A study of the interaction between vine vigour, crop level and harvest dates and their effects on grape and wine characteristics

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

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Name of candidate **Date**

SUMMARY

A common phenomenon in most South African vineyards, especially in the Western Cape region, is that of within vineyard variation. This variation phenomenon is caused by an array of controllable and non-controllable factors that interact with each other to affect vine vigour. Controllable factors can be managed by the grape grower, while the non-controllable factors have to be managed in the planning process in order not to negatively affect productivity or product quality.

The main goal of any grape grower is to optimise vine performance in an attempt to achieve the best possible yield while at the same time allowing vines to optimally ripen grapes towards optimal wine quality. A grape grower has to use every possible means and technique available to him in order to manage his vineyards in such a manner as to achieve this goal. In the past, it was difficult to visualize the extent and distribution of vigour variation in vineyards, but with modern technological improvements in the field of remote sensing, grape growers are able to identify and specify different vigour levels within a vineyard.

When remote sensing is applied in a vineyard, the grape grower can identify certain areas that may need more specific attention than others. Consequently, managerial decisions based on detailed information can be made in an attempt to improve the general condition and performance of a vine. Not only can the acquired information be used to plan managerial actions throughout the season, but it can also be used to plan and devise harvest strategies. Some areas in a vineyard may be at a certain point in the ripening process and need to be harvested, while grapes from other areas still need to develop the wanted flavours. One managerial action applied at véraison by some grape growers, is that of crop thinning. Different vigour areas can now be subjected to various crop thinning actions in an attempt to determine the best crop load for a vigour level.

With this in mind, two studies were launched to firstly investigate the interaction between vine vigour and harvest dates; and secondly to investigate the interaction between vine vigour and crop load and how their combined interaction might influence a vine's characteristics, grape composition and wine quality. Vigour variation was firstly identified through multispectral aerial imagery, and then visually verified by visits to the experimental vineyards. The multispectral aerial image was then "orthorectified" in order to produce a classified multispectral image. The image was classified through different colour codes that were assigned to the different vigour levels to clearly distinguish between them. A series of vegetative and reproductive measurements were conducted to try and establish if any correlations could be obtained of the interaction between vine vigour, different harvest dates and crop loads. In order to verify differences in vine vigour, underlying causes were also determined through soil analyses of which chemical analysis, bulk density, porosity, as well as root penetration and distribution were determined. Vegetative measurements that were conducted for both studies indicated good correlations between the different vigour levels and the image classifications. The results also identified the effect that topping (mechanical or manual)

had on the main and lateral leaf areas. Reproductive measurements throughout the season, in the form of berry sampling, showed changes in berry composition and accentuated the effects of the different treatments, which could also be confirmed through sensorial analysis of the wines. The results also emphasized the need to not only make use of one of two chemical parameters to identify grape ripeness, but to incorporate a number of parameters, such as sugar, pH and acid levels. From the varying grape chemical characteristics, a wine style can be identified that might carry the approval of the winemaker for the production of a specific type of wine. Soil studies of both vineyards also gave important evidence for the causes of vigour variation.

The data collected will hopefully provide grape growers with information that will enable them to make educated decisions concerning grape production and how vigour, in conjunction with different harvest dates and crop loads, will enable them to produce fruit of good quality and, so doing, improve their financial position.

OPSOMMING

’n Algemene verskynsel in meeste Suid Afrikaanse wingerde, veral in die Wes Kaapland, is variasie binne ‘n spesifieke wingerdblok. Die variasie verskynsel word veroorsaak deur ’n verskeidenheid van beheerbare en nie-beheerbare faktore. ‘n Interaksie vind plaas tussen die faktore wat sodoende die groeikrag van die wingerd kan affekteer. Beheerbare faktore kan deur die wingerdverbouer beheer word, terwyl die nie-beheerbare faktore in ag geneem moet word in beplanningsprossesse, sodat dit nie produktiwiteit en kwaliteit negatief beïnvloed nie.

Die hoofdoel van enige wingerdverbouer is om wingerdprestasie te optimiseer in ’n poging om die beste oes te produseer, terwyl die wingerdstokke toegelaat word om druiwe optimaal ryp te maak en in die proses die beste wynkwalteit te verkry. ’n Wingerd moet dus alle moontilke metodes en tegnieke tot sy beskikking, gebruik om sy wingerde te bestuur, sodat die bogenoemde doelwit bereik kan word. In die verlede was dit moeilik om die omvang en verspreiding van wingerdvariasie te visualiseer, maar met moderne tegnologiese vordering op die gebied van afstandswaarneming, is dit vir wingerdverbouers moontlik om wingerdvariasie binne ‘n spesifieke wingerdblok te identifisser en te spesifiseer.

As afstandswaarneming toegepas word, is die wingerdverbouer in staat om areas in ’n blok te identifiseer wat meer aandag as ander mag benodig. Hy kan dus bestuursbesluite neem gegrond op gedetaileerde inligting. ‘n Wingerdstok se algemene toestand en prestasie kan met behulp van die inligting verbeter word. Nie net kan die verkrygde inligting gebruik word om sekere bestuurspraktyke uit te voer nie, maar dit kan ook gebruik word om oesstrategieë te beplan. Sekere areas mag gereed wees om geoes te word, terwyl ander areas nog vir ’n langer tydperk moet hang om die gewensde geure en aromas te ontwikkel.

Nog ’n bestuursaksie wat uitgevoer word tydens deurslaan, is die van oes-vermindering. Verskillende groeikragareas kan blootgesel word aan ’n verskeidenheid van druifverminderingsaksies in ’n poging om vas te stel watter een die beste in ‘n gegewe situasie sal werk.

Met die bogenoemde in gedagte, is twee projekte van stapel gestuur om eerstens die interaksie tussen groeikrag en oesdatums te bepaal en tweedens om die interaksie tussen groeikrag en oesladings te bepaal, en voorts om vas te stel hoe hulle interaksies die wingerd se eienskappe, druifsamestelling en wyngehalte kan beïnvloed. Groeikrag-variasie was eers geïdentifiseer met behulp van ’n multispektrale lugfoto vanwaar die groeikragverskille visueel bevestig is. Die multispektrale lugfoto is toe met behulp van ‘n “orthoviewer” sagtewareprogram omskep in ’n geklassifiseerde multi-spektrale beeld. Die beeld is geklassifiseer deur gebruik te maak van ’n verskeidenheid kleure wat aan die verskillende groeikragte toegeken is. ’n Reeks vegetatiewe en reproduktiewe metings is uitgevoer om te probeer vasstel of enige korrelasies verkry kon word tussen die interaksie van groeikrag met verskillende oesdatums en verskillende oesladings. Om die oorsaak van die groeikragvariasie vas te stel, is grondontledings gedoen om die

chemiese samestelling, bulkdigtheid, porositeit, asook wortelpenetrasie en -verspreiding vas te stel. Vegetatiewe metings vir beide die studies het goeie korrelasies tussen die verskillende groeikragareas met die beeldklassifikasie getoon.

Die resultate het ook die effek wat top (meganies of met die hand) op die hoof- en syblaaroppervlakte gehad het, aangetoon. Reproduktiewe metings is deur die seisoen uitgevoer in die vorm van druifmonsterneming om aan te dui hoe die chemiese samestelling van die druiwe verander met die verloop van tyd; en het ook die effek van die verskillende behandelings beklemtoon. Laasgenoemde is ook uitgewys deur die sensories ontledings van die wyne. Die resultate het ook aangedui hoe belangrik dit is om nie slegs van een chemiese parameter gebruik te maak om druifrypheid te identifiseer nie, maar om ‘n hele aantal te inkorporeer, soos suiker, pH en suurvlakke. Van die verskillende chemiese druifsamestellings, kan ‘n spesifieke wynstyl verbou word wat aanvaarbaar sal wees vir die wynmaker. Grondstudies van beide wingerde het belangrike resultate opgelewer betreffende die oorsaak van groeikragvariasie.

Die data wat versamel is, sal hopelik druifprodusente van inligting voorsien wat hulle in staat sal stel om doelgerigte besluite te kan neem betreffend druifproduksie en hoe informasie rakende groeikrag, in samewerking met verskillende oesdatums en oesladings, hulle in staat sal stel om vrugte van goeie gehalte te produseer en sodoende die plaas se finansiële posisie te versterk.

This thesis is dedicated to my parents Cecil and Pieterina, and to my sisters Joy, Wendy and Tracy who supported and motivated me throughout my academic career.

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BIOGRAPHICAL SKETCH

Pieter C. Quixley was born in Bellville on 28 August 1982. He grew up on a vineyard farm in the Franschhoek valley and matriculated at Paarl Boys High in 2000. Pieter enrolled at Elsenburg Agricultural College in 2001 and obtained the Higher Certificate in Agriculture in December 2002. In 2003 he enrolled at the University of Stellenbosch and obtained the degree BAgricAdmin (Business Specific Farm Management - Viticulture) in 2004. He enrolled for the degree MAgricAdmin (Viticulture) in 2005, also at the University of Stellenbosch.

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PREFACE

This thesis is presented as a compilation of five chapters. Each chapter is introduced separately and is written according to the style of the *South African Journal of Enology and Viticulture*.

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Chapter 1

INTRODUCTION AND PROJECT AIMS

INTRODUCTION AND PROJECT AIMS

1.1 INTRODUCTION

South African grape growers are faced with the challenge of managing their vineyards in such a manner as to optimise vine performance in order to achieve better yields, while at the same time allowing vines to optimally ripen grapes in an attempt to optimise wine quality. Grape growers are thus faced with the ultimate challenge of constantly having to produce a quantity of quality fruit that is sufficient to cover all their production expenses and return a profit to the farm (Howell, 2001).

The optimisation of vine performance, while at the same time maintaining or even improving wine quality, is influenced by an array of complex factors, such as: i) geology and topography; ii) climate; iii) grape genotype/rootstock combination; iv) plant physiology and v) managerial decisions. Some of these factors can be directly manipulated by the grape grower, while other factors force the grape grower to manage around it.

Geological and environmental changes in the past have given rise to various soil types found in a relatively small area. The Western Cape is one such region (Saayman, 2003). Different soil types possess different characteristics. Some might be deep and rich in organic matter, while others are shallow and poor in organic content. Each soil type has its own unique characteristics and it is these characteristics that influence the vine’s structure and performance. A vine’s structure does not just consist of an aboveground structure, but also includes the subterranean growth, namely the roots.

The roots are the first part of a vine to be influenced by variation in the soil. A balanced vine can have a 2.5:1 ratio between aboveground and subterranean (root) growth (Archer & Hunter, 2004); which means an improvement in root growth can lead to a 2.5 times improvement in the aboveground growth. This ratio depends on factors such as soil fertility, texture and light factors. Vines that have more roots per allocated soil space will have a bigger shoot growth capacity than those with fewer roots (see Table 1.1) (Archer & Hunter, 2004). The vigour level of a vine with a few shoots might be higher than that of a vine with multiple shoots, but the capacity of a vine with more shoots will be higher than that of a vine with a few shoots (Figure 1.1) (Archer, 1985).

Table 1.1: Influence of the number of roots on the shoot mass for various rootstocks (Archer & Hunter, 2004).

Rootstock	Number of roots per m² profile wall.	Average shoot mass (t/ha).
Ramsey	595	4.22
99 Richter	402	3.06
101-4 Mgt	343	2.95
143-B Mgt	340	2.41
Jacquez	293	1.96
3306 Couderc	266	1.84
Teleki 5BB	136	1.24

Vines are mostly trained and pruned the same, irrespective of vigour levels. A vine with low vigour and a vine with high vigour will thus have the same number of bearers per cordon metre. Figure 1.1 indicates that vines with high vigour will have less shoots. This in affect cannot be true. If a vine possesses high vigour, it will be due to a well-developed root system that is able to sustain shoot growth. A vine experiencing a higher level of vigour will have the same number of shoots as a low-vigour vine, but it will have longer shoots, more leaves, larger leaves and a subsequently higher capacity to optimally ripen a bigger crop (Winkler *et al*., 1962; Archer, 1985). A stronger shoot has a higher capacity than a weaker shoot and it is obvious that initial high vigour is needed for the formation of a high capacity (Archer, 1985).

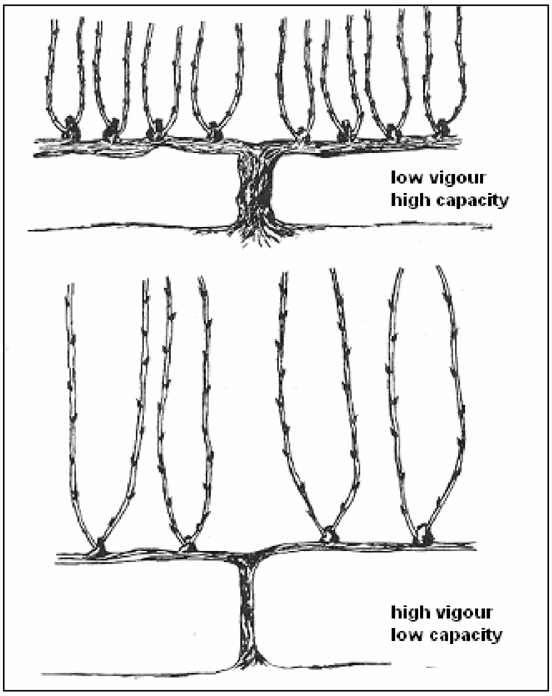

Figure 1.1: Vigour and capacity of a vine (Archer, 1985).

The influence that soil variation has on the roots will clearly be reflected in the aboveground structure, through shoot, foliage and fruit characteristics.

Soils with high levels of nutrients and moisture and high temperatures will cause a vine to become more vigorous. An increase in vigour will have a definite influence on the microclimate of a vine's canopy (Jackson & Lombard, 1993). A question often asked is how the optimum balances between vegetative growth (vigour) and reproductive performance (yield and fruit composition) can be achieved, while also making the right decisions with regard to the ripeness level at which grapes are harvested.

The optimum maturity level, according to Bisson (2001), will vary depending upon the specific style of wine being produced. There are various methods and parameters that grape growers and winemakers apply to try and determine optimum ripeness and, in the process, to decide at which point the grapes must be harvested. Sugar level, sugar to acid ratio, total acids, sugar x pH, sugar x pH^2, fruit colour and even cluster stems (Bisson, 2001; Van Schalkwyk & Archer, 2000) are a few methods applied by grape growers and winemakers in their search for optimum ripeness. Another method to determine grape ripeness is simply by tasting the grapes (Long, 1997). By tasting grapes throughout the season, the grape grower or winemaker can follow the progression of grape characteristics, and the grapes can then be harvested when the flavour and aroma components are adequately developed to produce good quality wine. On the basis of the many definitions of quality and optimum maturity levels and decisions on when to harvest, various authors state that to obtain certain aroma and flavour characteristics in the wine they must first exist in the grapes (Bisson, 2001; Hellman, 2004 and Watson, 2003).

Studying differences in vine vigour and its influence on fruit yield and optimal ripeness are of paramount importance. It is important to focus on a single-vineyard and even single-vine level to determine the optimal vine vigour x yield x harvest date combination. Single-vineyard or single-vine information can be gathered with the aid of high resolution multispectral remote sensing technology. This type of technology enables the grape grower to identify the vine's reaction to natural variability from season to season, while also identifying the vine's reaction to manipulations regarding the yield x vigour x ripeness balance induced via managerial inputs such as pruning and canopy management.

1.2 PROJECT AIMS

Various authors have investigated the effect that vigour might have on grape composition, the effect different crop loads might have on grape character and the effect that different harvest dates may have on grape chemical properties for the purpose of producing good quality wine (Archer, 2001; Chapman *et al.*, 2004). The fact remains, however, that limited literature is available concerning the interaction between vine vigour and different crop loads, as well as the interaction between vine vigour and different harvest dates and their combined influence on grape composition and wine quality.

Another aspect of modern-day grape production is the use of remote sensing techniques that is still an unknown field for many grape growers. Remote sensing can be applied in vineyards to identify various levels of vigour variation. Once the variation has been identified and visually verified, specific managerial decisions can be made on how to manage the different areas. The questions surrounding vine vigour and its interaction with different harvest dates and different crop loads and how this will relate to remote sensing is what prompted this investigation.

<u>Project 1</u> – A study of the interaction between vine vigour and crop level and their effect on grape and wine characteristics

- <u>Main aim:</u> Evaluating the effects that manipulation of vine crop load will have on the reproductive and vegetative balance of the vines from different vigour levels within a vineyard, and assessing the effects on grape composition.
- <u>Secondary aim:</u> Determining underlying causes of the vigour variability through soil analyses.

Project 2 – A study of the interaction between vine vigour and harvest dates and their effect on grape and wine characteristics.

- Main aim: Evaluating different combinations of grape maturity and vigour levels within a vineyard in order to quantify possible interactions between these two factors.
- Secondary aim: Determining the underlying causes of the vigour variability through soil analyses.

The data collected will hopefully provide grape growers with information that will enable them to make educated decisions concerning grape production and how vigour, in conjunction with different harvest dates and crop loads, will enable them to produce fruit of good quality and, so doing, better their financial position.

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Chapter 2

LITERATURE REVIEW

Causes of within-vineyard variation and its effects on the vine

LITERATURE REVIEW

2.1 INTRODUCTION

The potential of vineyard canopies to intercept sunlight depends on the interaction between solar radiation (sunlight) fluxes, solar position and canopy shape, size and orientation (Smart, 1988). A vine's canopy can be defined as the leaf and shoot system of that vine (Shaulis & Smart, 1974, in Smart *et al.*, 1990), described by dimensions in the boundaries of space (width, length, height, etc.) and by the amount of the system within this specified volume (leaf area). Winkler *et al*. (1962) state: "Vigour is the quality or condition that is expressed in rapid growth of the parts of the vine." Vineyard vigour depends on factors favouring vegetative growth, such as the type and depth of the soil, climate, moisture availability and sunlight exposure. Vigour can thus be seen as the state of health a vine is in.

If a vine is stressed, it will possess weak or low vigour, whereas vines experiencing favourable conditions for growth will have moderate to high vigour. The influential factors mentioned above will in some instances not be the same for every vine in a block. Different circumstances in a block will lead to variation between vines. Due to this variation, grapes will be produced that differ in composition, leading to the production of wines varying in characteristics.

Inter-vine variation is a common occurrence in vineyards the world over. This variation can have beneficial or detrimental effects on the composition of the grapes. Vigour variation is caused by a combination of different factors (Gladstone, 1992) that interact with each other to form a unique environmental system that influences the vine. These factors include: i) geology and topography; ii) climate; iii) plant physiology; iv) grape genotype/rootstock combination and v) managerial inputs (see Figure 2.1).

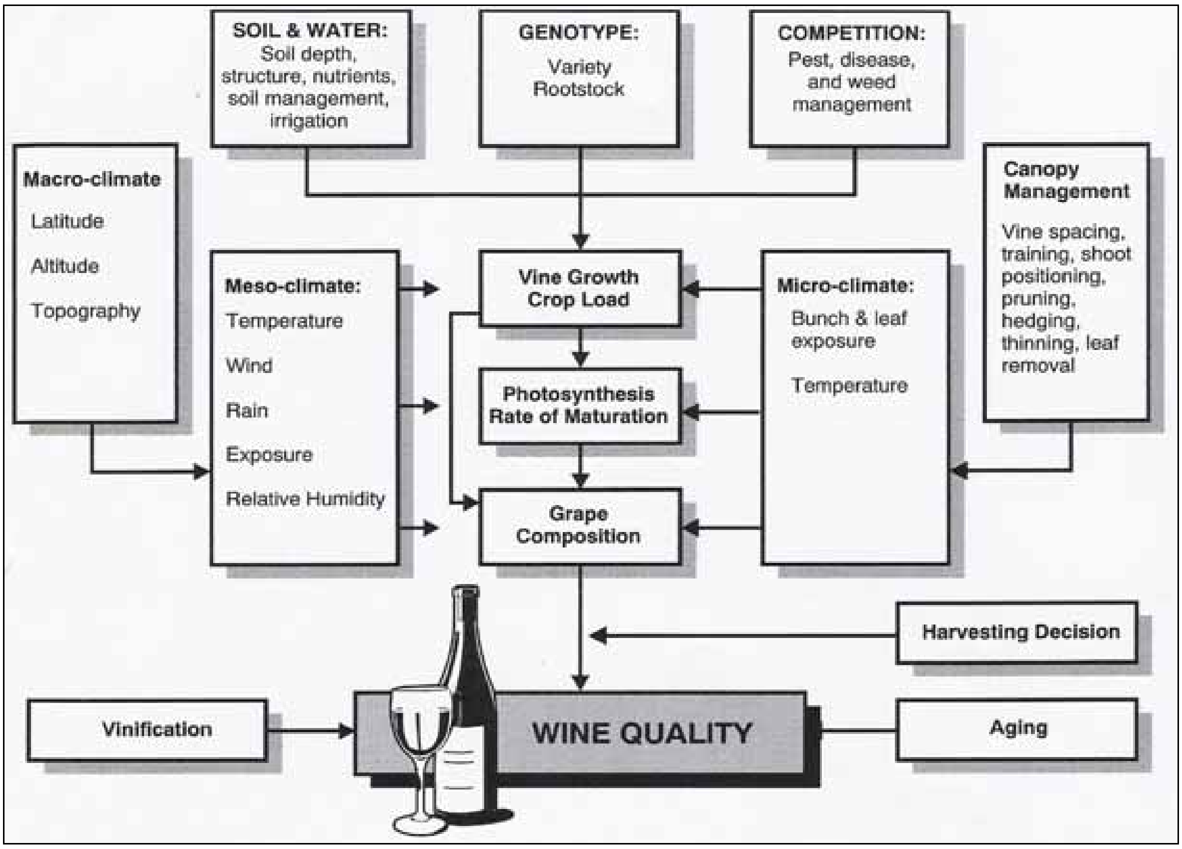

Figure 2.1: Soil, environmental, viticultural and managerial inputs affecting grape composition and wine quality (Jackson & Lombard, 1993).

Vigour variation within a vineyard block is not a strange phenomenon to grape growers (Bramley & Hamilton, 2004). It is generally accepted as part of the normal characteristics of a block and is therefore managed on the assumption that it is a homogenous unit. Blocks are managed in this way due to a lack of knowledge of existing technology that can be used to introduce different tools and methods to identify, measure and manage the variation.

In order to manage variation, it needs to be identified and quantified. Cook & Bramley (1998) compiled a model to simplify the agricultural management system (Figure 2.2). The model depicts agriculture as being a system comprising various inputs and outputs. Some inputs are controllable while others are not. The system as a whole is subjected to “noise”, which is a non-controllable entity and not well defined. The aim of this model was to give farmers a better understanding of the relationships that exist between inputs and outputs, and in doing so to try to maximise beneficial inputs and thereby to try to minimise harmful outputs.

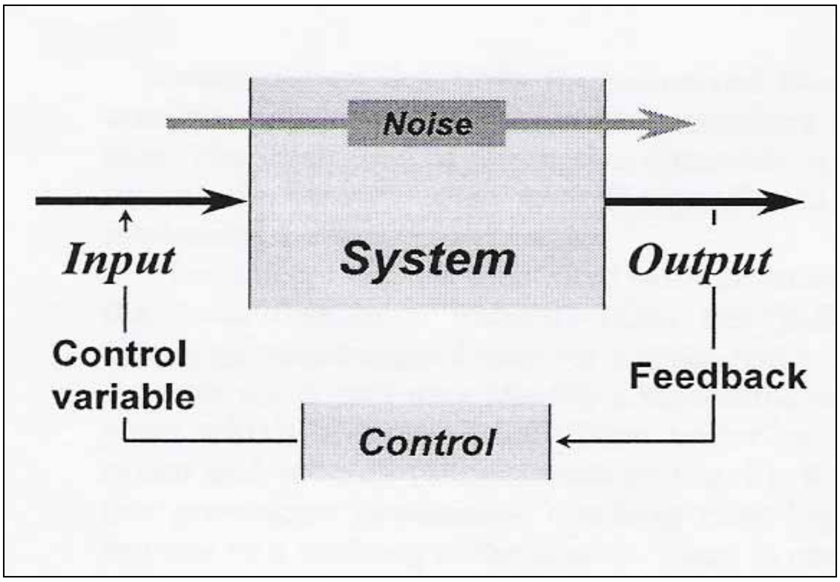

Figure 2.2: Agriculture as a simple controllable system (Cook & Bramley, 1998).

In the past, variability was seen as "noise". Only later on did researchers realise that by addressing the variability and not just accepting it, farmers could increase not only their production, but also the quality of the product. Different agricultural systems could be managed as separate units and not just as one single enterprise. By performing "unit-management" rather than management in the whole, precision agriculture technologies enable farmers to retrieve site-specific information from which the most appropriate course of action can be determined.

The term "Precision Agriculture" has been allocated to new management methods that strive to identify within-field (for example wheat fields) or within-vineyard variation, and to manage such variation in order to achieve a more homogenous unit. Robertson (2000) defines precision agriculture as "a comprehensive system designed to optimize agricultural production, through the application of crop information, advanced technology and managerial practices". Precision agriculture must thus be viewed in the sense that it provides a set of tools to improve the management of vineyards, and that it cannot replace good managerial inputs (Bramley, 2000).

Precision agriculture and precision viticulture are exactly the same in principle (Cook & Bramley, 1998), because the crop/vine is treated as a spatially variable entity. The only difference between the two is that precision viticulture is a more complex system; the reason being that whatever managerial inputs are applied to a vine will influence the composition and character of the berries, which in turn will have an influence on the composition and quality of the wine made from it. When precision management is applied to vines, not only is the aim to increase yield, but also to increase the quality of the grapes.

Due to the complexity of managing vines with precision, the model described by Cook & Bramley (1998) was adjusted (Figure 2.3) according to the different types of variation experienced in a vineyard block. With the aid of the new design, grape growers are able to form a better understanding of the different factors, controllable or non-controllable, that have an influence on their efforts to produce substantial yields and at the same time maintain quality.

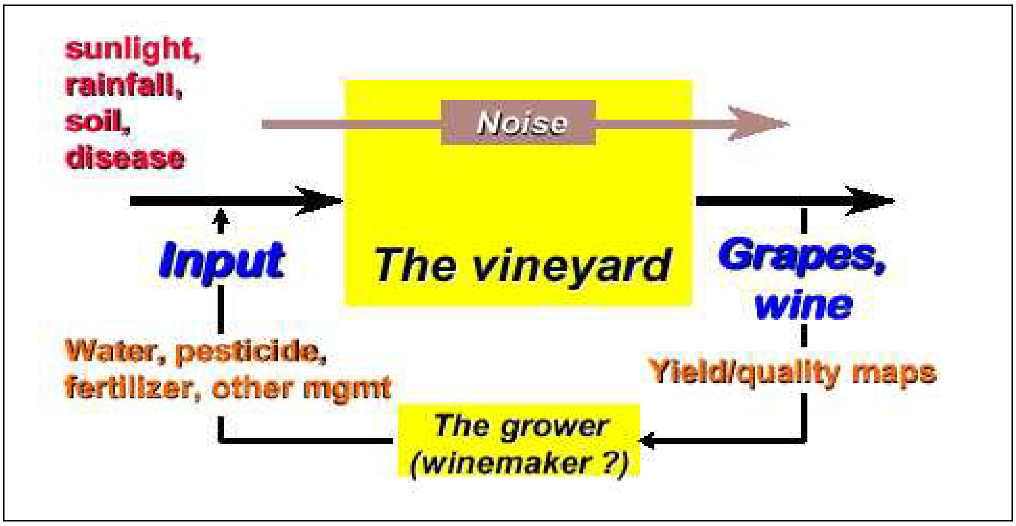

Figure 2.3: Viticulture predicted as an input-output system of controllable and non-controllable factors (Bramley, 2001).

Precision viticulture is thus a complex, interacting system that relies on information, reliable technology and management to optimise agricultural production, quality and profitability. If one aspect of precision viticulture is neglected, the complex production system will unravel and fail. An example that illustrates this aspect is that of a planting hole. It might seem insignificant, but if it is made when the soil moisture content is too high or too low, smeared or hardened walls will be formed that will act as barriers and prohibit the vine's roots from penetrating and spreading to the surrounding soil. The vine's roots will thus grow as if "pot bound" and will be unable to support the aboveground structure. A plant hole must be made with a fork rather than a spade. The ground will be much more porous if a fork is used. As mentioned earlier, a spade will cause smeared areas, resulting in impenetrable barriers. Figures 2.4a and b show two vines that were planted at the same time. The vine on the left was planted by making use of a spade, while the vine on the right was planted with a fork. The difference between to two vines is clear.

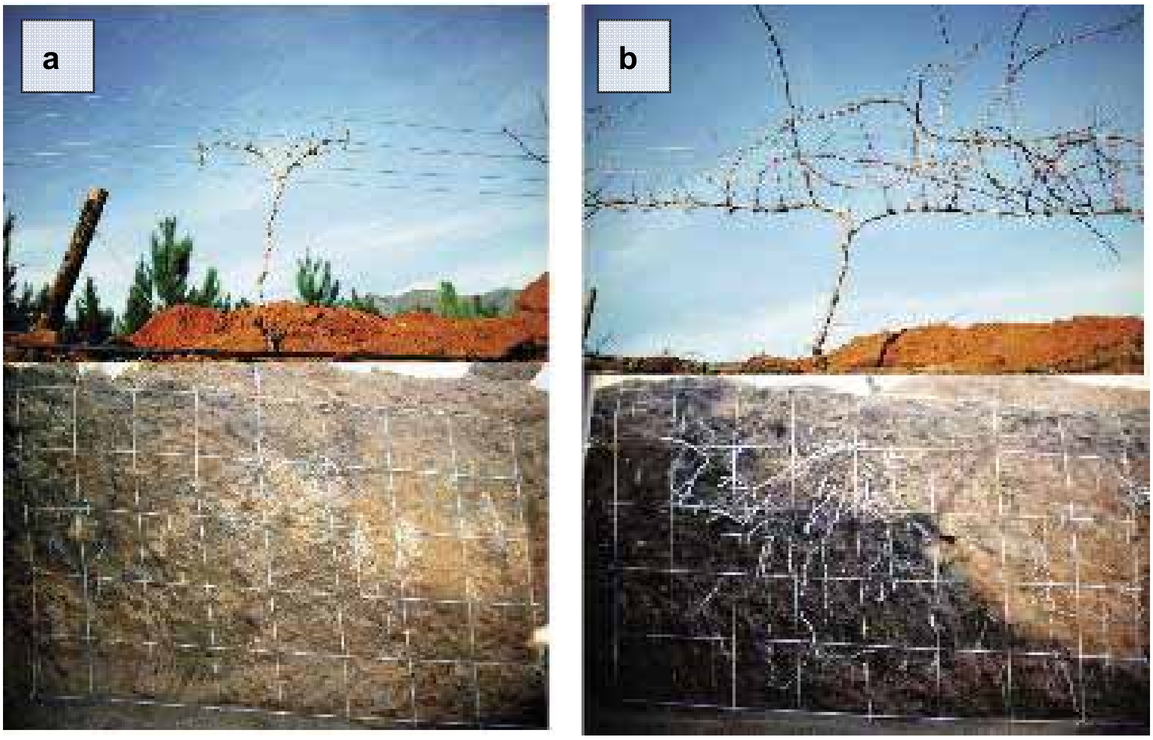

Figure 2.4a and b: Different root penetration patterns due to different establishing methods (Archer & Hunter, 2004).

The availability of new technology, such as geographical information systems (GIS), remote sensing (RS) and global positioning systems (GPS), makes it easier for grape growers to identify and target specific areas in a block (Smith 1998; Cook & Bramley, 2000). These specific areas can then be subdivided into management zones (Robertson, 2000) and managed according to their own managerial needs. These technological advances in the field of agriculture can aid grape growers to obtain more accurate information on which to base decision support systems to better manage vines and strive towards better grape quality.

Once vigour variability has been identified in a block, the grape grower is confronted by three equally important issues regarding his/her actions:

i) "Embracing" the variation
Farmers could embrace the variation by identifying different managerial and harvesting zones, and in so doing try to produce different styles of wine within one block.

ii) Managing the block towards uniformity
If areas of variability have been identified, the farmer can try to apply specific managerial actions in an attempt to try and homogenise those areas with the rest of the block. This could be done by performing extra suckering, tipping or topping actions if the areas possess high vigour, or by applying specific fertilisers or more frequent irrigation in areas where low vigour is found.

iii) Redeveloping the block
This option will only be considered in extreme situations. Examples of such a situation might be where soil preparation was done incorrectly and limiting barriers in the subsoil, such as acidic layers or hardpans, were not rectified. Another example of such an extreme

situation might occur when the wrong cultivar/rootstock combination was chosen for the specific conditions. When a grape grower decides to redevelop, he can re-design the block layout by taking into account the various factors that will have a direct impact on the vines. By redesigning, problematic areas such as pot clay or rock beds in the sub-soil, or poorly drained areas, can be avoided.

Before the grape grower can decide on the approach to be followed, the production goal must be looked at. Variability might lead to the production of certain wine styles, but if they are blended together, their different characteristics might clash, resulting in an inferior wine.

The increasing demand for grapes, and subsequently wine, of the highest quality is the most important driving force that will persuade farmers to start looking at the benefits that precision agriculture/viticulture has to offer. Only when farmers learn how to combine and act on different types of information, will optimal grape quality be reached. Relevant viticultural data can often be connected with geographical and spatially referenced information (Königer *et al*., 2001). By making a connection between actual vine characteristics and spatial observations, vine management can be improved and optimised considerably.

Commercial farmers are rather reluctant to implement precision agriculture due to the fact that the researchers' capacity to explain the new technological improvements and to identify and specify variation is being outweighed by the grower's capacity to acquire it (Cook & Bramley, 2001). The main deterrent for farmers involving precision techniques is the capital expense they will have to undergo to acquire the detailed information. It might be a large sum of money if information is obtained for all the existing blocks and potentially new sites (e.g. between R20 000 to R30 000 depending on farm size), but if the cost is broken down to a per hectare figure (± R1000), the cost of obtaining the information is outweighed by the benefits (personal communication, Nico Walters, viticulturist, Rustenberg Wines, Stellenbosch, 2006).

2.2 LEVELS OF VARIABILITY

The levels of plant variation within a vineyard block may be assessed in a similar fashion to climatic variation in and around vineyards. Climatic variability from a viticultural perspective can be divided into three distinctive levels: macro-, meso- and microclimate (Figure 2.5).

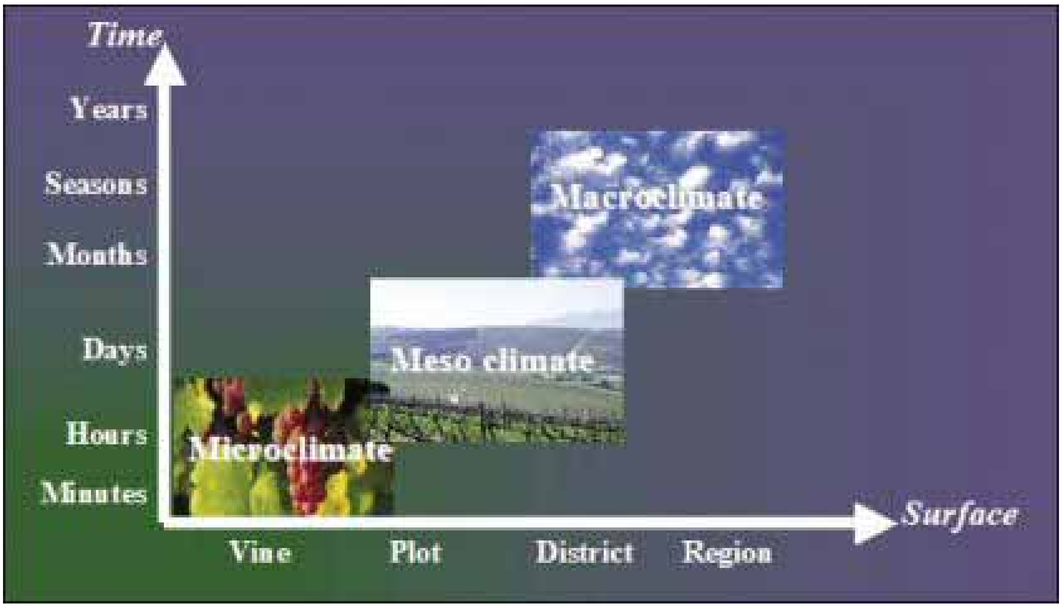

Figure 2.5: The different levels of climate influencing a vineyard (Bonnardot *et al*., 2004).

Macroclimate or regional climate refers to the climate of a region (Smart *et al*., 1981). It can be used to describe the general climatic pattern of a region, as determined by a central recording station (Dry & Smart, 1988). Mesoclimate or topographical climate (Figure 2.6) varies from macroclimate due to differences in elevation, slope, aspect and distance from large water bodies such as the sea, etc. (Dry & Smart, 1988). Mesoclimate represents the climatic variation within an area or within and around a block of vineyards.

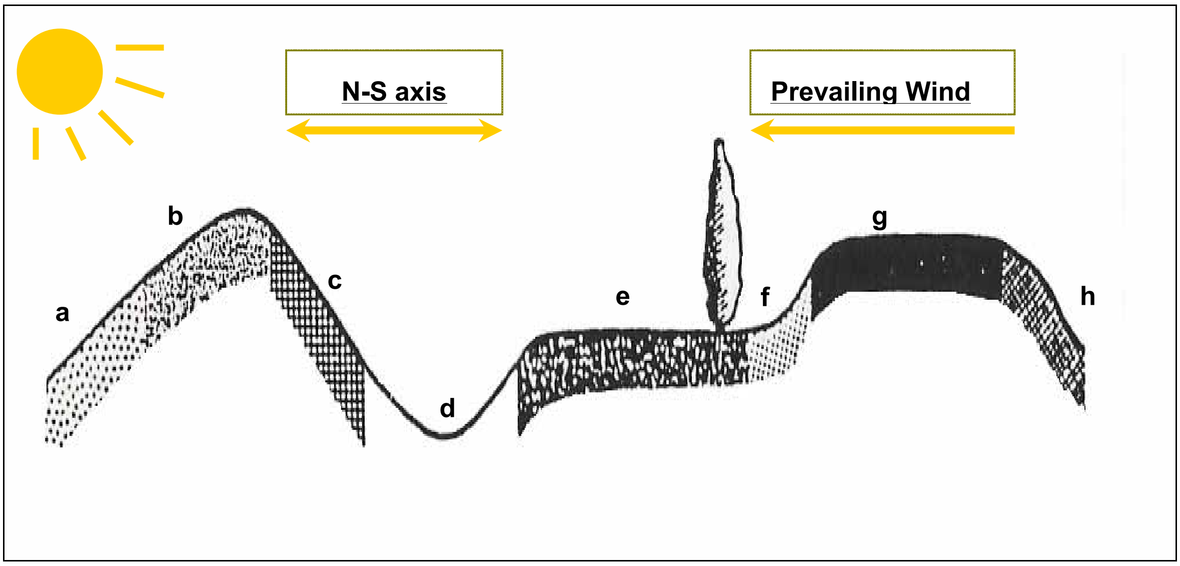

Figure 2.6: Association of mesoclimate with topography (Smart, 1995).

a) A warm site catching more sun due to the position of the land. It will not be subjected to late spring and early autumn frost, because of the cold air draining to low-lying areas.

b) The advantage of a) will be counteracted by cold as altitude increases.

c) The site might be free of any late spring or autumn frost, but it will be cold, due to exposure to wind and a poor angle to the sun, inhibiting heat accumulation.

d) The site will be very cold and susceptible to frost, due to the natural drainage of cold air from the higher areas.

e) The site will still be subjected to frosty conditions, but to a lesser extent than d). Might receive moderate shelter from wind because of the adjacent hill.

f) Trees that are planted closely together to form a barrier will cause cool air not to drain to the lower areas. A potential “frost-free” area has been lost.

g) A prevailing cold wind and altitude might prevent the accumulation of warm air in summer.

h) It will be a cold site, having the same characteristics as c).

Microclimate or canopy climate is the climate around and within a vine’s canopy. It is the modification of climate due to the plant cover being present (Smart *et al*., 1981), and is influenced by the viticulturist through the different managerial actions applied to the canopy. A microclimate variable such as light interception will contribute to the variability in fruit composition and maturity (Morrison & Noble, 1990). Dense canopies are characterised by an excess leaf area, which will result in shaded leaves and clusters. Shaded canopies will influence yield and quality negatively due to their influence on bud burst, fruit set, berry growth and fruit quality (Hanson, 2001). Rojas-Lara and Morrison (1989) established that shading delayed both grape ripening and growth. Open canopies will not only provide better light exposure inside the canopy, but will also cause a reduction in disease pressure, improve air circulation and provide better penetration for chemicals. Leaves of open canopies will also have a higher photosynthesis rate than leaves on dense canopies, especially the interior leaves. Hunter (2000) reported that the photosynthetic activity of leaves, as well as the export of photo-assimilates, increases due to an improved microclimate and lower sink:source ratio.

Smart *et al*. (1981) summarised certain characteristics that will distinguish a good from a poor microclimate. A good microclimate (Figure 2.7a) is characterised by a canopy that is: i) low in density; ii) has good leaf and fruit exposure; and iii) has many gaps in the canopy. A poor microclimate (Figure 2.7b) is characterised by: i) vines with large internal leaf area; ii) shaded leaves and fruit; and iii) no evident gaps in the canopy.

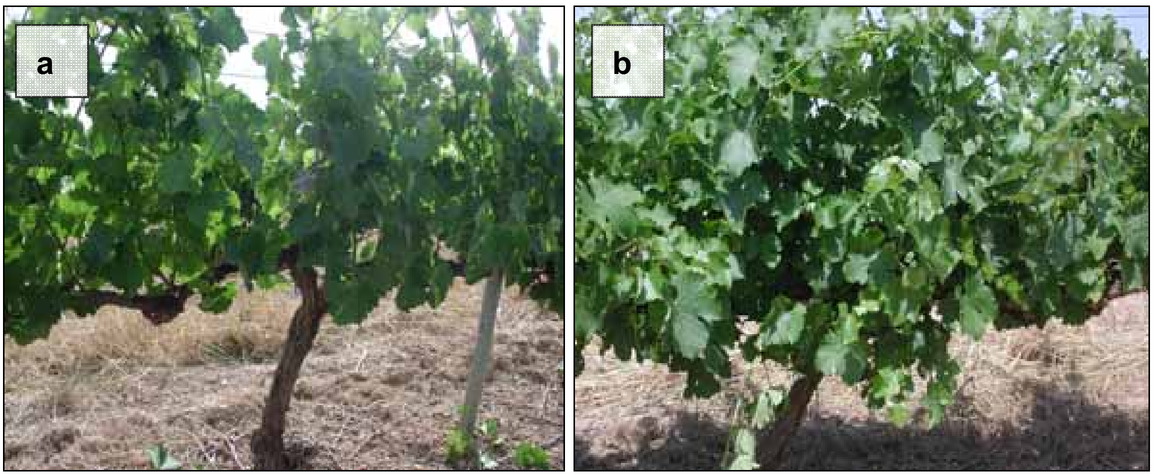

Figure 2.7a and b: A good microclimate, ensuring ample fruit and leaf exposure, and a poor microclimate, depicting a dense canopy with shaded leaves and fruit.

A good microclimate will benefit not only bud fertility and fruit set, but will have a marked influence on the berry composition due to its ability to acquire and convert radiant solar energy into chemical energy through photosynthesis. It is thus essential for the viticulturist or grape grower to strive for an optimal microclimate through the application of various managerial techniques such as pruning, suckering tipping and topping, and even crop thinning if necessary.

Vine variation, just like climate variation, can be subdivided into macro, meso and micro levels:

Macro level:
i) Vineyard variation within an area;
ii) Regional variation (nationally or globally).

Meso level:
Vine variation between different blocks due to topographical, geological, soil and climatic differences. This type of variation is visually noticeable through the variation in vine vigour. Areas of low and high vigour will all be visually distinguishable from each other.

Micro level:
i) Bunch variation on the vine;
ii) Berry variation within a bunch.

In most cases, variability is not in a straight line, as can be seen from Figure 2.8. The blue areas indicate areas of relatively high vigour; the green areas show relatively moderate vigour and the white areas indicate relatively low vigour.

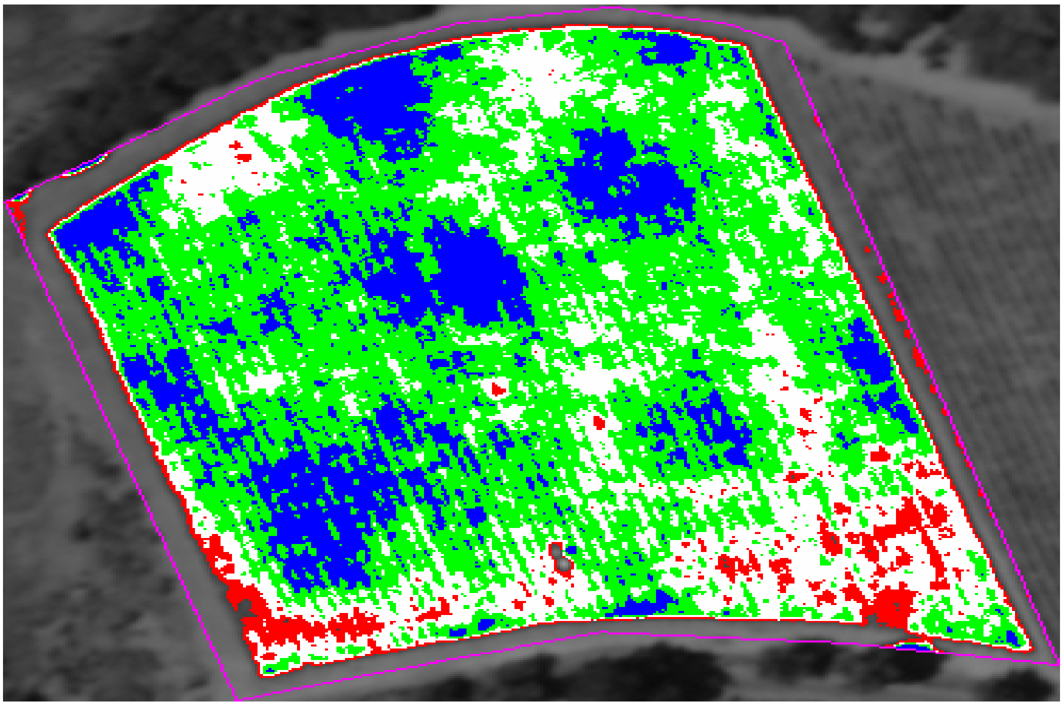

Figure 2.8: A classified multispectral image indicating different levels of vigour variation in a block.

Uniformity is the opposite of variability and has been identified by Long (1997) to be a crucial element in the achievement of optimal flavour and aroma concentrations in wine. In an experiment done by Long (1997), 400 berries from two different Cabernet Sauvignon blocks were sampled. One block produced grapes that were of Rosé quality, while the other produced Reserve quality grapes. The average Brix reading for both blocks was 23.5˚Brix, but when the ˚Brix distribution for each sample was plotted, the Brix readings for the Rosé ranged between 17 and 30˚Brix, while the Reserve berries ranged from 21 to 26˚Brix. Although the author concluded that sugar alone cannot be used to determine ripeness, it is also apparent that by making use of the average readings for a block, insufficient sugar readings will be produced and that in-vineyard variation has a definite influence on measurements, whether it be for sugar or acid. The same author reported that work done by a winery in the 1980s produced results that indicated that wines made from grapes at different maturity levels from the same vine produced wine that had dramatic differences due to the absence of uniformity.

If the results of the two mentioned experiments are compared, it is apparent that sugar levels will vary due to variation in vineyard blocks and even on the same vine, and if wines are to be made from such grapes, inferior wine quality may be the end result. In order to produce quality grapes, good vineyard management and subsequent quality control have to be carried out. Uniformity therefore seems to be the cornerstone of quality fruit and flavour. A wine can be labelled as good quality if it is satisfying and balanced, while at the same time reflects the character of the grapes used to make it (Zoecklein *et al*., 1995).

Long (1997), Kennedy (2002) and Taylor (2004) specified different types of uniformity that have to be addressed if good quality fruit are to be produced: i) berry uniformity (ripeness stage equality for berries within a cluster); ii) bunch uniformity (ripeness stage equality for bunches on a vine); iii) vine uniformity (similar ripeness patterns for vines within a block) and v) block uniformity (being based on soil differences and their influence on the vine). Another uniformity that is important for the production of quality grapes is that of shoot uniformity (Archer, 2001).

Shoot uniformity is important, because the quality of a bunch is directly related to the physiological characteristics of the shoot to which it is attached. This is why grapes from shoots that are either too short or too long differ in taste and colour from grapes from shoots of moderate length.

2.3 CAUSES OF VINE VARIABILITY

Long (1997) identified a number of causes of variability in different parts of the vine/vineyard (Table 2.1), from the berry through to the block. From the table it is apparent that there are three main causes of variability: i) soil; ii) environment and iii) incorrect managerial practices.

Table 2.1: Causes, actions and outcomes of variation (Long, 1997).

Type	Causes	Actions	Outcomes
Berry	▪ uneven cluster exposure ▪ weather at bloom ▪ tight clusters ▪ dense canopies	▪ good spur/bud distribution (15 cm apart) ▪ canopy management; good shoot location: careful leaf removal ▪ avoid tight clusters ▪ select training system to allow best display of clusters and leaves ▪ monitor berry variability: vine size data, establish sample size, berry sampling and Brix check	▪ even ripeness at harvest ▪ greater success of ripeness prediction from fruit samples
Cluster	▪ lack of vine balance ▪ excessive stress ▪ poor canopy ▪ disease (phylloxera) ▪ over-cropping	▪ véraison green cluster removal ▪ well-managed canopies ▪ remove fruit on short canopies ▪ proper crop and vine balance ▪ crop adjustment on diseased vines	▪ low Brix variability
Vine	▪ uneven soil ▪ blocked emitters ▪ disease ▪ irregular pruning ▪ varied vine age	▪ good block layout and design ▪ good initial stand (99%+) ▪ disease control ▪ segmented bock management ▪ vine removal ▪ good pruning technique; severe phylloxera	▪ more flavour intensity
Block	▪ block layout not correlated to soil changes	▪ initial layout critical to get manageable units for quality and flavour and ease of working ▪ differential harvesting within blocks based on ripening pattern	▪ more efficient vineyard ▪ lower variability within block

As can be seen from the table, variation does not just apply to the vine's canopy, but may affect the whole vine, from the vine structure to the composition of the fruit and then the composition of the wine.

2.3.1 SOIL VARIABILITY

Due to the influence of various weather cycles and complex geological variance (Saayman, 2003), the Western Cape region has developed as a landscape rich in soil diversity. Due to this geological and environmental variance, a number of different soil types are to be found in a very small radius (Figures 2.9 and 2.10).

Figure 2.9: Soil preparation on an old river bed reveals soil variation in a very small radius.

Figure 2.10: Soil variation due to the presence of “kraaltjies” or old termite nests. The termite nests are rich in organic material, resulting in the formation of high-vigour areas.

The difference in soil types will have a definite effect on the wellbeing of a vine and therefore on its vigour. Vine roots might penetrate some soils very easily, while other soils do not favour root penetration and distribution at all. If a vine’s roots cannot move into the soil and settle with ease, the aboveground structure of the vine will struggle (Figures 2.11a and b).

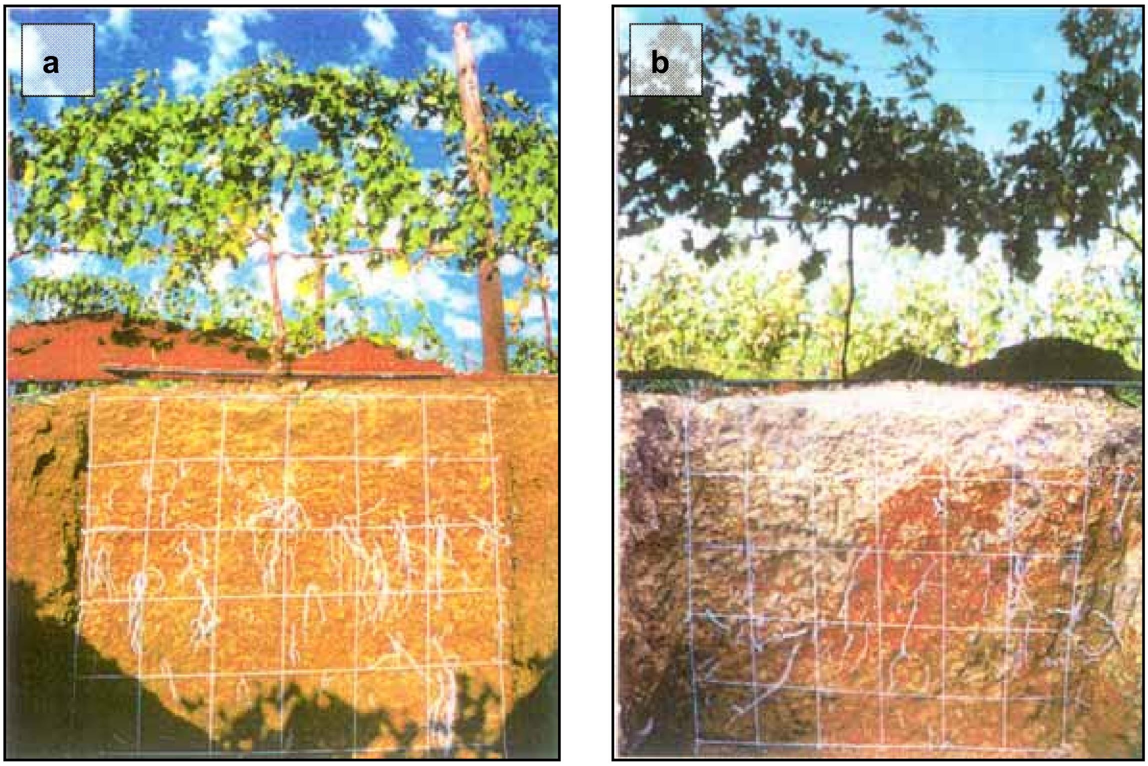

Figure 2.11a and b: Due to the difference in soil characteristics, the two vines differ with respect to root penetration and distribution, ratio of thick to thin roots, as well as aboveground structure (Archer & Hunter, 2004).

The influence that soil has on the viticultural system is sometimes mistakenly blamed on the variety/rootstock combination or on the climate (Fregoni, 1977) and, as pointed out by Saayman (1977), soil and the climatic conditions are automatically thought of if any quality parameters of the grapes are affected. The environment under the soil's surface is as important as the environment above; the only difference between the two is that any changes in the subsoil are difficult to observe (Van Huyssteen, 1987).

It is generally believed that soil can influence the composition of the grapes (Jackson & Lombard, 1993; Fregoni, 1977), and that this "influence" on composition can appear in the wine. Gladstone (1992) reports that French viticulturists of the nineteenth century made a definite association between soil type and the quality of the wine that originated from it. Various French authors believe that sandy soils produce a wine that is light and delicate but also lacking in colour, but at the same time is perfumed and lively. They also state that limestone and chalky soils increase alcoholic strength and that soils with high levels of iron and clay give depth and richness in colour to red varieties. Fregoni (1977) also indicated that soil has a marked influence on the grapes and wine produced from it and that the presence of calcium compounds (carbonates and sulphates) in particular favours the development of bouquet in the wines.

Rankine *et al*. (1971) related the quality of table wines to the grape variety, climate and soil type (depth, water-holding capacity and drainage being important for soil) in that particular order. The same author also indicated that soil had an influence on the nutrient content of the grapes and wine, but no significant effect on the wine quality. Jackson and

Lombard (1993), as well as Winkler *et al*. (1962), reported that this was also the view of various other authors.

Similarly, Saayman (1977) came to the conclusion that it is not the mineral composition of the soil that determines wine quality, but the actual physical properties of the soil. Amerine *et al*. (1967; quoted in Saayman, 1977) indicated that soil had a rather small part to play in determining wine quality and that the main focus must be on climate, blending and the method of aging. If all the various opinions are pooled concerning the topic of soil and its ability to influence the composition of wine, Saayman (1981b) said that soil cannot be separated from climate and that soil modifies the effect of climate in such a way that it plays an important role in determining wine quality.

Conversely, according to Gladstone (1992) and Jackson and Lombard (1993), soil can: (1) affect the plants water status (through soil depth, drainage and moisture retention); (2) influence nutrient availability; (3) influence effective heat absorption, storage and re-radiation; and (4) influence root development and penetration. If root penetration and development are sufficient, the vine will be buffered from any sudden fluctuations in moisture supply. A vine that has a good root system will be more likely to survive severe drought periods than a vine with an insufficient root system. Conradie (2002) indicated that the chemical composition of the soil, together with soil depth and water retention, will not just have an influence on the growth pattern of the vine, but also on the quality of fruit and wine produced. Bramley (2000) and White (2003) also indicated that the nutrition and moisture supplied by the soil will influence not only the vine's vigour status, but the balance between vegetative and reproductive growth as well as yield and berry quality. In order to ensure sustainable, quality yield production and long vine life, the soil's physical, chemical and biological conditions must be maintained.

Heat absorption and reflectance by the soil affect the vine quite dramatically. As heat penetrates the soil at deeper levels, root growth is benefited. This is due to the warming of the soil at deeper levels in early spring. The roots are much more active (Fregoni, 1977), resulting in earlier and more even bud burst, early growth of the shoots and more fruitfulness (Gladstone, 1992). A well-functioning root system will produce ample amounts of cytokinin, which is transported to the leaves and berries, to improve berry ripening and thus produce fruit of a high quality.

Soils that are high in nutritional value, together with high levels of nitrogen and an adequate temperature, will increase shoot growth, leading to an increase in vigour. If the increase in vigour is very severe, the quality of grapes and wine from those vines may be influenced negatively. According to Jackson and Lombard (1993), Champagnol (1984) indicated that the reduction in quality is due to the effects on phenolic and aromatic compounds in the grapes.

Nitrogen (N) is an element connected with different levels of vigour. An oversupply will lead to vigorous vines, while a shortage can be associated with low levels of vigour. Nitrogen is a basic element needed for cell augmentation and the development of vegetative organs, forming part of proteins, nucleic acids, auxine and chlorophyll (Saayman, 1981a). High levels of nitrogen reduce the concentration of anthocyanins in fruit (Winkler, 1977). The reduction in fruit colouration at high nitrogen levels is mainly due to a reduction in the carbohydrate accumulation, and an increase in amino acids and nitrogenous substances stored in the fruit.

Conversely, does inadequate nitrogen not only have a visual influence, but it will also lead to low levels in the must, which will have a negative influence on the fermentation process, which in turn may influence the quality of the wine negatively (Saayman, 1981a). High levels of nitrogen will enable the fermentation process to take place quickly and lead to higher levels of ester synthesis, which in turn is a positive quality aspect for the wine.

According to various authors, the environment and, more specifically, the climate can be seen as the main contributing factor influencing wine quality, but soil cannot be left out of the picture due to its definite influence on the microclimate of the vine. Climate, but more specifically water and temperature, is responsible for the formation of soil (White, 2003). Climate and the environment must thus be treated as a single entity when the quality of a wine is to be defined.

2.3.2 ENVIRONMENTAL VARIABILITY

A vine is a stationary plant that needs to adapt to the factors that influence it to survive. Factors such as rainfall, temperature, frost and wind are just some of the environmental factors that have an influence on the wellbeing of a plant. Winkler *et al*. (1962), Winkler (1977) and Coombe (1987) identified temperature as the most significant environmental factor that influences viticulture, and reported that it has a big influence on grape composition and quality. Other factors such as rainfall, fog, humidity, sunshine hours, etc. may have an influence on the vine, but do not have such a dramatic effect as heat summation (Winkler *et al*., 1974). Conradie (2002) also indicated that climate has a significant effect on a wine's character, but that it cannot be viewed in isolation.

Winkler *et al*. (1974) indicated that cooler climatic conditions are more favourable for the production of wines that have high levels of acidity and pH, and good colour, and also favour the optimum development of aroma and flavour constituents, while the aromatic characteristics lose delicacy and richness in warm climatic conditions. Rankine *et al*. (1971) also point out that a warm climate has a marked influence on grape composition and that grapes from a cooler region are of higher quality.

There seems to be a relationship between climate and quality, with quality being determined partially by the warmth and length of summer (Jackson & Lombard, 1993). Winkler and Williams (1936, cited in Winkler *et al*., 1962) and various other authors have reported that when a season experiences cool climatic conditions and heat summation is slow, the maturing of the grapes will take place at a slow pace, while a season that is hot and where heat summation is rapid will cause grapes to mature much quicker.

The specific shape of the landscape is important when considering the establishment of vines, because it will determine the climatic variance that will be experienced in a specific vineyard. Factors that need to be considered before a block is planted will include altitude (height above sea level), aspect (North-North-West or South-South-East), slope shape (convex or concave) and slope inclination (steepness).

Figure 2.12 indicates different vineyards situated on the slopes of Simonsberg Mountain and the Jonkershoek Mountain range in the Stellenbosch region. Each block (marked with a yellow arrow) will experience different climatic conditions. To optimise this variation in climate, cultivars have to be chosen in such a manner as to optimally utilise the climatic variance in order to produce fruit and wine of a good quality.

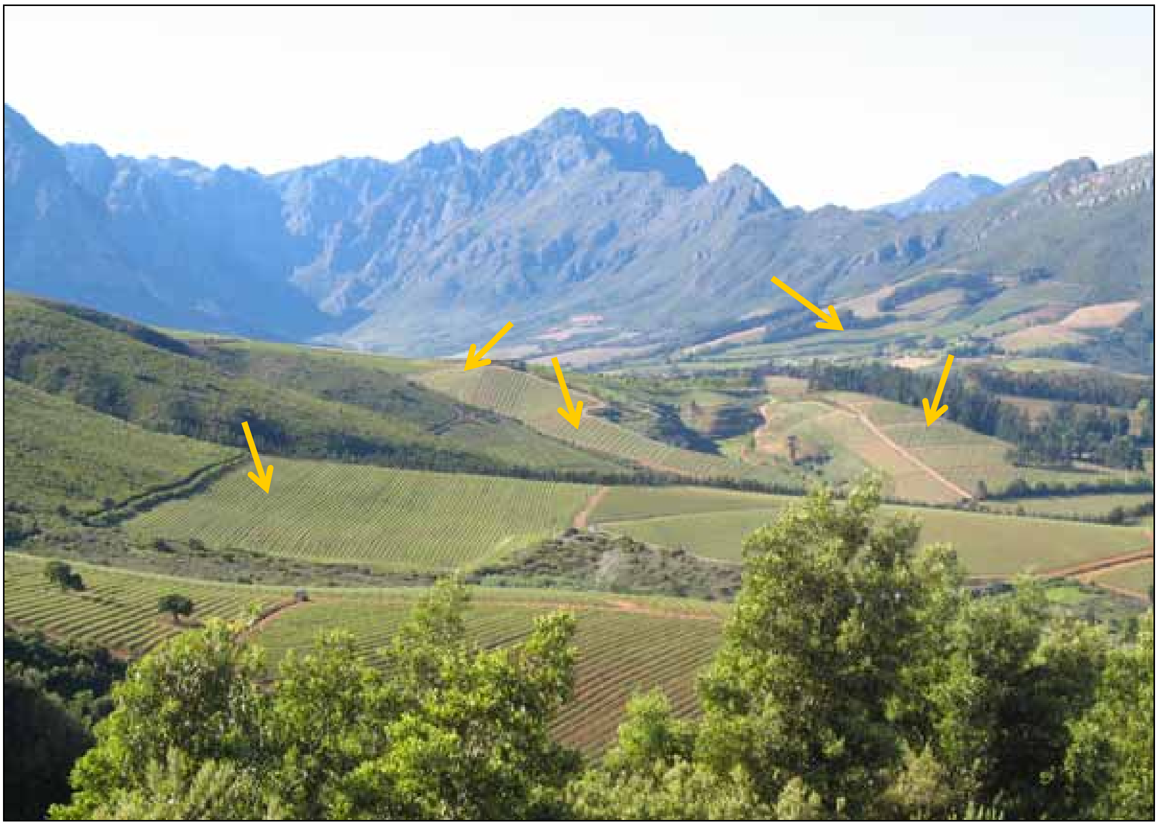

Figure 2.12: Vineyards planted on various slopes.

2.3.3 MANAGERIAL INPUTS

A lot of everyday management goes into the maintenance of vine balance or the restoration thereof. Water and soil management, trellising and training, and fertiliser application, to name just a few, are some farming activities that form the basis of grape production. Not a single one of these aspects is more important than another. Managerial inputs can combine with the natural environment to determine a vine's balance.

Managerial input is important during every phase of grape production and is probably the one aspect concerning variation that can be managed by the grape grower from the very start. Managerial inputs can be divided into long- and short-term practices.

2.3.3.1 Long-term practices

Long-term managerial practices include site selection, cultivar and rootstock specifications, soil study, site preparation, vine spacing, vine training, trellising and irrigation systems. All of these factors can be adjusted to manage variation within a certain area. Site selection can be performed to choose the correct variety and rootstock for the specific site. Different soil preparation techniques could be applied to address variation in the subsoil. Vine spacing, training and trellising could be adapted depending on the characteristics of the expected variation. The type of trellising system and the method of vine training that is decided upon will have an influence on the date of maturity and on the crop load (Winkler *et al*., 1962). A trellising system that will expose as many leaves as possible to the sun will have a positive effect on bud fertility and, indirectly, on crop load.

Shoot length plays an important part in determining uniformity in a block. Due to insufficient managerial inputs, such as poor training practices and insufficient suckering, vines with different physical characteristics will be the end result. Figure 2.13 shows a Chenin blanc block that is suffering from insufficient managerial input. It is clear from the picture that poor training techniques were applied. A shoot that would normally have acted as a bearer now has to fulfil the task of a left cordon arm. It will take a minimum of two years for the left arm to produce any grapes that can be picked for winemaking and, even then, the grapes will be of an inferior quality.

Figure 2.13: Poor training techniques on a Chenin blanc vine.

Figure 2.14 shows a vine from the same Chenin blanc block as in Figure 2.13. Figures 2.15a and b indicate the lack of uniformity and subsequent lack of balance in the vine. Shoot uniformity is important due to the fact that the quality of a bunch is directly related to the physiological characteristics of the shoot to which it is attached (Archer, 2001). A balanced vine, according to Wilson (2003), will have the ability to produce shoots of adequate length that will produce a sufficient number of nodes, which in turn will have a sufficient leaf area to support two bunches per shoot. The left cordon arm (Figure 2.15a) might be able to produce shoots of that character in this scenario, but it will take a while for the right-hand cordon side (Figure 2.15b) to do so. The left and right arm will never reach a point of uniformity. The one will always be weaker than the other and will lack quality and production.

Figure 2.14: An imbalance in vine structure due to poor vine training techniques.

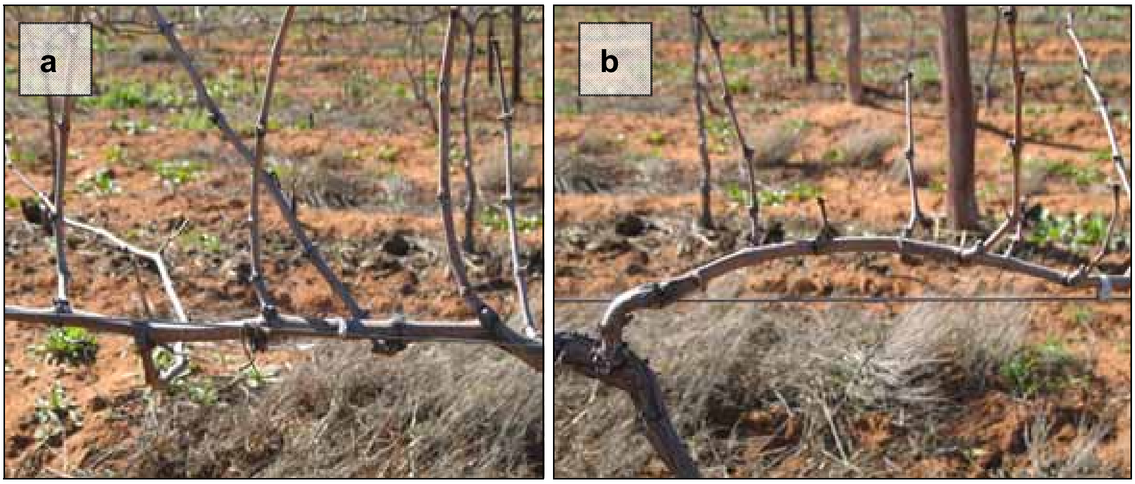

Figure 2.15a and b: Variance in shoot character on the same vine due to insufficient training practices.

Archer (2001) indicates that shorter shoots (Table 2.2) collected from different vines in a vineyard, will produce grapes that can be characterised as overripe, while grapes from longer shoots will be deemed unripe.

Table 2.2: Grape composition of Cabernet Sauvignon on R99 as affected by different shoot lengths (Archer, 2001).

Shoot length (cm)	Sugar concentration (°B)	Acid concentration (g/ℓ)	pH	Skin colour (520 nm)
± 60	23.4	5.2	3.8	1.203
± 120	24.5	7.4	3.3	2.761
>200	21.9	8.9	3.2	1.078

Grapes formed on the shoots in Figures 2.15a and 2.15b will differ in character and composition. The shoots in Figure 2.15a will be strong and the buds will produce adequate leaves for photosynthesis. The shoots formed in Figure 2.15b, however, will be weak, with inadequate leaf structure that can photosynthesise. The grapes in Figure 2.15b will also be subjected to severe sun burn, destroying any chance of good quality fruit. In each case, the composition and quality of the grapes will differ.

2.3.3.2 Short-term practices

Short-term managerial inputs include seasonal soil management, suckering, tipping and topping, shoot positioning, leaf removal, crop thinning, pruning and disease management. Short-term managerial inputs can also become long-term problems if the correct procedures that need to be followed are neglected.

Soil management, in particular soil moisture management, plays an important part in determining wine characteristics. Excessive soil moisture levels will lead to high juice acidity and the dilution of phenolic constituents (Gladstone, 1992). Conversely, according to Conradie (2002), wine from Cabernet Sauvignon vines that were subjected to high levels of water stress developed a strong vegetative character (grassy/sweet pepper), while wines from less stressed vines developed a berry (raspberry/strawberry) to black pepper character.

Figures 2.16 and 2.17 indicate a Sauvignon blanc vine that has not been suckered for a number of years. The end result is a vine with severely built-up bearers. It is evident from the pictures that the bunch zone for each bearer is at different levels. Shoot lengths will differ, especially if the shoots are to be topped, resulting in a difference in the composition and character of the grapes.

Figure 2.16: A vine that has not been suckered for a number of years.

Figure 2.17: Built-up bearers due to insufficient suckering.

Due to insufficient suckering (Figure 2.18), a number of shoots develop where there is supposed to be just one shoot with two buds. Grape character and quality will once again be affected negatively. Berry, cluster, shoot and vine uniformity will not be achieved due to intense competition between the shoots. A dense “bunch-zone” will be formed that will have poor microclimatic conditions.

Figure 2.18: A collection of shoots due to insufficient suckering.

Shoot positioning is another aspect of management that is important for achieving uniformity. Shoots are positioned vertically in order to achieve certain benefits, the one being to expose as many leaves as possible to the sun. Smart (1991) says that the two main advantages of shoot positioning are to stop canopies from becoming too dense and causing fruit shading.

Leaf removal is one managerial action that is rarely carried out on South African farms. This is probably due to the lack of knowledge and a lack of capital. Koblet (1987) and various other authors have reported that an increase in the colour and sugar content of the grapes was achieved due to a series of leaf removal actions, while, at the same time, bunch rot and malic acid content were reduced. Management practices, such as canopy and yield management, will have a definite influence on the estimated time of maturity, as well as on aroma and flavour development. If actions are carried out on vines at the right time, the vines will have the same maturity date if uniformity is not a problem. If uniformity is a problem, the vines can be managed separately to try and achieve synchronised maturity.

The ultimate art of the grape grower is to recognise variation, whether it be between adjacent vines or different cultivars, and to decide on the most appropriate course of action, and then to manage the vine in such a way as to correct the imbalance of each vine individually. Vine balance is the outcome of diverse varietal, environmental and managerial factors (Gladstone, 1992).

Coombe (1987) postulates whether the huge differences found between cool and warm climate wine could not be due to managerial "faults". In cooler areas, grapes might struggle to gain the necessary sugar levels to achieve optimum maturity levels, while grapes from warm areas might only possess optimum ripeness qualities for just a few days. Another factor that has to be considered when grapes are harvested at high temperatures, especially mechanically, is oxidation. The time of ripening is thus influenced by management decisions. Winkler *et al*. (1962) also posed the question about the time of ripening and whether it is not possibly influenced by vineyard management.

As mentioned earlier, crop thinning forms an important part of a farm's short-term managerial input. Commercial farmers are reluctant to perform crop thinning, primarily for two reasons. The first is that they will have to spend money to perform a seemingly insignificant procedure and the second is that they are paid on the basis of grape tonnage. The more tonnage per hectare they produce, the more money they will receive. A possible third problem that will act as a deterrent for farmers to apply crop thinning is that they sometimes are paid for their produce throughout the year, in the form of instalments. A farm's budget is thus stretched to break point due to an insufficient supply of capital.

Privately-owned wine estates, however, will do anything to produce better quality fruit in an attempt to produce better wine and, in so doing, try to better their market share. The procedure of crop thinning is performed differently on every farm, with each farm having its own unique recipe that they believe in. The following two chapters will look at the practice of crop thinning and the effect thereof.

The Practice of Crop Thinning

It is widely believed that low-yielding vines produce the best quality wine (Van Schalkwyk *et al*., 1995) and, as a result of this view, cultivars in South Africa have been divided into different quality categories according to production levels in the different regions.

Crop thinning, as reported by various authors in Van Schalkwyk *et al*. (1995), has been proven to reduce yields successfully and to improve the wine quality of cultivars that have the tendency to over-crop. If crop thinning is applied moderately after flowering, yield will not be reduced due to an increase in berry size and the number of berries per cluster

(Bravdo *et al.*, 1984). Vines that are subjected to crop thinning will experience an increase in pruning weight, as well as an increase in the capacity of the vines. According to Winkler *et al*. (1962), fruit quality and yield increase concomitantly with a vine's capacity as a result of pruning severity and fruit thinning.

Crop thinning is beneficial if it is carried out on young or weak vines that are not capable of carrying and optimally maturing a crop to its full potential. The question that then arises is why farmers apply, and wine makers insist on, crop thinning if the vines are fully developed and more than capable of carrying and optimally ripening a crop, as seen in Figure 2.19? The vines in Figure 2.19 have sufficient exposed leaves for adequate sunlight interception and will be able to produce enough photosynthetic substrate to ripen a substantial crop. It is important to balance the vigour of the vine with the amount of grapes/bunches that the vine produces.

Figure 2.19: Crop thinning performed on a block of Merlot.

Effect of Crop Thinning on the Grapes

Various authors, as reported by Van Schalkwyk *et al*. (1995), found that bunch removal improved wine quality for various cultivars and that wine made from vines that had undergone thinning treatments tend to have a more intense varietal character and was of superior quality compared to that from control treatments (no bunch removal). The same author also referred to findings that bunch removal had no significant effect on wine quality when applied to vines that are not over-cropped. Weaver *et al*. (1957) and Kasimatis (1977) reported that wine made from low-crop vines had high concentrations of nitrogen and phenols and possessed good aroma qualities and flavour intensity. Bravdo *et al*. (1984) observed that the tartaric to malic acid ratio tended to rise with an increase in crop load. Chapman *et al*. (2004) also reported that wine made from lower yielding vines had higher intensities of astringency and vegetative aromas and flavours.

Van Schalkwyk *et al*. (1995) carried out an experiment on Chardonnay to study the effect of bunch removal on grape composition and wine quality. Figure 2.20 indicates the differences in wine aroma profiles that where induced by different bunch removal treatments. With the aid of these results, the grape grower and winemaker alike can identify different characteristics that they would like to have in their wines and subsequently perform the various crop thinning actions to obtain the specific flavours.

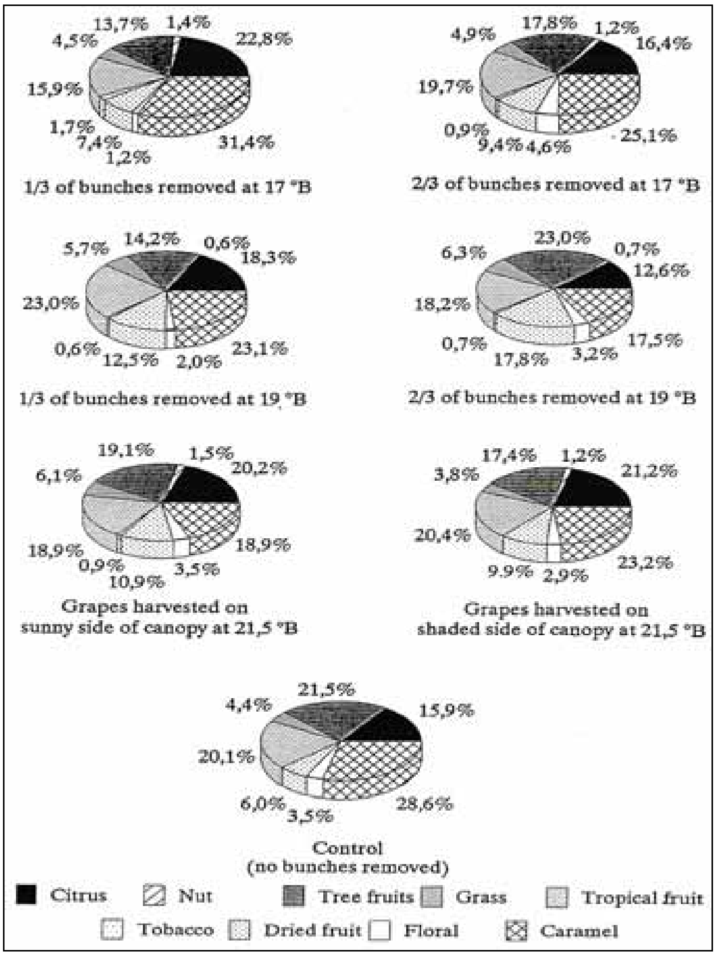

Figure 2.20: Differences in wine aroma profiles due to different crop thinning treatments (Van Schalkwyk *et al.*, 1995).

Van Schalkwyk *et al.* (1995) reported that if bunch removal was applied pre-bloom or at bloom, yield compensation of large cluster varieties would occur, while varieties with smaller bunches will compensate to a lesser extent. Compensation and the effect of a reduction in yield will be reduced when bunch removal is delayed until after berry set. Maximum crop reduction will be obtained when bunches are removed after véraison due to the end of cell division and growth at this stage.

2.4 EFFECTS OF VINE VARIABILITY ON THE VEGETATIVE AND REPRODUCTIVE BALANCE

"The vine is a climber and as such it is genetically inclined to favour shoot growth" (Archer & Hunter, 2004). As long as the vine experiences favourable conditions such as sufficient water supply, sufficient nutrients and a high temperature, vegetative growth will be favoured (often at the expense of reproductive growth). Due to within-vineyard variation (through soil variation, environmental variation or managerial inputs), some vines might experience these favourable conditions, while others might not. Vines possessing different structural characteristics will thus be visible in a vineyard.

The viticulturist is faced with the challenge to manage vines in conjunction with different in-vineyard conditions in an attempt to achieve controlled growth. Controlled growth will be achieved when the following balances occur within a vineyard (Archer & Hunter, 2004): a) a balance between subterranean and aboveground growth; b) a balance between fine and thick roots; c) a balance between the left and right cordon arms; d) a balance between young and old leaves in the canopy; and e) a balance between shoot growth (vegetative growth) and yield (reproductive growth).

2.4.1 VEGETATIVE EFFECTS

Vines that experience vigorous growth will become increasingly vegetative and disturb the reproductive/vegetative balance. Vigorous vines will produce less fruit due to the shade that depresses bud fertility and subsequent bud break, fruit set and berry size (Smart & Archer, 1990; White, 2003; Hansen, 2001; Smart, 1995). Fruit colour and flavour are also influenced negatively by shading caused by vigorous vines (White, 1993). Smart (1995) identified these characteristics as the "high vigour cycle" and also indicated that fruit ripening is delayed due to shading and that wine quality is substantially reduced. Smart *et al*. (1985) state that the term "high vigour" applies to vines with longer shoots, larger leaves, more shoots and larger yields. Weier (2000) defines vigour as: "The agricultural term for the health of the plant [which] is the result of the type and depth of a soil a plant is in, the water it receives and the sunlight it gets".

Highly vigorous vines are characterised by excessively dense foliage, because they have more leaves that can actively produce photosynthetic substrate. Dense foliage depends on factors that favour a high vegetative growth rate. Factors that stimulate vine vigour are vigorous rootstocks, a high availability of water and nutrients, freedom from pests and disease, etc. (Smart *et al*., 1985). Smart (1987) reported that it is generally recognised that shade reduces grape quality, and that light is an important factor in the accumulation of sugar through the photosynthesis of leaves that are exposed to sunlight. Light exposure is also important for anthocyanin content and PAL (phenylalanine ammonia lyase) activity. PAL is a key enzyme in the synthesis of phenols and anthocyanin. Leaves that are shaded manufacture and supply little or no sucrose, but still contain potassium (K) that is available to the fruit (Gladstone, 1992). The higher the proportion of shaded leaves, the higher the ratio of potassium to sucrose that is transported to the grapes.

Shoot density influences the canopy microclimate and subsequent fruit environment (Reynolds *et al*,, 1994). Smart (1987), Smart *et al*. (1985) and Smart and Archer (1990) report that shading in canopies increases the potassium content of the berries and must, resulting in a higher pH concentration. Shaded canopies also have a higher malic acid concentration (Koblet, 1987) and subsequent higher malic to tartaric acid ratio (Gladstone, 1992), which leads to an increase in pH if the wine undergoes malolactic fermentation. Koblet (1987) reports that Ruffner (1975) found that malic acid in ripening grapes was transformed to sugar at a much higher rate under warm ripening conditions. Smart and Archer (1990) say that shaded canopies reduce berry sugar, phenols, berry size and aroma.

In an experiment done by Smart *et al*. (1985), it was determined that wine made from shaded berries was low in titratable and tartaric acid levels, that it had a high pH, potassium and succinic acid content, that it had low colour density, anthocyanin content and total phenols; and that the wine possessed a high colour variance. Data gathered from the experiment indicates a correlation between high must pH and potassium, with a high leaf area and shading. High potassium levels in wine are due to the fact that potassium accumulates in the shoots before véraison and then is translocated to the fruit.

In a study done by Smart (1995) it was determined that shoot growth is very sensitive to water stress, and that canopies of stressed vines are less shaded and develop more fertile buds. It is apparent that vines with moderate canopies (not necessarily induced by stress factors) have much more fertile buds than highly vigorous vines.

2.4.2 REPRODUCTIVE EFFECTS

The main aim of every grape grower is to obtain and maintain vine balance. When vine balance is achieved, uniformity will be “automatic”. Gladstone (1992) defines balance as “When vegetative vigour and fruiting load are in equilibrium, and consistent with high fruit quality,” while White (1993) defines balance as being achieved “when vegetative growth and fruit load are in equilibrium”. Over-cropping and under-cropping are aspects that have to be avoided at all cost. Each scenario has certain disadvantages coupled to it. When a vine is caught up in one of these cycles, it is very difficult to get the vine’s balance back in order.

2.4.2.1 Bunch/berry Morphology

The grape berry consists primarily of skin, pulp and seeds (Figure 2.21). Each of these contains various components that change quite dramatically during the ripening season (Watson, 2003). Another problem that arises is that the different components are not equally distributed throughout the berry. This problem can be addressed by the grape grower to a certain extent by adjusting the berry size (Kennedy, 2002) through various managerial inputs.

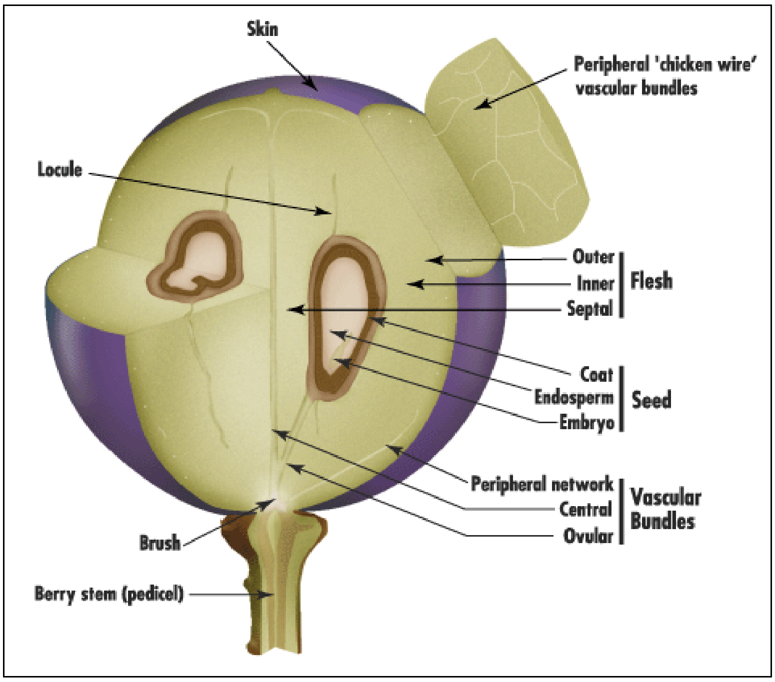

Figure 2.21: Berries structure divided into the various components (Kennedy, 2002).

Seeds contain nonflavonoid and flavonoid phenolic compounds, as well as a large amount of tannins (Watson, 2003). A grape berry consists of three main components, as mentioned, but it also comprises three distinctive juice zones (Zoecklein, 2001), each having different concentrations of certain components (Figure 2.22).

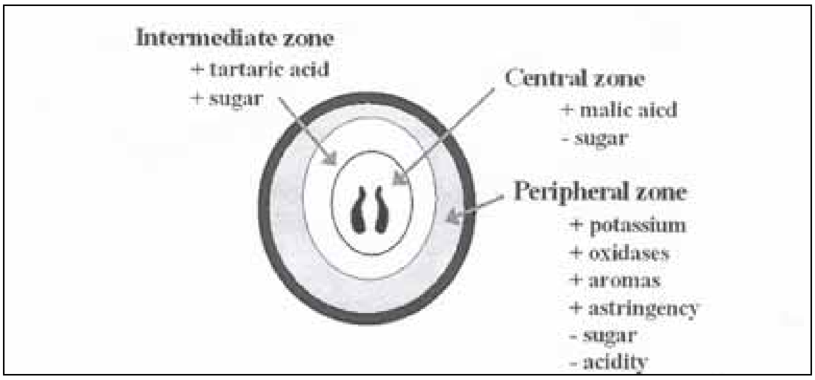

Figure 2.22: The grape berry divided into three different juice zones (Zoecklein, 2001).

2.4.2.2 Grape Chemical Composition

Jackson and Lombard (1993) describes the term "quality" as follows: "Quality is not easy to define, but ideally it should be related to intrinsic visual, taste or aroma characters which are perceived as above average for that type of wine". White (2003), on the other hand, divides the term "quality" into two separate categories. The first is that of "quality wines" and the second is that of "table wines". "Quality wines" are made from grapes originating from a specific region where soil and climate interact with each other and where managerial inputs are carried out with the production of high quality fruit the main objective. "Table wines" can be seen as being made with "run of the mill" type grapes, with the emphasis on the production of tonnage.

Long (1997) has identified three factors that are important for a wine to be classified as being of good quality. Firstly it must have flavour intensity (the amount of flavour concentration), secondly it must have good flavour length (time the flavour stays in the mouth), and thirdly it should have complexity (or diversity of flavours).

Gladstone (1992) and Winkler *et al*. (1962) perceive maturity to be that point in the grape development cycle when the grapes are most suitable for the production of a specific wine style and that the ripening period is the final month up to the estimated maturity date. An adjustment of the maturity date will have to be made for different styles of wine.

Optimum grape maturity and harvest dates are two descriptive terms that are markedly important if good quality fruit are to be produced. The quality of the fruit needs to be of a certain calibre for wine to achieve the maximum quality potential (Zoecklein, 2001). High quality wines are produced due to fruit attributes that interact with each other. Attributes such as fruit derived aroma and flavour components, the reduction of immature tannins and the production of mature tannins, are important. Zoecklein (2001) remarks that grape growers must not just make use of primary metabolites such as sugar to determine the quality of a wine, but must shift their attention towards secondary plant metabolites such as aroma/flavour and phenolic compounds. The same author emphasises the importance of grape-derived aroma/flavour and phenolic compounds as being the principle source of a wine’s flavour, aroma, colour and taste.

Hellman (2004) identifies grape ripeness or grape maturity as an elusive concept for a lot of people and as an elusive achievement for vineyards. According to various authors, the level of grape maturity will depend on what the grape grower and winemaker want to do with the grapes. Grape maturity is thus defined by the individual grape grower or winemaker. The grape characteristic for every type of wine style differs, as seen from Table 2.3, complied by Van Schalkwyk and Archer (2000).

Table 2.3: Different grape characteristics for the production of different wine styles (Van Schalkwyk & Archer, 2000).

Wine type	Sugar concentration (˚B)	Acid concentration (g/ℓ)	pH
Sparkling wine	18.0 - 20.0	7.0 - 9.0	2.8 – 3.2
White table wine	19.5 – 23.0	7.0 – 8.0	3.0 – 3.3
Red table wine	20.5 – 23.5	6.5 – 7.5	3.2 – 3.4
Sweet wine	22.0 – 25.0	6.5 – 8.0	3.2 – 3.4
Dessert wine	23.0 – 26.0	5.0 – 7.5	3.3 – 3.7

Every cultivar has distinctive fruit characteristics that come forth when grapes are “ripe” and “ready” to be harvested. Aroma, flavours, tannins, sugars and acids combine to form a unique varietal character, which is important for distinctive wine qualities (Hellman, 2004). It is also important to realise that optimum maturity for one variety may not be the same as for another. Red cultivars, for instance, need to develop mature tannins to produce a wine that has good body and character that can be labelled as being of good quality. Tannins from unripe grapes are undesirable, hard and coarse, while tannins from mature grapes are desirable, supple and smooth (Fiola, 2006).

While grapes remain on the vine, aroma and flavour character change. Sugar levels can increase while acid levels decrease, affecting grape and wine quality. Grapes that are subjected to a longer “hang-time” usually result in wines with high alcohol levels, which may not have adequate natural acidity to produce a balanced wine (Hellman, 2004). Table 2.4 illustrates the progression of character qualities for red grapes (Bisson, 2001). Zoecklein (2001) identified the same changes that occur as the “hanging time” of grapes is extended.

Table 2.4: Progression of grape character qualities of red grapes as a season progresses (Bisson, 2001).

Vegetation	Herbaceousness	Unripe fruit	Red fruit	Black fruit	Jam
Plant matter	Straw, herb, vegetable, tobacco	Green apple, citrus fruit	Cherry, strawberry, raspberry, cranberry	Plum, blackberry, black cherry	Prune, date, raisin

As a result of the many definitions of quality and optimum maturity levels and opinions on when to harvest, it is made apparent by various authors that, to obtain certain aromatic and flavour characteristics in the wine they must exist in the grapes.

Van Schalkwyk and Archer (2000) report that Du Plessis (1977) related optimum ripeness directly to the quality of the fruit, and that quality is reflected through the chemical composition of the grapes. From research done by Du Plessis (1977) it is apparent that optimum ripeness is reached at different sugar concentrations each year and that sugar alone cannot be used as a parameter to determine optimum ripeness.

Correct **sample collection** during the ripening period is very important to form a clear picture of the ripeness level of a block. Samples must be random, unbiased and representative of a whole block. Grapes that are more mature are usually selected, while unripe grapes are passed over. Even when ripe and unripe berries are sampled and placed in the same batch, insufficient results can be obtained due to the inferior grapes influencing the quality of the mature grapes.

It is important to note the following when grapes are sampled (Zoecklein, 2001):

- Avoid the first two rows on each side of a block;
- Sample shaded as well as sun-exposed berries from both sides of the vine;
- Berries from the top, middle and bottom part of a bunch must be sampled;
- Sample berries from all sides of a clusters;
- Maximum sample area < 2 ha.

The bigger a sample is, the more representative it will be of the sampled area and the better the results will be.

When within-vineyard variation occurs in a block (as in the case in Figure 2.8), samples of the different areas must be taken and analysed separately. Areas of low vigour might have high sugar levels, while high-vigour areas might not. If the grape samples are thrown together they will influence each other and insufficient readings will result. If vine variation occurs within a vineyard, different wine style can be produced from it. Correct sampling of the different areas is thus important in order to determine the ripeness level of the different areas.

It is important to realise that the physiological mechanisms responsible for the production of sugar are not responsible for the production of secondary metabolites. Brix and aroma/flavour concentrations are thus not connected in any way (Bisson, 2001; Zoecklein, 2001). Sugar can only indicate maturity levels and cannot be used in isolation to determine grape maturity. Grapes could have a high Brix reading while possessing no aroma and flavour characteristics.

2.4.2.3 Crop Level

The crop produced by a vine is an important component of a farm's financial wellbeing in today's competitive wine industry. More grapes will result in the production of more wine, but it is not only volume that is important, as quality cannot be overlooked.

According to Winkler *et al*. (1962), crop level is the most important factor influencing grape ripening and one that can be manipulated by viticulturists through the retention or removal of grapes. One fact that grape growers must realise is that a specific vine can only produce a certain amount of fruit. Forcing a vine to carry more than it is capable of ripening will have deleterious consequences. Winkler (1954), Weaver *et al*. (1957), Weaver and McCune (1959) and Bravdo *et al*. (1985) point out that over-cropping has a definite effect on the coloration and maturation levels of grapes. Grapes from over-cropped vines have less colour and lower sugar and higher total acid levels, and produce wine of an inferior quality (Bravdo *et al*., 1984).

Cropping can be established as "normal" if the vine is able to bring a certain quantity of fruit from bloom to a desired maturity level with a given summation of heat (Winkler, 1954). When the crop to leaf ratio is increased above a perceived "normal" level, it will take longer for the grapes to reach a certain sugar level. Winkler (1954) states that a greater leaf to fruit ratio is favourable for fruit development. White cultivars need 16 to 20 leaves per shoot for grapes to ripen optimally, while red cultivars need 20 to 26 leaves per shoot (Archer, 2001). Bravdo *et al*. (1985) reports that Buttrose (1968) indicated that even if crop levels are increased, berry growth and sugar accumulation will not be delayed if the leaf area increases parallel to that of the crop level.

Over-cropping does not just influence the composition of the grapes, but may also have an overall influence on the wellbeing of the vine. Winkler (1954) hypothesised that over-cropping deprives the root system of reserves that are needed for the new growth of the following season and that an adequate amount of carbohydrates (total sugars and starch) in the shoots usually accompanies conditions that are favourable for fruit development. Winkler's (1954) findings were backed by Weaver *et al*. (1959), who reported a reduction in the carbohydrate content of the roots and a delay in budding the next season.

Over-cropping not only reduces the carbohydrate levels of the roots, but also that of the shoots (basal segments), the overall crop weight per vine and of vine prunings, and trunk diameter. Weaver *et al*. (1957) have shown that two successive seasons of over-cropping weakens the vine to such an extent that a small crop is produced in the third year. Winkler (1954) reported a reduction in vine size due to over-cropping.

The overall wellbeing of a vine is hampered by over-cropping. Reserves that are supposed to help the vine cope in difficult situations or just enable a vine to function normally are gone due to the demand of the large amount of grapes. If any unfavourable conditions arise, the vine will not be able to get through that difficult period and will die.

Reynolds *et al*. (1994) determined that, for a higher crop load, canopy shade will increase and reduce light interception and that a reduction in clusters per vine will reduce yield per vine and overall crop load, but at the same time increase cluster weight, berry weight and berries per cluster, if done at the right time.

Under-cropping, just like over-cropping, is an important component of sustainable grape production that will have certain effects on the crop and the vine in the long run. The immediate effects will be an increase in sugar accumulation in the berries, an increase in cluster size and an increase in vegetative growth of the canopy (Kurtural, 2005). According to Jackson and Lombard (1993), lower yields will possibly lead to an increase in pH levels, a decrease in TA levels, and an increase in anthocyanins and aromatic constituents such as potential volatile terpenes.

The long-term effect of under-cropping will be a reduction in fruitfulness due to a vegetative imbalance. Grape berries represent the reproductive side of the reproductive/vegetative balance of a vine. If a too low crop load is placed on a vine through either crop thinning or pruning practices, this balance will sway in the favour of vegetative growth. If too few shoots are left in relation to the vine's growth capacity, the vine will compensate for the deficit through the stimulation of shoot growth from secondary, tertiary or latent buds, which will lead to an increase in shoot vigour and more extensive lateral leaf growth (Hellman, 2006). An excessively shaded canopy will be the consequence of this extensive leaf growth, leading to the formation of a poor fruit-ripening environment. Profitability will also be negatively affected by under-cropping due to insufficient quantities of grapes being harvested.

2.4.2.4 Grape Ripening

As a grape progresses from unripe to a "mature" state, certain characteristics change. Flavours evolve from green to herbal to red fruit to black fruit to jammy (Long, 1997). The grape texture changes from crisp to juicy to jammy. Berry skins become thin, and extractability and flavour characteristics increase. Tannins change from astringent to soft and the colour of the seeds change from green to brown.

Figure 2.23 indicates the ripening process of a grape berry. This process is characterised by a double sigmoid curve comprising four phases (Archer, 1981) – two phases in the first period of growth and two phases during the second. Each phase represents the chemical and physiological changes of a berry as it moves towards maturity.

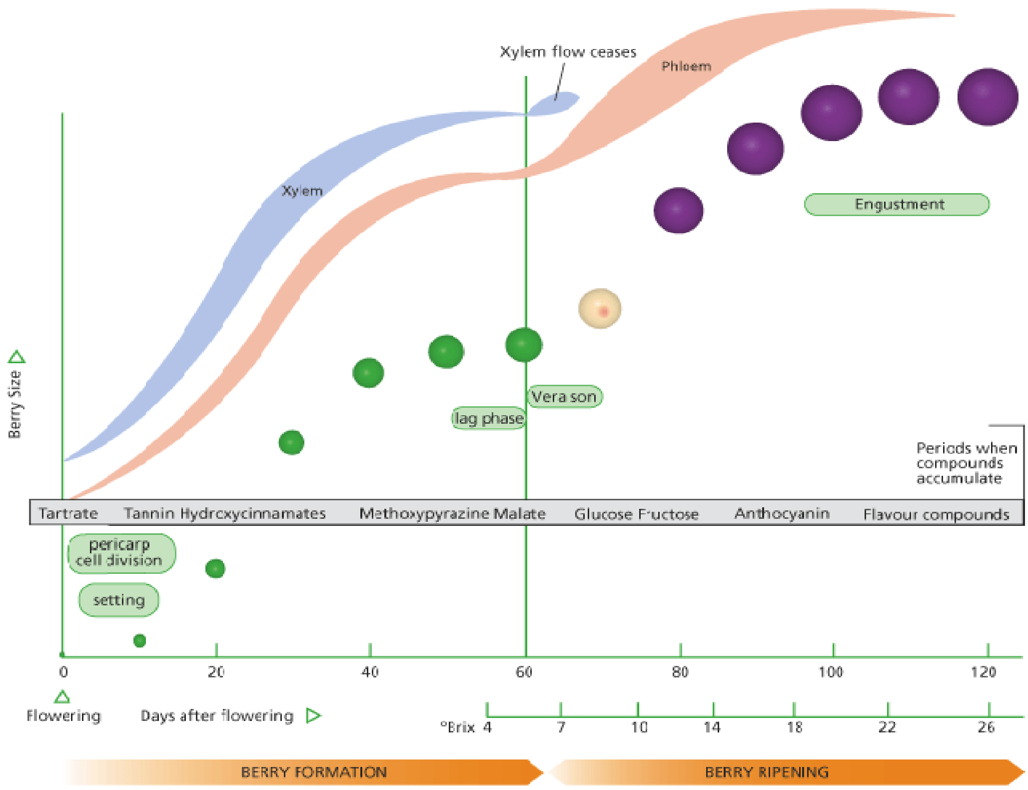

Figure 2.23: The ripening process of a grape berry (Kennedy, 2001).

<u>First Growth Period</u>

Phase one is characterised by berry set, during which an increase in mass is slow due to the slow development of the embryo (young berry) (Archer, 1981). *Phase two* experiences a rapid increase in berry size and mass, during which growth of the seed and pericarp takes place, while little development of the embryo occurs (Mullins *et al*., 1992). The rapid increase in size is as a result of cell division that is followed by a period of rapid cell enlargement. During this period the berries are green and hard due the accumulation of organic acids. These organic acids are measured as “titratable acids” or TA. Several solutes accumulate in the berry during the first growth period, among them tartaric and malic acid.

Tartaric and malic acid are distributed differently in the berry, with tartaric acid concentrations being the highest on the outside of the berry and malic acid concentrations being at their highest levels in the flesh (Kennedy, 2002). It also appears that tartaric acid accumulates during the initial stages of berry development and that malic acid accumulates just before véraison. Both of these acids are important for the production of good quality wines, because they provide the wine with acidity.

Tannins are present in the skin, seed and, to a much lesser extent, the flesh of a grape berry (Kennedy, 2002). Tannin concentrations are important, as they determine whether a red wine, in particular, will be expressed as bitter and astringent or soft and smooth.

During *phase three*, a “lag period” is observed. The duration of the “lag phase” will depend on a variety’s genetic make-up.

<u>Second Growth Period</u>

Phase four is characterised by the onset of berry ripening (véraison). Berries start to soften and change colour from green to yellow or red, depending on the type of cultivar. Berry mass and volume increase due to cell enlargement and not cell division, as is observed during phase two (Archer, 1981). During phase four, the sugar content of the berries increases, acidity decreases, pH increases and cations accumulate in the berry tissue (Watson, 2003).

Sugar is imported from the photosynthesising leaves via the phloem vascular system, in the form of sucrose, to the grape berry. The role of phloem is limited in the beginning of berry development, but it becomes the primary source of influx after véraison (Kennedy, 2002). Once the sucrose is transported into the berry, it is hydrolysed into glucose and fructose. The concentrations of glucose and fructose are determined by the length of time the grapes stay on the vine. The longer grapes remain on the vine, the higher the concentration levels of fructose become and the lower the levels of glucose.

Xylem transport of water and solutes is also important in the initial stages of berry development. This is a vascular system that transports water, minerals, nutrients and growth regulators from the root system to the upper parts of the vine. It appears, as reported by Kennedy (2002), that xylem is important at the beginning of berry development, but that its function is reduced or eliminated after véraison.

The phenolic composition of a berry’s skin changes during véraison, it loses chlorophyll and begins to synthesise and accumulate phenolic compounds that are responsible for the development of characteristic colours: yellow-gold (flavonols) and pink and red colours (anthocyanins) (Watson, 2003). Anthocyanins are especially important for the production of a wine rich in colour.

Berry seeds, as mentioned earlier, undergo physical changes concerning their phenolic composition as they turn from green to brown. The tannin concentration of the seeds decreases as the degree of phenolic polymerisation increases. This is why the tannins of unripe grapes are described as harsh and astringent, while the tannins of mature grapes are described as soft and smooth.

Berry stems also undergo dramatic changes as the fruit reach maturity. The stems turn from unripe green to brown, or ripe stems change to overripe or brittle (Bisson, 2001) and decrease in character from green to herbaceous (Watson, 2003). The changes in stem colour and physical properties are specific to a variety. It is believed (as reported by Bisson, 2001) that stem ripeness runs parallel to berry maturity. Stems that are still perceived as unripe might introduce undesirable components to the wine and, in doing so; affect wine quality (Table 2.5).

Table 2.5: Stem flavourant composition (Bisson, 2001).

Status	Colour	Characteristics
Unripe	Green	Vegetal, leafy
Ripe	Brown	Resinous wood, spice: cloves, cinnamon, pepper
Over-ripe	Brittle brown	Dried leaf, tea, herbal

2.5 CONCLUSION

Vineyard variation is a common occurrence in vineyards the world over. This variation has been seen in the past as “part of a block” and was managed as such. Only in recent years have researchers and grape growers alike realised the potential entailed by this within-vineyard variation. Different wine styles can be produced from a single block of vines by simply adjusting certain managerial actions and decisions. By deciding when to harvest, grapes that vary in composition and character can be obtained, each harbouring unique characteristics that will be placed in a bottle that might give rise to different brand ranges.

Different levels of variation can be identified. These range from macro-variation (regional variation), to meso-variation (topographical variation) and finally to micro-variation (canopy and canopy climate variation). Each level has an influence on the vine and the fruit it produces.

Within-vineyard variation is caused by various factors that have a direct impact on the wellbeing of a vine. These causes can range from soil and environmental variation to varying managerial inputs. The soil and the environment are the two factors that cannot be changed and thus force the grape grower to plan around them in an effort to utilise the potential beneficial effects or to try and avoid any negative aspects that these factors might cause. By performing certain managerial actions or not performing them at all, “managerial variation” can lead to vine variation.

It would seem that variation only occurs in the aboveground structure of the vine because it is visible; however, the fact remains that the entire vine, including the roots, is subject to variation. Archer and Hunter (2004) noted that a quality canopy is directly related to vine quality and, for this to be true, the vine must also possess a solid root system that can support the aboveground structure. With the aid of modern technology such as remote sensing, grape growers are able to identify within-vineyard variation. By identifying different areas, strategic managerial inputs can be targeted at those areas that need specific attention. Remote sensing technology is thus a helpful tool for the modern grape grower due to its ability to identify within-vineyard variation and, thereby, help the grape grower to make educated decisions.

For a vine to perform as optimally as possible it must possess five balances. These balances are (Archer & Hunter, 2004) i) aboveground and subterranean growth; ii) fine and thick (superficial and deep) roots; iii) left and right cordon arms; iv) shoot growth and yield; and v) young and old leaves. The one balance that incorporates all the above is the vegetative/reproductive balance (Figure 2.24).

From Figure 2.24 it is clear that vegetative and reproductive growth play an immense role in determining wine quality, with the more prominent of the two probably being the vegetative growth. When a vine experiences low vigour it will probably have a lighter crop load, an earlier ripening period and might suffer from a lower level of stress during the post-harvest period due to a small number of leaves that can cause water loss through transpiration. High-vigour vines will probably have a bigger crop load, a delayed ripening date and might suffer from a higher stress level during the post-harvest period through transpiration, primarily because of the large canopy surface area available for the process. If the crop load is high or low, it can have a certain effect on the chemical composition, morphology and ripening of the grapes. The number of grapes on a vine is thus an important aspect when it comes to determining grape composition and quality.

It is very important to take note of the various factors that will influence the vine and try to manage around them or to exploit the factors causing variation in order to optimise vine production, while also producing good quality fruit. Eventually the main focus of the grape grower is to produce ample amounts of quality fruit for the production of quality wine in order to return a profit to the farm.

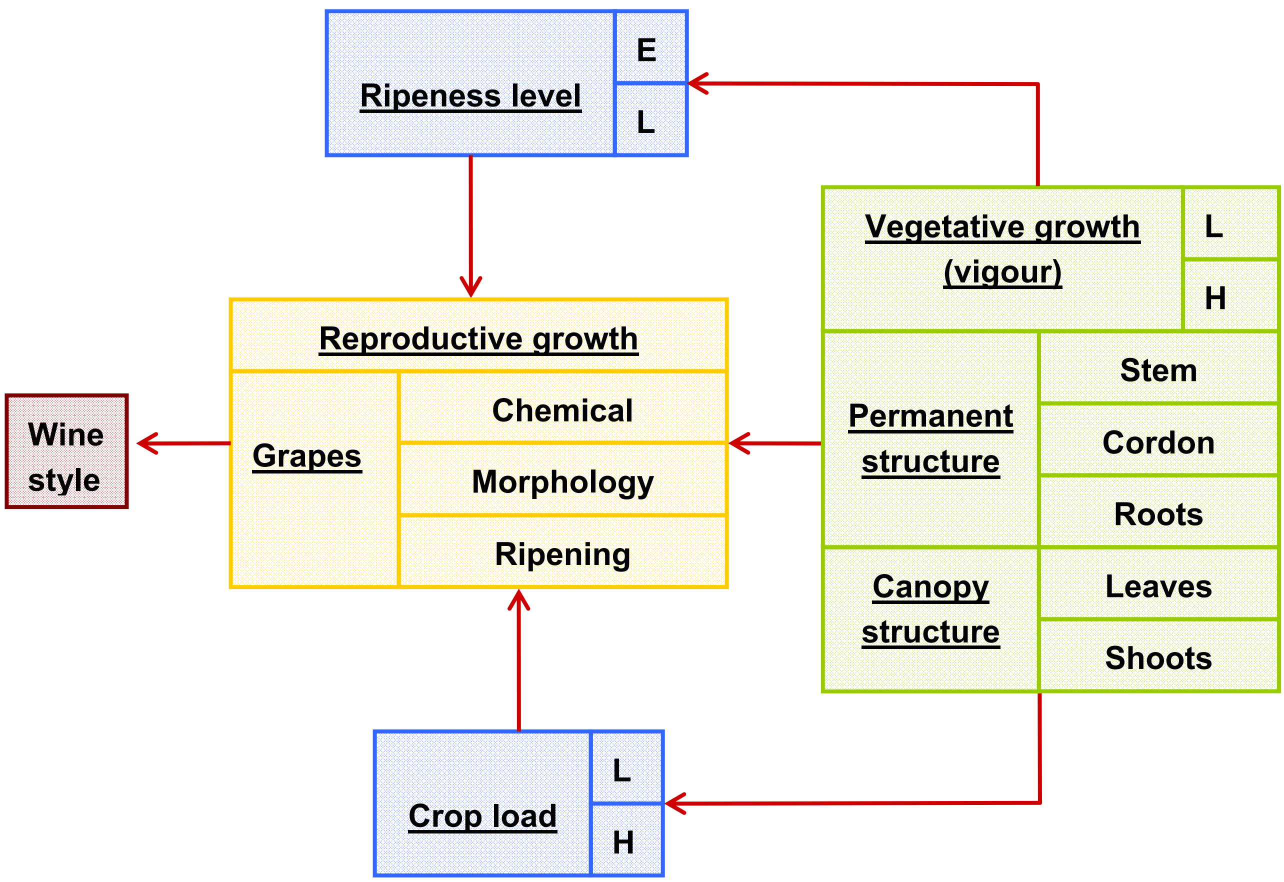

Figure 2.24: A simplified diagram of how the vegetative and reproductive parts of a vine intertwine.

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Chapter 3

RESEARCH RESULTS

A study of the interaction between vine vigour and crop level and their effect on grape and wine characteristics

RESEARCH RESULTS

3.1 ABSTRACT

The financial wellbeing of any farm, in this case a vineyard farm, is linked to the amount of produce that it produces, the quality of the produce and the cost of production. Commercial grape growers that deliver their produce to large wine companies or cooperatives are paid per ton, while wine estates receive returns per bottle sold locally or internationally. Commercial “large company/cooperative” grape growers will try to produce as many grapes as possible in order to gain financially, while commercial wine estates will try to produce the best quality fruit to gain financially through the sale of premium quality wine, even if it means that crop reduction has to be carried out. Crop load is an important yield component in the production of quality grapes and the need for crop reduction is often exaggerated without proper knowledge of the impact on vine structure, grape composition and wine characteristics. Remotely sensed multispectral imagery was used to identify three different vigour levels within a block of Shiraz on the lower slopes of the Simonsberg Mountain in the Stellenbosch region. These three vigour categories were subjected to three cluster-thinning actions, namely a control (no bunch removal), and 25% and 50% reduction in bunch number. Vegetative and reproductive measurements pointed out differences between the various vigour levels. Different aroma and flavour characteristics were found in the wine made from the different vigour/crop thinning treatments.

3.2 INTRODUCTION

The quantity and quality of a vintage determines the financial wellbeing and long-term survival of a farm. The bigger the yield, the more bottles of wine can be produced. The key to success does not lie solely in the production of large yields, however, but in the production of large yields of the best possible quality, while at the same time trying to minimize production costs.. It is no use to produce large amounts of grapes per hectare if the grapes are of such poor quality that they can only be used for the production of distilled wine or grape juice.

Crop thinning, according to Winkler *et al*. (1962), is the removal of flower clusters before flowering and of immature clusters or parts of such clusters after the fruit has set. *Flower cluster thinning* is done before flowering takes place, by simply removing the number of flower clusters without changing the number of leaves. With this increase in leaf area to fruit mass ratio, flowers on the retained clusters are better supplied with photosynthetic substrates that are manufactured in the leaves. The leaf-to-fruit ratio is considered to be an important factor influencing grape total soluble solids as well as other components. For a gram of fruit to ripen fully, it needs approximately $12cm^2$ of leaf area (Smart & Robinson, 1992). A larger leaf area to fruit mass ratio is favourable for fruit development (Winkler, 1954). According to Archer (2001), white cultivars need 16 to 20 leaves per shoot for grapes to ripen optimally and red cultivars need 20 to 26 leaves per shoot. Crop thinning, if performed moderately, can therefore increase quality due to an increase in the ratio of leaves to fruit. If too many grapes are removed, the vine can react by favouring vegetative growth because of the reduction in sources (grapes) and an increase in the level of reserves that can to be stored and later released. Another way in which the vine can react to a reduction in yield is by lowering the photosynthetic rate of the leaves on the basis of the reduction in the demand for substrates. The remaining grapes could struggle to ripen as a result of this reduction in leaf function, which may lead to the vine itself going into a state of stress.

Cluster thinning entails the removal of entire clusters after berry set has occurred. This practice is usually performed after véraison in order to identify and remove poorly coloured clusters. *Berry thinning* is another way in which crop reduction can be applied to reduce yield. It is performed by removing part of a bunch and, in the process, to form a bunch that has a unique shape. This type of thinning is mainly performed on table grapes, where bunches need to look appealing to the consumer.

Van Schalkwyk *et al.* (1995) reported that if bunch removal was applied pre-bloom or at bloom, yield compensation would occur in large-cluster varieties (such as Chenin blanc or Shiraz), while varieties with smaller bunches would compensate to a lesser extent. If crop thinning is applied moderately after flowering, yield will not be reduced, due to an increase in berry size and the number of berries per cluster (Bravdo *et al.*, 1984). Maximum crop reduction will be obtained when bunches are removed after véraison, because cell division and growth end at this stage.

According to Winkler *et al.* (1962), crop level is the most important factor influencing grape ripening, a factor that can be manipulated through the retention or removal of grapes. An important fact that grape growers must realise is that a vine can only produce a certain amount of fruit. Forcing it to carry more than it is capable of maturing will only lead to the production of grapes of inferior quality. Crop thinning makes it possible to grow as many grapes as the vine can bear, without sacrificing quality (Winkler *et al*., 1962).

It is traditionally believed that vineyards producing low yields tend to produce high-quality wines (Ross, 1999; Van Schalkwyk *et al*., 1995), while in actual fact high-quality wines are produced from high-yielding vines in the Bordeaux and Burgundy areas (Ross, 1999). The big question remains: Do low- or high-yielding vines produce the best quality? In order to answer this question, it is important to look at a vine's capacity. If the vine has developed a proper aboveground and subterranean structure, why will it not be able to ripen a crop of a substantial size?

Crop load experiments that have been carried out in the past seldom mention the vigour level of the vines (whether it be low, medium or high). Performing different crop-thinning actions might have an effect on the chemical composition and subsequent type of grapes produced. If vigour is incorporated into the equation with different crop levels, what will the end result be? Will the wine from vines with low vigour and a certain crop produce better or lesser quality wine than a medium- or high-vigour vine with the same crop?

With the aid of modern technology such as remote sensing, various vigour plots can be identified within a vineyard block. Before crop thinning actions can be performed, it is important to establish the different vigour levels and subsequent capacity of the vines in a block. Different levels of vigour with different levels of crop thinning (if any) could produce fruit of a certain quality that might give a farm a competitive edge over its rivals on the international wine market. By performing crop thinning when it is needed, for instance on weak, underdeveloped vines, the grape grower will not only improve the quality of the fruit produced, but will also improve the overall structure (above and subterranean) and lifespan of the vines.

Now that the grape grower is able to identify and manage various vigour levels, different combinations of vigour levels and crop loads within a vineyard can now be evaluated in order to quantify possible interactions between these two factors.

The main aim of this project was to evaluate the effects manipulation of vine crop level will have on the reproductive and vegetative balance of the vines from different vigour levels within a vineyard, and assessing the effects on grape composition. It was also important to determine the underling causes of the vigour variability by performing a soil study.

3.3 MATERIALS AND METHODS

3.3.1 EXPERIMENTAL VINEYARD

A Shiraz block on the slopes of the Simonsberg Mountain in the Stellenbosch region was chosen for the study. The block is situated at an altitude varying from 395 to 400 m above sea level. It is planted on a South to South-Western slope on a Hutton soil type, according to the classification of MacVicar *et al.* (1977). Vines are grafted on 101-14 Mgt and have been trained according to an eight-wire vertical trellising system.

3.3.2 PLOT LAYOUT

Multispectral aerial images were obtained for the Shiraz block (Figure 3.1). The colour (RGB) channels are shown in the figure. White panels were placed in the vineyard before imagery took place to identify different vigour classes. Three distinctive vigour levels (low, medium and high) were identified with the aid of multispectral image classification.

Figure 3.1: RGB aerial image indicating positions of white panels used to delineate plots of differing vigour in the Shiraz block.

3.3.3 EXPERIMENTAL LAYOUT

Each vigour plot was represented by a rectangular block of 48 vines. The experimental plot stretched over four rows consisting of 12 vines per row. A randomised block design was followed with three treatments and sixteen replicates of 16 vines per treatment. The latter was performed for each vigour level. The three treatments performed over the two seasons consisted of 25% crop removal, 50% crop removal and no crop removal (control). Crop thinning in the 2004/2005 season was carried out at véraison, while it was carried out just after pea size in the 2005/2006 season. Thinning actions were based on cluster counts. All the clusters on the vines were counted, and clusters were removed randomly from the vine according to the number required for each treatment.

3.3.4 MEASUREMENTS

Soil Survey

Three soil pits were dug in the Shiraz block, with one soil pit at each vigour level. The pits were dug 40 cm away from a vine's trunk at a sufficient depth of 100 cm and a width of 120 cm. Soil samples were collected at three depths: 0-30, 30-60 and 60-90 cm. The micro- and macro-element content and the base saturation of the soil were determined for each sample by an independent laboratory.

The bulk density of the soil was determined by applying the core method specified by Blake and Hartge (1986). The core method was carried out by driving a cylindrical metal sampler into the soil to a desired depth. The cylinder was then removed carefully to preserve a known volume of the sample as it existed *in situ*. The sample was dried in an oven for 48 hours at 100˚C. The sample was then weighed and the bulk density was determined by dividing the oven-dried mass of the sample by the sample volume. The porosity levels at the various depths were determined simultaneously. Porosity is defined as the percentage volume of the soil occupied by pores and pore space (Van der Watt & Van Rooyen, 1990).

Excess soil was removed from the pit wall closest to the vine until approximately 20 to 30 cm of soil was left adjacent to the vine's trunk. This was done in an effort to expose the vine's roots. The roots were then sprayed white to allow discrimination from the relatively dark soil background. A grid was constructed against the pit wall to form a grid of 20 by 20 cm. Photographs were taken from the plotted grid to show the root distribution.

Vegetative Measurements

One shoot per cordon arm was randomly selected per vigour level and removed to enable shoot and leaf measurements. The leaf areas of the main and lateral leaves were determined by a LiCor LAI 3000 area meter. Shoot growth rate was also determined for the 2006 season. Measurements were ceased when frequent mechanical topping was carried out by the grape grower.

Berry Sampling

Berry sampling was performed throughout the season for each treatment. An average of 180 berries was randomly sampled each time. Berries were sampled from the inside and outside of the canopy, as well as from the top, middle and bottom parts of a bunch. This was done in an attempt to obtain a representative sample of each vigour area. One hundred berries were weighed and their volume was determined by adding them to a known amount of water in a measuring flask. The volume of water displaced was calculated and noted as berry volume per 100 berries. Fifty berries were sent for chemical analysis to an independent laboratory to determine malic and tartaric acid levels, as well colour (520 nm) concentration. These analyses were supplemented with standard analyses of total soluble solids, pH and titratable acidity using an ATAGO pocket refractometer and a 785 DMP Metrohm Titrino automatic titration instrument.

Winter Pruning

All the vines were pruned to two node spurs in the 2005 and 2006 season. Pruning mass per vine and the amount of canes per vine were determined for all the treatments. Pruning mass per vine was determined by tying all the pruned canes from a single vine together in a bundle and then weighing them with a spring balance.

Harvest

The grapes were harvested on the same day for the 2005 and 2006 vintages respectively (this procedure has already been discussed). The number of bunches per vine was counted and weighed. Grapes from the different treatments were placed together and microvinification was performed. Six bunches were sampled from each vigour level to determine bunch mass and volume. Berry sampling throughout the season was conducted by sampling berries randomly from vines in the various vigour levels. Berry sampling during harvest occurred by randomly selecting six bunches from the crates in which grapes from the various vigour levels had been placed. The values from the latter may therefore differ, being less representative of berry variation on a bunch and bunch variation on a vine, as well as because of variability between vines in a plot from a specific vigour level.

Microvinification and Sensory Analysis

Microvinification was performed as specified by the Department of Viticulture and Oenology, Stellenbosch University. Aroma and flavour differences were determined through sensory analysis. The tasting sheet was compiled with the aid of various aroma components, as specified by Noble *et al*. (1987). In order for the tasters to identify different aromatic compounds that might be present in the wine, calibration sessions were held. The Latin Square method of randomisation, as specified by Cochran & Cox (1950), was used in order to randomise each taster’s wine. Groups representing the same vigour level and various thinning treatments for the two vintages were placed together to enable easy interpretation. Different aroma and flavour characteristics were grouped in order to simplify interpretation.

3.4 RESULTS AND DISCUSSION

3.4.1 PLOT LAYOUT

The orthorectified multispectral aerial image of the trial vineyard was classified with the aid of a software application called “Orthoviewer”, using a Ratio Vegetation Index (RVI) (Infrared/Red). In order to distinguish between different vigour areas, a specific colour was allocated to each vigour area (see legend in Figure 3.2). White was allocated to areas of low vigour, green allocated to areas with medium vigour and blue allocated to high-vigour areas.

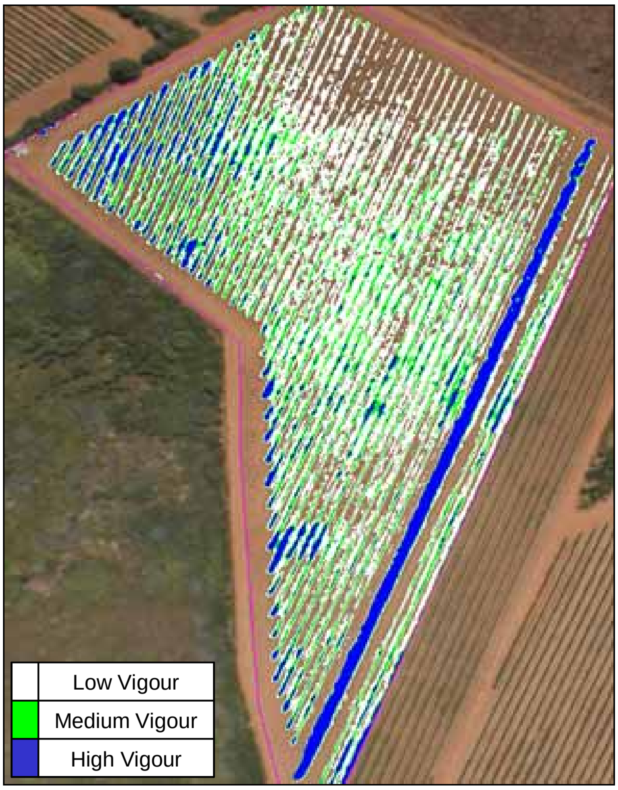

Figure 3.2: Classified multispectral image indicating vigour variation within a Shiraz block situated on the lower slopes of Simonsberg Mountain (see legend for classification).

3.4.2 SOIL SURVEY

3.4.2.1 Chemical Analyses

The results of the general soil analyses are depicted in Tables 3.1 to 3.4. Tests for micro- and macro-elements and base saturation, and mechanical analyses, were carried out. In addition, the bulk density and porosity of the soil were analysed on the recommendation of two soil scientists who questioned the mechanical analysis, specifically the clay percentage, analysed by the independent laboratory.

Table 3.1: Results of soil analyses of soils from the three vigour levels in the Shiraz vineyard.

Vigour Level	Depth (cm)	Soil type	pH (KCl)	Resist. (Ohm)	H^+ (cmol/kg)	Stone (Vol %)	P Bray II	K	Exchangeable cations (cmol(+)/kg)			
							mg/kg		Na	K	Ca	Mg
Low	30	loam	6	2110	0.45	3	6	115	0.07	0.3	5.68	0.32
	60	loam	4.8	2710	1.15	3	4	86	0.05	0.2	1.93	0.36
	90	loam	4.4	2680	1.81	5	5	51	0.04	0.1	0.66	0.39
Medium	30	clay	4.4	3260	1.61	4	6	30	0.1	0.1	1.7	0.13
	60	clay	4.5	3070	1.46	4	12	36	0.12	0.1	1.97	0.25
	90	clay	4.1	1740	1.36	2	2	32	0.07	0.1	0.87	2.12
High	30	loam	6.1	2220		5	5	125	0.04	0.3	3.77	0.41
	60	clay	4.7	3680	1.2	8	4	37	0.04	0.1	1.51	0.26
	90	clay	4.2	3930	1.46	7	2	26	0.03	0.1	0.72	0.33

Table 3.2: Results of micro-element and carbon analysis from soils from the three vigour levels in the Shiraz vineyard.

Vigour level	Depth (cm)	Soil type	Cu	Zn	Mn	B	C
			mg/kg				%
Low	30	loam	0.1	0.3	2.2	0.28	2.28
	60	loam	0.1	0.2	0.7	0.27	1.74
	90	loam	0.17	0.1	**0**	0.13	0.99
Medium	30	clay	0.17	0.2	1.1	0.15	0.64
	60	clay	0.19	0.3	2.7	0.18	0.62
	90	clay	0.22	0.3	2.8	0.19	0.09
High	30	loam	0.25	0.3	3.1	0.1	0.87
	60	clay	0.24	0.3	1.2	0.07	0.66
	90	clay	0.17	0.2	0.1	0.1	0.3

Table 3.3: Base saturation results from soils from the three vigour levels in the Shiraz vineyard.

Base saturation						
Vigour	Depth	Na %	K %	Ca %	Mg %	T-value cmol/kg
Low	30	1	4.31	83.43	4.65	6.81
	60	1.26	5.96	52.14	9.59	3.7
	90	1.35	4.32	21.77	12.95	3.04
Medium	30	2.78	2.12	46.95	3.62	3.62
	60	3.19	2.4	50.56	6.32	3.89
	90	1.48	1.81	19.38	47.06	4.49
High	30	0.82	7.04	83.06	9.08	4.54
	60	1.41	3.05	48.54	8.4	3.11
	90	0.97	2.53	27.54	12.72	2.6

Table 3.4: Mechanical analysis of the soils from the three vigour levels in the Shiraz vineyard.

Mechanical Analysis											
Vigour	Depth	Clay	Silt	Fine sand	Medium sand	Coarse sand	Stone	Class.	Water-holding capacity		
		%	%	%	%	%	% (v/v)		10 kPa %	100 kPa %	mm/m
Low	30	4.4	7.2	52.4	19.4	16.6	2.3	Sa	23.3	11	122
	60	5.2	7.8	51.1	19.2	16.7	2.1	LmSa	23.7	12	121
	90	7	11.6	46.9	19	15.5	4.6	LmSa	24.5	13	116
Medium	30	17.8	21.4	36.9	13	11	3.8	SaLm	31	19	116
	60	19.4	24	33.6	13.5	9.5	4.3	SaLm	31.7	20	113
	90	18.2	27.6	34.7	13.7	5.8	1.1	SaLm	33.8	22	121
High	30	14	17.6	42.7	16	9.7	4.8	SaLm	28.3	17	117
	60	20.2	20	36.2	13	10.6	7.7	SaClLm	29.7	19	109
	90	23.2	19.4	32.9	12.7	11.8	6.5	SaClLm	30.3	20	106

3.4.2.2 Bulk Density and Porosity

Richards (1983) indicates that a vine's roots will readily penetrate the soil at a bulk density of 1.1-1.2 g/cm² and that root penetration markedly declined at values greater than 1.5g/cm³. This was verified by Hoffman (2006, personal communication), according to whom a realistic bulk density favourable for vine root penetration is found at 1.3-1.5 g/cm³, with any value greater than 1.5 g/cm³ being regarded as compacted.

Figure 3.3 shows the different bulk densities of soils at the different vigour levels. Low bulk densities are to be found for the soils at each vigour level for the first two depths, ranging from 0-30 cm and 30-60 cm. At the third depth levels, that of 60-90 cm, the medium-vigour level showed a significantly greater increase in bulk density. This could be ascribed to a high percentage of clay at that depth, as can be seen from the low porosity level indicated in Figure 3.4. The high-vigour level also displayed higher bulk density levels at the 60-90 cm depth, but not as significant as that of the medium-vigour level. The low-vigour level displayed low bulk density and high porosity levels throughout the entire soil profile. As a result of the low bulk density and high porosity levels for all the vigour levels at the different depth levels, good root penetration and distribution was favoured, and is also visible. Due to a well-developed root system, the above ground structure was also fully developed with a canopy characterised by a strong shoots and large leaves.

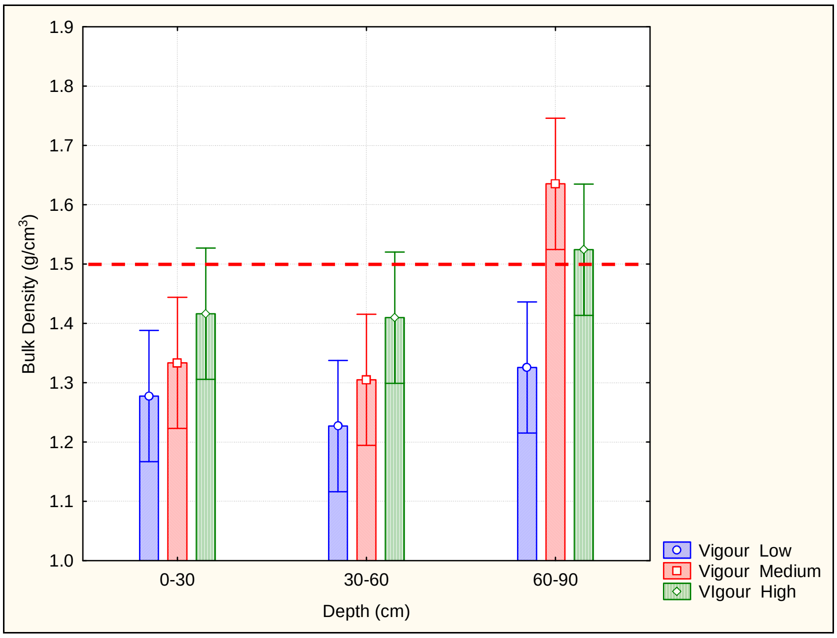

Figure 3.3: Factorial ANOVA of the bulk density, at three depths of the various vigour levels (low, medium and high) in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

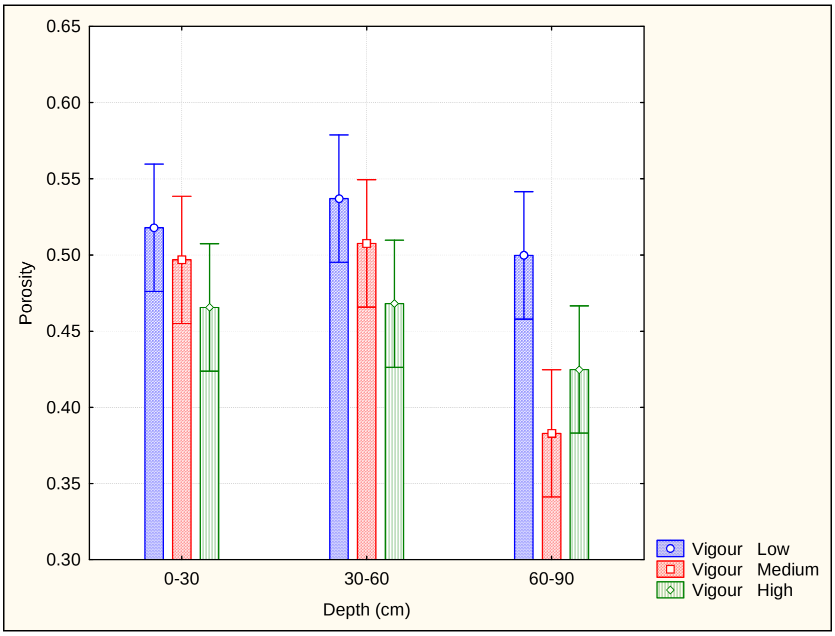

Figure 3.4: Factorial ANOVA of the porosity level of the different vigour levels (low, medium and high) at three specified depths in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.).

3.4.3.3 Root penetration and distribution

Root penetration and distribution were evaluated with the use of photos that had been taken in the various profile pits (see Addendum A).

Low vigour: An interesting observation that can be made from the low-vigour soil pit is that the roots are well distributed throughout the whole soil profile. The large numbers of thin roots indicate low bulk densities (Figure 3.3) and high porosity levels (Figure 3.4) in the first 60 cm, from where the number of roots decline due to an increase in bulk density and a decrease in porosity. A decline in root numbers can also be ascribed to very low pH levels in the deeper soil levels, ranging from 4.8 to 4.4 (Table 3.1). Conradie (1988) has shown that, for a vine root to penetrate the soil effectively, a pH of at least 5.5 is required.

Medium vigour: Roots are also well distributed in the medium-vigour soil pit. A large network of fine roots in the 0-60 cm level indicates low levels of bulk density (Figure 3.3) and high levels of porosity (Figure 3.4). From the 60 cm depth downwards, root numbers decrease due to an increase in the percentage of clay, which leads to high bulk density and low porosity levels. The pH levels at a depth of 60-90 cm are very low, at 4.1 (Table 3.1), also contributing to the decrease in root number and penetration.

High vigour: A network of fine roots is visible throughout the entire soil profile as a result of a “crumbly/loose” soil structure that enables easy root penetration. This loose soil structure is supported by the low bulk densities and high porosity levels up to a depth of 90 cm, from where the number of roots decreases. Low pH levels of 4.7 and 4.2 in the subsoil (Table 3.1), accompanied by high bulk densities and low porosity levels, can be seen as the main reasons for a low number of roots in this zone.

3.4.3 VEGETATIVE MEASUREMENTS

The main and lateral leaf area were determined for the 2005 and 2006 seasons. Figures 3.5 (2005 season) and 3.6 (2006 season) indicate the differences in leaf area for the various vigour areas. During the 2005 season, the main leaf area per vigour level showed the expected result, with the high-vigour vines having the largest main leaf area of all the vigour levels. In the 2006 season, the high-vigour vines had a higher lateral than main leaf area. This could possibly be ascribed to frequent mechanical topping that was performed by the grape grower. Shoots in the high-vigour area grew very vigorously and might have reached a certain length, causing them to be topped, while the shoots of the low- and medium-vigour areas were shorter and were only tipped, if tipped at all.

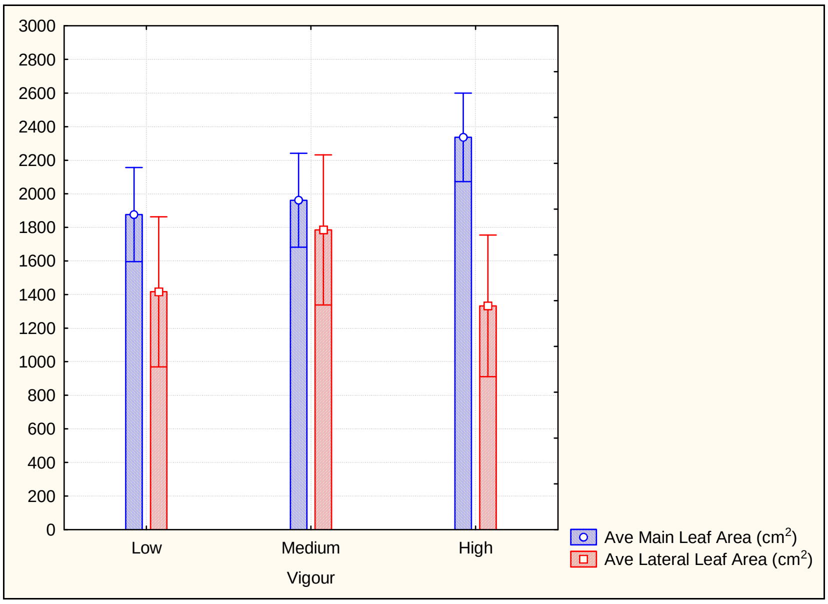

Figure 3.5: One way ANOVA of the average main and lateral leaf areas for the 2005 season to distinguish between the different vigour levels in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

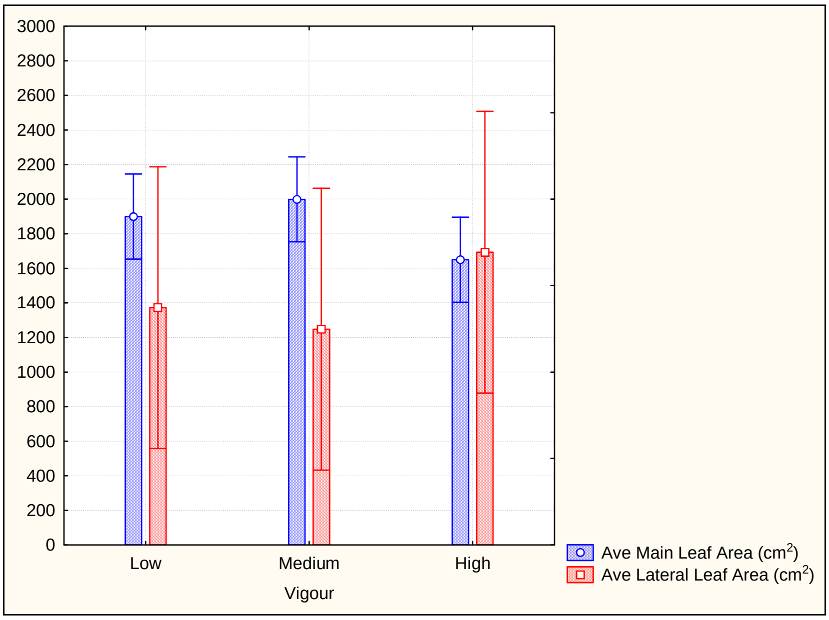

Figure 3.6: One way ANOVA of the average main and lateral leaf areas for the 2006 season to distinguish between the different vigour levels in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

Figures 3.7 and 3.8 indicate the difference in main shoot length in the Shiraz vineyard during the two consecutive seasons. The medium-vigour vines had shorter main shoots than the low- and high-vigour vines in the 2005 season. The reason for the high-vigour vines having a certain length can be ascribed to frequent topping actions performed by the grape grower, causing the shoots to be cut off at a certain length. The 2006 season produced the expected results, namely with the shortest shoot lengths on the low-vigour vines and the longest shoots on the high-vigour vines.

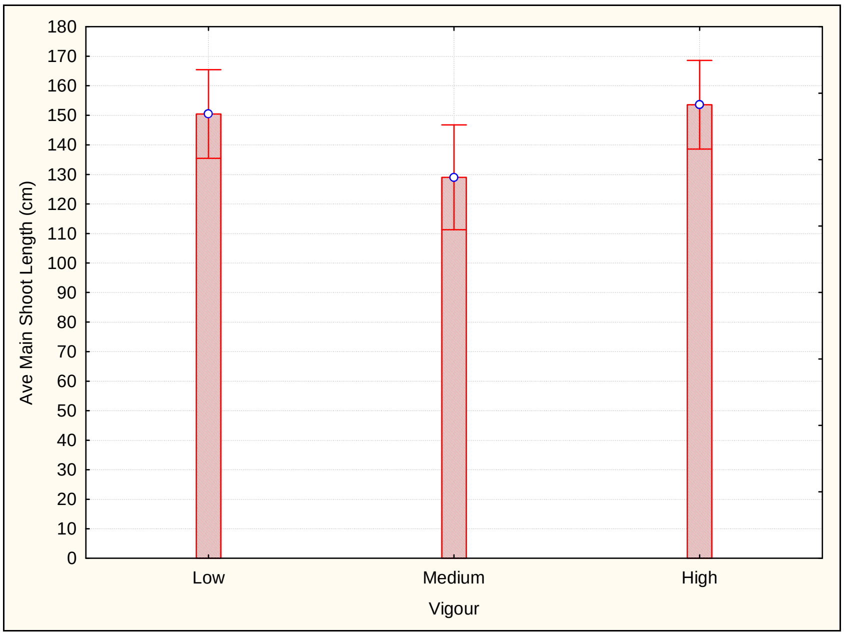

Figure 3.7: One way ANOVA of the main shoot length for the various vigour levels during the 2005 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals; p= 0.0881.)

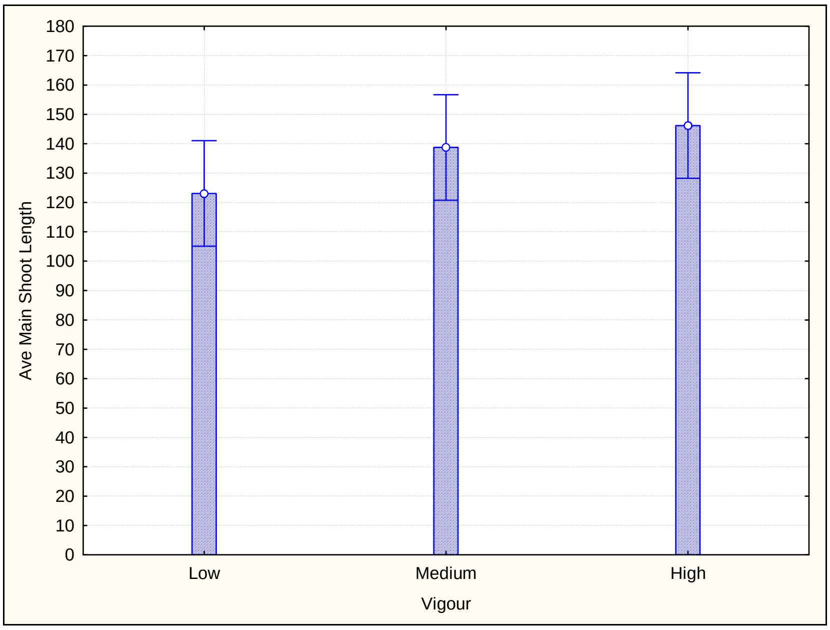

Figure 3.8: One way ANOVA of the main shoot length for the various vigour levels during the 2006 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals; p= 0.1660.)

Shoot growth was monitored during the 2005/2006 season to give an indication of how it varied between the different vigour levels (Figure 3.9). All the vigour levels experienced a steady increase during the season, with the low-vigour level experiencing faster growth than the other vigour levels up to a certain point, from which the high-vigour levels had the highest growth rate and ended up with the longest shoots. The cause of the decline in shoot growth for the low vigour vines might be stress conditions occurring due to an insufficient moisture supply caused by drainage due to the high sand and low clay content of the soil in this area, or through irrigation irregularities. Notwithstanding the tendencies of shoot growth, no significant differences could be detected at the end of the season between the vigour levels.

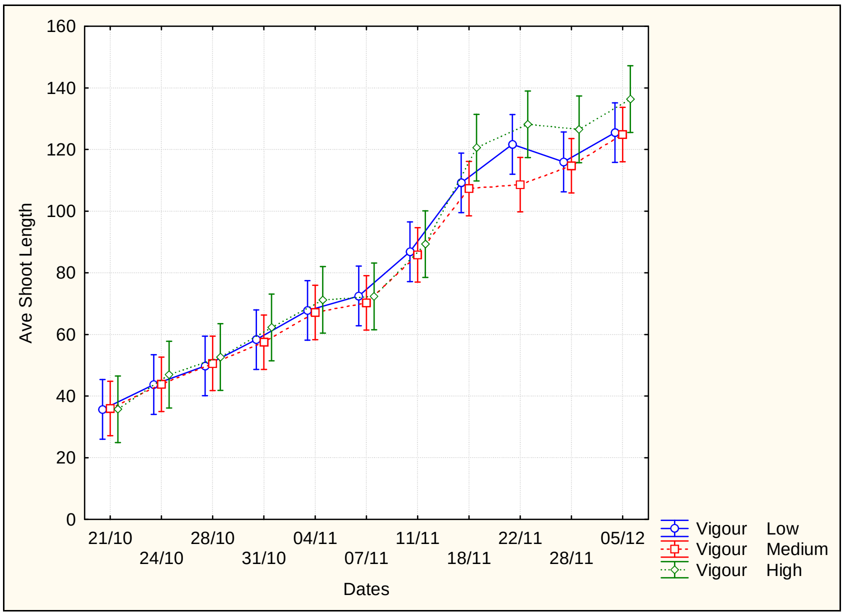

Figure 3.9: Repeated measurements ANOVA of shoot growth during the 2005/2006 season for the various vigour levels in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

3.4.4 CROP THINNING

The 2005 season (Figure 3.10) had no significant differences between the various vigour levels concerning the number of bunches per vine, with the medium-vigour vines having almost as many bunches as the high-vigour vines and the low-vigour vines having the least. In the 2006 season, the number of bunches per vine at the various vigour levels (Figure 3.11) increased significantly from that of the 2005 season, with the medium- and high-vigour vines having significantly more bunches than the low-vigour vines.

All the vines in a block can technically have the same number of bunches per vine, but as soon as the various vigour levels are specified, bunch number can vary. The reason for the low-vigour vines having the lowest bunch number could be the stress conditions to which they were subjected. Stress conditions can have a profound influence on bud fertility. The medium-vigour vines from both vintages had almost the same number of bunches per vine than the high-vigour vines. The high-vigour vines, having larger leaf areas and more vigorous growth, still have fruitful buds.

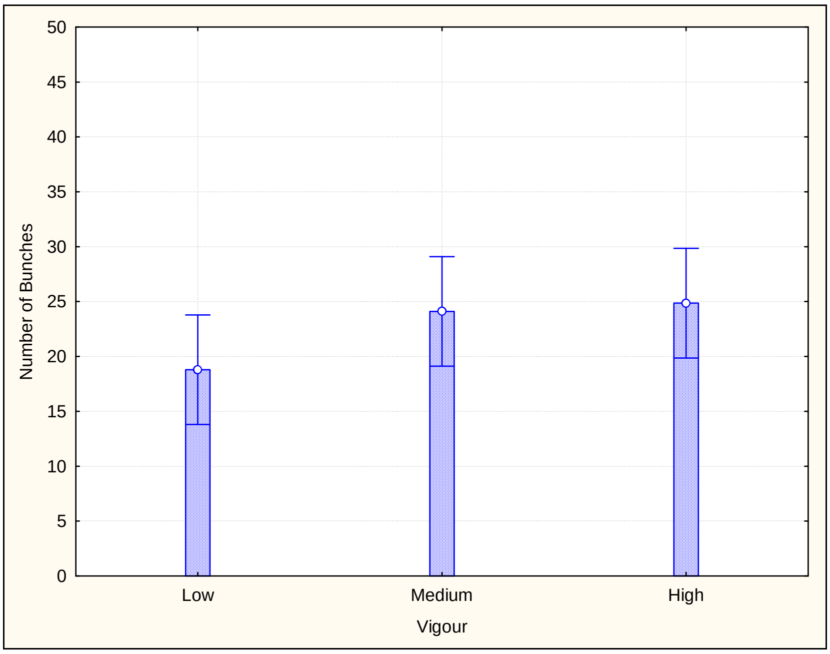

Figure 3.10: One way ANOVA of the number of bunches per vine for the different vigour levels (low, medium, and high) during the 2004/2005 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals; p= 0.1842.)

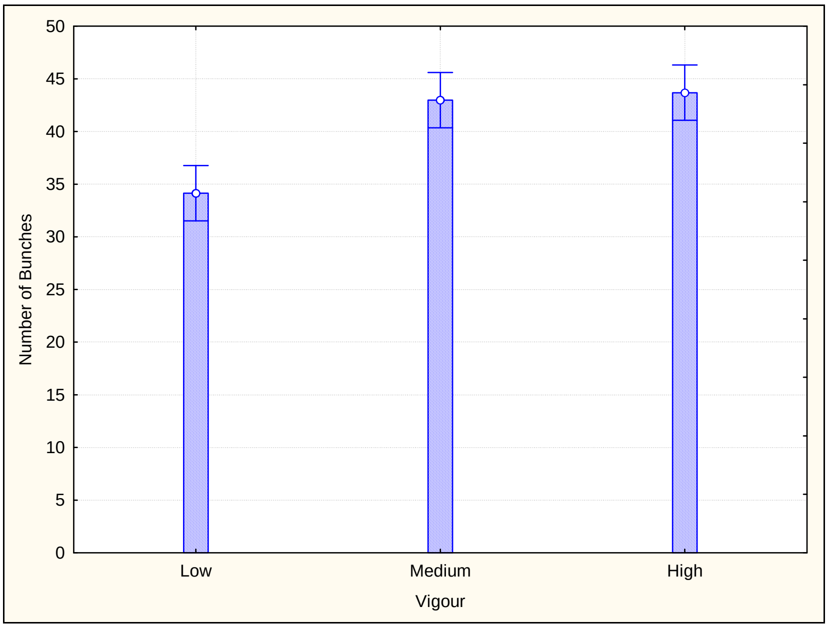

Figure 3.11: One way ANOVA of the number of bunches per vine for the different vigour levels (low, medium, and high) during the 2005/2006 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals; p= 0.0000.)

If the various vigour levels and crop thinning treatments are compared (Figures 3.12 and 3.13) for the two seasons, the low vigour vines had the least number of bunches per vine, while the high vigour vines had the most. An interesting result was that of the 25% crop-thinning treatment for the medium vigour vines in the 2006 season, which had a greater number of bunches than the high-vigour vines. The reason for the control treatment of the 2004/2005 season not having a value for the number of bunches, was that due to experimental error, the bunches per vine were not counted.

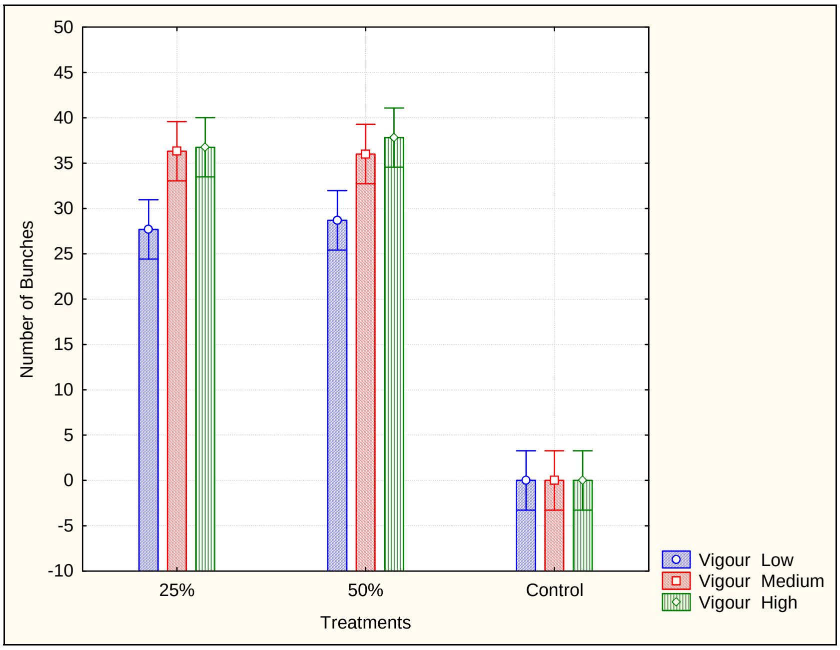

Figure 3.12: Factorial ANOVA of the number of bunches per vine for the different vigour (low, medium and high)/crop thinning treatments (25%, 50% and control) during the 2004/2005 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

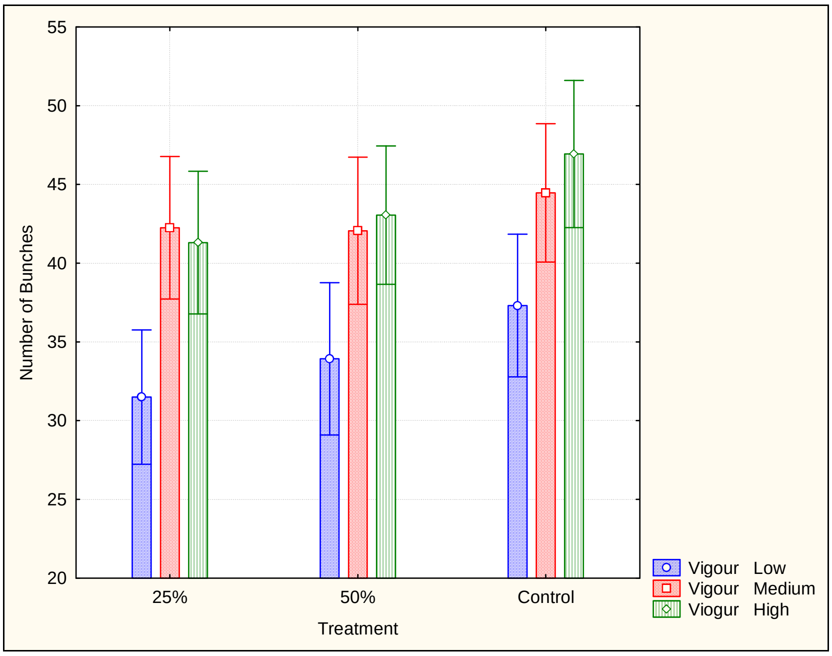

Figure 3.13: Factorial ANOVA of the number of bunches per vine for the different vigour (low, medium and high)/crop thinning treatments (25%, 50% and control) during the 2005/2006 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

During the 2004/2005 season, the average bunch mass removed in the crop-thinning treatments of the medium-vigour vines was higher than that of the low- and high-vigour treatments (Figure 3.14). However, this effect was not visible during the 2005/2006 season (Figure 3.15). The average bunch mass removed in the 2005 season was also significantly higher than that of the 2006 season. Bunch mass across the various vigour areas in the 2006 season showed an expected trend, with low-vigour vines having the lowest bunch mass and the high-vigour vines having the highest.

A possible explanation for the high bunch mass of the 25% and 50% thinning treatments of the medium-vigour vines is that this vigour level compensated for the reduction in crop load by increasing the average bunch mass, although the low- and high-vigour levels also followed this trend (but to a lesser extent).

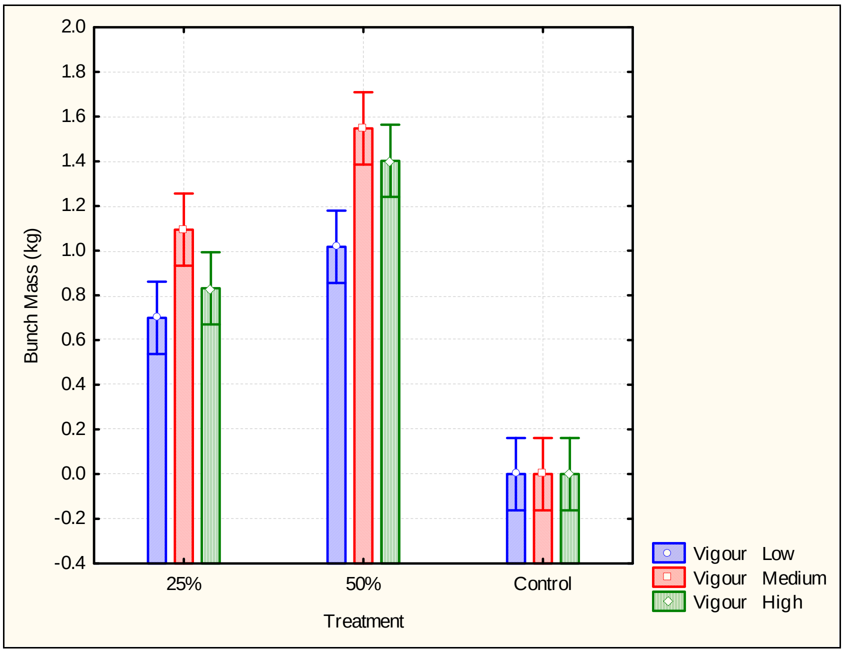

Figure 3.14: Factorial ANOVA of the bunch mass removed per vine for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) during the 2004/2005 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.)

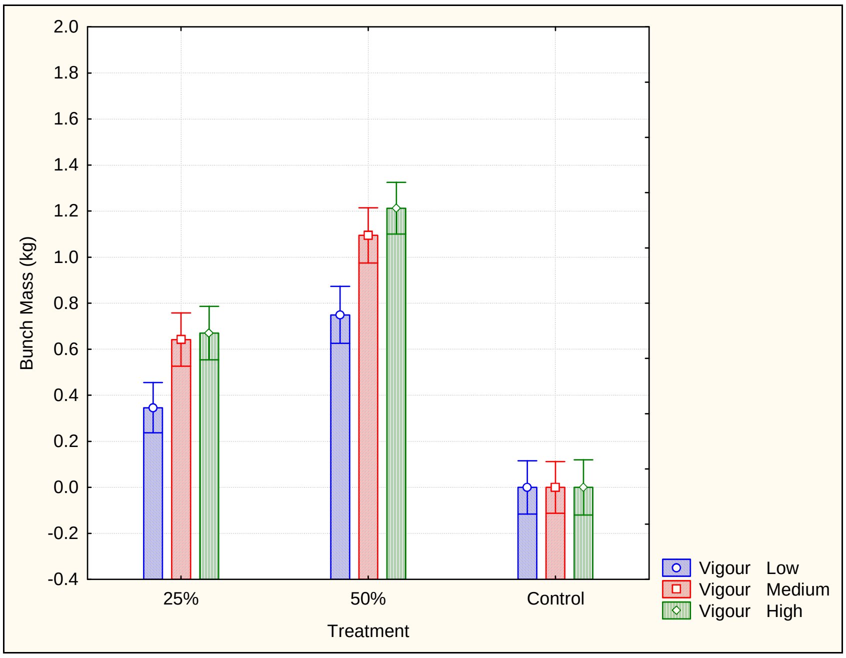

Figure 3.15: Factorial ANOVA of the bunch mass removed per vine for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) during the 2005/2006 season in the Shiraz vineyard. (Vertical bars denote 0.95 confidence intervals.) .

3.4.5 BERRY SAMPLING

Berry mass increased steadily throughout the season, and then seemed to stabilise for a while before increasing dramatically for the low- and high-vigour vines (Figure 3.16). It would seem that the 25% thinning treatment had an increasing effect on berry mass for the various vigour levels, with the high vigour vines having the highest mass per 100 berries. The 50% thinning treatment also caused a reduction effect in the low- and medium-vigour vines up until harvest.

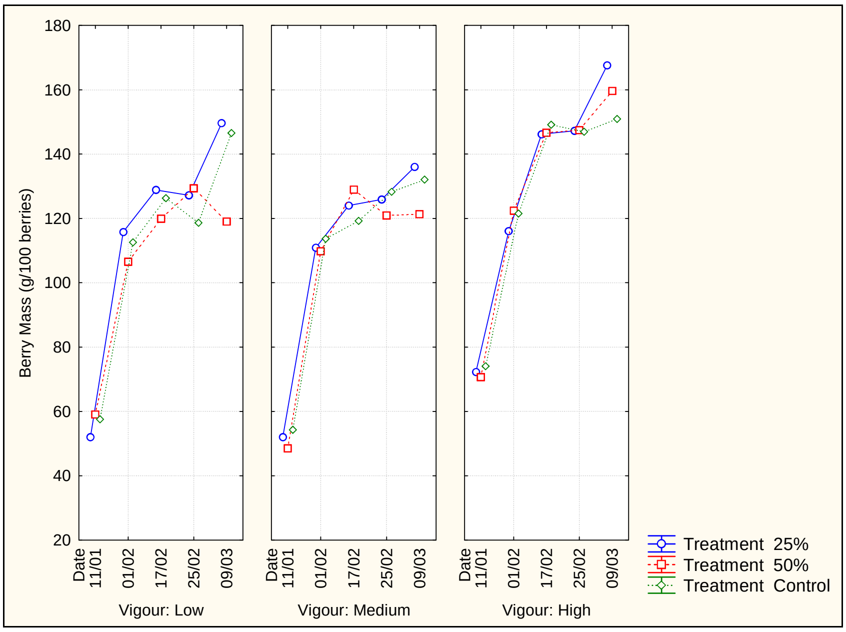

Figure 3.16: Graphs indicating trends in the change of grape berry mass during the 2005/2006 season for the different vigour (low, medium and high)/crop-thinning treatments (25%, 50% and control) in the Shiraz vineyard.

Berry volume (Figure 3.17) increased steadily throughout the season for all the vigour levels. The 25% crop reduction and control vines of the high-vigour level experienced an increase in volume during the whole season, while the low- and medium-vigour vines experienced a reduction in berry volume until harvest. The high-vigour control vines experienced a decline in berry volume just before harvest and the high-vigour 25% treatment ended up with the largest berry volume.

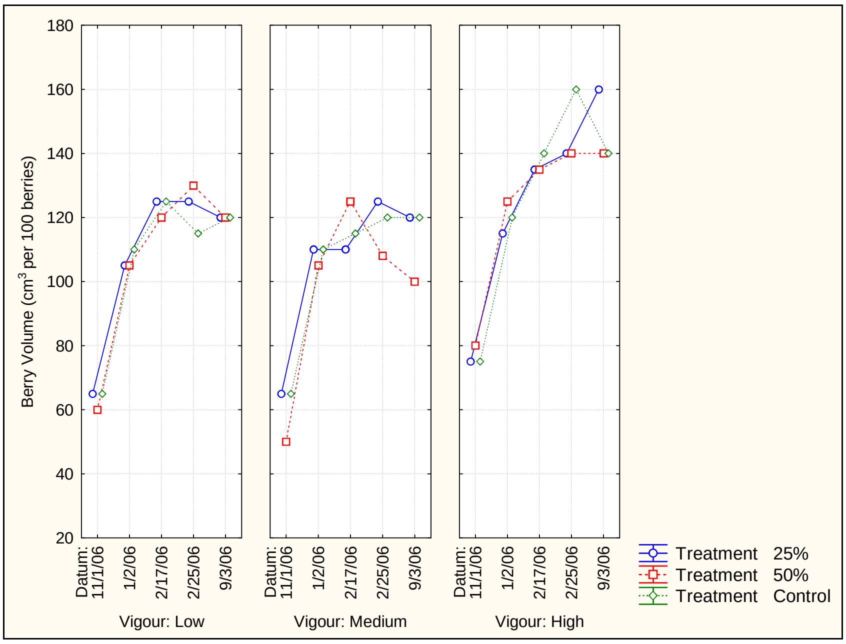

Figure 3.17: Graphs indicating trends in the change of grape berry volume during the 2005/2006 season for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard.

Crop thinning had an effect on the sugar content of especially the low- and high-vigour vines (Figure 3.18), whereas only the 50% treatment had an effect on the sugar accumulation of the medium-vigour level. Crop thinning might have caused an increase in sugar content in some vigour levels, but it also caused a general increase in pH (Figure 3.19). This effect is especially visible in the 50% thinning treatment for all the vigour levels. The low-vigour level was especially affected by the 50% crop thinning treatment, resulting in the highest pH levels of all the vigour levels at harvest. The 25% thinning treatment for the high-vigour level had the most favourable pH for winemaking purposes, as well as the most favourable acid levels (Figure 3.20).

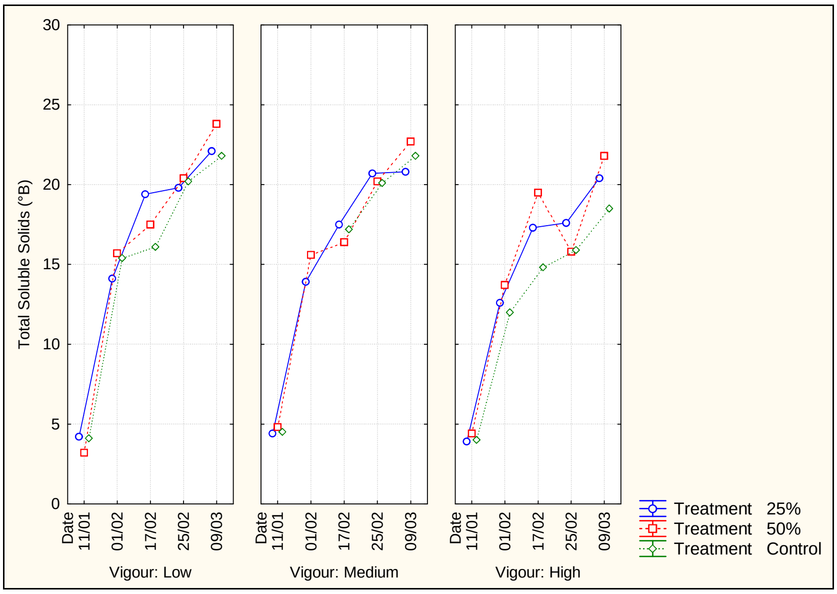

Figure 3.18: Graphs indicating trends in the change of sugar accumulation for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) during the 2005/2006 season in the Shiraz vineyard.

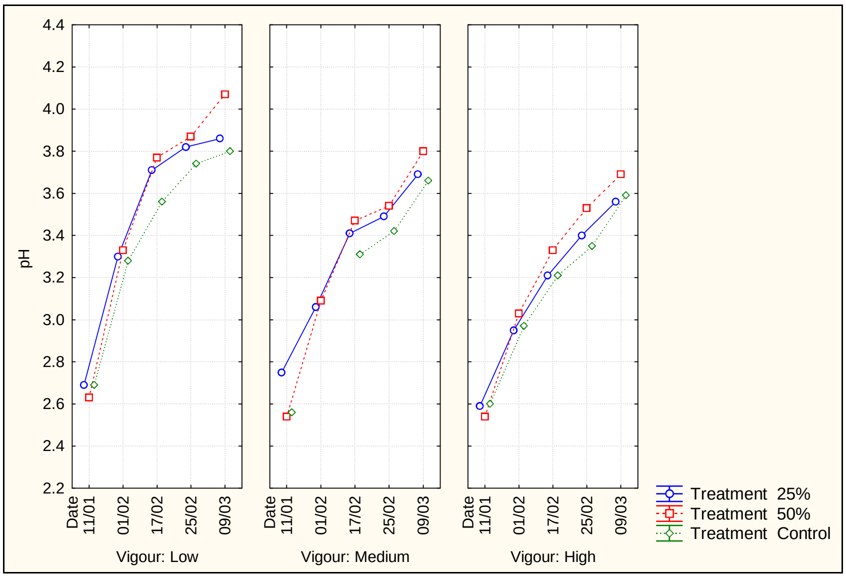

Figure 3.19: Graphs indicating trends in the change of juice pH during the ripening period for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) during the 2005/2006 season in the Shiraz vineyard.

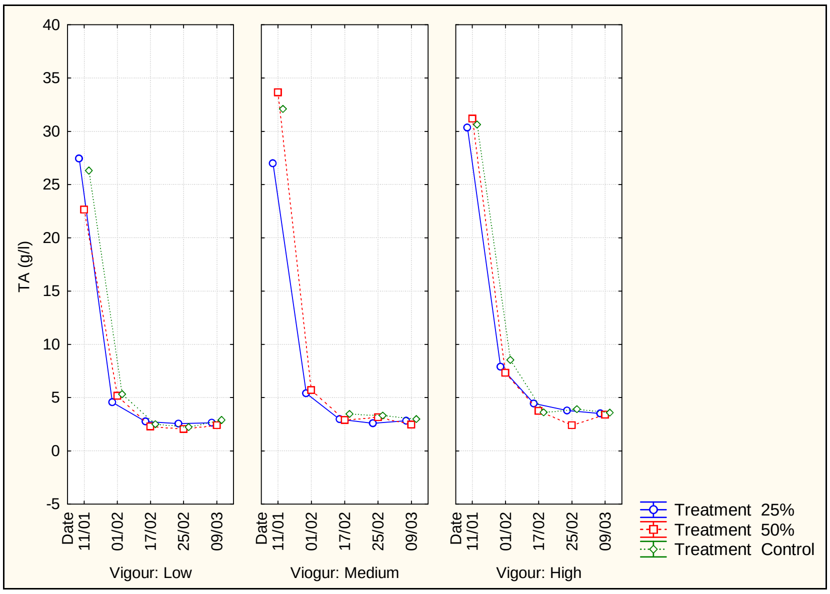

Figure 3.20: Graphs indicating trends in the change of juice titratable acidity during the 2005/2006 season for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard.

Crop thinning had no significant effect on the malic acid concentration (Figure 3.21) in all the treatments, except for a possible reducing effect in the lower vigour level.

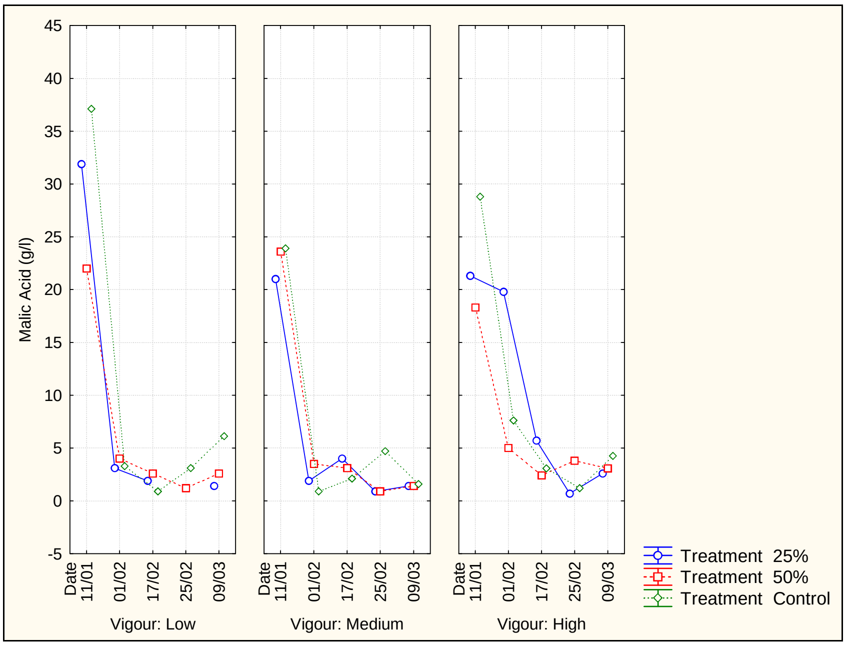

Figure 3.21: Graphs indicating trends in the change of malic acid levels during the 2005/2006 season for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard.

Crop thinning did not have any significant effect on tartaric acid levels (Figure 3.22) in all the vigour treatments. The medium-vigour control is the only treatment that showed an effect. The low tartaric acid levels at the beginning of the season for the high-vigour vines can be ascribed to an analytical mistake by the independent laboratory.

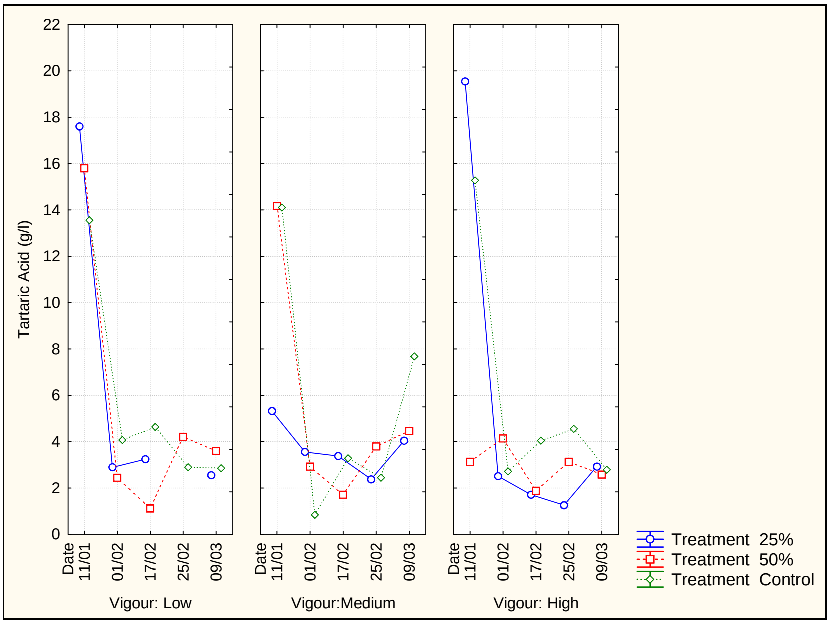

Figure 3.22: Graphs indicating trends in the change of tartaric acid during the 2005/2006 season for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard.

From the juice colour analyses (520 nm) (Figure 3.23), it would appear that crop thinning had a positive effect on the medium- and high-vigour areas.

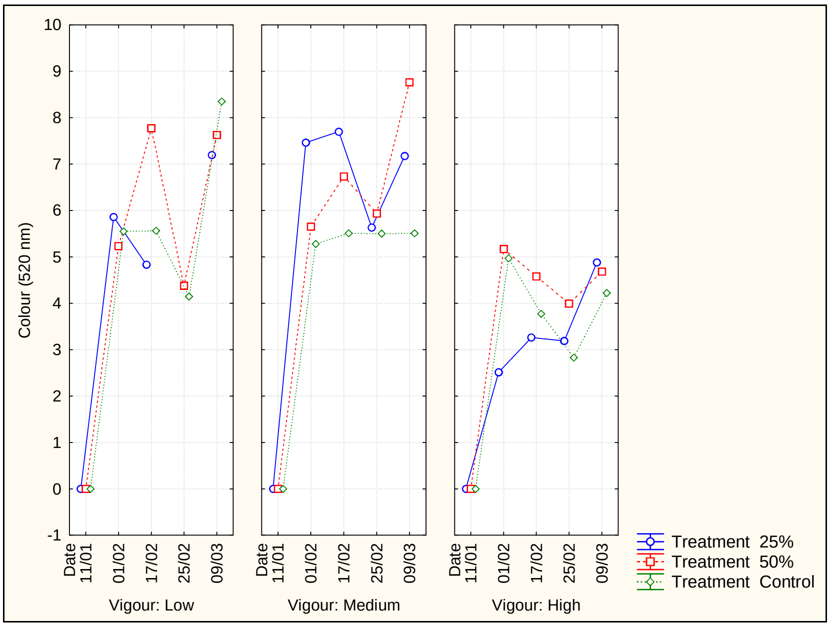

Figure 3.23: Graphs indicating trends in the change of juice absorbency (520 nm) during the 2005/2006 season for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard.

3.4.6 WINTER PRUNING

The pruning mass of the 2005 season (Figure 3.24) showed significant differences between each vigour level, with the low-vigour vines having the lowest pruning mass and the high-vigour vines having the highest. The significant differences in pruning mass values for the 2004/2005 season served as an important confirmation of the image classification of the different vigour levels.

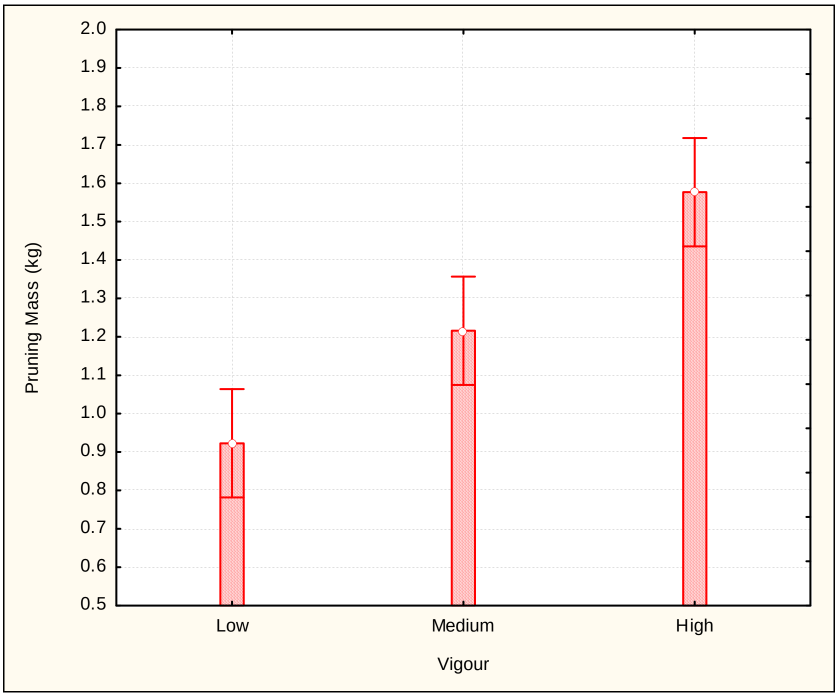

Figure 3.24: One way ANOVA of the pruning mass for the different vigour levels (low, medium and high) in the Shiraz vineyard (2005 winter pruning). (Vertical bars denote 0.95 confidence intervals; p= 0.0000.)

The pruning mass for the various vigour levels was almost the same in 2006 (Figure 3.25) as during the 2005 season. An interesting result was that of the medium-vigour vines, which had a slightly lighter pruning mass than the low-vigour vines.

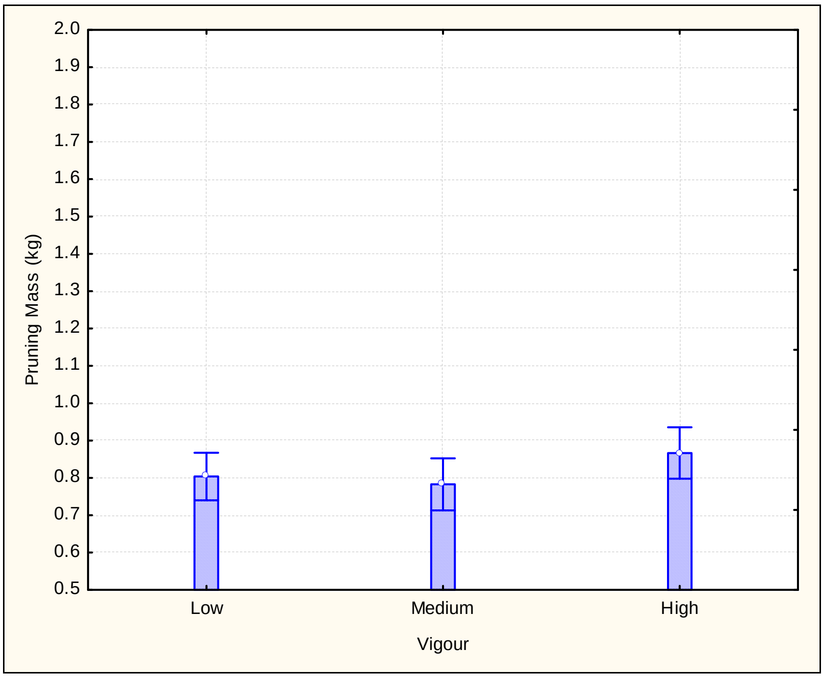

Figure 3.25: One way ANOVA of the pruning mass for the different vigour levels (low, medium and high) in the Shiraz vineyard (2006 winter pruning). (Vertical bars denote 0.95 confidence intervals; p= 0.2111.)

When the pruning mass values for the 2005 and 2006 seasons are compared to those of the different vigour/thinning treatments (Figures 3.26 and 3.27), it would appear that crop thinning had an effect on pruning mass for the medium-vigour vines. This effect is much more visible in the 2005 than in the 2006 season. The 25% and 50% crop-reduction treatments had much higher pruning mass values than those for the control vines. If the medium-vigour level is compared to the low- and high-vigour levels, the exact opposite trend is visible. The only possible explanation is that, after being thinned, the medium-vigour vines compensated for the loss in yield by favouring substrate accumulation in the remaining grapes instead of vegetative growth.

The lower-vigour vines are severely stressed throughout the whole season, possibly due to the high sand content and subsequent low clay content of the soil, leading to quick drainage of any moisture in the soil. The stress conditions are so severe that the vines lose a large number of leaves, even before harvest. These vines probably reacted to the crop-thinning treatments by reducing the photosynthetic rate of the leaves. This reduction in substrate production caused the vine even more stress and affected substrate accumulation. This can be seen clearly in the high sugar levels (Figure 3.18), high pH levels (Figure 3.19) and low acid levels (Figure 3.20) of the 25% thinning treatment in the low-vigour vines. The high-vigour vines probably responded to the reduction in yield by favouring vegetative growth.

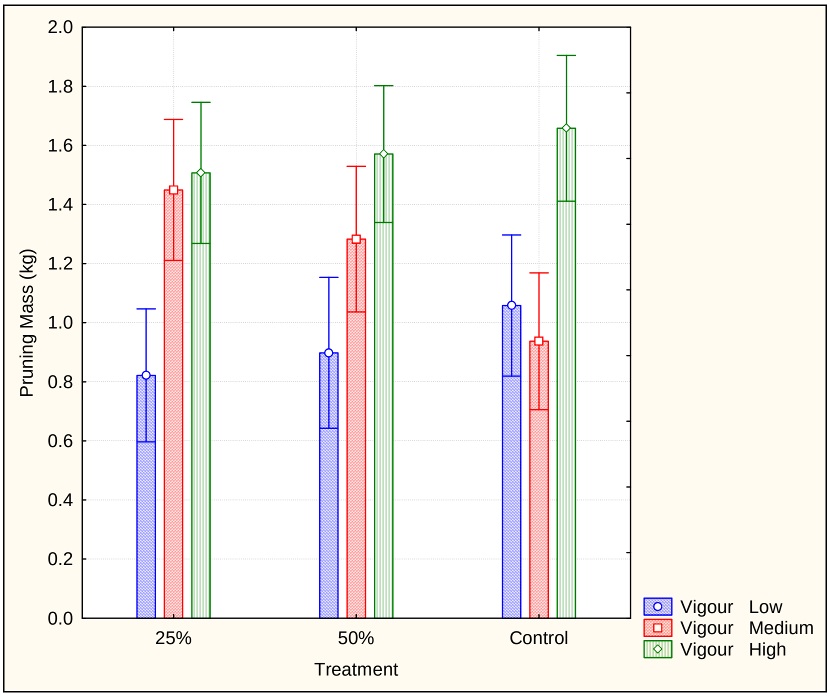

Figure 3.26: Factorial ANOVA of the pruning mass for the different vigour (low, medium and high)/crop thinning treatments (25%, 50% and control) in the Shiraz vineyard (2005 winter pruning). (Vertical bars denote 0.95 confidence intervals.)

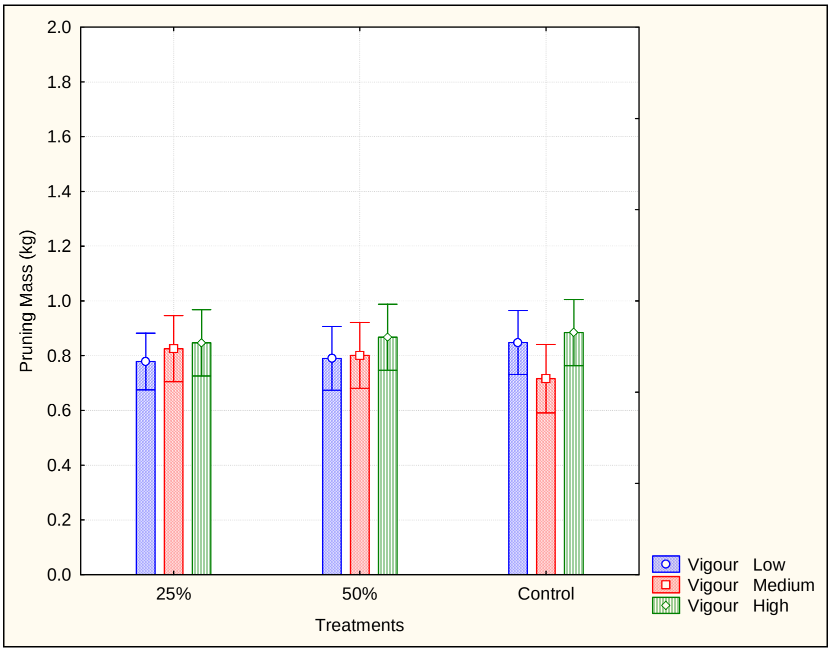

Figure 3.27: Factorial ANOVA of the pruning mass compared to the vigour (low, medium and high)/crop thinning treatments (25%, 50% and control) in the Shiraz vineyard (2006 winter pruning). (Vertical bars denote 0.95 confidence intervals.)

3.4.7 HARVESTING

The thinning actions in the 2004/2005 season had an effect on yield per vine for the medium-vigour level (Figure 3.28). Although the yield from the thinning treatments was still lower than the control, the medium-vigour vines had a higher yield than the high-vigour vines.

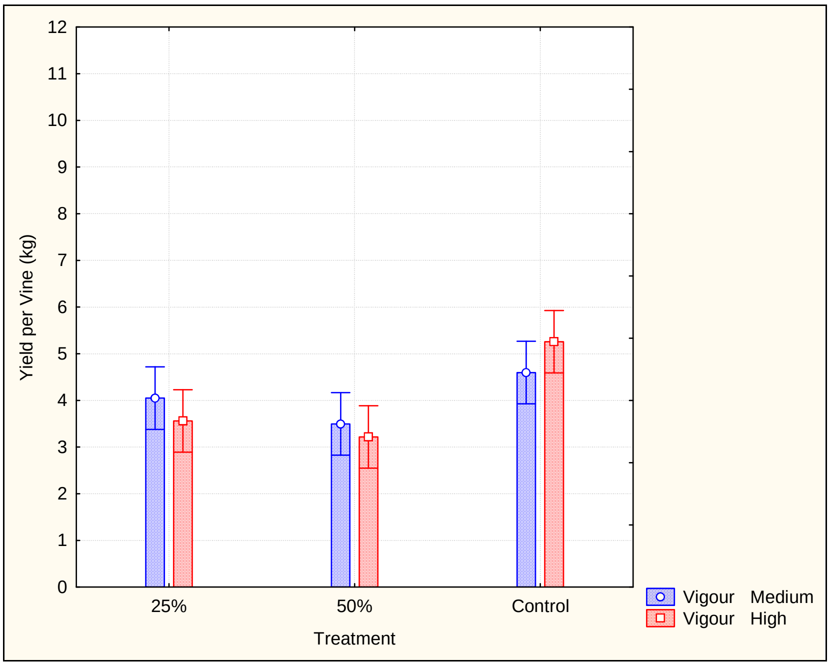

Figure 3.28: Factorial ANOVA of the average yield per vine for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard (2005 season). (Vertical bars denote 0.95 confidence intervals.)

Crop thinning of 50% during the 2006 season reduced yield per vine for all the vigour levels (Figure 3.29), which is more pronounced in the high-vigour vines, which could not compensate for the relatively large reduction in crop load. The medium-vigour vines showed the best ability to compensate for the removed crop, with the 25% crop thinning even showing an increase in the yield per vine at harvest.

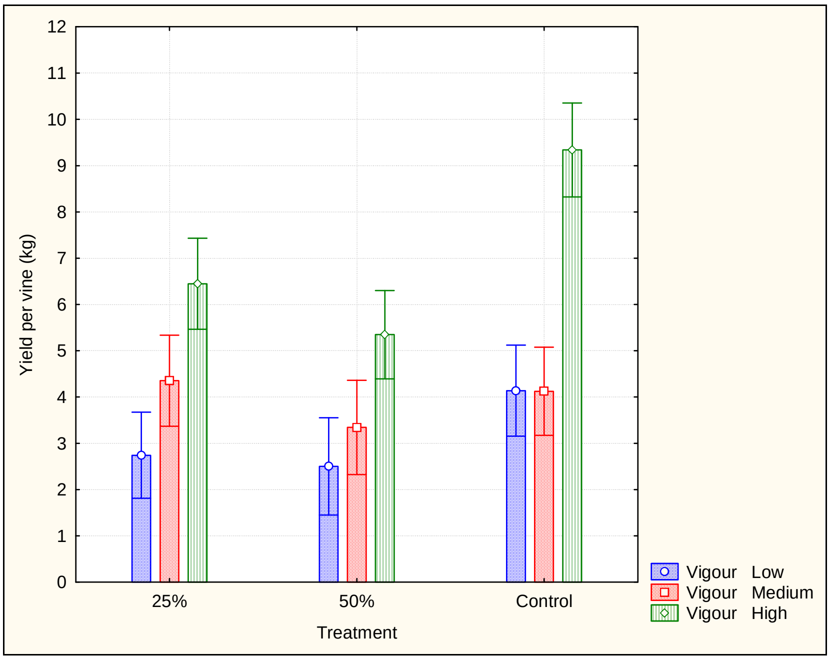

Figure 3.29: Factorial ANOVA of the average yield per vine for the different vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard (2006 season). (Vertical bars denote 0.95 confidence intervals.)

The low- and high-vigour levels experienced a slight but non-significant increase in average bunch mass in the 50% thinning treatment (Figure 3.30), but experienced a drop in the 25% thinning treatment. Reducing the crop load of the medium-vigour levels by 25 and 50% seemingly had no effect on the average bunch mass. The high vigour level vines had a significant higher bunch mass compared to that of the low and medium vigour vines.

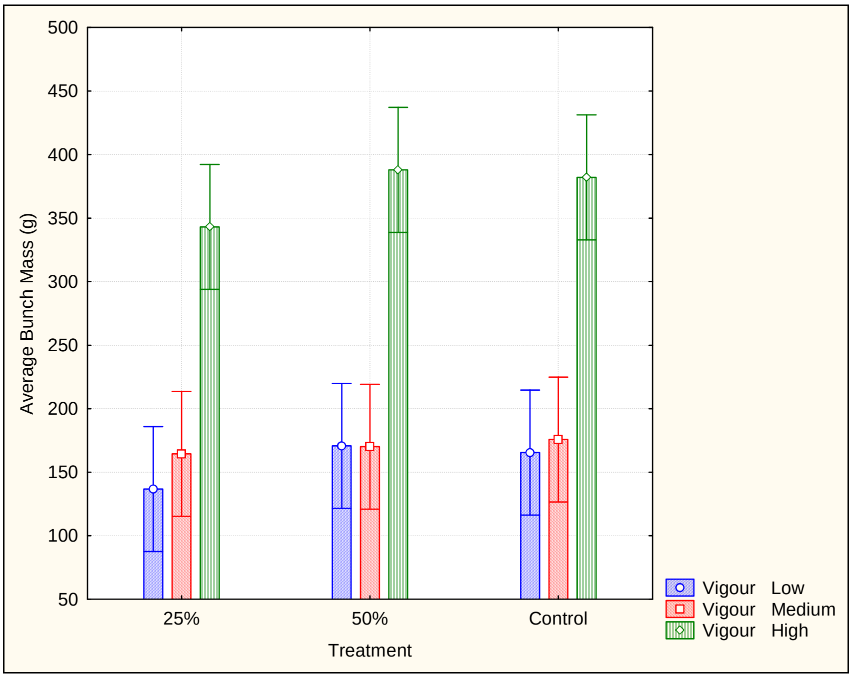

Figure 3.30: Factorial ANOVA of the average bunch mass of the various vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard at harvest (2006 season). (Vertical bars denote 0.95 confidence intervals.)

The average bunch volume followed the same trend as the average bunch mass. The low- and high-vigour levels experienced a slight increase in bunch volume with a 50% thinning in crop load (Figure 3.31), while a decrease in volume was caused by a 25% reduction. Bunch volume for the medium-vigour levels was not significantly affected by any crop thinning.

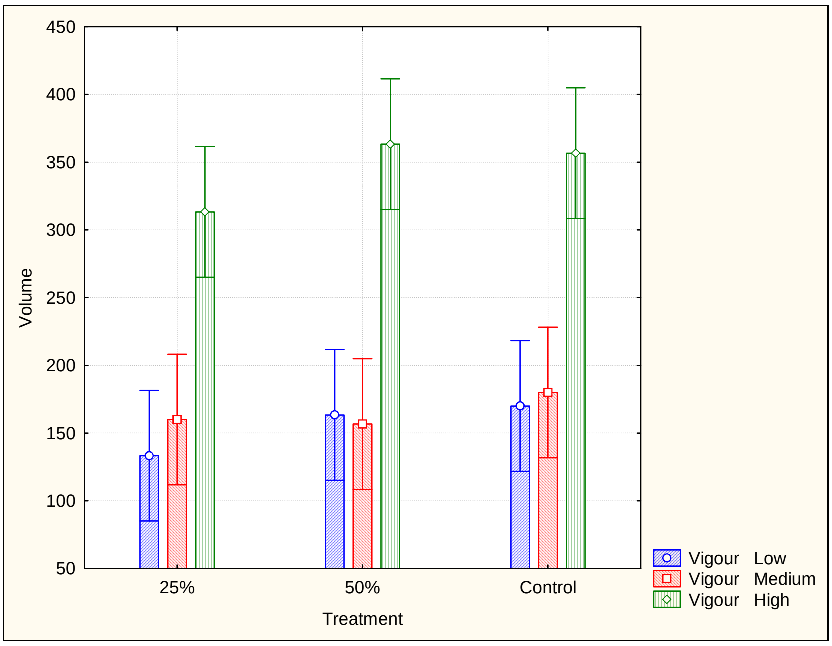

Figure 3.31: Factorial ANOVA of the bunch volume of the various vigour (low, medium and high)/thinning treatments (25%, 50% and control) in the Shiraz vineyard at harvest (2006 season). (Vertical bars denote 0.95 confidence intervals.)

3.4.8 SENSORY ANALYSES

The sensory analyses will be explained in conjunction with the graphs included in Addendum B.

Wines from the low-vigour levels for the two vintages.

Wines from both vintages and treatments expressed low levels of cooked, fresh and dried vegetative characters, except for the low-vigour 2005 control, which showed more cooked vegetative characteristics. All the wines from the 2006 season showed higher levels of fruity, berry characteristics than wines from the 2005 vintage. Wines from both vintages had very low levels of earthy, mocha and chemical characters. Wines from the 2005 vintage had more spicy, black pepper, cloves, cinnamon and liquorice characters than the wines from the 2006 vintage. Wines from both vintages showed excellent colour, with a high score for fullness and moderate tannin levels. All the wines scored moderately high with regard to alcohol, acidity and balance.

Wines from the medium-vigour levels for the two vintages.

Wines from both vintages had low levels of cooked, fresh and dried vegetative characteristics. The medium-vigour 2006 wines with a 50% crop reduction were scored higher for fresh vegetative and dried vegetative characters. Wines from both vintages had high levels of fruity, berry characteristics and low levels of fruity, dried fruit and floral characteristics. Earthy, mocha/coffee and chemical characteristics were very low for all the wines, except for the medium-vigour 2005 control wines, which showed of a more mocha/coffee character. Spicy, black pepper, cloves, cinnamon and liquorice characters were low for all the wines, except for the medium-vigour 2005 wines with 50% crop reduction, which had a slightly higher level of spiciness and black pepper taste. All the wines had excellent colour and moderate tannin levels, as well as moderate fullness. All the wines had moderately high alcohol and acidity and were well balanced.

Wines from the high-vigour levels for the two vintages.

Wines from the 2006 vintage expressed more fresh vegetative characteristics than the wines from the 2005 vintage. The wines from high-vigour vines in 2005, with a 50% crop reduction, were the only wines that showed a high cooked vegetative character. All the wines from the 2006 vintage, as well as wines from high-vigour vines with a 25% crop reduction in 2005, possessed high levels of fruity, berry character. Earthy, mocha/coffee and chemical characters levels were low for wines of both vintages. Spicy, black pepper, cloves, cinnamon and liquorice characteristics also scored low for all the wines. All the wines were scored high for colour, with the wines from high-vigour vines with a 50% crop reduction in 2006 scoring exceptionally high. All the wines were scored high for tannins and fullness, with the latter wine again standing out. Alcohol, acidity and balance were all scored quite high for wines of both vintages.

3.5 CONCLUSION

Aerial imagery is a very important part of modern viticulture. To date it is still not implemented on most South African farms; mainly due to the high input costs involved in obtaining the images. Aerial imagery has justified its usefulness in modern viticulture by not only directly identifying variations within a vineyard, but also by indirectly aiding the grape grower in the adoption of various managerial practices assisting him to manage the variation and even to plan selective harvesting procedures. Remote sensing technology is not just a tool for the identification of variation in a vineyard, but can also enable the grape grower to identify the causes of variability. By identifying the causes of the variation, for example soil chemical differences, it can be addressed and rectified if so wished.

There are two important factors that need to be considered before crop thinning practices can be applied within a vineyard. The *first* important factor is to distinguish between the different vigour levels found in a vineyard and the *second* factor is to consider the vine's capacity. If a vine has a well-developed above ground structure, it will have a sufficiently developed subterranean structure that will be more than capable of supplying the vine with the needed substrates important for survival. If a vine possesses good capacity, it will be able to carry and ripen a bigger crop load to its full potential.

When a determined amount of crop thinning is to be carried out, it is important to sample according to the intended procedure. As seen from the results obtained, different berry characteristics are to be found if the various vigour levels, with their various crop thinning treatments, are sampled and analysed separately.

The modern "buzz phrase" in the wine media is: "low yielding vines, good quality wine". This statement is backed by an article by Ross (1999) where he states that "talk about low yields does sell wine" and "growers like to talk to journalists about low yields, and journalists like to hear things like that". "Low yielding vines" is terminology that is used too loosely by various people, without understanding the different circumstances that might lead up to it. Low yields might be the result of old vines or vines that have poor capacity and are not able to ripen grapes to their full potential. In the same article written by Ross (1999), he reports that high quality wines from the Bordeaux and Burgundy region, in fact came from high yielding vines.

Crop thinning must not only be performed in order to produce a certain tonnage per hectare, the result being that the wines made from these grapes can be specified as being produced from a low yielding vineyard. The most important factor that needs to be considered before crop thinning is performed is the vine's capacity to carry and ripen the amount of grapes naturally produced. Results indicate that it is clear that crop thinning has a definite effect on all the vigour levels. It is evident that crop thinning should not be carried out on low vigour vines that are sure to be in a stressed state later in the season. Results indicate that the reduction in crop seemed to enhance the stress level of the vine. A 25% thinning treatment seemed to favour the high vigour vines, due to the more favourable grape composition for the production of wine, when compared to the other treatments.

Sugar (°B), pH and acid levels varied between the various treatments. The 50% thinning treatment for all the vigour levels had the highest sugar level, but also the highest pH and lowest acid levels. The control treatment might have had the lowest sugar level in some vigour/thinning treatments, but it had lower pH and higher acid levels than the thinning treatments, just proving that grapes do not have to be thrown off in order to achieve better grape chemical composition.

The different vigour level/crop thinning treatments produced an array of wines with different aroma and flavour characteristics. There was not a single treatment that stood out as being the perfect wine, with seasonal differences only being visible at some vigour levels for certain characteristics.

The vine is surrounded by natural (rain, frost, wind, etc.) and unnatural factors (managerial actions) that have a distinct influence on it and the grapes that it produces. The low vigour vines for instance, are situated on a soil that has a high percentage of sand and low percentage of clay in comparison with the other vigour levels. As a result of this, low bulk densities and high porosity levels are to be found in all three subsoil layers (0-30, 30-60 and 60-90 cm). This soil characteristic enables the vine to develop a network of fine roots. Fine roots are important for the uptake of needed moisture and nutrients from the soil, because the roots are spread more throughout the soil profile thus having a big contact surface. The only problem with such a root system is that soil moisture will be quickly depleted early-on in the season, raising the need for additional irrigation. The water holding capacity of the soil is also lessoned by the high sand and low clay content of the soil, stressing the need for additional irrigation even more. The low vigour vines in the Shiraz block clearly has some kind of moisture problem leading to severe stress conditions before harvest. This stress conditions are visually visible through a huge amount of yellow leaves, and even leaves being thrown off. This yellowing of the leaves causes potassium translocation to be favoured above that of sucrose, increasing the pH levels of the must. Not only is the pH levels increased, but the sugar levels as well, while the acid levels are decreased. These characteristics do not seem favourable for the production of good wine, but still managed to produce a wine that had interesting characteristics.

An interesting result that was produced was that of the cane mass during the two consecutive seasons. It would appear as if the medium vigour vines favoured reserve accumulation when crop thinning was applied instead of favouring vegetative growth, which would have been expected due to the reduction in sinks. This effect was visible in the high vigour levels. It would appear as if crop thinning had a negative effect on the low vigour vines. Due to the stressed condition it is subjected to, the photosynthetic effectivity of the leaves decreased, not favouring reserve accumulation or shoot growth.

Soil variation, as seen from the gathered data, is one of the main causes, if not the main cause, of vine variation. The root system is the part of the vine that is directly influenced by the variation in soil character. Soil type, bulk density, porosity and chemical elements are all factors that have a direct influence on root penetration and distribution patterns.

This study showed that different wine styles can be produced, without a single wine character being more prominent than another, emphasising the importance of carefully deciding if crop thinning needs to be performed in order to produce a quality wine. Different vintages cannot be compared to each other due to the variance that occurs every season.

Managerial actions needs to be adapted if "problem areas" occur within a block of vines. Grape growers must be alert for any variation between vines and must determine the cause there-off. A vine under stress conditions will still produce grapes, but it is important to assess the quality of the fruit and if possible address the problem causing the problem. Vines with different characteristics, will lead to the production of wine with various characteristics. By pooling this wine, unique characteristics might be lost. Vines, such as the low vigour vines, that suffer from severe stress conditions every year, can produce wine that will be favoured by some consumers.

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Chapter 4

RESEARCH RESULTS

A study of the interaction between vine vigour and harvesting dates and their effect on grape and wine characteristics

RESEARCH RESULTS

4.1 ABSTRACT

Vigour variation is a common phenomenon in most South African vineyards. This variation in vigour is caused by a number of different factors, such as soil and environmental variation, as well as managerial inputs. Each factor may potentially have an effect on the aboveground and subterranean structure of the vine. Variation in vigour can cause differences in canopy structure that may have a direct impact on the photosynthetic effectiveness of the vine. Not only may canopy structure be influenced by variation, but grape composition and maturity levels might also be affected. Multispectral images depicting within-vineyard variation were used to identify areas of differing vigour in a Cabernet Sauvignon block situated on the lower slopes of Simonsberg Mountain in the Stellenbosch region, as well as a Chenin blanc block located in the Perdeberg region. Ground truth measurements were carried out at the single-vine level to gather data from the different blocks and their respective vigour areas. Plots of differing vigour were harvested on three different dates. Results from grape ripeness monitoring, as well as certain vine parameters, are presented, as well as results from the wine sensory analysis conducted on wines from the different vigour/harvest date combinations. Harvesting grapes at different periods did have an effect on the chemical composition and subsequent character of the grapes produced. Wines with different aroma and flavour characteristics were produced, as a result of the varying characteristics.

4.2 INTRODUCTION

Determining the best time to harvest requires experience and a careful assessment of wine grape maturity (Watson, 2003). Each variety has its own unique characteristics that unfold as the ripening period progresses. Cabernet Sauvignon, for instance, has flavours ranging from vegetative to red fruit (cherry, strawberry, raspberry, cranberry) and jammy (prune, raisin, date) characteristics (Bisson, 2001), while those of Chardonnay vary from stone fruit (apple, pear, peach, apricot) and tropical fruit (pineapple, banana, mango, guava, kiwi) to light oak (vanilla, sweet wood, coconut) and heavy oak (oak, smoke, toast, lees, yeast) (LaMar, 2005).

Various authors (Bisson, 2001; Hellman, 2004; Van Schalkwyk & Archer, 2000) identified and investigated various ripeness indices in an attempt to quantify grape ripeness through complex chemical analyses, but it is highly unlikely that there will ever be a single set of parameters to define ripeness for a specific grape variety due to the high variation between regions, vineyards and even vines. Zoecklein *et al.* (1995) describe grape maturity as being a multi-dimensional phenomenon that must be viewed in relative, but not absolute, terms, and says that it is dependent on the type and style of wine preferred, similarly Hellman (2004) defines ripeness as being defined by the individual, whether it be the grape grower or winemaker, being primarily a function of the intended use of the grapes. By timing harvesting date (Table 4.1), different wine types and styles can be produced on a farm, from sparkling wine to dessert wines. For a sparkling wine, the preferred characteristics are that of lower sugar, higher acidity and more neutral flavours, in comparison to dessert wines, which require higher sugar levels. If a farm is thus able to produce more than one wine range, it will increase its financial income and financial stability dramatically.

Table 4.1: Different grape characteristics for the production of different wine styles (Van Schalkwyk & Archer, 2000).

Wine type	Sugar concentration (˚B)	Acid concentration (g/ℓ)	pH
Sparkling wine	18.0 – 20.0	7.0 – 9.0	2.8 – 3.2
White table wine	19.5 – 23.0	7.0 – 8.0	3.0 – 3.3
Red table wine	20.5 – 23.5	6.5 – 7.5	3.2 – 3.4
Sweet wine	22.0 – 25.0	6.5 – 8.0	3.2 – 3.4
Dessert wine	23.0 – 26.0	5.0 – 7.5	3.3 – 3.7

In order to harvest grapes at different levels of ripeness, specific and detailed grape sampling techniques are required. Figure 4.1 indicates different observations that are of importance for the grape producer to determine different levels of ripeness as it progresses throughout the season. According to Zoecklein *et al.* (1995), important aspects that need to be considered when deciding on an appropriate harvest date are: a) general fruit condition; b) taste assessment of grape flavour and tannin maturity (especially concerning red varieties); c) assessment of varietal aroma and aroma intensity; d) soluble solids, titratable acidity, tartaric/malic ratio and pH; e) berry softness; and f) the ability to ripen further.

Berry sampling will be very easy to perform if a vineyard block is uniform, meaning that it adheres to the vegetative/reproductive balance. This scenario of “perfect balance” is a somewhat elusive concept in many South African vineyards, due to the large variation in soil and the environment. South Africa is a country rich in soil diversity and different soil types are to be found in a close proximity. In addition, the “curved shape” of the landscape, and variations in altitude, aspect, slope inclination and slope shape can cause variation within a vineyard.

Grape growers tend to plant large vineyards, regardless of the variation in soil and the surrounding environment, in an attempt to reduce capital expenses (McVeigh, 2001). This tendency is especially noticeable on commercial farms that produce grapes for large companies or cooperatives. Such farms are paid per ton for their produce. In this scenario, quantity rather than quality is the main objective. Even if the grape grower made an effort to produce good quality grapes, quality may be reduced due to the pooling with “lesser quality” grapes from other producers who are focussed on quantity and not quality. The main objective of smaller commercial wine estates differs from that of larger wine companies or cooperatives, due to their "quality over quantity" principle. A smaller wine estate will go to great lengths to produce good quality fruit, which, in turn, will ensure the production of premium quality wine able to compete on the international market.

Factors	*Observations/Importance*
°Brix	Potential alcohol content, calculation of sugar additions
Titratable acidity	Acidity, flavor balance, and wine style
pH	Intensity of acidity, chemical and microbial stability of wine
Sensory evaluation	Development of characteristic varietal aromas and flavors
Fruit color	Color intensity and uniformity among clusters, ease of extraction during maceration/processing
Color of seeds, stems	Transition from green to brown during later stages of ripening
Fermentable nitrogen	Fermentation rate; deficiencies may affect production of sulfide odors and accelerated wine aging (UTA)
Condition of fruit	Berries soften at full maturity after reaching maximum size; pronounced shriveling/berry shatter indicates overripeness; fruit should be free of mold, rot, and insect and bird damage
Vine condition and weather	Assessment of further ripening potential; extremes of weather can delay or arrest maturation, excess heat/drought can cause premature berry shriveling (dehydration), excess rain can cause berry swelling (dilution)

Figure 4.1: Parameters used in grape maturity assessment (Watson, 2003).

Grape growers are starting to realise that size does not always matter, and the need thus arises to plan and plant a block in such a manner as to embrace the respective terroir units, regardless of the size and shape of a block (McVeigh, 2001). The fact that grape growers plant a block without studying and considering the different aspects that might have an impact on the vines, was and probably still is the most important cause of within-vineyard variation on South African farms.

With the aid of modern technological advances, grape growers are able to map important factors that will have an influence on their decision-making process when deciding on the variety to be planted, the rootstock combination, row direction, etc., to be sure that a suitable cultivar is planted in the right area. Another modern technique that can be applied to manage vineyards better is making use of aerial or satellite imagery. This enables the grape grower to identify within-vineyard variation and, with this information, to plan how to manage the various vigour levels in an attempt to produce quality fruit.

Now that the grape grower is able to identify and mange various vigour levels, different combinations of vigour levels and grape maturity within a vineyard can now be evaluated in order to quantify possible interactions between these two factors.

The main aim of this project was to evaluate different combinations of grape maturity and vigour levels within a vineyard in order to quantify possible interactions between these two factors. It was also important to determine the underling causes of the vigour variability by performing a soil study.

4.3 MATERIALS AND METHODS

4.3.1 EXPERIMENTAL VINEYARDS

This study was conducted in both Cabernet Sauvignon and Chenin blanc vineyard blocks. The Cabernet Sauvignon block is situated on the lower slopes of the Simonsberg Mountain in the Stellenbosch region at an altitude varying from 350 to 400m above sea level, and planted on a south-western slope underlaid by a Hutton soil type (according to the classification of MacVicar *et al.* 1977). The vines are grafted on Richter 110 and have been trained according to a six-wire vertical trellising system. Spurs are pruned back to two nodes during winter pruning and the block is under drip irrigation.

The Chenin blanc block is situated in the Perdeberg region, on a crest position in an undulating shale landscape, with duplex Swartland and residual Glenrosa (MacVicar *et al.*, 1977) being the dominant soil forms throughout the vineyard. Soil preparation was done incorrectly, resulting in the undulating shale being spread throughout the whole soil profile, causing extremely high pH levels and salinity in certain areas. Vines are grafted on Richter 99, and have been trained according to a three-wire vertical trellising system. Spurs are pruned back to two nodes during the winter and the block is rainfed (non-irrigated).

4.3.2 PLOT LAYOUT

Multispectral aerial images were acquired for the Cabernet Sauvignon (Figure 4.2) and Chenin blanc blocks (Figure 4.3), of which the colour (RGB) channels are shown. White panels were placed in the vineyard before the imagery took place to locate plot positions. Three distinctive vigour areas (low, medium and high) were identified with the aid of multispectral image classification.

Figure 4.2: RGB aerial image indicating positions of white panels used to delineate plots of differing vigour in the Cabernet Sauvignon block.

Figure 4.3: RGB aerial image indicating positions of white panels used to delineate plots of differing vigour in the Chenin blanc block.

4.3.3 EXPERIMENTAL LAYOUT

For the Cabernet Sauvignon trial, each vigour plot was represented by six vines, while the Chenin blanc trial was represented by seven. Each vigour grouping consisted of repetitions in other parts of the blocks. Areas of different vigour were subjected to three different harvest dates. The exact time of harvest is indicated in Tables 4.2 and 4.3.

Tables 4.2 and 4.3: Harvest dates for the Cabernet Sauvignon and Chenin blanc vines for 2005 and 2006.

Cabernet Sauvignon		
	2005	**2006**
1	21-Feb	10-Mar
2	03-Mar	16-Mar
3	11-Mar	27-Mar

Chenin blanc		
	2005	**2006**
1	06-Feb	10-Feb
2	10-Feb	03-Mar
3	18-Feb	08-Mar

The vines were numbered 1 to 6 for the Cabernet Sauvignon and 1 to 7 for the Chenin blanc. Grapes from vines one and four were harvested on the first harvest date, from vines two and five on the second harvest date and from vines three and six on the last harvest date. For the third harvest date in the Chenin blanc block, grapes from vine seven were added to those of vines three and six.

4.3.4 MEASUREMENTS

Soil survey

Various soil profile pits were dug in the Cabernet Sauvignon block – one at each vigour classification. Pits were dug 40 cm away from a vine's trunk, to a sufficient depth of 100 cm and 120 cm wide. Soil samples were collected at three depth levels: 0-30, 30-60 and 60-90 cm. The micro- and macro-element content, as well as the base saturation of the soil, was determined for each sample by an independent laboratory. The bulk density of the soil was determined by applying the core method specified by Blake & Hartge (1986).

The core method was carried out by driving a cylindrical metal sampler into the soil and then carefully removing it to preserve a known volume of the sample as it exists *in situ*. The sample was oven-dried for 48 hours at 100˚C, weighed, and then the bulk density was determined by dividing the oven-dried mass of the sample by the sample volume.

Approximately 10 cm of excess soil was removed from the pit-wall closest to the vine in an effort to expose the vine's roots. The roots were then sprayed white to allow discrimination from the relatively dark soil background. A grid was constructed against the pit wall to form blocks of 20 cm by 20 cm in diameter. Photographs were taken from the plotted grid to study root distribution.

A complete soil survey of the Chenin blanc block can be found in Strever (2003).

Vegetative measurements

One representative shoot per cordon arm was selected per vigour area and removed for shoot and leaf measurements. The leaf areas of the main and lateral leaves were determined with a LiCor LAI 3000 area meter. Shoot growth was also determined for the 2006 season. This was done by randomly choosing a vine per vigour area and then choosing one representative shoot per cordon arm and measuring that shoot every time. Measurements were ceased when frequent mechanical topping was carried out by the grape grower.

Berry sampling

Berry sampling was performed for each treatment throughout the season. An average of 180 berries were randomly sampled each time. Grapes were sampled from the inside and outside of the canopy and from the top, middle and bottom part of a bunch to get a representative sample. One hundred berries were weighed and their volume determined by adding the berries to a known amount of water in a measuring flask. The volume of water displaced was calculated and noted as berry volume per 100. A further 50 berries were sent for chemical analyses to an independent laboratory to determine the malic and tartaric acid levels, as well colour (520 nm) concentration. These analyses were supplemented by standard analyses of total soluble solids, pH and titratable acidity using an ATAGO pocket refractometer and a 785 DMP Metrohm Titrino automatic titration instrument.

Winter pruning

All the vines were pruned to two node spurs in the 2005 and 2006 seasons. Pruning mass per vine and the number of canes per vine was determined for all the treatments. Pruning mass per vine was determined by tying al the pruned canes from a single vine together in a bundle and then weighing it with a spring balance.

Harvesting

Grapes were harvested on three different dates for each year of the study, using the procedure already discussed. The number of bunches per vine was counted and weighed. Grapes from the different treatments were placed together and small-scale vinification was performed. Six bunches were sampled from each vigour level to determine bunch weight and volume. Berry sampling throughout the season was conducted by sampling berries randomly from vines in the various vigour areas. Berry sampling during harvest occurred by randomly selecting six bunches from the crates in which grapes from the various vigour areas had been placed. The values from the latter may therefore differ, being less representative of berry variation on a bunch and bunch variation on a vine, as well as because of variability between vines in a plot from a specific vigour level.

Microvinification and Sensory Analysis

Standard winemaking procedures were carried out as specified by the Department of Viticulture and Oenology, Stellenbosch University. Sensory analyses were performed to determine if any aroma and flavour differences could be identified. Tasting sheets were created, making use of different aroma components as specified by Noble *et al.* (1987). Calibration sessions were held to familiarise the twelve tasters with the different aromatic and flavour compounds that might be present in the wines. The wines were randomised for each taster by making use of the Latin Square method, as specified by Cochran & Cox (1950). Wines were marked early, middle or late to represent the different harvest dates.

4.4 RESULTS AND DISCUSSION

4.4.1 PLOT LAYOUT

The multispectral orthorectified aerial images were classified with the aid of a software application called "Orthoviewer" (Afrimap GIS, South Africa) (Figure 4.4), using a Ratio Vegetation Index (RVI) (Infrared/Red). Three classification levels were assigned manually to the index image, taking care to classify only the vineyard rows and not the in-between vegetation. This was possible due to high image resolution (0,5 m). The three classification levels (Tables 4.4 and 4.5) were confirmed in the field to correspond to three different vigour levels in the vineyard. White was allocated to low vigour for both vineyards, green to medium vigour and blue to high vigour.

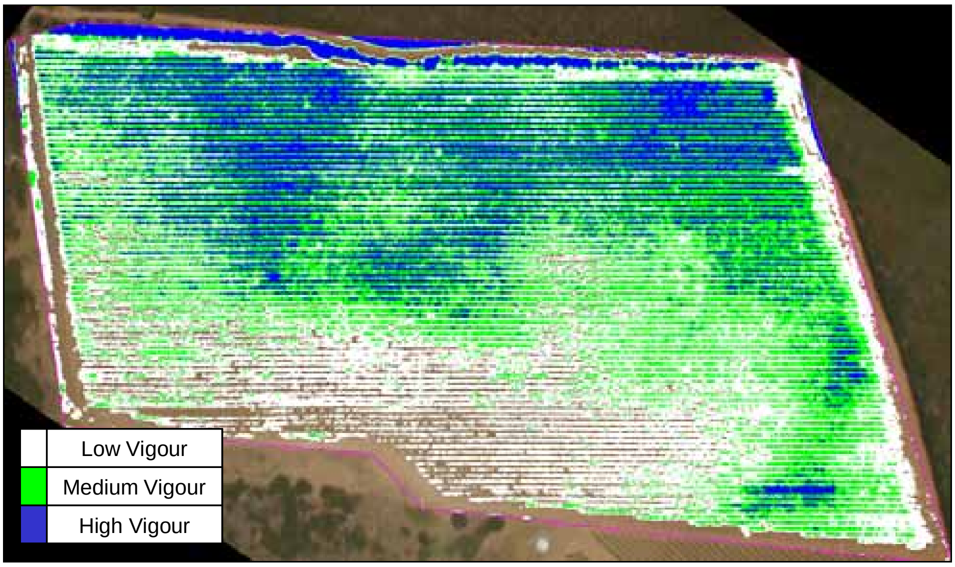

Figure 4.4: Classified multispectral image indicating vigour variation within a Cabernet Sauvignon block situated on the lower slopes of Simonsberg Mountain (see legend for classification).

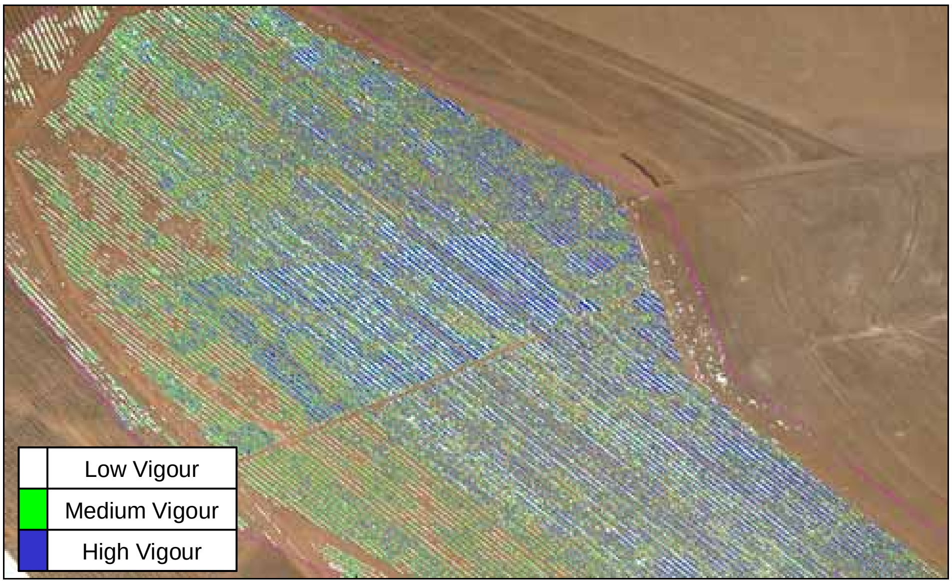

Figure 4.5: Classified multispectral image indicating vigour variation within a Chenin blanc block situated in the Perdeberg region.

4.4.2 SOIL SURVEY

4.4.2.1 Chemical Analysis

The results of the general soil analyses are depicted in tables 4.6 to 4.9. Micro- and macro-elements, base saturation and mechanical analyses were conducted. The bulk density and porosity of the soil were also analysed on the recommendation of two soil scientists, who questioned the validation of the mechanical analysis that was done by the independent laboratory. The percentage clay for the different vigour areas at all the depths was questioned in particular.

Table 4.6: Results of the soil analyses from sampling done in different vigour areas in the Cabernet Sauvignon vineyard.

Vigour	Depth	Soil	pH	Resist.	H^+	Stone	P Bray II	K	Exchangeable cations (cmol(+)/kg)			
	(cm)		(KCl)	(Ohm)	(cmol/kg)	(Vol %)	mg/kg		Na	K	Ca	Mg
Low	30	loam	6.5	1550		14	70	96	0.08	0.25	6.16	1.13
	60	loam	5.8	1680	0.5	17	5	43	0.1	0.11	3.18	0.98
	90	clay	4.1	2760	1.46	5	1	52	0.09	0.13	1.54	0.66
Medium/Low 1	30	loam	6.6	2220		9	42	213	0.04	0.54	5.94	1.42
	60	loam	6.1	1840		9	7	62	0.12	0.16	4.05	1.02
	90	clay	4.3	3060	1.1	9	2	47	0.07	0.12	1.27	0.59
Medium/Low 2	30	loam	6.3	2040		10	55	89	0.06	0.23	5.28	1.24
	60	loam	5.2	2640	0.8	15	10	51	0.09	0.13	2.49	1.03
	90	loam	4	4040	1.86	40	4	50	0.07	0.13	0.69	0.69
Medium	30	loam	5.4	2140	0.75	17	19	57	0.09	0.15	3.31	0.8
	60	clay	4.2	3810	1.61	11	5	35	0.08	0.09	1.11	0.38
	90	clay	4	3180	1.71	15	2	41	0.07	0.11	0.97	0.34
High 1	30	loam	5.6	3020	0.8	10	26	161	0.09	0.41	5.52	1.5
	60	loam	5.1	3850	1.46	11	12	65	0.13	0.17	2.99	1.15
	90	loam	4.5	4440	2.21	13	9	50	0.17	0.13	0.98	0.46
High 2	30	loam	5.0	3460	1.51	11	13	141	0.09	0.36	2.65	0.99
	60	loam	4.6	4190	1.91	10	11	59	0.11	0.15	1.63	0.6
	90	loam	4.2	6500	2.31	7	9	48	0.08	0.12	0.41	0.2
High 3	30	loam	6.1	2220		8	32	71	0.07	0.18	4.48	1.27
	60	loam	6.1	2090		8	14	35	0.1	0.09	3.71	0.96
	90	clay	4.2	3860	1.46	19	3	28	0.14	0.07	1.21	0.44
High 4	30	loam	6.3	2840		7	31	226	0.05	0.58	5.41	1.53
	60	loam	5	3890	1.26	6	9	73	0.11	0.19	2.16	0.78
	90	loam	4.2	6180	1.96	8	9	46	0.08	0.12	0.44	0.19

Table 4.7: Results of the micro-elements and carbon analyses from sampling done in different vigour areas in the Cabernet Sauvignon vineyard.

Vigour	Depth (cm)	Soil type	Cu	Zn	Mn	B	C
			mg/kg				%
Low	30	loam	0.66	0.9	5.4	0.15	1.37
	60	loam	0.21	0.2	0.6	0.1	0.79
	90	clay	0.19	0.1	**0**	0.22	0.32
Medium/Low 1	30	loam	0.63	0.8	7.8	0.37	1.25
	60	loam	0.31	0.3	2.3	0.22	0.87
	90	clay	0.14	0.1	0.3	0.22	0.35
Medium/Low 2	30	loam	0.63	0.5	3.7	0.25	1.44
	60	loam	0.2	0.2	0.3	0.05	0.74
	90	loam	0.13	0.1	**0**	0.1	0.41
Medium	30	loam	0.63	0.3	0.9	0.42	1.08
	60	clay	0.15	0.2	**0**	0.12	0.46
	90	clay	0.11	0.2	**0**	**0**	0.21
High 1	30	loam	0.13	0.5	0.6	0.19	3.3
	60	loam	0.12	0.2	0.3	0.14	3.19
	90	loam	0.12	0.1	**0**	0.11	2.54
High 2	30	loam	0.12	0.2	0.4	0.09	2.91
	60	loam	0.17	0.2	0.3	0.07	2.47
	90	loam	0.06	0.2	**0**	0.09	1.72
High 3	30	loam	0.4	0.4	2	0.06	1.32
	60	loam	0.32	0.2	0.8	**0.02**	0.85
	90	clay	0.11	0.1	**0**	0.03	0.43
High 4	30	loam	0.29	0.5	2.7	0.15	1.98
	60	loam	0.15	0.1	0.2	0.11	1.62
	90	loam	0.14	0.1	**0**	0.19	1

Table 4.8: Base saturation results of the soil analyses from sampling done in different vigour areas in the Cabernet Sauvignon vineyard.

Base Saturation						
Vigour	Depth	Na %	K %	Ca %	Mg %	T value cmol/kg
Low	30	1.05	3.24	80.83	14.89	7.62
	60	2.1	2.26	65.27	20.12	4.88
	90	2.29	3.4	39.71	16.99	3.88
Medium/Low 1	30	0.51	6.86	74.79	17.84	7.94
	60	2.27	2.96	75.71	19.07	5.35
	90	2.36	3.85	40.23	18.66	3.15
Medium/Low 2	30	0.94	3.35	77.5	18.21	6.82
	60	2.03	2.88	54.73	22.74	4.54
	90	2.02	3.75	20.03	20.03	3.43
Medium	30	1.72	2.85	65	15.69	5.09
	60	2.4	2.75	33.89	11.74	3.27
	90	2.11	3.32	30.3	10.71	3.19
High 1	30	1.07	4.95	66.32	18.04	8.32
	60	2.18	2.84	50.71	19.51	5.89
	90	4.23	3.26	24.8	11.57	3.94
High 2	30	1.68	6.44	47.29	17.65	5.61
	60	2.49	3.42	36.99	13.68	4.4
	90	2.57	3.94	13.23	6.25	3.12
High 3	30	1.25	3.02	74.63	21.1	6.01
	60	2.02	1.84	76.38	19.76	4.85
	90	4.14	2.16	36.5	13.29	3.33
High 4	30	0.64	7.64	71.49	20.23	7.57
	60	2.47	4.13	48.05	17.38	4.5
	90	2.84	4.21	15.88	6.7	2.79

Table 4.9: Mechanical analysis results from soil sampling done in different vigour areas in the Cabernet Sauvignon vineyard.

Mechanical Analysis											
Vigour	Depth	Clay	Silt	Fine sand	Medium sand	Coarse sand	Stone	Class.	Water-holding capacity		
		%	%	%	%	%	% (v/v)		10 kPa %	100 kPa %	mm/m
Low	30	13.6	19	37.6	10.9	18.9	14.1	SaLm	26.7	16.2	104
	60	18.6	21.8	33.3	9	17.3	17.2	SaLm	27.5	17.6	99
	90	25.6	23.8	32.5	6.3	11.8	4.9	SaClLm	34.4	22.7	116
Medium/Low 1	30	6.4	19.4	42.4	12.1	19.7	9.4	SaLm	27	15.4	116
	60	12.8	23.8	35.3	11.2	16.9	9.5	SaLm	29.3	18.2	111
	90	15.4	20	34.8	12.8	17	8.9	SaLm	28.3	17.7	107
Medium/Low 2	30	6.6	19.4	42.5	12.4	19.1	9.7	SaLm	26.8	15.3	115
	60	11	18.6	37.4	12.7	20.3	15.5	SaLm	25.2	15.1	101
	90	16.6	16.6	34.1	12.4	20.3	37.9	SaLm	18.7	11.7	70.4
Medium	30	20.6	19	36.4	10.7	13.3	16.9	SaClLm	27	17.1	99.7
	60	17.8	15.2	37.5	13.8	15.7	11.5	SaLm	26.4	16.2	102
	90	23.4	17.2	31.7	11.3	16.4	14.9	SaClLm	27.1	17.7	94.8
High 1	30	19.2	19.6	36	6.8	18.4	10.4	SaLm	29.9	18.9	110
	60	16.8	16	41.6	6.8	18.8	10.9	SaLm	28.5	17.2	114
	90	15.6	20.4	41.6	5.2	17.2	12.8	SaLm	29.5	17.9	116
High 2	30	16	18.8	38.2	7.8	19.2	11.3	SaLm	28.7	17.6	111
	60	12.8	21.2	38.6	7.6	19.8	9.8	SaLm	29.4	17.9	115
	90	1.6	9.6	47	15.8	26	6.8	Sa	22.9	11.5	114
High 3	30	11.8	16.8	42	12.5	16.9	8.6	SaLm	27.3	15.9	114
	60	12	16.4	39.6	13.5	18.5	8	SaLm	26.9	15.9	110
	90	14.8	16.8	34.7	13	20.7	18.8	SaLm	24.1	14.9	92.6
High 4	30	3.8	11.4	42.9	17.7	24.2	7.1	LmSa	23.1	12.3	109
	60	4.2	12.4	41.5	16.6	25.3	5.7	LmSa	24	13	110
	90	5.4	11	39.3	17.5	26.8	8	LmSa	22.8	12.6	103

4.4.2.2 Bulk Density and Porosity

Richards (1983) indicates that a vine's roots will readily penetrate the soil at a bulk density of 1.1-1.2 g/cm³ and that root penetration declines markedly at values greater than 1.5 g/cm². This was verified by Hoffman (2006, personal communication), who remarked that bulk densities of between 1.3-1.5 g/cm³ are acceptable, while any value greater than 1.5 g/cm³ can be regarded as compacted.

Lower bulk densities are found within the first two soil depths (0-30 cm and 30-60 cm) for all the vigour classes, except for the low-vigour area, which showed signs of compaction as early as at the second soil depth (Figure 4.6). This could be due to the high level of clay found at that depth, as is depicted by the low porosity values in Figure 4.7. All the vigour areas, except the high-vigour areas, showed signs of compaction at a depth of 60 to 90 cm. The reason for the high-vigour areas not experiencing any compaction at all the three depths is the high organic content and subsequent "loose and crumbly" soil structure. These areas also have a high porosity level (Figure 4.7). Porosity is defined as the percentage volume of the soil occupied by pores and pore space (Van der Watt & Van Rooyen, 1990). Root penetration is affected by soil porosity, through both pore size and pore rigidity (Richards, 1983). The soil was classified as “Sweet Water” by Ellis (2006, personal communication) and Lambrechts (2006, personal communication). The vines situated on this soil type had a good root system that penetrated and distributed throughout the soil profile. According to Richards (1983), the importance of soil porosity is considered the major factor controlling the distribution and growth of grapevine roots. As a result of this good root penetration and distribution, the aboveground canopy structure of the vines was also well developed.

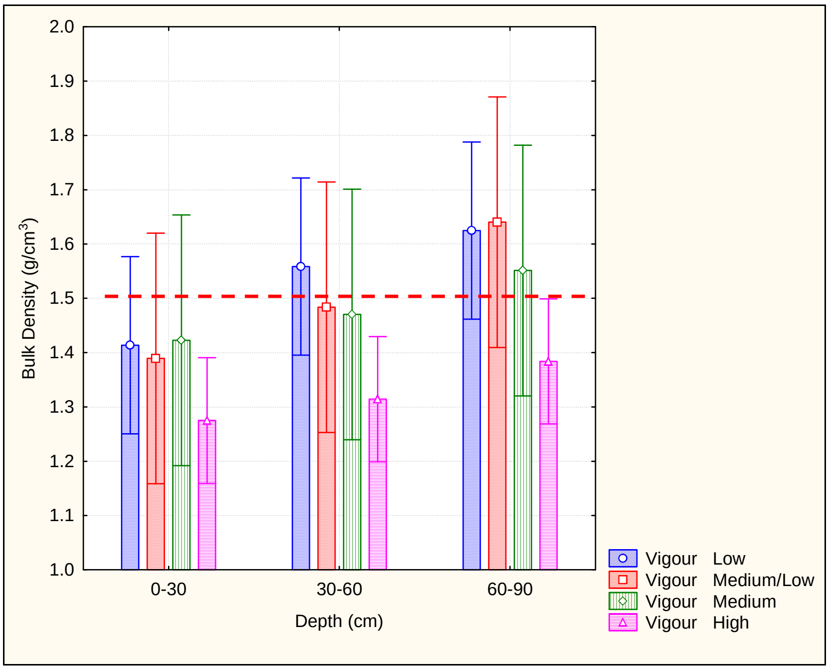

Figure 4.6: Factorial ANOVA of the bulk density at various depths for the various vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard. The dotted line is the maximum level at which root penetration and distribution will be allowed; anything above that level will be compacted. (Vertical bars denote 0.95 confidence intervals.)

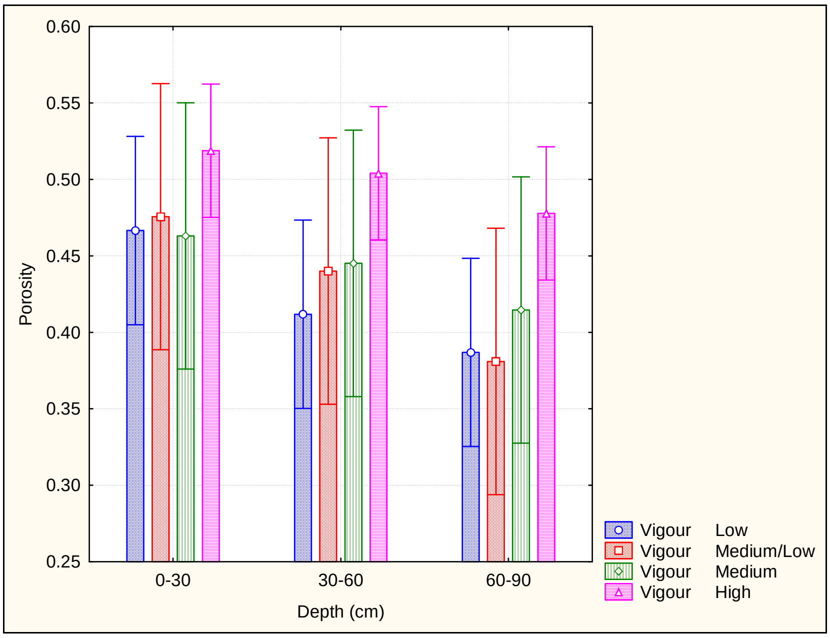

Figure 4.7: Factorial ANOVA of the porosity at various depths for various vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard. (Vertical bars denote 0.95 confidence intervals.)

4.4.2.3 Root penetration and distribution

Root penetration and distribution were evaluated through the use of photos that were taken in the various profile pits (see Addendum A).

Low Vigour: The most important observation that can be made from the profile photos is the shortage of roots occurring at a depth of 40 cm and more. This can be ascribed to a low pH in the subsoil. Conradie (1988) indicates that a soil must have a pH of at least 5.5 for a vine root to penetrate it. The shortage of roots can also be ascribed to a high bulk density and subsequent low porosity level (as shown in Figures 46 and 4.7), due to the high clay level at a depth of 60 to 80 cm.

Medium/Low Vigour: The medium/low-vigour areas are characterised by poor root distribution and penetration. The roots are only visible up to a depth of 60 to 80 cm. This can be ascribed to a low pH level at a depth of 30 to 60 cm and a very low pH level at 60 to 90 cm. This reduction in the number of roots is supported by the high bulk density and low porosity at the lower soil levels.

Medium Vigour: The medium-vigour area does not have a very good root penetration and distribution pattern. Roots are absent at a depth of 60 cm. pH could be a contributing factor, although the bulk density is high and the porosity low at the 60 to 90 cm level.

High Vigour: These areas are characterised by very good root penetration and distribution. The soil is rich in organic material, with a subsequent low bulk density and high porosity. The fact that some of the soils in the high-vigour areas have low pH level in the subsoil does not influence root penetration as severely as in the lower-vigour areas.

4.4.3 VEGETATIVE MEASUREMENTS

Main and lateral leaf areas were determined over the two vintages for the Cabernet Sauvignon (Figures 4.8 and 4.9) and the Chenin blanc (Figure 4.10) vineyards. During the 2005 season, the medium and high-vigour vines had high main leaf areas despite being topped during the season. Topping during the 2005 season did not have such a influence on lateral leaf area as during the 2006 season, when lateral leaf areas for the medium- and high-vigour areas were higher than that of the main leaves (Figure 4.10). This phenomenon could only be ascribed to frequent mechanical topping that was performed by the grape grower throughout the season. Longer shoots in the medium- and high-vigour areas could have been topped, while the shorter shoots in the low-vigour area were only tipped. The topping of the medium- and high-vigour shoots caused hormonal production (auxine) to stop temporarily (Archer, 1981), enabling lateral shoot growth to occur.

During the 2005 season, the high-vigour areas in the Chenin blanc block had a tendency to have a higher lateral than main leaf area (Figure 4.10). This could be ascribed to vigorous growth during that season, especially of the high-vigour vines, causing vegetative growth of both main and lateral shoots. Topping can be ruled out as the main cause of lateral shoot growth because the grape grower does not apply this technique.

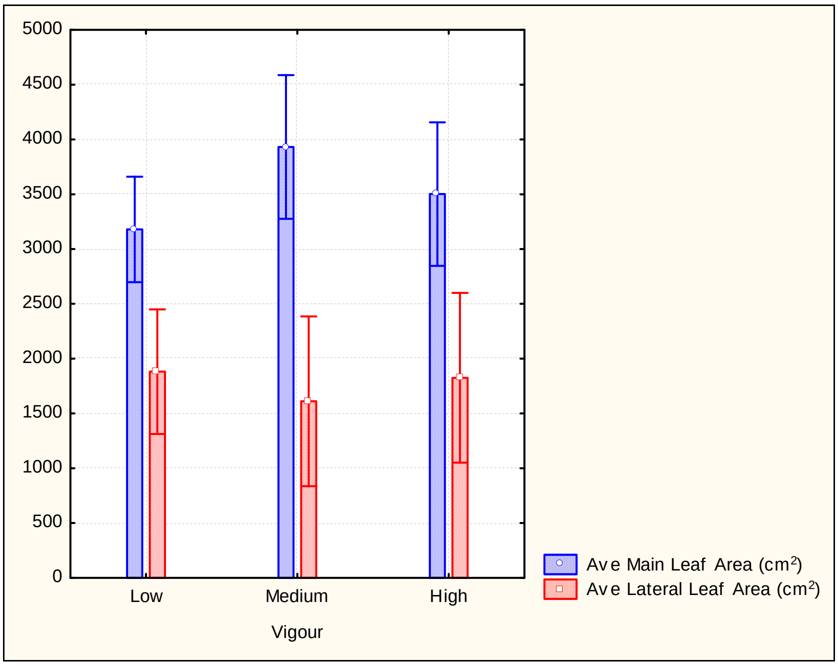

Figure 4.8: One way ANOVA of the average main and lateral leaf areas for the different vigour levels (low, medium and high) in the Cabernet Sauvignon vineyard in the 2005 season (Vertical bars denote 0.95 confidence intervals).

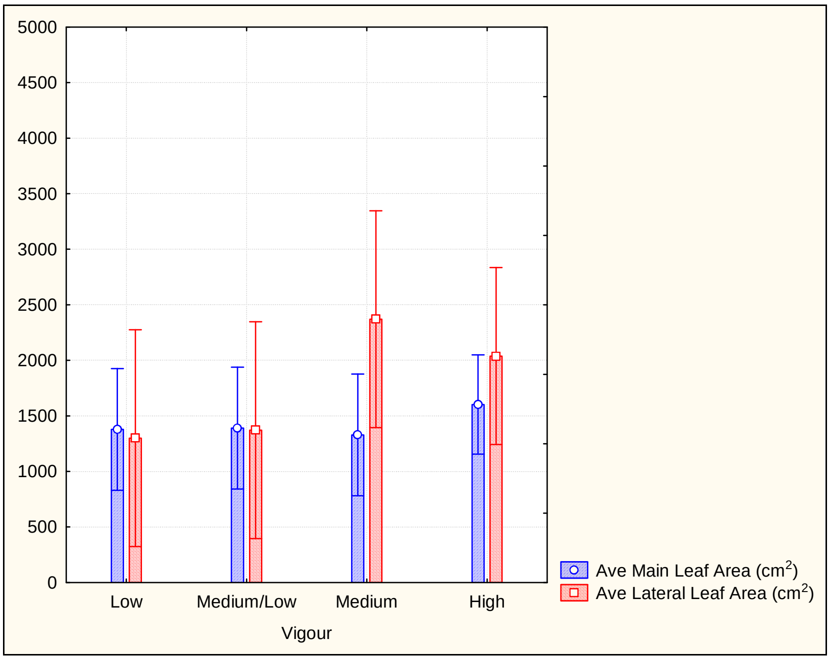

Figure 4.9: One way ANOVA of the average main and lateral leaf areas for the different vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard in the 2006 season (Vertical bars denote 0.95 confidence intervals).

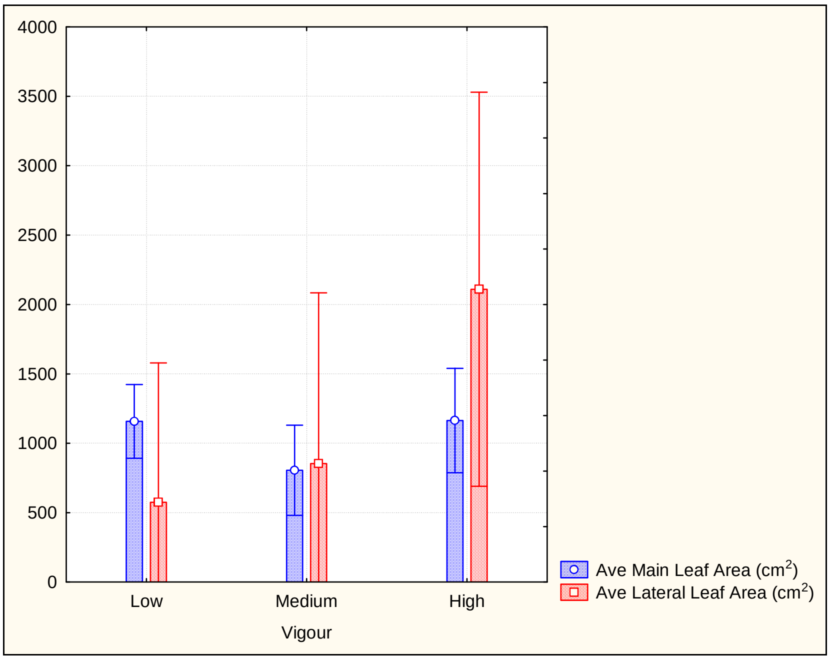

Figure 4.10: One way ANOVA of the average main and lateral leaf areas to distinguish between the different vigour levels (low, medium and high) in the Chenin blanc block in the 2005 season (Vertical bars denote 0.95 confidence intervals).

Figures 4.11 and 4.12 indicate the difference in main shoot length of the Cabernet Sauvignon in the two consecutive seasons. The high-vigour area has longer shoots than the other vigour areas during the 2005 season. This effect is reduced during the 2006 season, when all the different vigour areas had substantially shorter shoots. Topping during the 2006 season might have caused all the main shoots to be of more or less same length. Figure 4.13 indicates the difference in main shoot length in the Chenin blanc vineyard for the 2005 season.

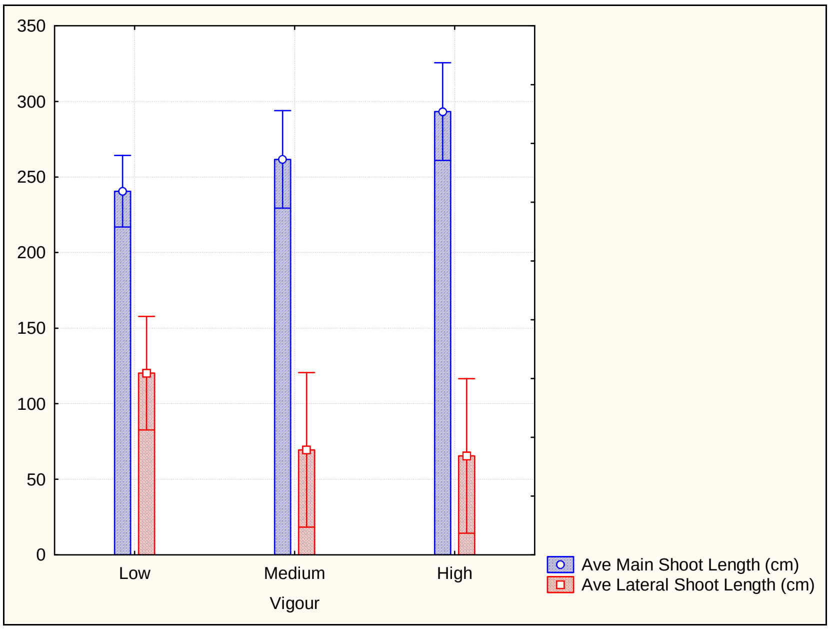

Figure 4.11: One way ANOVA of the average main and lateral shoot length for the various vigour levels (low, medium and high) in the Cabernet Sauvignon vineyard during the 2005 season (Vertical bars denote 0.95 confidence intervals).

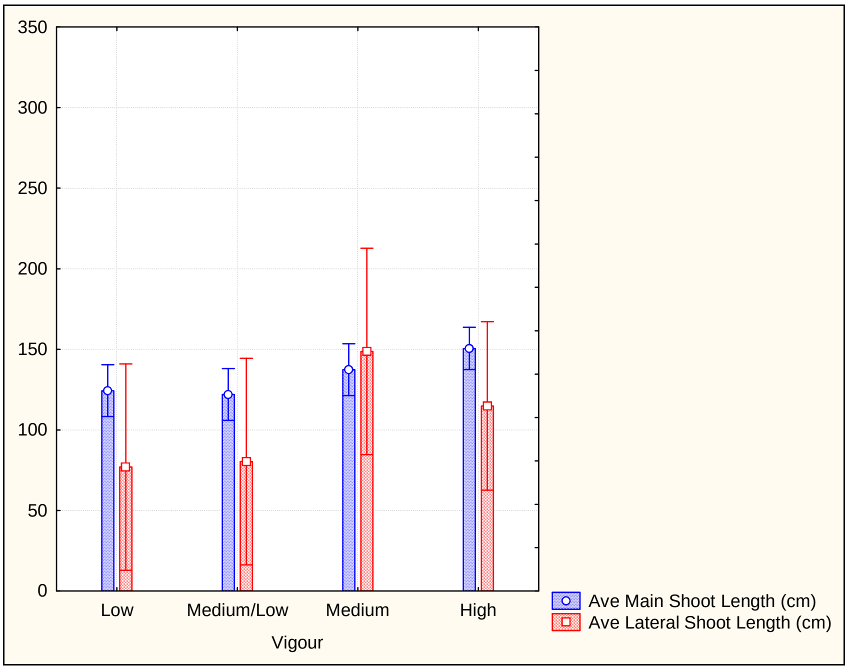

Figure 4.12: One way ANOVA of the average main and lateral shoot length of the various vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard during the 2006 season (Vertical bars denote 0.95 confidence intervals).

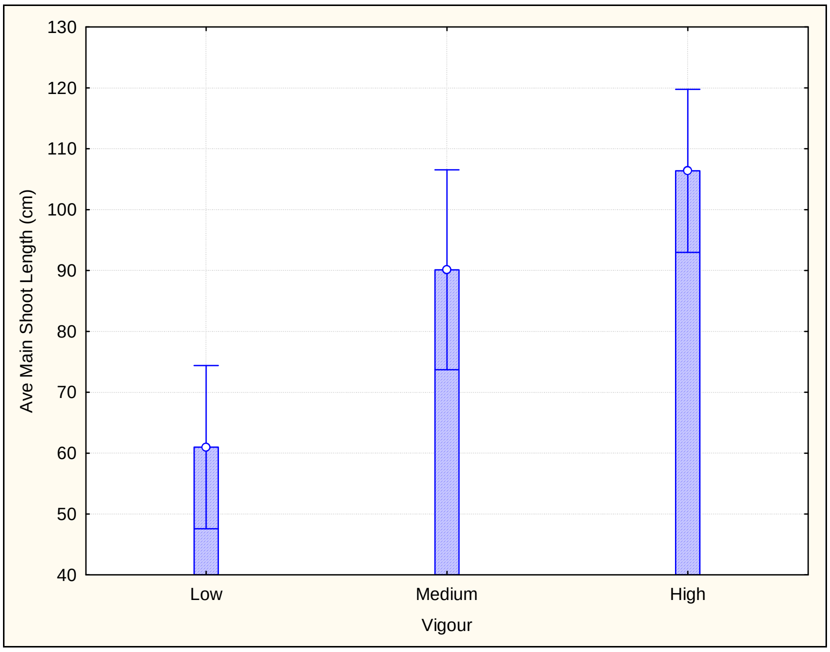

Figure 4.13: One way ANOVA of the average main shoot length of the various vigour levels (low, medium and high) in the Chenin blanc vineyard during the 2005 season (Vertical bars denote 0.95 confidence intervals, p= 0.0025).

Shoot growth was monitored during the 2005/2006 season in both the Cabernet Sauvignon (Figure 4.14) and Chenin blanc (Figure 4.15) vineyards to give an indication of how the shoot growth curve varied between the different vigour areas.

All the vigour areas in the Cabernet Sauvignon vineyard showed a substantial increase in shoot length as the season progressed, with the low vigour areas starting to grow at a later date than the other vigour areas.

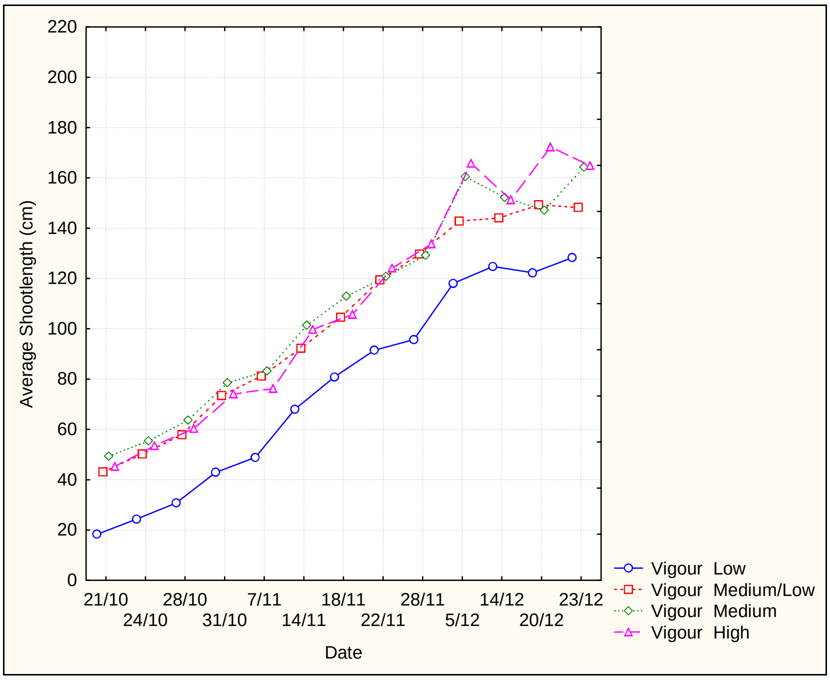

Figure 4.14: Graph indicating the trend in shoot growth of the various vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard during the 2005/2006 season.

All the vigour areas in the Chenin blanc vineyard gradually increased in shoot length during the season. Shoot growth of the low-vigour levels was substantially lower than that of the high-vigour levels. This could be ascribed to salinity, which causes water tension and inhibits the shoots from growing at a steady rate.

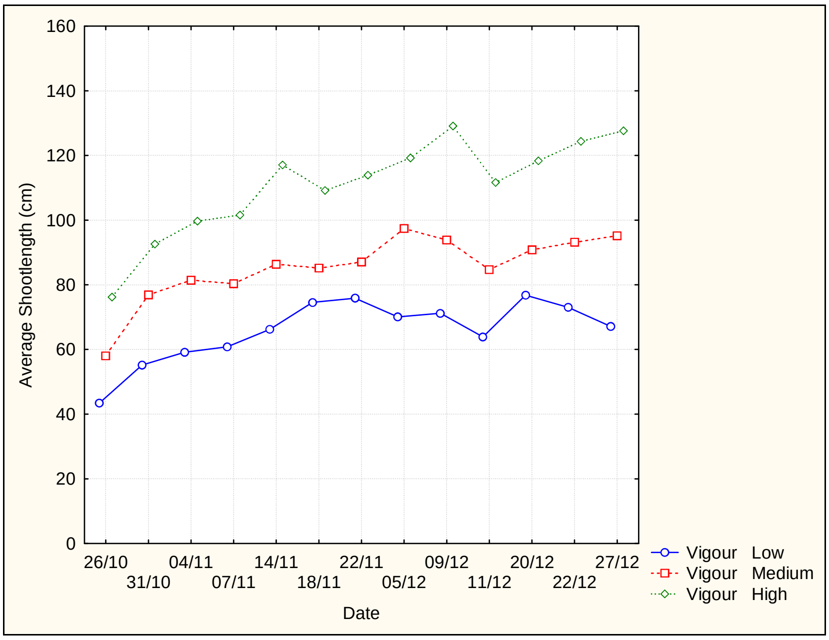

Figure 4.15: Graph indicating the trend in shoot growth for the various vigour levels (low, medium and high) in the Chenin blanc vineyard during the 2005/2006 season.

4.4.4 BERRY SAMPLING

The berry mass (Figure 4.16) of the Cabernet Sauvignon increased steadily during the 2005/2006 season in all the vigour levels. The most prominent effect relating to berry mass can be seen between the low- and high-vigour levels. The low-vigour levels experienced a decrease in berry mass from the first harvest date onwards, while the high-vigour levels experienced an increase in berry mass. The reason for this may be the substantial amount of rain that fell during the week before harvesting started. The low-vigour levels quickly lost the benefit of the added soil moisture, due to high bulk density and low porosity levels in the subsoil that caused the soil to lose the moisture quicker, probably through run-off and/or drainage, while the high-vigour levels with low bulk density and high porosity levels benefited by holding on to the moisture for longer due to a high organic content, and thus improving berry mass. The low-vigour levels also has a poorly developed root system and could not extract as much moisture from the soil as the high-vigour levels, which has a well developed network of fine roots. The medium-vigour vines experienced a decrease in berry weight up until the first harvest, after which the berries increased in weight until the second harvest date, from where it decreased again until the last harvest date. The “mix” is a combination of all the different vigour classes to assess the possible chemical composition if all the classes are combined.

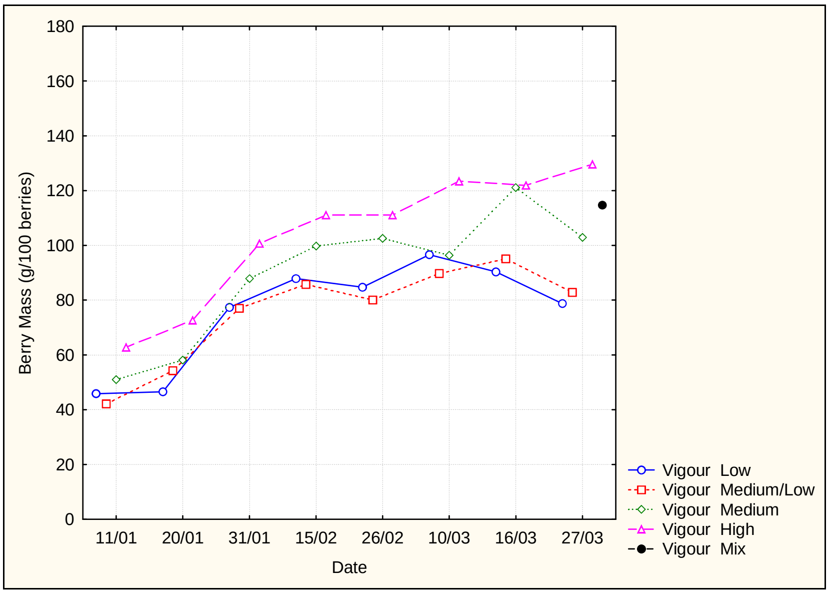

Figure 4.16: Graph indicating the trend in the change of grape berry mass during the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard.

The berry mass (Figure 4.17) of the Chenin blanc increased steadily during the 2005/2006 season in all the vigour areas. Similarly to Cabernet Sauvignon, the low- and high-vigour levels experienced opposite reactions concerning their berry mass. This could also be ascribed to the substantial amount of rain that fell a week before harvest, which favoured the high-vigour vines but not the low-vigour vines. The low-vigour vines could not utilise the added moisture in the soil due to the high levels of salinity. The high-vigour vines, not having such high levels of salinity, benefited from the moisture by favouring an increase in berry mass. Berry mass for the medium-vigour levels also decreased dramatically from the second harvest date until the last.

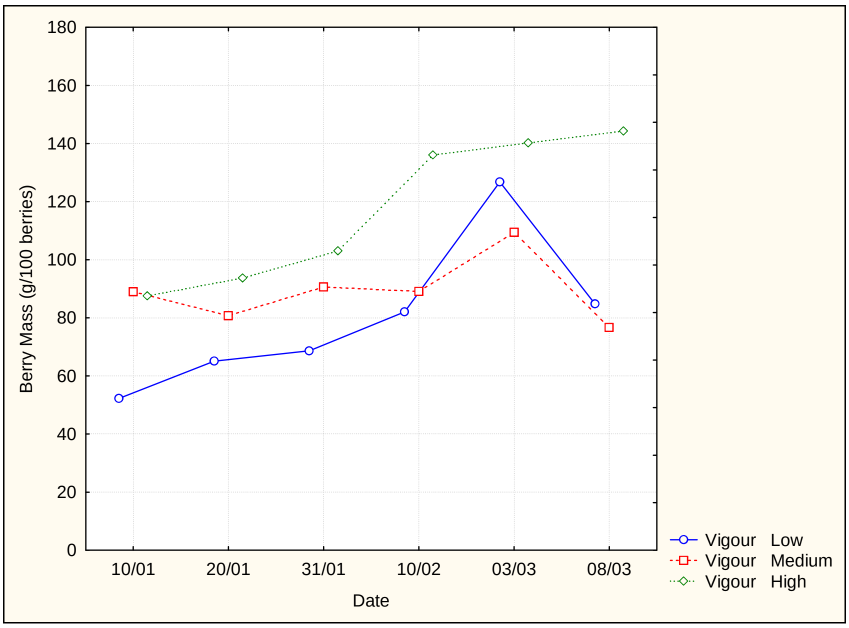

Figure 4.17: Graph indicating the trend in the change of grape berry mass during the 2005/2006 ripening period for the different vigour levels (low, medium and high) in the Chenin blanc vineyard.

The sugar levels of the Cabernet Sauvignon (Figure 4.18) increased steadily throughout the season until the first harvest date, when the levels dropped, and then increased again until the last harvest date. The low-vigour levels ended up with the highest sugar level, while the medium/low levels had the lowest sugar. Medium- and high-vigour vines ended up with the same amount of sugar at the third harvest date. The sudden drop at the time of the second harvest date can be ascribed to 9.8 mm of rain four days prior to harvest. The "mix" had the second lowest sugar level. The beneficial effect of the higher sugar levels of the low-, medium- and high-vigour levels was reduced due to the low sugar levels of the medium/low-vigour vines.

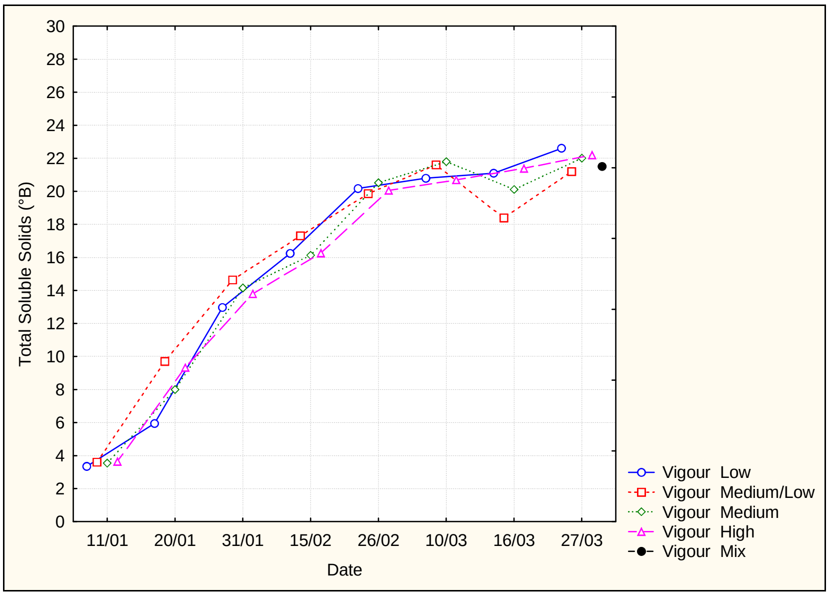

Figure 4.18: Graph indicating the trend in the change of total soluble solids (°B) as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium, high and mix) in the Cabernet Sauvignon vineyard.

The sugar levels of the Chenin blanc (Figure 4.19) increased steadily throughout the season until the first harvest date. The high-vigour vines stagnated in terms of sugar accumulation between the first and second harvest dates, although sugar levels increased up to the third harvest date. The medium-vigour vines experienced a drop in sugar level between the first and second harvest dates, but recovered to end up with the highest sugar content for 2006. The low-vigour vines increased in sugar content throughout the entire season up to the last harvest date.

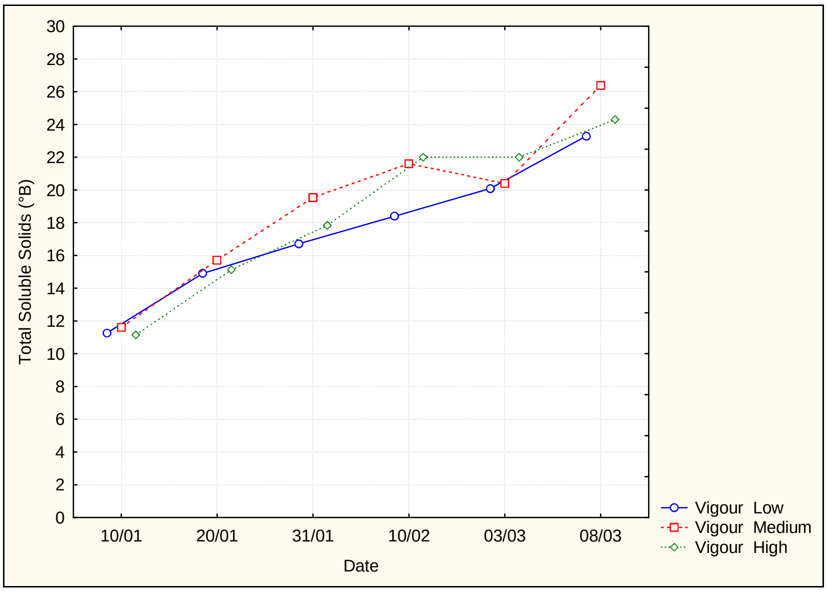

Figure 3.19: Graph indicating the trend in the change of total soluble solids (°B) as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium and high) in the Chenin blanc vineyard.

The juice pH levels (Figure 4.20) of the Cabernet Sauvignon rose consistently throughout the season, with the low- and medium/low-vigour vines experiencing a more rapid increase in pH. The low-vigour vines experienced a rapid increase in juice pH levels up to the last harvest date, which gave rise to the highest pH of the season of all the treatments. The high-vigour vines also experienced an increase in pH levels from the second to the last harvest date. The juice pH levels of the Chenin blanc (Figure 4.21) increased during the season up until the second harvest date, from which point forward up until the last harvest date (08/03/2006) the pH levels of the low- and high-vigour levels increased, while that of the medium-vigour levels decreased. The pH levels of the “mix” were the second highest after the low-vigour vines.

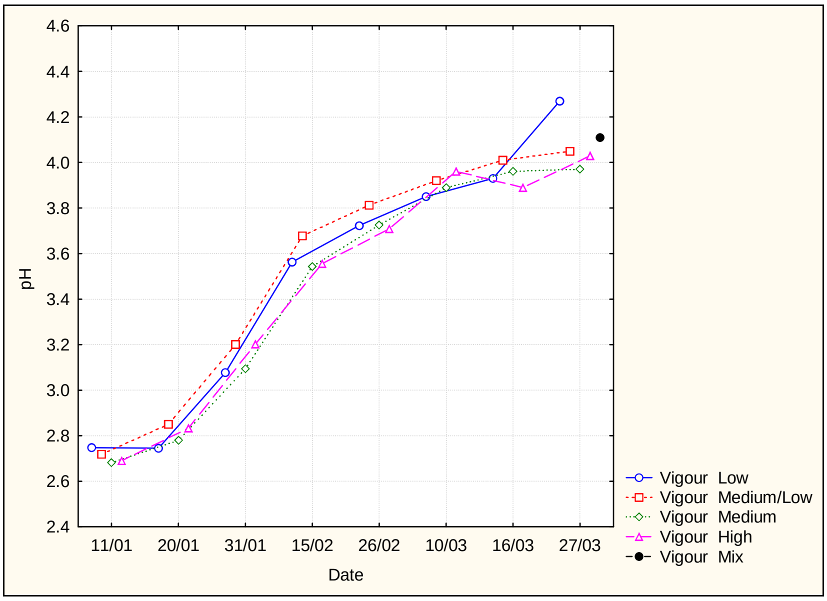

Figure 4.20: Graph indicating the trend in the change of juice pH levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium, high and mix) in the Cabernet Sauvignon vineyard.

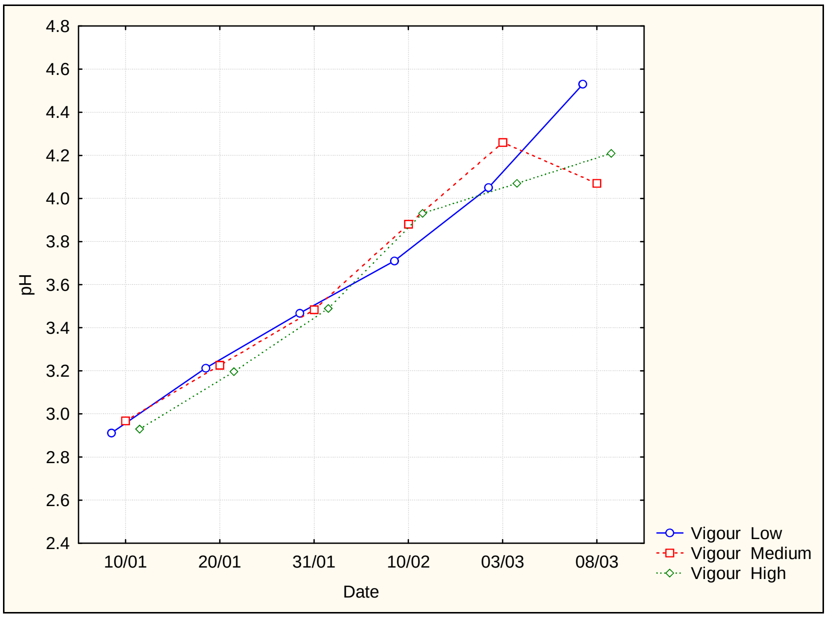

Figure 4.21: Graph indicating the trend in the change of juice pH levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium and high) in the Chenin blanc vineyard.

Organic acids in the Cabernet Sauvignon (Figure 4.22) and Chenin blanc (Figure 4.23) declined gradually as the season progressed and did not show any variation between the different treatments, except for the high-vigour vines of the Cabernet Sauvignon, which ended up with the highest TA levels.

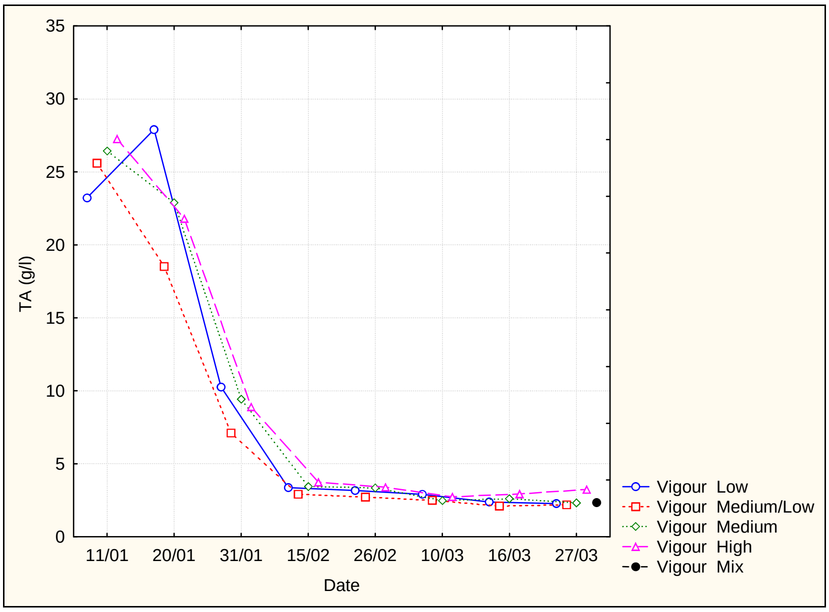

Figure 4.22: Graph indicating the trend in the change of juice TA levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium, high and mix) in the Cabernet Sauvignon vineyard.

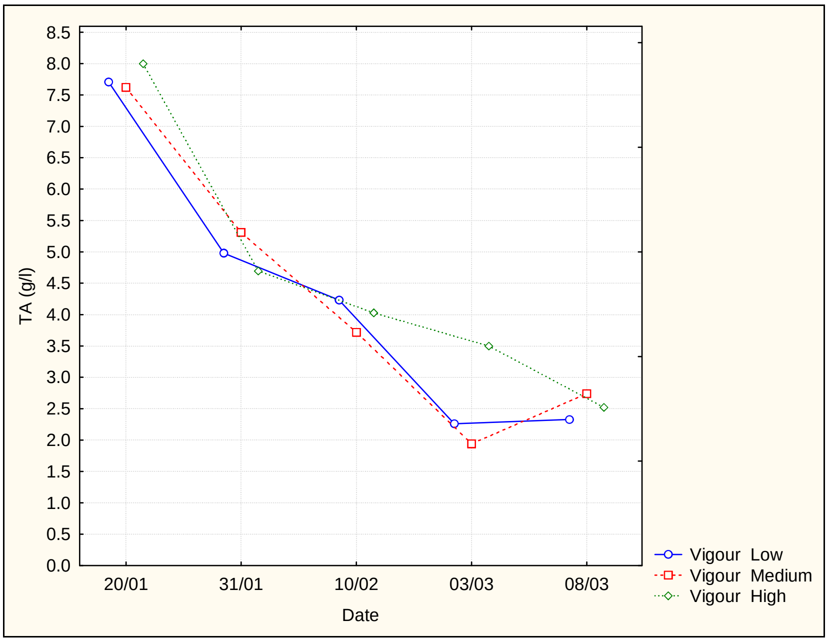

Figure 4.23: Graph indicating the trend in the change of juice TA levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium and high) in the Chenin blanc vineyard.

The malic acid levels of the Cabernet Sauvignon (Figure 4.24) decreased gradually as the season progressed, with the low-vigour areas ending up with a slightly higher level than the other vigour areas, which had more or less the same levels. The malic acid levels of the Chenin blanc (Figure 4.25) decreased throughout the season, but experienced an increase in levels between the second and last harvest date.

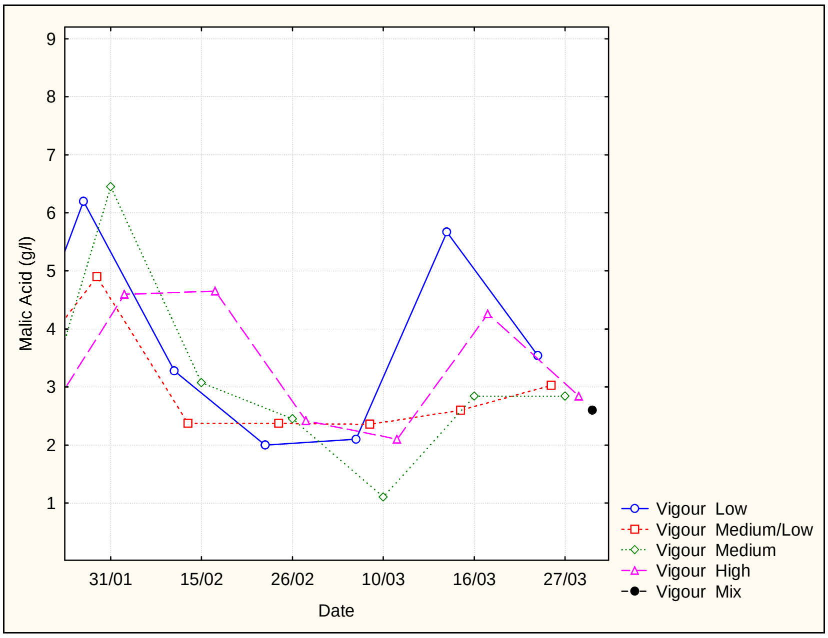

Figure 4.24: Graph indicating the trend in the change of malic acid levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium, high and mix) in the Cabernet Sauvignon vineyard.

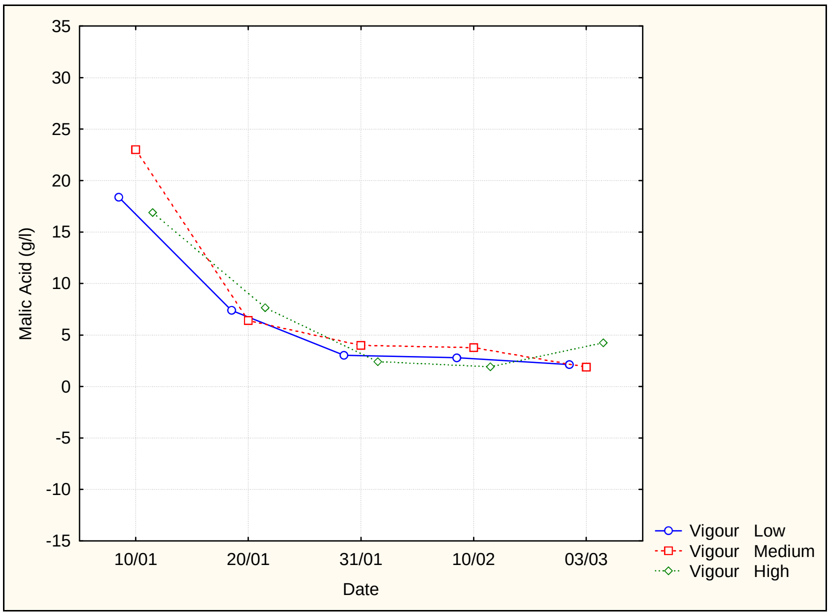

Figure 4.25: Graph indicating the trend in the change of malic acid levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium and high) in the Chenin blanc vineyard.

The tartaric acid levels of the Cabernet Sauvignon (Figure 4.26) decreased during the season up to a point where they increased, and then experienced a number of small increases and decreases for all the vigour levels. The tartaric acid levels of the low-vigour areas increased in concentration from the first until the last harvest date, and ended up with the highest concentration levels. The tartaric acid levels of the Chenin blanc (Figure 4.27) decreased steadily during the season and then stagnated up until the second harvest date, when the low- and high-vigour areas experienced an increase in concentration levels, while the medium-vigour area experienced a decrease.

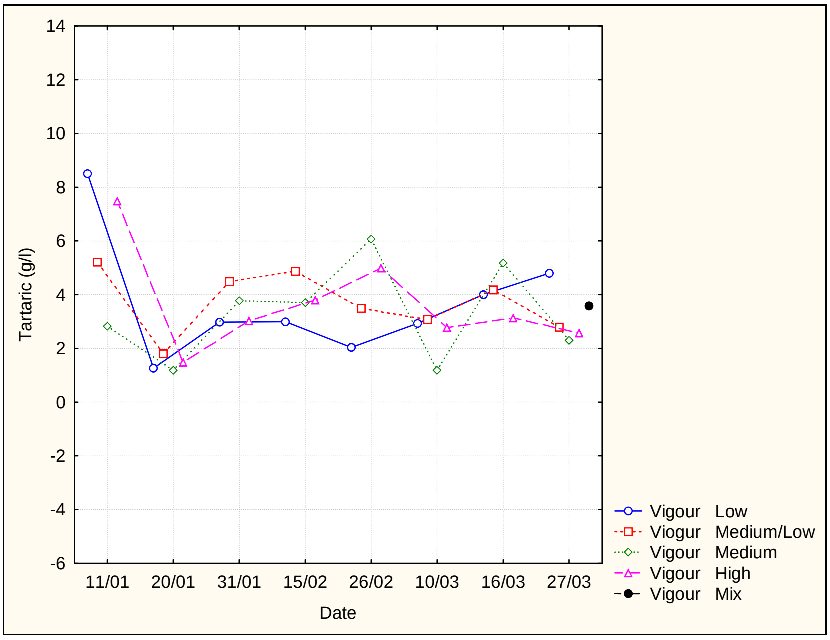

Figure 4.26: Graph indicating the trend in the change of tartaric acid levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium, high and mix) in the Cabernet Sauvignon vineyard.

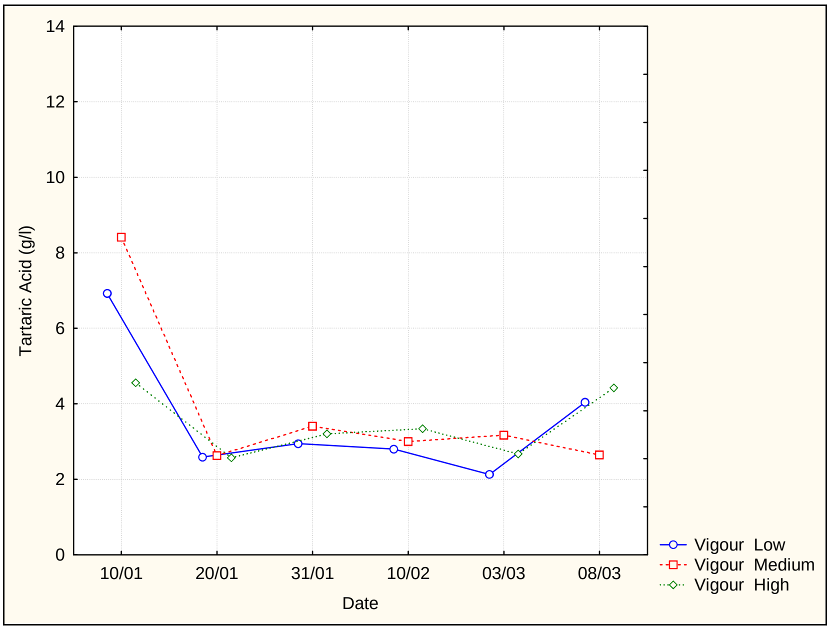

Figure 4.27: Graph indicating the trend in the change of tartaric acid levels as monitored throughout the 2005/2006 ripening period for the different vigour levels (low, medium and high) in the Chenin blanc vineyard.

The colours (520 nm) of the Cabernet Sauvignon (Figure 4.28) increased steadily throughout the season, but experienced a decline until about 12 days prior to the first harvest date, from were it increased to reach a peak at the first harvest date for the medium/low, medium and high vigour vines.

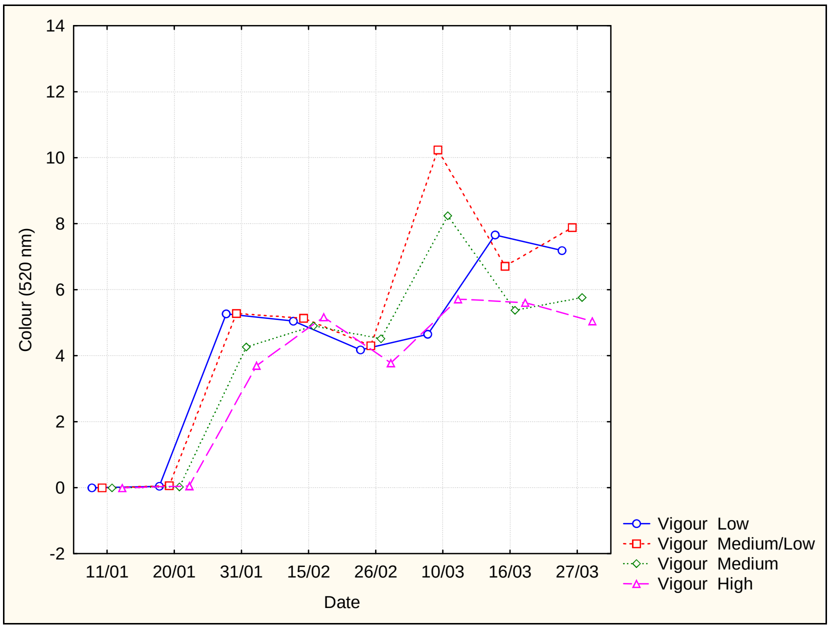

Figure 4.28: Graph indicating the trend in the change of juice colour (520 nm) throughout the 2005/2006 ripening period for the different vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard.

4.4.5 WINTER PRUNING

The pruning mass for the 2005 season of both the Cabernet Sauvignon (Figure 4.29) and Chenin blanc (Figure 4.30) showed significant differences between each vigour level. The significant differences in pruning mass values for the 2005 season were important to confirm the image classification of the different vigour levels. The pruning mass during the 2006 season showed no significant differences between the vigour levels of the Cabernet Sauvignon (Figure 4.31), while there were significant differences between those of the Chenin blanc (Figure 4.32).

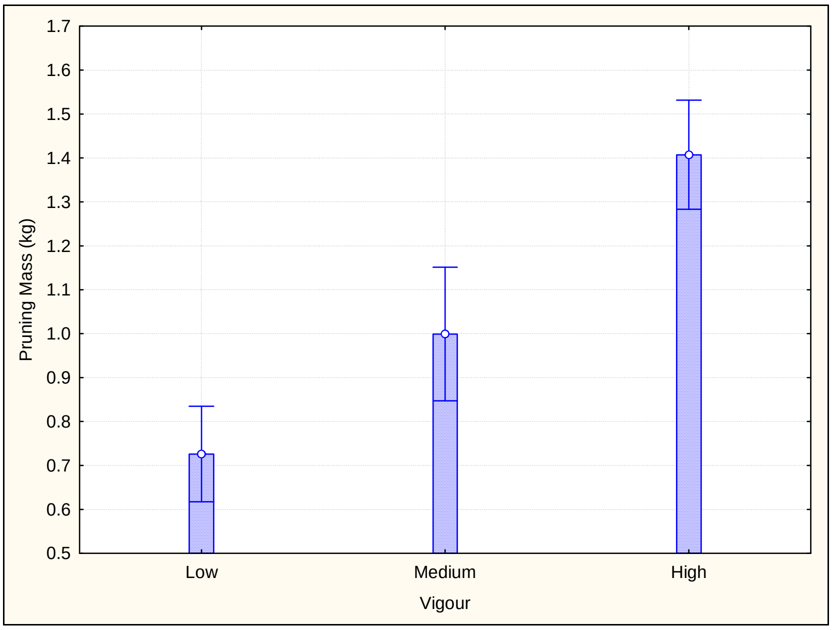

Figure 4.29: One way ANOVA of the pruning mass for the different vigour levels (low, medium and high) in the Cabernet Sauvignon vineyard during the winter of 2005. (Vertical bars denote 0.95 confidence intervals; p= 0.0000.)

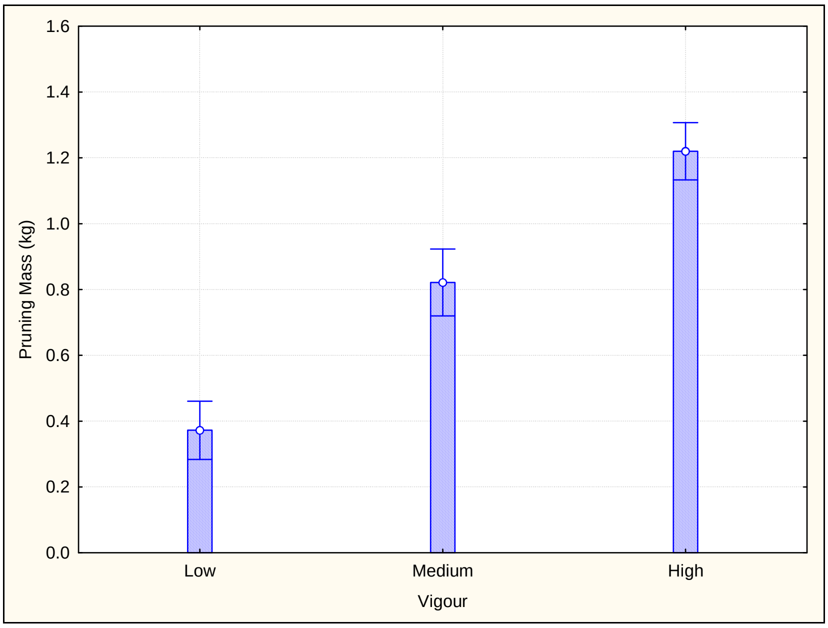

Figure 4.30: One way ANOVA of the pruning mass for the different vigour levels (low, medium and high) in the Chenin blanc vineyard during the winter of 2005. (Vertical bars denote 0.95 confidence intervals; p= 0.0000.)

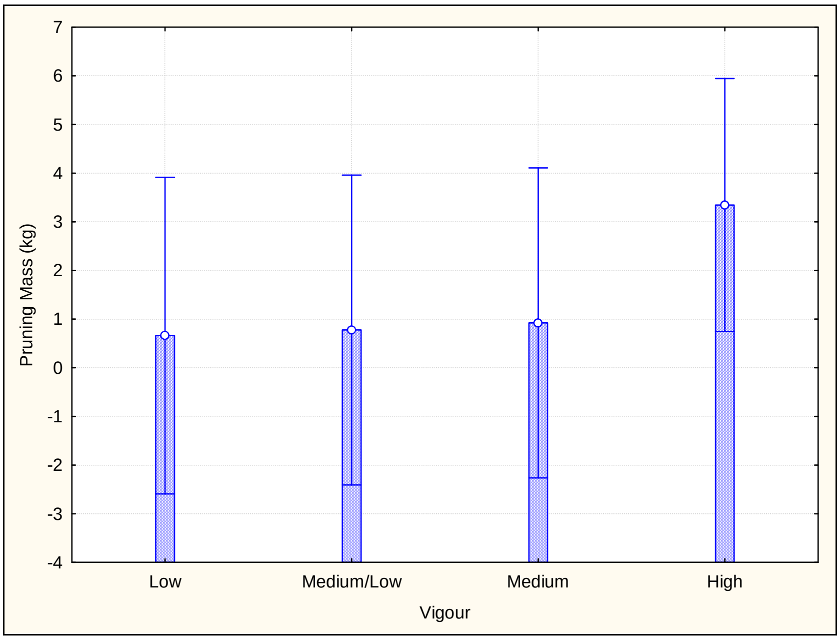

Figure 4.31: One way ANOVA of the pruning mass for the different vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard during the winter of 2006. (Vertical bars denote 0.95 confidence intervals; p= 0.4724.)

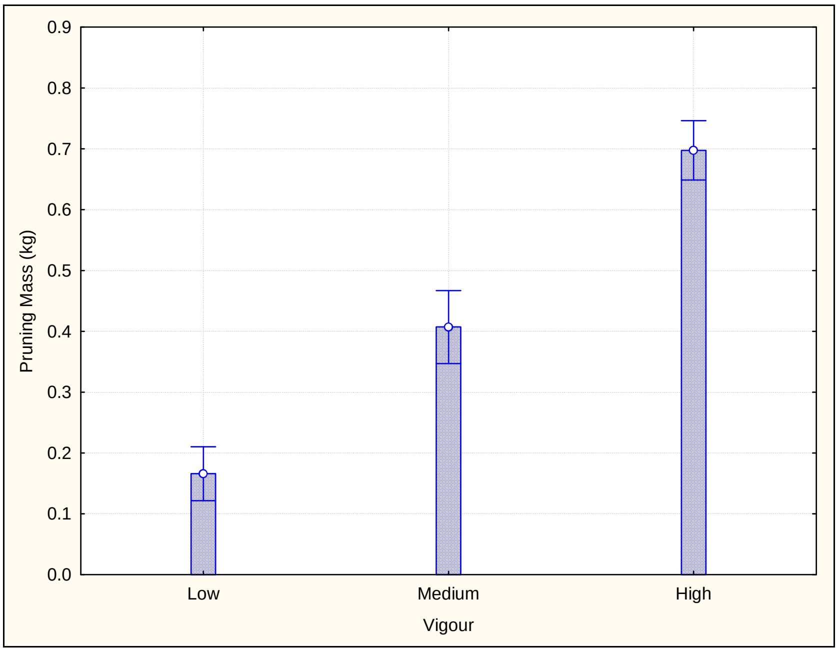

Figure 4.32: One way ANOVA of the pruning mass for the different vigour levels (low, medium and high) in the Chenin blanc vineyard during the winter of 2006. (Vertical bars denote 0.95 confidence intervals; p= 0.0000.)

4.4.6 HARVESTING

The average bunch mass for the high-vigour vines in the Cabernet Sauvignon vineyard during the 2006 harvest was significantly higher than that of the other vigour groups (Figure 4.33). The average bunch mass for the high-vigour vines in the Chenin blanc vineyard was significantly higher than that of the low- and medium-vigour vines (Figure 4.34).

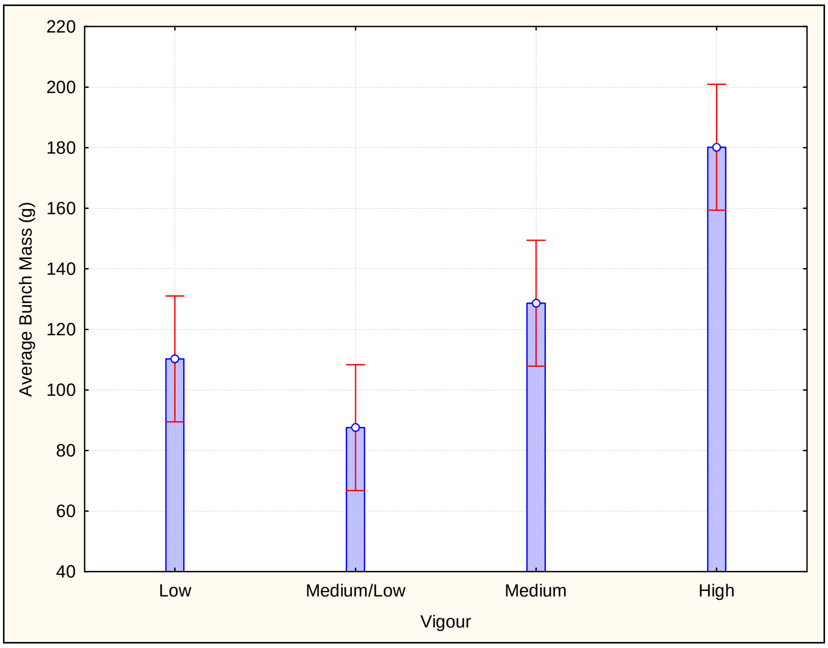

Figure 4.33: One way ANOVA of the average bunch mass (g) over three harvest dates for the various vigour levels (low, medium/low, medium and high) in the Cabernet Sauvignon vineyard (2006 season). (Vertical bars denote 0.95 confidence intervals.)

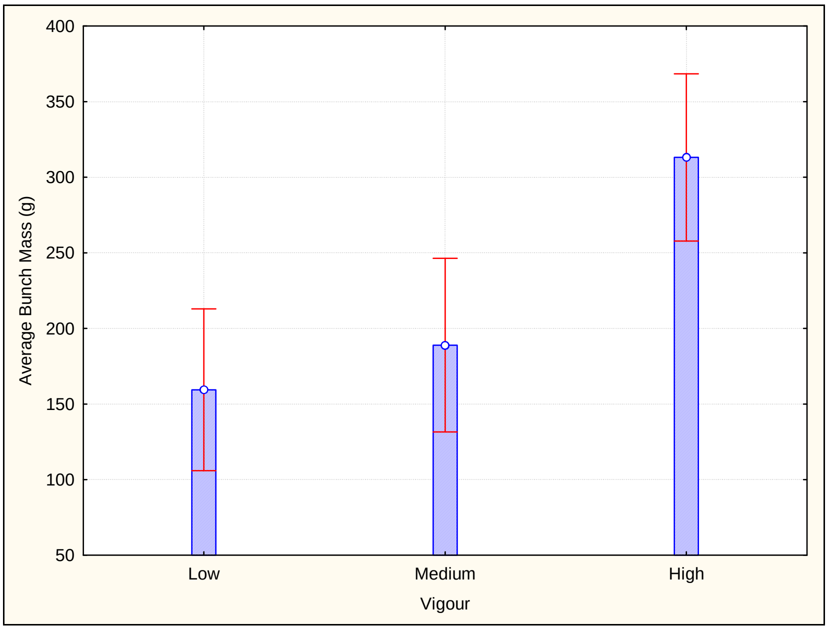

Figure 4.34: One way ANOVA of the average bunch mass (g) over three harvest dates for the various vigour levels (low, medium and high) in the Chenin blanc (2006 season). (Vertical bars denote 0.95 confidence intervals; p=0.0006.)

The average yield per vine was determined over the course of the three harvest dates for both the Cabernet Sauvignon (Figure 4.35) and the Chenin blanc (Figure 4.36). No significant differences concerning yield per vigour area over the three harvest dates, could be identified.

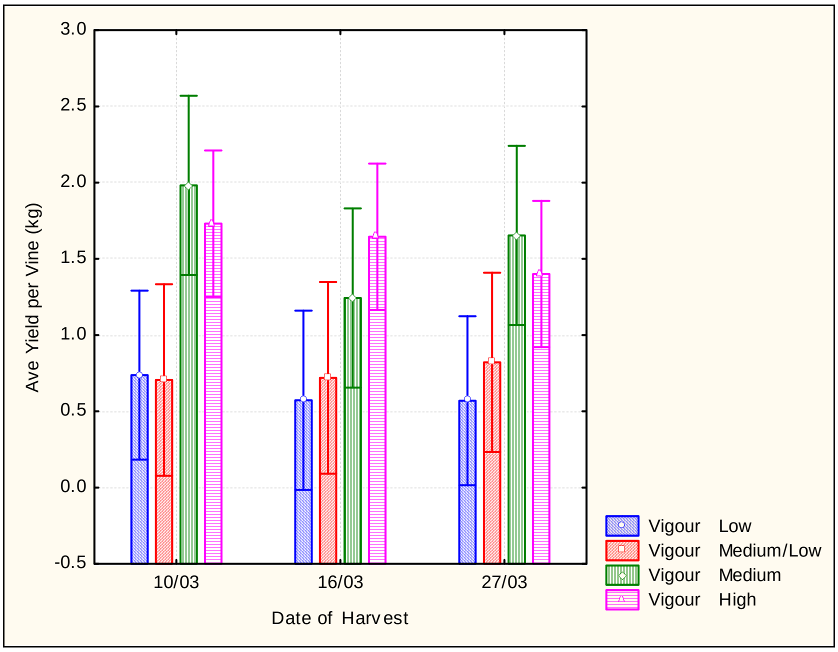

Figure 4.35: Factorial ANOVA of the average yield per vigour level (low, medium/low, medium and high) over three harvest dates for the Cabernet Sauvignon (2006 season). (Vertical bars denote 0.95 confidence intervals.)

Throughout the harvesting period, the pattern for yield per vine in the Chenin blanc vineyard stayed as may be expected, with the low-vigour area having the lowest yield per vine compared to the highest yield per vine for the high-vigour vines.

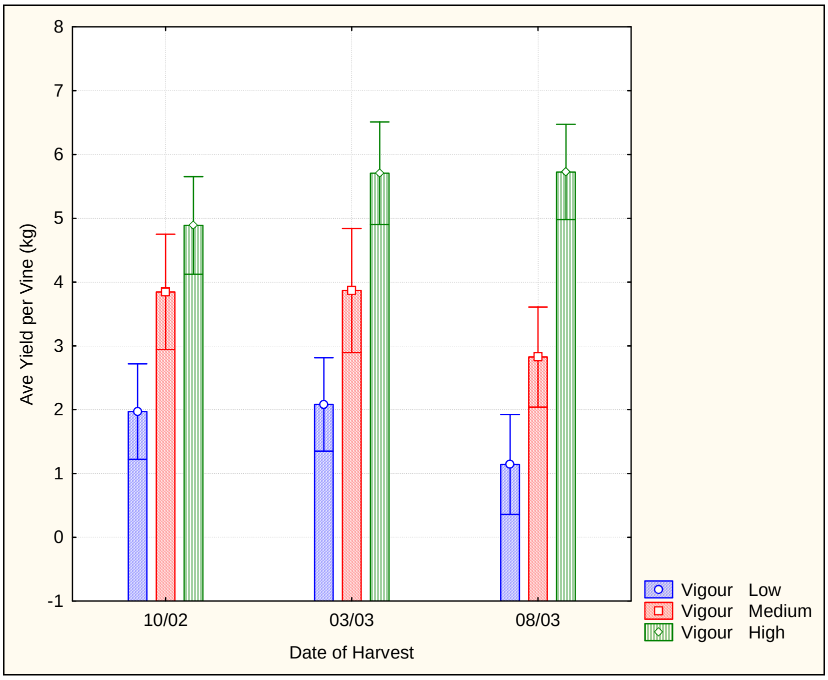

Figure 4.36: Factorial ANOVA of the average yield per vigour level (low, medium and high) over three harvest dates for the Chenin blanc (2006 season). (Vertical bars denote 0.95 confidence intervals.)

4.4.7 SENSORY ANALYSIS

The sensory analysis will be explained with the aid of graphs, forming Addendum B for the Cabernet Sauvignon and Addendum C for the Chenin blanc.

Cabernet Sauvignon: Low-vigour Wines

Wines from both vintages were scored similarly for cooked, fresh and dried vegetative character. It would appear as if the low-vigour mid-2005 and low-vigour late 2006 wines had a stronger cooked vegetative character when compared to the other wines, which had a stronger fresh vegetative character. The low-vigour early 2006 wine had a significantly stronger fruity, berry character than the other wines. All the low-vigour wines were scored low for a fruity, dried fruit character, with the low-vigour mid-2006 wine being scored as having a bit more of this character than the other wines. All the wines were scored rather low for the earthy, spicy black pepper character, with the low-vigour late 2005 wine being scored higher for spicy black pepper character. All the wines were scored moderately high for alcohol and acidity character and for having a good balance. The low-vigour late 2006 wines were scored a bit higher for alcohol character, while the low-vigour early 2006 wines were scored a bit higher on balance. All the wines were scored high concerning colour content, but the highest score was for the low-vigour early 2006 wine. Tannins and fullness scored the same for all the wines over the two seasons. Colour was scored high for most of the wines, except for the low-vigour mid-2005 wine, which scored a bit lower.

Cabernet Sauvignon: Medium- and Medium/Low-vigour Wines

The medium-vigour mid-2006 wine had the highest scoring for cooked and fresh vegetative character, but also scored high for the dried vegetative character. The medium/low-vigour mid-2006 wine seemed to have high levels of all the vegetative characters. Wines from the 2005 vintage seemed to have more of a cooked vegetative character, while the wines from the 2006 vintage had more of a fresh, dried fruit character. Medium-vigour early 2006 and medium-vigour mid-2006 wines had a stronger cooked, fresh vegetative character than the other wines. The medium/low-vigour early, middle and late 2006 wines had a higher fruity, berry character than the other wines, with the medium/low-vigour early 2006 wine being scored higher for fruity dried fruit character than the other wines. All the wines were scored rather low for possessing earthy and spicy, black pepper characteristics. All the wines were scored moderately high for alcohol, acidity and balance characters, with medium/low-vigour mid-2006 wines being scored higher for alcohol than the other wines. All the medium/low-vigour wines and medium-vigour early wines for 2006 were scored higher than the other wines for colour character, fullness and tannins.

Cabernet Sauvignon: High-vigour Wines

Wines from the 2005 vintage were scored the highest for cooked vegetative character in comparison to the 2006 wines. All the wines were scored low for fresh and dried vegetative character, with the high-vigour early 2006 wines being scored the highest for fresh vegetative character. The 2006 vintage wines were scored the highest for fruity, berry and fruity, dried fruit character. Earthy, spicy and black pepper were scored very low for wines of both vintages. All the wines were scored moderately high for alcohol, acidity and balance, with the high-vigour late 2006 wines being score a bit higher on alcohol than the other wines. Wines from the 2006 vintage were scored the highest on colour, tannins and fullness in comparison to the 2005 vintage.

Cabernet Sauvignon: Mix

Grapes form the “mix” trial had berries with a sugar of about 22°B, a pH of 4.1 and an acid of about 2.4. The wine made from these grapes had a fruity, berry character as well as a fresh vegetative character. It had high levels of alcohol, acidity and balance, as well as fullness.

Chenin blanc: Low-vigour Wines

The low-vigour late 2006 and low-vigour early 2006 wines were scored higher for possessing pineapple and fresh, cooked vegetative characters than the other wines, except for the low-vigour mid-2005 and low-vigour late 2005 wines, which were scored moderately high for fresh, cooked vegetative characters. All the wines were scored very low for the possession of litchi character. The scores for all the wines for guava and apricot/peach characteristics were similar, except for the low-vigour early 2006 wine, which scored high for all the characteristics, particularly for guava. Low-vigour early 2006 wines were scored higher than all the other wines for apple, guava, pear and apricot/peach characters, while their scores for the honey, citrus and floral characteristics were relatively low. All the wines scored moderately high for alcohol, acidity, balance and fullness characteristics, with the low-vigour early 2006 wine having the least fullness character. Except for the low-vigour mid-2005 and low-vigour late 2005 wines, all the wines indicated high levels of salty character for the 2005 and 2006 seasons, with mineral character following the same trend as that of the salty.

Chenin blanc: Medium-vigour Wines

Fresh, cooked vegetative characters were scored high for all the wines except the medium-vigour early and mid-2006 wines. Pineapple character was also scored moderately high for some of the wines, with litchi being scored very low. Medium-vigour mid-2006 wines were scored higher for pear and guava characteristics, while medium-vigour early-2006 wines also had high levels of guava. Medium-vigour early 2006 wines were scored higher for citrus and floral characters than the other wines. A honey character was scored higher for the medium-vigour mid-2005 and late 2005 wines than for the other wines. All the treatments of the 2005 vintage were scored higher than those of the 2006 season for the possession of salty and mineral characters. Alcohol, acidity, balance and fullness characters were scored moderately high for wines from both vintages.

Chenin blanc: High-vigour Wines

A pineapple character was scored moderately high for the high-vigour mid-2006 season, with the 2005 wines being scored high for a fresh, cooked vegetative character. High-vigour mid-2006 and early 2006 wines were scored moderately high for a guava character in comparison to the other wines, which were scored low. High-vigour late 2006 wines were scored moderately low for floral character and high-vigour mid-2005 and late 2005 wines were scored moderately low for honey character. High-vigour early 2005 wines where scored moderately high for a salty and mineral character in comparison to the other wines. All the wines were scored moderately high for alcohol, acidity, balance and fullness.

4.5 CONCLUSION

Vigour variation is a common occurrence found in most vineyards worldwide, and is the result of various complex factors. In the past variability was perceived as being part of the vineyard's natural growth and was managed as such. In recent years however, grape growers have realised the potential of embracing this natural phenomenon instead of trying to eradicate it.

Through precision agricultural techniques, modern grape growers are able to improve their managerial decisions. Better educated decisions based on this information, can now be made. One such precision technique is that of remote sensing. With the aid of this type of technology, grape growers are able to identify the various levels of vigour within a block of vines. Not only does this type of technology enable variation identification, but it aids the grape grower in making educated decisions, enabling him to perform certain managerial actions in specific areas. It is important to realize that remote sensing is only a tool for the identification of variability, and that it cannot eradicate the causes thereof. By applying precision technology, grape growers are also able to identify the causes of variability and in the process address it, if the need arises to do so.

There are three important factors to consider when determining where and when to start harvesting in a block:

The *first* factor is to distinguish vigour. It is important to identify various levels of vigour within a block and to sample according to these variations. Total soluble solid levels (°B) for the Cabernet Sauvignon increased steadily throughout the season, but from the first harvest date onward, differences appeared between the different vigour levels. The low vigour and high vigour vines had higher sugar levels, with the low vigour vines having substantially higher pH levels than the high vigour vines, which in turn had the highest acid levels. These differences once again stress the need to identify different vigour levels and structure berry sampling accordingly.

Differing chemical analyses can be interpreted incorrectly if grapes from alternate vigour levels are processed as a single entity. This can be seen in the "mix" trial implemented in the Cabernet Sauvignon vineyard during the last day of harvesting. The grapes from this trial had a lower sugar level than that of the low and high vigour vines, but a higher pH level than the high vigour vines; and a higher acid level than low vigour vines. This just indicates the importance of keeping grapes from various vigour levels apart.

The *second* important factor to consider is how vintages differ from one another. Vintages may differ from each other due to the influence of, for example climatic factors, which in return influences the chemical composition of the grapes. This in turn will have an effect on the aroma and flavour characteristics of the wine made from these grapes.

The *third* factor of importance is the optimum time to commence harvesting. The majority of grape growers and wine makers will concur that when to harvest, will be determined solely by the style of wine the winemaker wishes to produce in order to compete in a certain wine market. From the results of the sensory analysis, it would appear as if there is not a single combination that will define the perfect wine. It is also apparent that the seasonal variance over the two seasons had a stronger effect on wine style and character than did the actual vigour/harvest date interaction. By embracing and managing rather than eradicating the various levels of variation in a block, a variation of wines with different aroma and flavour characteristics can be produced.

The main parameters to determine grape ripeness is sugar, pH and acid levels. From the results it is clear that not a single set of parameters can be used to determine the ripeness level of the grapes. The low vigour vines of the Cabernet Sauvignon for example, had the highest sugar level on the last harvest date which would appear to be favourable, but as soon as pH and acid levels are combined with that of the sugar, a whole different scenario is sketched.

Natural (rain, frost, wind, etc.) and unnatural (managerial inputs) factors accompanies the vine throughout its lifecycle, having profound influences on it and that of the grapes it produces. Soil variation is an important part in the vine's life cycle and is also one of the main causes, if not the most, of vine variation. The soil survey done by the independent laboratory of the Cabernet Sauvignon vineyard did not produce significant information to separate the various vigour levels from each other. Interesting results were however obtained from the bulk density and porosity data gathered of the various vigour levels. The high vigour levels clearly had a lower bulk density and higher porosity than the other vigour levels. This could be ascribed to the high level of organic material present at the different sub soil depths (0-30, 30-60 cm). The reason for the roots not affectively penetrating the 60-90 cm depth is due to inadequate soil preparation that took place. According to the soil analysis of the independent laboratory and the visual inspection of the various soil pits, it appears as if the soil was only correctly prepared up to a depth of approximately 60cm. The soil was thus not loosened properly and its chemical composition bettered by the addition of, for instance, lime. As a result of this, a hardened layer with a low pH is found at a deeper depth range.

A network of vine roots developed, especially in the high vigour levels, due to the low bulk density and high porosity characteristics of the soil. A fine root system is important for the optimal absorption of available moisture and nutrients present in the soil. The low, medium/low and medium vigour levels have a poorly developed root system, throughout the whole soil profile.

The insufficient root system of the low vigour vines clearly had an impact on the berry mass of the grapes as the season progressed, while the root system of the high vigour vines positively effected the grape berries by increasing their mass. Although the low, medium/low and medium vigour levels have poorly developed root systems, their total titratable sugar levels were almost the same as the high vigour levels, with the low vigour levels having the highest sugar and pH levels, while all the vigour levels had the almost the same acid levels.

Although a soil survey of the Chenin blanc vineyard was not done by this author, the influence of the shale was clearly visible on the low vigour vines and to a lesser extent on the medium vigour vines. The grapes of the low vigour levels struggled to gain sugar, but as the season progressed and the salinity took its toll in the vine structure by causing leaf necroses and leaf fall, the grapes were exposed to the rays of the sun and burned severely. These grapes had the highest pH levels of all the vigour levels and very low acid levels. Although the grapes of this vigour level did not have good chemical characteristics, it still produced a wine with certain flavour and aroma characteristics. An interesting result was that of the high levels of salinity noticed by the tasters, indicating that the chemical composition of the soil can affect the berries.

The aim of the project was to determine if differences in vine vigour, as shown by multispectral imaging, leads to variance in grape and wine characteristics, as determined at different harvest dates. This was true through the various analysis and data interpretations carried out. Unfortunately a recipe for a certain wine style could not be determined due to an array of various wine styles produced over the two vintages. It would appear as if grape ripeness must be defined by the individual, be it the grape grower or wine maker, with regard to the intended use of the grapes.

One aspect of proper managerial inputs that came to light during the duration of the study is that of proper soil preparation. In both vineyards the soil preparation was not correctly applied. The Cabernet Sauvignon vineyard could still be approved upon deep ripping in an endeavour to break the hardened layers in the sub soil, while at the same time applying adequate lime to address the pH problem. The Chenin blanc block however, has been permanently scared by the mixing of the shale in the underground with the rest of the soil, causing permanent salinity problems in some areas.

4.6 REFERENCES

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Chapter 5

GENERAL DISCUSSION AND CONCLUSIONS

GENERAL DISCUSSION AND CONCLUSIONS

5.1 GENERAL CONCLUSIONS

South African grape growers are faced with the challenge of managing their vineyards in such a manner as to optimise vine performance in order to achieve better yields, Vineyard variation is a natural phenomenon that will always be found in most vineyards throughout the world. This variation is caused by to an array of controllable and non-controllable factors that which will influence the vine. The influences on the vine will in turn be reflected in the chemical composition of the grapes. The varying chemical composition of the grapes will in turn lead to the production of wines that vary in aroma and flavour composition.

Due to the rising input costs of agricultural production, grape growers are forced to look at new methods that will enable them to farm more cost effectively. One of these methods is aerial imagery.

Aerial imagery was used in both projects as a precision viticulture method to identify variation within the vineyard. Aerial images correlated well with vegetative measurements that were taken, in order to distinguish between the various vigour levels. Through this identification, the causes of variation, namely differences in soil type and characteristics, could be established. The chemical differences in the soil could be corrected by adding certain fertilizers or lime, and even addressing the hardened layers in the sub soil by performing a deep ripping action.

Grape growers must learn to embrace this phenomenon of variation instead of trying to eradicate it.

From the two projects that were conducted, it has been proved that varying chemical results will be obtained if berry sampling is specified, either by 1) different vigour levels or by 2) vigour levels in conjunction with different crop loads or harvest dates.

Grape chemical characteristics will change during the season. This change can be fuelled by high or low temperatures, and even rainfall, that will have an effect on sugar, pH and acid levels. Optimal grape character might only be present for a short period of time in the ripening continuum of the grapes. Grapes can thus be harvested at different times, each having different chemical characteristics. When to harvest will be determined by the individual and the specific wine style to be produced. Many researchers emphasise the need for multiple chemical analyses to be performed on grapes to determine when to harvest. These analyses will only determine the chemical composition of the grapes. Chemical composition of grapes, as seen in both studies, varies dramatically concerning sugar, pH and acid levels. It is thus clear that not one parameter must be used to determine grape ripeness, but a combination of parameters. Misleading information could be given to the winemaker if not all the parameters are considered during the establishment of optimum harvest time. If grapes are to be harvested at the correct time, it has to be tasted continuously until the desired flavours are present. The flavours that are present at the time of sampling will also be present in the wines produced from these grapes.

When a vine is be subjected to any manipulation such as pruning or crop thinning treatments, it is vital that the capacity of the vine is taken into account. If a vine has a good developed above-ground structure, it will also have a good developed subterranean structure to support it that is if soil conditions are favourable. Vines that have a poorly developed aboveground structure will therefore also have a poorly developed subterranean structure. If a vine does not have a good developed root system, is will be unable to support any strong vegetative and reproductive growth.

Crop thinning is a treatment that must be carried out on young and struggling vines, in order for them to develop a strong above- and subterranean structure. Crop thinning must be done very selectively on mature vines, if done at all. If a vine has good balance, meaning that it does not favour vegetative growth above that of reproductive growth or the other way around, crop thinning should not be done at all.

Good managerial decisions are vital for success in today's competitive business driven society. If a grape grower makes a fatal mistake due to negligence, the consequences may last for generations to come. For instance wrong choices made during soil preparation may induce vine variation in a block (as an example consider the Chenin blanc block in this study). The vines in areas were soil salinity has been aggravated through mixing of the underlying shale, will never be able to reach full potential. Not only will these low vigour vines cost the producer money, in the form of pruning, suckering and harvesting costs, but it will never be able to produce enough grapes of required quality, with subsequent loss of income.

It can therefore be concluded that studies investigating the interaction of the vine with its environment, as well as the effects of producer manipulations such as crop thinning or harvesting at different ripeness levels should be conducted with incorporation of vigour quantification prior to planning the experiments. Knowledge about vine vigour will not only enhance our understanding of the vine's reaction to manipulations, but also aid in targeted management practices such as targeted sampling or zoned harvesting practices. The objective of these strategies should be to "exploit" vigour differences either to teach us more about vine reaction, or to enhance wine complexity through separate harvesting and intelligent blending. Whatever the case, it is clear that research on vine vigour and its effects on grape/wine characteristics have only just started, and will still yield a lot of interesting results in future.

<u>Addendum A</u>: Root penetration and distribution in the Shiraz vineyard.

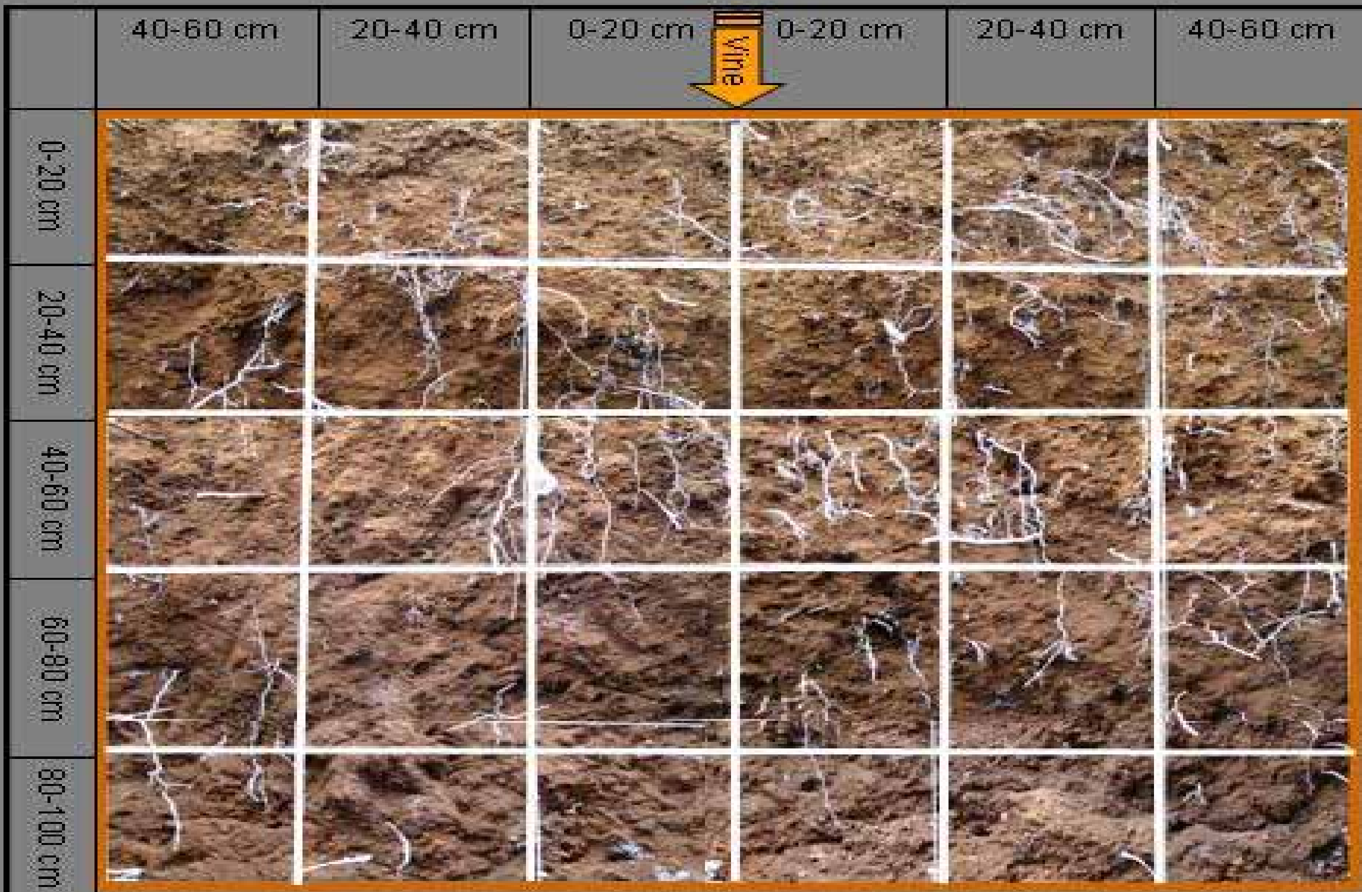


Figure A1: Low vigour soil pit in a Shiraz/101-14 Mgt vineyard.

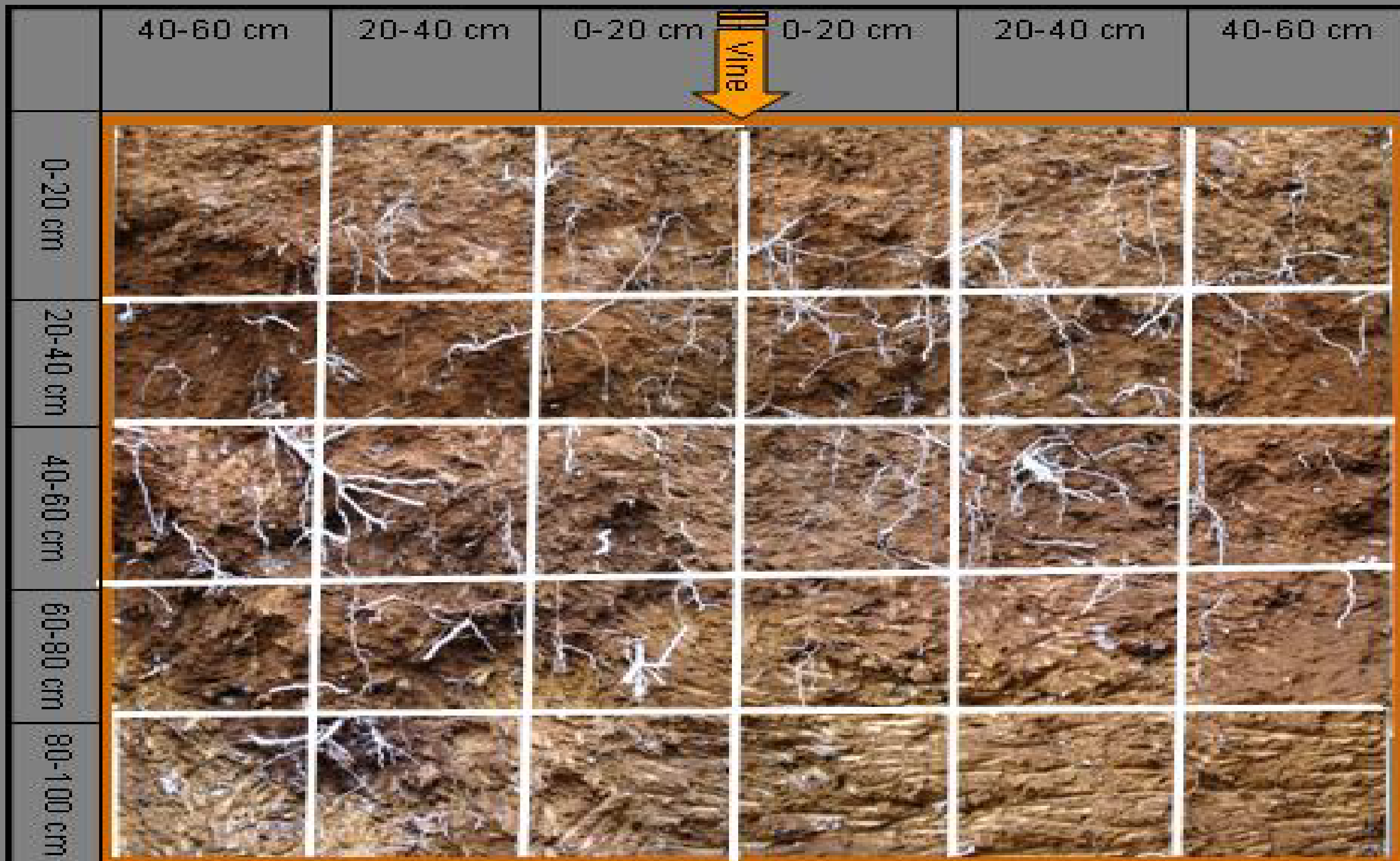


Figure A2: Medium vigour soil pit in a Shiraz/101-14 Mgt vineyard.

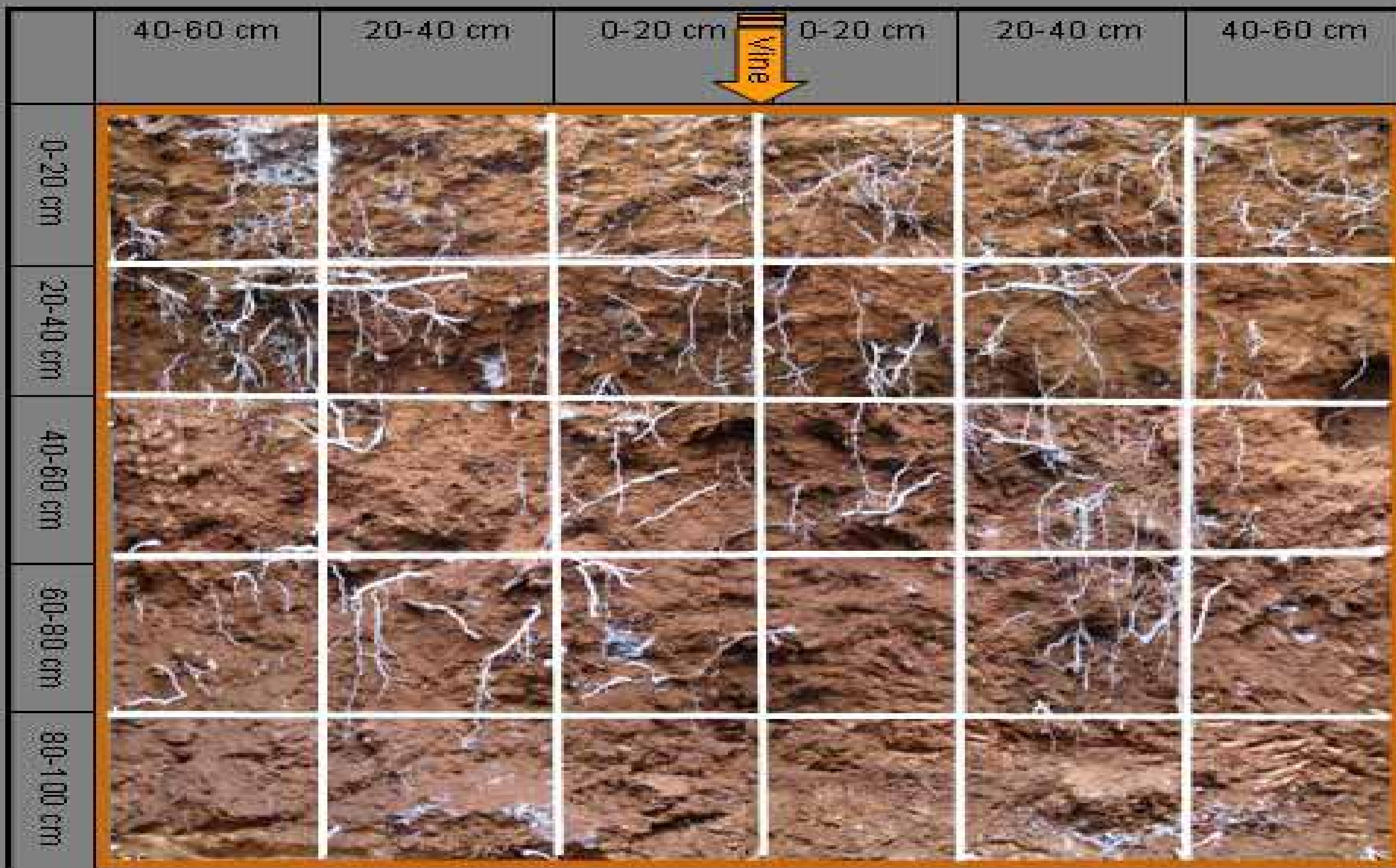
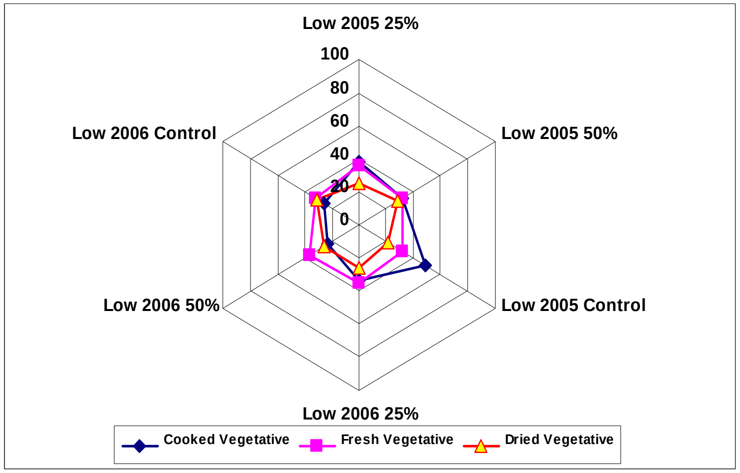
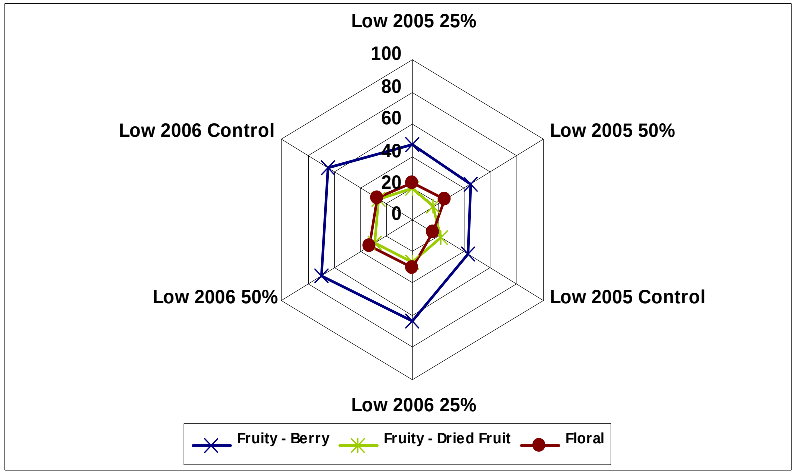


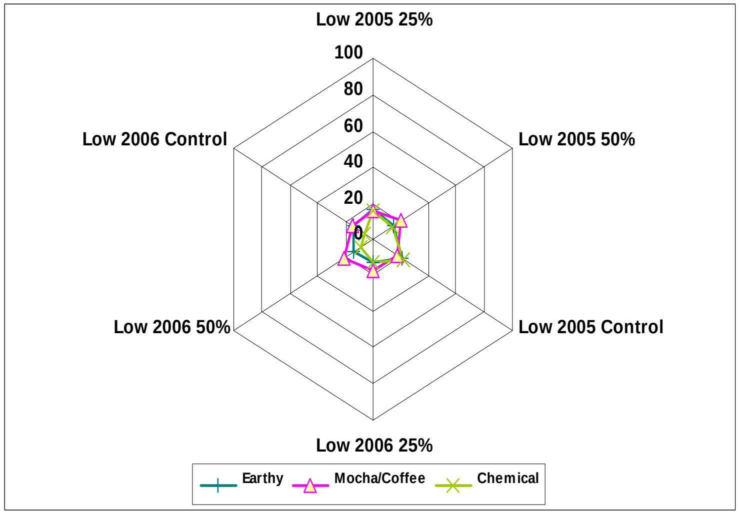
Figure A3: High vigour soil pit in a Shiraz/101-14 Mgt vineyard.

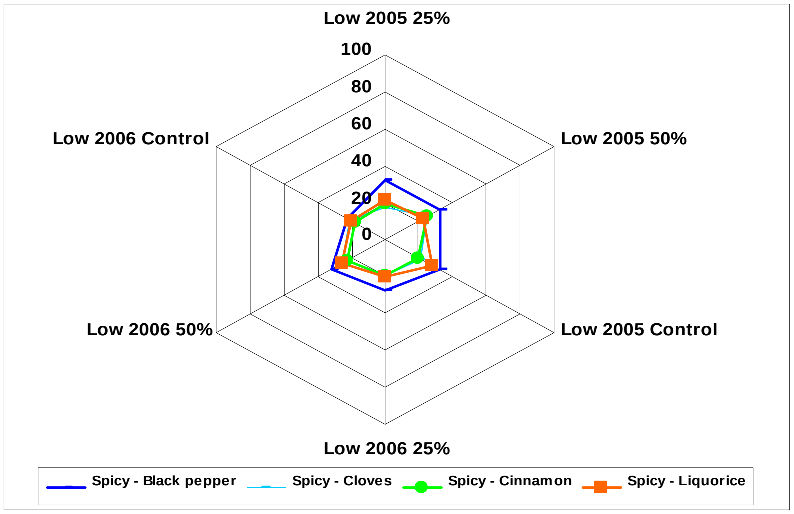
Addendum B: **Sensory analyses of the wines made from the vigour/crop thinning experiment.**

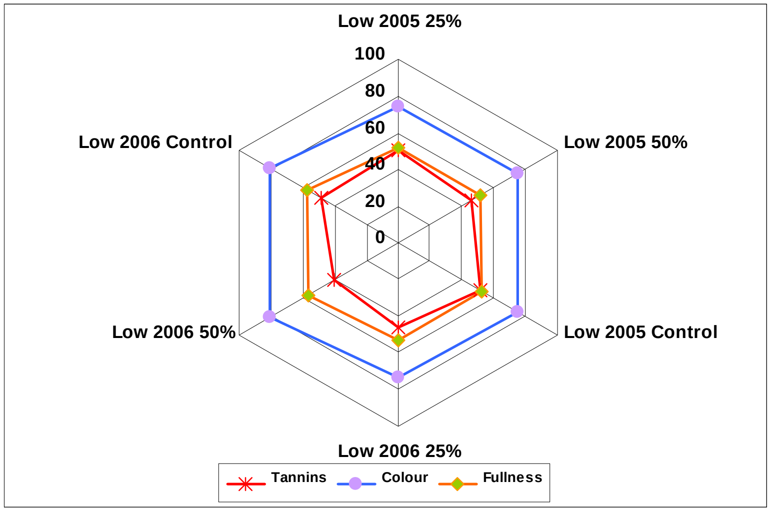
Wines from the low-vigour vines for the two vintages

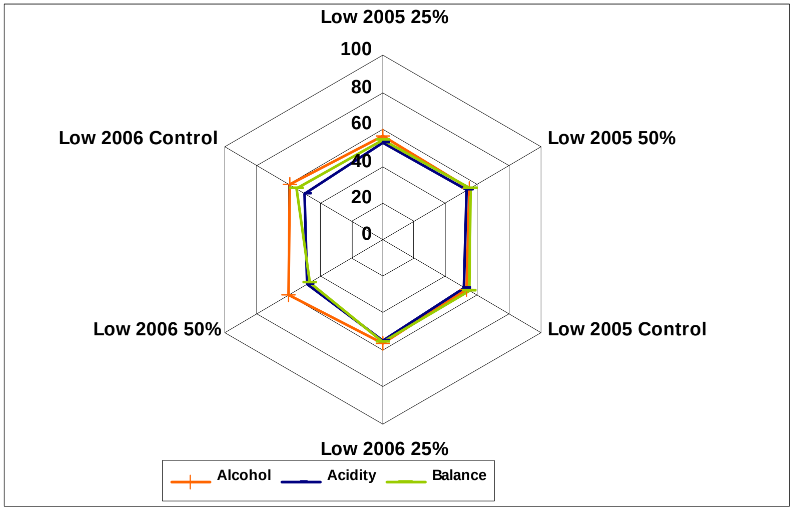




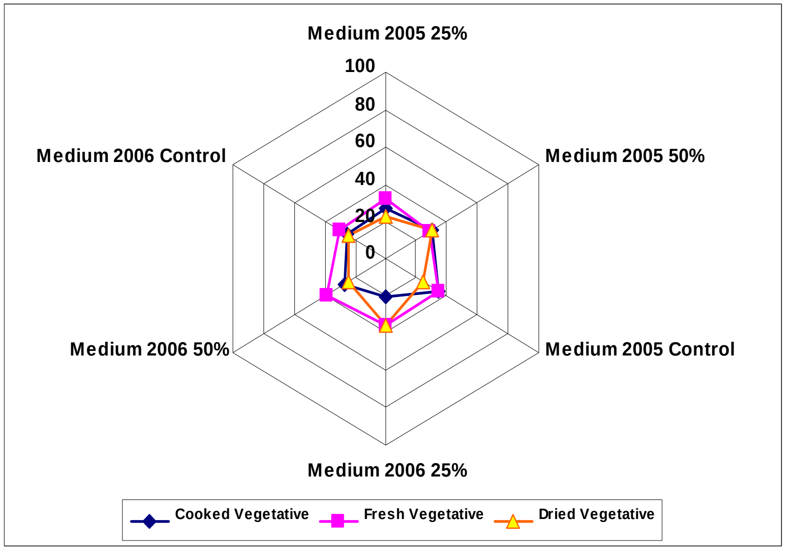


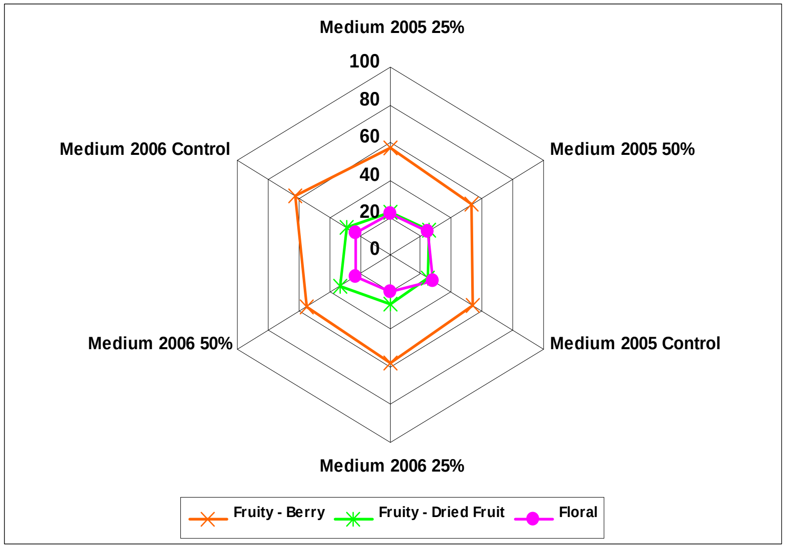


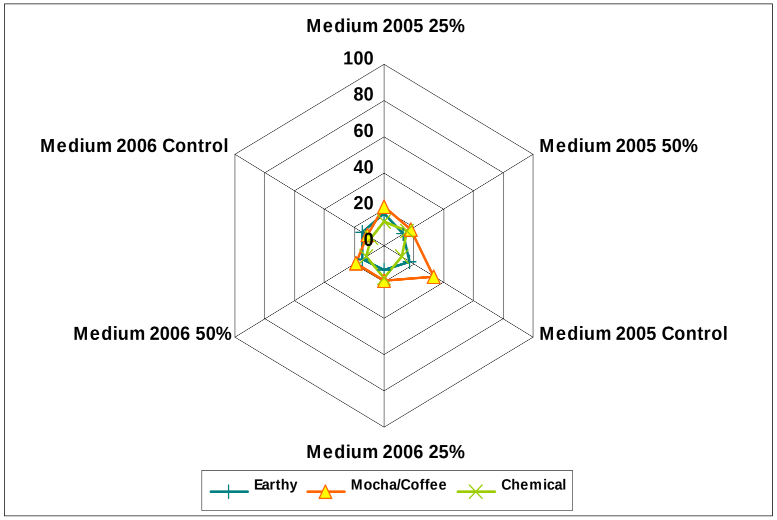

Low 2005 25%
100
80
60
40
20
0
Low 2005 50%
Low 2005 Control
Low 2006 25%
Low 2006 50%
Low 2006 Control
Tannins
Colour
Fullness

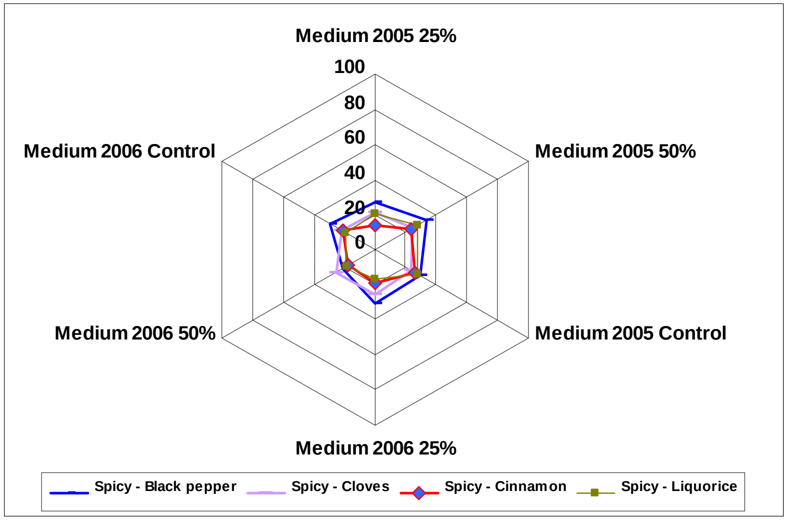

Low 2005 25%
100
80
60
40
20
0
Low 2005 50%
Low 2005 Control
Low 2006 25%
Low 2006 50%
Low 2006 Control
Alcohol
Acidity
Balance

Wines from the medium-vigour vines for the two vintages.

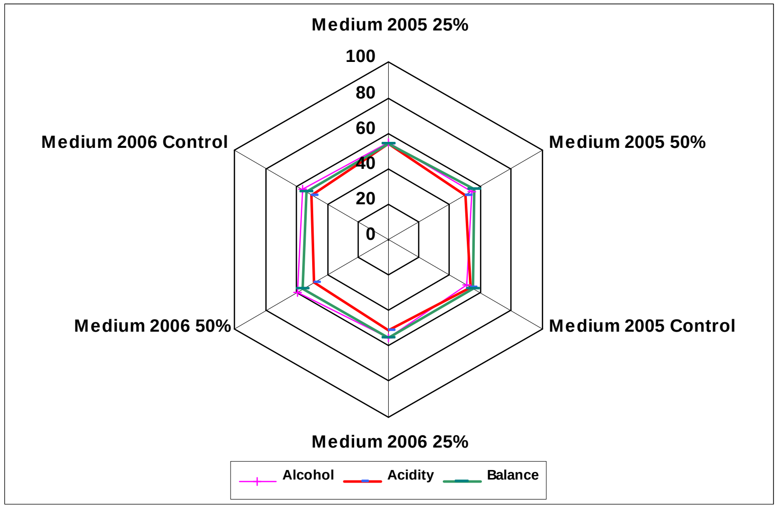




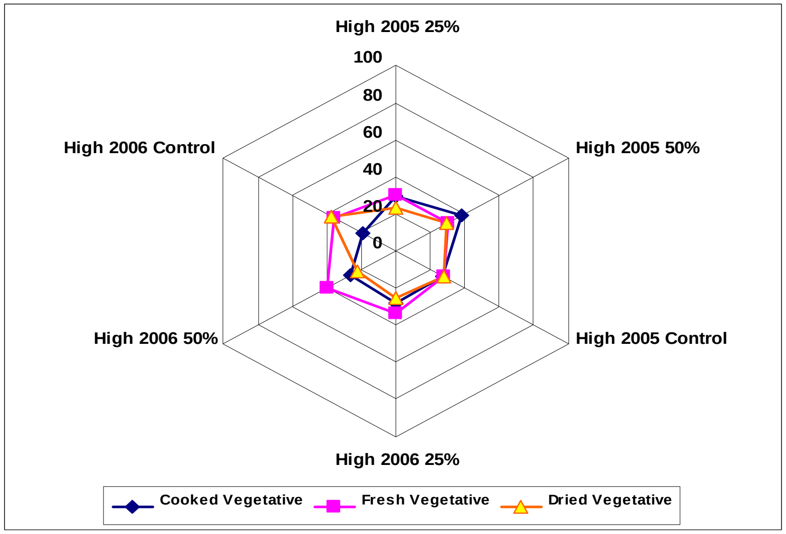


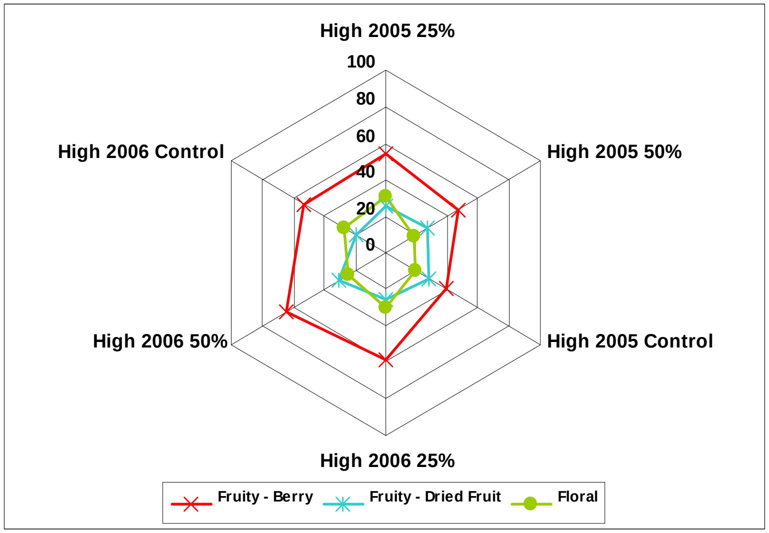


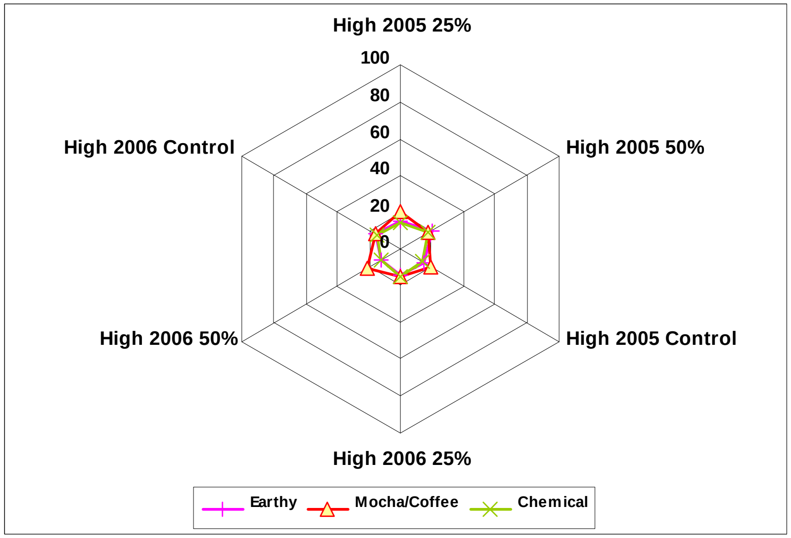

Medium 2005 25%
100
80
60
40
20
0
Medium 2005 50%
Medium 2005 Control
Medium 2006 25%
Medium 2006 50%
Medium 2006 Control
Tannins
Colour
Fullness

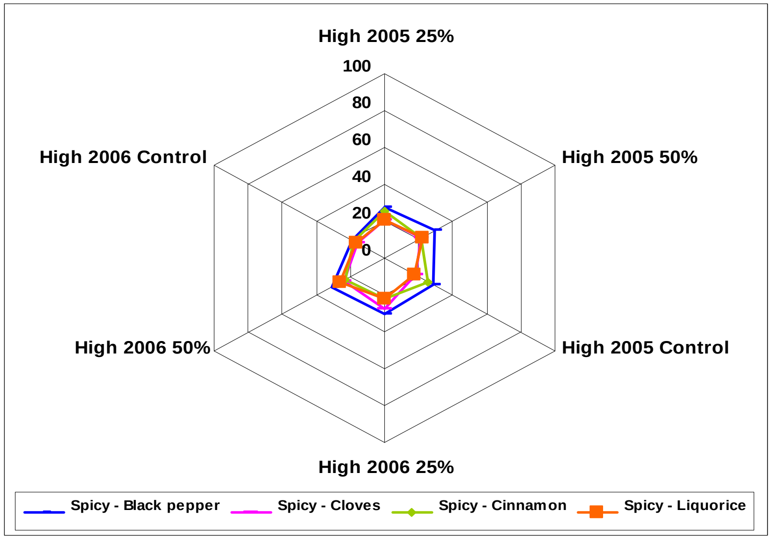

Medium 2005 25%
100
80
60
40
20
0
Medium 2005 50%
Medium 2005 Control
Medium 2006 25%
Medium 2006 50%
Medium 2006 Control
Alcohol
Acidity
Balance

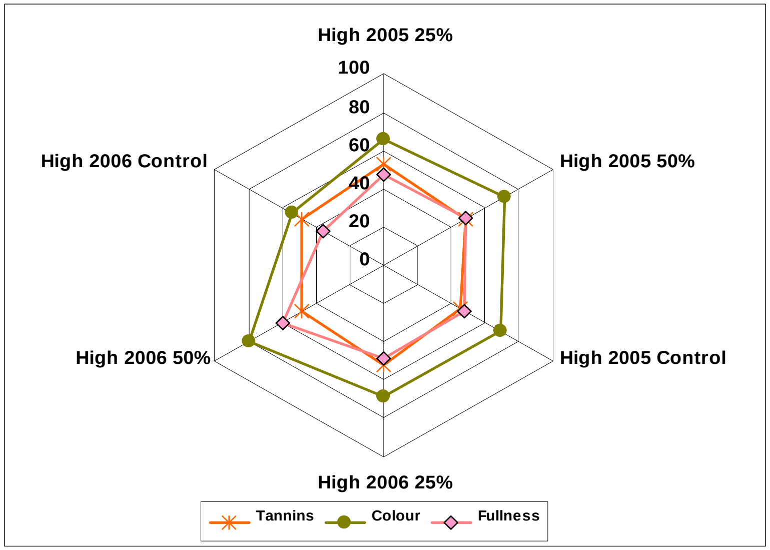
Wines from the high-vigour vines for the two vintages










High 2005 25%
100
80
60
40
20
0
High 2005 50%
High 2005 Control
High 2006 25%
High 2006 50%
High 2006 Control
Tannins
Colour
Fullness


High 2005 25%
100
80
60
40
20
0
High 2005 50%
High 2005 Control
High 2006 25%
High 2006 50%
High 2006 Control
Alcohol
Acidity
Balance

<u>Addendum A</u>: Root penetration and distribution in the Cabernet Sauvignon/Richter 110 vineyard.

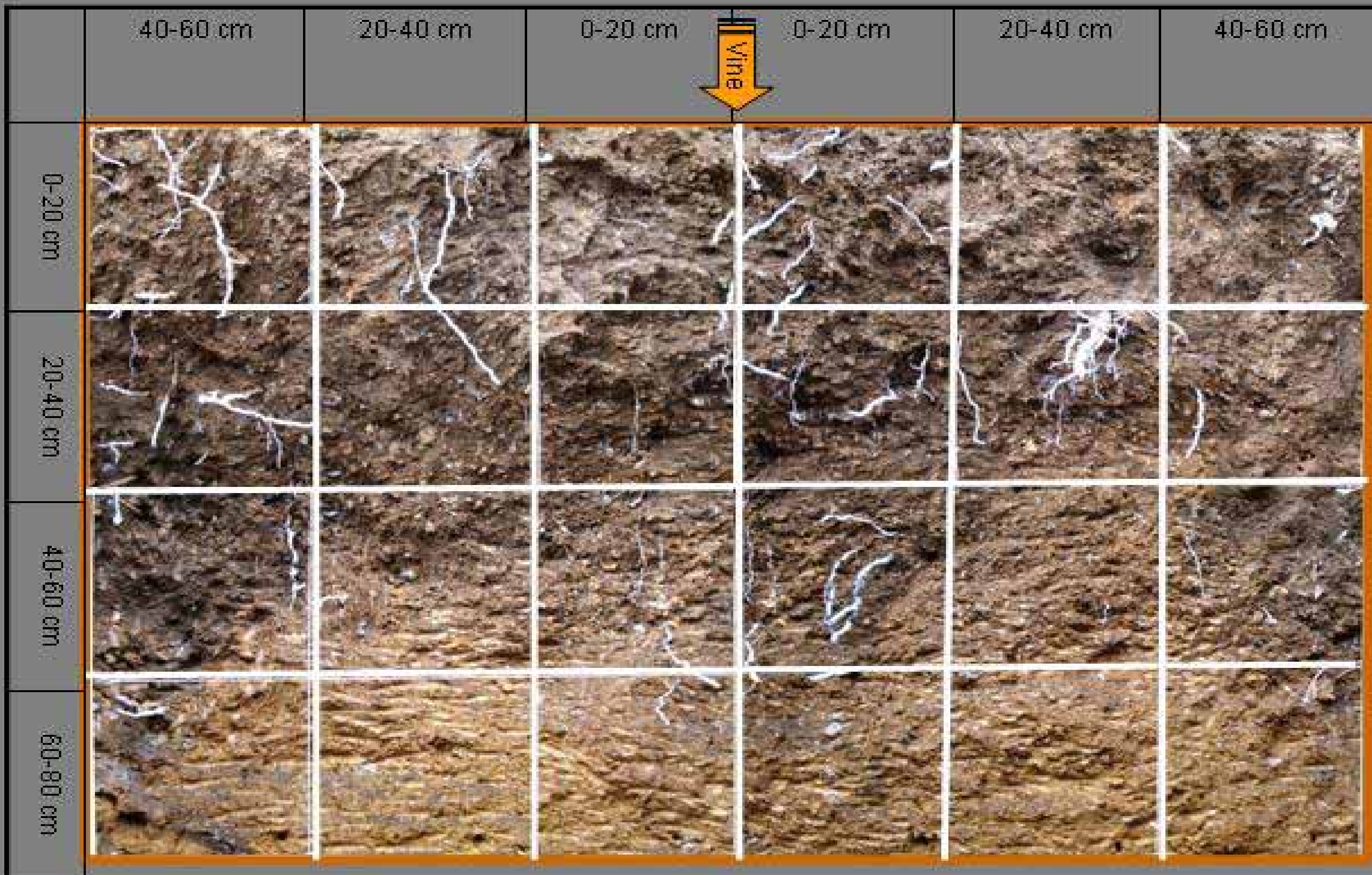


Figure A1: Low vigour soil pit in a Cabernet Sauvignon/Richter 110 vineyard.

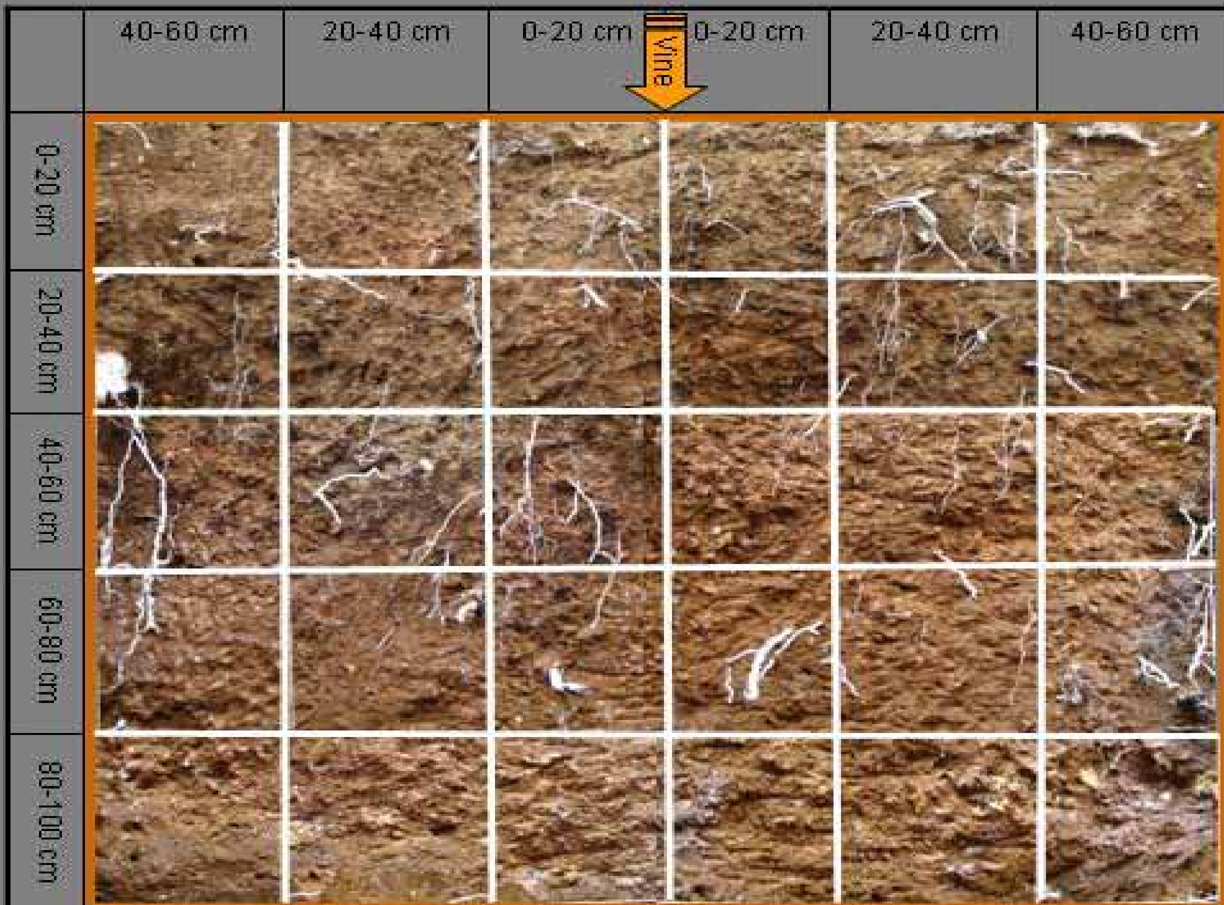


Figure A2: Medium/Low vigour soil pit (medium/low 1) in a Cabernet Sauvignon/Richter 110 vineyard.

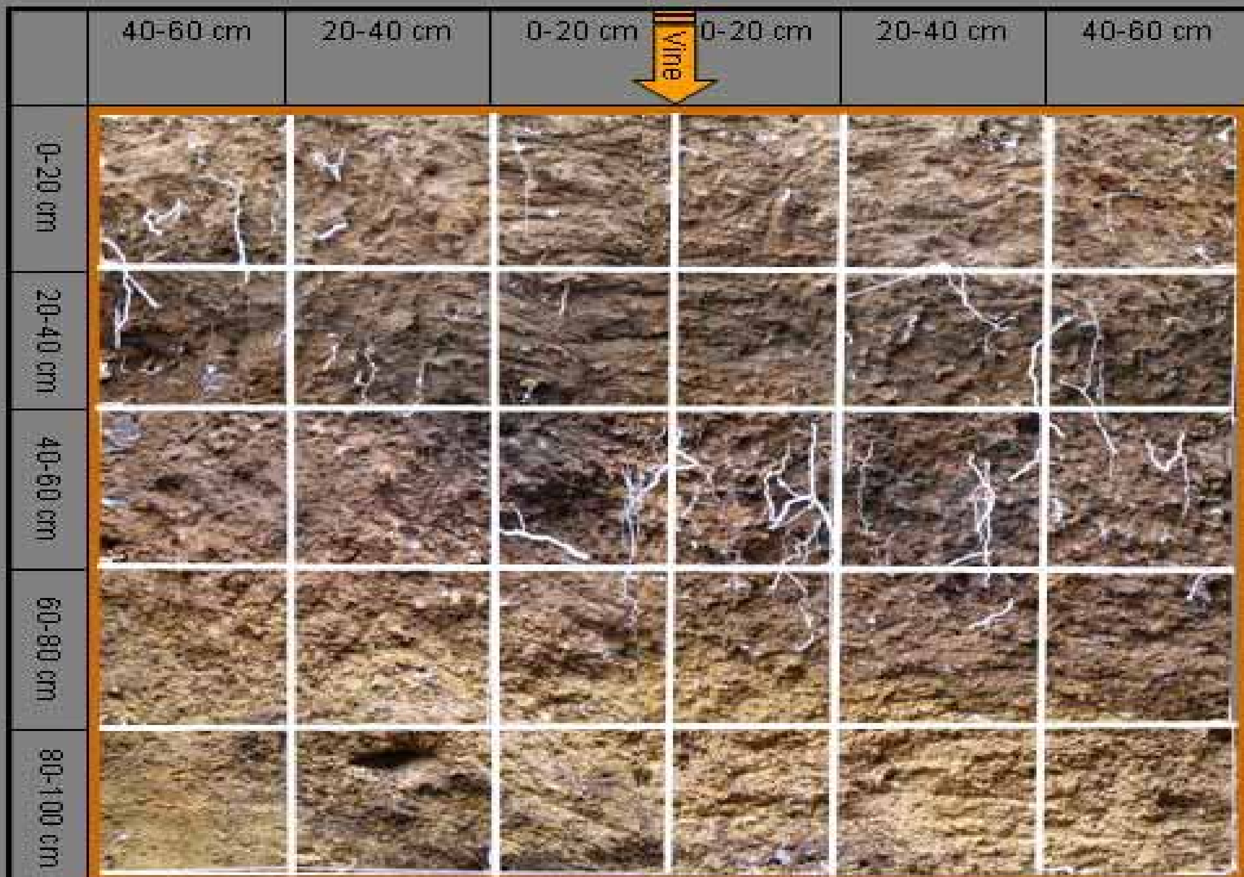


Figure A3: Medium/Low vigour soil pit (medium/low 2) in a Cabernet Sauvignon/Richter 110 vineyard.

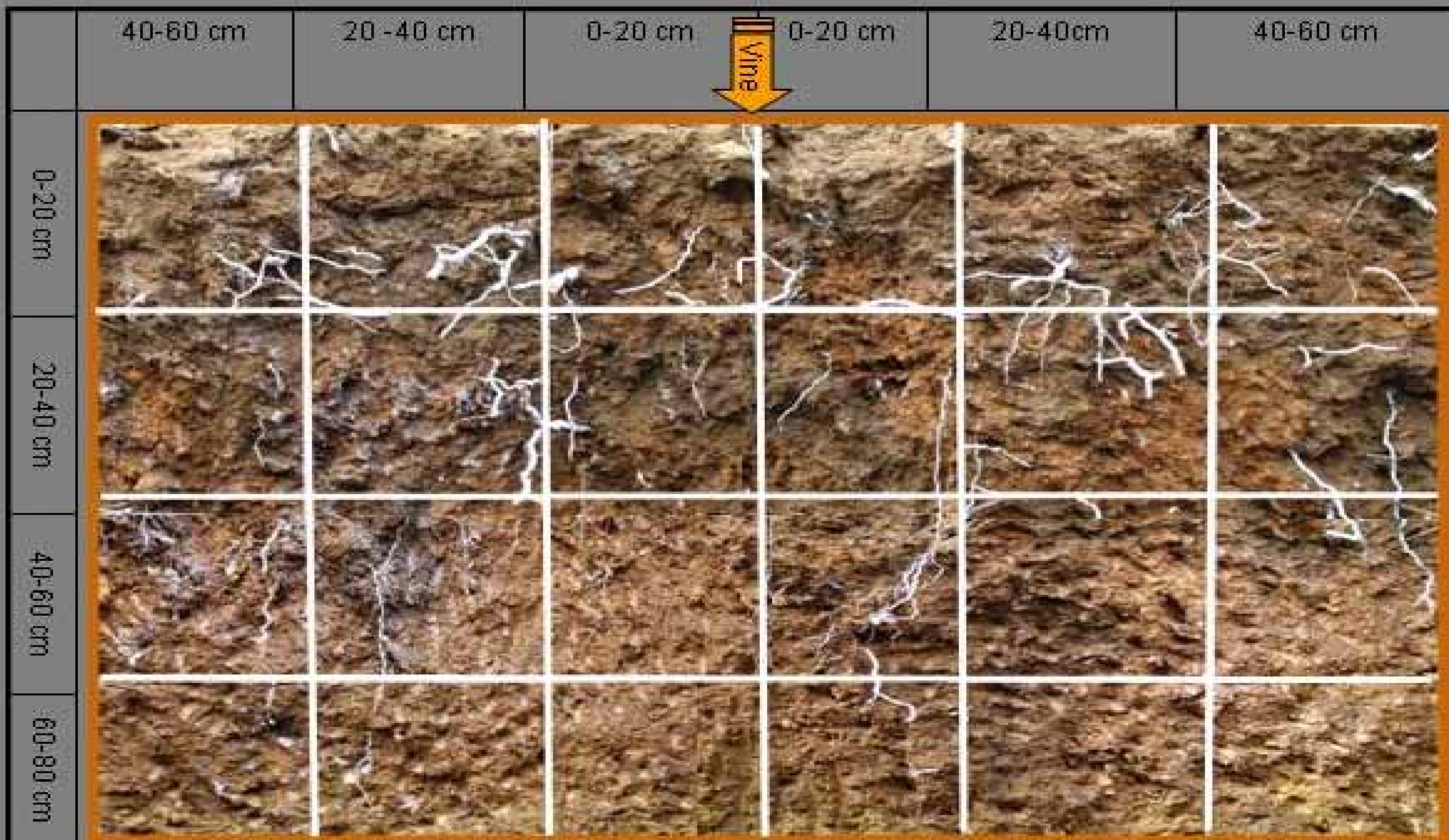


Figure A4: Medium vigour soil pit in a Cabernet Sauvignon/Richter 110 vineyard.

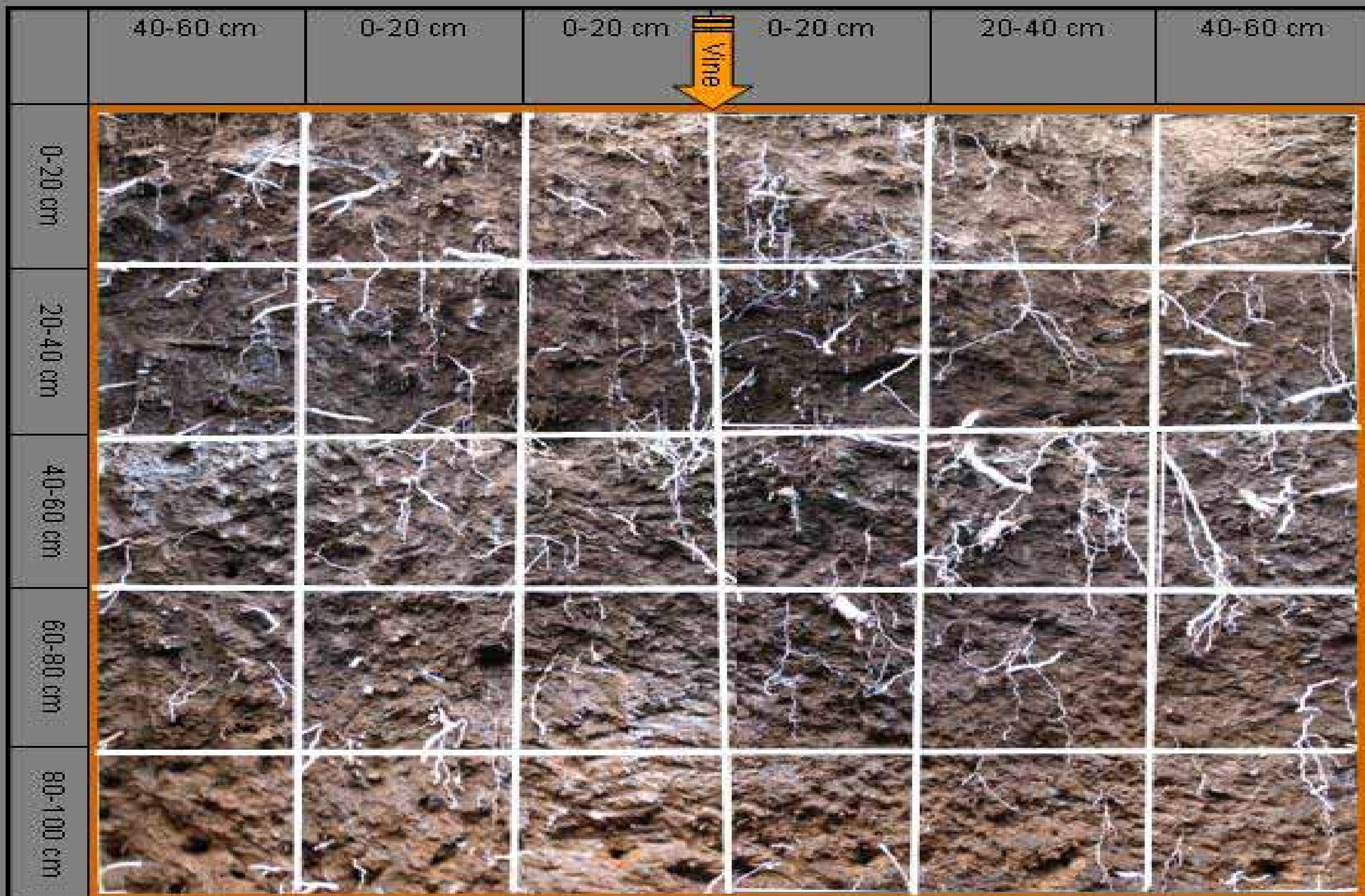


Figure A5: High vigour soil pit (high 1) in a Cabernet Sauvignon/Richter 110 vineyard.

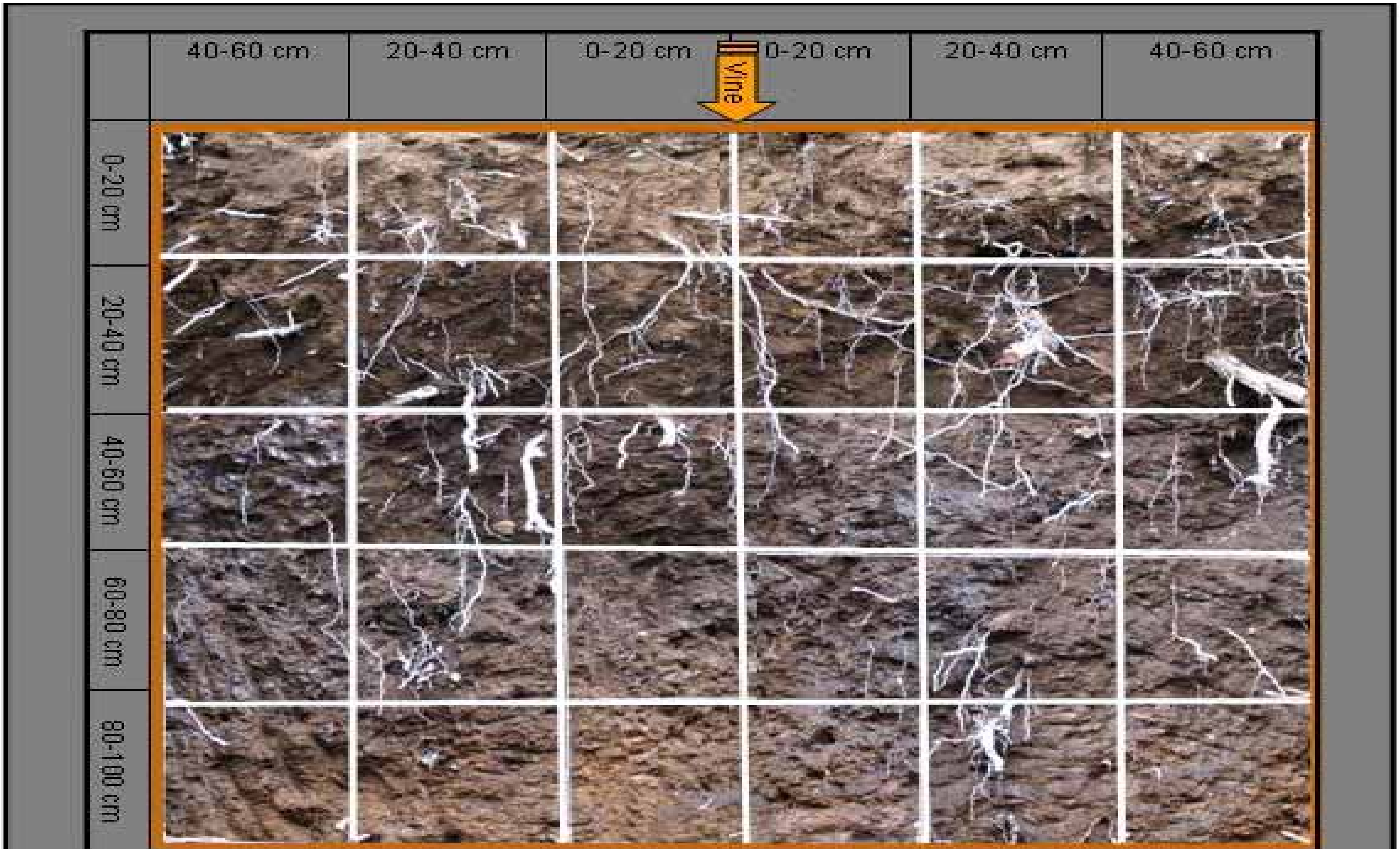


Figure A6: High vigour soil pit (high 2) in a Cabernet Sauvignon/Richter 110 vineyard.

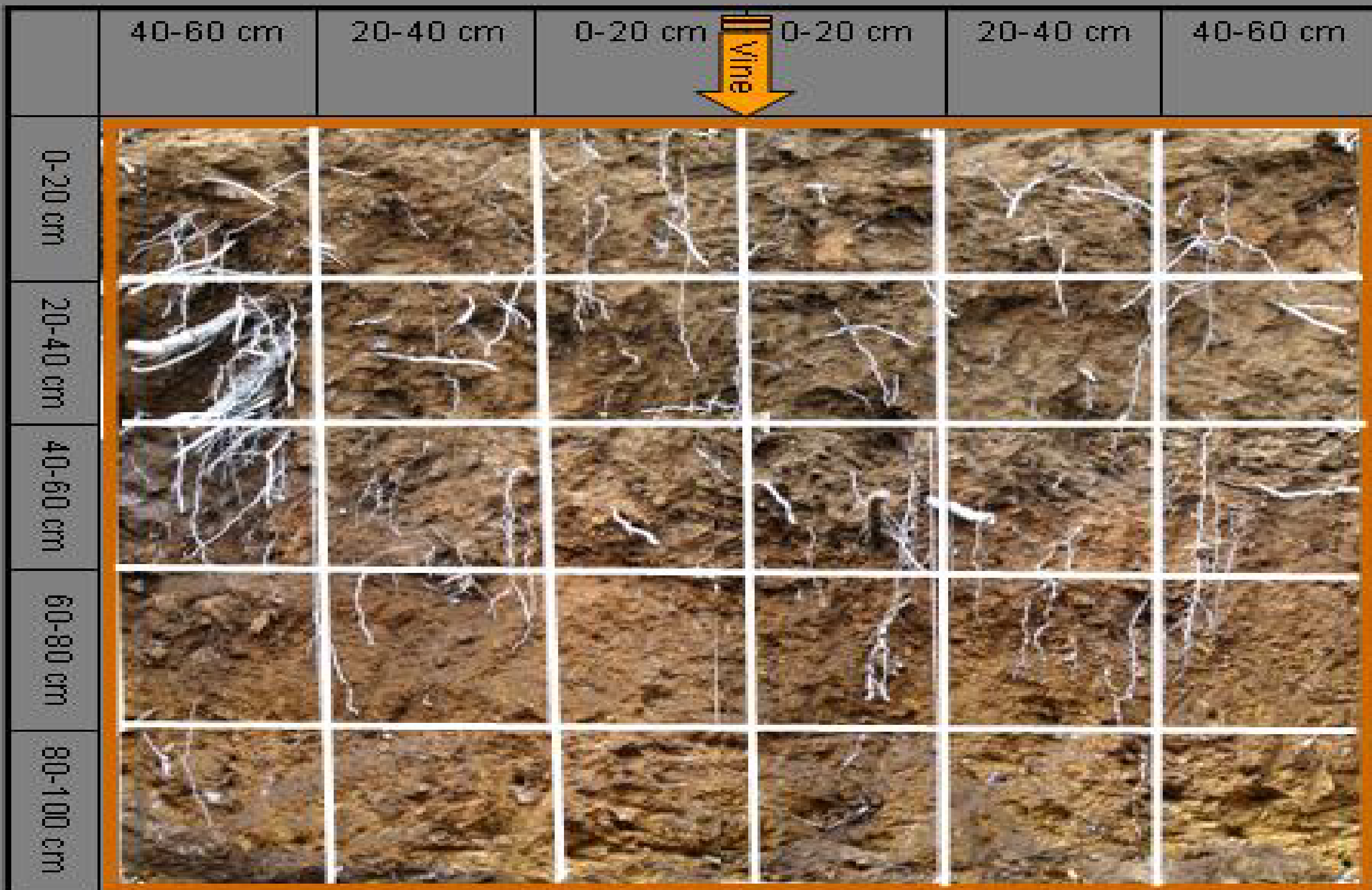


Figure A7: High vigour soil pit (high 3) in a Cabernet Sauvignon/Richter 110 vineyard.

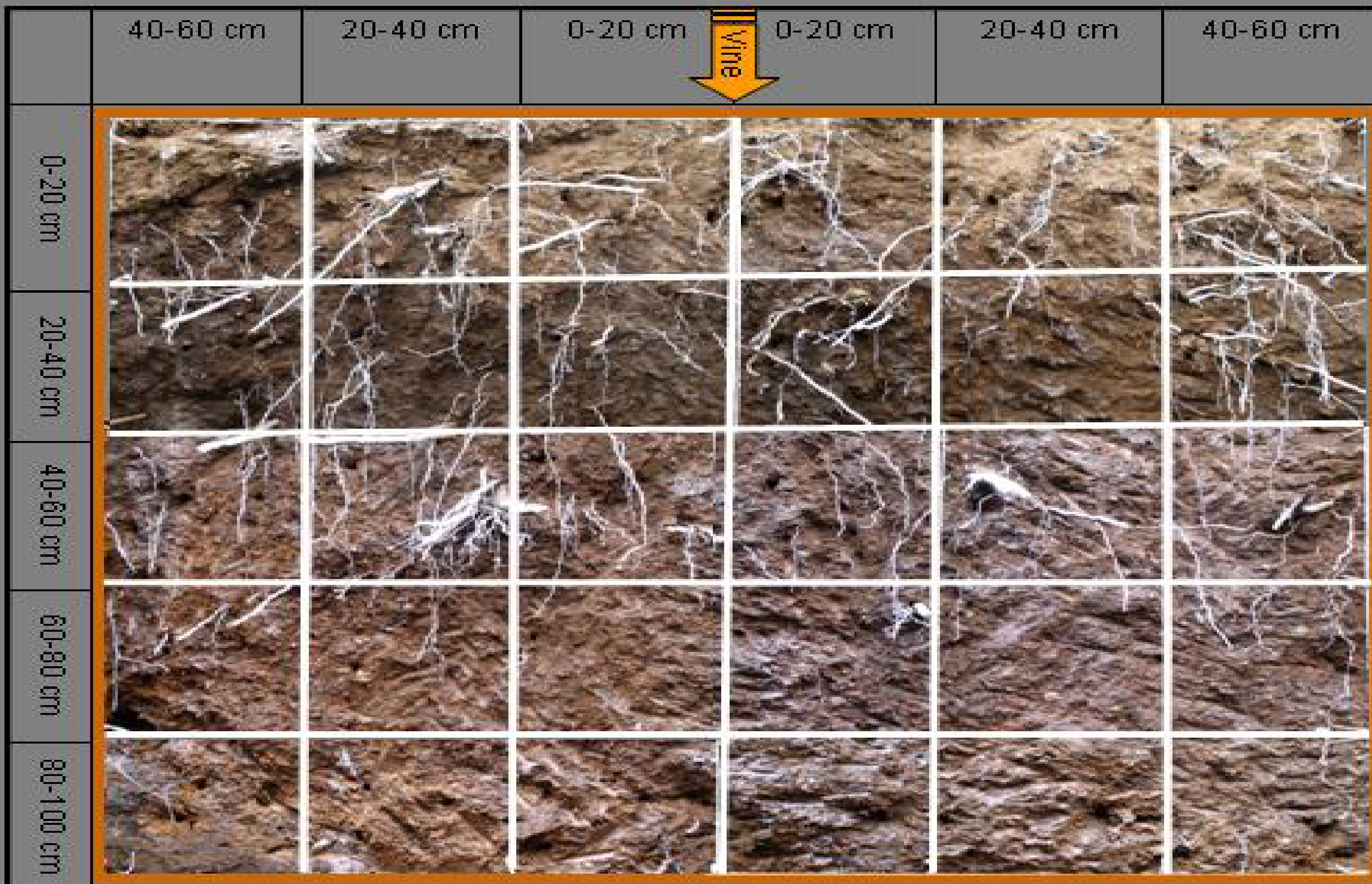
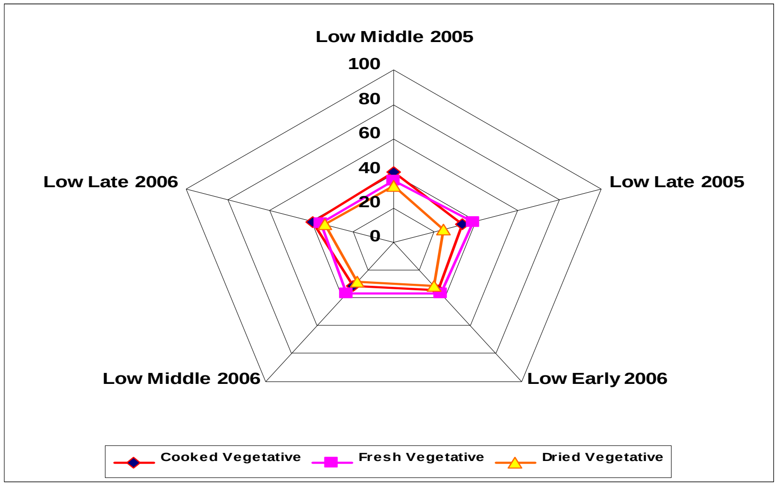
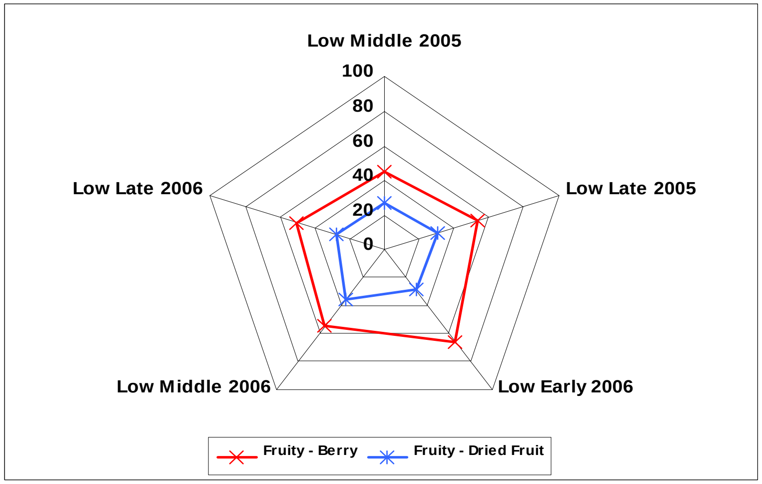
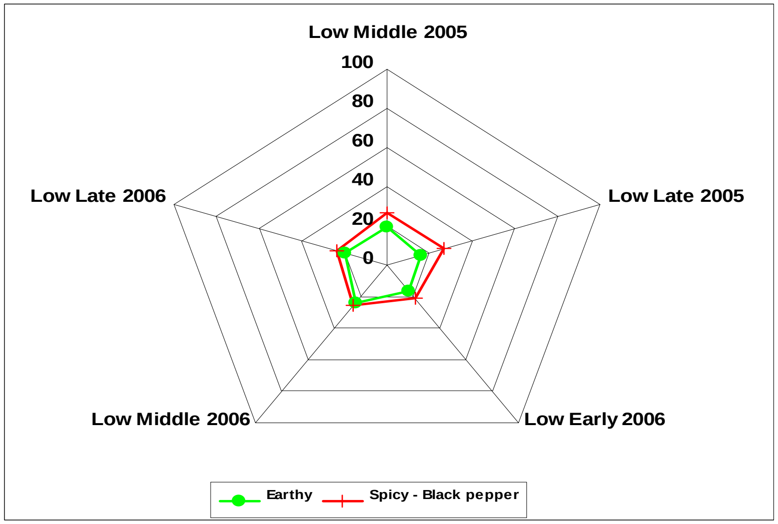


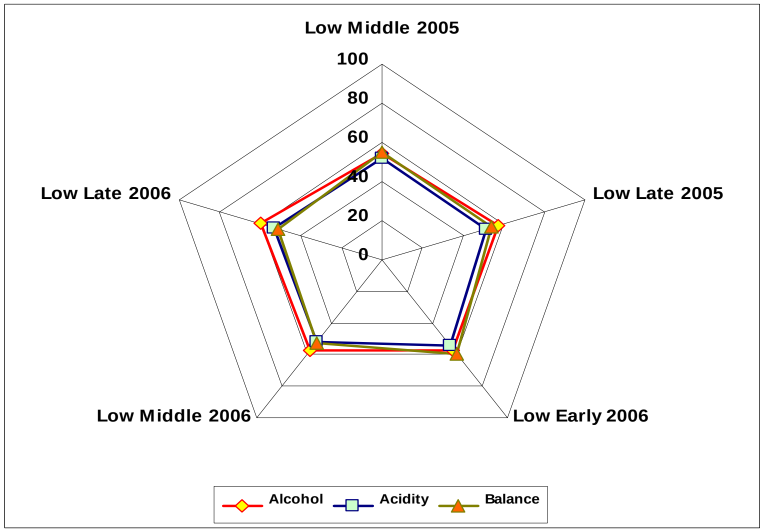
Figure A8:High vigour soil pit (high 4) in a Cabernet Sauvignon/Richter 110 vineyard.

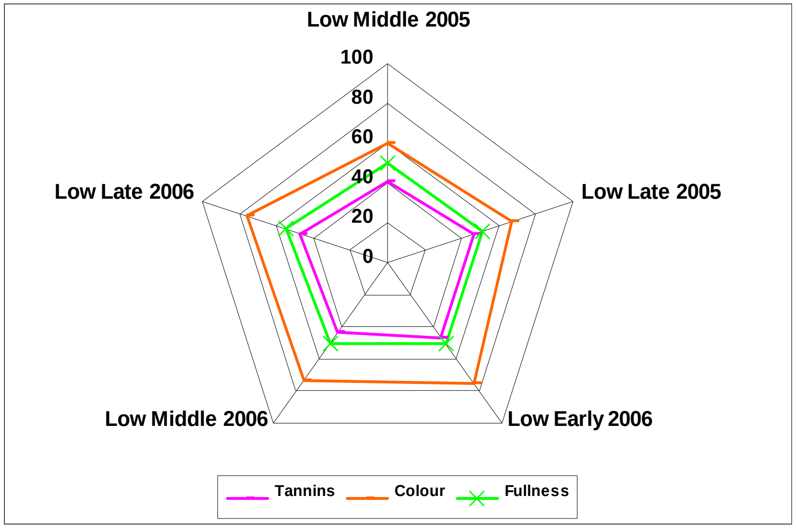
<u>Addendum B</u>: Sensory analyses of the wines made from the Cabernet Sauvignon vigour/harvest date experiment. Wines from the low-vigour vines for the 2005 and 2006 vintages.



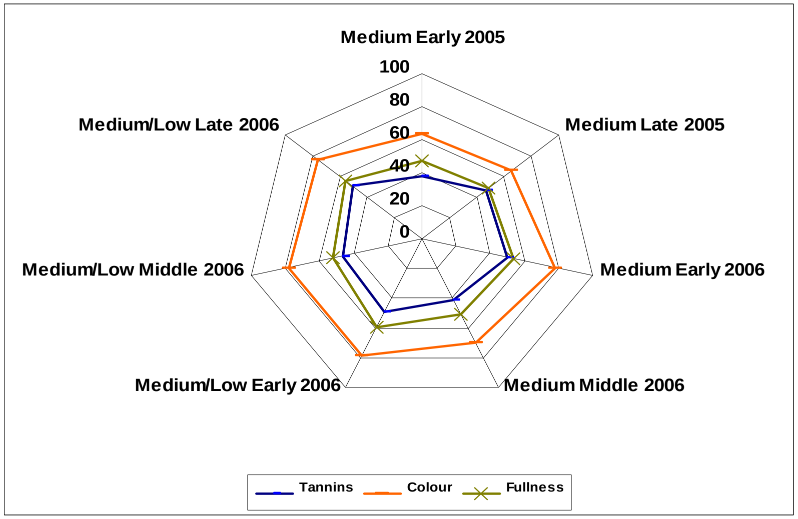


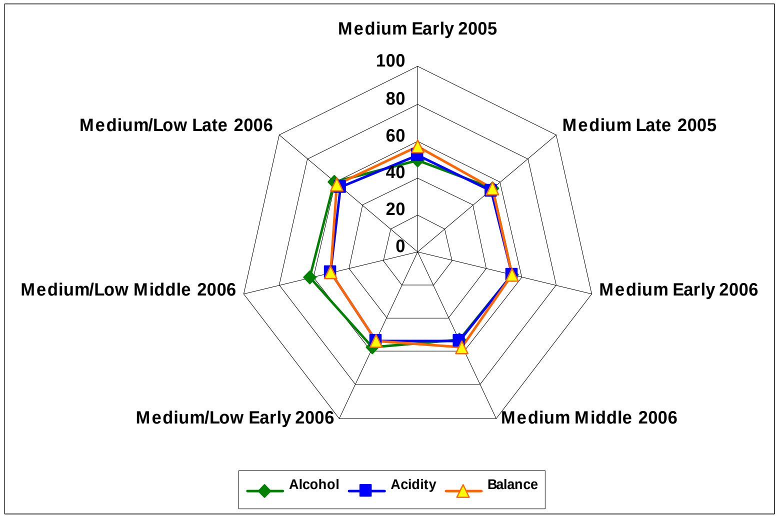


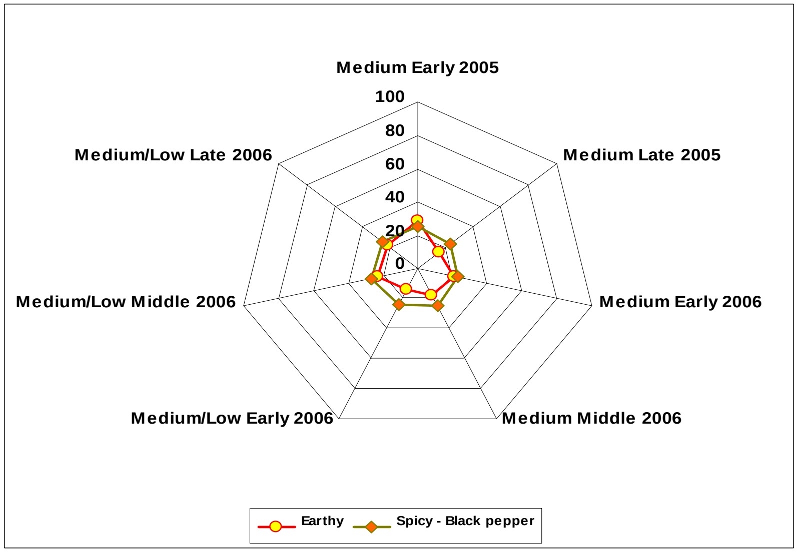


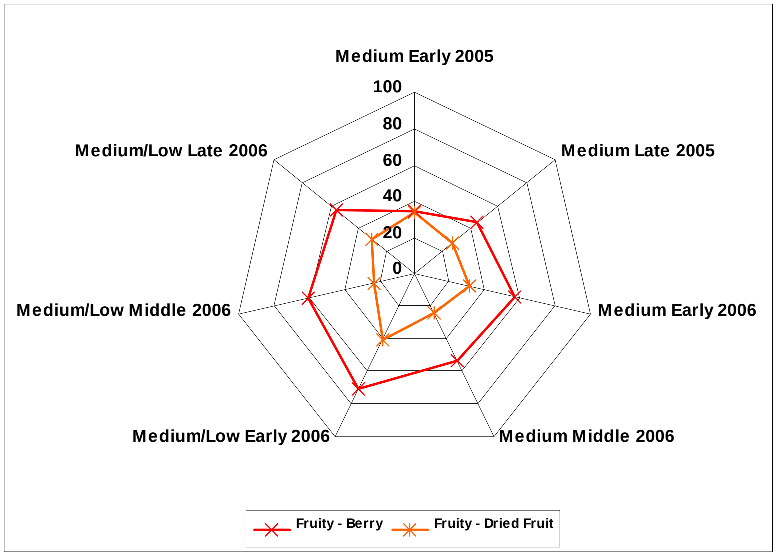

Low Middle 2005
100
80
60
40
20
0
Low Late 2005
Low Early 2006
Low Middle 2006
Low Late 2006
Tannins
Colour
Fullness

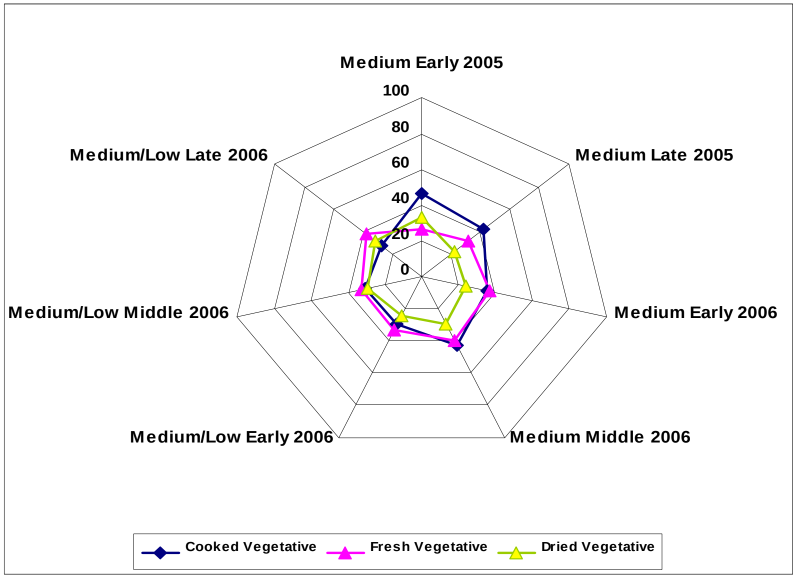
Wines from the medium-vigour vines for the 2005 and 2006 vintages.



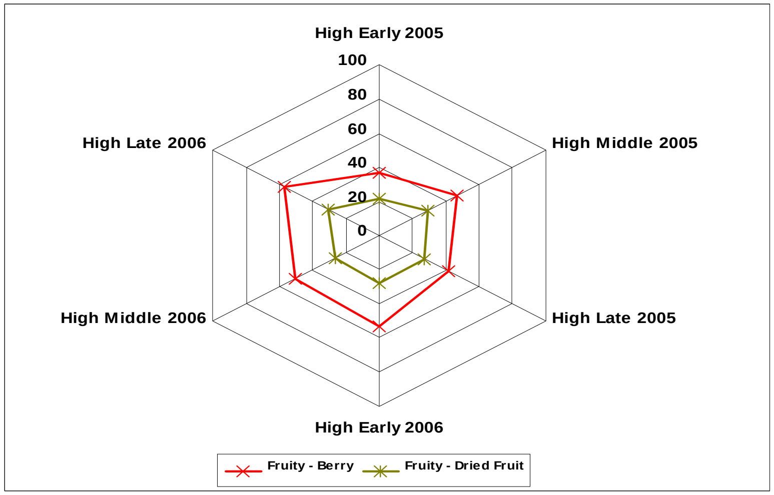


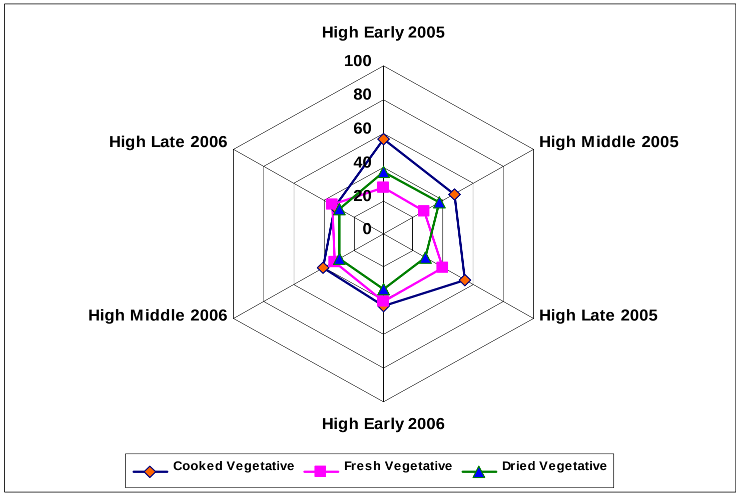


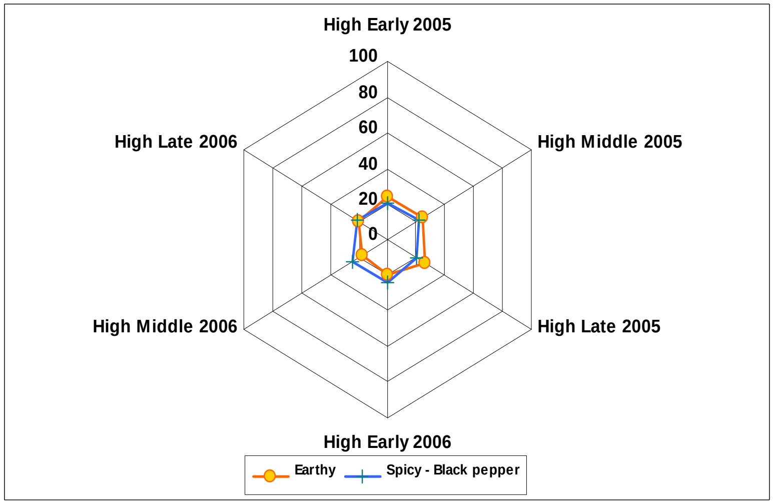


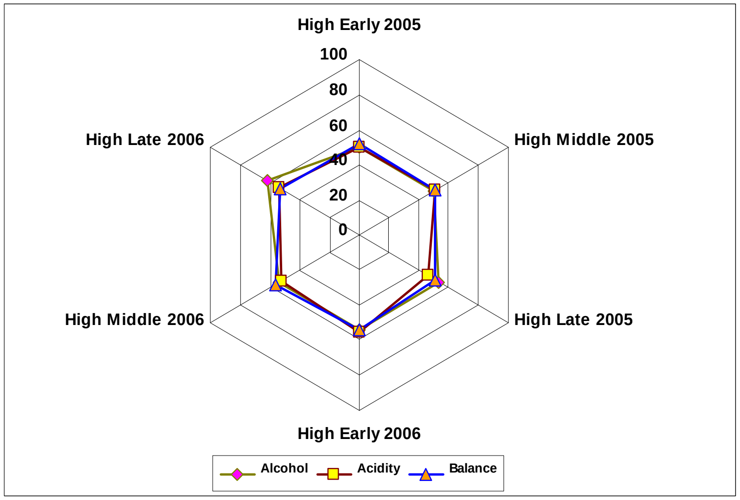

Medium Early 2005
100
80
60
40
20
0
Medium Late 2005
Medium Early 2006
Medium Middle 2006
Medium/Low Early 2006
Medium/Low Middle 2006
Medium/Low Late 2006
Cooked Vegetative
Fresh Vegetative
Dried Vegetative

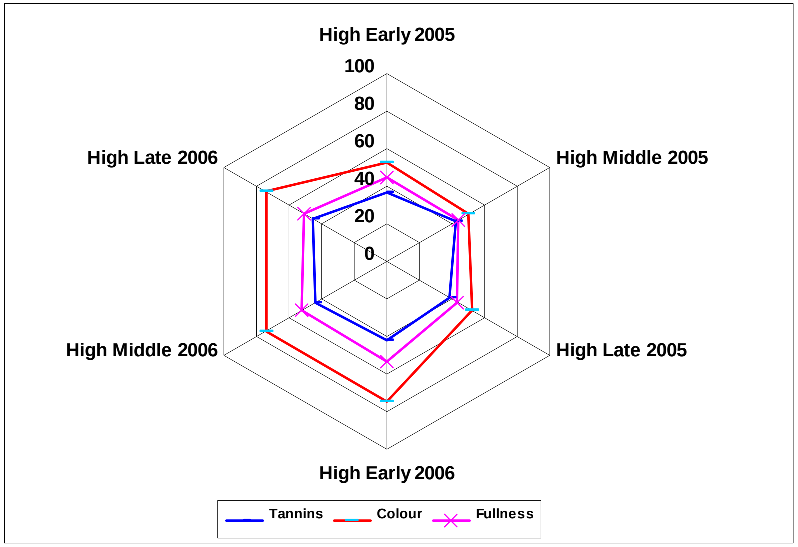
Wines from the high-vigour vines for the 2005 and 2006 vintages.



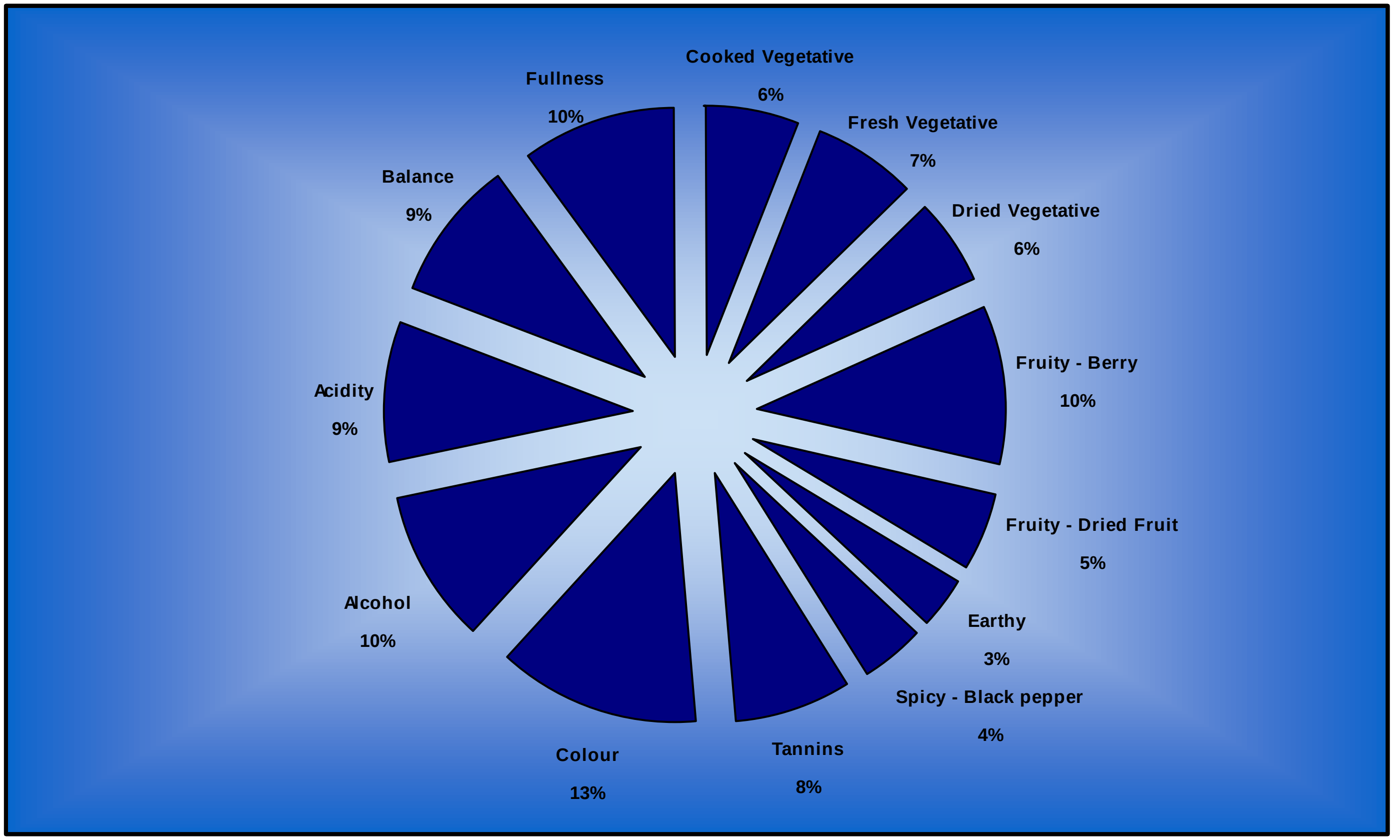




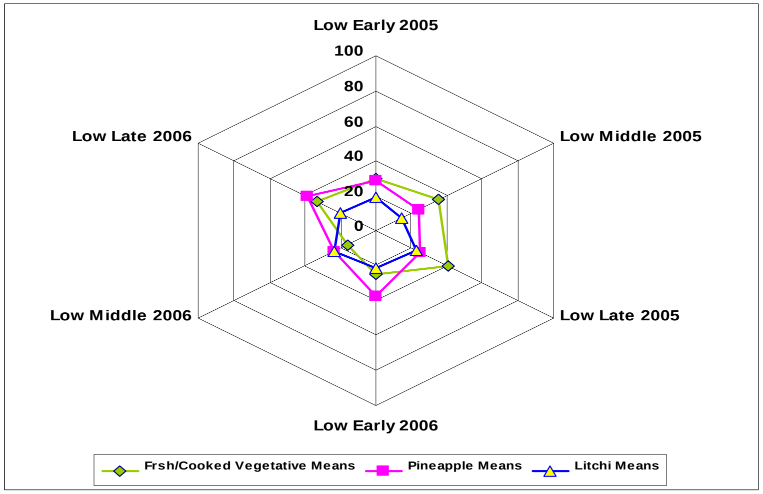


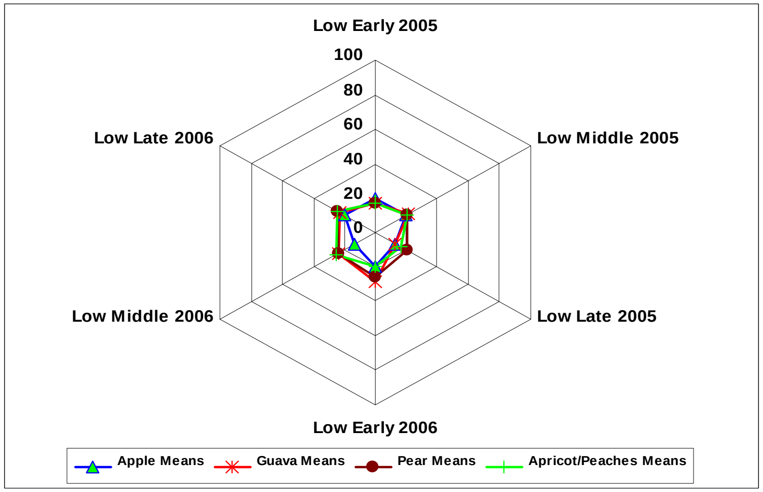

High Early 2005
100
80
60
40
20
0
High Middle 2005
High Late 2005
High Early 2006
High Middle 2006
High Late 2006
Tannins
Colour
Fullness

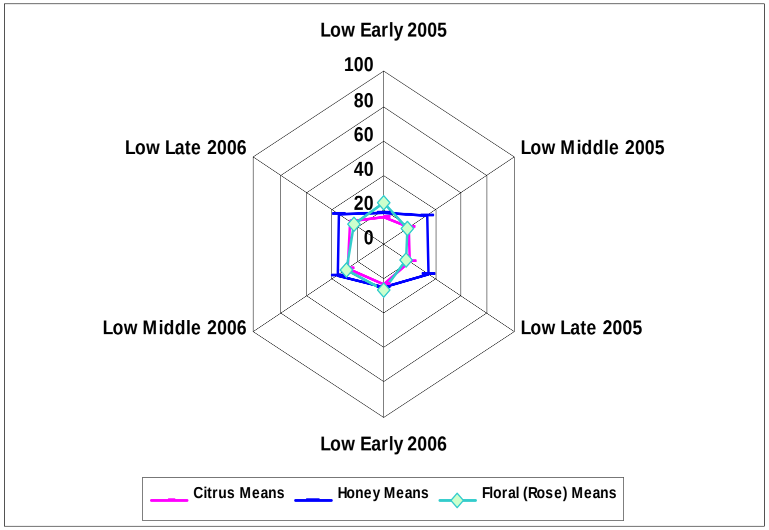
Different aroma and flavour characteristics present in the “mix” trial.

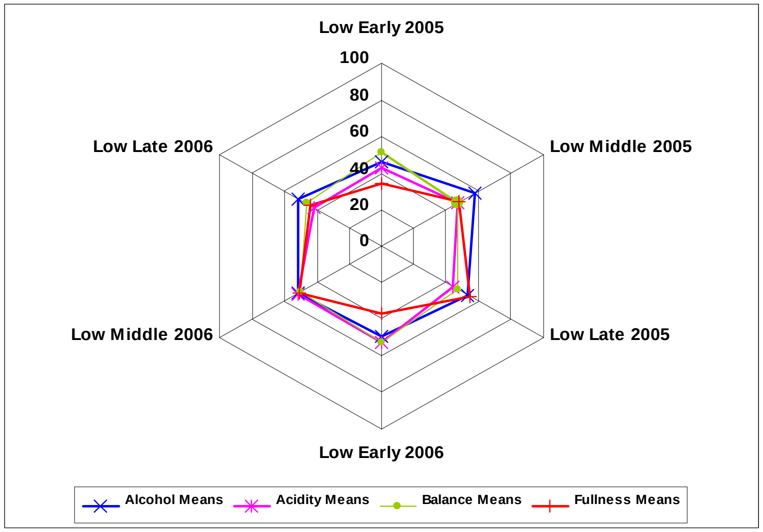


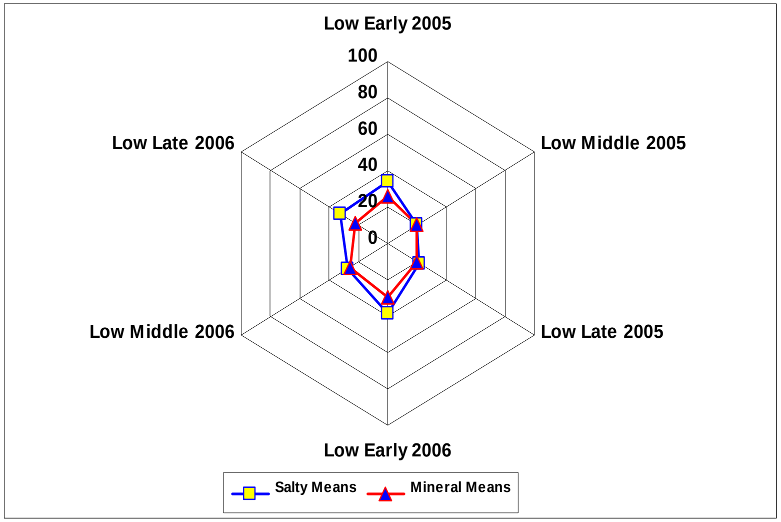
<u>Addendum C</u>: Sensory analyses of the wines made from the Chenin blanc vigour/harvest date experiment. Wines from the low-vigour vines for the 2005 and 2006 vintages.



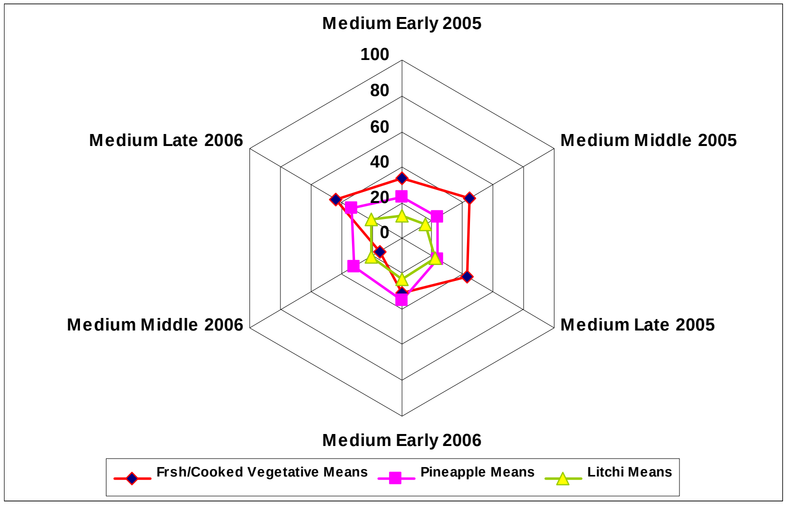


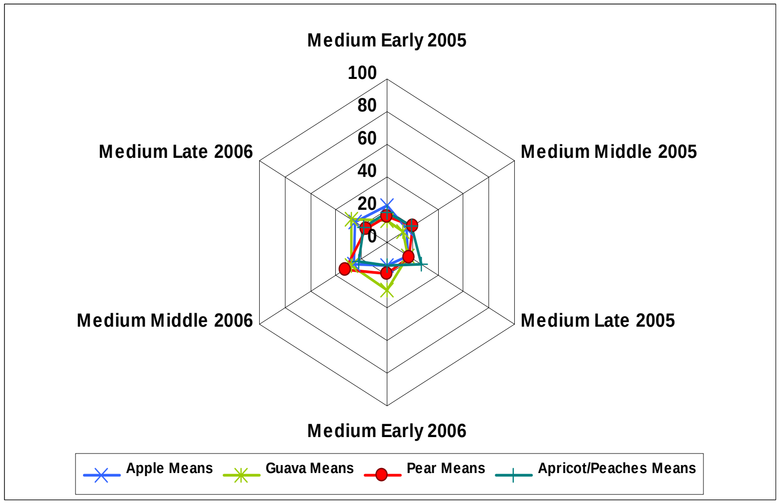


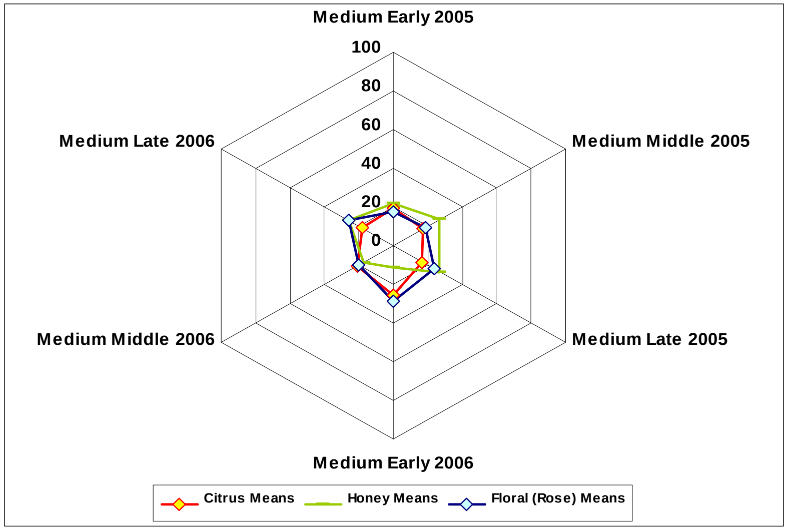


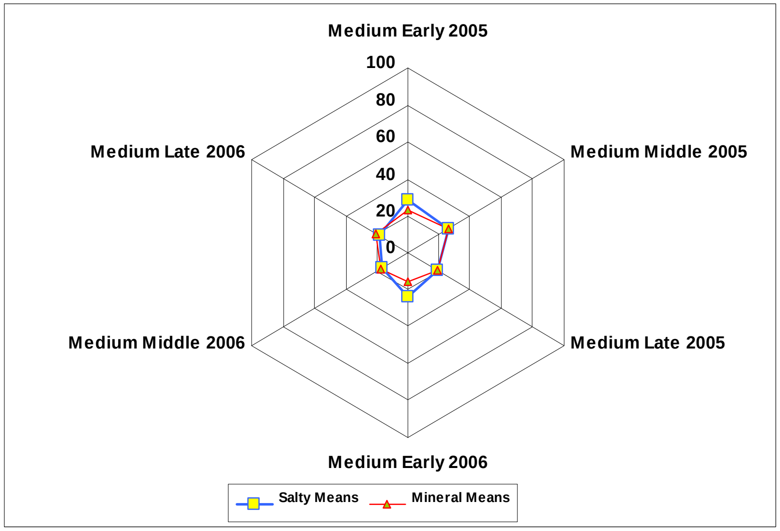

Low Early 2005
100
80
60
40
20
0
Low Middle 2005
Low Late 2005
Low Early 2006
Low Middle 2006
Low Late 2006
Salty Means
Mineral Means

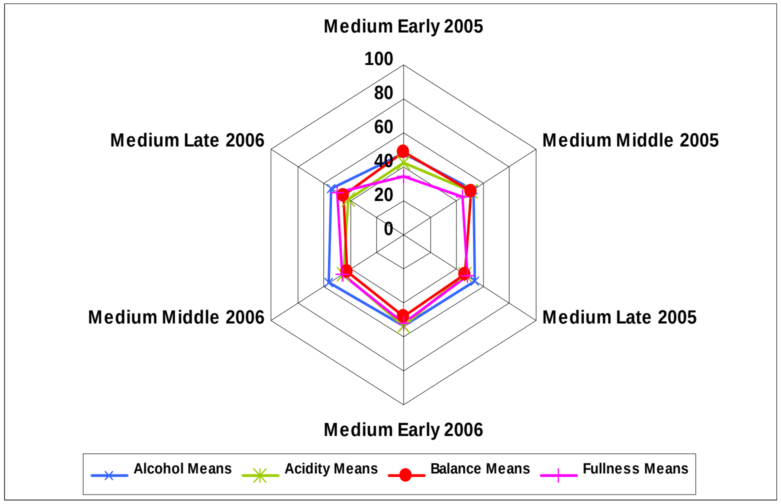
Wines from the medium-vigour vines for the 2005 and 2006 vintages.



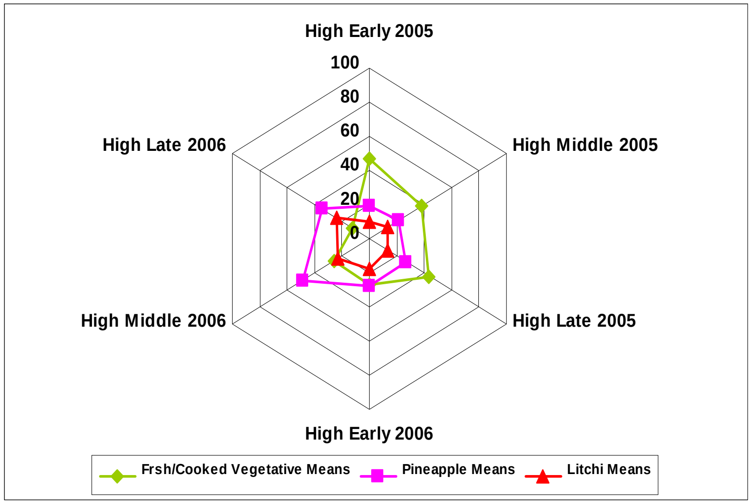


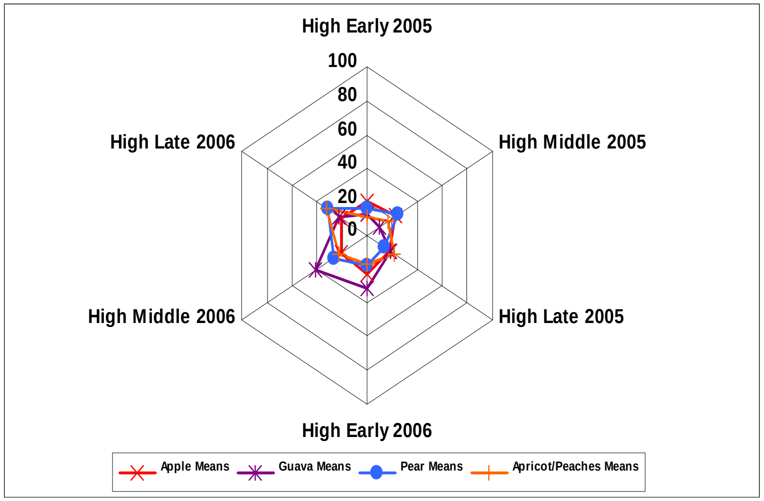


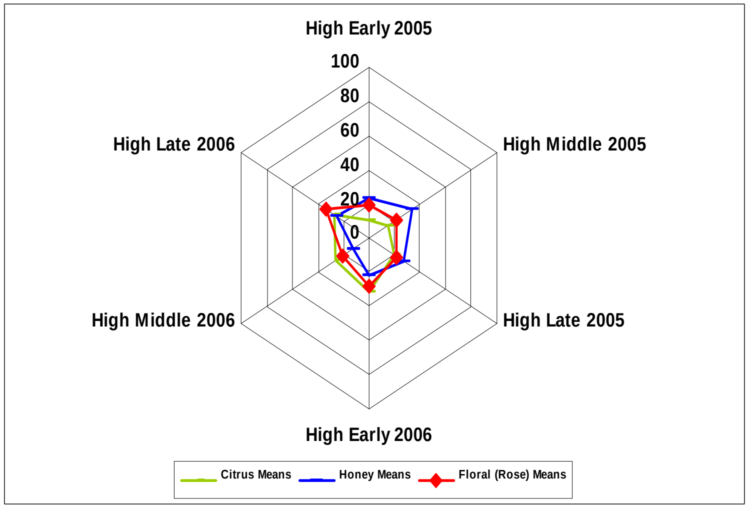


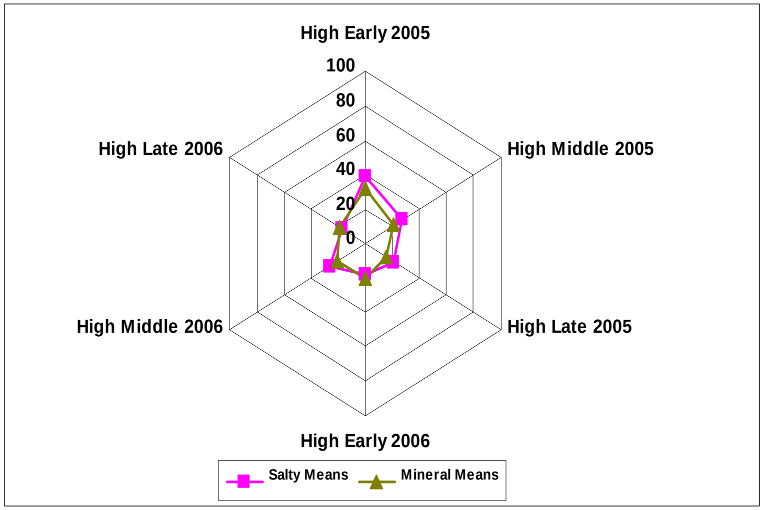

Medium Early 2005
100
80
60
40
20
0
Medium Middle 2005
Medium Late 2005
Medium Early 2006
Medium Middle 2006
Medium Late 2006
Alcohol Means
Acidity Means
Balance Means
Fullness Means

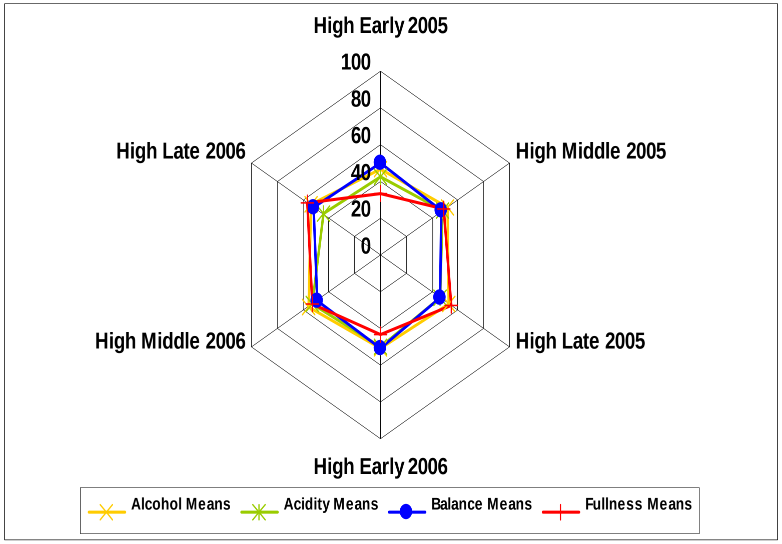
Wines from the high-vigour vines for the 2005 and 2006 vintages.










High Early 2005
100
80
60
40
20
0
High Middle 2005
High Late 2005
High Early 2006
High Middle 2006
High Late 2006
Alcohol Means
Acidity Means
Balance Means
Fullness Means