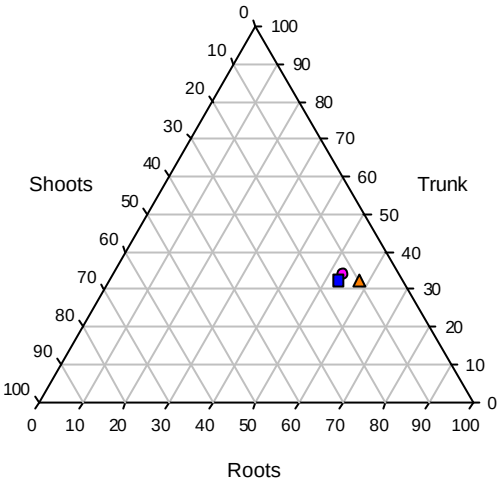


Figure 3.11. Vine components (%DW) affected by post-harvest leaf removal and early crop removal at harvest and leaf fall of (a) shoots, (b) trunk and (c) roots and (d) total vine mass (standard errors of the means are shown as bars, n=6).

a) Harvest



b) Leaf-fall

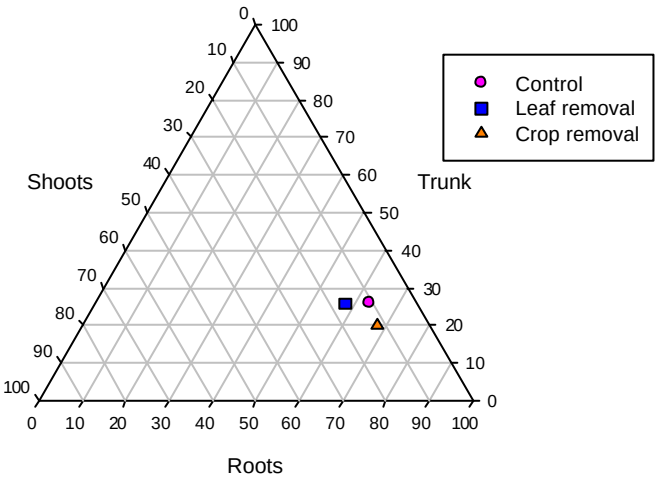


Figure 3.12. Partitioning of vine components (shoots, trunk, roots) at harvest and leaf fall.

3 GENERAL DISCUSSION AND FUTURE WORK

This extensive study of the post-harvest period was conducted for its potential importance in vine productivity and the likely connections to industry issues like restricted spring growth (RSG) or Semillon decline. Information on this period was rather limited and the most relevant study was conducted on Sultana (Scholefield *et al.*, 1978), despite the importance of vine reserves on early spring growth (Glad *et al.*,1992a). Over the last few years other researchers have identified the significance of vine reserves on generative development (Bennett *et al.*, 2002, Zapata *et al.*, 1999). This project has shown the importance of reserve accumulation particularly in the roots after harvest (Figure 3.1), and the strong relationship with vegetative and generative development.

The comparison of different vineyards shows a range of productivity levels in two regions, and also some differences in starch levels between vineyards in the post-harvest period. These differences between wood reserve levels between regions suggest that the length of the post-harvest period, and or effectiveness, would have been a factor. The variation between vineyards in a region in wood starch levels at harvest and pruning suggests that management can have an impact on these reserves. Therefore, a change of the vine reserve capacity can be implemented for the following season(s). Despite the considerable variation of yield and vine size in a vineyard, the vine starch reserves were not altered, this means there was no relationship between yield or vine size and wood starch levels. The vines were influenced by soil conditions, producing these differences in vine productivity or size in different sections of the vineyards. The role of root reserves in concentration at total amount might be a further contributing factor in explaining the productivity levels between and within a vineyard.

The field trials in which the vine reserves were changed, by extending, shortening or making the post-harvest period less effective, indicates that roots are an important storage area for reserves. The roots are major part of the vine, as shown in the pot experiment (50%), with a considerable increase over the post-harvest period, particularly if that period is long. Roots represent about 30% of the weight of the permanent structure of field grown vines (Mullins *et al.*, 1992; Williams and Smith, 1991), and with the capacity to store higher concentrations of starch, may contain up to 50% of the total vines reserves (after pruning). The treatments have clearly shown that harvest, leaf fall and bud-burst starch levels can be altered, particularly in the Riverina vineyards. These differences between wine regions suggest that the Riverina has a very effective post-harvest period; not only because of the climatic conditions, but also since irrigation water is not limited. In addition, the Riverina region had much higher root reserve levels, which fluctuated considerably more over the three seasons of the study than above ground reserves (Figure 3.1). The results of the 2002/03 growing season suggest these reserves may be particularly important for fruit ripening. In the leaf removal treatment, which had lower yields, root reserves were highest at harvest. In contrast, the high yielding crop removal treatment had high reserves from two previous seasons of early fruit removal, but had the lowest root reserves at harvest. The higher reserves at harvest might also be a reason for faster ripening of leaf removal treatment, since they seem to become a more important sink than the crop after mid berry ripening (Candolfi-Vasconcelos *et al.*, 1994; Koblet *et al.*, 1996; Keller, 1993). The lighter crop may have also allowed the fruit to mature faster, but vines from the leaf removal treatment also had less leaf area.

Vine productivity was considerably changed by the altered post-harvest period, while an extended period (early crop removal) resulted into higher pruning levels and yields. A shortening of the period (leaf removal after harvest) and, to some extent, the reduction of the effectiveness (leaf damage after harvest) reduced pruning weights and yields. Surprisingly, the juice spray did not have a negative effect on vine productivity or vine reserve, but increased yield significantly in one of the Riverina vineyards. However, despite being sprayed to saturation with juice collected at the time of harvest, the juice spray did not induce the leaf burning sometimes seen after machine harvesting in Semillon. The effect was not always significant, but the trend was for the juice spray to promote larger bunches in the following season. For the leaf and crop removal treatments, the changes in vine productivity were mainly due to

differences in early shoot growth and inflorescence development (numbers and size). The dramatic impact on early shoot growth could be a form of restricted spring growth (RSG), but no effect on time of bud burst was present (Hackett and Holzapfel, 2002). Despite visual appearances on some vines, the low reserve treatment caused a uniform reduction in shoot growth, and did not change the proportions of long and short shoots. The cumulative effect (over two years) on vine productivity over two seasons could be seen as a form of vine decline, but while vigour was reduced, the vines were otherwise healthy. The wood starch reserves correlated with early canopy development, since its dependency on vine reserves during the bud-burst to bloom period has been shown by others (Yang and Hori, 1979).

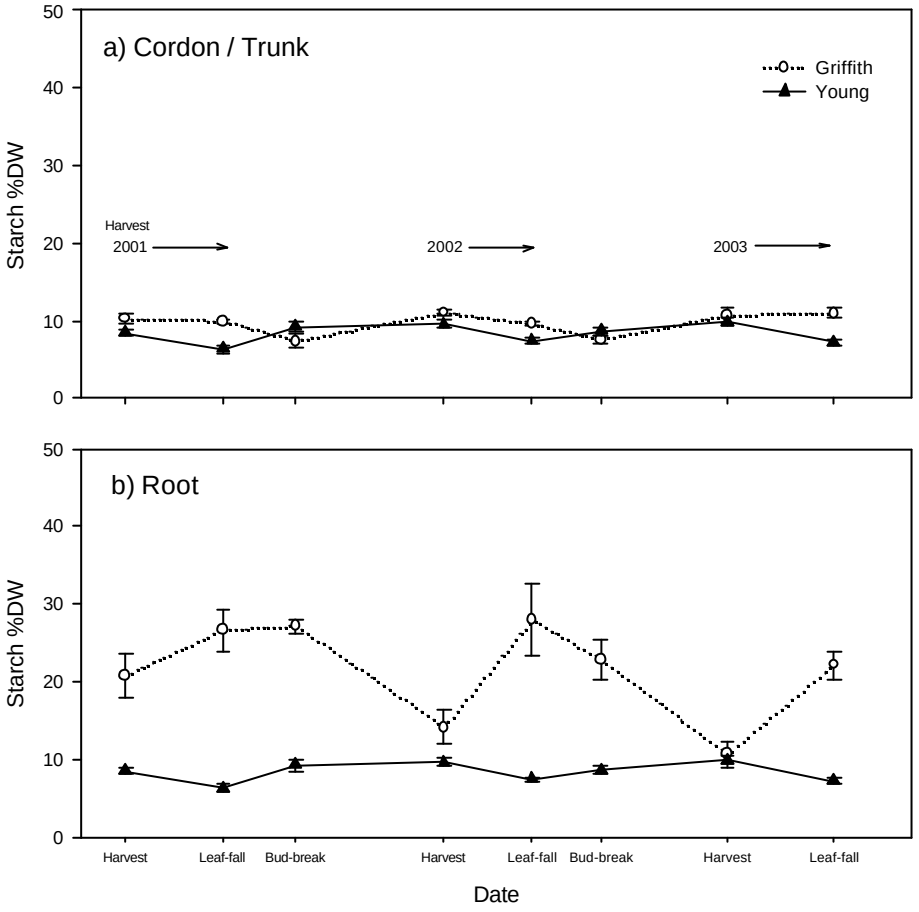
The effect of vine reserves on inflorescence and bunch development was also clearly shown, although the stronger relationship with above ground reserves contrasts the apparent importance of root reserves shown by Bennett *et al.* (2002). It has been demonstrated that wood starch reserves are of particular importance in unfavourable weather conditions during flowering and fruit set (Zapata *et al.*, 1999). The soluble sugar levels in the wood were higher at leaf-fall than at harvest, and the proportion was greater in the shoots as reported by Mullins *et al.* (1992). The higher soluble sugar levels in the wood during the dormant period of the vines are seen as providing grape vines with better cold tolerance (Currle *et al.*, 1983). In addition, treatments which lowered starch levels commonly had higher soluble sugar levels. The reason for this is not clear. However, the negative correlations (not shown) between sugars and shoot growth rates in spring seem consistent with earlier findings that propagation success with cuttings decreases if soluble sugars are high (Treeby and Considine, 1982). Vine nutrient accumulation was altered by the post-harvest treatments and accumulation took place from harvest to leaf fall in the wood. The changes of nutrients implemented by the treatments were particularly pronounced in the Riverina vineyards and were similar, but not as significant, as the responses observed with starch reserves. This indicates that the period after harvest is important for storage and for the second major flush of roots, then some nutrients (eg. Mg) require new roots for their uptake (Mengel and Kirkby, 2001). The results are supported by earlier work (Conradie, 1980), that the post-harvest period is an important period for nutrient uptake.

The project has outlined the importance of vines post-harvest period for vine photosynthesis and reserve accumulation, for root growth and nutrient uptake in this period and vine productivity the following season(s). The findings suggest that faster ripening of grapes, or an earlier harvest (eg. sparkling wine, disease pressure), could have a strong impact on reserve accumulation. Vineyard management after harvest will influence the canopy effectiveness (eg. irrigation, nutrition, pests and disease control). The difference in the amount of reserves (and nutrients) accumulated in autumn would result in different productivity levels the following year(s). Detailed studies on the depletion of these reserves, and the locations they are drawn from during the early shoot development, would be important to understand shoot growth dynamics (bud-burst to fruit set) and the impact on inflorescence and bunch development. Further work is required to examine the vineyard management possibilities of carbohydrate reserves (particularly from harvest to bloom) and the sequential effect of different levels on vegetative and generative development. Such work will include the development of a wood reserve test (and nutrients) and determining appropriate levels at harvest (range) for next year's vine development. This will allow the vineyard management to have a further tool to manage canopy size and yield. Such work might need to be extended to other varieties with different productivity levels or aims for production (high quality grapes).

The starch analysis method used in the present study would be suitable for the development of a commercial starch test. More work is required to refine and validate vineyard sampling methods, and also the longer term usefulness of such information. However, some preliminary suggestions can be made regarding sampling protocols. Firstly root, wood (trunk/cordon), and spur samples would need to be collected initially. Starch levels in the spurs are strongly correlated with the trunk and cordon, so the more easily collected spurs may ultimately be enough to indicate above-ground reserve status. Within

vineyard variability in reserves appears low, and this may simplify sampling strategies compared to those required for yield estimations. The effect of vine size on total reserves is harder to account for. Therefore it may make it difficult to establish universal relationship between starch concentration values and vine productivity. Consequently, relationships between reserve concentrations and yield may differ between vineyards (as was the case in the current study). However, these limitations might be avoided if starch analysis was used to monitor the dynamics of reserve concentrations over several seasons. Comparisons of absolute concentrations across vineyards may not be meaningful, but within a vineyard would provide information on the status of vines relative to previous years. Management decisions, such as buds retained at pruning, could then made regarding the vines capacity to carry a particular crop load in the coming season. In addition, information on vine reserves would provide the opportunity for altering post-harvest management to maintain consistent productivity between seasons.

Figure 3.1. Changes of vine reserves from harvest 2001 to leaf-fall 2003 in two districts (Riverina, Hilltops) in the (a) wood (Cordon/trunk) and (b) roots (standard errors of the means are shown as bars, n=8). Values are from the control vines in each vineyard (no treatments).



4 SUMMARY

The period after harvest is important for root growth, nutrient uptake and starch reserve accumulation. Grapevines require stored energy for early growth in spring. It has also been shown that vine reserves are important for inflorescence development and fruit set. The focus of this study was to investigate the importance of the post-harvest period on carbohydrate reserve accumulation and vine productivity.

The project consisted of two surveys on the variety Semillon; one was conducted in two Australian wine growing regions (Riverina and Hilltops, NSW) which have different lengths of post-harvest periods. There was a range of vine productivity levels (yield, pruning weights) between vineyards. The vine starch reserves in the wood were not only at different levels between vineyards, but also the changes in concentrations from harvest to leaf-fall was different between these vineyards. The Riverina vineyards with the longer post-harvest period also had higher reserves at leaf-fall. Another survey conducted in one vineyard in the Riverina demonstrates the variation within vineyard sections identified by the EM survey in relation to vine productivity and vine reserves. Despite large differences in vine productivity, there was no relationship between either yield or vine size with starch concentrations in the wood.

For the second part of the project Semillon vineyards were selected in each of two grape growing regions. Treatments were imposed at harvest to alter vine reserve accumulation (or length of the post harvest period) over two growing seasons. The effects on vine productivity was assessed over three years, although impacts were already present at pruning in the first year, the importance of the post-harvest period was shown particularly in the last year of the study. The vines with the extended post-harvest period (early crop removal) had up to more than double the yield and shoot growth than vines which had no post-harvest period (leaf removal after harvest). These effects were strongly correlated with starch reserves at bud-burst, the levels of some nutrients were also altered by the treatments. An experiment conducted in pots which also received some post-harvest treatments, showed the importance of the post-harvest period on the root system.

The post-harvest period in Australia is important for reserve accumulation in grapevines and these reserves are critical for the following season's vegetative and reproductive development. Vineyard management and environmental conditions influence the significance of the post-harvest period, since both the length and effectiveness of the period are important.

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7 OUTPUTS

Referred Scientific Publications

HOLZAPFEL, B., SMITH, J., MANDEL, R., and KELLER, M. (2004): Altering the post-harvest period in the field I. Effect on vine productivity. Aust. J. Grape & Wine Res. (in preparation)

SMITH, J. and HOLZAPFEL, B. (2004): Altering the post-harvest period in the field II. Effect on vine carbohydrates. Aust. J. Grape & Wine Res. (in preparation)

SMITH, J. and HOLZAPFEL, B. (2004): Altering the post-harvest period in the field III. Relationship between vine reserves and vegetative and generative development. Aust. J. Grape & Wine Res. (in preparation)

Conference & Symposium Presentation

MANDEL, R., HOLZAPFEL, B., and KELLER, M. (2001): Summary Poster: Identifying manageable factors determining carbohydrate accumulation in reserves of grapevines after harvest. Proc. 11th Australian Wine Ind. Tech. Conf. Adelaide, Australia

SMITH, J., HOLZAPFEL, B., HACKETT, S., MANDEL R. and ROGIERS, S. (2002). Post-harvest vine management effect on spring growth, fruit quality and yield in Semillon. Poster presentation. Engagement with the Wine Industry in Research, Extension, Education and Training Meeting. National Wine & Grape Industry Centre (NWGIC) Wagga Wagga, 13th June 2002.

SMITH, J., HOLZAPFEL, B., HACKETT, J., MANDEL, R. and ROGIERS, S. (2003): Post-harvest vine reserve accumulation in Semillon. I. Effect on shoot and canopy development Poster presentation. NWGIC Annual Meeting, Wagga Wagga, June 19

SMITH, J., HOLZAPFEL, B. and LAMONT R. (2003): Post-harvest vine reserve accumulation in Semillon II. Effect on bunch and fruit development. Poster presentation. NWGIC Annual Meeting, Wagga Wagga, June 19

SMITH, J., MANDEL, R, ROGIERS, S. HACKETT, S. and HOLZAPFEL, B. (2003): Effect of post-harvest vine reserves on shoot, bunch and fruit development. International Conference on Phloem Transport, Bayreuth, Germany, 104

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MANDEL, R., HOLZAPFEL, B., DEGARIS, K. and KELLER, M. (2001): Identifying manageable factors determining carbohydrate accumulation in reserves and root growth of grapevines at harvest. The Australian Grapegrower & Winemaker 445, 10-13

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HOLZAPFEL, B. and SMITH, J. (2003): Effect of post-harvest vine reserves on shoot, bunch and fruit development. Flowering Workshop report, Tatura, May 22-23

SMITH, J. and HOLZAPFEL, B. (2003): The post-harvest period, carbohydrate reserves and vine productivity. The Australian and NZ Grapegrower & Winemaker, 31st Technical Issue, 29-32

Other Presentations (workshop presentations, seminars, guest lectures)

MANDEL, R. (2000): Carbohydrate reserves in grapevines. NWGIC Seminar Series, 2nd Session, Wagga Wagga, 19 July

MANDEL, R. (2000): Carbohydrate reserves in grapevines. WGMB seminar, Griffith, 28 August

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SMITH, J. (2003): Rootstocks and vine carbohydrates. Guest lecture, July 6 (CSU, Wagga Wagga)

SMITH, J. (2003): The root system and vine performance. NWGIC Annual Meeting, Wagga Wagga, June 19

GREY, J. (2003): Maintaining your reserves, reducing your shrivel. NWGIC Annual Meeting, Wagga Wagga, June 19

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