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# 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*

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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 ($\leq$ 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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