METHODOLOGY TO ASSESS VINE CULTIVATION SUITABILITY USING CLIMATIC RANGES FOR KEY PHYSIOLOGICAL PROCESSES: RESULTS FOR THREE SOUTH AFRICAN REGIONS

METHODE POUR EVALUER L'APTITUDE D'UNE REGION A LA CULTURE DE LA VIGNE EN UTILISANT DES SEUILS CLIMATIQUES POUR LES PROCESSUS PHYSIOLOGIQUES CLES: RESULTATS POUR TROIS REGIONS SUD AFRICAINES

J.J. Hunter[1] and V. Bonnardot[2]

[1)] Infruitec/Nietvoorbij-Institute for Fruit, Vine and Wine of the Agricultural Research Council (ARC) Private Bag X5026, 7599 Stellenbosch, South Africa
[2)] ARC-Institute for Soil, Climate and Water (ISCW), Private Bag X5026, 7599 Stellenbosch, South Africa
hunterk@arc.agric.za

Climate has serious implications on proper physiological functioning of grapevines and needs to be quantified in order to determine the vine cultivation suitability of grape growing regions. Methodology is proposed that may eventually be used to predict the suitability of regions/terroirs for grapevine cultivation. Climatic ranges of temperature, wind speed and relative humidity for key physiological processes (photosynthesis of the leaves as well as sugar and potassium accumulation, organic acid formation and respiration, and colour and flavour development in the grapes) were studied in three wine producing regions of South Africa (Stellenbosch, Robertson and Upington) during the pre- and post-véraison growth periods. Both optimum and extreme climatic ranges were considered. Marked variation in the number of hours available for optimal physiological functioning (according to the parameters studied) occurred between the regions. All factors considered, the Stellenbosch region would seem to be best suited to the studied physiological requirements for grapevine cultivation.

Le climat a de fortes implications sur le bon fonctionnement physiologique de la vigne et a besoin d'être quantifié afin de déterminer l'aptitude des régions à la culture de la vigne. Une méthode, qui pourrait éventuellement servir à prévoir l'aptitude des régions à la culture de la vigne, est proposée. Les seuils climatiques (température, vitesse du vent et humidité relative) pour les processus physiologiques (aussi bien photosynthèse des feuilles qu'accumulation des sucres et potassium et formation d'acide organique et respiration) ont été étudiés dans trois régions viticoles d'Afrique du Sud (Stellenbosch, Roberston et Upington) pendant les périodes de pré-et post-véraison. Sont considérés à la fois les seuils climatiques optimum et extrêmes. Une variation importante dans le nombre d'heures disponibles pour le fonctionnement physiologique optimal (selon les paramètres étudiés) apparait entre les régions. En considérant tous les facteurs, la région de Stellenbosch semblerait être la plus appropiée aux besoins physiologiques étudiés pour la culture de la vigne.

Introduction

Soil and climate are primary environmental factors to which the grapevine is subjected. Terroir-related studies therefore mainly focused on effects of soil and climate on typicity and quality expression of wine (Saayman, 1977, 1992; Saayman & Kleynhans, 1978; Noble, 1979; Conradie, 1988, Morlat, 1989, 1997; Falcetti, 1994; Falcetti & Iacono, 1996; De Villiers, 1997; Vaudour, 2000; Conradie *et al.*, 2002; Carey *et al.*, 2003). Seasonal morphological development of bunches and eventual chemical composition of the berry result from the interaction between the chosen soil and accompanying climate and consequences of long term practices (e.g. establishment techniques, row direction, vine spacing, trellising and pruning system), short term practices (e.g. seasonal irrigation, fertilisation, canopy management programs), and harvest criteria applied by growers (Jackson & Lombard, 1993; Hunter & Archer, 2001a, 2001b; Deloire *et al.*, 2002). Despite the dependence of proper physiological functioning of the grapevine on climate: e.g. temperature (Kriedemann, 1968; Kliewer, 1971, 1977; Lakso & Kliewer, 1978; Coombe, 1987; Marais *et al.*, 1999), humidity

(Champagnol, 1984) and wind velocity (Freeman *et al*., 1982; Kobriger *et al*., 1984; Hamilton, 1989), threshold values of regions and terroirs for various quality-important physiological processes, such as photosynthesis of leaves as well as colour development, sugar and organic acid formation, mineral accumulation and flavour development of grapes, were only briefly referred to in the past (Pirie, 1979; Coombe, 1987; Iland, 1989).

Temperature ranges for optimum photosynthetic activity (as key physiological process indicating the physiological condition of the plant, subjected to a particular environment) were previously studied in three wine producing regions of South Africa (Stellenbosch, Roberston and Upington) during pre- and post-véraison growth periods (Hunter & Bonnardot, 2002a). In this paper, climatic suitability for optimal grapevine physiology and production of high grape and wine quality is further investigated by considering additional key physiological parameters as well as temperature, wind speed and relative humidity profiles.

Materials and Methods

Daily and monthly temperature and rainfall data from three mechanical weather stations located in the main town of each of three South African wine-producing regions, namely Stellenbosch in the winter-rainfall coastal area, Robertson in the semi-arid Breede River Valley and Upington in the semi-arid Orange River Valley, were used to describe the general climate of the locations (Fig. 1). The study locations are hereafter referred to as Stellenbosch, Robertson and Upington Regions.

To assess the climatic potential of the regions for viticulture, the bioclimatic indices of Winkler (WINKLER *et al.*, 1974) and HUGLIN (1978) and Tonietto's climatic classification based on the Huglin index values (TONIETTO, 1999) were calculated. Hourly climatic data from the automatic weather station network of the Institute for Soil, Climate and Water (ISCW) of the Agricultural Research Council in the three grape growing regions were used: 14 stations in the Stellenbosch Region, 12 stations in the Robertson Region and 4 stations in the Upington Region (Table I). The climatic requirements of the physiological processes were studied using temperature, wind speed and relative humidity data of five seasons (1998/1999 - 2002/03) for Stellenbosch and Robertson Regions and four seasons (1999/2000 - 2002/03) for the Upington Region during pre- and post-véraison periods (November-December and January-February, respectively). The climatic profile of each region (mean hourly temperature, relative humidity and wind speed) was drawn. The period between 09:00 and 15:00 (time is expressed as for the South African Standard Time: Greenwich Meridian Time +2) was taken as the window for optimum photosynthetic activity (HUNTER *et al.*, 1994). The temperature (25 – 30°C, adapted from KRIEDEMANN, 1968, 1977), wind speed (≤ 4 m/s, FREEMAN *et al*., 1982; HAMILTON, 1989) and relative humidity (60 – 70%, CHAMPAGNOL, 1984) requirements for optimum grapevine photosynthetic activity were superimposed onto the respective mean climatic profiles. The percentage of time during the study period and within the diurnal window that temperature, wind speed and relative humidity fell inside and outside (below and above) the range for maximum photosynthetic activity was also calculated for both periods. For the time falling inside the range, and therefore suitable for maximum photosynthetic activity, a distinction was made between the morning (before 12:00) and the afternoon (after 12:00) occurrences and whether the remaining time within the time window was above or below the optimum range. A mean total percentage of time suitable ("Opt" referring to optimum conditions) and unsuitable ("Ext" referring to extreme conditions) for maximum photosynthetic activity was calculated. In this calculation, a coefficient of 3 was given to temperature, 2 to relative humidity and 1 to wind speed, due to temperature being considered the most important climatic variable, followed by relative humidity and wind speed. It was also assumed that the extremes (below and above optimum ranges) were equal, although low temperature should actually be more detrimental than high temperature, the reasoning being that the latter would be more bearable when water is available. Light intensity was accepted as being sufficient.

In addition to photosynthesis, optimum temperature requirements for other physiological parameters were also investigated (based on KLIEWER, 1971, 1977; LAKSO and KLIEWER, 1978; PIRIE, 1979; COOMBE, 1987; ILAND, 1989; MARAIS *et al*., 1999). A diurnal temperature range of 20 –

25°C between 06:00 and 18:00 and a night temperature range of 10 – 15°C between 18:00 and 06:00 for both grape colour and flavour development and maintenance were used. The temperature range of 25 – 30°C, as used for photosynthesis, was also applied to sugar and potassium accumulation, organic acid formation and respiration. For photosynthesis, sugar, potassium and organic acid levels, a diurnal minimum/maximum temperature range of 20°C / 35°C was used, below or above which levels in the leaves/berries will be seriously affected. For colour and flavour, a maximum night and maximum day temperature range of 20°C and 30°C was used, above which levels in the berries will stabilise/decrease. The different locations in the respective regions (represented by the weather stations) were also classified (sorted) according to their potential for meeting the climatic requirements of each of the physiological parameters as well as of the physiological parameters all-together.

An ANNOVA procedure (Waller grouping) using the seasons as replicates and performed with the Statistical Analysis System 8.2 version, was used to determine whether the differences between the weather stations were statistically significant.

Results and discussion

The results showed that climatic profiles in different regions may have serious implications for the physiological functioning of grapevines (Tables 1 – 5). Mean climatic data are seemingly not sufficient to properly understand variation in climatic conditions and consequently to quantify the impact on grapevine physiological behaviour at a particular location. This may lead to the selection and zoning of only apparently homogeneous terroirs, resulting in heterogeneous grapevine response. In this regard, the frequency of occurrence inside and outside an optimum range, and including extreme climatic conditions, would seem to be more suitable parameters for climatic profile quantification aimed at grapevine physiological requirements and behaviour. The impact of potential climatic stress (direct and indirect) on grapevine physiological processes, growth and grape development and quality should be further quantified. The methodology that is described can lead to the development of a modelling system for terroir classification and zoning taking climatic conditions and grapevine physiology into account. In this approach, climatic conditions and various key physiological processes are integrated. Further research, including correlation with wine quality (e.g. colour and flavour in particular), should be undertaken.

On a macro-scale, climatic indices used to classify different terroirs and which are applied for zoning, seem to be only an indication of what in reality is experienced between vine rows and by the root system and canopy in particular. The more macro-, meso-, micro- and even nano- (e.g. inside the bunches and at soil-root interface level) climate conditions and cultivating conditions in a particular region and at a particular site favour physiological requirements of the grapevine cultivar-rootstock combination to the benefit of grapevine functioning and grape development, the better expression of terroir potential and the less seasonal variation in growth as well as grape and wine quality will be obtained. Conversely, failure to successfully marry these concepts will result in an under-exploitation of the real potential of the chosen grapevine cultivar and terroir and will only result in an apparent zoning. In order to understand the behaviour of the grapevine within a particular terroir and to facilitate future terroir selection and zoning, these concepts must be studied in concert.

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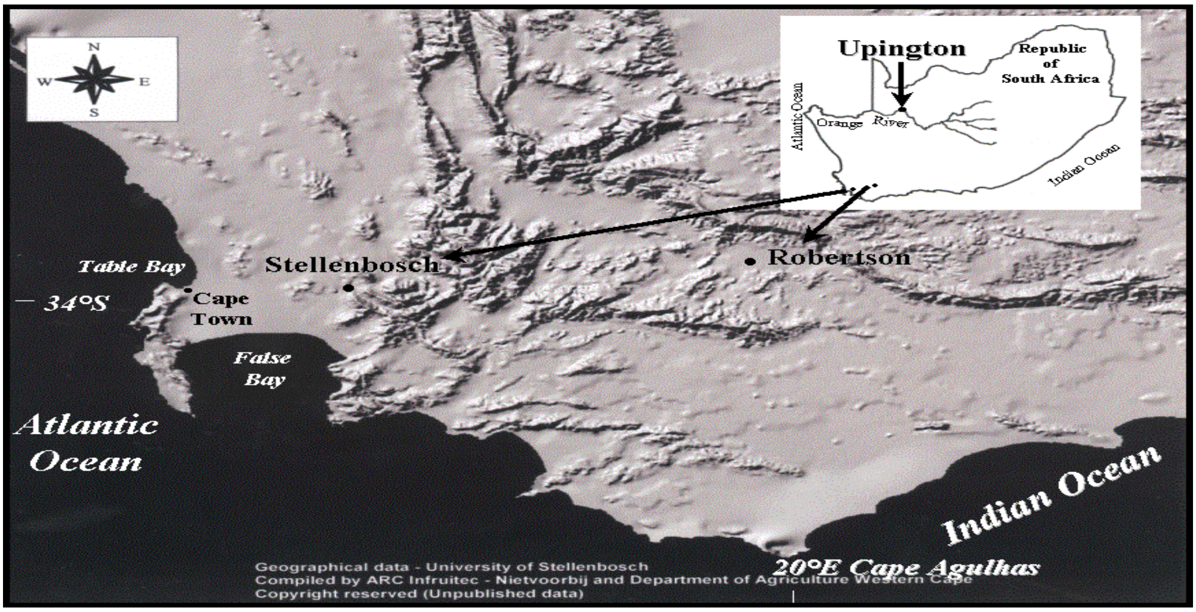
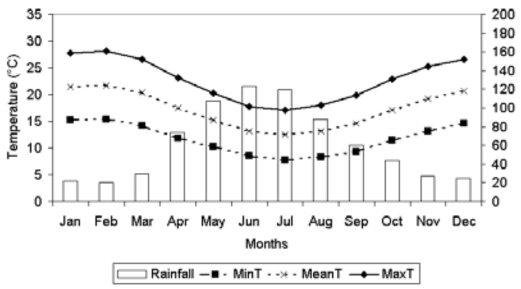
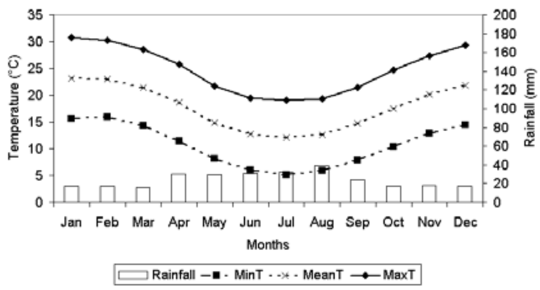


Fig. 1. Location of studied South African grape growing regions (Stellenbosch, Robertson, Upington).
Fig. 1. Localisation régions viticoles d'Afrique du Sud étudiées (Stellenbosch, Robertson, Upington).

a)



b)



c)

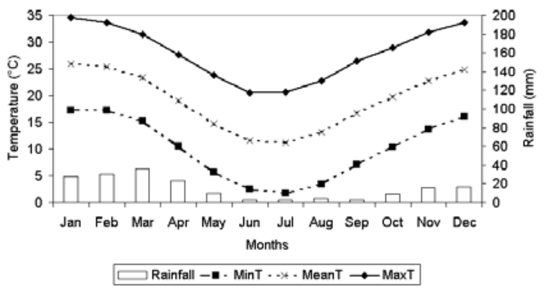


Fig. 2. Mean monthly rainfall and temperature for a) Stellenbosch (33°9'S/18°9'E) (Period 1967-2002), b) Robertson (33°5'S/19°5'E) (Period 1961-1997) and c) Upington (28°5'S/21°25'E) (Period 1949-1995). Source ARC-ISCW, AgroMet Division, Pretoria.

Fig. 2. Précipitations et températures moyennes mensuelles à a) Stellenbosch (33°9'S/18°9'E) (Période 1967-2002), b) Robertson (33°5'S/19°5'E) (Période 1961-1997) et c) Upington (28°5'S/21°25'E) (Période 1949-1995). Source ARC-ISCW, AgroMet Division, Pretoria.

Table I. List and characteristics of the automatic weather stations used in the study. The location in different regions, districts and wards is given according to Wine of Origin demarcation (Anon, 1998).
Tableau I. Liste et caractéristiques des stations météorologiques automatiques utilisées dans l'étude. Leur localisation dans les différentes régions, districts et quartiers est donnée en fonction de la démarcation des Vins d'Origine (Anon, 1998).

Weather station	Lat (S) Lon (E)	Alt (m)	Period (no of years)	Region	District	Ward
Nietvoorbij	33°54' 18°52'	146	1998-2003 (5)	Coastal Region	Stellenbosch	Simonsberg
Thelema	33°54' 18°55'	423	1998-2003 (5)	Coastal Region	Stellenbosch	
Middelvlei	33°56' 18°50'	147	1998-2003 (5)	Coastal Region	Stellenbosch	Papegaaiberg
Grootvlei	33°55' 18°50'	200	1998-2003 (5)	Coastal Region	Stellenbosch	Devon Valley
Skoonheid	33°57' 18°44'	250	1998-2003 (5)	Coastal Region	Stellenbosch	
Morgenstêr	33°50' 18°37'	230	1998-2003 (5)	Coastal Region	Stellenbosch	Durbanville
Goedehoop	33°55' 18°46'	235	1998-2003 (5)	Coastal Region	Stellenbosch	Bottelary
Jacobsdal	33°58' 18°44'	130	1998-2003 (5)	Coastal Region	Stellenbosch	
Alto	34°01' 18°51'	225	1998-2003 (5)	Coastal Region	Stellenbosch	Helderberg
Rustenhof	34°03' 18°47'	56	1998-2003 (5)	Coastal Region	Stellenbosch	
Meerlust	34°01' 18°45'	33	1998-2003 (5)	Coastal Region	Stellenbosch	
Bonfoi	33°56' 18°47'	153	1998-2003 (5)	Coastal Region	Stellenbosch	
Le Bonheur	33°50' 18°52'	260	1998-2003 (5)	Coastal Region	Stellenbosch	Simonsberg
Elsenburg	33°51' 18°50'	177	1998-2003 (5)	Coastal Region	Stellenbosch	Simonsberg
Boesmansrivier	33°54' 20°12'	300	1998-2003 (5)	Breede River Valley	Robertson	Boesmansriver
Vink Rivier	33°46' 19°46'	250	1998-2003 (5)	Breede River Valley	Robertson	Vink River
Le Chasseur	33°50' 19°44'	180	1998-2003 (5)	Breede River Valley	Robertson	Le Chasseur
Zandvliet	33°51' 20°04'	170	1998-2003 (5)	Breede River Valley	Robertson	
Merwespont	33°58' 20°09'	110	1998-2003 (5)	Breede River Valley	Robertson	
Langverwacht	33°56' 20°01'	140	1998-2003 (5)	Breede River Valley	Robertson	
Koningsrivier	33°54' 18°52'	180	1998-2003 (5)	Breede River Valley	Robertson	
Goudmyn	33°53' 20°01'	120	1998-2003 (5)	Breede River Valley	Robertson	
Goree	33°49' 19°47'	180	1998-2003 (5)	Breede River Valley	Robertson	
Goedemoed	33°51' 19°59'	160	1998-2003 (5)	Breede River Valley	Robertson	
De Hoop	33°45' 18°57'	340	1998-2003 (5)	Breede River Valley	Robertson	
Bonnievale	33°56' 20°06'	115	1998-2003 (5)	Breede River Valley	Robertson	Bonnievale
Kromhout	28°77' 20°62'	690	1999-2003 (4)			Lower Orange River
Upington	28°45' 21°25'	793	1999-2003 (4)			Lower Orange River
Groblershoop	28°88' 22°00'	881	1999-2003 (4)			Lower Orange River
Augrabies	28°63' 20°35'	650	1999-2003 (4)			Lower Orange River

Table II. Winkler and Huglin indices and corresponding climatic classification according to J. Tonietto (1999). Average for 5 seasons (1998-2003) for Stellenbosch and Robertson Regions and 4 seasons (1999-2003) for the Upington Region. The stations are classified within their Region by ascending Winkler index. Indices followed by a similar letter or group of letters in brackets are not significantly different (Waller grouping, p=0.005).

Tableau II. Indices de Winkler et d'Huglin avec classification climatique correspondante de J. Tonietto (1999). Moyenne de 5 saisons (1998-2003) pour les régions de Stellenbosch et Robertson et de 4 saisons (1999-2003) pour la région d'Upington. Les stations sont classées par région et par ordre décroissant de l'indice de Winkler. Les indices suivis d'une même lettre ou groupe de lettres entre parenthèses indiquent que leur différence n'est pas statistiquement significative (Groupement de Waller, p=0.005).

Region	Stations	Winkler Index	Winkler Regions	Huglin Index	Tonietto classification from Huglin index
Stellenbosch	Morgenstêr	1701 (m)	III	2095 (j)	Temperate
Stellenbosch	Jacobsdal	1737 (ml)	III	2154 (ji)	Warm Temperate
Stellenbosch	Skoonheid	1751 (ml)	III	2179 (ji)	Warm Temperate
Stellenbosch	Thelema	1791 (mlk)	III	2222 (hji)	Warm Temperate
Stellenbosch	Goedehoop	1814 (mljk)	III	2155 (ji)	Warm Temperate
Stellenbosch	Nietvoorbij	1943 (ihj)	III	2379 (hfg)	Warm Temperate
Stellenbosch	Bonfoi	1965 (ih)	IV	2312 (hgi)	Warm Temperate
Stellenbosch	Elsenburg	1982 (ihgf)	IV	2498 (dfe)	Hot
Stellenbosch	Rustenhof	1990 (ihgf)	IV	2382 (hfg)	Warm Temperate
Stellenbosch	Grootvlei	2008 (ihgf)	IV	2485 (dfge)	Hot
Stellenbosch	Middelvlei	2008 (ihgf)	IV	2489 (dfge)	Hot
Stellenbosch	Meerlust	2019 (ihgf)	IV	2403 (fg)	Hot
Stellenbosch	Alto	2041 (hgf)	IV	2455 (fge)	Hot
Stellenbosch	Le Bonheur	2051 (hgf)	IV	2402 (fg)	Hot
Average for Stellenbosch region		***1914***	***III***	***2329***	***Warm temperate***
Robertson	De Hoop	1877 (iljk)	III	2447 (fge)	Hot
Robertson	Vink Rivier	1926 (ihjk)	III	2401 (fg)	Hot
Robertson	Goree	1968 (ihg)	IV	2439 (fhe)	Hot
Robertson	Boesmansrivier	1997 (ihgf)	IV	2478 (dfge)	Hot
Robertson	Merwespont	2027 (hgf)	IV	2557 (dfce)	Hot
Robertson	Goedemoed	2030 (hgf)	IV	2590 (dce)	Hot
Robertson	Goudmyn	2050 (hgf)	IV	2551 (dfce)	Hot
Robertson	Zandvliet	2053 (hgf)	IV	2592 (dce)	Hot
Robertson	Koningsrivier	2058 (hgf)	IV	2530 (dfce)	Hot
Robertson	Bonnievale	2061 (ehgf)	IV	2608 (dce)	Hot
Robertson	Le Chasseur	2110 (efg)	IV	2640 (dc)	Hot
Robertson	Langverwacht	2120 (d)	IV	2650 (dc)	Hot
Average for Robertson region		***2023***	***IV***	***2540***	***Hot***
Upington	Upington	2901 (c)	V	3402 (b)	Very Hot
Upington	Groblershoop	2968 (c)	V	3459 (b)	Very Hot
Upington	Kromhout	3114 (b)	V	3529 (b)	Very Hot
Upington	Augrabies	3273 (a)	V	3755 (a)	Very Hot
Average for Upington region		***3064***	***V***	***3536***	***Very hot***

Table III. Total frequency of time (%) within the optimum (Opt) and extreme (Ext) ranges for photosynthesis and colour and flavour during pre-véraison. Stations are classified according to descending "Diff" (difference between final "Opt" and final "Ext"). Average for 5 seasons (1998-2003) for Stellenbosch and Robertson Regions and 4 seasons (1999-2003) for the Upington Region.

Tableau III. Fréquences totales de temps (%) à l'intérieur de la fourchette optimale (Opt) et des fourchettes extrêmes (Ext) pour la photosynthèse, la couleur et les arômes pendant la période de pré-véraison. Les stations sont classées par ordre décroissant de "Diff" (différence entre le "Opt" final et le "Ext" final). Moyenne de 5 saisons (1998-2003) pour les régions de Stellenbosch et Robertson et de 4 saisons (1999-2003) pour la région d'Upington.

Region	Station	Total % Photosynthesis			Total % Colour & Flavour			Mean Final %		
		Opt	Ext	Diff	Opt	Ext	Diff	Opt	Ext	Diff
Stellenbosch	Meerlust	79	32	48	33	18	15	56	25	31
Stellenbosch	Middelvlei	81	39	42	33	19	14	57	29	28
Stellenbosch	Grootvlei	74	46	28	34	19	15	54	32	21
Stellenbosch	Morgenstêr	68	54	14	38	11	28	53	32	21
Stellenbosch	Thelema	73	53	20	36	19	17	55	36	18
Robertson	Langverwacht	78	52	26	27	22	5	52	37	16
Stellenbosch	Rustenhof	65	48	17	32	17	15	48	32	16
Stellenbosch	Skoonheid	66	58	9	35	14	22	51	36	15
Stellenbosch	Alto	73	51	22	28	21	8	51	36	15
Robertson	Bonnievale	75	51	24	27	21	6	51	36	15
Stellenbosch	Jacobsdal	62	57	5	35	12	23	48	34	14
Robertson	Merwespont	73	55	18	28	20	8	50	37	13
Robertson	Boesmansrivier	71	57	14	28	19	9	49	38	11
Robertson	Zandvliet	70	51	18	27	23	4	48	37	11
Robertson	De Hoop	71	61	10	29	19	11	50	40	10
Stellenbosch	Elsenburg	65	60	5	34	19	15	49	39	10
Stellenbosch	Le Bonheur	66	56	10	31	21	10	48	38	10
Robertson	Goudmyn	71	58	13	26	22	4	48	40	8
Stellenbosch	Bonfoi	63	62	1	32	17	15	47	39	8
Stellenbosch	Nietvoorbij	62	65	-3	32	19	13	47	42	5
Stellenbosch	Goedehoop	58	64	-5	31	15	16	45	39	5
Robertson	Vink Rivier	68	63	4	27	26	1	47	44	3
Robertson	Koningsrivier	67	64	3	27	24	3	47	44	3
Robertson	Goree	65	65	0	27	22	5	46	43	3
Robertson	Goedemoed	66	65	1	27	21	6	46	43	3
Robertson	Le Chasseur	62	71	-9	26	26	0	44	48	-5
Upington	Groblershoop	69	77	-8	13	56	-43	41	66	-26
Upington	Upington	66	82	-16	15	54	-39	40	68	-28
Upington	Kromhout	66	79	-13	11	61	-50	39	70	-31
Upington	Augrabies	63	88	-25	11	64	-54	37	76	-39
Average for Stellenbosch Region		***68***	***53***	***15***	***33***	***17***	***16***	***51***	***35***	***15***
Average for Robertson Region		***70***	***59***	***10***	***27***	***22***	***5***	***48***	***41***	***8***
Average for Upington Region		***66***	***82***	***-16***	***12***	***58***	***-46***	***39***	***70***	***-31***

Table IV. Total frequency of time (%) within the optimum (Opt) and extreme (Ext) ranges for photosynthesis and colour and flavour during post-véraison. Stations are classified according to descending "Diff" (difference between final "Opt" and final "Ext"). Average for 5 seasons (1998-2003) for Stellenbosch and Robertson Regions and 4 seasons (1999-2003) for the Upington Region.
Tableau IV. Fréquences totales de temps (%) à l'intérieur de la fourchette optimale (Opt) et des fourchettes extrêmes (Ext) pour la photosynthèse, la couleur et les arômes pendant la période de post-véraison. Les stations sont classées par ordre décroissant de "Diff" (différence entre le "Opt" final et le "Ext" final). Moyenne de 5 saisons (1998-2003) pour les régions de Stellenbosch et Robertson et de 4 saisons (1999-2003) pour la région d'Upington.

Region	Station	Total % Photosynthesis			Total % Colour & Flavour			Mean Final %		
		Opt	Ext	Diff	Opt	Ext	Diff	Opt	Ext	Diff
Stellenbosch	Morgenstêr	76	38	38	30	15	15	53	26	27
Stellenbosch	Meerlust	85	28	58	24	29	-5	54	28	26
Stellenbosch	Middelvlei	85	35	50	22	30	-8	53	32	21
Robertson	Langverwacht	87	38	49	20	34	-15	53	36	17
Stellenbosch	Thelema	77	46	31	27	25	2	52	35	16
Stellenbosch	Skoonheid	74	50	24	26	19	8	50	34	16
Stellenbosch	Grootvlei	77	42	36	22	28	-7	49	35	15
Robertson	Bonnievale	80	42	39	21	32	-11	50	37	14
Stellenbosch	Bonfoi	73	42	31	24	30	-6	48	36	13
Stellenbosch	Jacobsdal	64	49	15	27	17	10	45	33	13
Robertson	Zandvliet	78	41	37	20	33	-13	49	37	12
Stellenbosch	Rustenhof	71	41	30	21	29	-8	46	35	11
Stellenbosch	Alto	78	47	31	20	30	-10	49	38	10
Robertson	Goudmyn	78	45	34	19	32	-14	48	38	10
Robertson	De Hoop	77	54	23	23	29	-6	50	41	9
Robertson	Merwespont	76	48	28	20	32	-12	48	40	8
Robertson	Koningsrivier	76	48	29	20	32	-13	48	40	8
Robertson	Boesmansrivier	76	50	26	20	30	-10	48	40	8
Stellenbosch	Le Bonheur	70	51	19	22	26	-4	46	38	8
Robertson	Vink Rivier	76	50	26	20	34	-14	48	42	6
Stellenbosch	Goedehoop	64	54	10	24	22	3	44	38	6
Robertson	Goree	74	53	21	21	31	-11	47	42	5
Robertson	Goedemoed	74	53	21	20	33	-13	47	43	4
Stellenbosch	Elsenburg	69	60	9	23	27	-5	46	43	2
Stellenbosch	Nietvoorbij	69	55	14	22	31	-10	45	43	2
Robertson	Le Chasseur	69	59	11	19	37	-18	44	48	-4
Upington	Groblershoop	67	75	-7	10	67	-58	38	71	-32
Upington	Upington	67	82	-15	11	64	-53	39	73	-34
Upington	Kromhout	64	83	-19	9	71	-62	37	77	-40
Upington	Augrabies	63	86	-23	9	73	-64	36	79	-43
Average for Stellenbosch Region		***74***	***46***	***28***	***24***	***25***	***-2***	***49***	***35***	***13***
Average for Robertson Region		***77***	***48***	***29***	***20***	***32***	***-12***	***48***	***40***	***8***
Average for Upington Region		***65***	***81***	***-16***	***10***	***68***	***-59***	***37***	***75***	***-37***

Table V. Final frequency of time (%) within the optimum (Opt) and extreme (Ext) ranges for photosynthesis and colour & flavour both pre- and post-véraison. Stations are classified according to "Diff" (difference between season Opt and season Ext). Average for 5 seasons (1998-2003) for Stellenbosch and Robertson Regions and 4 seasons (1999-2003) for the Upington Region.

Tableau V. Fréquences finales de temps (%) à l'intérieur de la fourchette optimale (Opt) et des fourchettes extremes (Ext) pour la photosynthèse, la couleur et les arômes pendant les deux périodes de pré- et post-véraison. Les stations sont classées par ordre décroissant de "Diff" (différence entre le "Opt" saisonnier et le "Ext" saisonnier). Moyenne de 5 saisons (1998-2003) pour les régions de Stellenbosch et Robertson et de 4 saisons (1999-2003) pour la région d'Upington.

Region	Station	Total % Pre-véraison			Total % Post-véraison			Mean Total % Season		
		Opt	Ext	Diff	Opt	Ext	Diff	Opt	Ext	Diff
Stellenbosch	Meerlust	56	25	31	54	28	26	55	26	29
Stellenbosch	Middelvlei	57	29	28	53	32	21	55	31	24
Stellenbosch	Morgenstêr	53	32	21	53	26	27	53	29	24
Stellenbosch	Grootvlei	54	32	21	49	35	15	52	34	18
Stellenbosch	Thelema	55	36	18	52	35	16	53	36	17
Robertson	Langverwacht	52	37	16	53	36	17	53	36	16
Stellenbosch	Skoonheid	51	36	15	50	34	16	50	35	15
Robertson	Bonnievale	51	36	15	50	37	14	51	36	14
Stellenbosch	Alto	51	36	15	49	38	10	50	37	13
Stellenbosch	Rustenhof	48	32	16	46	35	11	47	34	13
Stellenbosch	Jacobsdal	48	34	14	45	33	13	47	34	13
Robertson	Zandvliet	48	37	11	49	37	12	49	37	12
Robertson	Merwespont	50	37	13	48	40	8	49	39	10
Robertson	Boesmansrivier	49	38	11	48	40	8	49	39	10
Stellenbosch	Bonfoi	47	39	8	48	36	13	48	38	10
Robertson	De Hoop	50	40	10	50	41	9	50	41	9
Robertson	Goudmyn	48	40	8	48	38	10	48	39	9
Stellenbosch	Le Bonheur	48	38	10	46	38	8	47	38	9
Stellenbosch	Elsenburg	49	39	10	46	43	2	47	41	6
Stellenbosch	Goedhoop	45	39	5	44	38	6	44	39	6
Robertson	Koningsrivier	47	44	3	48	40	8	47	42	5
Robertson	Vink Rivier	47	44	3	48	42	6	47	43	4
Robertson	Goedemoed	46	43	3	47	43	4	47	43	4
Robertson	Goree	46	43	3	47	42	5	46	42	4
Stellenbosch	Nietvoorbij	47	42	5	45	43	2	46	43	4
Robertson	Le Chasseur	44	48	-5	44	48	-4	44	48	-4
Upington	Groblershoop	41	66	-26	38	71	-32	40	69	-29
Upington	Upington	40	68	-28	39	73	-34	40	70	-31
Upington	Kromhout	39	70	-31	37	77	-40	38	73	-36
Upington	Augrabies	37	76	-39	36	79	-43	36	78	-41
Average for Stellenbosch Region		***51***	***35***	***15***	***49***	***35***	***13***	***50***	***35***	***14***
Average for Robertson Region		***48***	***41***	***8***	***48***	***40***	***8***	***48***	***40***	***8***
Average for Upington Region		***39***	***70***	***-31***	***37***	***75***	***-37***	***38***	***72***	***-34***