The ecophysiological characterisation of terroirs in Stellenbosch: the contribution of soil surface colour

by

Erna Hailey Witbooi

Thesis presented in partial fulfilment of the requirements for the degree of Master of AgriSciences at Stellenbosch University.

March 2008

Supervisor:
Dr. VA Carey

Co-supervisors:
Dr. JE Hoffman
Mr. AE Strever

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.

Erna Witbooi **Date**

Copyright © 2008 Stellenbosch University
All rights reserved

SUMMARY

Soil is a component of the environment and sustains growth of several plants and animals. It forms part of the biosphere and can be described as the interface between the atmosphere and the lithosphere. The interaction between soil, climate and topography and the resulting agricultural aptitude forms the concept of terroir. This relationship is complex and it is difficult to quantify the contribution of each.

Grapevines are exposed to an array of soil types. Soils have varying colours, which can be ascribed to their origin from different parent materials and pedogenetic factors. Historical and experimental evidence points to the key role that soil physical conditions play in determining grape berry composition, but other soil related factors may also play a role.

This study was conducted to investigate the effect of soil surface colour on the vegetative and reproductive growth characteristics of Cabernet Sauvignon. The aim was to determine whether a relationship exists between soil colour, reflective light quality below and inside the grapevine canopy, vegetative growth of the grapevine and the berry and wine composition.

The reflected light from soils was measured in three positions of the canopy and across the light spectrum (300–2500 nm) for three different soil surface treatments (black, red and grey). The effect of soil colour on vegetative parameters, yield and berry composition and wine quality was investigated. Soil surface colour resulted in differences in the reflected light quality below and in the canopy. The differences in the light quality were associated with differences in vegetative parameters such as mean main leaf, with grey soils inducing higher values. Potassium levels of the grapes and berry number per bunch appeared to be influenced by soil surface colour throughout berry development with red and black soils having higher levels of potassium and berry number per bunch than grey soils. Grape ripening parameters were not influenced by soil surface colour, but the grey treatment had a significantly more intense grape colour measured at 520 nm (red pigments).

It is assumed that the importance of soil colour is its association with the physical and the pedogenetic properties that contribute to the grapevine water balance. From these results

it can be concluded that soil surface colour appeared to have a direct effect on some aspects of vegetative and reproductive growth, and berry composition, but the contribution of different wavebands and mechanism of their effect deserves further study.

OPSOMMING

Grond is 'n komponent van die omgewing en onderhou groei van verskeie plante en diere. Dit maak deel uit van die biosfeer en kan beskryf word as die koppelvlak tussen die atmosfeer en die litosfeer. Die interaksie tussen grond, klimaat en topografie en die voortspruitende agronomiese begaafdheid daarvan vorm die konsep van terroir. Hierdie verhouding is kompleks en dit is moeilik om die bydrae van elk te kwantifiseer.

Wingerdstokke is blootgestel aan ’n verskeidenheid grondtipes. Gronde het wisselende kleure wat toegeskryf kan word aan hul oorsprong, te wete verskillende moedergesteentes, asook pedogenetiese faktore. Historiese en eksperimentele bewyse dui op die sleutelrol wat die fisiese toestande van grond speel in druifsamestelling, maar ander grond verwante faktore mag ook ’n rol speel.

Hierdie studie is uitgevoer om die effek van die grondkleur op die vegetatiewe en reproduktiewe eienskappe van Cabernet Sauvignon te ondersoek. Die doel was om te bepaal of 'n verhouding tussen grondkleur, gereflekteerde ligkwaliteit onder en binne-in die lower, vegetatiewe groei van die wingerd en die korrel- en wynsamestelling bestaan.

Die gereflekteerde ligeienskappe van gronde in drie posisies van die lower en oor die ligspektrum (300–2500 nm) is gemeet by drie verskillende grondoppervlak behandelings (swart, rooi en grys). Die effek van die grondkleur op vegetatiewe parameters, opbrengs, druifsamestelling en wynkwaliteit is ondersoek. Die kleur van grondoppervlak het verskille in die ligkwaliteit onder en binne die lower. Die verskille in die ligkwaliteit was geassosieer met verskille in vegetatiewe parameters soos hoofblaararea, met grys gronde wat die hoogste waardes geïnduseer het. Kaliumvlakke van die druiwe en getal korrels per tros was deur grondoppervlak kleur beïnvloed, korrelontwikkeling met rooi en swart gronde het deurgaans hoër vlakke van kalium en getal korrels per tros as grys grond getoon. Druif rypwording parameters is nie beïnvloed deur die kleur van die grondoppervlak nie, maar by die grys behandeling is beduidend meer intense druifkleur gemeet by 520 nm (rooi pigmente).

Dit kan aangeneem word dat die belangrikheid van grondkleur toegeskryf kan word as die assosiasie met die fisiese en pedogenetiese eienskappe van die grond, wat bydra tot die

waterbalans van die druifplant. Vanaf die resultate kan afgelei word dat grondkleur ’n direkte effek het op sommige aspekte van vegetatiewe en reproduktiewe groei, asook op druif samestelling, maar die bydrae van verskillende golflengtes en meganismes daarvan verdien verdere studie.

This thesis is dedicated to

My mother Hendriena Witbooi my sisters, Hildegard Witbooi and Verlencia Pageault and my brother-in-law, Olivier Pageault.

BIOGRAPHICAL SKETCH

Erna Hailey Witbooi was born in Paarl on 18 September 1983. She matriculated at Klein Nederburg Secondary in 2001. She enrolled for a degree in BSc Agric (Viticulture and Oenology) and graduated in 2005. In 2006, Erna enrolled for the degree MSc Agric (Viticulture).

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude and appreciation to the following persons and institutions:

Dr Victoria Carey of the Department of Viticulture and Oenology, for acting as my supervisor, for her guidance, advice, encouragement, passion and enthusiasm which stimulated my interest in viticultural terroir;

Dr. Eduard Hoffman of the Department of Soil Science, for acting as my co-supervisor and for his guidance and support;

Mr. Albert Strever of the Department of Viticulture and Oenology, for acting as my co-supervisor and for his guidance and support;

Prof. Martin Kidd, for his help with the statistical data interpretation;

Mr. Graham and Rhona Beck of the Kangra group (Graham Beck Wines);

The academic and technical staff at the Department of Viticulture and Oenology for their assistance;

University of Stellenbosch and Winetech for financial support throughout my study;

Conrad Schutte, Laure Du Cos Saint Barthelemy, Albertus van Zyl and Gerhard Rossouw for their support and help in the field;

My friends, for their support, love and reassurance throughout my studies;

Maarten Blancquaert, for his love and support;

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 Oenology and Viticulture.

Chapter 1	**Introduction and Project Aims**
Chapter 2	**Literature Review** Soil surface colour as a component of terroir and its potential contribution to grape colour development
Chapter 3	**Research Results** The relationship between soil surface colour and the performance of *Vitis vinifera* L. cv. Cabernet Sauvignon. I. Vegetative growth
Chapter 4	**Research results** The relationship between soil surface colour and the performance of *Vitis vinifera* L. cv. Cabernet Sauvignon. II. Yield, berry composition and wine
Chapter 5	**General discussion and final conclusions**

CONTENTS

Chapter 1

INTRODUCTION AND PROJECT AIMS

INTRODUCTION AND PROJECT AIMS

1.1 INTRODUCTION

Global wine industries are committed to increasing grape and wine quality, as market competition constantly increases. The growing demand for quality grapes according to winery specifications strengthens the relationship between the grape grower and winemaker as well as the profitability of the product (Krstic *et al*., 2003). Quality assessment of grapes in the vineyard and at harvest is crucial and dependent on an array of short and long-term practices. Long-term decisions influence the ecophysiological response of the grapevine to a specific site, which has an effect on plant growth and metabolism. Soil and climatic factors are considered the most important for site selection and are major contributors to wine quality (Saayman, 1977). These two factors, together with topography, are encompassed in the concept of terroir, which embraces both soil and mesoclimate influences on grape growth and wine quality.

Soil has been singled out as having the greatest influence on the determination of quality within viticultural environments (Fregoni, 1977). Saayman (1977) suggests that an interrelationship exists between climate and soil. Soil colour is the most conspicuous feature, describing both the physical and chemical nature of the soil, and is influenced by the mineralogy. The combination of three key pigment types, namely (i) iron oxides and hydroxides (red to yellow), (ii) humus (black) and (iii) silicate and carbonate minerals (white to grey), result in different soil colours (Sánchez-Marañón *et al*., 2004). Soil colour may influence or be associated with (i) temperature close to the soil, (ii) soil water availability and root growth and (iii) quality and quantity of reflected light. Soil reflectance is a cumulative property derived from the inherent spectral behaviour of the combination of mineral, organic and fluid matter (Stoner & Baumgardener, 1981). Soil-dependent properties and independent (environmental) characteristics, such as, soil colour, soil temperature, texture and structure, soil depth and water status, determine the amount of solar radiation absorbed or the soil albedo (reflection) (Post *et al*., 2000; Dobos, 2002). Therefore, the light reflected from different soil surfaces will differ. The prevailing conditions during pedogenesis primarily determine the physical, chemical and biological content of the soil and influence colour development. Oxidation and reduction processes in soil give rise to the formation of red and yellow crystals respectively. Aerobic conditions in the soil lead to gradual colour change, while anaerobic conditions result in disrupted colour. Soil temperatures are influenced by soil colour; dark soils absorb more solar radiation, reducing the albedo, while light-coloured soils reflect solar radiation, increasing the albedo (Dobos, 2002).

Solar radiation fluxes have an effect on grapevine physiology through photosynthetic, thermal and phytochrome responses (Smart, 1989). Light quality and quantity have a direct influence on grapevine metabolism (Dokoozlian, 1990). The light environment within grapevine canopies and its influence on fruit and wine composition have been studied extensively (literature reviewed in Dokoozlian, 1990). Canopy management practices improve the light quality surrounding the vegetation, influencing the photo-equilibrium (red to far-red ratio) of phytochrome, The light-dependent development of a plant is complex and involves numerous photoreceptor systems. The latter regulate plant growth aspects and respond to light intensities of different wavelengths and intensities, leading to appropriate modifications in plant response (e.g. stem elongation, leaf expansion and anthocyanin synthesis) of the grapevine. (Chory, 1997).

Fregoni (1977) discussed the experiments of Ravaz in the beginning of the twentieth century with artificially-coloured soil and studies on natural soil colour by various other scientists. Robin *et al*. (2000) showed that both the quality and quantity of reflected light have an effect on sugar concentration and colour of grapes. The reflectance from soil surfaces influences the light quality and the quantity available for the vine physiological processes.

1.2 PROJECT AIMS

The main aim of this project was to determine whether a relationship exists between soil colour, reflective light quality below and inside the grapevine canopy, and berry and wine composition. These aspects are addressed by the following research aims:

- I: To determine whether soil surface colour affects light quality in the bunch zone
- II: To determine whether soil surface colour affects grapevine performance
- III: To determine whether soil surface colour affects grape colour and composition and the resulting wine composition

1.3 REFERENCES

Chory, J., 1997. Light modulation of vegetative development. The Plant Cell 9, 1225 - 1234.

Dobos, E., 2002 (2nd ed). Albedo. In: Rattan Lal (eds). Encyclopedia of Soil Science. Marcel Dekker Inc. New York. pp. 64-66.

Dokoozlian, N.K., 1990. Light quantity and light quality within *Vitis vinifera L.* grapevine canopies and their relative influence on berry growth and composition. PhD Dissertation, University of California, Davis.

Fregoni, M., 1977. Effects of soil and water on the quality of the harvest. In: Proc. Int. Sym. Quality of the Vintage, February, 1977, Cape Town, South Africa, 151-168.

Krstic, M., Moulds, G., Panagiotopulos, B. & West, S., 2003. Growing quality grapes to winery specifications quality measurement and management options for grapegrowers. Winetitles, Adelaide.

Post, D.F., Fimbres, A., Matthias, A.D., Sano, E.E., Accioloy, L., Batchilly, A.K. & Ferreira, L.G., 2000. Predicting soil albedo from soil color and spectral reflectance data. Soil Sci. Soc. Am. J. 64, 1027-1034.

Robin, J.P., Sauvage, F.X., Pradal, M. & Chovelon, M., 2000. Soil reflectance and colouring of grape. Vine red light excitation could be decisive for grape berry quality. J. Int. Sci. Vigne Vin 34 (3), 101-119.

Saayman, D., 1977. The effect of soil and climate on wine quality. In: Proc. Int. Sym. Quality of the Vintage, February, 1977, Cape Town, South Africa, 197-226.

Sánchez-Marañón, M., Soriano, M., Melgosa, M., Delgado, G. & Delgado, R., 2004. Quantifying the effects of aggregation, particle size and components on the colour of Mediterranean soils. Eur. J. of Soil Sci 55, 551-565.

Smart, R.E., 1989. Solar radiation interception as a guide to the design of horticultural plantings. II Twenty years experience with grapevines. Acta Hort. 240, 87-94.

Stoner, E.R. & Baumgardener, M.F., 1981. Characteristic variations in reflectance of surface soils. Soil Sci. Soc. Am. J. 45, 1161-1165.

Chapter 2

LITERATURE REVIEW

Soil surface colour as a component of terroir and its potential contribution to grape colour development

LITERATURE REVIEW

2.1 INTRODUCTION

The contribution of environmental parameters and viticultural practices to wine quality is a widely discussed topic (Jackson & Lombard, 1993). The interaction between soil, climate and grapevine cultivar is considered to contribute to the concept of terroir (Van Leeuwen *et al*., 2004; Deloire *et al*., 2005). A complex relationship exists between the factors that influence wine quality and style. These factors include the complex interaction between temperature, sunlight, soil water availability and physiological processes (Fig 2.1) (Jackson & Lombard, 1993). Soil and climate are the two main factors taken into consideration with regards to the influence on wine quality (Saayman, 1977). Fregoni (1977) and Huglin, according to Carey (2001), suggest that soil characteristics such as texture, structure, colour, composition and mineralogy contribute to the qualitative potential of a viticultural environment. Fregoni (1977) suggests that soil type has an effect on wine components such as alcohol, colour, acidity and aroma, and a significant influence on the quality of wine.

This review is an attempt to summarise the importance of soil, and particularly soil colour, as a terroir component and the implications that it has for growth reactions, metabolism of the grapevine, berry development and wine quality. Therefore the other terroir components (climate and topography) will only be discussed briefly, as it did not fall within the scope of this study.

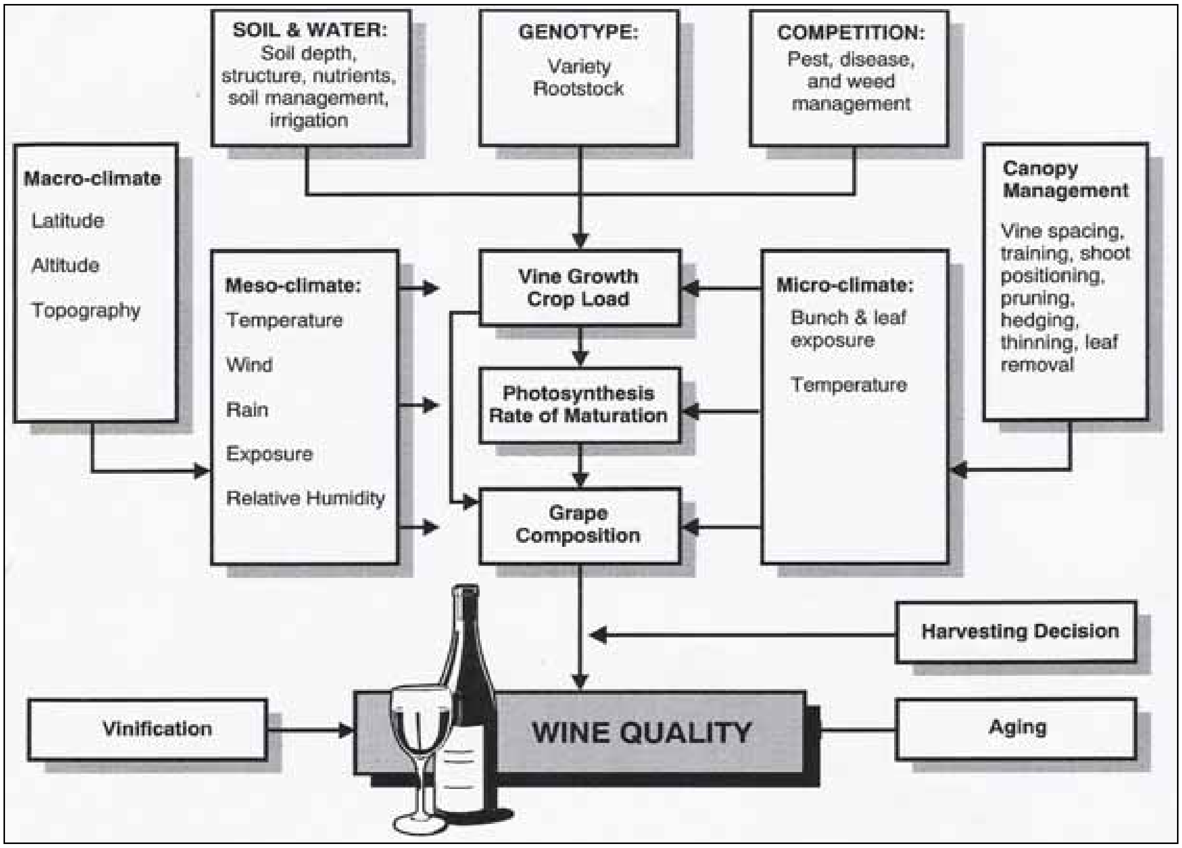


Figure 2.1 Environmental and viticultural inputs that affect grape composition and wine quality (Jackson & Lombard, 1993).

2.2 THE TERROIR CONCEPT

2.2.1 A DEFINITION

Terroir can be described as the total natural environment characterised by homogenous or dominant features (soil, topography and climate) within a territory that also influences the character and quality of an agricultural product (Deloire *et al*., 2005). Morlat (in Carey, 2005) describes viticultural terroir as an interaction between (i) natural factors (climate, soil and geology) and (ii) human factors (viticultural and oenological practices). Vaudour (2001) highlighted the diversity of the term terroir and described the term in four categories namely, ”material”, ”spatial”, ”conscience” and ”slogan” terroir. Moran (in Mouton, 2006) describes terroir through six different approaches (Fig 2.2). From the schools of Vaudour (2001) and Moran (in Mouton, 2006) it can be seen that no single diagram can depict the complex interactions among the various concepts of terroir. Deloire *et al*. (2002) describe the basic terroir unit as referring to the interaction between mesoclimate and soil for a series of years at the vineyard level, or at the level of a group of vineyards: UTB (Unité Terroir de Base) = Mesoclimate X Soil/Substratum". A viticultural terroir unit refers to the interaction between the basic terroir unit, the cultivar and viticultural and oenological practices: "VTU (Unité de Terroir Viticole) = UTB X cultivar and oenological technology". The UTB is influenced during the implementation of viticultural practices, (light, temperature or moisture - related microclimate) (Vaudour, 2001). Laville (1993) (in Carey, 2005) describes the static variables of a basic terroir unit to be those of climate, relief and soil.

Terroir is a complex subject with many definitions, but there is a similar focus on the interdependence of each of the factors associated with terroir. It is therefore crucial for a grape grower to understand the natural environmental influences on the grapes in order to comprehend the impact thereof on wine quality. The optimisation of wine quality is dependent on the natural environmental conditions, together with the evaluation and selection of the site.

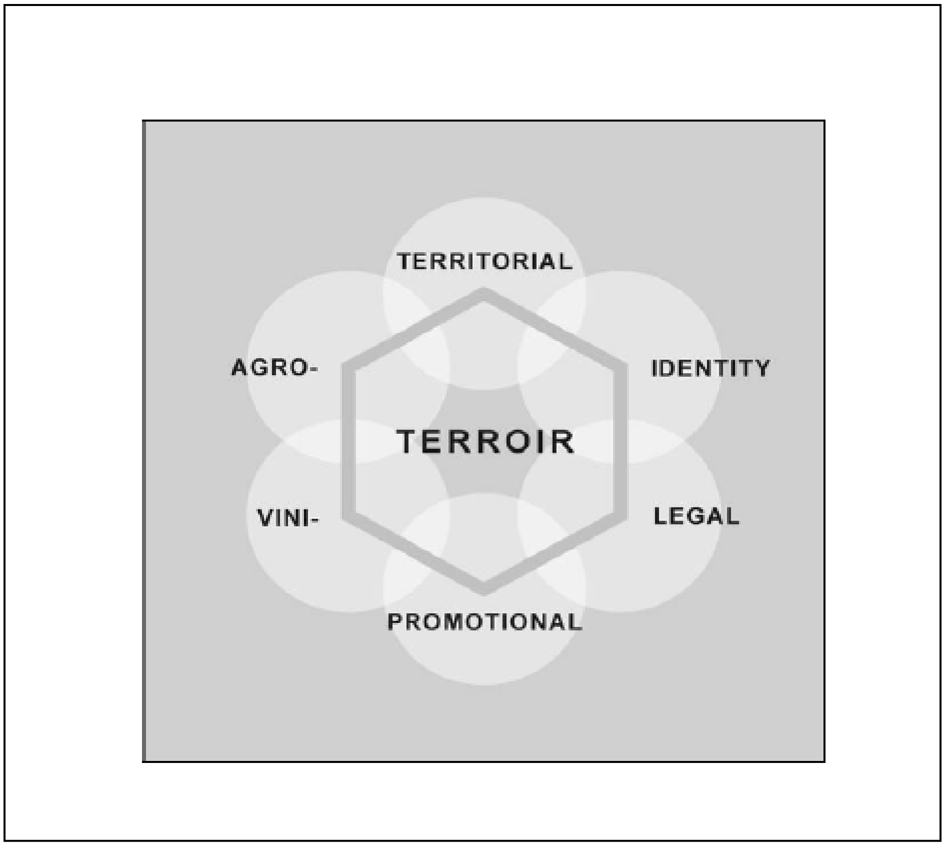


Figure 2.2 Six components of terroir described by Moran, (cited in Mouton, 2006).

2.2.2 THE ROLE OF CLIMATE

Climate combines various components, such as temperature, changes in rainfall, humidity and wind and can be described on three levels, namely macroclimate, mesoclimate and microclimate (Jackson & Lombard, 1993; Deloire *et al*., 2005). Climate is highly variable and affects the physiology of the vine to a great extent (Pienaar, 2005). Vine growth is influenced by climate and is dependent on water balance and evapotranspiration. Grape quality is influenced primarily by the prevailing microclimate in each specific vine.

Bioclimatic indices for macro-scale viticulture were developed to determine the viticultural potential of an area, based on the realisation that climate drives the feasibility of viticulture and largely determines wine style. Monthly or daily data are used as the main indices while others are a combination of different data (e.g. Huglin) (Deloire *et al*., 2005). Temperature plays a crucial role in grape development, growth and ripening. The accumulation of solids, acids, pH, the development of flavour, aroma and colour components, carbohydrate production and the process of photosynthesis are enzyme-driven and therefore regulated by temperature (Jackson & Lombard, 1993). The effect of temperature on the grapevine has been summarised by researchers such as Coombe (1987), Gladstones (1992) and Jackson and Lombard (1993). The effect of temperature on grape composition is summarised in Fig 2.3 (Coombe, 1987). Mean temperatures prior to harvest of between 15°C and 21°C result in a well-balanced must for dry or sweet wines, while a temperature range of 21°C to 24°C in the final ripening month is optimal for ports and muscats (Gladstones, 1992). Gladstones (1992) suggests that pigment formation and the optimal physiological ripening of grapes for the synthesis of colour, flavour and aroma compounds takes place between 20°C and 22°C. A constant intermediate temperature together with minimal day-night and day-to-day temperatures favour biochemical processes related to colour, flavour and aroma development (Gladstones, 1992). When day temperature is high, low night temperatures are necessary to ensure a low pH and high natural acidity (Jackson & Lombard, 1993).

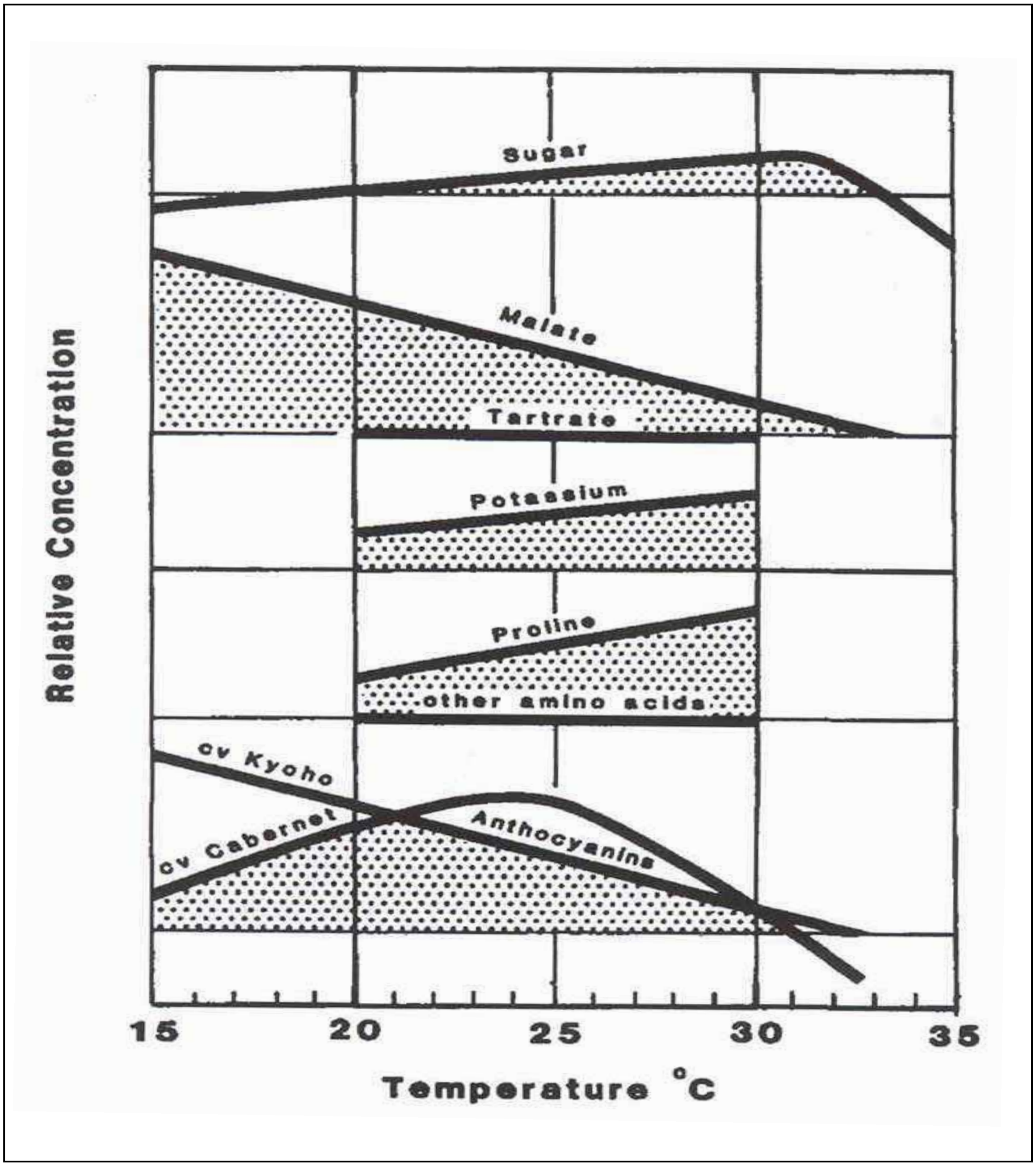


Figure 2.3 Temperature effect on the accumulation of chemical grape composites (Coombe, 1987).

2.2.3 THE ROLE OF TOPOGRAPHY

Topography is regarded as the link between soil type, climate and viticulture in terroir identification, as it includes the composition of a surface, relief and the position of its natural features (Gladstones, 1992). Topography therefore determines the detail of the localised climate (Becker, 1977). It can be described as a static feature of the landscape and is determined by the altitude as it changes over distance (Carey, 2001). The landscape attributes affecting the mesoclimate are altitude, aspect, inclination of the slope and the proximity of water bodies (Carey, 2001).

2.2.4 THE ROLE OF GEOLOGY

Geology is described as the most static component of the terroir complex, having an influence on wine quality (Carey, 2001). The geological origin and age of soils are considered to influence the qualitative characteristics of wine (Fregoni, 1977). Soils originating from different parent materials have been found to result in wines with varying chemical composition. Fregoni (1977) has suggested that cultivars planted on a specific soil type give rise to a unique character (e.g. Pinot noir grapes in Burgundy are produced on calcareous soils and the more frequent-occurring soils containing clay). However, wine of excellent quality is produced on very diverse geological formations (Seguin, 1986). This could be ascribed to the parent material, and aspects such as soil type, texture and chemical properties and water supply. Therefore, no geological formation can be singled out as being the best.

Certain aspects of geology are regarded as abstract (e.g. wine quality), due to its soil physical conditions which determine the supply of soil water to the vine (Carey, 2001). Wooldridge (2000) suggest that other factors as being direct, practical and significant such as (i) potassium (K), (ii) soil texture which is related to rock type, (iii) vine growth and wine characteristics through its effects on landscape form, (iv) changes in the sea level and (v) structural geology. From the above mentioned it can be seen that the effects of geology and geological processes are extremely diverse.

2.2.5 THE ROLE OF SOIL

Historical and practical evidence points to the key role of soil physical conditions in determining quality of wine (Gladstones, 1992). However, the effect of soil on grape composition and wine quality is a topic of great controversy (Saayman, 1977). The influence of soil can often be confused with the climate, cultivar and rootstock combination (Fregoni, 1977). It was suggested by Rankine *et al*. (1971) that soil type influences the amounts of grape and wine constituents, but has no significant effect on wine quality. Soil depth, drainage and the water holding-capacity appears to be more important than the chemical composition of the soil. It was found that soil has a definite effect on the quality of Chenin blanc and Cinsaut noir cultivated under the same climatic conditions (Saayman, 1977). This effect was not consistent over vintage years, therefore suggesting an interaction between soil and climate. A similar interrelationship has been found with Sauvignon blanc under dry-land conditions (Conradie, 1998).

2.2.5.1 SOIL CHEMICAL COMPOSITION AND pH

Sixteen elements are necessary to grow and sustain normal vine growth (White, 2003). Based on their concentration in grapevines, these elements are subdivided into macro- and micro nutrients. Mineral availability is influenced by soil pH (Fig 2.4). The uptake of nutrients in the proper quantity and ratio to each other and at a sufficient rate will result in adequate growth (Carey, 2001).

Some inorganic elements are derived from the soil parent material. Their concentrations differ considerably, being dependent on the presence of limiting factors such as poor nitrogen nutrition, ion antagonism and management factors (draining, liming, fertilisers) (Seguin, 1986; Carey, 2001). Danielson (1972) suggests that the release of nutrients from organic material and soil minerals is regulated by soil temperature, aeration and water supply. Soil moisture regimes influence plant nutrition and the physical condition of the plant (Dry & Coombe, 2004). Nitrogen and potassium are considered to be the most important elements having an effect on grape quality (Saayman, 1977).

Fregoni (1977) suggested that the qualitative characteristics of wine are correlated with soil chemical composition. Three diverse wines (Barolo, Barbaresco and Nebbiolo d'Alba) were produced on different soil types and under different climatic conditions. The quality decreased from Barolo to Barbaresco to Nebbiolo d' Alba, as elements such as active lime, potassium, boron, iron and manganese decreased. Copper increased from Barolo to Nebbiolo d' Alba. The highest quality Barolo was obtained from vines with the highest concentration of microelements (Fe, Mn and Zn) present in the grapevine leaves.

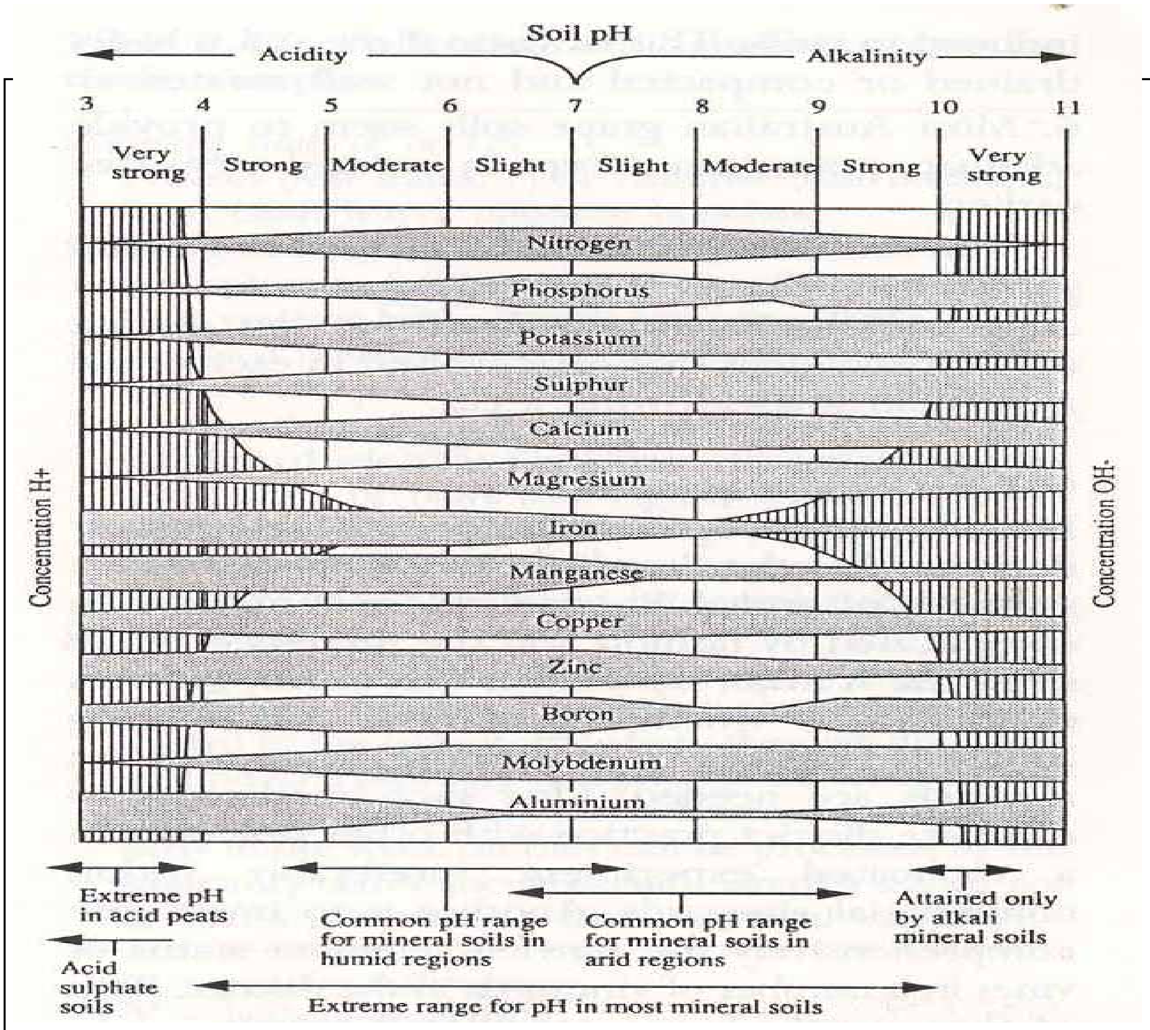


Figure 2.4 Effect of soil pH on mineral availability (cited in Dry & Coombe, 2004).

2.2.5.2 SOIL TEMPERATURE

Soil temperature is a function of the colour, texture and water content of the soil (Carey, 2001). The water - holding capacity of clays is higher (due to texture and structural differences) than that of the latter varying from fine to coarsely textured. Water modifies the soil temperature due to its high heat capacity (White, 2003). The temperature regime of vineyards is also influenced by the stoniness of the surface, e.g. large stones act as a heat sink throughout the day and reradiate heat energy during the night, resulting in a favourable microclimate within the vine rows (White, 2003). Readily warmed soils result in early and quick growth in spring (Gladstones, 1992). Gladstones (1992) emphasised the central role of soil temperature in controlling the whole plant growth and physiological development and the hormonal basis for this has been elucidated. Plant species each have a minimum soil temperature at which root elongation occurs (Hillel, 1972). Woodham and Alexander showed that Sultana grapevines grown in a culture solution at 11°C, 20°C and 30°C resulted in variation of growth. Vegetative growth occurred for the full eight weeks at 30°C while 20°C resulted in slow growth after flowering and no growth at 11°C. Gladstones (1992) has suggested that the production of cytokinins is the source for these differences.

Skene and Kerridge (1967) conducted similar research and found that roots formed at 30°C were longer and thinner than those formed at 20°C. It was not clear whether this was a result of a soil temperature effect on cytokinin production or interconversion or due to use of cytokinins by the roots. Root metabolic activity is influenced considerably by a change in soil temperature, which also leads to changes in the viscosity of water, the hydraulic conductivity of the roots and root-cell wall physics (Hillel, 1972). Kliewer (1975) and Zelleke and Kliewer (1979) found that considerably more Cabernet Sauvignon buds burst with high root temperature.

2.2.5.3 SOIL TEXTURE AND STRUCTURE

Soil texture refers to the relative relationship of various particle sizes (sand, silt, clay) (Fig 2.5).

White (2003) and Sánchez-Marañón *et al*. (2004) suggested that distribution of particle size, frequency and the distribution/aggregation ratio, and chemical composition influence soil colour. Iron oxides exhibit a small particle size, which improves the capacity for pigmentation (Sánchez-Marañón *et al*., 1997). Torrent and Barrón (1993) cited in (Sánchez-Marañón *et al*., 2004) suggested that the surface area and size of the particle influences soil colour. Post *et al*. cited in Sánchez-Marañón *et al*. (2004), suggested that coarse fragments (>2 mm) resulted in a greater chroma values of Munsell colour system, than fine earth (<2 mm). The Munsell scorecard consists of scoring value, hue and chroma.

Texture influences soil behaviour in various ways, mainly through its effect on soil structure, water retention, aeration, drainage, temperature and nutrient retention (White, 2003). Dry and Coombe (2004) regard soil texture as the most crucial soil property, as it affects the water-holding capacity, nutrient storage capacity and the erodability under Australian conditions.

The total porosity found between soil particles will determine the amount of water and oxygen harboured in a soil, which in turn influences the soil moisture content (Roux, 2005). Sandy soils are free-draining and have a lower soil water-holding capacity due to the presence of gravel and stones (White, 2003). Fine and medium-textured soils (clay, silty clays and clay loams) have a heavy texture and a higher water-holding capacity than sandy soils. Clay particles have a big surface area to volume ratio and the negative charge of the particles bring changes in the physical and chemical properties, as well as the nutrient status. This not only influences water uptake, but water storage is also much higher than in sandy soils (White, 2003).

Seguin (1986) suggests that wine quality does not seem to be linked to textural classes, but to gravel, pebble and clay content. Bordeaux terroirs are marked by extensive deviation in the gravel and pebble content. Sandy and stony soils have the highest conductivity and result in rapid heating, growth and nutrient and water uptake by roots (Fregoni, 1977). These characteristics have a positive influence on wine quality in the Northern Hemisphere, but can have adverse effects in the Southern Hemisphere leading to the degradation of acids, aroma components and polyphenols (Carey, 2001).

Soil structure refers to the arrangement of primary soil particles into secondary units, also referred to as “peds” (White, 2003). The secondary units are characterised and classified on the basis of size, shape and distinctness into four types. Water and nutrient movement and root penetration are influenced by soil structure (Roux, 2005). Soil structure is highlighted as a more important factor contributing to water availability than texture due to the high degree of macro-porosity resulting in water percolation which prevents the development of a water table at root level (Seguin, 1986). McCarthy *et al*. cited in Dry and Coombe (1992), suggest that structured clay will be more suitable for root growth than sand. This is due to the fusion of particles of the structured clays allowing root entry and oxygen diffusion in the large pores.

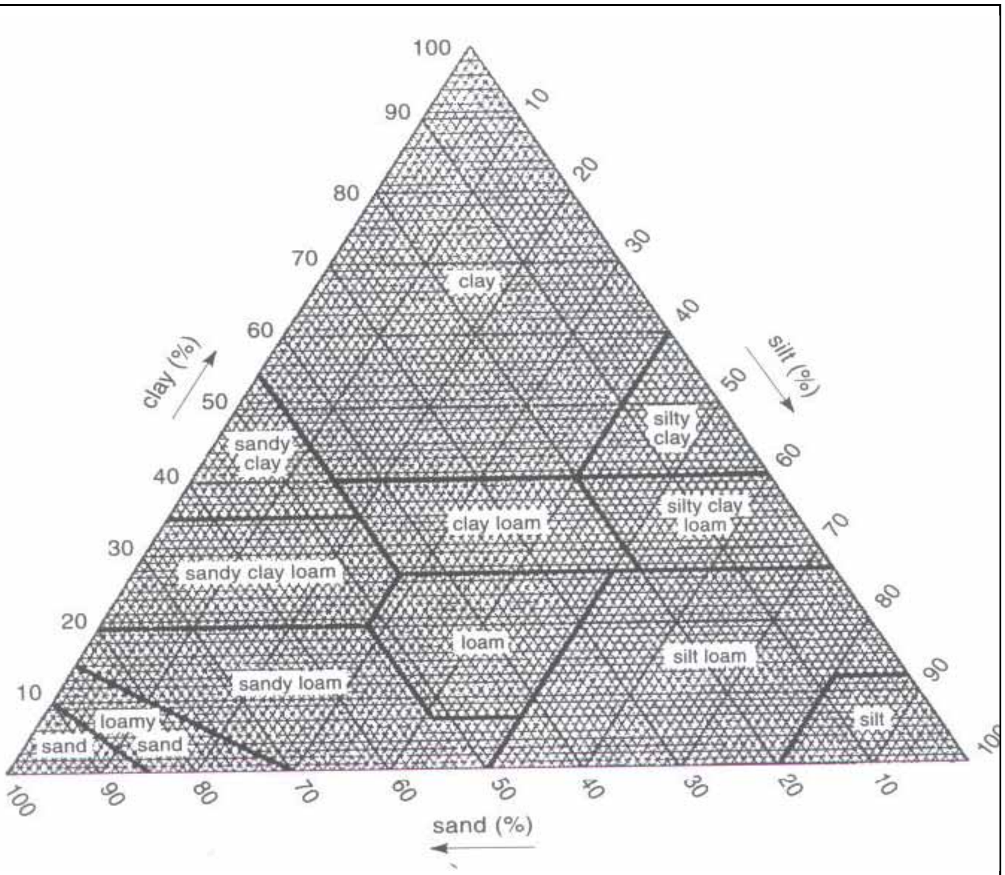


Figure 2.5 Textural triangle based on the USDA particle-size classification (White, 2003).

2.2.5.4 SOIL COLOUR

Soil colour is regarded as one of the most useful attributes to characterise and differentiate between soils and is used widely in the classification of soils. It is a very prominent feature of the landscape in some regions. Different colours occur due to different forms, degrees of hydration and concentrations of iron oxides and mineral properties (Table 2.1). Soil colour is dependant on parent material from which it was formed (Saayman, 1981). Pedogenetic factors, such as wetness, illuviation and biological activity, contribute to colour formation of the soil. Soil colour is significant in that it (i) is associated with moisture availability to the plant, (ii) is associated with nutrient availability, (iii) influences microclimate and root growth due to its heat-retaining and light-reflecting capacity and (iv) is associated with certain soil properties (Jackson & Lombard, 1993; Carey, 2001). The colour of soil is not only dependent on the inherent spectral behaviour of the heterogeneous mineral combination of reflecting properties, but also on the spectral distribution of the illuminating light (The Soil Color, 1993; Post *et al*., 2000).

Damp and iron-rich soils absorb more light while light coloured soils reflect solar radiation more than soils with intermediate colours (e.g. grey) (Fregoni, 1977). Dark soils have been found to be associated with strong vegetative growth, but a lower yield due to *coloure* (berry shatter). The duration of the growth cycle of grapevines has also been found to vary with colour, with white soils resulting in the longest vegetative cycle. According to Fregoni (1977), soil colour has effects on the aboveground growth (vegetatively) and the root growth. Other researchers, according to Fregoni (1977), found that the resulting soil temperature affected the onset of root activity rather more than the aboveground growth and production. Readily warmed soils in combination with an early and quick growth start in spring have always been essential for ripening in cool viticultural areas (Gladstones, 1992). Aboveground microclimate can be considered important and thus soil temperature can control whole plant physiology and development.

Reflected white, yellow, orange and reddish light in the lower vine canopy and bunch area is expected to increase the red to far-red ratio, which should result in increased fertility and anthocyanin synthesis (Gladstones, 1992). Infrared light is not influenced by light reflected from the visible light spectrum, as it has wavelengths of about 750 nm to 1 mm, spanning five orders of magnitude. Light at the 400nm to 700 nm wavelengths is effective for photosynthesis and therefore light in the visible light spectrum will not influence the infrared spectrum of light.

Artificial solarisation experiments by Robin *et al*. (2000) showed that both the quality and the quantity of reflected light have an effect on the sugar concentrations in the grape berries and grape colour being predominately influenced by the amount of reflected red light. The authors suggested that the effects were via the phytochrome system of the leaves.

Different drainage characteristics are associated with variations in soil colour. In high rainfall climates, red to yellow soils are associated with good soil drainage, while darker soils imply poor internal drainage (Carey, 2001). The chemical composition would therefore differ due to leaching, deposition and variations in parent material.

Table 2.1 Properties of soil minerals (adapted from The Soil Color, 1993).

Properties of Minerals				
Mineral	**Formula**	**Size**	**Munsell**	**Color**
goethite	FeOOH	(1-2 mm)	10YR 8/6	yellow
hematite	Fe_2O_3	(~0.4 mm)	5R 3/6	red
hematite	Fe_2O_3	(~0.1 mm)	10R 4/8	red
lepidocrocite	FeOOH	(~0.5 mm)	5YR 6/8	reddish-yellow
lepidocrocite	FeOOH	(~0.1 mm)	2.5YR 4/6	red
ferrihydrite	$Fe\ (OH)_3$		2.5YR 3/6	dark red
glauconite	$K(Si_xAl_{4x})(Al,Fe,Mg)O_{10}(OH)_2$		5Y 5/1	dark grey
iron sulfide	FeS		10YR 2/1	black
pyrite	FeS_2		10YR 2/1	black (metallic)
jarosite	$K\ Fe_3\ (OH)_6\ (SO_4)_2$		5Y 6/4	pale yellow
todorokite	MnO_4		10YR 2/1	black
humus			10YR 2/1	black
calcite	$CaCO_3$		10YR 8/2	white
dolomite	$CaMg\ (CO_3)_2$		10YR 8/2	white
gypsum	$CaSO_{4\times}\ 2H_2O$		10YR 8/3	very pale brown
quartz	SiO_2		10YR 6/1	light grey

2.3 FACTORS INFLUENCING LIGHT QUALITY

2.3.1 LIGHT AS A BIOLOGICAL AGENT

2.3.1.1 THE PHYSICAL NATURE OF LIGHT

Light comprises a small region of the continuous electromagnetic spectrum of radiant energy emitted by the sun. The term “light” can be described as psychophysical rather than physical and can be defined as those regions of the radiant energy spectrum to which the average light-adapted human eye is sensitive (Smith, 1975; Smith, 1982; Kendrick & Kronenberg, 1986). The term not only encompasses the regions detectable by the human eye, or “visible” light, but it also includes the near ultraviolet (relatively short waves) and the near infrared regions (relatively long waves) of the spectrum (Smith, 1975; Smith, 1982; Kendrick & Kronenberg, 1986). The “visible” spectrum of light consists of a band of colours that represent a specific waveband: red, orange, yellow, green, blue, indigo and violet (Smith, 1975). Visible light thus only comprises a small amount of the total radiation and only a smaller amount is effective for photosynthesis (400 nm to 700 nm) (Fig 2.6) (Smart, 1989).

The electromagnetic spectrum can be described as radiant energy that is emitted by the sun. This electromagnetic spectrum is of a dual nature, since in propagation it behaves as a waveform, while on interaction with matter it behaves as a stream of discrete packets of energy known as *light quanta* (Smith 1975; Smith, 1982; Kendrick & Kronenberg, 1986). The spectrum extends from the very long wave, low-energy quanta of radio waves to the extremely high-energy quanta of the cosmic rays (Fig 2.6.) (Smith, 1975).

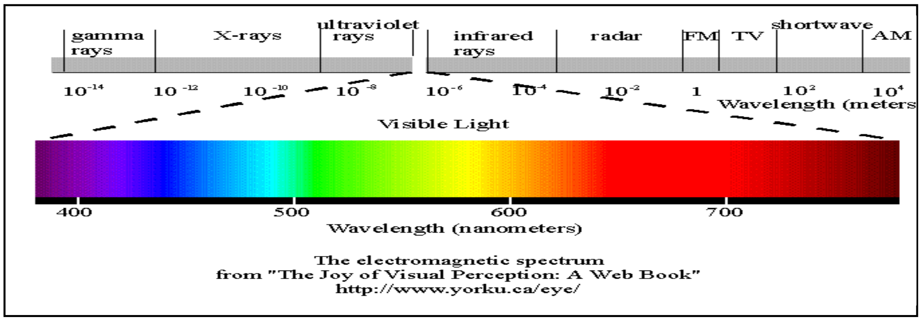


Figure 2.6 The light spectrum (The Joy of Visual Perception, 2005).

2.3.1.2 THE ABSORPTION OF LIGHT

Penetration of light into an absorbing substance results in attenuation to a degree that is determined by the probability that individual quanta will be sorted by atoms and molecules (Smith, 1975). During the absorption of a photon, the atom or the molecule gains all the energy of the photon and is therefore energised (Smith, 1975; Shropshire & Mohr, 1983). Photon absorption is dependent on the frequency of the radiant energy that is absorbed (Smith, 1975). Energy quanta in short-wave gamma rays and X-rays are relatively high and absorption of this energy results in complete ejection of an electron from a molecule, causing ionization (Smith, 1975). From 290 nm to 800 nm, the absorption of quanta leads to a change in the energy levels of the outer electrons, resulting in photochemical reactions (Smith, 1975; Smith 1982).

2.4 LIGHT QUALITY

2.4.1 THE PERCEPTION OF LIGHT QUALITY BY C_3 PLANTS

The activity of plant photoreceptors is dependant on the light environment. Therefore plants are restricted to the “visible” range of the spectrum on the earth’s surface (400 nm to 800 nm) that consists of wavelengths in which the energy per photon is sufficient to initiate photochemical reactions (Smith, 1975). The radiation between these wavelengths is also referred to as the photosynthetic photon flux density (PPFD). This spectrum range comprises up to 55% of all the radiation reaching the earth, and sustains almost all life on earth (Kendrick & Kronenberg, 1986). Daylight can vary with respect to (i) the amount of light, (ii) its distribution across the spectrum, and (iii) its timing and direction. Polarisation and the extent of scattering of light may also be influenced (Smith, 1982; Shropshire & Mohr, 1983; Kendrick & Kronenberg, 1986). Various plant growth aspects (e.g. stem elongation, phototropism and flowering) are controlled by light. Blue and red light have the greatest effect on plant growth. Vegetative growth is dependant on blue light, while reproductive growth stages are dependent on a combination of red and blue light.

Phototropins and cryptochromes are blue-light and UVA-radiation receptors that respond to light in the 400 nm to 500 nm waveband of the visible light spectrum. Phytochrome responds to light in the 600 nm to 800 nm waveband. Perception of fluctuations in the red to far-red (R:FR) ratio ensures that the plant is provided with information on (i) the timing of the daily photoperiod and (ii) shading by other vegetation (Smith, 1982). Phytochrome acts as a sensitive sensor of shading by vegetation, since a relatively small degree of shade would yield a relatively large depression of Pfr/Pr (Smith, 1982; Rockwell *et al*., 2006).

2.4.2 CONTRIBUTION OF SOIL TO LIGHT QUALITY

Gladstones (1992) suggests that the reflection of white, yellow or especially orange or red light into the lower vine canopy could lead to the raising of red to far-red ratios, which is favourable for fruitfulness and cytokinin dominance. Kasperbauer and Hunt (1987) found that blue light was reflected upward from variously coloured soils and is dependent on the moisture content and surface covering. The presence of crop residues over dark soils doubled the PPFD while the reflectance from white soils decreased (Kasperbauer & Hunt, 1987). The spectral distribution (quality) of reflected light has an influence on the photosynthate partitioning within seedlings (Kasperbauer & Hunt, 1987). The depth of penetration into the soil and diffuse reflectance properties would seem to be important, as they determine the spectral distribution of the light available for plant physiology (Ciani *et al.*, 2005).

2.4.3 CAUSES OF THE SPECTRAL VARIATION OF SOILS

Global radiation consists of two main components, namely direct radiation and scattered or diffuse radiation, which interact with molecules or particles in the atmosphere before reaching a plant sensor (Smith, 1982). The spectrum of global radiation is relatively constant if the angle of the sun is above the horizon and more than ten degrees in daylight (Smith, 1982). Climatic and cloud conditions rarely affect the R:FR ratio, although heavily overcast sky can reduce the total 400 to 800 nm irradiance by more than ten fold (Smith, 1982). Light quality within vegetation canopies is primarily determined by the density (canopy architecture) and depth of the plant sensors within the canopy.

The reflectance and emmitance behaviour of soil is dependent on its biochemical and physical composition. Contributing factors to the spectral response of bare soil have been categorised as intrinsic factors, which are stable and include factors such as soil colour, mineral constituents and organic matter, and extrinsic factors, which are dependent on soil preparation (tillage practices which influences the surface roughness), climatic conditions (soil water), as well as viewing conditions (solar altitude) (Courault *et al*., 1993). Slaking on different soil types causes changes in the soil surface and soil properties (e.g. roughness, surface texture, soil water content and surface colour) (Courault *et al*., 1993). Water content of soils is primarily influenced through evaporation and roughness indices (Courault *et al*., 1993). The reflectance of soils is a collective property that is derived from intrinsic spectral behaviour and particle distribution of the heterogeneous combination of mineral, organic and fluid matter. Reflectance is thus influenced by an array of parameters, including soil surface colours, soil water content and soil surface roughness.

2.5 CANOPY SUNLIGHT PENETRATION

2.5.1 GENERAL CONCEPT

Fruit composition is influenced by an array of sunlight parameters, such as photosynthetic, thermal or phytochrome effects (Smart, 1987). The light environment within grapevine canopies is characterised by spatial and temporal variations (Mabrouk *et al*., 1997). Radiation is the most attenuated within plant canopies, and the flux density varies. Plants can be described as a complex optical system by which light movement occurs through a passage of different tissue layers via light scattering (Smith, 1975). After light passes through the plant surface, the spectral quality and quantity may be altered by wavelength-dependent absorption (Smith, 1975).

2.5.2 PLANT PHYSIOLOGICAL RESPONSE

2.5.2.1 PHOTOSYNTHETIC EFFECTS

Photosynthesis occurs readily at light saturation levels of one-third (800 µmol m^2s^1) of full sunlight and at temperatures of 30°C and is repressed by stomatal closure at a leaf water potential of more than 15 bars (Smart, 1989). Light compensation is at 15-30 µmol m^{-2} s^{-1} or 1 % of full sunlight (Smart, 1987). Only

9 - 10% of sunlight received by the leaf is used during photosynthesis. Light distribution will vary according to the radiation wavelength (Fig. 2.7), cultivar and leaf age. Due to the orientation of leaves within the canopy, leaves are affected differently by the photon flux density.

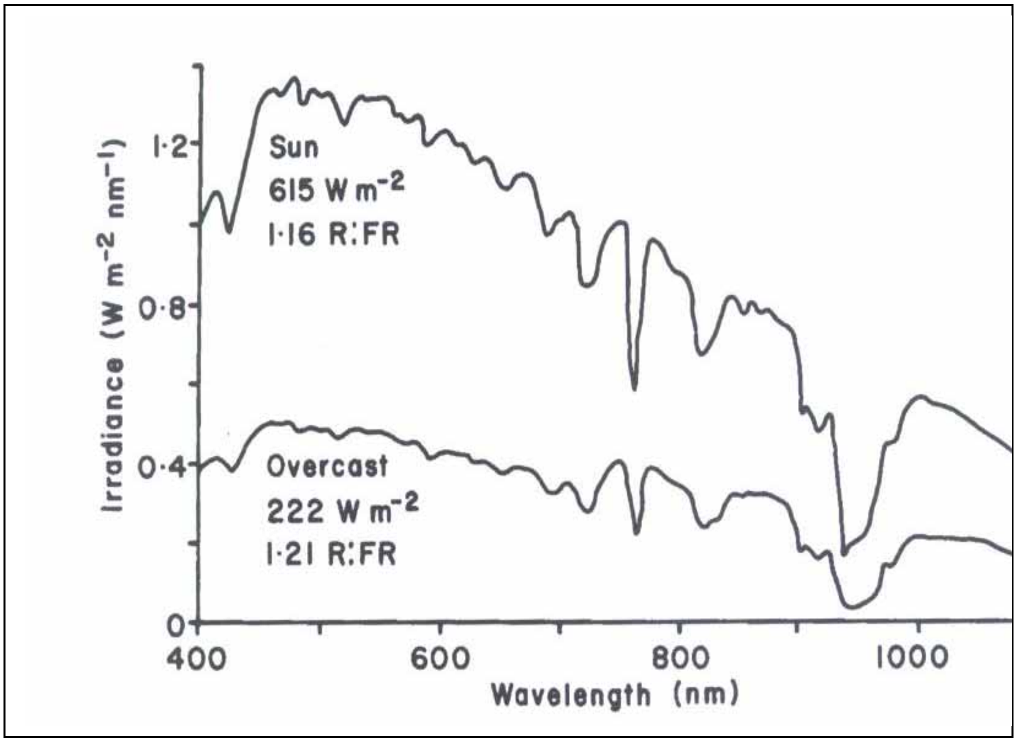


Figure 2.7 Spectral distribution of sunlight (Smart, 1989).

2.5.2.2 THERMAL EFFECTS

Berry surface temperature varies by 10°C to 15 °C more than the air temperature due to forced convection energy dissipation, which dominates within the bunch zone (Smart, 1989). Leaf temperature is modified by plant water status due to the effect of transpirational cooling. Tissue heating effects occur at 300 nm to 1500 nm and are influenced by radiation wavelength, cultivar, and leaf age. The internal structure of various tissues leads to a cooling effect within the leaf. Sun leaves are typically thicker resulting in longer palisade parenchyma (Salisbury & Ross, 1978).

2.5.2.3 PHYTOCHROME EFFECTS

Phytochromes are proteinaceous pigments associated with the absorption of light. All higher plants appear to share the same basic structure of a dimer of ~ 125 kDa polypeptides. The relation of phytochrome with light quality shows absorption maxima at 660 nm and 730 nm respectively (Briggs, 1972; Smith, 1975; Kendrick & Kronenberg, 1986; Chory, 1997; Casal, 2000; Chen *et al*., 2004; Rockwell *et al*., 2006). Since phytochrome is involved in the processes of growth and development, it is thought that phytochrome is present at a maximum rate in those regions where these processes occur at a maximum rate (Smith, 1975). During extraction and spectrophotometrical analysis, phytochrome was found in the roots, stems, leaf blades, petioles, cotyledons, hypocotyls, vegetative buds, floral receptacles, inflorescences, and developing fruits of a variety of plants (Hillman, 1967; Smith, 1975; Møller *et al.,* 2002). The localization of the phytochromes within their different families is dependent on factors such as (i) the light quality requirements and (ii) nuclear import kinetics (Smith, 1975). A Pr to Pfr conformational change is required for nuclear import (Fig 2.8) (Smith, 1975; Møller *et al*., 2002).

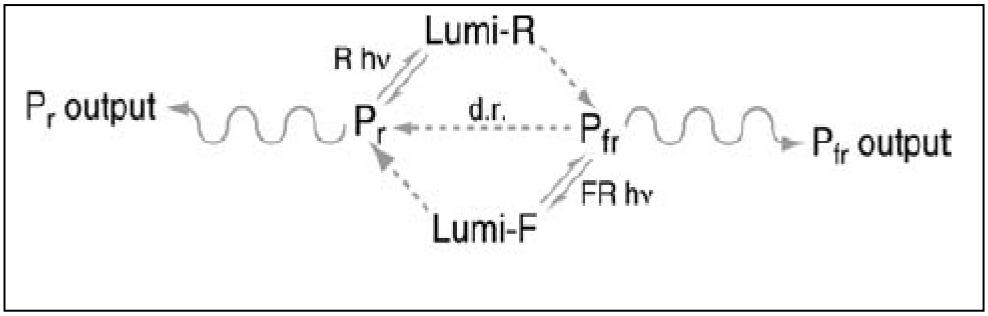


Figure 2.8 The phytochrome photocycle. Illumination of Pr phytochrome with red light (R) produces lumi-R as the primary photoproduct. This is subsequently converted to Pfr via multiple light-independent steps. Pfr can be converted into Pr either by illumination with far-red light (FR), producing lumi-F and then Pr via subsequent thermal steps, or by an entirely thermal process known as dark reversion (d.r., *center*). The ratio between Pr and Pfr (and hence between the two physiological outputs) is thus determined by the light environment and by the rate of dark reversion (Rockwell *et al*., 2006).

Phytochrome levels are highest in meristimatic or recently meristematic tissue, such as root and shoots during the development of seedling growth (Smith, 1975; Møller *et al*., 2002). Throughout the life cycle of the plant, phytochrome photoreceptors play a crucial role in the plant, adaptation to its light environment (Smith, 1975; Smith 1982). The light environment is used to modulate a range of growth responses, including (i) seed germination, (ii) seedling de-etiolation (leaf and growth promotion and stem growth inhibition), (iii) gene expression (vi) chlorophyll differentiation, (v) regulation of the plant architecture and (vi) the onset of flowering (Smith, 1975; Kendrick & Kronenberg, 1986; Møller *et al*., 2002; Nagy & Schafer, 2002). In addition, phytochrome interact with the gravity-sensing apparatus for the control of gravitropism and sensing of the proximity of neighbouring plants, and the effects that these have on light quality due to the spatial and temporal changing light environment (Kendrick & Kronenberg, 1986; Ballare, 1999; Fankhauser, 2000).

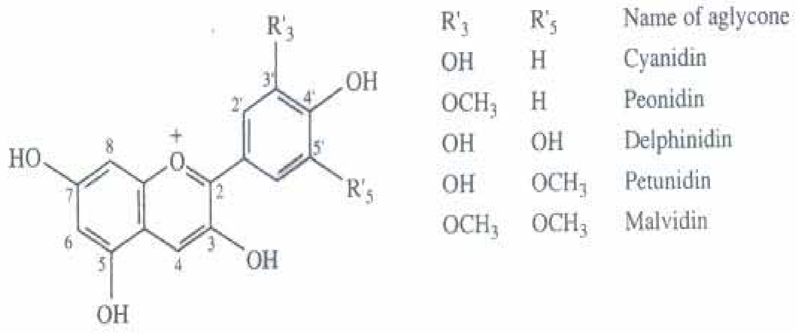
Phytochrome plays a role in the development, adaptation and information transmission from the environment to the metabolic centre of the plant. Phytochrome far-red (P_{fr}) controls many critical enzymes (glyceraldehydes-3-P dehydrogenase amino acid activating enzyme, phenylalanine ammonia lyase, ribulose-1, 5-bisP carboxylase, malate dehydrogenase and amylase). Nitrate and ammonium are the most common forms of nitrogen available to plants (Roubelakis-Angelakis, 2001). Once inside the root, nitrate is can be stored in the root vacuoles, reduced, or translocated through xylem to the shoots and leaves (Roubelakis-Angelakis, 2001). The assimilation of nitrate requires a complex biochemical reaction as nitrate is converted to nitrite by nitrate reductase (NR) enzyme and nitrite is converted to ammonia by nitrite reductase (NiR). The assimilation process is controlled by carbohydrate oxidation and is associated with the production of organic acids. The presence of secondary metabolites (e.g. phenolics) complicates the utilisation of nitrates in grapevines. Nitrate reductase (NR), phenylalanine ammonia lyase (PAL) and flavanone synthetase, play a direct role in anthocyanin biosynthesis and are influenced by the spectral distribution of the light in the grapevine canopy. The production of anthocyanins is of economic value, as they contribute to the taste and colour of grapes.

2.6 ANTHOCYANIN BIOSYNTHESIS

2.6.1 ANTHOCYANIN STRUCTURE

Anthocyanins are found in almost all higher plants and are the principle phenolic compounds that give rise to the red colour of grapes (Roubelakis-Angelakis, 2001). Proanthocyanidins give rise to the grape colour in white grapes. All of these compounds form part of the flavonoids with a C_{15} (C_6-C_3) skeleton. The basic anthocyanin "backbone" is known as the anthocyanidins or aglycones due to the absence of a sugar molecule in the aromatic rings (Roubelakis-Angelakis, 2001).

Anthocyanin pigments are located in the vacuoles of the berry skins and are mostly limited to the first three to six subepidermal cell layers (Moskowitz & Hradzina, 1981). Six common anthocyanidins exist within plants (see Fig 2.9). *Vitis vinifera* contains only anthocyanidin-3-monoglucosides with malvidin-3-monoglucosides being the most prominent. Anthocyanins are soluble in water and low-alcohol levels. Moskowitz and Hradzina (1981) have suggested that anthocyanins are present in grape skins in a free, non-complexed form in equilibrium with the red-coloured flavylium salt, the purple-coloured anhydro-base and the carbinol base, which is colourless.



R'_3	R'_5	Name of aglycone
OH	H	Cyanidin
OCH_3	H	Peonidin
OH	OH	Delphinidin
OH	OCH_3	Petunidin
OCH_3	OCH_3	Malvidin

Figure 2.9 Anthocyanin structure in *V.vinifera* species (Ribereau-Gayon, *et al*., 2000)

2.6.2. ANTHOCYANIN BIOSYNTHESIS DURING RIPENING

Grape berry development takes place in a double sigmoid growth pattern (Fig. 2.10). These development stages can be divided into three, each having its own traits, and are dependent on the cultivation practices giving rise to different wine styles. Stage I take place after fertilisation of the flower (berry set) and is characterised by rapid growth of the seed and berry (through cell division and the expansion of existing cells). Stage II is known as the lag phase as the berry itself grows only slowly, the embryo and sugar increase, acidity weakens, with an increase in cell volume. The anthocyanin content increases throughout ripening and accumulation begins at véraison (Roubelakis-Angelakis, 2001). Grape colour can be an objective measurement for the prediction of red wine quality (Illand, 1987). Phenolic compounds are major constituents of wine and contribute to the sensorial properties, such as colour, mouth feel characteristics and taste (Rossouw *et al*., 2003). Castia *et al*. and Gonzalez-Neves *et al.* cited in Rossouw *et al*., (2003) found that anthocyanin levels and type are cultivar associated. Genetic factors are highlighted as the reason for these cultivar differences.

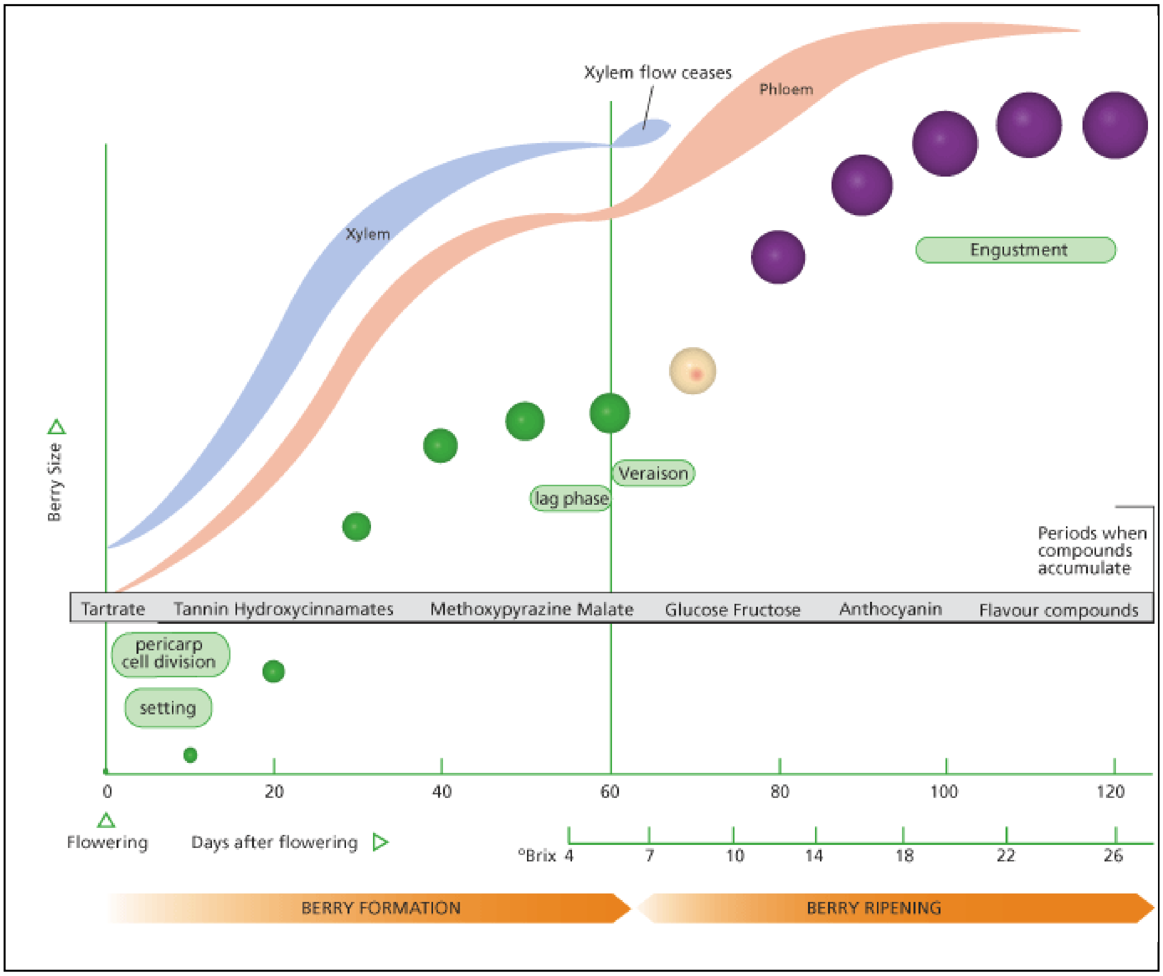


Figure 2.10 Berry development at ten day after flowering (Kennedy, 2002).

Anthocyanin production has been shown to be the factor that influences the transport of sucrose in the grapevine leaf and fruit tissue (Pirie & Mullins, 1977). Pigment production is synchronised due to changes in the sugar levels which occur in the grape berry skin and the site of anthocyanin accumulation. Anthocyanin content is influenced by environmental conditions, cultivar, seasons and cultural practices (Roubelakis-Angelakis, 2001; Pirie & Mullins, 1977).

Anthocyanin production depends on enzyme activity and the production of enzymes (Strydom, 2006). Phenylalanine ammonia lyase (PAL) and flavanone synthetase are two important enzymes in this flavonoid pathway. PAL is the first enzyme in anthocyanin production and channels phenylalanine away from protein synthesis toward phenylpropanoid, flavonoid and anthocyanins

(Moskowitz & Hradzina; 1981). Chalcone synthetase (CHS) activity in the flavonoid pathway increases rapidly at stage III of berry development, and decreases sharply thereafter. Cinnamic acid is formed through the catalysis of phenylalanine. The cinnamic acid which is formed is then converted to p-coumaric acid by cinnamate-4-hydroxylase (C_4H). Meng *et al*., (2004) have suggested that blue light promotes the expression of the chalcone synthetase (CHS) and dihydroflavonol 4-reductase (DFR) genes while red light enhances CHS gene expression.

Chalcones are the first flavonoids that are produced by chalcone synthase (CHS) (Fig. 2.11). The enzymes which catalyse the hydroxylation of the B rings emerge to act on flavonoids or dehydro flavonols and products of flavonone-3-hydroxylase (F3’H). Stolz in Roubelakis-Angelakis (2001) suggested that enzymes which catalyses the hydroxylation of the B rings seem to act on the flavonones and dihydroflavononls (substrate and products) of F3’H. The enzymes F3’H and flavonoid 3’5’-hydroxylases (F3’5’H) determine the anthocyanin species. F3’H results in cyanidin-like anthocyanins, whereas F3’H5’ leads to delphinidin species. Anthocyanidins are stabilised through the addition of a glucose residue at position 3 of the C ring. This reaction is catalysed by UDP-glucose flavonoid-3-O-glucosyl transferase (UFGT). This UFGT gene is expressed only in coloured grapes.

Understanding grape berry development and component development is crucial in the understanding of wine quality. These developmental stages are dependent on the environmental aspects of a site, namely, soil, water and the climate, which influence light, temperature and moisture. Temperatures should be optimal for phase II of fruit development. Gene expression is dependent on light quality.

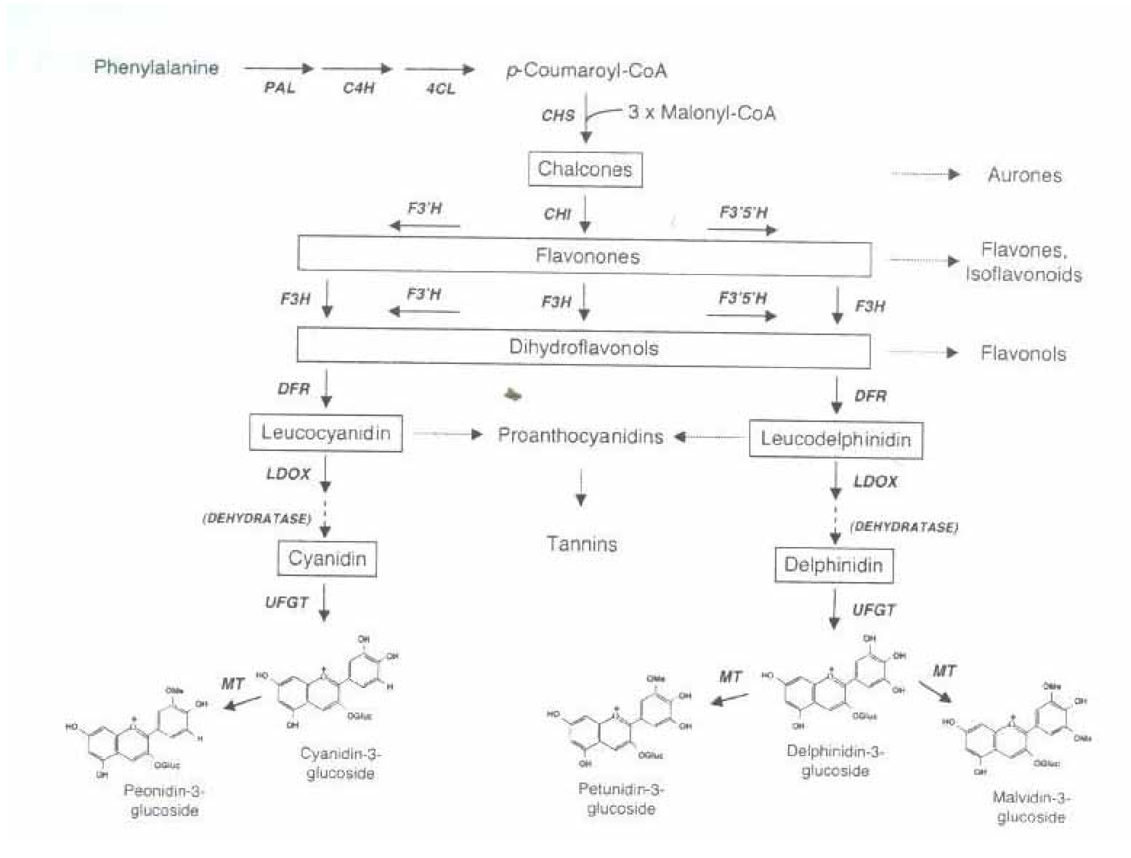


Figure 2.11 Anthocyanin biosynthesis pathway (Roubelakis-Angelakis *et al.*, 2001).

2.7. CONCLUSION

Since terroir is influenced by a variety of factors, no single factor can be singled out as being the most important. The study of the grapevine response to terroir requires an understanding of the soil-climate–plant interaction. This interaction entails the study of soil, climate and sensorial monitoring of the wine. Due to the diversity and variety of environmental conditions, a whole plant-berry approach is needed. The whole plant-berry approach looks at the grapevine performance and the effect thereof on the grape berry in relation with the environment.

Climate is the predominant determinant of wine style. The interaction between cultivar and genotype is dependent on soil factors (e.g. chemical composition and pH, texture and structure, depth and soil colour). Whether the effect is direct or indirect is unknown, but it can be seen as a combined effect of climate, vine and soil property interactions on the vine balance (vegetative and reproductive growth). The latter is dependent on the light quality and quantity which are required to sustain the grapevine physiology and plant receptors for vine development.

Plants are complex optical systems that are dependant on the light environment. Light conditions are dependant on the source and the microclimatic conditions of the pant. The light environment is affected by both long - (row direction, etc.) and short-term practices (canopy management practices, pruning). Grape berry composition is influenced both directly (light quality and light quantity) and indirectly through environmental and short - term practices. The photosynthetic capacity of leaves exposed to the sun is influenced by light quality. Bud fertility is increased due to favourable light conditions and the stimulation of growth tips due to phototropism.

Berry temperature is important, as it is affected by an increase in sunlight exposure. The increased exposure of sunlight has an effect on the fruit composition. Sunlight exposure leads to increased phenolic compounds such as anthocyanins and total phenolics. Sunlight and temperature are dependent on each other and influence the mineral and metabolic profiles of the grapes.

From these factors it can be seen that soil plays a crucial role in sustaining plant metabolism (photosynthesis, nutrient and water uptake) and the light environment (reflectance from soil surfaces with different colours) influences the quality and quantity of light.

The colour of the soil surface is expected to have an effect on grape composition as it determines the intensity and quality of reflected light. Light quality and quantity also determine temperature, which affect the formation of phenolic components.

Therefore an extended knowledge of the physical and chemical properties of the soil is crucial to understand the bigger concept of terroir and soil surface colour can be expected to affect the grapevine response.

2.8 REFERENCES

Ballare, C.L., 1999. Keeping up with the neighbours: phytochrome sensing and other signaling mechanisms. Trends in Plant Science 4, 97-126.

Becker, N.J., 1977. The influence of geographical and topographical factors on the quality of the grape crop. In: Proc. Int. Sym.Quality of the Vintage. February 1977, Cape Town, South Africa, 169-188.

Briggs, W.R. 1972. Phytochrome: chemical and physical properties and mechanism of action. Annual Review of Plant Physiology 23, 293-334.

Carey, V.A., 2001. Spatial characterisation of natural terroir units for viticulture in the Bottelaryberg-Simonsberg-Helderberg winegrowing area. MScAgric thesis, Stellenbosch University, Private Bag X1, 7602, Matieland (Stellenbosch), South Africa.

Carey, V.A., 2005. The use of viticultural terroir units for demarcation of geographical indications for wine production in Stellenbosch and surrounds. PhDAgric dissertation, Stellenbosch University, Private Bag X1, 7602, Matieland (Stellenbosch), South Africa.

Casal, J.J., 2000. Phytochromes, cryptochromes, phototropin: photoreceptor interactions in plants. Photochemistry and photobiology 71 (1), 1-11.

Chen, M., Chory, J. & Fankhauser, C., 2004. Light signal transduction in higher plants. Annual Review of Genetics 38, 87-117.

Chory, J., 1997. Light modulation of vegetative development. The Plant Cell 9, 1225-1234.

Ciani, A., Goss, K.U. & Schwarzenbach, R.P., 2005. Light penetration in soil and particulate minerals. Eur. J. Soil Sci. 56, 561-574.

Coombe, B.G., 1987. Influence on temperature on composition and quality of grapes. Acta Hort. 206, 23-33.

Conradie, W.J., 1998. The effect of soil and climate on the character of Sauvignon blanc wine. In: Proc. SASEV Congress, November 1998, Cape Town, South Africa.

Courault, D., Bertuzzi, P and Girard, M.C., 1993. Monitoring surface changes of bare soils due to slaking using spectral measurements. Soil Sci. Soc. America J. 57, (6) 1595-1601.

Danielson, R.E., 1972. Nutrient supply and uptake in relation to soil physical conditions. In: Hillel, D. (ed). Optimizing the soil physical environment toward greater crop yields, Academic Press, New York & London, 193-221.

Deloire, A., Lopez, F. & Carbonneau, A., 2002. Grapevine responses and terroir: aspects of a study method. Progrès Agricole et Viticole 119 (4), 78-86.

Deloire, A., Vadour, E., Carey, V., Bonnardot, V. & Van Leeuwen, C., 2005. Grapevine response to terroir: A global approach. J. Int. Sci. Vigne.Vin. 39 (4), 149-162.

Dry, P.R. & Coombe, B.G., 2004 (2nd ed). Viticulture resources. Volume 1. Winetitles, Adelaide.

Dry, P.R. & Coombe, B.G., 1992. Viticulture practices. Volume 2, Winetitles, Adelaide.

Fankhauser, C., 2000. Phytochromes as light-modulated protein kinases. Cell & Development Biology 11, 467-477.

Fregoni, M., 1977. Effects of soils and water on the quality of the harvest. In: Proc. Int. Sym. Quality of the Vintage. February 1977, Cape Town, South Africa, 151-168.

Gladstones, J., 1992. Viticulture and Environment. Winetitles, Adelaide.

Hillel, D., (ed), 1972. Optimizing the soil physical environment toward greater crop yields. Academic Press. New York.

Hillman, W.S., 1967. The physiology of phytochrome. Annual Review of Plant Physiology 18, 301-324.

Jackson, D.I. & Lombard, P.B., 1993. Environment and management practices affecting grape composition and wine quality – A review. Am. J. Enol. Vitic. 44, 409-430.

Kasperbauer, M.J. & Hunt , P.G., 1987. Shoot/root assimilate allocation and nodulation of Vigna unguiculata seedlings as influenced by shoot light environment. Plant and Soil, 161 (1), 97-101.

Kendrick, R.E. & Kronenberg, G.H.M., 1986. Photomorphogenesis in plants. Kluwer Academic, Dordrecht.

Kennedy, J., 2002. Understanding grape berry development. Practical Winery. Available: http://www.practicalwinery.com?JulyAugust02/julaug02p14.htm. (Accessed: 23/11/2007).

Kliewer, W.M., 1974. Effect of root temperature on budbreak, shoot growth, and fruit set of ‘Cabernet Sauvignon’ grape vines. Am. J. Enol. Vitic. 26, 82-89.

Mabrouk, H., Sinoquet, H. & Carbonneau, A., 1997. Canopy structure and radiation regime in grapevine. II. Modelling radiation interception and distribution in side the canopy. Vitis 36 (3), 125-132.

Meng, X., Xing, T. & Wang, X., 2004. The role of light in the regulation of anthocyanin accumulation of Gerbera hybrida. Plant Growth Regulation 44, 243-250.

Moskowitz, A.H. & Hrazdina, G., 1981. Vacuolar contents of fruit supepidermal cells from *Vitis* species. Plant physiology 68, 686-692.

Møller, S.G., Ingles, P.J. & Whitelam G.C. 2002. The cell biology of phytochrome signaling. New Phytologist 154, 553-590.

Mouton, G., 2006. Terroir - the footprint of great wines. Cape Wine Master Diploma Thesis. Available:www.capewineacademy.co.za/seminars/TerroirThe%20Footprint%20of%20Great%20Wines.pdf. (Accessed 19/07/2007)

Nagy, F. & Schafer. E., 2002. Phytochromes control photomorphogenesis by differentially regulated, interacting signaling pathways in higher plants. Annual Review of Plant Biology 53, 329-355.

Pienaar, J.W., 2005. The effect of wind on the performance of the grapevine. MScAgric thesis, Stellenbosch University, Private Bag X1, 7602, Matieland (Stellenbosch), South Africa.

Pirie, A. & Mullins, M.G., 1977. Interrelation of sugars, anthocyanins total phenols, and dry weight in the skins of grape berries during ripening. Amer. J. Enol. Vitic. 28, 204-209.

Post, D.F., Fimbres, A., Matthias, A.D., Sano, E.E., Accioloy, L., Batchilly, A.K. & Ferreira, L.G., 2000. Predicting soil albedo from soil color and spectral reflectance data. Soil Sci. Soc. Am. J. 64, 1027-1034

Rankine, B.C., Fornachon, J.C.M, Boehm, E.W. & Cellier, K.M., 1971. Influence of grape variety, climate and soil on grape composition and quality of table wines. Vitis 10, 33-50.

Ribereau-Gayon, P., Glories, Y., Maujean, A., Dubourdieu, D., 2002. The Handbook of Enology: Volume 2, The chemistry of wine stabilization and treatments. John Wiley & Sons. New York.

Robin, J.P., Sauvage, F.X. & Chovelon, M., 2000. Les propiertes de reflectance du sol de la parcelle sont a comsiderer des parametres du terroir. In: Proc. 3rd Int. Sym. Viticultural Zoning, May, Puerto de la Cruz, Tenerife.

Rockwell, N.C., Su, Y. & Lagarias, J.C., 2006. Phytochrome structure and signaling mechanisms. Annual Review of Plant Biology 57, 837-858.

Rossouw, M. & Marais, J., 2003. Phenolic compounds in South African red wines: A preliminary study. Available: http://www.wynboer.co.za/recentaricles/0203phenolic.php3. (Accessed: 20/11/2007).

Roubelakis - Angelakis, K.A., 2001. Molecular biology & biotechnology of the grapevine. Kluwer Academic Publishers. Dordrecht.

Roux, F.A., 2005. Die invloed van spesifieke grond en klimaats parameters op wingerdprestasie. wynkwaliteit en -karakter. MScAgric thesis, Stellenbosch University, Private Bag X1, 7602, Matieland (Stellenbosch), South Africa.

Saayman, D., 1977. The effect of soil and climate on wine quality. In: Proc. Int. Sym. Quality of the Vintage, February 1977, Cape Town, South Africa, 197 - 226.

Saayman, D., 1981. Klimaat, grond en wingerdbougebiede. In: Burger, J. & Deist,J. (eds). Wingerdbou in Suid-Afrika. Maskew Miller, Cape Town, 48-66.

Salisbury, F.B. & Ross, C.W., 1978. (2nd ed). Plant Physiology. Wadsworth, Belmont.

Sánchez-Marañón, M.,Delgado., Melgosa, M., Hita, E. & Delgado, R., 1997. CIELAB color parameters and their relationship to soil characteristics in Mediterranean red soils. Soil Sci. 162, 833-842.

Sánchez-Marañón, M., Soriano, M., Melgosa, M., Delgado, G. & Delgado, R., 2004. Quantifying the effects of aggregation, particle size and components on the colour of Mediterranean soils. Eur. J. Soil. Sci. 55, 551-565.

Seguin, G., 1986. 'Terroirs and pedology of wine growing. Experentia 42, 861-873.

Shropshire, W., Jr. & Mohr, H., 1983. Photomorphogenesis. Encyclopedia of Plant Physiology, New Series, Volume 16 B, Springer, New York.

Skene, K.G.M and Kerridge, G.H., 1967. Effect of root temperature on cytokine activity in root exudates of *Vitis vinifera* L. Plant physiology 42, 1131-1139.

Smart, R.E., 1987. Influence of light composition and quality of grapes. Acta Hort. 206, 37-47.

Smart, R.E., 1989. Solar radiation as a guide to the design of horticultural plantings. II Twenty years experience with grapevines. Acta Hort. 240, 87-94.

Smith, H., 1975. Phytochrome and Photomorphogenesis: an introduction to the photocontrol of plant development. McGraw – Hill, London.

Smith, H., 1982. Light quality, photoreception, and plant strategy. Annual Review Plant Physiology 33, 481-518.

Stoner, E.R. & Baumgardener, M.F., 1981. Characteristic Variation in Reflectance of Surface Soils. Soil Sci. Soc. Am. J., 45. 1161-1165.

Strydom, J., 2006. Canopy manipulation for optimum colour of Redglobe (V. vinifera L.). MScAgric Thesis, Stellenbosch University, Private Bag X1, 7602, Matieland (Stellenbosch). South Africa.

The Joy of Visual Perception. A Web book. The electromagnetic spectrum. 2005. Available : http://www.yorku/ca/eye/. (Accessed 21/07/2006).

The Soil Color, 1993. Available: http://soils.usda.gov/education/resources/k_12/lessons/color/. (Accessed 15/06/2007).

Van Leeuwen, C., Friant, P., Choné, X., Tregoat, O., Kondouras, S. & Dubourdieu, D., 2004. Influence of climate, soil, and cultivar on terroir. Am. J. Enol. Vitic. 55 (3) 207-217.

Vaudour, E., 2001. Diversity of notions of terroir: towards and operational concept of terroir. Revue des Oenologues et des techniques vitivinicole et oenologique, 101, 39-41.

White, R.E, 2003. Soils for fine wines. Oxford University Press, New York.

Woodham, R.C. & Alexander, D., Mc, E., 1996. The effect of root temoerature on the development of small fruiting sultana vines. Hort. Abstr. 37 (1). Abstract 585, 81.

Wooldridge, J., 2000. Geology: A central aspect of terroir. Available: http://www.wynboer.co.za/recentarticles/1200geology.php3. (Accessed: 16/02/2008).

Zelleke, A. & Kliewer, W.M., 1979. Influence of root temperature and rootstock on budbreak, shoot growth, and fruit composition of Cabernet Sauvignon grapevines grown under controlled conditions. Am. J. Enol. Vitic. 30, 312-317.

Chapter 3

RESEARCH RESULTS

The relationship between soil surface colour and the performance of *Vitis vinifera* L. cv. Cabernet Sauvignon. I. Vegetative growth

RESEARCH RESULTS

3.1 ABSTRACT

Historical and practical evidence points to the key role of soil physical conditions in the governing of wine quality. Soil colour is regarded as one of the useful attributes to rapidly identify soil variability. Soil colour determines the quality and the quantity of the reflected light in the grapevine canopy and may therefore influence grapevine performance.

Three different soil surface colours (black, red and grey) were assigned in five replicates in a block of *Vitis vinifera* L. cv. Cabernet Sauvignon. Light reflectance for the full spectrum (350-2500 nm) and as a ratio of 660 and 730 nm was measured. Grey treatments had the highest R: FR ratios and highest reflectance in the blue band (450-500 nm). Red treatments had intermediate R: FR ratios and higher reflectance in the red band (650-690 nm) and the far-red band (710-750 nm). Black treatments had low R: FR ratios and limited reflective properties. Vegetative growth was primarily stimulated by the grey soil surfaces as a greater mean main leaf area was measured.

Keywords: Cabernet Sauvignon, leaf area, reflectance, R: FR, vegetative growth

3.2 INTRODUCTION

Intrinsic and extrinsic spectral properties of natural soil and plant residues results in the reflectance of a wide range of photosynthetic and morphogenic light which influences the productive and reproductive growth of plants (Antonious & Kasperbauer, 2002). Environmental and cultivation conditions (long and short term practices) influence the balances between vegetative and reproductive growth and influence the radiation climate within the grapevine canopies.

Growth capacity refers to the total vegetative and reproductive biomass produced in a single growth season. Vines with a large growth capacity will result in a dense canopy or vegetative growth and poor inner light exposure. In contrast a small growth capacity results in a less dense canopy and favourable light exposure (Dokoozlian, 1990).

The reflectance from soil surfaces influences the light quality and the quantity available for the vine physiology. Hofäcker, in Fregoni (1977) found that dark soils absorb more solar radiation which resulted in more vegetative growth, but lower yield due to *coloure* (berry shatter). Morgan, in Smart (1987), found that artificially shaded light initiated an elongated responses in leaf area and petiole length. Kasperbauer, in Antonious & Kasperbauer (2002) found that above-ground growth and yield of tomatoes and strawberries were influenced by red plastic mulch reflecting higher red than far-red photons.

Blue and red light have the greatest effect on plant growth as the blue and red portions of the visible light spectra are absorbed by plants while, light in the green spectrum is either reflected or transmitted (Jackson, 2000). Physiological responses such as photomorphogenesis, vegetative growth and flowering induction have been found to be influenced by the red to far-red ratios and UV-A/blue light plant photoreceptors (Takemiya *et al*., 2005). These authors suggested that exposure of green plant tissue to low blue light resulted in strong growth response. Pirie and Mullins (1980) and Jackson (2000) suggested that direct exposure to ultraviolet and blue light has a positive influence on the accumulation of phenolic compounds in the grapevine.

The purpose of this study was to determine whether soil surface colour affected the light quality in the bunch zone and whether this resulted in changes in the vegetative growth parameters of the grapevine.

3.3 MATERIALS AND METHODS

3.3.1 VINEYARD CHARACTERISTICS

The study was conducted in a *Vitis vinifera* L. cv*.* Cabernet Sauvignon clone CS 388C, grafted on Mgt 101-14 (*Vitis riparia X Vitis rupestris)*. The vineyard is situated on the terraces of the Eerste River with light to medium textured alluvial soils. The vines are trained on a six-wire vertical trellis system and the block was subjected to irrigation during critical phenological stages (e.g. fruitset and véraison) and as required through the season.

3.3.2 EXPERIMENTAL LAYOUT

Ninety vines were divided into fifteen mini-experimental plots consisting of six vines each, in zones of similar vigour determined from the Normalized Difference Vegetation Index (NDVI) image for 2006 (Addendum A). The mini-experimental plots were then randomly assigned between three treatments with five repetitions each. Three buffer rows and ca. twelve buffer vines were situated between each plot. The black treatment plots were covered with an eighty percent black shade cloth, the red treatment plots were painted with polyvinyl acetate (PVA) Red Jasper from Dulux and the grey treatment plots were painted with PVA Scorer from Plascon.

The treatments were applied in August 2006 within the working rows on each side of the plot (Addendum B). The paint was applied with a MATABI 20 L (Goizper, S. Coop.) knapsack sprayer at a pressure of 3-bar. Application occurred as soon as the surface area was disrupted due to mechanical, human movement and environmental conditions (e.g. rain and wind). The Red Jasper was applied in a 60:40 and Scorer as 50:50 ratio, with water. The reason for these specific ratios was due to the respective pastel and transparent base of the paints.

3.3.3 MEASUREMENT OF LIGHT QUALITY

Light quality was measured as a ratio of 660 nm and 730 nm wavebands (Skye Instruments, SPD - 110). Measurements were performed at the end of January, mid-

February and prior to harvest in four, two hour cycles from 9:00 am–15:00 pm. These measurements were performed in triplicate at four positions for each repetition: (i) on the soil surface (within the rows) with the sensor turned upside down at an angle of forty-five degrees to the soil surface (ii) at cordon height, sixty centimetre height from the soil surface and at a forty-five degree angle with the soil surface, (iii) in the middle of the leaf canopy (90-100 centimetres from the soil), (iv) above the canopy where ambient light was measured.

Light quality measurements were also conducted with a field spectrometer (Analytical Spectral Devices Inc., Boulder, Colorado). The measurements were performed at cordon and mid canopy height for each of the treatments on 25 September 2007 at 11:00 am.

3.3.4 TEMPERATURE MEASUREMENTS

Soil surface, bunch, mid-canopy and leaf temperatures were measured (Raytek Corporation, USA, Raytek, ST 20 Pro Thermometer). Temperature measurements were performed perpendicular to the surface of the item to be measured at ca. 30 cm distance. Measurements were performed in triplicate for each of the positions and the mean value calculated.

3.3.5 VINEYARD MEASUREMENTS

CANOPY MEASUREMENTS

The point quadrat method was used to determine canopy density (Smart & Robinson, 1991). The measurements were conducted by means of inserting a thin metal rod perpendicularly into the canopy (fruit zone), ca. 100 cm above the ground during the first week of February 2007 (post véraison). Fifty insertions were made in each plot and contacts with leaves and clusters noted.

LEAF MEASUREMENTS

Destructive measurements were performed at three stages (pea size, véraison and pre-harvest). Due to the limited number of vines within a plot in each treatment and the repetitive sampling, two shoots were randomly harvested from each of the repetitions. The shoots were stored overnight at 4°C. Shoot length, internode length, node number and leaf number (main and lateral) were determined. Leaves were removed from the shoots and the leaf area of primary and lateral shoots determined separately, using a Delta-T leaf area meter (Delta-T Devices, Cambridge, UK).

CANE MEASUREMENTS

Each vine within the experimental plots was pruned in July 2007, and the canes weighed, using a Micro Digital Hanging Scale (FS 30) (Scalerite, SA). Taking logistical factors into account, three winter canes were selected randomly at each plot and their cane length, internode length and node number determined for these canes. Due to the number of repetitions within each treatment it is statistical acceptable to use three shoots.

3.3.6 SOIL ANALYSES

Soil samples were collected for each plot with a soil bore at 0-30cm and 30-60 cm respectively. The micro- and macro-element content, pH, electrical conductivity and base saturation for each sample were determined. Analyses were performed by an independent laboratory.

3.3.7 LEAF NUTRIENT ANALYSES

Leaves were sampled after harvest and analysed for leaf nutrient status. Ten leaves in each zone (bunch, mid-canopy and top-canopy) were sampled and separated from the petioles. The samples were then stored at 4°C until being analysed. The analyses were performed by an independent laboratory.

3.3.8 STATISTICAL ANALYSIS

The data were analysed by using Repeated Measures Analysis of Variance (ANOVA). Bonferroni and Tukey tests were used to investigate the effects between groups as well as the interactions between repeated measures and between effects. Descriptive statistics were performed on vegetative data to display the means and standard deviations for variables.

3.4 RESULTS AND DISCUSSION

3.4.1 LIGHT QUALITY (RED: FAR-RED)

The light quality reflected in the red to far-red waveband (660-730 nm) and full light spectrum (300-2500 nm) for the three treatments (black, red and grey) varied considerably. The mean R: FR ratios were the highest on the grey treatment, intermediate on the red and the lowest on the black treatments (Fig 1a). These ratios between the 660 and 730 nm wavebands differed between three positions (i) bunch zone and canopy, (ii) soil surface and (iii) above canopy (Fig 1b). This can be ascribed to light that is absorbed and scattered on the soil surface and above the canopy. Another contributing factor to the variation in the mean R: FR within the bunch zone could be ascribed to the leaf area per vine and the distribution thereof. The R: FR ratios were highest in the grey treatment and higher in the red, compared to the black, at the soil level, but these measurements did not differ significantly in the grapevine canopy with respect to the R: FR ratios (data not shown).

The light quantity decreased further from the soil surface and in specific wavebands ranging between (300 nm–2500 nm) (Addendum C). Light intensity was higher at cordon height and lower in mid-canopy. Light quantity was higher in the red waveband (660 nm to 730 nm) and far-red waveband (710 nm to 750 nm) for the red treatments and higher in the blue waveband (450 nm to 550 nm) for the grey treatment, whereas the black treatment showed no increase in the specific wavebands as light was absorbed and very little is reflected from this treatment (Addendum C).

Based on literature (Gladstone, 1992; Robin *et al*., 2000; Shahak *et al*., (2004) reflection of white, yellow and particularly orange or reddish light into the lower vine canopy will lead to an increase in the R: FR ratios. Shahak *et al*. (2004) found that various Colornet® resulted in modification of light in the visible light spectrum (VIS), ultra-violet (UV), far-red (FR) and infra-red (IR) regions. Crawford *et al*. (2006) found that shell mulch had a positive effect on the amount of reflected UV radiation in the canopy. Conventry *et al*. (2005) suggested that the surface under the vine can have an effect on light levels within the canopy. Morgan *et al*. (cited in Dokoozlian, 1990), suggest that many plant growth aspects and metabolites are influenced by the R: FR ratio. Therefore, it is clear that reflected light can alter the quality of light in the canopy.

Temperatures were influenced by the position of measurement (e.g. bunch zone, canopy, soil surface and above canopy) (Fig. 1c), but not by treatment. Significant statistical differences were marked for canopy and bunch zone temperatures (data not shown). Bunch zone temperatures were the highest and canopy temperatures lower which could be ascribed to the distribution of leaves which results in shading and reduction in temperature.

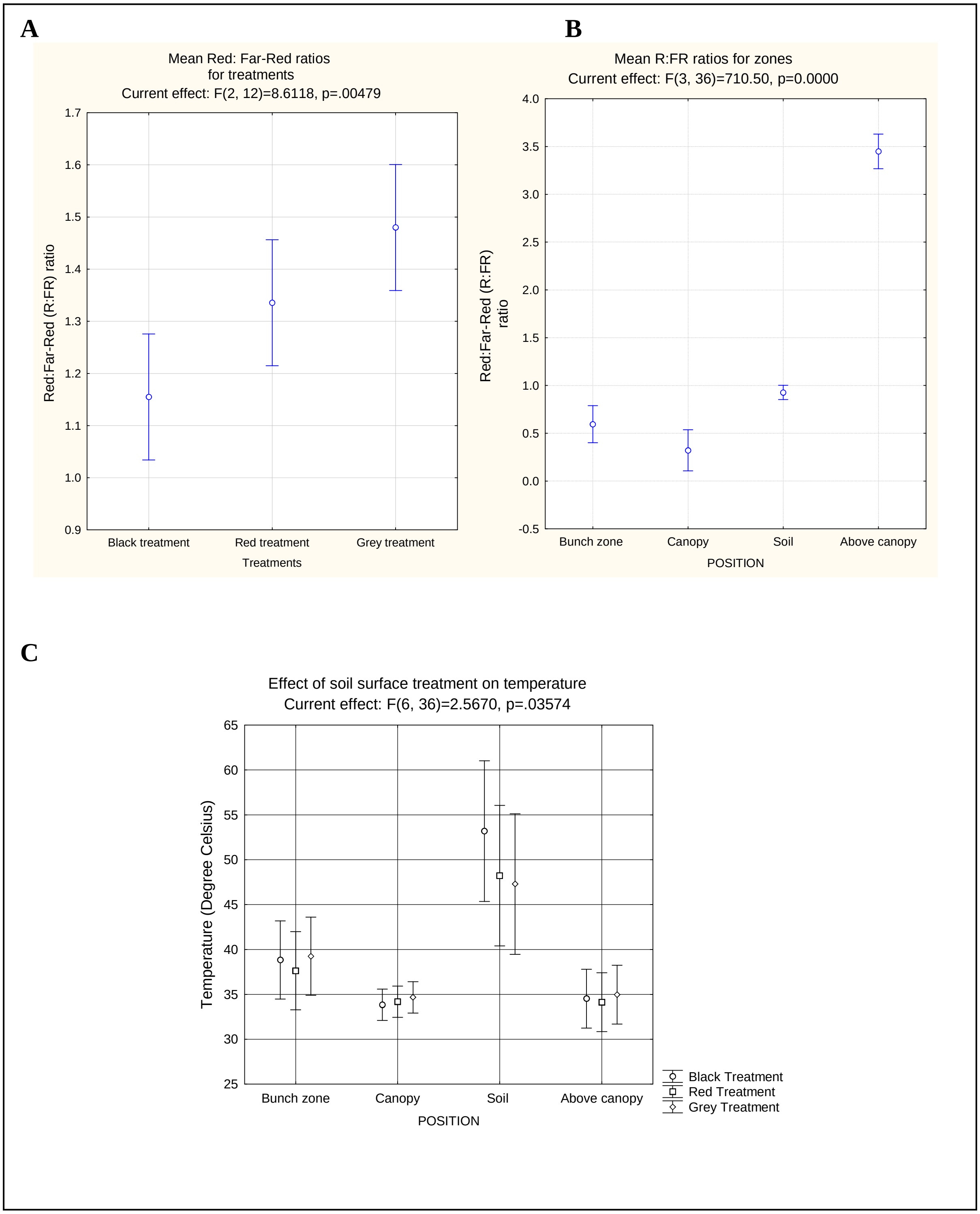


Figure 1 Effect of soil surface colour and vertical measurement position on R: FR ratio. (a) Mean R: FR ratios on different soil treatments. (b) Mean R: FR ratios at four vertical positions. (c) Effect of different soil surface colours on temperatures at four different positions.

3.4.2 GRAPEVINE VEGETATIVE GROWTH

3.4.2.1 CANOPY CHARACTERISTICS

Leaf area is a determinant of the efficacy of photosynthesis, interception of light, nutrient and water usage and crop yield. Cabernet Sauvignon is a vigorous grower and is planted in this vineyard on a medium to high potential soil leading to moderately vigorous growth.

Canopy density was not influenced by soil surface treatments. In this study the grey treatments resulted in significantly higher mean main leaf area than the black treatments (Table 1). Differences were not as evident for each sampling date. Mean total and lateral leaf areas were not influenced by the soil surface treatments, but changes occurred throughout the season (data not shown). Internode length for grey treatments and number of nodes for red treatments were the higher than the other treatments, but variation was not of statistical significance (Table 2). Ravaz in Fregoni (1977) suggested that vegetative characteristics were influenced by modified soil surface colour and similar trends were marked in this study.

Dokoozlian (1990) suggested that primary shoot length had a major influence on the light quality in the fruit zone. Leaf area density is controlled by canopy length, total leaf area per shoot and leaf angle for primary shoots (Smart, 1987). An increase in leaf area caused by an increase in shoot length decreases the light quality due to overshadowing if the trellis system is not able to support additional growth. In this study, however, the higher mean main leaf area of the grey treatment did not translate into a significantly denser canopy (data not shown). Cane measurements (pruning mass and number of shoots per vine) were not influenced by soil surface treatment (data not shown).

3.4.3 LEAF AND SOIL NUTRIENT STATUS

Leaf macro- and micronutrients are influenced by the genetic, developmental and the physiological status of the plant and soil properties (e.g. soil colour, texture, structure, chemical composition and water content). Significant differences were marked between petiole ammonium (NH_4), ranging between (640 - 875 mg kg^{-1}) for red treatments and black treatments (570 - 705 mg kg^{-1}) (Table 3). Nitrogen percentage (N %) in the leaf blades were not influenced by soil surface treatment. Petiole ammonium (NH_4), nitrate (NO_3) and nitrogen percentage in the leaf blades resulted in higher values for the red soil treatment, but differences were not significant (Table 3).

Stamatiadis *et al*. (2005) suggested that soil reflectance in the blue and green wavebands are correlated with soil water content, organic material and extractable potassium and phosphorous. Red and near infrared wavebands were correlated with soil carbonate, total nitrogen, electrical conductivity and foliar nutrients. Similar results were found in this study with the petiole ammonium, nitrate and total nitrogen percentage values which were higher in red soil treatments.

Soil depth influenced the availability of potassium and sodium for vine growth, as the potassium content decreased with depth and sodium content increased (data not shown).

Table 1. Repeated measures of mean main leaf area for each treatment

Date	Mean Main Leaf area (cm^2)		
	Treatment		
	Black	Red	Grey
3 December ‘06	113.63	96.16	102.17
7 February ‘07	99.16	103.10	120.42
7 March ‘07	104.27	86.22	108.51
Significance			
Treatment	0.01		
Time	ns		
Time X Treatment	ns		

ns= Non-significant

Table 2. The effect of soil surface colour on vegetative growth parameters of *Vitis vinifera* L. cv. Cabernet Sauvignon .

Parameters	**Black Treatment**	**Red Treatment**	**Grey Treatment**	**p-value**
Mean shoot length (cm)	135.21	124.72	142.50	0.34
Mean internode length (cm)	99.17	95.83	99.88	0.91
Mean number of nodes	18.60	19.90	18.60	0.86
Mean cane mass (g)	68.47	68.75	74.29	0.53

Table 3. Leaf nitrogen analysis of Cabernet Sauvignon

Parameters	**Black Treatment**	**Red Treatment**	**Grey Treatment**	**p-value**
Mean Petiole Ammonium (NH_4) (mg kg^{-1})	650.00^a	780.00^b	675.00^{ab}	0.04
Mean Petiole Nitrate (NO_3) (mg kg^{-1})	45.00	140.00	75.00	0.06
Mean Leaf blade Nitrogen (%)	1.82	1.89	1.84	0.28

3.5 CONCLUSIONS

The influence of the light environment on the vegetative growth of Cabernet Sauvignon on soils with three different soil surface colours was investigated. Soil surface can be expected to have an effect on grapevine performance by means of the altered light environment as a result of the attenuation or increase of light in specific wavebands. This could be expected to be perceived by the light sensing apparatus of the grapevine, resulting in altered growth.

The modified surface colour resulted in considerable variation of the light quality in the red and far-red wavebands (660-730 nm) and full light spectrum (300-2500 nm). Light quality was influenced at the measured positions (i) bunch zone and canopy, (ii) soil surface and (iii) above canopy, but the biggest effect is that of the light on the soil surface. Light intensity at cordon height was the highest and lowest at mid-canopy level.

The effect of soil surface colour on the vegetative characteristics was seen only in the influence of the grey treatment on main leaf area. This influence of grey treatment on grapevine performance was unexpected, but the effects of light in the blue waveband make this interesting as little is known about the effect of blue light on grapevine performance. Red treatments resulted in significantly higher petiolar ammonium levels than black and grey treatments respectively.

The present study confirms that the colour of light reflected from the soil surfaces into the grapevine canopy appears to be used by the grapevine natural growth regulatory system (which is controlled by photoreceptors) to alter vegetative growth. Further studies are necessary to understand the continuous effect of light quality and quantity on grapevine development and growth. In the companion paper (Chapter 4), the effect of light quality on yield, berry and wine composition will be discussed.

3.6 REFERENCES

Antonious, G.F. & Kasperbauer, M.J., 2002. Color of light reflected to leaves modifies nutrient content of carrot roots. Crop Sci. 42 1211-1216.

Conventry, J.M., Fisher, K.H., Strommer, J.N. & Reynolds, A.G., 2005. Reflective mulch to enhance berry quality in Ontario wine grapes. Acta Hort. 689, 95-101.

Crawford, M.H., Creasy, G.L., Gladstone, P., Kavanagh, J. & Ibbotson, L., 2006. Mussel shell mulch alters Pinot Noir grapevine development and wine qualities. Australian and New Zealand grapegrower and winemaker 509, 12-18.

Dokoozlian, N.K. 1990. Light quantity and Light quality within Vitis Vinifera L. grapevine canopies and their relative influence on berry growth and composition. PhD dissertation, University of California, Davis.

Fregoni, M., 1977. Effects of soils and water on the quality of the harvest. In: Proc. Int. Sym. Quality of the Vintage. February 1977, Cape Town, South Africa, 151-168.

Gladstones, J., 1992. Viticulture and Environment. Winetitles, Adelaide.

Jackson, R. S. 2000. (2nd ed) Wine Science: Principles, Practice, Perception**.** Academic Press, California.

Pirie, A.J.G. & Mullins, M.G., 1980. Concentration of phenolics in the skin of grape berries during fruit development and ripening Am. J. Enol. Vitic. 31 1, 34-36 .

Robin, J.P., Sauvage, F.X. & Chovelon, M., 2000. Les propiertes de reflectance du sol de la parcelle sont a comsiderer des parametres du terroir. In: Proc. 3 rd Int. Sym. Viticultural Zoning, May, Puerto de la Cruz, Tenerife.

Shahak, Y., Gussakovsky, E.E, Gal, E & Ganevevin, R., 2004. ColorNets: Crop protection and light-quality manipulation in one technology. Acta Hort. 659, 143-151.

Smart, R.E., 1987. Influence of light composition and quality of grapes. *Acta Hort*. 206, 37-47.

Smart, R.E. & Robinson, M., 1991. Sunlight into Wine. A handbook for winegrape Canopy Management. Winetitles, Adelaide.

Stamatiadis, S., Christofides, C., Tsadilas, C., Samaras, V., Schepers, J.S. & Francis, D., 2005. Ground-sensor soil reflectance as related to soil properties and crop response in a cotton field. Precision Viticulture 6, 399-411.

Takemiya, A., Inoue, S., Doi, M., Kinoshita, T. & Shimazaki, K., 2005. Phototropins promote plant growth in response to blue light in low light environments. The plant cell Preview 1-8.

Chapter 4

RESEARCH RESULTS

The relationship between soil surface colour and the performance of *Vitis vinifera* L. cv. Cabernet Sauvignon II. Yield, berry composition and wine

RESEARCH RESULTS

4.1 ABSTRACT

The response to the composition of the light environment within grapevine canopies on berry, yield and wine composition was studied. A previous study showed the effects of the light environment on the vegetative characteristics. The same environment was used to study the effect of the altered light environment on the grapevine reproductive parameters.

Berry number per bunch for black treatments differed significantly. Total red pigments (colour at 520 nm) were influenced significantly by grey treatment. Potassium content of the pulp in red treatments resulted in higher values relative to black and grey treatments.

Keywords: Soil surface colour, light quality, light quantity, reflection, berry colour, yield

4.2 INTRODUCTION

Light conditions in the canopy of the grapevine are fundamentally important for the development of quality grapes as this affects photosynthesis and secondary metabolite formation (Katoaka *et al*., 2004; Conventry *et al*., 2005). Long term practices (e.g. site selection, vine spacing and trellising) and short term practices (e.g. pruning, leaf removal) affect light quality in the grapevine canopy and fruit zone (Conventry *et al*., 2005).

Conventry *et al*. (2005) found that the distance between the soil surface and vine also has an influence on light levels within the canopy (e.g. Chateaneuf-du-Pape) where light coloured rocks reflect light back into grapevine canopy of goblet vines. Robin *et al*. (2000) found that red reflective plastic (maximum reflectivity at 680 nm) improved berry quality and led to an increase in the blue and a decrease in red anthocyanins. They attributed this to increased red light in the canopy.

Grape colour is an important part of red grape and red wine quality. Wine colour is one of the principal parameters of wine quality and the first attribute to be perceived by winemakers, wine show judges and wine consumers. Gómez-Míguez *et al*. (2007) suggest that colour is one of the most important sensory attributes that affects the consumer acceptability of the product. Parameters such as grape composition (e.g. anthocyanins), vinification and storage conditions of the wine have an influence on final colour.

Intrinsic and extrinsic factors (climatic conditions, soil, region and cultivation techniques) can influence the grape composition, which in turn affects the sensory attributes of the wine. Wine aroma is dependant on many factors such as the cultivar, environment, management practices and winemaking practices. Sayed, Wiebe and Anderson in Gómez-Míguez *et al*. (2007) suggested that soil can be singled out as an independent parameter having an influence on major wine quality parameters.

The objective of this study was to investigate the effect of soil colour and light quality on grape quality parameters and yield of Cabernet Sauvignon grapes.

4.3 MATERIALS AND METHODS

4.3.1 VINEYARD CHARACTERISTICS

Details of the vineyard characteristics, experimental layout and light quality measurements have been described in a companion paper (Chapter 3, paragraph 3.3.1-3.3.3).

4.3.2 BERRY ANALYSES

Sampling

Berry sampling were performed every two weeks from véraison to harvest. An average of 150 berries was randomly sampled each time, from the inside and outside of the canopy and from the top, middle and bottom part of a bunch for each replication. 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 measured and noted as berry volume per 100 berries. Fifty berries were analysed by an independent laboratory for malic and tartaric acids, colour (at 420 nm and 520 nm), total polyphenols, tannins and anthocyanin equivalent. All the absorbance values were determined with a Secoman Anthelie Advanced UV/UV-VIS spectrophotometer.

Anthocyanin determination: Fifty berries were kept in the refrigerator and processed as soon as possible (after sampling) and homogenised with an IKA Ultra Turrax T18 basic blender. Anthocyanin determination was performed through weighing 1 gram of homogenate and extracting in 10 ml 50% ethanol at pH 2 overnight. The supernatant was then centrifuged and filtered. One millilitre of the supernatant was diluted in 1N HCl. Three hours later, the absorbance values were read at 520 nm and 280 nm, once for every sample.

Total polyphenol index: The total polyphenol index was determined by diluting 1 gram of homogenate with 50 ml distilled water. The samples were centrifuged and the absorbance was read at 280 nm in a 10 mm quartz cuvet**.**

Total tannins: Two test tubes (A-hydrolized tannins and B- monomeric tannins) were filled with 4 ml diluted sample (1:50), 2 ml distilled water and 6 ml concentrated HCl 12N (36%). Test tube A were cooked at 100 degrees Celsius for 30 minutes, cooled down and 1 ml EtOH (96%) were added and Vortexed for 5-10 minutes. One millilitre of EtOH (96%) was added to test tube B and vortexed for 5-10 minutes. Absorbance was read at 550 nm in a 10 mm plastic cuvet and the necessary calculations made.

Colour: One gram of homogenate was centrifuged and the absorbance measured at 420 nm and 520 nm in 1 mm quartz cuvet

Organic acids

Malic acid: Malic acid was determined enzymatically through the use of L-MalicEnzymatic BioAnalysis kit provided by Boehringer Mannheim/R-Biopharm. One gram of homogenate was weighed in a 10 ml centrifuge tube and extracted in 10 ml 1N HCl. Extraction was performed for one hour on a rotary shaker and was centrifuged and the supernantant was kept. One millilitre of the HCl extract was prepared through the addition of 0.1 mg Polyvinylpolypyrrlidone (PVPP) and filtered to remove all the phenolic compounds. One millilitre of the filtered extract was diluted (1:50) and analysed according to the L-Malic kit instructions. Absorbance values were read at 340 nm.

Tartaric acids: ISITEC-LCAI (L'INSTRUMENTATION ACTIVE) kit was used for analysis. One millilitre of the HCl extract was prepared through the addition of 0.1 mg PVPP and then filtered to remove phenolic compounds. Analysis was performed according to the ISITEC-LCAI (L'INSTRUMENTATION ACTIVE) kit instructions and left to stand for 15 minutes. Absorbance values were read at 500 nm.

Analysis of maturity: Fifty berries were crushed in a glass beaker and the juice seperated from the skins in a centrifuge and then passed through a sieve. The samples were split to obtain duplicate samples. Total soluble solids (°B) were measured using an ATAGO pocket refractometer. The pH and titratable acidity (TA) were measured using a 785 DMP Metrohm Titrino automatic titration instrument.

4.3.3 HARVESTING

Grape ripening was monitored every two weeks and harvested at maturity. The grapes were harvested at (23°B) between 07:00 and 10:00. The number of bunches per vine were counted and weighed. Five bunches were randomly sampled from each experimental plot, placed in a plastic bag and transported to the laboratory to determine bunch mass, berry number and berry mass. Bunches were frozen and the berries carefully removed by hand from the rachis, counted and weighed.

4.3.4 MICROVINIFICATION

Standard winemaking procedures were carried out as specified by the Department of Viticulture and Oenology, Stellenbosch University. The grapes were crushed and inoculated with standard yeast (WE 372) from Anchor. The fermentation took place at 23°C in plastic 20 litre buckets and the cap was punched down twice daily to extract colour. No cold maceration or extended skin contact was allowed. The wines were racked and underwent stabilisation at -4°C. The wines were then filtered and bottled. No malolactic fermentation was performed on the wines.

WINE ANALYSES

Wine analyses were performed after bottling by an independent laboratory. Alcohol (% v/v), extract, colour (420 nm), total red pigments (colour at 520 nm), polyphenols and total tannins ($g.l^{-1}$) were determined. Gas Chromatography–Flame Ionozation Detector (GC-FID) analyses were performed to determine the volatile components. Five millilitre of wine, internal standard (4-Methyl-2-Pentanol) and (100 µl of 0.5 mg/l soaking solution) were extracted with 1 ml of diethyl ether by placing the ether/wine mixture in an ultrasonic bath for 5 minutes. The wine/ether mixture was then centrifuged at 4000 rpm for 3 minutes. The ether layer was removed and dried on $NaSO_4$. This extract was then injected into the GC-FID (Coetzee *et al*., 2005).

4.4 STATISTICAL ANALYSIS

The data were analysed by using Repeated Measures Analysis of Variance (ANOVA). GC-FID data were analysed with the Kruskall – Wallis test for a non-parametric analysis between groups. Bonferroni and Tukey tests were applied to investigate the effects between groups as well as the interactions between repeated measures and between effects.

4.5 RESULTS AND DISCUSSION

4.5.1 YIELD PARAMETERS

The red treatment induced significantly fewer berries per bunch. Other parameters did not differ significantly (Table 1). The reason for the limited statistical differences between treatments could be ascribed to the fact that the treatments were not applied 18 months before harvest, during the induction phase. Srinivasan and Mullins (1981) described grapevine yield as the result of phenological events in the preceding 18 months which determine the parameters such as shoots per hectare, inflorescences per shoot, flowers per inflorescences, fruit set and berry mass. Yield and the components thereof are described as a function of the cultivar, environmental effects and canopy management (Affonso & Striegler, 1999). Statistical differences between treatments are expected to be observed in the next harvest season. De Villiers, according to Van Schalkwyk (2004), suggested that berry mass and size are influenced by genetic origin, berry set, number of seeds, climate and degree of ripeness. The fact that differences occured in the number of berries per bunch can also be attributed to effects on berryset which are linked to growth regulator balances. Davies *et al*. (2007) suggested that the plant hormones such as abscisic acid, castasterone and ethylene are involved in grape ripening. The effect of soil surface colour on plant hormones did not form part of this study, but there could be a link due to the complex interaction between the grapevine and its environment.

Table 1. The effect of soil surface colour on grape yield (*Vitis vinifera* L. cv. Cabernet Sauvignon).

Parameters	Black Treatment	Red Treatment	Grey Treatment	p-value
Berry number per bunch	164.60^{a}	128.88^{b}	147.36^{ab}	0.04
Berry mass (g)	195.21	156.3	176.99	0.14
Bunch mass (g)	207.77	168.13	189.69	0.10
Yield per vine (kg)	3.25	3.38	3.12	0.64

4.5.2 BERRY COMPOSITION

Berry composition is a key determinant of wine quality. Soil surface colour had no significant effect on the total soluble solids (TSS) (Table 2). Potassium concentrations in berries of the red and black treatments were higher compared to the grey treatment, but not of statistical significance and were influenced by time (Table 2). Time of measurement influenced berry composition, but there were treatment affects, with grey treatments having the highest total red pigment (colour at 520 nm).

This corresponds with the findings of Delgado *et al*. (2006) where potassium levels affected colour stability. Berry potassium increases over the season as a result of berry growth, with a sharp increase at the onset of véraison (Mpelasoka *et al*., 2003). Factors that influence on the potassium levels in the grapevine are the soil, cultivar, rootstock and viticultural practices (Mpelasoka *et al*., 2003; Davies *et al*., 2006). Potassium levels are linked to sucrose transport in grapes (Freeman *et al*., 1982). Pienaar (2005) suggested from evidence in the literature that reduced leaf sucrose concentration results in potassium loading into the phloem to sustain turgor pressure in the phloem. This suggests that the increased blue light in the canopy of the grey treatment, which may have been associated with more efficient photosynthesis and thus increased sucrose concentration, reduced phloem loading of potassium, but this deserve further study.

Grape colour at 520 nm (total red pigments) was significantly influenced by soil surface colour, but this was not the case for colour at 420 nm, or other ripening parameters (Table 2). Robin *et al*. (2000) and Conventry *et al*. (2005) found that reflective mulch improved the quality and quantity of light in the fruiting zone which lead to an increase in sugar, total phenolics, flavonols and anthocyanins. The fact that this was not the case in this study could be ascribed to study being the cordon height. In the studies of Robin *et al*. (2000) and Conventry *et al*. (2005) the cordon is closer to the soil surface, resulting in greater reflection in the bunch zone (Chapter 3, paragraph 3.4.1). Kataoka *et al*. (2004) found that the irradiation of berry sections with blue light at 450 nm led to an increase in anthocyanins. According to Pirie and Mullins (1980) and Jackson (2000), direct exposure to ultraviolet and blue light influences the synthesis of phenolic compounds. Continuous irradiation with high R: FR led to an increase in anthocyanins in the skin of other grape cultivars such as Cardinal and Red Globe (Dokoozlian, 1990). Grey soil surface treatments had the highest intensity of the light in the blue-waveband (Addendum C), which appeared to enhance red pigment (anthocyanin) accumulation (Table 2).

Table 2. The effect of soil surface colour on grape ripening parameters (*Vitis vinifera* L. cv. Cabernet Sauvignon).

Date	TSS	pH	TA (g.l^{-1})	Anthocyanins (mg g^{-1} berry)	Potassium (mg.l^{-1})	Colour (420 nm)	Colour (520 nm)
Treatment	**Black**						
10 Jan ‘07	11.6	2.88	22.7	3.32	328.6	1.20	1.16
24 Jan ‘07	15.5	3.01	9.2	1.50	313.8	0.89	0.94
07 Feb ‘07	18.2	3.53	6.2	1.19	274.4	2.49	6.14
21 Feb ‘07	19.8	3.59	5.6	5.41	291.6	3.50	7.17
07 Mar ‘07	21.7	3.67	6.1	3.76	239.8	2.45	6.55
14 Mar ’07	21.3	3.74	5.4	2.75	285.8	2.52	5.57
Treatment	**Red**						
10 Jan ‘07	12	2.89	23.6	2.35	327.6	1.17	1.12
24 Jan ‘07	15.9	2.98	9.7	1.72	312	0.89	1.05
07 Feb ‘07	18.1	3.53	7.1	1.85	290.6	2.49	6.04
21 Feb ‘07	19.5	3.63	5.9	4.45	314.6	3.29	5.83
07 Mar ‘07	21.1	3.68	5.8	3.41	278.4	2.43	6.38
14 Mar ’07	21.5	3.76	5.3	2.71	300.8	2.38	5.22
Treatment	**Grey**						
10 Jan ‘07	11.6	2.90	23.8	3.29	287	1.17	1.19
24 Jan ‘07	15.7	3.00	9.7	1.78	305	0.90	0.99
07 Feb ‘07	18.4	3.50	7.0	1.75	220.2	2.60	6.63
21 Feb ‘07	18.1	3.54	6.0	5.41	247.4	3.50	7.44
07 Mar ‘07	21.5	3.58	6.1	3.82	223.4	2.44	6.65
14 Mar ’07	20.9	3.66	5.3	3.5	230.4	2.85	6.26
Significance (p-value)							
Treatment	ns	ns	ns	ns	ns	ns	0.003
Time	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Time X treatment	ns	ns	ns	ns	ns	ns	ns

4.5.3 WINE COMPONENTS

Wine is a complex medium. Wine quality parameters are linked to grape components which are influenced by terroir components (soil, climate and topography) and viticultural practices (pruning, leaf removal and tipping and topping). Wine quality parameters such as alcohol % v/v, colour at 420 nm, polyphenols and total tannins did not show significant differences between soil surface treatments. Grape quality parameters were not carried through to the wines as although slight differences in wine could be seen between treatments, these were not statistically different (Table 3).

Table 3. The influence of soil surface colour on wine quality parameters.

Parameters	Black Treatment	Red Treatment	Grey Treatment	p-value
Alcohol (% v/v)	12.74	12.69	13.09	0.34
Extract	28.3	29.76	30.00	0.72
Colour (420 nm)	4.87	4.68	5.12	0.41
Colour (520 nm)	9.36	8.98	10.82	0.06
Polyphenols	0.87	0.86	0.87	0.97
Total Tannins ($g.l^{-1}$)	1.69	2.10	1.69	0.48

4.6 CONCLUSIONS

The soil colour treatments did not influence the yield parameters significantly and only berry number per bunch was significantly reduced by the red soil colour. Yield parameters are expected to be influenced in the next harvest season as the induction phase (phenological event determining inflorescenes per shoot and flowers per inflorescences occurring 18 months prior to harvest) are dependant on the environmental and hormonal factors occurring at that time. It would therefore not yet have been influenced by this trial.

Colour at 520 nm was the only grape ripening parameter that was influenced significantly by soil surface treatments. Grey treatments induced the highest colour at 520 nm. Sugar, pH, titratable acidity (TA) were not influenced by the soil surface colour, but changes occurred as the season progressed. Differences in the latter grape ripening parameters due to soil colour may have been evident if the trellis system was closer to the soil surface.

The effect of soil colour on grape ripening parameters was not carried through to the wine quality. This could be ascribed to wine pigments being influenced during the vinification processes, fermentation and maturation. No statistical differences was noticed.

More research is necessary to explain the effect of light quality and especially blue light on grape colour and the implications thereof for wine quality.

4.7 REFERENCES

Affonso, J.A. & Striegler, R.K., 1999. Evaluation of cultivar and canopy management practices for wine grape production in the southern San Joaquin valley. Research publications. Available: http://cati.csufresno.edu/VERC/rese/99/990103/index.html. (Accessed 14/11/2007).

Coetzee, K., Tredoux, A. & Nieuwoudt, H., 2005. Final method for extraction and analysis of wine aroma compounds on the GC-FID 20/08/2005. Chemical-Analytical Laboratory, Stellenbosch University.

Conventry, J.M., Fisher, K.H., Strommer, J.N. & Reynolds, A.G., 2005. Reflective mulch to enhance berry quality in Ontario wine grapes. Acta Hort. 689, 95-101.

Davies, C., Wheeler, S., Symons, G.M., Reid, J.B., Shavrukov, Y., Dry, I.B., Ford, C., Loveys, B. & Thomas, M.R. 2007. The role of hormones in grape berry ripening. Available: www.nysaes.cornell.edu/pp/faculty/dry/Role%20of%20hormones%20in%20berry%20r.pdf. (Accessed: 02/01/2008).

Delgado, R., González, M. & Martin, P., 2006. "Interaction effects of nitrogen and potassium fertilization on anthocyanin composition and chromatic features of Tempranillo grapes". Int. J. of Vine and Wine Sci. 40, 141-150.

Dokoozlian, NK. 1990. Light quantity and light quality within *Vitis vinifera* L cv. grapevine canopies and their relative influence on berry growth and composition. PhD Dissertation, University of California, Davis.

Freeman, B.M., Kliewer, M. & Stern P., 1982. Influence of Windbreaks and Climatic Region on Diurnal Fluctuation of Leaf Water Potential, Stomatal Conductance, and Leaf Temperature of Grapevines. Am. J. Enol. Vitic. 33 233-236.

Gómez-Miguez, M., VIcario, I. & Heredia, F., 2007. Assessment of colour and aroma in white wines vinifications: Effects of grape maturity and soil type. Journal of Food Eng.

Jackson, R.S., (2000) 'Wine science: principles and applications. (2nd ed.). Academic Press, San Diego.

Kataoka, I., Beppu, K., Yanagi, T. & Okamoto, K., 2004. Light components contributing to accumulation of anthocyanins in 'Gros Colman' grape berries. Acta Hort. 640, 333-338.

Mpelasoka B, Schachtman D.P, Treeby, M.T. & Thomas M.R, 2003. A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Australian Journal of Grape and Wine Research 9,154–168.

Pienaar, J.W., 2005. The effect of wind on the performance of the grapevine. MSc Agric thesis, Stellenbosch University, Private Bag X1, 7602, Matieland (Stellenbosch), South Africa.

Robin, J.P., Sauvage, F.X. & Chovelon, M., 2000. Les propiertes de reflectance du sol de la parcelle sont a comsiderer des parametres du terroir. In: Proc. 3 rd Int. Sym. Viticultural Zoning, May, Puerto de la Cruz, Tenerife.

Srinivasan, C. & Mullins, M.G., 1981. Physiology of flowering in the grapevine - A review. Am. J. Enol.Vitic. 31 (1) 47-63.

Van Schalkwyk, D., 2004. Methods to determine berry mass, berry volume and bunch mass. Available: http:www.wynboer.co.za/recentarticles/0409methods.php3. (Accessed 14/11/2007).

Chapter 5

GENERAL DISCUSSION AND CONCLUSION

CHAPTER 5

5.1 INTRODUCTION

The aim of this study was to determine whether soil surface colour had an effect on light quality and grapevine vegetative and reproductive growth.

5.2 GENERAL DISCUSSION

It became clear that soil surface colour influences the reflective properties of various coloured soils. Absorbance of solar radiation was influenced by soil surface colour. No statistical differences were found between the temperatures of the treatments. Red to far-red ratios at soil level were influenced by soil surface colour. Grey soil treatments had high reflective properties and higher blue wavelengths. Red soil treatments had reflected light in the red and far-red wavelengths in the canopy. Red to far-red ratios did not differ within the canopy between treatments, but from examining individual wavebands, differences in light quality were evident for each of the treatments.

Mean main leaf area was increased by grey soil surface colour. Grape berry composition parameters were not affected by soil surface colour, but changes occurred throughout the season as berry ripening progressed which resulted in the chemical composition being influenced. Grey treatments induced the lowest potassium levels and the highest colour at 520 nm.

Little is known about the grapevine response to soil surface colour. Potential grapevine response to soil surface colour can be divided into two categories. The first category focuses on the indirect effects of soil colour, namely its association with soil water holding capacity and nutritional status. The second category (including this study) focuses on the direct influence of light reflected from soil surfaces on vegetative growth (canopy effects) and grape berry composition. The light quality is modified due to the change in the absorption and reflective properties of solar radiation.

It was expected in this study that the altered R: FR ratios would have an influence on grapevine, particularly colour performance and in particular that the red soil would have a positive effect on berry composition. The outcome of the grey treatment influencing grapevine quality parameters and grapevine performance was unexpected, but documented effects of blue light on plant growth might explain the results. Although the effect of altered light quality did not appear to have a strong effects on the final wine characteristics, this might be due to the fact that the period of study was too short. Important questions were raised from this study about the photoreceptors and the proteins associated with grapevine regulatory sequences.

5.3 PERSPECTIVES AND FUTURE RESEARCH

Due to genomic flexibility, all organisms can adapt to conditions in their environment. The stationary lifestyle of plants resulted in the dependency of plants on diverse sets of inherent responses. This helps plants to cope with environmental stimuli causing stress. In depth research is necessary to identify the light response elements and the appropriate gene response initiated by light of various wavelengths and to have a better understanding of the grapevine and its metabolism.

A further question that was raised entails the cultivar susceptibility to light environments and the impact thereof on grape berry composition and aroma. Grape berry composition and aroma is dependent on both the genetic and environmental conditions. Further research on the effect of different light qualities is essential to optimise grape quality parameters.

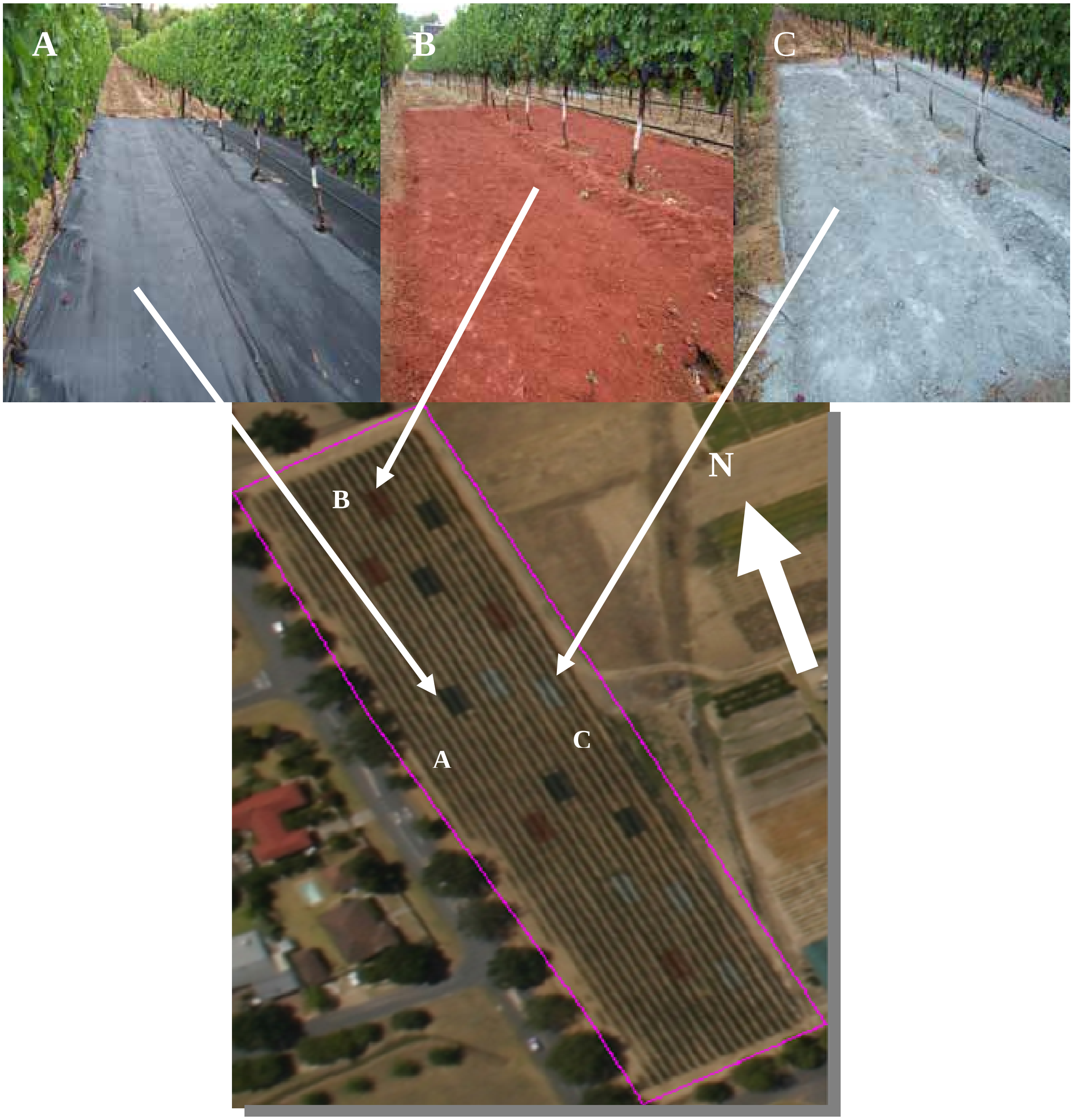
5.4 CONCLUSIONS

The results that were obtained indicate that soil surface colour can play a role in determining light quality within the canopy and that this can alter the grapevine’s response both vegetatively and in terms of berry composition. Nevertheless, molecular grapevine research and environmental research is necessary, to provide an improved understanding of the physiological response of the grapevine, in order to make recommendations to optimise quality.

Addendum A

Normalized Difference Vegetation Index (NDVI): Identification of differences in canopy density at Krigeville, experimental vineyard in Stellenbosch. Red indicates the ground surface, dark blue the high canopy density and light blue low canopy.

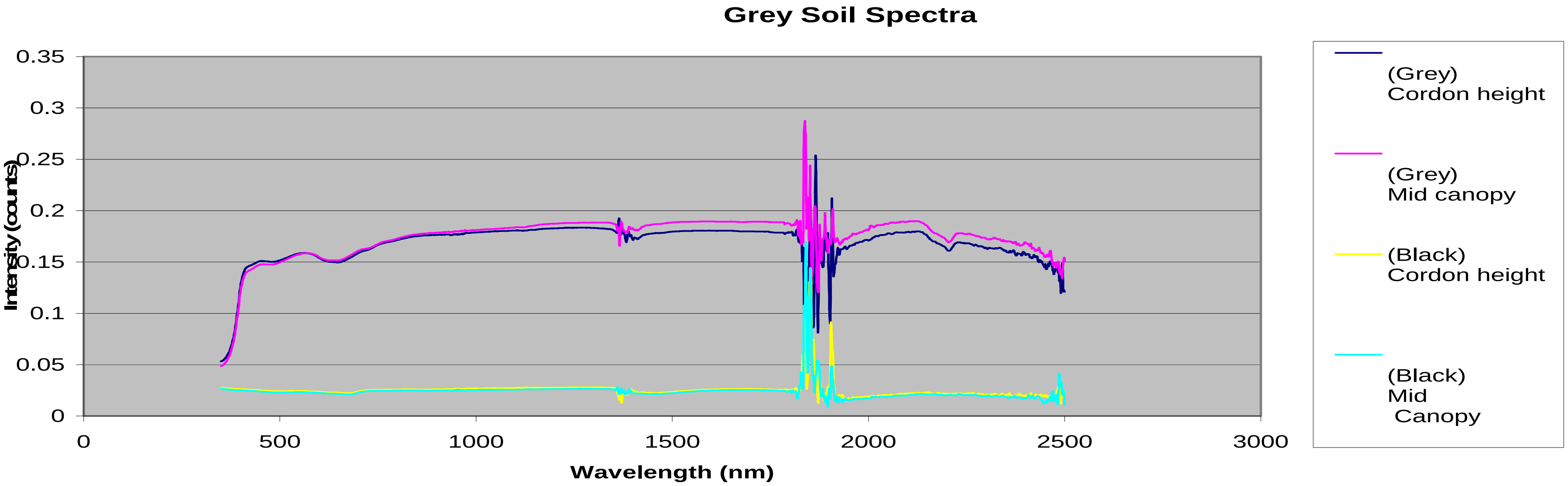
Addendum B

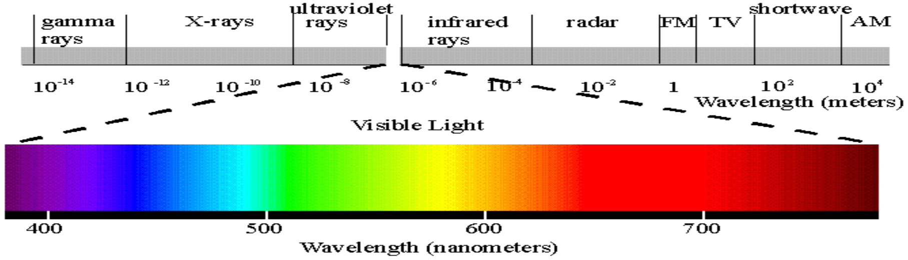


Experimental layout:

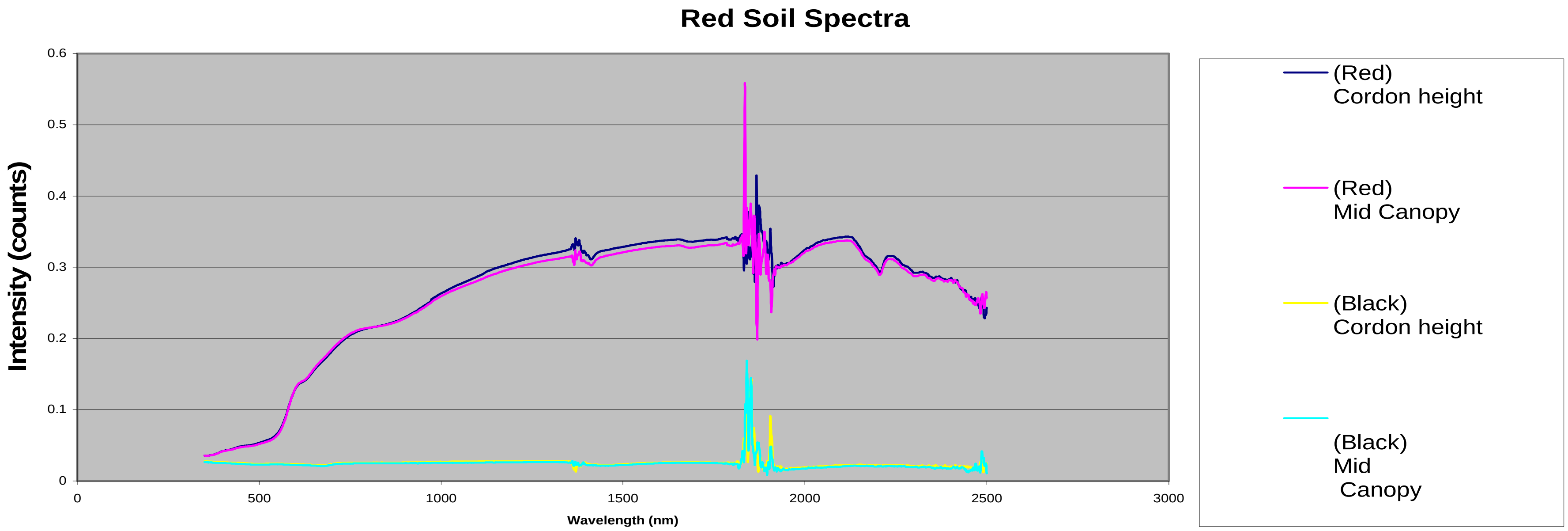
The position of the Krigeville, experimental vineyard in Stellenbosch and the mini-experimental sites, (a) Black treatment, (b) Red treatment and (c) Grey treatment.

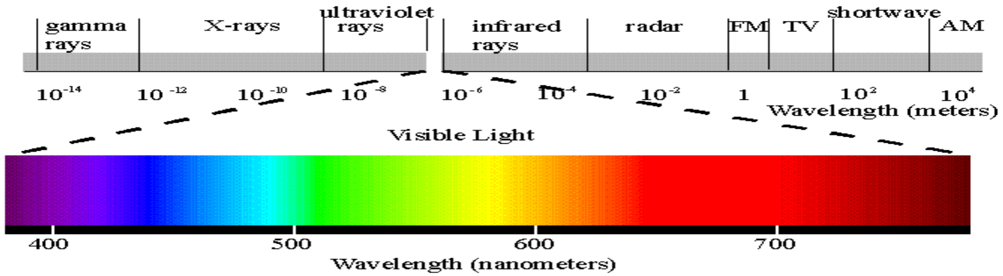
Addendum C





The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/eye/





The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/eye/