The influence of vine vigour and crop load on Sauvignon blanc vine growth and fruit composition in Marlborough, New Zealand

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ABSTRACT

Aims: Sauvignon blanc is the flagship wine of Marlborough, with its style described as the definitive benchmark of the varietal. The majority of Marlborough's vineyard plantings are in the Wairau plain; where the young alluvial soils were formed by sedimentation from the Wairau River. The braided nature of the river and frequent flood events has created significant vertical and horizontal soil texture variation. This soil texture variation has been shown to reflect changes in trunk circumference, which lead to the use of trunk circumference as an indicator of soil texture. The aim of this study was to investigate the impact of soil texture and yield on vine performance and fruit composition, within a single vineyard.

Methods: Trunk circumference measurements were grouped to create five vine size classes, while two pruning methods (two and four-cane VSP) were applied to create two crop load treatments with two different canopy types. Vine vigour, canopy density, vine phenology, yield and fruit composition measurements were taken from each vine size and crop load treatment throughout the season.

Results: Vine vigour and canopy density increased with increasing vine size while increases in crop load resulted in decreased vigour and increased canopy density. Vine phenology was delayed with both increasing vine size and increasing crop load. Vine size did not influence yield but did influence fruit composition; increases in vine size delayed ripening with lower soluble solids and higher titratable acidity levels measured at harvest. Crop load influenced both yield and fruit composition with increases in crop load leading to higher yields and delayed ripening. Lower soluble solids and higher titratable acidity levels were measured at harvest as crop load increased.

Conclusions: The variation in soil texture found in the Squire Vineyard lead to variation in vine vigour, canopy density and phenology. These differences in vine growth had no influence on vine yield but did have a significant impact on fruit composition at harvest. Variation in vine growth and fruit composition within a single vineyard creates

challenges with vineyard management; particularly with canopy management, irrigation, nutrition, and harvest decisions.

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CHAPTER 1

INTRODUCTION

In 1895, Romeo Bragato submitted a report to the New Zealand Government indicating the suitability of New Zealand for the production of fine wine. In the report he states, 'the varied configuration of the country and the diversity of soil can afford conditions, both of climate and soil admirably adapted for the growth of various kinds of vines' (Bragato 1895). However, it was only in the 1970's that Marlborough, the 'sun capital of New Zealand' was recognised for its viticultural potential (Brooks, 1992). The region's first modern commercial plantings were led by Montana Wines at their Brancott Estate in 1973 (Brooks, 1992).

Today, Sauvignon blanc is the flagship wine of Marlborough, with its style described as the definitive benchmark of the varietal (Materman, 2002). Wendy Parr of the Marlborough Wine Research Centre believes the success of Marlborough Sauvignon blanc is due to the wine's highly distinctive characteristics (Parr *et al.*, 2004).

Although wine production is steadily increasing in Marlborough, it made up only 0.3% of the total world production in 2003 (NZWG Annual report, 2003). In the case of an oversupply and falling price of wine, a quality focus for Marlborough Sauvignon blanc would be necessary to safeguard the reputation and success of the region.

Geographically Marlborough is a large area; comprised of distinct sub-regions differing in aspect, soil type and climate. However, the majority of vineyard plantings are in the Wairau plain; where the alluvial soils were formed less than 20 000 years ago by sedimentation from the Wairau River and its tributaries (Basher *et al.*, 1995; Rae and Tozer, 1990). The braided nature of the river and frequent flood events has created a floodplain and terraces with significant vertical and horizontal soil variation (Trought, 1997). This variation in soil type reflects variation in vine growth, where vigorous vines with a dense canopy and a heavy crop, grow alongside weaker vines with little or no crop (Brooks, 1992).

The main objectives of this study were to investigate the influence of soil characteristics and crop load on Sauvignon blanc vine growth and fruit composition in Marlborough. Particular emphasis is placed on the development of varietal Sauvignon blanc aroma and flavour compounds in the fruit.

Research reported in a companion study has shown a strong relationship between grapevine trunk circumference and soil texture in Marlborough vineyards (Mills, 2006). In the study, deep silt loam soils were associated with large trunk circumferences while stony soils were associated with small trunk circumferences. As a result, trunk circumference was used as an indicator of soil characteristics in this trial.

The importance of soil characteristics on vine growth is well documented in literature, while only several papers describe the influence of soil characteristics on wine quality

and style. The information reported on wine quality and style was derived from studies on red grape varieties or from trials comparing wines produced from different sites and regions with different winemaking techniques (Barbeau *et al*., 2001).

This study, conducted in a single vineyard in the Wairau plain, provides a unique situation where terroir parameters such as climate, aspect, clone, rootstock and management practices are stable while soil characteristics vary.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 WINE QUALITY

Wine quality is difficult to define due to a lack of measurable units (Turner and Creasy, 2003). Jackson and Lombard (1993), suggest quality is related to the intrinsic visual, taste, or aroma characters, which are perceived as above average for that type of wine, while Marais *et al.* (1999) define quality as the development of typical characteristics of the cultivar with complexity and optimum flavour balance.

There is a wide appreciation of the need to find indices of grape quality for several reasons: to guide the choice of harvest date; to improve negotiations on grape pricing; to enable growers to judge their viticultural practices; and to assist viticultural research (Coombe, 1992; Marais *et al.*, 2001).

The most commonly used quality parameter is berry sugar concentration, usually estimated as soluble solids using the °Brix or °Baume scale. The optimal sugar content depends on the style of wine to be produced. In many viticultural regions grape growers are rewarded a quality bonus for fruit above a specified soluble solids level. In cool climate regions where sugar accumulation can be difficult, this "Brix bonus" system may be used effectively to separate fruit into quality categories. However, in warmer regions where a target soluble solid level is easily obtained, other quality parameters are likely to be applied (Coombe, 1992).

Du Plessis and van Rooyen (1982) developed a system using the sugar: acid ratio of the wine as a quality determinant. This system considers the importance acid on wine quality. The pH of a wine has a significant impact on the microbial activity, colour stability and flavour while the sugar/acid balance of a wine influences the palatability of the wine (Du Plessis and van Rooyen, 1982).

Coombe believes that indices based on the primary components of sugar and acid are inadequate for defining wine grape quality. He states, "In addition to sugar and acid, there are a number of compounds involved in the berry composition and their importance organoleptically is unknown" (Coombe, 1992). More recently, a red wine colour index was developed as a quality indicator of red wines (Holgate, 2000). This method is currently being trialed in commercial wineries throughout the world.

In Sauvignon blanc in particular, a positive relationship was found between the 1986 National Australian Wine Show scores and the methoxypyrazine content of Sauvignon blanc (Allen *et al.*, 1988). These results suggest methoxypyrazines contribute favourably to Sauvignon blanc wine quality.

Although aroma compounds are obviously an important quality parameter, the routine measurement of these compounds is currently impractical in a commercial situation due to the complicated and expensive methods required for quantification.

Several groups of researchers have been investigating the factors which impact on the development of aroma compounds, with the aim of developing quality indicators. For example, Marias *et al.* (2001) investigated the effect of temperature and radiation on aroma compound concentration and wine quality for the purpose of developing a model for predicting wine quality. Results show that there is a significant relationship between analysed grape aroma components, sensorially evaluated wine quality parameters and microclimate data. The researchers conclude that it is possible to model microclimate data to predict wine quality under South African conditions. The effect of microclimate on aroma compound development will be looked at in more detail later in this review.

2.2 AROMA COMPOUNDS IN SAUVIGNON BLANC

Sauvignon blanc wine has a distinctive aroma that is described as 'grassy', 'green capsicum', 'citrus', 'stone fruit', 'sweaty armpit', and 'passionfruit' (Parr *et al.*, 2004). Extensive research into the compounds responsible for these aromas is leading the way to a greater understanding of the variety. These compounds can be divided into 2 groups, those that are present in the grapes (methoxypyrazines, norisoprenoids and monoterpenes etc.), and those that are formed during alcoholic fermentation (thiols, esters and higher alcohols) (Marais *et al*., 1999). Of these, methoxypyrazines are the most distinctive, while thiols contribute to the varietal character (Parr *et al.*, 2004).

2.2.1 Methoxypyrazines

Methoxypyrazines have a ring structure (Figure 2.1) and are nitrogen-containing secondary products of amino acid catabolism (Marais, 1994). Leucine, isoleucine, valine, glycine and methionine are thought to be precursors, however the exact pathway for their formation is unknown (Marais, 1994; Roujou de Boubee, 2003). Allen *et al.* (1997) suggest that the different methoxypyrazines are created with the involvement of leucine, isoleucine or valine as a source of the alkyl side chain (Figure 2.1)

Figure 2.1 Methoxypyrazine structures (modified from Allen *et al.*, 1997)

Of the methoxypyrazine compounds identified in Sauvignon blanc, 2-methoxy-3-isobutylpyrazine (ibMP) is the most prominent, perceived sensorially at a concentration of 2ng/L in water and neutral wine (Marais, 1994). Although 2-methoxy-3-isopropylpyrazine (ipMP) and 2-methoxy-3-sec-butylpyrazine (sbMP) have also been detected, they are normally present at lower concentrations, often below their perception threshold (Marais, 1994). More recently, Allen *et al.* (1997) successfully identified ethylmethoypyrazine in Sauvignon blanc grapes and wine at a level that exceeds its sensory detection threshold. Each methoxypyrazine compound contributes a unique aroma to Sauvignon blanc; ibMP produces a green pepper-like aroma and ipMP, pea/asparagus-like aromas (Marais, 1994).

Methoxypyrazines also occur in raw vegetables such as peas, green peppers, french beans, potatoes and beetroot and in other grape varieties such as Cabernet Sauvignon (Allen *et al.*, 1988; Chapman *et al.*, 2004a; Lacey *et al.*, 1991; Marais, 1994).

Methoxypyrazines were first identified in Cabernet Sauvignon in 1975 (Marais, 1994). However, the exact amounts were not quantifiable due to the extremely low concentrations. The use of specialised equipment, and many years of extensive research, now makes qualification and quantification of these important compounds possible (Allen *et al.*, 1988).

Until recently, the method for methoxypyrazine quantification required distillation of the volatile material followed by isolation using an ion-exchange resin and finally analysis by gas chromatography/mass spectrometry (GC-MS) (Lacey *et al.*, 1991). More recently a method that allows for direct analysis of the juice, wine or even berries using a headspace solid-phase microinjection (SPME) technique coupled with GC-MS has been developed (Chapman *et al.*, 2004b; Parr, *et al.*, 2007). As methoxypyrazines are not modified during vinification or bottle aging, one can use the same analysis technique for juice and wine (Roujou de Boubee, 2003).

In a study of 22 Sauvignon blanc wines from Australia, New Zealand, and France, and 16 juice samples from 4 Australian regions, Lacey *et al.* (1991) found that ibMP was found in all wine (0.6-38.1 ng/L) and all juice samples (0.6-78.5 ng/L). It was the major

methoxypyrazine. Lesser quantities of ipMP could be detected in many cases, while small quantities of sbMP were identified in a few samples.

2.2.2 Thiols

Several highly aromatic volatile thiols have been shown to contribute to the varietal character of Sauvignon blanc; 4-mercapto-4-methypentan-2-one (4MMP) and 3-mercaptohexyl acetate (A3MH) both have a strong box-tree aroma, while 4-mercapto-4-methylpentan-2-ol (4MMPOH), 3-mercaptohexan-1-ol (3MH) and 3-mercapto-3-methylbutan-1-ol (3MMB) have aromas of grapefruit and passion fruit, citrus zest and cooked leeks respectively (Tominaga *et al.*, 2000a; Tominaga *et al.*, 2000b; Tominaga *et al.*, 1998b). The compounds 2-mercaptoethyl acetate and 3-mercaptopropyl acetate have also been found in Sauvignon blanc, contributing toasty and roast meat odours (Tominaga *et al.*, 2000b).

Due to extremely low odour thresholds these compounds can have a significant impact on the aroma of the wine when present (Tominaga *et al.*, 2000b). Concentrations of 4MMP in some Sauvignon blanc wines are much higher than its perception threshold of 0.1ng/L in water, therefore contributing to the aroma (Marais, 1994; Tominaga *et al.*, 1998a). The exact concentrations of the other volatile thiol compounds are unknown, so their contribution to the aroma of Sauvignon blanc has yet to be proven (Tominaga *et al.*, 1998a).

Tominaga *et al.* (2000a) reported that 4MMP and A3MH had an impact on Muscat d'Alsace, while 3MH is likely to contribute to the grapefruit and passionfruit odours in wines made from Gewürztraminer, Riesling, Petit Manseng, and botrytised Semillon.

Unlike methoxypyrazines, volatile thiol compounds are almost completely absent from must, as they are released during alcoholic fermentation due to the degradation of their corresponding S-cysteine conjugates (precursors) by yeast (Tominaga *et al.*, 1998b). The yeast strain used and the winemaking process probably has an influence on the release of the thiols from their precursors (Swiegers *et al.*, 2009).

Quantification of volatile thiols in wine requires extraction of the volatile thiols using a method derived by Tominaga *et al.* (1998a), followed by GC-MS analysis. In juice, the aromatic potential of a wine can be determined by the assay of the volatile thiol precursors (Peyrot Des Gachons *et al.*, 2000). This requires enzymatic cleavage of the thiol from its precursor prior to GC-MS analysis, achieved by passing the sample through a column containing the enzyme tryptophanase (Peyrot Des Gachons *et al.*, 2000).

2.3 GRAPE BERRY DEVELOPMENT

Grape berry development precedes over three distinct stages, following a double sigmoid growth curve (Coombe, 1959; Coombe and Hale, 1973). Environmental factors such as post-flowering air temperature and water stress have an influence on the duration of each stage (Coombe, 1980; Coombe, 1992). During the first stage, the size and mass of the berry increases rapidly as a result of cell division and expansion (Coombe, 1959), the berries remain green and hard, organic acids accumulate, and the seed and pericarp grow (Coombe, 1959; Mullins *et al.*, 1992). The duration of this stage can be 40-60 days (Mullins *et al.*, 1992). Stage two is referred to as the lag phase. During this stage, organic acids reach their maximum concentration, the rates of photosynthesis and respiration decrease, the pericarp slowly grows, the seeds mature and embryo development is rapid (Mullins *et al.*, 1992). Prior to stage two, malic acid is the most abundant solute in the berry (Gutierrez-Granda and Morrison, 1992). This stage can take 7-40 days (Mullins *et al.*, 1992). The onset of stage three is marked by berry softening and a colour change in red varieties or an increase in berry transparency in white varieties (Coombe, 1992). This is referred to as veraison, based on a French word (véraison) meaning the colour change of the grape (Coombe, 1992). During this stage, berry volume increases dramatically, concentration of acids declines and there is a large accumulation of the hexoses, glucose and fructose (Coombe, 1992). The increase in berry volume at this stage is a result of cell expansion rather than cell division (Coombe, 1959). Sugar accumulation is dramatic and coincides with the recommencement of growth during the ripening stage (Coombe, 1959). The decline in acid is a result of an increased rate of malic acid respiration coupled with a dilution effect, resulting from

water and solute accumulation (Gutierrez-Granda and Morrison, 1992). Stage three lasts approximately 35-55 days (Mullins *et al.*, 1992).

It is of viticultural benefit to clearly determine the stage of berry development within a vineyard for guidance of cultural practices such as pest and disease control, to more accurately predict harvest date and to aid research (Coombe, 1995).

2.4 AROMA COMPOUND DEVELOPMENT IN THE BERRY

2.4.1 Methoxypyrazines

Roujou de Boubee (2003) showed that the ibMP content of a wine is affected only minimally by winemaking techniques and is therefore a direct reflection of the ibMP content of the grapes at harvest. The ibMP concentration of grapes increases from fruit set until about two or three weeks before veraison where its maximum concentration is reached. The biosynthetic pathway of ibMP, ipMP and sbMP is affected by viticultural conditions such as microclimate and berry ripeness (Allen *et al.*, 1997). Allen *et al.* (1997) suggest that the biosynthesis of ethylmethoxypyrazine follows a different production pathway than the other methoxypyrazines and its biosynthesis is unaffected by viticultural conditions.

After veraison, as ripening progresses, the concentration of methoxypyrazines in the berry decline markedly as a result of photodegradation (Marais, 1994). Lacey *et al.* (1991) showed the decline is dramatic, with more than 96% of the veraison level of ibMP lost by normal harvesting maturity. Roujou de Boubee (2003) suggests that

methoxypyrazines are continuously degraded and synthesised, however the synthesis pre-veraison occurs faster than the breakdown. Conversely, Hunter *et al.* (2004) believe the methoxypyrazine concentration at harvest is a balance between the biochemical formation of the compound pre-veraison and it photo-degradation post-veraison. In Cabernet Sauvignon, both ibMP and ipMP increased in the early developmental stage. Thereafter, ipMP decreased before veraison, while ibMP decreased after veraison (Roujou de Boubee *et al.*, 2002; Sala *et al.*, 2004; Hashizume and Samuta, 1999).

Roujou De Boubee et. al. (2002) and Hashizume and Samuta (1997) showed that regardless of ripeness, ibMP in Cabernet Sauvignon was mainly located in rachis, then in skins and seeds, while the flesh contained very little. During ripening, the proportion of ibMP in the stems and seeds decreased, while it increased in the skins.

2.4.2 Thiols

Thiols are present in the berry as odourless precursors, in the form of S-cysteine conjugates (Tominaga *et al.*, 1998b). They are released during alcoholic fermentation due to the degradation of their corresponding S-cysteine conjugates by yeast. Peyrot Des Gachons *et al.* (2000) suggest that these S-cysteine conjugates are intermediate chemicals, produced by the breakdown of the corresponding S-glutathione conjugates as part of a detoxification process by the plant. The detoxification process involves binding of the toxin with glutathione and subsequent breakdown of the product into several compounds, including S-cysteine (Peyrot Des Gachons *et al.*, 2000). It has been shown that the glutathione content of grapes increases at the onset of ripening (Okuda and

Yokotsuka, 1999) and continues to increase as ripening progresses (Adams and Chandrika, 1993). The accumulation of glutathione in ripening berries is positively correlated to an increase in soluble solids (Adams and Chandrika, 1993).

2.5 TERROIR

Terroir is a French word used to define the influences involved in producing quality wine. The exact meaning of *terroir* is surrounded by ambiguity; further complicated by simplification of the meaning to 'soil', 'arable land' or 'native land' upon translation into other languages (Vaudour, 2002). The true meaning is far more complex and various interpretations have been published (Turner and Creasy, 2003).

Johnson *et al.* (2001) describes *terroir* as "The whole ecology of the vineyard including every aspect of its surroundings from bedrock to late frosts and autumn mists, not excluding the way the vineyard is tended, nor the soul of the vigneron" (Wilson, 1998).

Turner and Creasy (2003), state that a viticultural environment or *terroir* can be traced back to some form of geology "the geological processes are the mechanisms responsible for topography, land orientation to the sun, prevailing winds, and also altitude; all factors which contribute to *terroir*".

In French viticulture, 'Appelations d'Origne Controlee' boundaries are fixed by the concept of *terroir* (Seguin, 1986). However, for *terroir* to be accepted by the scientific community, Vaudour (2002) believes that objective measurement must be possible and

the mythical and mystical facets removed. Various studies have been conducted in an attempt to scientifically prove the existence of *terroir* (Seguin, 1986; van Leeuwen *et al.*, 2004)

In Saint-Emilion, a simultaneous study of three *terroir* parameters-climate, soil and cultivar- showed that each had a highly significant effect on vine development and berry composition (van Leeuwen *et al.*, 2004). Similarly, tasting trials have revealed that the elegance and finesse of a wine produced on one soil type is often not replicated on another (Seguin, 1986).

The influence of the *terroir* factors soil and microclimate on vine growth and fruit and wine composition will be discussed in more detail.

2.5.1 Soil

Soil is a relatively stable parameter changing only very slowly over thousands of years. Soils vary in the type of parent rock, level of weathering, and the texture and structure of the different horizons (Barbeau *et al.*, 2001). It is the texture, structure and mineral content of the soil that determines the physical and chemical properties of the profile (Porter, 1994).

The proportion of sand, silt and clay fractions in the soil defines soil texture (White, 2003). Texture is an important soil characteristic influencing water infiltration rates,

hydraulic conductivity, soil water holding capacity, ease of soil tillage, and soil aeration (Rice, 2002).

Structure is the manner in which soil particles are arranged to form aggregates within the soil (Davidson, 1991). Aggregate formation creates pores within the soil profile in a process which is dependent on the soil texture, organic matter content, mineralogy (clay content) and soil chemistry (Davidson, 1991; Wilson, 1998). The structure of the soil influences the bulk strength and water content of the soil, by influencing water infiltration and drainage (Davidson, 1991). Wright (2001) describes how pebbles and rocks in the soil profile increase permeability of soil to water and reduce compaction, while on the surface they act to absorb heat during the day and promote slow cooling in the evening.

It has been said that 'good' *terroirs* are those which permit complete, but quite slow, maturation of grapes with certain regularity in quality between vintages (Seguin, 1986). Expanding on this, White (2003) states "It is the physical and chemical properties of the soil in a 'good' *terroir* that moderate climatic fluctuations, to provide a stable environment for the production of quality wine".

Relatively few studies have looked at the direct relationship between soil and wine quality. The studies that do investigate this interaction often lack viticultural consistency, comparing wines produced from different vineyard sites where the influence of other terroir parameters is overlooked. These studies give an interesting insight into the interaction; however no direct correlation can be concluded. One study by Seguin (1986)

compares wines produced from different soil types in France. He states, "At Saint-Emilion, the flat sandy soils produce wines which are not deeply-coloured but are thin and lacking in finish, and do not have the body and elegance of those obtained only a few hundred meters away on the calcareous sandstone of Sannoisian." A similar study by Barbeau *et al.* (2001), also found a correlation between soil type and wine quality. Results show that vines grown on shallow soils had richer musts, and higher quality wines, compared to deeper soils that produced wines of higher acidity and lower quality. Other studies have investigated the influence of soil on fruit and wine composition. Rankine *et al.* (1971) showed that soil type influenced the composition of grapes and wine, but had no significant impact on juice or wine aroma and flavour scores. An Australian study showed that soil salinity increased the Cl- and Na+ concentration of fruit, which affected wine quality (Lanyon *et al.*, 2004).

More commonly, research has been directed towards the influence of soil on vine growth and its indirect effect on wine quality. Several studies have shown that soil physical properties have a significant impact on vine root growth and good correlation exists between the amount of roots on a vine and the vigour of its aerial parts (Morlat and Jacquet, 1993; Rowe, 1993). Passioura (1991) and Morlat and Jacquet (1993) showed that increased penetrometric strength bulk density, hydromorphy intensity and clay percentage decreased root elongation. In a review by Lanyon *et al.* (2004) an interaction between soil properties and vine survival and growth was found. However, in an attempt to examine the influence of soil properties on berry quality and wine flavour, the results were not clear.

It is commonly noted that the soil properties determining water supply to vines have the most significant impact on vine performance (Rankine *et al.*, 1971; Seguin, 1986; van Leeuwen *et al.*, 2004). In viticultural areas where rainfall is the sole water source, soils that regulate vine water supply and reduce the impact of heavy rain or drought, produce the highest quality wines (Seguin, 1986). Van Leeuwen *et al.* (2004) found that optimum wine quality for Merlot, Cabernet Sauvignon and Shiraz was achieved under conditions of water deficit stress. High wine quality was a result of an early reduction in shoot growth, reduced berry size and increased grape sugar and anthocyanin concentration. Conversely, a study in South Africa showed that low vigour in Sauvignon blanc resulting from water stress, reduced the fresh vegetative character of the wine; a nuance required for quality Sauvignon blanc (van Schoor, 2001). The findings of Peyrot des Gachons *et al.* (2004) show that grape aroma potential in French Sauvignon blanc was highest in vines under mild water deficit and moderate nitrogen supply, while severe water stress or nitrogen deficiency reduced aroma potential. It is not clear whether the results from these trials show a direct or indirect effect of nitrogen and water on aroma compound development.

Results presented by Peyrot Des Gachons (2004) show that over two vintages in Bordeaux (one dry and one "normal"), shallow sandy/gravely soils showed the highest amount of water deficit, followed by deep gravely/sandy soils. Both deep and shallow sandy/clay soils showed minimal water deficit. These results support the findings of Chone *et al.* (2001) and van Leeuwen *et al.* (2004), who found that the gravely soils

showed severe water stress in seasons where water deficit between flowering and harvest were severe.

2.5.2 Microclimate

Microclimate is the climate within and immediately surrounding a plant canopy (Smart and Robinson, 1991). Temperature and light are major microclimatic parameters that influence the rate of compound development and degradation in the berry by regulating important enzymatic and chemical reactions (Marais *et al.*, 2001). Various studies show that methoxypyrazines are light sensitive and easily degradable to odourless products (Hunter *et al.*, 2004; Marais, 1994; Marais *et al.*, 2001).

Marais *et al.* (2001) showed that increased sun exposure reduced the vegetative intensity of the wine by decreasing the ibMP concentration. In another study, artificial light exposure increased both berry ibMP and ipMP concentrations preveraison, but reduced the levels of these compounds in ripening berries (Hashizume and Samuta, 1999). The authors hypothesise that light has a positive influence on the formation of methoxypyrazines during early berry development and a negative influence during berry ripening. A study by Sala *et al.* (2004), found that Cabernet Sauvignon berries protected from sunlight with pieces of sackcloth had significantly lower ibMP levels than the sun exposed berries. They suggest sunlight is required for the biological formation of methoxypyrazines during the whole developmental process.

Several studies have employed viticultural practices to manipulate canopy microclimate. In a trial by Arnold and Bledsoe (1990), severe leaf removal during the early and middle stages of berry development reduced the vegetal aromas of Sauvignon blanc. However, later leaf removal treatments were less effective. Contrary to these findings Hunter *et al.* (2004) found increased sunlight exposure, as a result of pre-veraison leaf plucking, actually increased the ibMP content of Sauvignon blanc berries.

These studies show that the timing and severity of viticultural practices have an impact on aroma compound development of Sauvignon blanc.

Although the microclimate of a vine canopy can be influenced by viticultural practices it is most strongly related to the regional climate. The climate of a viticultural region often varies significantly from year to year. Several studies investigate the influence of climate on the aroma compound development of Sauvignon blanc. Carey *et al.* (2001) showed that in South Africa, the climatic conditions of a particular season had a significant effect on the wine quality of several cultivars. For Sauvignon blanc, cool conditions during the season resulted in intense fresh vegetative characters compared to the more intense tropical fruit characters of a warmer season. These results support the findings of Marais (1994) who reported enhanced levels of vegetative character (methoxypyrazines) of Sauvignon blanc in cooler seasons. Similarly, in an Australian study, Lacey *et al.* (1991) found ibMP was present in Sauvignon blanc berries at higher levels (8.6 - 15.9 ng/L) in the three cooler regions than in the hot area of Wagga Wagga (0.6 – 2.3 ng/L) at comparable stages of sugar accumulation. Even in the same region, a cooler year in

Wagga Wagga produced berries with higher ibMP levels than berries produced in a warmer year.

2.5.3 Crop load

Various studies have shown that crop load has a significant effect on vine development and fruit and wine composition. In a study by McCarthy *et al.* (1986) the authors state that crop load appears to be the major determinant of grape quality. They found that over two seasons crop load reduction by bunch removal in irrigated Shiraz vines resulted in a significant improvement in wine colour density. Similarly, the grape monoterpene content of irrigated Riesling vines was significantly improved by crop reduction. In a study by Naor *et al.* (2002), results show that berry maturation of Sauvignon blanc was delayed in higher cropped vines and wine sensory evaluation scores decreased with increasing crop load. These results support the findings of Kliewer and Dokoozlian (2005) who found that improved fruit composition and earlier harvest maturity was achieved in lower yielding vines compared to higher yielding vines.

Several studies have shown that a significant relationship exists between the leaf area to crop load ratio of a vine, and vine and fruit development. A study by Kliewer and Dokoozlian (2005) showed that the total leaf area and trellis system of a grapevine largely determines its fruiting capacity within a climatic region. A lower leaf area to fruit weight ratio was required to ripen fruit on a divided canopy compared to a single canopy. Petrie *et al.* (2000) found that in vines where photosynthate availability was restricted by severe leaf removal, the onset of veraison was delayed by several weeks. They also

found that leaves of vines with a high leaf area to crop load ratio senesced more rapidly than leaves of the leaf area to crop load ratio treatments (Petrie *et al.*, 2000).

2.6 VINEYARD VARIABILITY

Variation within a vineyard can be described as: vine-to-vine variation within a vineyard; bunch-to-bunch variation within a vine; or berry-to-berry variation within a bunch (Trought, 1997). Variation in vine health, vigour, root system or yield can lead to differences in the rate of berry ripening and fruit characteristics having an important impact on wine quality (Long, 1987; Trought, 1997). Asynchronous berry development has repercussions on wine quality in that the proportion of berries with optimum characteristics are diluted by those that are inferior (Jackson and Lombard, 1993).

In New Zealand, Trought (1996) measured marked within vineyard variation in fruit composition as differences in soluble solids. He found that in one season more vigorous vines produced higher levels of soluble solids than less vigorous vines.

One of the largest wine companies in Australia, Orlando-Wyndham, has conducted extensive research into vineyard variation and how it affects wine quality (Smart, 1997). Results have shown that wine quality is enhanced by the fermentation of homogeneous batches of fruit, which increases blending options for greater wine complexity. In striving to continuously improve wine quality, Orlando-Wyndham now uses variation in the soluble solids of fruit, to indicate the potential of each site to produce excellent quality wine (Smart, 1997).

Vineyard variation is such an important factor in the production of quality wine that extensive research is being targeted toward understanding and managing this variability. In particular, the CSIRO Land and Water and the Cooperative Research Centre for Viticulture (CRCV) in South Australia have been looking at the use of precision viticulture technology to understand vineyard variability (Bramley, 2003). Bramley *et al.* (2003) define precision viticulture as "the use of information technologies that enable grape growers and winemakers to better understand variability in their production systems, and to use the understanding to better match the production inputs to desired or expected outcomes". Global positioning systems (GPS), geographical information system software (GIS), grape yield monitors, remotely-sensed imagery and soil-sensing technologies (EM38 sensors) are just a few of the tools utilised in precision viticulture (Bramley *et al.*, 2003). Precision viticulture has already shown its value in the improvement of wine quality both in Australia and around the world (Bramley, 2001; Bramley, 2003; Bramley *et al.*, 2003; Bramley and Proffitt, 1999; Johnson *et al.*, 2001). Bramley *et al.* (2003) combined the use of yield mapping and remotely-sensed imagery to investigate the within vineyard variation of a Western Australian vineyard and its effect on wine quality. Results showed significant vine vigour variation, which translated into significant vine yield variation. Furthermore, reduced fruit character intensity was noted in the high vigour, high yielding areas resulting in a significant reduction in wine quality. Separate harvesting of these areas allowed sections to be assigned to a higher quality wine than previously achieved. Similar results were found by Johnson *et al.* (2001) in a Californian study where remote sensing was used to divide a three hectare commercial

Chardonnay block into vigour zones. Both research groups stress the value of producing "unique wine lots" for greater flexibility in final blending.

A number of studies suggest the principal causes of vineyard variation are differences in soil characteristics (Bramley *et al.*, 2003; Raphael, 2005; Smart, 1997; Trought, 1997). With this insight, Orlando-Wyndham now designs each new vineyard block to be on one soil type, measured by a detailed soil survey of the vineyard (Smart, 1997). Bramley (2003) and Raphael (2005) suggest the advantage of using precision viticulture to target soil sampling has the potential for reducing the number of sample sites required and therefore the subsequent cost of the soil survey.

2.7 TERROIR OF MARLBOROUGH

Geographically Marlborough is a large area; comprised of distinct sub-regions differing in aspect, soil type and climate. However, the majority of vineyard plantings are in the Wairau plain, where the alluvial soils were formed less than 20, 000 years ago by sedimentation from the Wairau River and its tributaries (Basher *et al.*, 1995; Rae and Tozer, 1990). The braided nature of the river and frequent flood events has created a floodplain and terraces with significant vertical and horizontal soil variation (Trought, 1997). This variation in soil type is transcribed into variation in vine growth, where vigorous vines with a dense canopy and a heavy crop grow alongside weaker vines with little or no crop (Brooks, 1992).

In 1990, Laffan and Vincent conducted an extensive soil survey of the south side of the Wairau plain (1:25 000 scale) to classify and map the different soil types (Basher *et al.*, 1995; Rae and Tozer, 1990). Rapaura is located on the younger terraces and is comprised predominantly of Wairau series soils (Rae and Tozer, 1990). The soil profile commonly consists of a silt loam on top of fine sand with coarse gravel but the depth of each layer can vary significantly (Rae and Tozer, 1990). The Wairau planes provide a unique environment to study the effect of soil characteristics on vine performance with many other terroir parameters being the same, such as climate, aspect, clone, rootstock and management practices.

2.8 GRAPEVINE PHENOLOGY

Budburst signifies the start of the growing season for grapevines. The timing of budburst is dependent on soil temperature; it is generally accepted that when soil temperatures increase to above 10°C, bud burst is triggered (May, 2004). Once budburst has triggered shoot growth, vegetative growth continues in a near exponential manner until flowering (Mullins *et al.*, 1992). This early season growth is fuelled by carbohydrate reserves stored in the permanent structures of the vines (Mullins *et al.*, 1992) and is also affected by temperature (Zelleke and Kliewer, 1979). After flowering, carbohydrates are required for fruit growth so vegetative growth slows in an asymptotic manner (Mullins *et al.*, 1992). Shoot growth is influenced by climatic conditions, particularly degree-days above 10°C (Mullins *et al.*, 1992), and also limiting factors such as water stress, nutrient deficiencies and various pests and diseases.

Flowering date is highly dependent on temperature: a heat summation of 350 degree-days above 10°C, received over a period of at least 20 days, is required before flowering will occur (May, 2004). Flowering data have also been shown to correlate with shoot growth: *Vitis vinifera* cultivars flower when shoots have 13-20 internodes (May, 2004; Pratt and Coombe, 1978). Flowering progression is also very dependent on weather conditions: both the speed of flower opening and the extent of flowering are affected by temperature and rain (May, 2004). The rate of flower opening increases as temperatures increase from 15°C up to 25°C, while the flowers open badly and irregularly in cold rainy weather (May, 2004; Friend et. al., 2003). The opening of individual flowers is also influenced by competition for metabolites with other flowers in close proximity (Buttrosse and Hale, 1973).

The next major phenological event to be measured after flowering is veraison. Veraison occurs in stage III of berry growth and is marked by softening of the berry and by colour change in pigmented varieties (Mullins et. al., 1992). Veraison triggers the ripening of berries. During ripening, several physiological changes take place in the berry including the accumulation of hexoses and metabolism of malate with a subsequent decrease in titratable acidity and an increase in pH (Mullins et. al., 1992).

The end of the season for the grapevines is marked by the senescence and abscission of leaves as the vines enter dormancy. Senescence is characterised by the reduction of chlorophyll content in the leaves and a subsequent decrease in their photosynthetic rate. Leaf senescence can occur in leaves that are completely shaded from sunlight, as a result

of severe water or nutrient stress or naturally at the end of the season as the vines move into dormancy (Mullins et. al., 1992). In cool climate regions such as New Zealand, leaves begin to senesce before berries reach their optimum ripeness (pers. com. 2009).

2.9 GRAPEVINE YIELD

Grapevine yield is determined by a combination of parameters: the number of shoots per vine, the number of bunches per shoot, the number of berries per bunch and the final berry weight. The final yield is a result of a series of processes that take place over a period of about 17 months before the grapes are harvested (Smart and Robinson, 1991).

The first process, known as bunch initiation, occurs around flowering of the previous season, and involves the development of inflorescence primordia within the compound buds of developing shoots. In spring of the following year budburst signals the end of winter dormancy and shoot growth for the season begins. Bud burst is a complicated process which is affected not only by the capacity of the vine and the number of buds retained at pruning but also temperatures over winter and budburst, or more importantly, the change in temperature from winter to budburst (pers. com. with Trought, 2009; Mullins et. al., 1992). A significant winter chill has been shown to increase budburst coupled with warm temperatures over budburst (pers. com. with Trought, 2009).

During budburst another important process is taking place: the inflorescence primordium are converted into inflorescence and individual flowers are formed (May, 2004; Mullins et. al., 1992). The number of flowers formed on each inflorescence at budburst is influenced by temperature: significantly more flowers are formed at budburst temperatures of 12°C compared to temperatures higher than 25°C (May, 2004). However, since temperatures at budburst are not likely to reach 25°C in New Zealand, flower formation will be less influenced by temperature.

The onset of summer brings warm temperatures and flowering in the grapevine proceeds. Flowering is then followed by pollination, where pollen grains produced by the anthers (male part of flower) land on the stigma (female part of flower) and germinate to produce a pollen tube (May, 2004). Once pollination has occurred, the pollen tube grows from the stigma through the style and the central part of the ovary toward the ovule where it fertilises an egg (May, 2004). Growth of the pollen tube is strongly influenced by temperature with temperatures lower than 15°C resulting in insufficient pollen tube elongation to make fertilisation possible (May, 2004). Fruitset is very dependent on reserve materials including carbohydrate and nitrogen and on the availability of minor elements such as Boron, Zinc, Molybdenum and Iron as well as water deficits (May, 2004).

Once fertilisation has occurred, fruit growth commences. Fruit growth occurs over three stages; I, the initial phase of rapid growth; II, the lag phase of slow growth: III, the final phase of resumed growth and maturation (Mullins *et al.*, 1992). During stage I the

berries increase rapidly in size and mass due to growth of the pericarp and seeds (Mullins *et al.*, 1992). Initially growth is a result of cell division but after approximately 3 weeks cell expansion takes over (Mullins *et al.*, 1992). The number of pericarp cells is dependent upon several factors under both genetic and environmental control including temperature and water status (Mullins *et al.*, 1992). During stage III the resumption of rapid growth is due to cell expansion (Mullins *et al.*, 1992). Cell expansion at this stage is dependant on water status and the supply of photosynthate which, inturn, is dependent on the leaf area to crop load ratio and weather conditions affecting photosynthesis (temperature, humidity, wind) (Mullins *et al.*, 1992).

CHAPTER 3

MATERIALS AND METHODS

3.1 VITICULTURAL PARAMETERS

3.1.1 Trial site

This experiment was conducted over a single growing season in the D block of Pernod-Ricard's Squire Estate in Marlborough. The block consists of eight-year-old vines (cv. Sauvignon blanc, clone MC UDC 1) grafted on SO4 rootstock. The vines are approximately North-South oriented and planted to 2.4 m row spacing and 1.8 m vine spacing.

The experiment contains 48 bays, which are divided across eight rows. Treatment rows are separated by a buffer row. The experiment is a two by six factorial design with 12 unique replicates repeated four times.

The Squire D Block is a commercial vineyard, managed throughout the season by Pernod-Ricard staff according to best commercial practice. Management of the vineyard is typically as follows:

- Trimming of the canopy is performed on several occasions throughout the season to maintain a canopy size of approximately 1.2 m tall and 0.5 m wide.
- Mechanical leaf plucking is conducted in the fruit zone on two occasions, post-flowering and at veraison.
- Pest and disease management was undertaken using Sustainable Winegrowing New Zealand protocols (http://www.nzwine.com.swnz/)

- To minimise bird damage, quad bikes patrol the vineyard from veraison to harvest.
- The mid row is maintained as a permanent mown sward and the under-row weed free using herbicides.
- Vines are drip irrigated to minimise water stress through the growing season.

3.1.2 Crop load

In previous seasons, the vineyard had been pruned to four canes. After commercial pruning in August 2004, vines were pruned to either two or four canes each of approximately 12 nodes. The two treatments alternate across the treatment rows of the vineyard.

3.1.3 Vine size treatment

In September 2004 the trunk circumference of each vine in the eight trial rows was measured 10 cm above and below the graft union by HortResearch staff. Six bays of four vines were selected in each row to represent five vine size categories. The vines in each bay had the correct number of canes, minimal standard deviation between trunk circumferences and represented a particular size category.

One extra small (XS), small (S), large (L) and extra large (XL) experimental bay and two medium (M) experimental bays were chosen in each trial row. The XS bay in each row had the smallest average trunk circumference while the S, M, L and XL bays were progressively larger (Table 3.1). These classifications were used to represent vine size categories.

Table 3.1 Average trunk circumference of each trial bay in the Squire Vineyard, measured in spring 2004

Row	Bay	Cane	Size	Trunk Circumference (mm)
323	2	2	M	73.4
	15	2	M	73.4
	26	2	XS	68.3
	31	2	S	70.6
	40	2	L	78.4
	59	2	XL	84.2
325	5	4	M	73.9
	26	4	XS	64.6
	29	4	S	68.5
	43	4	L	79.1
	47	4	M	72.8
	59	4	XL	91.3
327	5	2	L	75.5
	18	2	M	70.8
	27	2	XS	61.6
	30	2	M	70.6
	33	2	S	64.6
	60	2	XL	83.9
329	26	4	XS	62.8
	36	4	S	68.3
	45	4	L	79
	54	4	M	74
	56	4	M	73.1
	61	4	XL	91.6
358	10	4	S	72.3
	28	4	L	82.8
	33	4	XS	65.2
	41	4	M	77.9
	48	4	M	77.7
	63	4	XL	85.6
360	11	2	XS	66.3
	12	2	S	71.1
	15	2	M	75.2
	35	2	M	75
	39	2	L	82.3
	58	2	XL	90.4
362	3	4	L	83.4
	8	4	XS	68.6
	9	4	S	72.1
	20	4	M	79.6
	55	4	M	79.6
	63	4	XL	87.9
364	10	2	S	75.6
	19	2	L	85.1
	22	2	M	79.7
	27	2	XL	90
	33	2	XS	65.8
	53	2	M	79.6

3.1.4 Trial preparation

One vine in each experimental bay was tagged with coloured tape. Within this vine one shoot arising from a node close to the vine head, two along the mid cane section and one at the end of the cane on the upper northern orientated cane were also tagged. Phenological and canopy measurements were taken from these tagged shoots to monitor the uniformity between experimental bays.

3.2 PHENOLOGICAL MEASUREMENTS

3.2.1 Flowering

Within each experimental bay all bunches on the tagged shoots were monitored for flowering progression using a scoring system developed by the Marlborough Wine Research Centre. The percent cap fall per bunch was visually determined every three days from the start of cap fall and a percent score of 5, 25, 50, 75 and 100 percent was subsequently recorded for each bunch. The same bunches were monitored for the duration of flowering.

3.2.2 Veraison

The date of veraison was established using a scoring system developed by the Marlborough Wine Research Centre. The scoring system measures the physical changes that occur in the berry during veraison, being a decrease in berry firmness (determined by gently squeezing the berries) and an increase in translucency (determined by visual inspection). The same bunches that were monitored for flowering progression were monitored for veraison progression. On each bunch, four randomly chosen berries from

the apical, ventral, dorsal and basal regions of the bunch were given a veraison score. A score of zero was given to the bunch when none of the sampled berries had gone through veraison and a score of four was given when all four berries had gone through veraison (Table 3.2). Veraison was monitored weekly from the start of February until each bunch had at least reached at least 50 percent veraison.

Table 3.2 Veraison monitoring method

Score	Number of Soft Monitor Berries	Veraison Score
1	1	25%
2	2	50%
3	3	75%
4	4	100%

3.3 VINE NUTRITIONAL MEASUREMENTS

Petiole samples were collected at flowering from each XS, M, and XL experimental bays for nutrient analysis. Nutrient analysis is an expensive procedure so only the XS, M and XL vines were sampled. Sampling involved the removal of petioles from 20 healthy leaves found in the fruiting zone of the eastern side of the canopy. Samples were stored in brown paper bags and dried in an 80°C oven for 3 days. The dried petioles were sent to Hill Laboratories (Hamilton, New Zealand) for inorganic nutrient analysis including nitrogen, calcium, potassium, phosphorus, sulphur, sodium, magnesium, manganese, iron, zinc, copper and boron.

3.4 CANOPY MEASUREMENTS

3.4.1 Canopy density

Smart and Robinson's (1991) point quadrat system was used to characterise the canopy of the tagged vines in each experimental bay. This involved the insertion of a 1m long, 2 mm diameter steel rod into the vine canopy at five different heights, three within the fruiting zone and two in the upper regions of the canopy. On the 27th of January 2005, rod insertions were made at 10cm intervals through holes in a vertically positioned PVC tube held at the various canopy heights. The leaf layer number, percentage gaps and bunch and leaf shading of the tagged vine in each treatment bay were determined using the system. Measurements were taken from the eastern side of the canopy at flowering and veraison.

3.4.2 Leaf senescence measurements

The visible symptom of leaf senescence is yellowing or chlorosis, characterised by a decline in leaf chlorophyll content (Marschner, 2002). The Konica Minolta SPAD-502 Chlorophyll Meter measures the relative amount of chlorophyll present in plant leaves (Fanizza et al., 1991). In this experiment, results were used to indicate the rate of leaf senescence.

Fortnightly 'SPAD' measurements were taken on 12 tagged leaves of similar age, health and sun exposure on the eastern side of the fruiting zone of each experimental bay (three leaves per vine). Averages of the 12 readings were recorded. If a tagged leaf was removed prior to the completion of measurements, an adjacent leaf was tagged and used

for the remaining measurements. All measurements were taken from the right apical lobe of each leaf. Measurements commenced at approximately two weeks post fruit set and continued until harvest.

3.5 FRUIT SAMPLING

3.5.1 Weekly Berry Sampling

A weekly 32 berry sample was collected from each experimental bay from approximately two weeks post fruit set until harvest. To allow for the comparison of results between treatments, a systematic sampling technique was applied. Berry sampling proceeded as follows:

- Berries were sampled from the eastern side of each vine within an experimental bay.
- Berries were harvested from the fourth, fifth and sixth shoots of the two lower canes
- Shoots tagged for non-destructive monitoring purposes were excluded from the weekly sampling.

In the first sampling session, shoots in the fourth position were sampled followed consecutively by shoots five and six in the following sampling sessions. The fourth shoot was sampled again in the fourth sampling session. This pattern continued until harvest. A total of four berries were harvested from the basal bunch of each shoot, one berry from the top, mid, back and bottom of the bunch.

3.5.2 Random bunch sampling

Bunch samples were collected from each experimental bay at specific soluble solid levels. The first samples were taken when the two cane vines reached an average soluble solids level of 21°Brix, as indicated by the berry sampling results. The second samples were taken when the four cane vines reached an average soluble solids level of 21°Brix. The third samples were taken at harvest. At the various sampling times all bunches from two randomly chosen shoots were collected from each plot, avoiding tagged shoots. The samples were stored at 5°C in plastic bags for berry density separation.

3.6 MEASUREMENTS AT HARVEST

Two days prior to commercial harvest all bunches in each treatment bay were harvested into labelled bins, counted and weighed. Average bunch weight per bay and per vine was determined for each treatment.

3.7 MEASUREMENTS AT PRUNING

3.7.1 Shoot number

At winter pruning, count nodes per vine, count shoots per vine, non-count shoots per vine and percent budburst were determined for each treatment bay.

3.7.2 Shoot vigour

The vigour of each shoot within the trial vines was given a score using a method developed by the Marlborough Wine Research Centre. A score of zero was given to

shoots of “straw” thickness (>0.5 mm), 0.5 for “pencil” thickness (6-10 mm), one for “little finger” thickness (11-15 mm) and two for “thumb” thickness or greater (>15 mm).

3.7.3 Pruning weights

All vines in each experimental bay were pruned to their corresponding two and four canes and the resulting one year (this seasons) and two year (last seasons) wood was weighed separately. The pruning weights/bay of the one year wood was divided by the total shoot number/bay data to give the average shoot weight/bay.

3.8 FRUIT ANALYSIS

3.8.1 Berry weight

The fresh weight of the weekly 32 berry samples was measured using a Sartorius three decimal place laboratory balance. An average berry weight was determined by dividing the total berry weight by 32.

3.8.2 Extraction of fresh juice from 32 berry samples

On the day of sampling, the weekly 32 berry samples were crushed using a Seward Stomacher 400 crusher for 30 seconds. The fresh juice was filtered through a small metal sieve and allowed to settle briefly in an airtight container.

3.8.3 Berry soluble solids concentration

The fresh filtered juice of the weekly 32 berry samples was analysed for soluble solids (°Brix) using a digital Atago Pocket PAL-1 pocket refractometer.

3.8.4 Titratable acidity analysis

The titratable acidity of 10mL of the fresh filtered juice of the weekly 32 berry samples was determined using a Mettler Toledo DL50 autotitrator and pH electrode to an endpoint of 8.2.

3.8.5 pH analysis

The pH of the fresh filtered juice of the weekly 32 berry samples was determined using a Metrohm 744 pH meter and Metrohm electrode.

3.8.6 Preparation of frozen berry samples methoxypyrazine analysis

At harvest, 4 randomly selected bunches were harvested from each treatment plot. The berries were separated from the rachis with their pedicels intact and then density separated into ripeness categories by floating the fruit in solutions containing a range of sugar concentrations from 14 to 27°Brix. The density separated berries had their pedicels removed and were placed in strong polythene bags, with 100 mg of PMS added per kg of fruit. The bags of berries were thoroughly crushed by hand and left at 20°C for 21 hours. The crushed fruit was then pressed in a 2.5 kg bag press to 2 atm (200kPA, 30 psi) for 10 minutes with the juice collected in a jug. The juice was frozen immediately in 3 x 1 mL microtubes, 2 x 250 mL vials and 2 x 35 mL vials.

3.8.7 Methoxypyrazine analysis of juice

3-isobutyl-2-methoxypyrazine (ibMP) and 3-isopropyl-2-methoxypyrazine (ipMP) concentrations in each juice sample were determined using an automated HS-SPME (Head Space Solid-Phase Micro-Extraction) technique described in detail by Parr *et al.* (2007).

3.9 STATISTICAL ANALYSIS

Analysis of variance was performed using Genstat 5 release 4.1.

Trend lines on graphs were inserted using SigmaPlot 8.1.

CHAPTER 4

RESULTS

4.1 VINE GROWTH PARAMETERS

Infra red aerial photographs of the Squire Vineyard show marked variation in vine canopy and cover crop colour throughout the block with the variation moving down the north-south oriented rows and appearing to reflect historical sedimentation changes caused by the Wairau River (Figure 4.1). Variation was also observed across the block with the western side being more vigorous than the eastern side despite uniformity in vine age.

Trunk circumference measurements in the Squire vineyard revealed differences in trunk circumference along the experimental rows (Figure 4.1). The changes in circumference were not randomly distributed, but appeared to reflect the historical river channels. Vine trunk circumference ranged from 61.6mm to 91.6mm. The extra small (XS) vines were the smallest vines within a row and had a trunk circumference that ranged from 61.6mm to 68.3mm on the eastern side of the block and from 65.2mm to 68.6mm on the western side; small (S) vine trunk circumferences ranged from 64.6 to 70.6mm on the eastern side of the block and from 71.1mm to 75.6mm on the western side; medium (M) vine trunk circumferences ranged from 70.6 to 74mm on the eastern side of the block and from 75mm to 79.7 on the western side; large (L) vine trunk circumferences ranged from 75.5 to 79.1mm on the eastern side of the block and from 82.3mm to 85.1mm on the western side; and finally the extra large (XL) vine trunk circumferences ranged from 83.9mm to

91.6mm on the eastern side of the block and from 85.6 to 90.4 on the western side (Table 3.1).

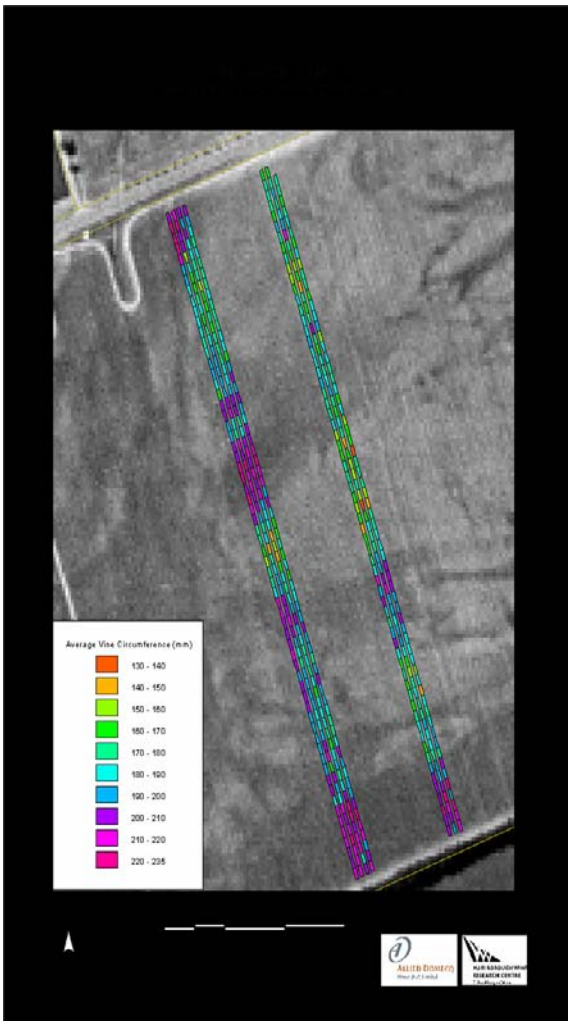


Figure 4.1 Aerial photograph of the Squire Vineyard showing differences in vine canopy and cover crop colour overlayed with trunk circumference data

4.1.1 Point Quadrat Measurements

Point quadrat measurements were used to assess the vigour of trial vines. The results presented in Table 4.1 show that both cane number and vine size had an effect on the canopy density of Sauvignon blanc vines. The larger vines had denser canopies than the smaller vines and the four cane vines had denser canopies than the two cane vines.

Vine size had a significant effect on leaf layer number, the percent canopy gaps, and bunch shading within the fruit zone of treatment vines; but no significant effect on the percent of internal leaves in the fruit zone. The larger vines had a lower percent of canopy gap, a higher percent internal bunches and leaves and a higher leaf layer number than the smaller vines. The extra small vines had 42% less shaded bunches than the extra large vines, 94% more canopy gaps and a leaf layer number 19% lower than the extra large vines.

Cane number had no significant effect on the percent of canopy gaps, but did have a significant effect on the percent of internal leaves and bunches and the leaf layer number. The four cane vines had a higher percent of internal leaves and bunches and a higher leaf layer number than the two cane vines.

There was no significant interaction between cane number and vine size.

4.1.2 Pruning Measurements

The pruning measurements presented in Table 4.2 show that vine size is associated with pruning weight and cane weight while crop load is associated with percent of blind buds, cane weight and the percent of shoots in the size zero, one and two shoot width categories.

Vine size had no significant effect on the number of count nodes retained or the percent of blind buds produced; but vine size did have a significant effect on pruning weight and cane weight. The large and extra large vines had a significantly higher pruning weight and cane weight than the extra small and small vines. Vine size had an effect on the percent of shoots in the largest shoot size category (size two) but no significant effect on the percent of shoots in the smaller shoot size categories. The larger vines had a higher percent of shoots in the size two category compared to the smaller vines.

Crop load had a significant effect on the percent of blind buds and cane weight but no significant effect on pruning weight. The four cane vines had a higher percent of blind buds and a lower cane weight than the two cane vines. Crop load had a significant effect on the percent of shoots in the size zero, size one and size two shoot width categories: a significantly higher percent of shoots from the four cane vines resided in the size zero and size one categories, while a significantly higher percent of shoots from the two cane vines resided in the size two category.

There was no significant interaction between cane number and vine size.

Table 4.1 The effect of vine size and crop load on canopy density parameters

	Gaps in Canopy (%)	Internal Leaves (%)	Internal Bunches (%)	LLN
Factor				
Vine Size				
XS	3.2a	29.9	24.7b	1.7c
S	1.7ab	32.7	25.2b	1.8bc
M	0.5b	34.4	43.4a	1.9ab
L	0.8b	34.7	41.1a	1.9ab
XL	0.2b	38	41.5a	2.0a
Significance[x]	**	ns	*	*
Crop Load Treatment				
2 Cane	1.6	32.3b	27.6b	1.8b
4 Cane	0.7a	35.8a	45.7a	1.9a
Significance[x]	ns	*	***	*
Interaction[x]	ns	ns	ns	ns
Interactions				
XS; 2 Cane	3.7a	29.9b	23.3b	1.7cd
S; 2 Cane	2.7ab	30.6b	15.0b	1.7cd
M; 2 Cane	0.7bc	32.3ab	33.2ab	1.8abcd
L; 2 Cane	1.8abc	32.1ab	24.4b	1.8bcd
XL; 2 Cane	0.0c	36.2ab	34.1ab	2.0abc
XS; 4 Cane	2.7ab	29.9b	26.0b	1.6d
S; 4 Cane	0.7bc	34.7ab	35.3ab	1.9abcd
M; 4 Cane	0.3c	36.5ab	53.9a	2.0ab
L; 4 Cane	0	37.1ab	55.9a	2.0ab
XL; 4 Cane	0.3c	39.8a	49.0a	2.1a

[*] [**] [***] ns: Significant at p<0.05, 0.01, 0.001, or not significant, respectively.

Table 4.2 The effect of vine size and crop load on pruning measurements

				Shoot Size Category			
	Blind Buds (%)	Pruning Weight (Kg/bay)	Cane Weight (Kg/bay)	Size 0 (% of shoots/bay)	Size 0.5 (% of shoots/bay)	Size 1 (% of shoots/bay)	Size 2 (% of shoots/bay)
Factor							
Vine Size							
XS	31	8.6c	0.8c	35.1	29.9	31.4	3.6bc
S	24.8	8.5c	0.8c	38.6	32.0	27.0	2.3c
M	22.9	9.9bc	1.0bc	52.8	28.1	18.0	1.1ab
L	23.7	11.3ab	1.1ab	17.6	25.2	46.2	10.9a
XL	25.7	11.9a	1.2a	21.0	29.0	37.1	12.9a
Significance[x]	ns	**	**	ns	ns	ns	**
Crop Load Treatment							
2 Cane	14.9b	10.3	1.3a	24.2b	28.0b	39.8b	8.0a
4 Cane	35.4a	9.8	0.6b	40.9a	29.3a	28.2a	1.6b
Significance[x]	***	ns	***	***	***	*	***
Interaction[x]	ns	ns	ns	ns	ns	ns	Ns
Interactions							
XS; 2 Cane	20.0c	8.1c	1.0c	26.6b	26.2b	39.3b	7.9bcd
S; 2 Cane	12.3c	9.3bc	1.2bc	26.2b	34.4b	37.3b	4.1de
M; 2 Cane	13.8c	10.1bc	1.3b	23.5b	28.3b	40.8ab	7.4abc
L; 2 Cane	15.0c	11.2ab	1.4ab	23.0b	26.2b	40.7b	10.2ab
XL; 2 Cane	14.3c	13.0a	1.6a	22.9b	26.8b	39.4b	10.9a
XS; 4 Cane	42.0a	9.1bc	0.6d	39.9a	31.9a	27.1ab	1.1e
S; 4 Cane	37.3ab	7.8c	0.45d	46.9a	31.8a	20.2b	1.2e
M; 4 Cane	32.0b	9.8bc	0.6d	39.4a	27.5a	31.4ab	1.7e
L; 4 Cane	32.3b	11.3ab	0.7d	36.2a	29.4a	32.4a	2.0cde
XL; 4 Cane	37.0ab	10.7ab	0.7d	44.1a	27.7a	26.4ab	1.9cd

[x],[xx],[xxx],ns: Significant at $p<0.05$, 0.01, 0.001, or not significant, respectively.

4.2 PHENOLOGY

Differences in vine phenological development reflected changes in vine size and crop load.

4.2.1 Flowering

Results presented in Figure 4.2 show that both crop load and vine size influenced the timing of flowering. The four cane pruned vines flowered later than the two cane pruned vines and the extra large vines flowered later than the extra small vines.

Flowering assessment showed that flowering progressed in a sigmoid fashion and more importantly, that both crop load and vine size affected its progression Measurements were stopped before all treatments had reached 100% flowering.

Vine size had a significant effect on flowering, with the extra large vines behind the other vine size categories. There was no significant difference between the vine size categories on the first sample date, December 6, 2004. The extra large vines reached 80% flowering approximately three days behind of the small vines.

Crop load had a significant effect on flowering on every sample date with the two cane vines ahead of the four cane vines. The two cane vines reached 80% flowering approximately two days ahead of the four cane vines.

There was no significant interaction between cane number, vine size and flowering.

4.2.2 Veraison

Results presented in Figures 4.3 show that both crop load and vine size influenced the timing of veraison. The four cane pruned vines went through veraison later than the two cane pruned vines and the extra large vines went through veraison later than the extra small vines.

Weekly veraison measurements showed that veraison progressed in a sigmoid fashion and more importantly that both crop load and vine size affected its progression. Measurements were stopped before all treatments had reached 100% veraison.

Vine size had a significant effect on veraison on every sample date with the extra large vines behind the other vine size categories. The extra large vines reach 50% veraison approximately seven days behind of the extra small vines.

Crop load had a significant effect on veraison on every sample date with the two cane vines ahead of the four cane vines. The two cane vines reached 50% veraison approximately three days ahead of the four cane vines.

There was no significant interaction between cane number, vine size and veraison.

4.2.3 Senescence

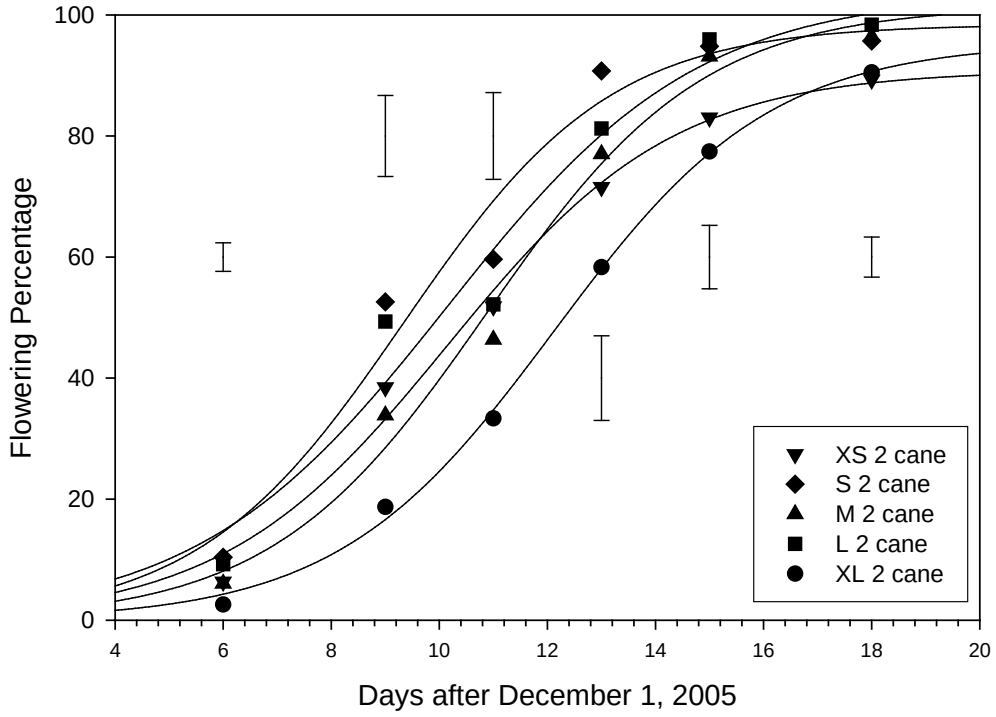
Results presented in Figures 4.4 show that both crop load and vine size had an influence on the timing of leaf senescence. The four cane pruned vines started to senesce earlier than the two cane pruned vines, and the extra small vines started to senescence before the extra large vines.

Results also show that as time progressed from the 1st of February, the basal leaf SPAD values of trial vines decreased at varying rates.

Vine size had a significant effect on leaf senescence on every assessment date except the first, February 2 2005; SPAD values were higher in the larger vines. For example, in the four cane vines, a 30% drop in the SPAD value of leaves from extra small vines was measured between February 2, 2005 and April 7, 2005 (64 days).

Crop load had a significant effect on leaf senescence from February 2 ,2005 until February 22, 2005; but from March 8, 2005 until April 7, 2005 no significant crop load effect was evident; the two cane vines started off with a significantly higher SPAD value than the four cane vines but by March no significant difference was measured.

There was no significant interaction between cane number, vine size and leaf senescence.



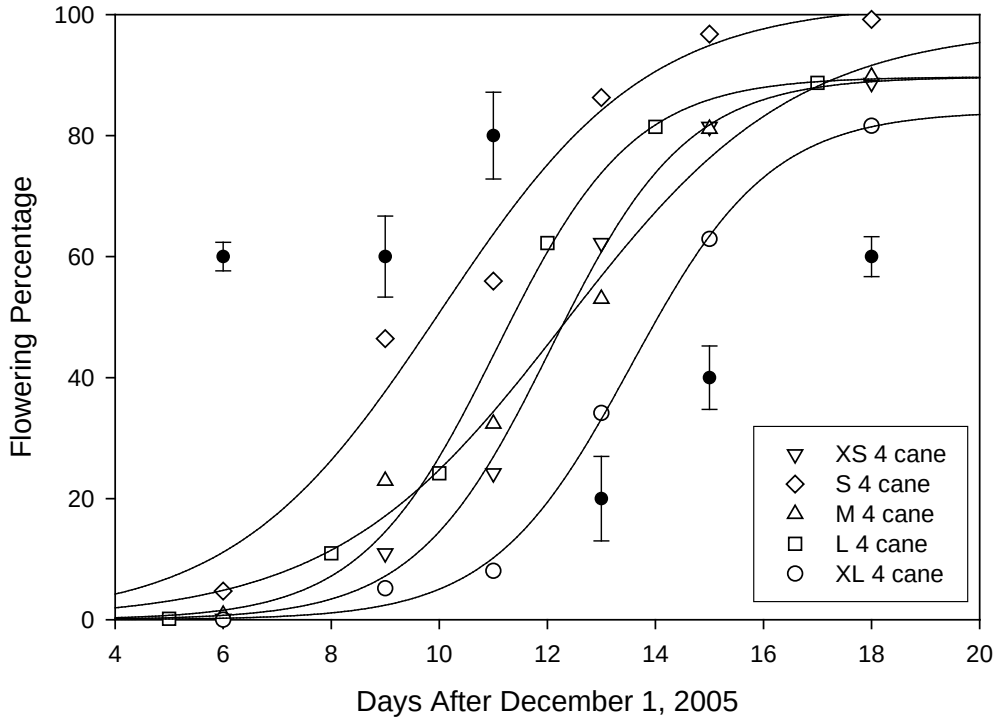


Figure 4.2 The effect of vine size on flowering progression in two and four cane pruned Sauvignon blanc vines
Vertical bars represent LSD P < 0.05

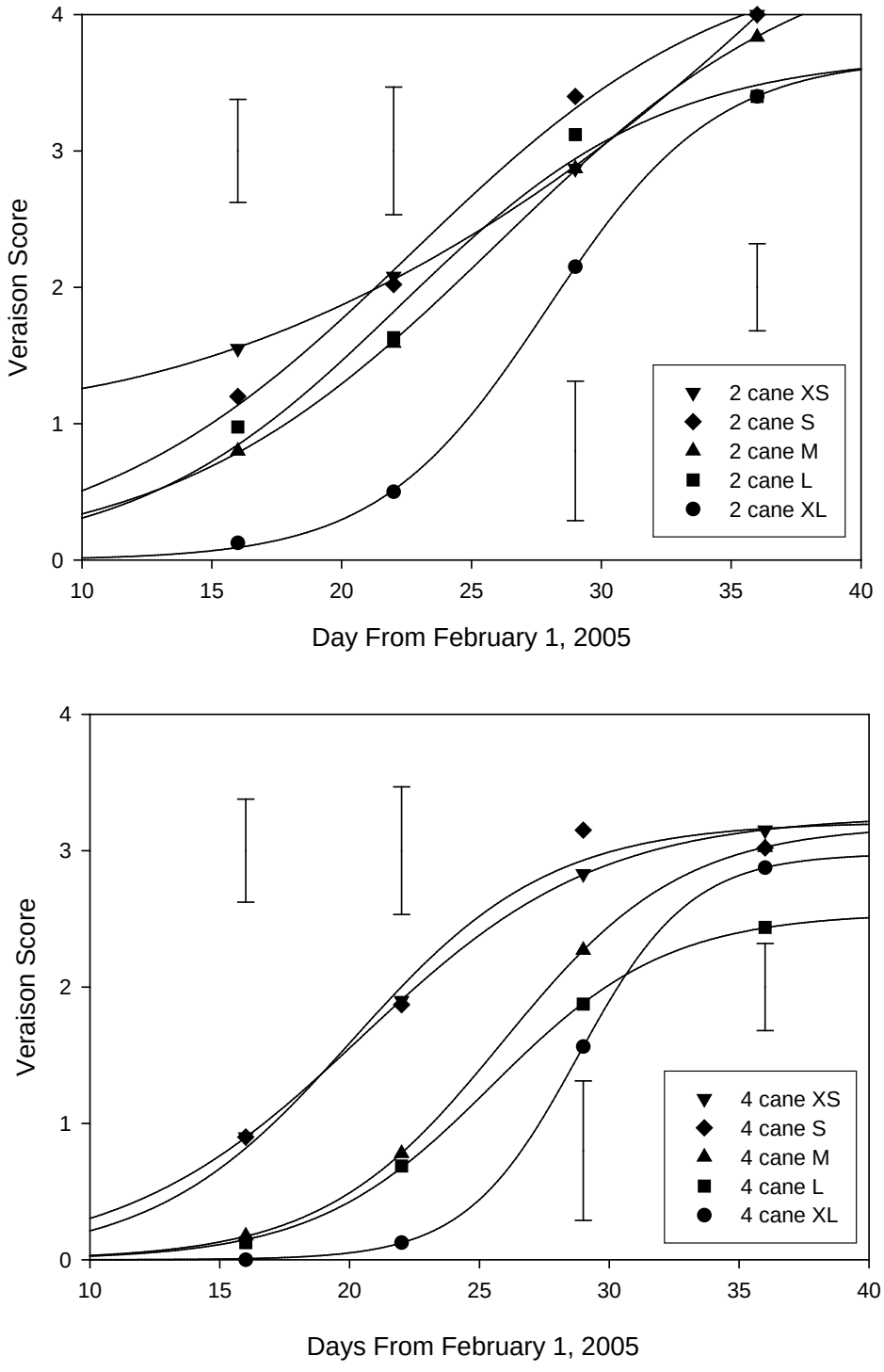
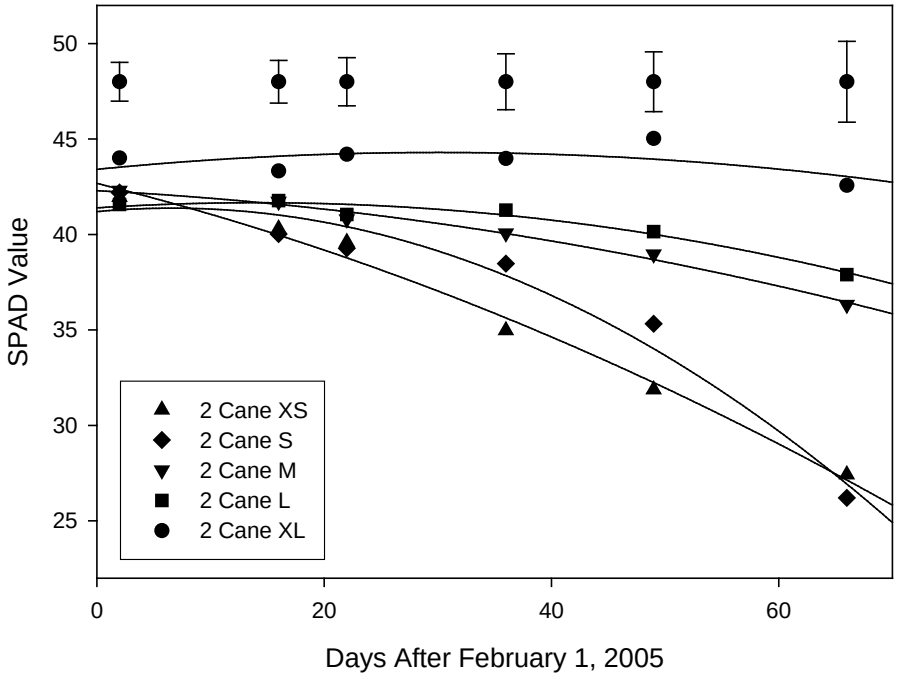


Figure 4.3 The effect of vine size on veraison progression in two and four cane pruned Sauvignon blanc vines
Vertical bars represent LSD P < 0.05



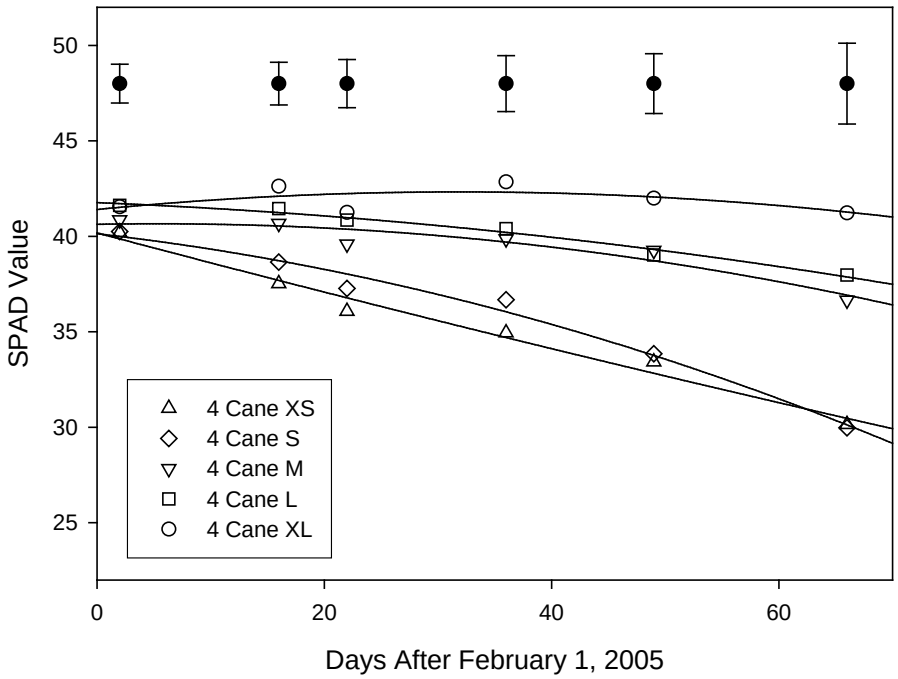


Figure 4.4 The effect of vine size on leaf chlorophyll content in two and four cane pruned Sauvignon blanc vines
Vertical bars represent LSD P < 0.05

4.3 YIELD AND YIELD PARAMETERS

Results presented in Table 4.3 show that crop load had a significant effect on final yield per vine, the number of count nodes retained, the percent bud burst, shoots per vine, bunches per shoot and bunches per vine, while vine size only had an affect on percent budburst.

A significant cane number effect was evident when comparing the fruit yield per vine of the two and four cane vines. The two cane pruned vines had an average fruit yield per vine 47 percent lower than that of the four cane pruned vines. Fruit yield per vine did not change with vine size category. No significant vine size, cane number and fruit yield interaction was evident.

Crop load had a significant effect on the percent budburst with the two cane vines having a significantly higher percent bud burst compared to the four cane vines, 130.8 percent compared to 103.2 percent. Vine size had a significant effect on percent bud burst with the extra small vines having a lower percent budburst than the medium, large and extra large vines. No significant vine size, cane number and percent budburst interaction was evident.

Crop load had a significant effect on shoot number per vine with the two cane pruned vines having 37 percent less shoots per vine than the four cane vines. Count node number did not change with vine size, and no significant vine size, cane number and count node number interaction was evident.

Crop load had a significant effect on bunches per shoot with shoots from the four cane vines being 36 percent more fruitful than shoots from the two cane vines. Bunch number per shoot did not change with vine size, and no significant vine size, cane number and count node number interaction was evident.

Crop load had a significant effect on bunch number per vine with the four cane vines having 80 percent more bunches per vine than the two cane vines. Bunch number per vine did not change with vine size, and no significant vine size, cane number and count node number interaction was evident.

No significant cane number or vine size effect was evident when comparing the number of berries per bunch, the average berry weight or the average bunch weight between treatments.

Berry weight reached a maximum and then began to decrease in all treatments.

Berry weight at veraison was an average of 1.2g between treatments; this weight increased by 40 percent to an average harvest berry weight of 1.9g.

Table 4.3 The effect of vine size and crop load on yield parameters in Sauvignon blanc

	Count Nodes Retained	Percent Budburst	Shoot Number per Vine	Bunch Number per Shoot	Bunch Number/Vine	Berries per Bunch	Berry Weight (g)	Bunch Weight (g)	Yield per Vine (Kg)
Factor									
Vine Size									
XS	35.1	104.9b	35.1	1.5	58.4	52.2	1.9	95.8	5.7
S	33.6	113.7ab	36.3	1.4	55.9	55.2	1.8	99.6	5.6
M	32.1	120.6a	37	1.3	54.3	50.6	1.8	95	5.2
L	34.3	117.3a	38.9	1.3	54.5	56.5	1.9	103.8	5.9
XL	33.4	121.6a	39.1	1.2	57.1	54.4	1.7	86	4.9
Significance[x]	Ns	*	ns	ns	ns	ns	ns	ns	ns
Crop load									
2 Cane	22.1b	130.8a	28.9b	1.1b	39.6b	54.1	1.8	92.3	3.7
4 Cane	44.2a	103.2b	45.4a	1.5a	71.2a	52.5	1.9	99.2	7
Significance[x]	***	***	***	**	***	ns	ns	ns	***
Interaction[x]	Ns	ns	ns	ns	ns	ns	ns	ns	ns
Interactions									
XS; 2 Cane	22.1c	115.3b	25.3e	1.3ab	41.7b	53.9ab	1.8a	95.4ab	4.1b
S; 2 Cane	22.4c	130.0ab	29.0de	1.1ab	39.0b	55.6ab	1.8a	96.4ab	3.8b
M; 2 Cane	21.9c	136.0a	29.7d	1.1ab	40.7b	51.2ab	1.9a	92.2ab	3.8b
L; 2 Cane	22.2c	128.5ab	28.5de	1.1ab	37.6b	52.0ab	1.8a	91.9ab	3.5b
XL; 2 Cane	22.3c	135.0a	30.1d	1.0b	38.1b	60.6a	1.6b	86.5b	3.4b
XS; 4 Cane	47.2a	94.0d	44.3bc	1.7a	74.1a	51.1ab	1.9a	96.9ab	7.2a
S; 4 Cane	41.8b	98.0cd	43.3c	1.7a	72.1a	54.9ab	1.9a	102.6ab	7.4a
M; 4 Cane	44.3ab	105.9bcd	44.0bc	1.5ab	67.3a	49.9ab	1.8a	97.6ab	6.5a
L; 4 Cane	45.9a	106.8bcd	49.0a	1.5ab	70.7a	61.0a	1.9a	115.5a	8.2a
XL; 4 Cane	44.0ab	108.8bc	47.8ab	1.3ab	75.4a	48.2b	1.8a	85.2b	6.4a

[x]*, **, ***,ns: Significant at p<0.05, 0.01, 0.001, or not significant, respectively.

4.4 FRUIT COMPOSITION

Results presented in Table 4.4 show that both cane number and vine size had an effect on weekly soluble solids over the ripening period, while results presented in Table 4.5 show that both crop load and vine size had an effect on soluble solids, pH and titratable acidity levels at harvest, but no significant effect on ibMP or ipMP levels at harvest.

Vine size had a significant effect on the weekly soluble solids levels during berry ripening: the smaller the vine size, the higher the soluble solids (Table 4.4). On every sample date, the extra small vines had significantly higher soluble solids than the extra large vines. The average daily accumulation rate of soluble solids did not change with vine size (Table 4.4). Vine size had a significant effect on soluble solids, pH and titratable acidity levels at harvest (Table 4.5). The smaller vines had a higher soluble solid and pH level at harvest and a lower titratable acidity than the larger vines. The ibMP ipMP levels in the juice at harvest did not change with vine size.

Crop load had a significant effect on the weekly soluble solids levels during berry ripening (Table 4.4). On every sample date, the 2 cane vines had significantly higher soluble solids than the 4 cane vines. The 2 cane pruned vines reached 15°Brix 5 days earlier than the 4 cane pruned vines and 20°Brix 10 days earlier. Crop load had a significant effect on the average daily accumulation rate of soluble solids with the 2 cane pruned vines having a higher average accumulation rate than the 4 cane pruned vines (Table 4.4). Crop load had a significant effect on the level of soluble solids and pH at harvest but no significant effect on the final titratable acidity (Table 4.5). The two cane

vines had a significantly higher final level of soluble solids and pH than the 4 cane vines. The ibMP ipMP levels in the juice at harvest did not change with crop load (Table 4.5).

No significant vine size, cane number and final fruit analysis interaction was evident (Table 4.4).

In the two cane treatment, the extra small vines reached 15°Brix about 10 days earlier than the extra large vines and 20°Brix 12.5 days earlier (Table 4.4). In the 4 cane treatment, the extra small vines reached 15°Brix 7.5 days earlier than extra large vines and 20°Brix 10 days earlier (Table 4.4).

Table 4.4 The effect of vine size and crop load on weekly soluble solids (°Brix) in Sauvignon blanc berries

	Soluble Solids (°Brix)									Average Daily Soluble Solids Accumulation Rate
	18/02/2005	28/02/2005	7/03/2005	14/03/2005	21/03/2005	28/03/2005	4/04/2005	11/04/2005	19/04/2005	
Factor										
Vine Size										
XS	5.9a	11.6a	13.5a	15.5a	17.5a	18.3a	20.0a	21.8a	22.0a	0.27
S	5.5a	10.6b	12.9ab	14.6bc	17.0a	18.0a	19.4b	21.9a	21.0ab	0.26
M	5.1b	9.7bc	12.06b1	14.8b	17.0a	18.1a	19.5b	21.9a	21.8a	0.28
L	4.7b	9.2c	12.5b	14.3c	16.8a	17.7a	19.2b	21.2b	21.4ab	0.28
XL	4.3c	7.8d	10.5c	13.2d	16.0b	16.6b	18.3c	19.7c	20.3b	0.27
Significance[x]	***	***	***	***	***	***	***	***	***	ns
Crop load										
2 Cane	5.2a	10.4a	12.9a	15.5a	17.8a	18.7a	20.1a	21.4a	22.3a	0.28a
4 Cane	4.9b	9.1b	11.7b	13.6b	16.0b	16.9b	18.5b	20.0b	20.5b	0.26b
Significance[x]	*	***	***	***	**	***	**	***	*	***
Interaction[x]	Ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Interactions										
XS; 2 Cane	6.1a	12.4a	14.5a	16.9a	18.3a	19.6a	20.9a	21.9a	23.2a	0.29a
S; 2 Cane	5.6ab	11.5ab	13.7ab	15.8ab	18.3a	19.3a	20.6a	21.9a	22.3ab	0.28abc
M; 2 Cane	5.2bc	10.5bc	13.1bc	15.9ab	18.2a	18.9ab	20.5a	21.9a	22.8a	0.29a
L; 2 Cane	4.9cd	9.7cd	11.9cd	15.1bc	17.3ab	18.1bc	19.8ab	21.1ab	22.1ab	0.29ab
XL; 2 Cane	4.4de	8.2ef	10.8de	13.7de	16.4bc	17.1d	18.7bcd	19.7cd	20.4c	0.27abc
XS; 4 Cane	5.7ab	11.1b	12.4bc	14.5cd	16.6bc	16.9de	19.2bc	20.6bc	20.9bc	0.26cd
S; 4 Cane	5.4bc	9.6cd	12.1cd	13.5de	15.6c	16.7de	18.2cd	19.8cd	19.6c	0.24d
M; 4 Cane	4.9cd	9.0de	11.8cd	13.6de	15.9c	17.2cd	18.4cd	20.1bcd	20.7c	0.26bcd
L; 4 Cane	4.6de	8.6def	12.2c	13.6de	16.3bc	17.3cd	18.6bcd	20.0bcd	20.7bc	0.27abc
XL; 4 Cane	4.3e	7.8f	10.2e	12.8e	15.6c	16.1e	17.9d	19.3d	20.2c	0.27abc

[x]*, **, ***,ns: Significant at p<0.05, 0.01, 0.001, or not significant, respectively.

Table 4.5 The effect of vine size and crop load on the final fruit composition of Sauvignon blanc berries

	Soluble Solids (°Brix)	pH	TA (g/L)	IBMP (ng/L)	IPMP (ng/L)
Factor					
Vine Size					
XS	22.0a	3.1a	8.4c	16.9	3.3
S	21.0ab	3.0b	9.4b	20.8	4.2
M	21.8a	3.0b	9.5b	13.7	2.5
L	21.4ab	3.0b	9.7b	15.1	2.8
XL	20.3b	3.0b	10.4a	10.4	2.1
Significance[x]	*	**	***	ns	ns
Crop load					
2 Cane	22.3a	3.1a	9.3	17.8	3.4
4 Cane	20.5b	3.0b	9.6	13.2	2.6
Significance[x]	***	***	ns	ns	ns
Interaction[x]	Ns	ns	ns	ns	ns
Interactions					
XS; 2 Cane	23.1a	3.1a	8.0e		
S; 2 Cane	22.3a	3.1ab	9.34bcd		
M; 2 Cane	22.8a	3.1ab	9.1cd		
L; 2 Cane	22.1a	3.1bcd	9.9abc		
XL; 2 Cane	20.4b	3.0bcde	10.3ab		
XS; 4 Cane	20.9ab	3.1bc	8.7de		
S; 4 Cane	19.6b	3.0cde	9.4bcd		
M; 4 Cane	20.7ab	3.0e	9.8abc		
L; 4 Cane	20.7ab	3.0de	9.4bcd		
XL; 4 Cane	20.2b	3.0e	10.6a		

[x] *, **, ***,ns: Significant at p<0.05, 0.01, 0.001, or not significant, respectively.

4.5 NUTRITION

Nutrition results presented in Tables 4.6 and 4.7 show that both crop load and vine size had an effect on the nutrient content of Sauvignon blanc petioles collected at flowering.

The larger vines had lower petiole phosphorus (%), potassium (%) and manganese (mg/Kg) levels and higher petiole calcium (%), magnesium (%) and boron (mg/Kg) levels than the smaller vines.

The higher the cane number, the lower the petiole manganese (mg/Kg) and zinc (mg/Kg) levles.

Table 4.6 The effect of vine size and crop load on macronutrient levels in Sauvignon blanc petioles collected at flowering

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Factor						
Vine Size						
XS	0.7	0.5	4.1	1.6	0.2	0.2
M	0.8	0.4	3.1	1.9	0.3	0.2
XL	0.8	0.4	2.6	2	0.5	0.2
Significance[x]	Ns	*	***	***	***	ns
Crop load						
2 Cane	0.8	0.4	3.1	1.9	0.4	0.2
4 Cane	0.7	0.4	3.4	1.8	0.4	0.2
Significance[x]	Ns	ns	ns	ns	ns	ns
Interaction[x]	Ns	ns	ns	ns	ns	ns

[x]*, **, ***,ns: Significant at p<0.05, 0.01, 0.001, or not significant, respectively.

Table 4.7 The effect of vine size and crop load on micronutrient levels in Sauvignon blanc petioles collected at flowering

	B (mg/Kg)	Cu (mg/Kg)	Fe (mg/Kg)	Mn (mg/Kg)	Zn (mg/Kg)
Factor					
Vine Size					
XS	33.8	9	20.2	106	53.9
M	34.4	9.4	30.5	73.9	52.1
XL	39.4	9.8	20.4	40.7	53
Significance[x]	***	ns	*	***	ns
Treatment					
2 Cane	36	9.5	25.3	84.5	56.2
4 Cane	35.7	9.3	22.1	62.6	49.8
Significance[x]	Ns	ns	ns	**	*
Interaction[x]	Ns	ns	ns	ns	ns

[x]*, **, ***,ns: Significant at p<0.05, 0.01, 0.001, or not significant, respectively.

CHAPTER 5

DISCUSSION

Variation in vine health, vigour, root system or yield can lead to differences in the rate of berry ripening and fruit characteristics, having an important impact on wine quality (Long, 1987; Trought, 1997). Asynchronous berry development has repercussions on wine quality in that the proportion of berries with optimum characteristics are diluted by those that are inferior (Jackson and Lombard, 1993).

Bramley *et al.* (2003) reported significant within vineyard variation in an Australian vineyard measured as vine vigour. He showed that significant within vineyard vine vigour variation resulted in significant vine yield and wine quality variation. Similar results were found by Johnson *et al.* (2001) in a Californian study.

In Marlborough, Trought (1996) measured marked within vineyard variation in vine vigour.

Aerial photographs of the Squire Vineyard show marked variation in vine canopy and cover crop colour throughout the block with the variation moving perpendicular to the north-south oriented rows. Trunk circumference measurements in the Squire vineyard revealed significant trunk circumference variation. The changes in trunk circumference were not randomly distributed, but appear to reflect the historical river channels. A number of studies suggest the principal causes of vineyard variation are differences in soil characteristics (Bramley *et al.*, 2003; Raphael, 2005; Trought, 1997).

Results from a companion study by Mills (2006) into the relations among geology, soil type and Sauvignon blanc vineyard variation in Marlborough, showed there are 5 main soil types present in the Squire Vineyard, with their distribution varying significantly throughout the block. He describes the soils as (1) gravel topsoil, (2) gravel subsoil, (3) sand subsoil, (4) loam topsoil and (5) sandy loam subsoil. Mills found that although these soil types differ in their physical, mineralogical and chemical properties the greatest variation is in soil texture, defined by White (2003) as the proportion of sand, silt and clay fractions in the soil. Mills (2006) found that the distribution of these soils had a significant impact on vine trunk circumference with a clear pattern existing between the depth to gravel and vine trunk circumference. As the depth to gravel increases, vine trunk circumference increases. Mills (2006) found that all of the extra small and small vines occur on soils with gravel topsoil and gravel subsoil; medium vines occur on loam topsoil overlaying a shallow, sandy loam subsoil, overlaying gravels at an average depth of 30cm; large vines occur on loam topsoils with relatively deep, sandy loam subsoil horizons, overlaying gravels at an average depth of 41cm; and finally, the extra large vines occur on loam topsoils with sandy loam subsoils and an average depth to gravel of at least 125cm.

Texture is an important soil characteristic which influences water infiltration rates, hydraulic conductivity, soil water holding capacity, water availability to the plant, soil aeration, soil nutrient content, and nutrient availability to the plant (Rice, 2002; White, 2003). Soil properties determining water and nutrient supply to vines have the most

significant impact on vine growth (Rankine et. al., 1971; Seguin, 1986; van Leeuwen et. al., 2004). When water or nutrients are not in limited supply, vines have the luxury of using their energy to increase shoot growth rather than root growth, however; when water or nutrients are in limited supply, vines are forced to put more energy into root growth rather than shoot growth, in an effort to increase root surface area to search for water and nutrients and to enhance their uptake (Rice, 2002; White, 2003; Lanyon et. al. 2004).

Mills (2006) found that soil texture influenced soil nutrient content. He found that in all soil profiles, the concentration of several elements, Olsen P (mg/L), CEC (me/100g), base saturation calcium, phosphorus, aluminium, anaerobically mineralised nitrogen, available nitrogen, organic matter, total carbon and total nitrogen, decreased with depth. Furthermore, the extra small vines growing on gravel based topsoil and subsoil have a lower pH, CEC (mg/100g) and base saturation compared to the extra large vines growing on loam topsoils with sandy loam subsoils and much lower (60-85%) mass balance nutrient concentrations, particularly Olsen P (mg/L), potassium (me/100g), Magnesium (me/100g) and available Nitrogen (kg/ha). Mass balance values give an indication of the concentration of nutrients available in a particular soil type (Mills, 2006). Figures are related to the grain size distribution of a particular soil (Mills, 2006).

Mills also found that soil texture influenced small root density. He found that the small root density decreases with depth regardless of soil type; but more interestingly, that the small root density of extra small vines growing on gravel based topsoil and subsoil was almost 70% more than the small root density of the extra large vines growing on loam

topsoils with sandy loam subsoils. This is most likely a response to the low nutrient and water availability in the gravel soils.

The main objective of this study was to investigate the influence of vine size and crop load on Sauvignon blanc vine growth and fruit composition in Marlborough. However, since Mills (2006) showed, in his companion study, that soil texture significantly influences vine size, it is likely that soil texture is the underlying factor affecting all parameters that are influenced by vine size. These results suggest that, in the Squire Vineyard, or any vineyard significantly influenced by alluvial soils, vine size is a good visual indicator of soil texture.

5.1 VINE SIZE AND CROP LOAD EFFECTS ON VINE VIGOUR AND CANOPY DENSITY

Variation in vine vigour within a vineyard block creates vineyard management challenges. Canopy management practices such as trimming, leaf plucking and wire lifting, as well as irrigation and nutrient management, all depend on vine vigour. Vasconcelos et. al. (2008) showed that vine vigour had an influence on irrigation demand, from veraison to harvest; as vine vigour increased, soil moisture decreased. They suggest that this may be a result of the higher leaf area leading to a higher evaporative demand and therefore a higher requirement for irrigation in a dry season.

Vine size is a measure of vine vigour, so it was not unexpected that vine size had an influence on the other vine vigour parameters measured in this study, including pruning weight, cane weight and shoot size. Vine size also had an effect on canopy density, measured as canopy gaps, leaf layer number and bunch shading. Since vine size was shown by Mills (2006) to be influenced by soil texture it can be concluded that soil texture is also the underlying factor influencing vine vigour and canopy density, and is most likely related to the influence of soil texture on mass nutrient concentration and water availability.

These conclusions are supported by Peyrot des Gachons *et al.* (2004), who showed that as soil gravel content increases and soil depth decreases, water deficit increases and vine vigour (measured as leaf area) decreases. Chone *et al.* (2001) and van Leeuwen *et al.* (2004) also found that the gravely soils lead to severe water stress in vines, while

Conradie and Saayman (1989) showed that increasing the levels of phosphorus, potassium and nitrogen in the soil significantly increased the shoot size of Chenin blanc vines.

Crop load also influenced vine vigour and canopy density, but to a lesser extent than vine size. As the crop load increased, vine vigour (measured as cane weight and shoot size) decreased, but canopy density (measured as leaf layer number, leaf shading and bunch shading) increased.

The relationship between crop load and vine vigour is supported by Reynolds *et al.* (1994), who showed that cane weights were reduced by almost half in vines pruned to 20 shoots per meter compared to 10 shoots per meter. Miller and Howell (1998) and Hardie and Martin (1989) all found that pruning weights were affected by pruning treatments and that pruning treatments that resulted in a higher crop load also had significantly lower pruning weights. Hardie and Martin (1989) suggest that the relationship is attributed to the competition of fruit with leaves for mineral salts, sugars and amino acids from veraison onwards.

The relationship between crop load and canopy density is supported by Reynolds *et al.* (1994) who showed that increasing node numbers per meter of row from 10 to 20 increased the leaf layer number and the number of shaded bunches and shaded leaves in Pinot Noir vines. In contrast, Miller and Howell (1998) showed that pruning treatments that increased crop load without changing shoot density, had a lower leaf area per shoot

than pruning treatments with lower crop loads. They attribute the higher leaf area per shoot in low crop load vines with an increase in lateral growth and an increase in leaf size.

The results of these studies by Reynolds *et al.* (1994) and Hardie and Martin (1989) suggest that:

1. When crop load is increased by increasing the number of shoots per meter of row, canopy density (measured as leaf and bunch shading) increases;
2. However, when crop load is increased without increasing the number of shoots per meter of row, canopy density (measured as leaf area per shoot) is decreased.

In this study, the treatments created two different crop loads by altering the number of shoots per meter of row. Therefore the increase in canopy density with increasing crop load is more likely a function of increased shoot density rather than a direct crop load effect. The decrease in vine vigour with increasing crop load is likely to be directly related to competition between the shoots for assimilates and between shoots and fruit.

Crop load adjustment may be a useful tool to manage vigour variation in highly variable blocks like the Squire vineyard. Pruning vines to their capacity would mean that the low vigour vines would be pruned to a lower node number than the high vigour vines. A higher crop load would help to reduce the vigour of the large vines while the lower crop load would allow the small vines to put more assimilates into growing shoots rather than fruit.

Vertically dividing a canopy is an effective way of increasing crop load without increasing shoot and canopy density; however a reduction in vine vigour is still observed (Reynolds et. al., 1994). Reynolds et. al. (1994), found that training vines to the Scott Henry system, compared to a standard vertically shoot positioned (VSP) system, increased yields without increasing shoot density or canopy density (measured as leaf layer number and leaf and bunch shading).

5.2 VINE SIZE AND CROP LOAD EFFECTS ON GRAPEVINE PHENOLOGY

Vine phenology is an important trigger for the timing of several key vineyard operations. These include frost control, fungicide applications, nutrient applications, leaf plucking, colour thinning and harvest. Variations in vine phenology within a vineyard block create significant challenges relating to these operations.

Phenological measurements from this study show that there is significant variability between vines in the Squire Vineyard, and that the differences reflect changes in vine size and therefore soil texture (extrapolation from Mills, 2006). As vine size increased, the onset of flowering, veraison and leaf senescence was delayed. Crop load also had an influence on vine phenological development, but to a lesser extent than vine size. As the crop load increased, the onset of flowering and veraison was delayed, while the onset of leaf senescence was unaffected.

Flowering date is dependent on node number (Pratt and Coombe, 1978), inflorescence size and number (Buttrosse and Hale, 1973), weather (May, 2004; Buttrose and Hale, 1973) and the timing of budburst (May, 2004).

In this study, flowering was delayed as vine size increased and the depth to gravels increased. This was not related to yield, since yield was not affected by vine size. Instead it is believed that this result is related to the effect of soil texture on soil temperature and the timing of bud burst. Budburst timing was not recorded in this study, however it is well understood that the timing of budburst is triggered when soil

temperatures increase above 10°C (Mullins et. al., 1992). Subsequent studies on the Squire vineyard (Trought *et al.*, 2008) showed that higher soil temperatures were recorded in the soil profiles where the gravels came to the surface. These results suggest that vines growing on stony soils would burst bud earlier than vines growing on colder silty soils. May (2004) describes how the number of days between budburst and flowering are relatively stable within cultivars and regions, which suggests that vines which burst bud early would also flower early.

The delay in flowering with increased crop load was most likely a result of the higher inflorescence number and the increased competition between inflorescence for assimilates, an interaction described by Buttrosse and Hale (1973).

Veraison date is dependent on flowering date (McCarthy, 2008) and leaf area to crop load ratio (Petrie et. al., 2000 and Ollat and Gaudillere, 1998). Matthews and Anderson (1989) showed that the timing of veraison was not influenced by vine water status.

In this study, veraison was delayed as vine size increased and the depth to gravels increased. This is most likely a direct result of the delayed flowering in these vines, a theory that is supported by the findings of McCarthy (2008), who reported that veraison date was more closely correlated to days from flowering than with temperature summations.

The influence of crop load on the timing of veraison is most likely a result of a change in the leaf area to crop load ratio, and its effect on competition for assimilates. This is supported by Petrie et. al. (2000) and Ollat and Gaudillere (1998) who showed that veraison can be delayed by reducing the leaf area to fruit weight ratio after flowering. On the 25th of April 2005 (six days after harvest), a severe frost caused premature leaf drop at the Squire vineyard. If it wasn't for this, the leaf area to crop load ratio could easily have been determined by measuring the leaf area of treatment vines around harvest.

The timing of leaf senescence is dependent on water and nutrient status (Mullins et. al., 1992), leaf age (Mullins et. al., 1992), weather (particularly frost) (personal experience, 2005) and leaf area to crop load ratios (Petrie et. al., 2000).

In this study, the onset of leaf senescence was delayed as vine size increased and the depth to gravels increased. This is most likely to be a result of variations in water and nutrient status with changes in soil texture. This is supported by Mullens et. al. (1992) who describes how water and nutrient stress can lead to leaf senescence. The earlier leaf senescence in the small vines on the stony soils may also be partly a result of the earlier flowering and veraison experienced in these vines.

Petrie et. al. (2000) showed that leaves senesced more rapidly when high leaf area to crop load ratios were maintained. The absence of an influence of crop load on leaf senescence suggests that the leaf area to crop load ratios between the two and four cane vines in the study were not different enough to affect leaf senescence.

To reduce variability in the timing of flowering and veraison within a vineyard, it is important to reduce variability in the timing of bud burst as well as crop load. Increasing the crop load of the larger vines by retaining more buds at pruning, will help to moderate vine vigour, but will exacerbate phenological differences between the silts and stones. Delaying pruning on the stony sites may help to delay bud burst. However, this is not an option with the distribution of variability at the Squire vineyard. Under vine mulch, compost or a low grow cover crop may help to reduce the soil temperature difference between the stony and silty sites, and inturn, reduce variability in the timing of bud burst.

5.3 VINE SIZE AND CROP LOAD EFFECTS ON VINE NUTRITION

Vine nutrient status has a significant effect on vine growth, vine yield, fruit composition and pest and disease resistance (May, 2004). Nitrogen and potassium are particularly important for vine growth, with increasing nitrogen and potassium levels leading to increased vine vigour (Conradie and Saayman, 1989). Boron, Zinc and Iron levels influence fruitset (May, 2004) and calcium is important for skin thickness and *Botrytis* resistance. Potassium has been shown to influence the acids and pH of berries. High potassium levels in juice have been associated with high malic acid concentrations, high pH and poor colour in red wines (Jackson and Lombard, 1993; Wood and Parish, 2003).

Mills (2006) found, in his companion study, that as the depth to gravels increased, the soil pH, CEC (mg/100g) and base saturation levels increased, as did the mass balance nutrient concentrations, particularly Olsen P (mg/L), potassium (me/100g), magnesium (me/100g) and available nitrogen (kg/ha).

Results of this study show that vine size, and therefore soil texture has an influence on petiole nutrient levels at flowering. As vine size increased, and the depth to gravel increased, calcium, magnesium and boron levels increased while phosphorus, potassium and manganese levels decreased.

The petiole nutrient levels at flowering reflect changes in soil nutrient levels, except for potassium, phosphorus and manganese. As the depth to gravels increased, Mills (2006) showed that soil potassium, phosphorus and manganese increased, but in this study

petiole potassium, phosphorus and manganese decreased. These results are unexpected and demonstrate the complex interactions between soils and plants. It shows that adequate nutrient levels in soils do not necessarily result in adequate petiole nutrient levels in petioles.

Soil texture is an important soil characteristic which influences water infiltration rates, hydraulic conductivity, soil water holding capacity, water availability to the plant, soil aeration, soil nutrient content, and nutrient availability to the plant (Rice, 2002; White, 2003). Other soil properties such as pH, cation exchange capacity, and competition between nutrients also influence the availability of nutrients to the plant (McLaren and Cameron, 1996). The uptake of potassium by vines is highly dependent on soil moisture content and interactions with calcium and magnesium (McLaren and Cameron, 1996). Potassium is a very mobile nutrient in the plant, moving from older leaves to younger growing points (McLaren and Cameron, 1996). Petioles are sampled from the older leaves found adjacent to the first bunch on a shoot. It is likely that the larger vines on silty soils have a higher demand for potassium due to a larger leaf area. This would result in low potassium levels in the older leaves due to translocation of potassium to the younger actively growing leaves. Phosphorus has a high tendency to become fixed in the soil, which reduces its availability to plants (McLaren and Cameron, 1996). Fixation is affected by soil properties such as pH, texture and microbial activity (McLaren and Cameron, 1996). The silty soils of the larger vines are higher in pH than the more stony soils. This shift in pH may be enough to effect phosphorus fixation and phosphorus availability to the plant. The uptake of manganese is also highly dependent on pH, with

availability decreasing as the pH increases above 6.5 (McLaren and Cameron, 1996). Again, the shift in pH between the stony and silty soils may be enough to affect manganese availability.

Crop load also had an influence on petiole magnesium levels at flowering, but to a lesser extent than vine size. Magnesium plays a major role in photosynthesis (McLaren and Cameron, 1996). It is likely that the lower Magnesium levels in the 4 cane pruned vines is a result of the higher leaf area and photosynthetic capacity of these vines. Crop load also had a significant effect on petiole zinc levels while vine size did not. Zinc is an essential element required for good fruitset, so the higher the crop load, the higher the zinc demand (McLaren and Cameron, 1996).

5.4 VINE SIZE AND CROP LOAD EFFECTS ON VINE YIELD

Grapevine yield is a result of a series of processes that take place over a period of about 17 months before the grapes are harvested (Smart and Robinson, 1991). The final yield is determined by a combination of parameters including: the number of shoots per vine, the number of bunches per shoot, the number of berries per bunch and the final berry weight.

Vine size had no effect on the final yield or any of the yield parameters (shoot number per vine, bunch number per shoot, bunch number per vine, berry number per bunch, berry weight and bunch weight). Vine size did influence budburst with an increase in vine size leading to an increase in the percentage of budburst.

Crop load had a significant influence on final vine yield and on some of the yield parameters (shoots number per vine, bunch number per shoot and bunch number per vine). Crop load had a significant influence on budburst (to a greater extent than vine size) but did not influence yield parameters such as berries per bunch, berry weight and bunch weight.

Vines have the ability to self regulate shoot and fruit growth to reflect their capacity; they have a fixed capacity and regulate this by adjusting the number of buds that burst at the start of the growing season (Coombe and Dry, 1992). Studies show that percent budburst depends largely on the number of nodes retained at pruning, the capacity of the vine and the weather conditions over winter and at budburst (Coombe and Dry, 1992; Mullins et. al., 1992).

In this study, the influence of vine size on budburst is most likely to be an indirect effect relating to the influence of soil texture on vine capacity, with decreased water and nutrient availability resulting in lower vine capacity.

$$\downarrow \text{vine size} \rightarrow \downarrow \text{vine capacity} \rightarrow \text{self regulation} \rightarrow \downarrow \text{bud burst}$$

The influence of cane number on budburst is likely to be directly related to the number of nodes retained at pruning.

$$\uparrow \text{cane number} \rightarrow \uparrow \text{nodes} \rightarrow \text{self regulation} \rightarrow \downarrow \text{bud burst}$$

It is interesting to note here that the 50 percent difference in nodes retained at pruning between the low and high crop load treatments was reduced to a 36 percent difference in shoot number after budburst. This reflects the ability of vines to self regulate shoot growth by adjusting budburst; the low crop load treatment had a 27 percent higher budburst than the high crop load treatment.

The number of bunches per shoot is controlled by bunch initiation. Various studies show that sunlight onto buds in the fruit zone increases the number and size of inflorescence primordia (May, 2004 and Mullins *et al.*, 1992), while water stress reduces the number and size of the inflorescence primordia (Mullins *et al.*, 1992). Budburst can also have a significant effect on the average bunch number per shoot. It is well understood that primary shoots are more fruitful than secondary shoots which, in turn, are more fruitful

than tertiary shoots (Mullins *et al.*, 1992). As budburst increases above 100 percent, the number of secondary and tertiary buds to burst increases. Although this acts to increase the overall bunch number per vine, the average bunch number per shoot is actually reduced. The crop load effect on bunch number per shoot is likely to be a reflection of the crop load effect on budburst.

↑ crop load → ↓ % bud burst → ↓ secondary + tertiary buds → ↑ average bunches/shoot

The fact that both berry numbers per bunch and berry weight are not influenced by vine size or crop load is unexpected and contradicts the findings of others. Edson *et al.* (1995) and Miller and Howell (1998) found that fruit set was reduced when high bunch numbers per vine were present while Reynolds *et al.* (1994) found that increasing crop levels reduced berry weights. Interestingly, Miller and Howell (1998) showed that increasing the crop loads from 4kg/vine to 16kg/vine significantly decreased berry weights while smaller increases from 4kg/vine to 13kg/vine had no significant effect on berry weight. This information suggests that small increases in crop load do not affect berry weight while larger increases are more likely to have an effect.

5.5 VINE SIZE AND CROP LOAD EFFECTS ON FRUIT COMPOSITION

Fruit composition (particularly °Brix, pH and titratable acidity) is a key factor that guides harvest date and influences wine quality (Coombe, 1992; Marais *et al.*, 2001).

In this study, vine size influenced fruit composition (°Brix, pH and titratable acidity) at harvest by influencing the start date of berry ripening (veraison). Veraison marks the onset of berry ripening, where sugars start to accumulate and acidity declines (Coombe, 1959). Vine size did not affect the average daily accumulation rate of soluble solids and had no influence on the concentration of methoxypyrazines (ibMP and ipMP) in the fruit at harvest. The influence of vine size on the start date of veraison was most likely a follow on effect from the influence of soil texture on the timing of budburst and flowering. As explained earlier, the number of days between budburst and flowering and flowering and veraison is relatively stable (McCarthy, 2008).

The lack of vine size influence on accumulation rate of soluble solids is unexpected. Vine size influenced canopy density (measured as canopy gaps, bunch shading and leaf layer number), and increases in canopy density are known to decrease light intensity, which in turn, decrease photosynthesis, metabolic activity and the accumulation of sugars in the berry (Jackson and Lombard, 1993). Another interesting result from this study is that vine size significantly influenced leaf chlorophyll content (measured as SPAD units), with significant differences measured between treatments as early as veraison (Figures 5 and 6). Reductions in leaf chlorophyll content have been found to decrease leaf photosynthetic rate which in turn, reduces carbohydrate production (Petrie *et al.*, 2000

and Mullins *et al.*, 1992). However, Kliewer and Antcliffe (1970) showed that grape berries can ripen even after leaf removal due to their high sink strength. They suggest that the accumulating sugars can be derived from mobilisation of reserves from roots and stems. If this is the case in the Squire vineyard, the consequence would be a reduction in carbohydrate storage post harvest leading to further reductions in vine size and vine capacity.

The lack of vine size influence on methoxypyrazine levels in the juice at harvest was also unexpected. It was hypothesised that an increase in canopy density with increasing depth to gravel would result in an increase in methoxypyrazine concentration. Although there is a lack of study into the effect of soil characteristics on methoxypyrazines, the effect of canopy microclimate on methoxypyrazines is well researched (Hunter et al, 2004; Sala *et al.*, 2004; Marais *et al.*, 1999; Hashizume and Samuta, 1999). It is well understood that methoxypyrazine levels decrease with increasing soluble solid levels however; contradictions on the effect of microclimate on methoxypyrazines are evident (Hunter et al, 2004; Sala *et al.*, 2004; Marais *et al.*, 1999; Hashizume and Samuta, 1999). Marais et al, (1999) showed that increasing canopy density, decreased solar radiation, and increased 2-methoxy-3-isobutylpyrazine (ibMP) concentration at harvest, while Hunter *et al.* (2004) showed that leaf plucking pre-veraison increased light intensity, and increased ibMP concentration at harvest. Sala *et al.* (2004) found that there was no significant difference between the ibMP levels in exposed fruit, and fruit artificially shaded with sackcloth, while Hashizume and Samuta (1999) found that exposure to artificial light pre-veraison increased ibMP levels in fruit but exposure to artificial light post-veraison actually

decreased ibMP levels in fruit. The conclusion that each of these researchers make is that methoxypyrazine concentration at harvest is a balance between the biological formation pre-veraison and the photo-degradation post-veraison, and that increased light intensity increases the rate of both processes. This suggests that increases in canopy density decrease methoxypyrazine formation pre-veraison, and reduce methoxypyrazine degradation post-veraison. Hunter *et al.* (2004) go one step further in their theory and suggest that increases in methoxypyrazine levels in the berry pre-veraison found with increased light exposure is a result of an increases in photosynthetic activity and leaf nitrate reductase enzyme activity in the leaf.

Crop load influenced the start date of berry ripening (to less of an extent than vine size), the average daily accumulation rate of soluble solids, and the final soluble solids and pH levels at harvest. Increases in crop load resulted in a delay in the onset of ripening; a decrease in the average daily accumulation rate of soluble solids; and a decrease in the final soluble solids and pH levels at harvest. These results were expected and support the findings of others. Crop load did not influence the final titratable acidity or methoxypyrazine (ibMP and ipMP) concentration of the fruit at harvest. These results were not expected particularly due to the fact that cane number had an effect on canopy density, and that it has been shown that increasing canopy density, decreases solar radiation, and increases 2-methoxy-3-isobutylpyrazine (ibMP) concentration at harvest (Marais et al, 1999).

To understand the impact of vine size (and soil texture) on methoxypyrazines concentration in the fruit at harvest, it would be beneficial to measure their changes in concentration from fruit set until harvest. This would give an understanding of the effect of vine size (and soil texture) on methoxypyrazines synthesis pre-veraison and degradation post-veraison.

The impact of vine size on methoxypyrazines synthesis and degradation is likely to be related to the effect of soil texture on plant water relations, photosynthetic and metabolic activity and bunch light interception. Measurements such as canopy temperature, berry light interception, plant water stress, and leaf photosynthetic rate would give a better understanding of these potential indirect effects.

CHAPTER 6

CONCLUSION

The majority of Marlborough's Sauvignon blanc plantings are on the Wairau Plain where alluvial soils were deposited by the Wairau River. The braided nature of the river and frequent flood events has created significant vertical and horizontal soil texture variation. Changes in soil texture create differences in soil physical properties, for example, as the depth to gravels decreases, the soils water holding capacity and nutrient content decreases, and the ability of a soil to retain heat increases.

In the Squire Vineyard, changes in soil texture reflect changes in vine size, measured as truck circumference. As the depth to gravel increased, trunk circumference increased. This relationship suggests that vine size is a visual indicator of soil texture.

Increases in vine size across the Squire vineyard increased vine vigour and canopy density, and also delayed vine phonological development and fruit ripening to result in a lower Brix and higher titratable acidity at harvest. Interestingly vine size had no effect on yield in this study.

It is suggested that changes in the parameters above are actually a result of soil texture changes, and more importantly, changes in the soils physical properties, rather than purely a result of vine size. It is most likely that the increased availability of water and nutrients in deeper soils, has lead to an increase in vine vigour and canopy density, while the decreased ability of these soils to warm up early season, has resulted in delayed

phenological development from budburst all the way through to fruit ripening and leaf senescence.

Increasing crop load by increasing the number of canes retained in a vertical shoot positioned system, from two canes to four, increased the yield but also increased the shoot density. The higher crop load resulted in a decrease in vine vigour and an increase in canopy density. It also resulted in a delay in the onset of flowering, veraison and ripening. As well as a decrease in the average daily accumulation rate of soluble solids and lower final soluble solids and pH levels at harvest.

The decrease in vine vigour along with the delay in phenological development, in higher cropping vines, was most likely a result of increased competition between shoots, flowers and bunches for assimilates. While the increased canopy density in higher cropping vines, was most likely a direct result of the increased shoot density. The decreased accumulation rate of soluble solids and the lower final soluble solids and pH levels at harvest, in higher cropping vines, was most likely due to a combined effect of increased canopy density and therefore decreased in sunlight exposure, and competition for assimilates.

In the Squire vineyard, vine size had a greater effect on vine vigour, canopy density and phenological development than crop load. While neither vine size nor crop load had an effect on methoxypyrazine (ibMP and ipMP) concentrations in the fruit at harvest.

Variation in vine growth and fruit composition within a single vineyard creates challenges with vineyard management; particularly with canopy management, irrigation, nutrition, and harvest decisions.

Variation in ripeness levels within a vineyard, create challenges with harvest decisions, especially in situation when Brix and titratable acid levels are used as key indicators of quality.

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