Effect of Canopy Microclimate, Season and Region on Sauvignon blanc Grape Composition and Wine Quality

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The effect of canopy microclimate on the grape aroma composition and wine quality of Sauvignon blanc was investigated in three climatically-different regions, i.e. in the Stellenbosch (1996 and 1997 season), Robertson and Elgin regions (1997 and 1998 season). A canopy shade treatment altering microclimate in a natural way, was applied to Sauvignon blanc vineyards in the three regions. Control vines were not manipulated. The concentrations of aroma compounds in the grapes, namely monoterpenes, C_{13}-norisoprenoids and 2-methoxy-3-isobutylpyrazine, were determined weekly during the respective ripening periods. Solar radiation above and within the canopies as well as temperature within the canopies were also measured continually during the ripening periods. The highest canopy solar radiation, temperature, and monoterpene and C_{13}-norisoprenoid concentrations were found for the control treatments, followed by the shaded treatments. An opposite tendency was found for 2-methoxy-3-isobutylpyrazine, which is one of the most important components responsible for the typical green pepper/asparagus aroma of Sauvignon blanc. There appears to be a relationship between chemical and microclimatic data in each region and over seasons. Marked temperature and aroma component concentration differences were observed among the three regions during the cool 1997 season, which manifested in wine aroma parameters such as fruitiness and vegetative/asparagus/green pepper nuances. Two definite wine styles emerged, namely the green pepper/asparagus "cool climate" style and the "warm climate" fruity/tropical style. However, differences in 2-methoxy-3-isobutylpyrazine and C_{13}-norisoprenoid levels and wine characteristics between regions were not as pronounced during the warm 1998 season. The data contribute to establishing guidelines for canopy manipulation for obtaining a specific wine character and quality. The choice lies with the viticulturist and winemaker to strive for and obtain, within limits, the style that they prefer.

It is well known that climate has a pronounced effect on grape and wine composition and quality. Considering the fact that climatic conditions between wine regions in South Africa differ greatly from regions II to IV (1389 to 2222 degree days) (Le Roux, 1974), it can be expected that wine composition, style and quality will differ between these regions. Furthermore, mesoclimate can differ between vineyards within a region and depends on factors such as aspect, slope, altitude, surrounding vegetation, etc. The effect of canopy microclimate on grape and wine composition is equally important (Smart *et al.*, 1985a; 1985b; Smart *et al.*, 1990). In this regard, climatic parameters such as temperature and solar radiation seem to be of special significance (Iland, 1989a; 1989b; Dokoozlian & Kliewer, 1996; Marais *et al.*, 1996; Versini *et al.*, 1996). Intervention by means of canopy management practices may affect grape composition to a great extent and different wine styles can be produced from the same vineyard (Hunter & Visser, 1988a; 1988b; Morrison & Noble, 1990; Hunter, De Villiers & Watts, 1991; Iacono & Scienza, 1995).

Sauvignon blanc has become one of the most important white wine cultivars in South Africa. The area planted to this cultivar has increased by 99% from 2255 (1985) to 4479 (1996) hectares (Booysen & Truter, 1997). Although high quality wines with the typical cultivar aroma characteristics are produced, a high proportion of wines show a neutral character. In view of greater international and local competition, it is of utmost importance to enhance the cultivar typicity and quality of Sauvignon blanc wine in general. To achieve this goal, specific guidelines for the cultivation of this cultivar in different climatic regions are needed. Local studies (De Villiers *et al.*, 1995; W.J. Conradie, 1997. Personal communication; Hunter & Le Roux, 1997) aimed at identifying regions and canopy management practices best suited to the cultivation of Sauvignon blanc are continuing. Knowledge about the relationship between microclimate, aroma development and wine quality of Sauvignon blanc is, however, limited (Allen & Lacey, 1993; Hunter & Ruffner, 1998). The purpose of this investigation was therefore to determine the effect of canopy microclimate on Sauvignon blanc grape composition and wine quality in different climatic regions over different seasons.

MATERIALS AND METHODS

Canopy manipulations: *Vitis vinifera* L. cv. Sauvignon blanc in three climatically-different regions, namely Robertson, Stellenbosch and Elgin, was used. According to a local degree day model (Le Roux, 1974), the three regions are classified as regions IV (1945 – 2222 degree days), III (1668 – 1944 degree days) and II (1389 – 1667 degree days), respectively. Grapes were obtained over two seasons, namely 1996 and 1997 in the case of the Stellenbosch region, and 1997 and 1998 for the remaining two regions.

One canopy manipulation treatment which altered microclimate in a natural way, was applied in each region (based on the method of Archer & Strauss, 1989). During winter, two one-year

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old canes from each adjacent vine were trained to the middle of the cordon of the treated vine, allowing a natural shading of the vine in summer. Control vines were not manipulated. Three replications, consisting of 15 vines per replicate, were used. Suckering of shoots not located on spurs and shoot positioning were applied to all treatments. Shoots on canes used for shading were defruited to stimulate growth. The long-term annual rainfall for the Stellenbosch, Elgin and Robertson regions is : 737 mm, 1042 mm and 327 mm, respectively. The vineyards in the Stellenbosch and Elgin regions were therefore supplementarily irrigated (two irrigations per season), while the Robertson vineyard was irrigated intensively to evapotranspiration demand.

Microclimatic parameters: MCS data loggers were installed and continually measured temperature within the canopies (in the vicinity of clusters) and within the clusters, as well as mainly visible light radiation (300-1200 nm) within the canopies of selected vines over the whole ripening period on an hourly basis. Each radiation sensor consisted of 10 individual sensors, fitted in parallel onto a metre-long rod, thus giving a more reliable, average reading in the canopy.

Sampling and harvesting of grapes: Whole bunches (approximately 2 kg per sample) were collected weekly at random from each treatment between approximately 16°B (close to véraison) and 21°B (ripeness). In the Elgin region, sampling started at approximately 17°B. Grapes were harvested at ripeness for wine production. Wines were produced according to standard Nietvoorbij practices for small-scale white wine production.

Aroma component analyses: Techniques for the extraction and analyses of free monoterpenes, glycosidically bound monoterpenes and C_{13}-norisoprenoids, and 2-methoxy-3-isobutylpyrazine (ibMP) were given in a previous publication (Marais *et al.*, 1996). The relative concentrations of linalool, hotrienol, alpha-terpineol, *trans*- and *cis*-pyran linalool oxide, citronellol, nerol and diendiol-1 were summed and expressed as total monoterpene concentration. The relative concentrations of *trans*- and *cis*-furan linalool oxide, *cis*-8-hydroxy linalool, *trans*-1,8-terpin, *trans*- and *cis*-vitispirane, 1,1,6-trimethyl-1,2-dihydronaphthalene, beta-damascenone, and actinidol 1 and 2 were summed and expressed as total acid-released monoterpene and C_{13}-norisoprenoid concentrations. During 1998, ibMP analyses were done on a new GCMS (Finnigan MAT GCQ^{TM}) instrument. The same conditions applied as with the former instrument (Finnigan 4600 Quadrupole MS).

Sensory analyses: Wines were sensorially evaluated for fruitiness and vegetative/asparagus/green pepper intensities by a panel of six experienced judges. A line-method was used, i.e. evaluating the intensity of each characteristic by making a mark on an unstructured, straight 10 cm line. The left-hand and right-hand ends of the line were indicated by the terms, "undetectable" and "prominent", respectively. The wines of the 1996 season (Stellenbosch region) were not evaluated, due to faulty characters.

Statistical analysis: Statistical differences between treatments were determined by applying standard analysis of variance methods to the data, obtained from each respective region and season. Least significant differences (LSD) were used to separate the means of the treatments.

RESULTS AND DISCUSSION

The concentrations of total monoterpenes and C_{13}-norisoprenoids, generally considered as important components of Sauvignon blanc (Lacey *et al.*, 1991; Sefton, Francis & Williams, 1994), decreased with an increase in canopy density, and increased during ripening between approximately 16°B and 21°B (Figs. 1 to 6). Similar tendencies were found in all three regions and during all seasons, confirming previous results from the Stellenbosch region (Marais *et al.*, 1996). In some cases, increases in compound concentrations were followed by slight decreases close to ripeness, which could be ascribed to transformations to other compounds (Marais & Van Wyk, 1986; and references therein).

The effect of canopy microclimate on the concentration of ibMP is shown in Figures 7 to 9. This methoxypyrazine is considered one of the most important cultivar-typical components of Sauvignon blanc (Lacey *et al.*, 1991; Allen & Lacey, 1993). Contrary to monoterpenes and C_{13}-norisoprenoids, the concentration of ibMP decreased with increasing grape exposure to sunlight as well as during ripening (Figs. 7 to 9). Again, similar tendencies were found in all three regions and during all seasons, and confirmed previous results (Marais *et al.*, 1996).

Average temperatures within the canopies, measured continually during the respective grape ripening periods, are shown in Figure 10. Temperature differences between "within clusters" (between berries) and "in the vicinity of clusters" were minimal and can be ascribed to air movement or wind, which had an equalising effect on temperature (Rojas-Lara & Morrison, 1989; Hunter & Visser, 1990). Therefore these two temperature measurements were considered as repetitions and referred to as "temperature within the canopy" for the purpose of this investigation. However, temperature of berry juice can differ greatly from that of the environment, an aspect which should also be considered when temperature effects on grape composition and quality are investigated (Smart & Sinclair, 1976; Marais & Fourie, 1997). Generally, average maximum temperatures were only slightly lowered by denser canopies (Fig. 10). Therefore canopy manipulation may, to a certain degree, be successful in obtaining cooler grapes in warm locations. The benefits of cool grapes for the production of high quality wines are widely recognised (Marais, 1998; and references therein).

The average temperatures (Fig. 10) are in agreement with the degree day model of Le Roux (1974), indicating Robertson as the warmer, Elgin as the cooler and Stellenbosch as the intermediate region. The fact that the 1997 season was cooler than both the 1996 and 1998 seasons (meteorological data not shown), is not completely evident in Figure 10, apart from high average minimum temperatures in the Elgin region in 1998, probably due to overcast nights. However, when variation in temperature, expressed as the number of hours below 12°C and above 30°C, is considered, it is evident that 1997 was the cooler season of the three (Fig. 11). Outlier temperatures or variation in temperature may therefore be a more important parameter than average temperatures. The apparent contradiction between the 1998 Elgin average minimum temperatures in Figures 10 and 11 may be explained by the fact that the data in Figure 10 represent only about three weeks, while those in Figure 11 represent three months. Incidentally, no <12°C hours occurred during February, the month in which ripening took place.

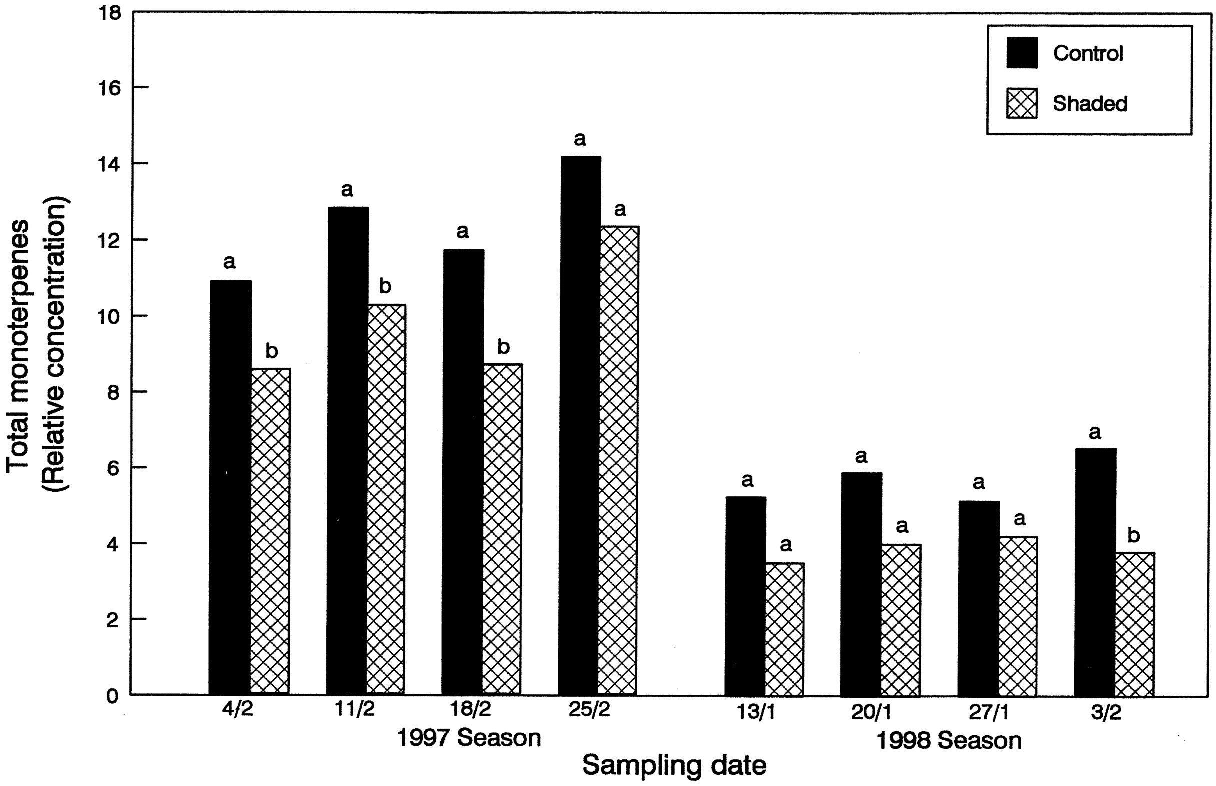

FIGURE 1

Effect of canopy microclimate on total monoterpene concentrations (average of three replicates) in Robertson Sauvignon blanc grapes over two seasons (1997 and 1998). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

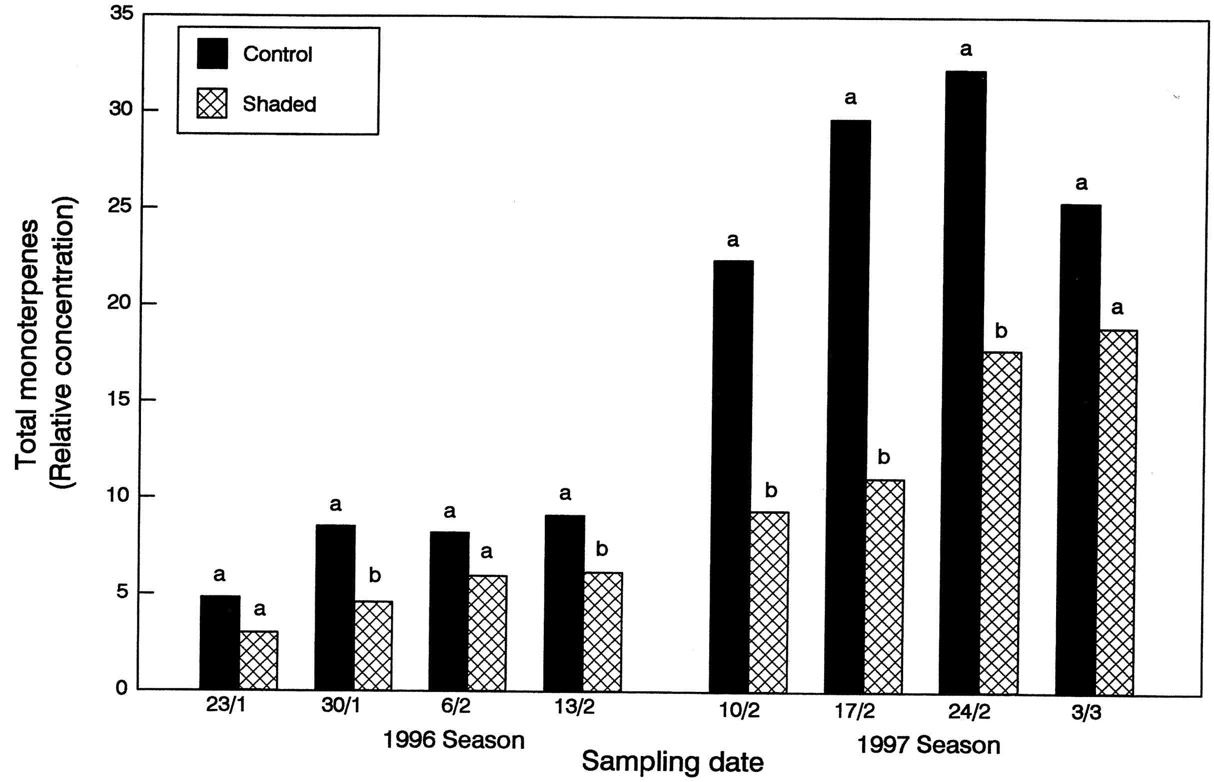

FIGURE 2

Effect of canopy microclimate on total monoterpene concentrations (average of three replicates) in Stellenbosch Sauvignon blanc grapes over two seasons (1996 and 1997). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

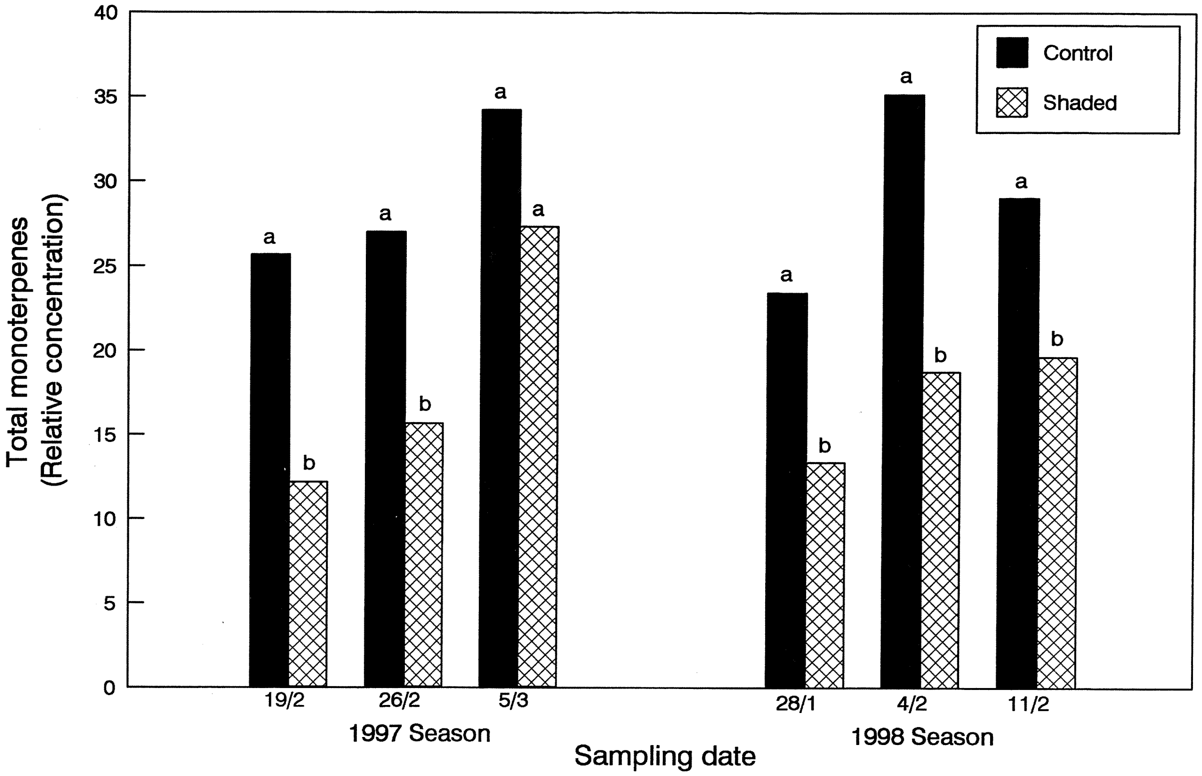

FIGURE 3

Effect of canopy microclimate on total monoterpene concentrations (average of three replicates) in Elgin Sauvignon blanc grapes over two seasons (1997 and 1998). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

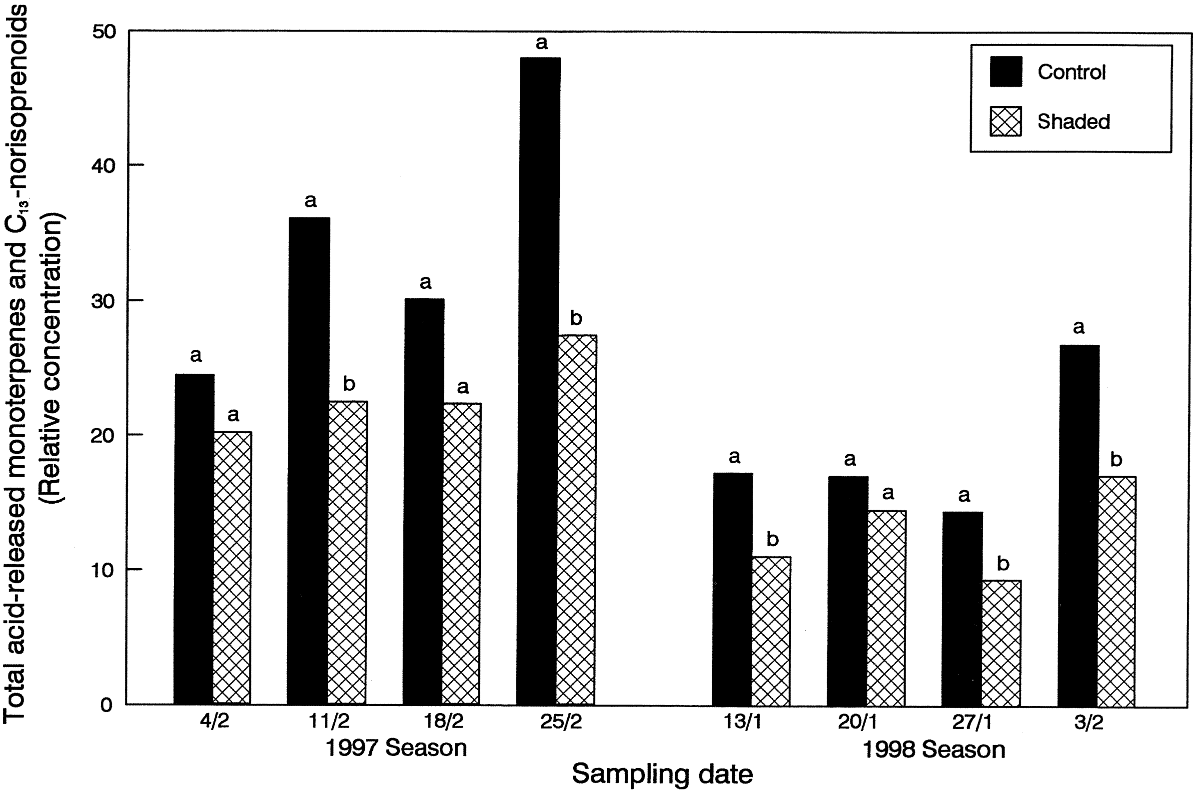

FIGURE 4

Effect of canopy microclimate on total acid-released monoterpene and C_{13}-norisoprenoid concentrations (average of three replicates) in Robertson Sauvignon blanc grapes over two seasons (1997 and 1998). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

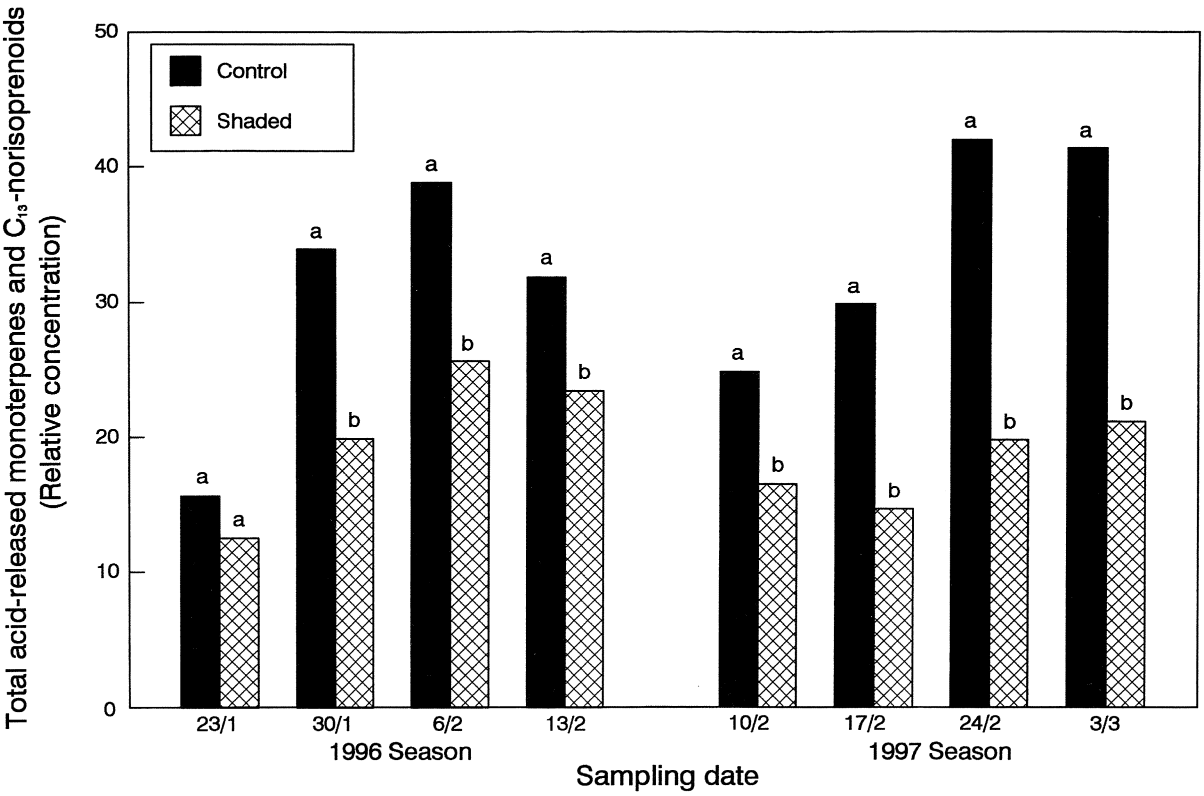

FIGURE 5

Effect of canopy microclimate on total acid-released monoterpene and C_{13}-norisoprenoid concentrations (average of three replicates) in Stellenbosch Sauvignon blanc grapes over two seasons (1996 and 1997). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

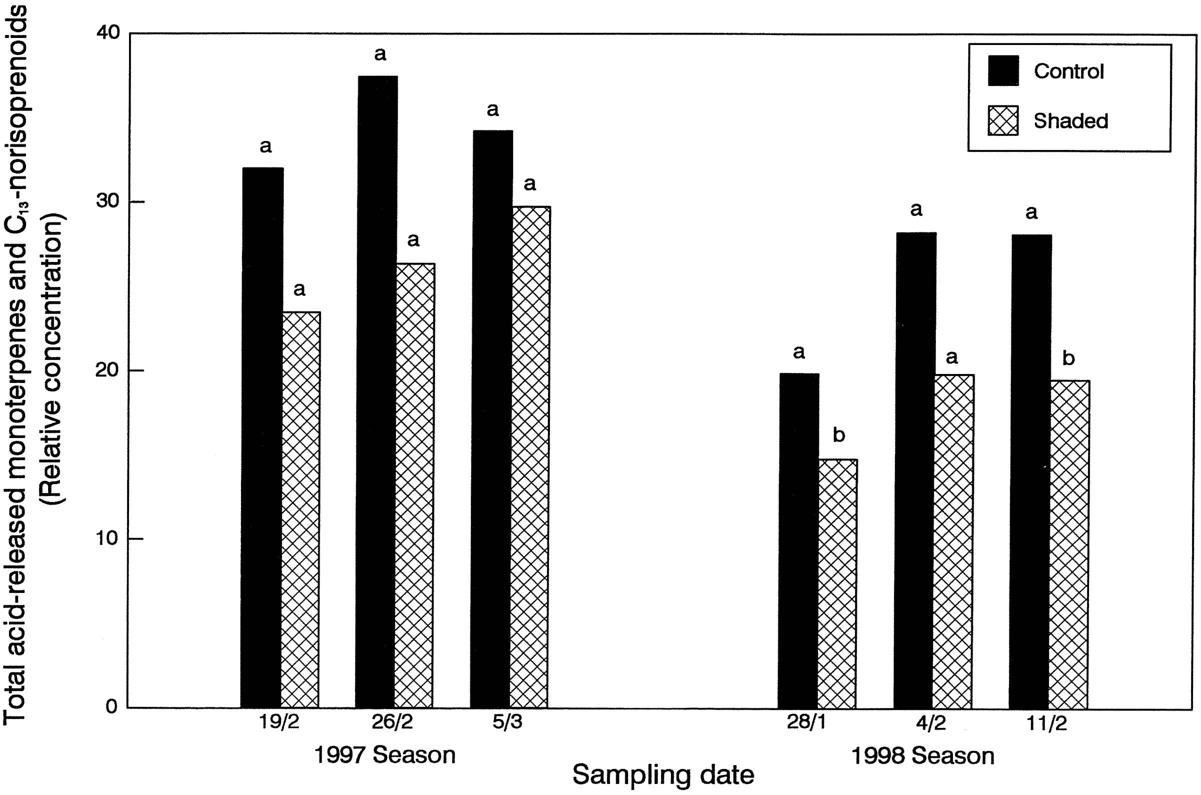

FIGURE 6

Effect of canopy microclimate on total acid-released monoterpene and C_{13}-norisoprenoid concentrations (average of three replicates) in Elgin Sauvignon blanc grapes over two seasons (1997 and 1998). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

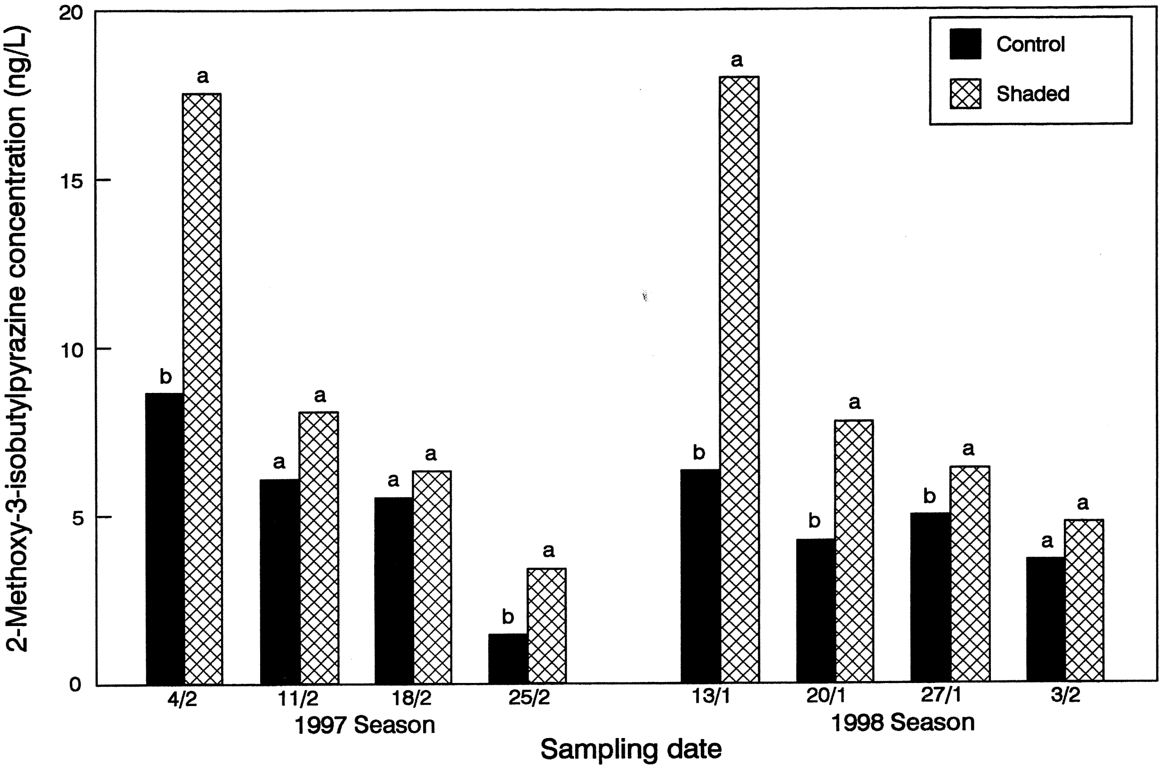

FIGURE 7

Effect of canopy microclimate on 2-methoxy-3-isobutylpyrazine concentration (average of three replicates) in Robertson Sauvignon blanc grapes over two seasons (1997 and 1998). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

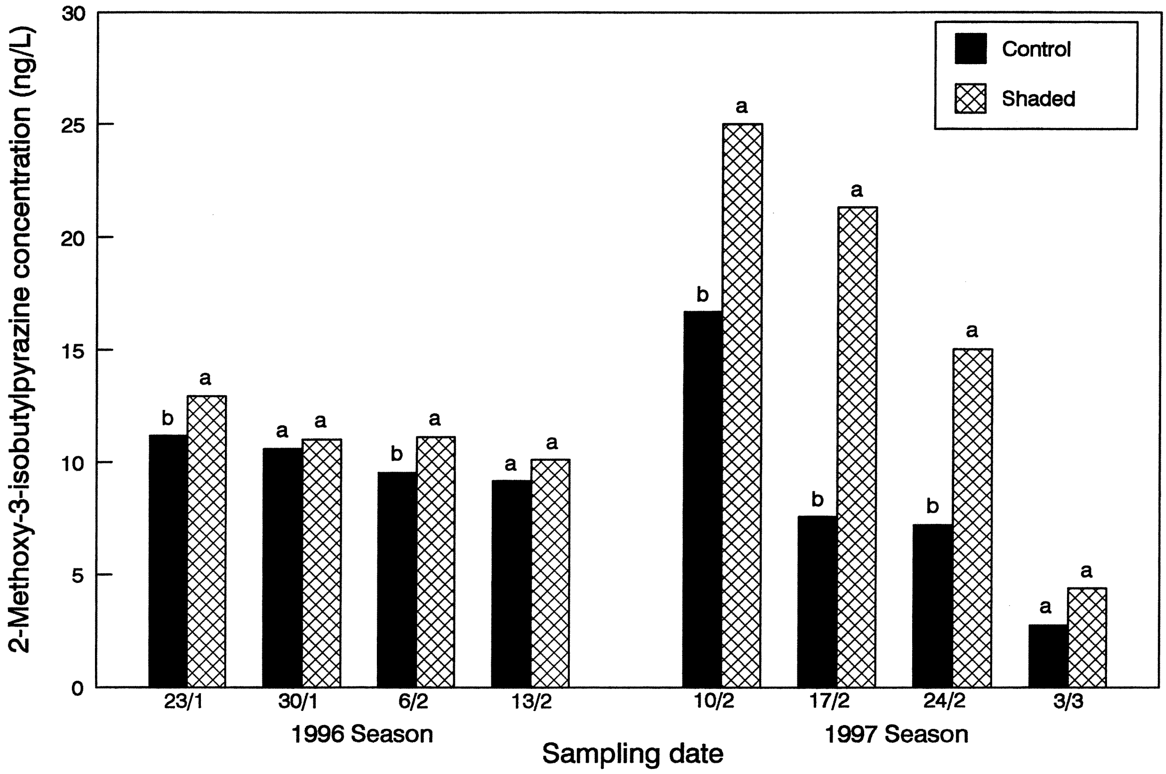

FIGURE 8

Effect of canopy microclimate on 2-methoxy-3-isobutylpyrazine concentration (average of three replicates) in Stellenbosch Sauvignon blanc grapes over two seasons (1996 and 1997). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

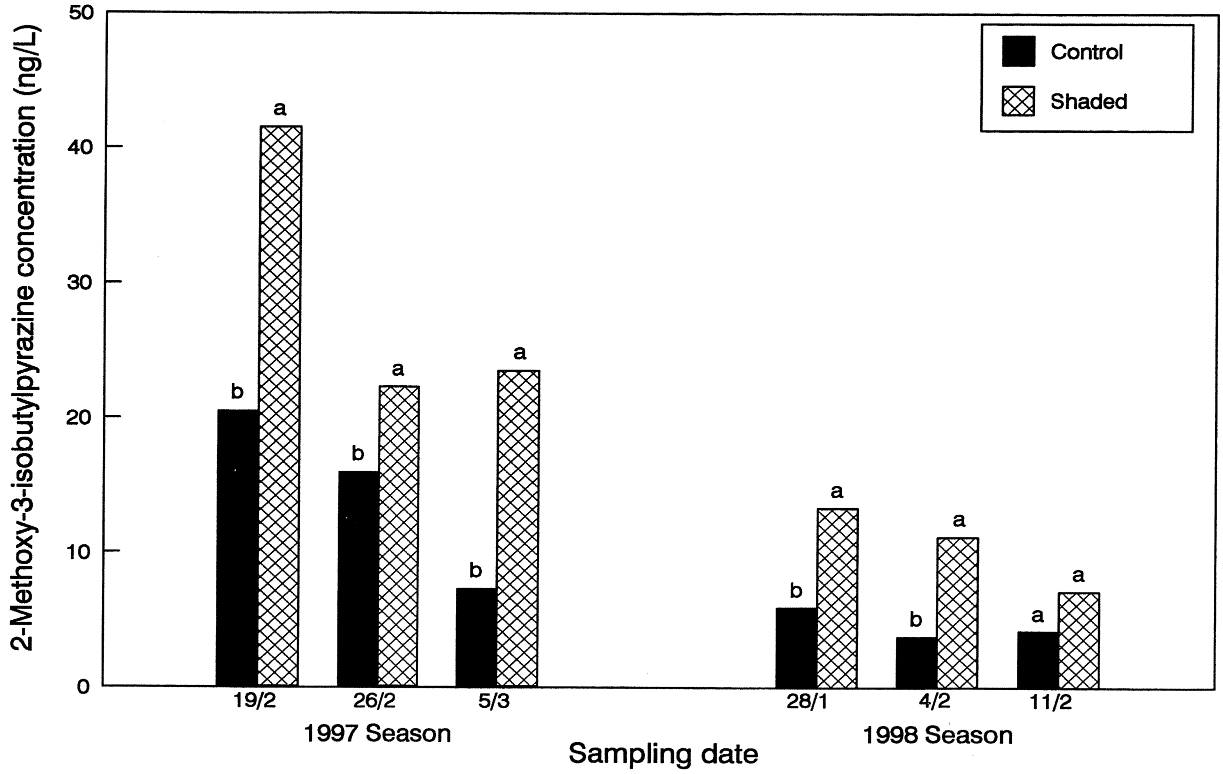

FIGURE 9

Effect of canopy microclimate on 2-methoxy-3-isobutylpyrazine concentration (average of three replicates) in Elgin Sauvignon blanc grapes over two seasons (1997 and 1998). Treatments at each sampling date designated by the same letter do not differ significantly (p≤0,05).

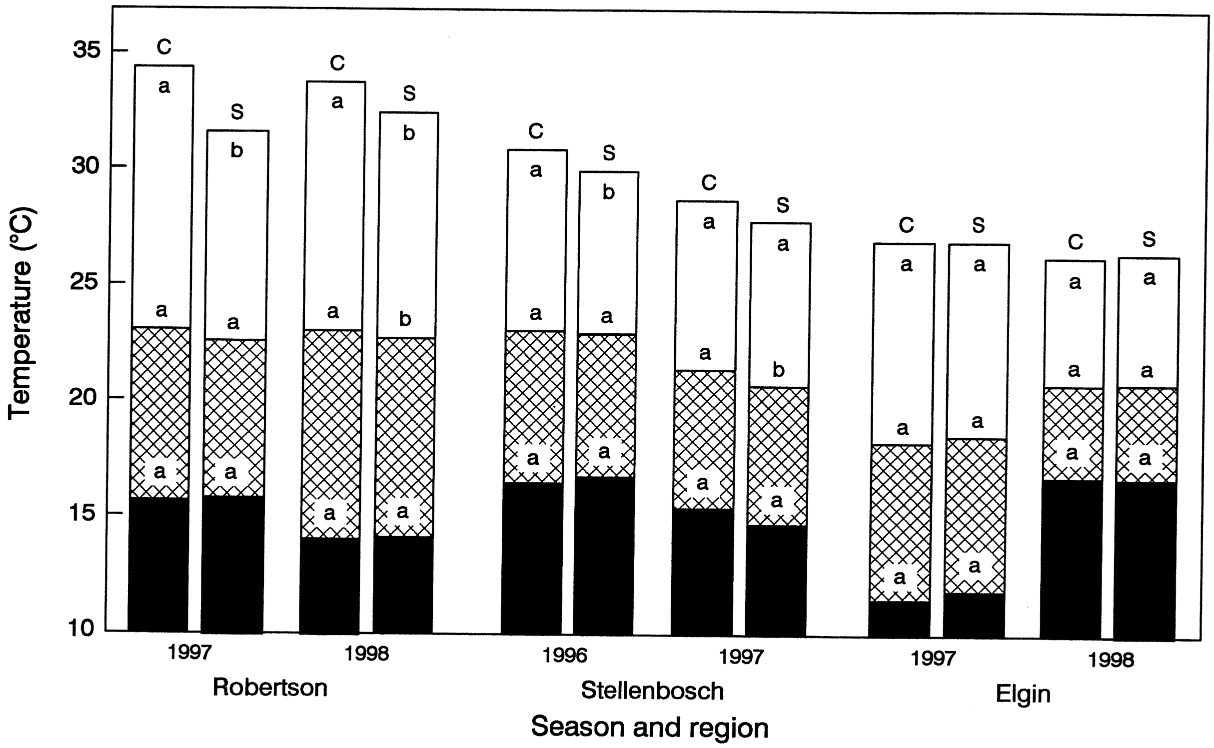

FIGURE 10

Average maximum □, average minimum ■ and average ⊠ temperatures within differently manipulated Sauvignon blanc canopies in three regions and over three seasons. Temperatures represent averages during each ripening period between véraison (±15°B) and harvest (±22°B). C = control, S = shaded. Treatments in each respective region and season designated by the same letter do not differ significantly (p≤0,05).

It can be expected that, as a result of temperature differences between regions and seasons, respective ripening periods will differ to some extent. This in fact happened, since the 1997 season was approximately three weeks later than the other two seasons, and ripening in the Elgin region is normally about one and two weeks later than in the Stellenbosch and Robertson regions, respectively. These differences in temperature conditions may strongly affect grape composition, although other factors such as clone, soil water supply and solar radiation naturally also play a role in aroma development.

As expected, solar radiation within the canopy decreased with increasing density in the vineyards in all three regions and during all three seasons (Fig. 12). Comparison between regions and seasons gives varying tendencies, which may be ascribed to the light intensity above the canopy, sunlight hours per day, row direction and canopy density of which the latter is affected by various cultivation practices.

Different climatic conditions manifest differently in aroma component concentrations and grape and wine quality. Generally, total monoterpene and C_{13}-norisoprenoid levels were higher in the cooler 1997 season, compared to the two warmer seasons (Figs. 1 to 6). Within one season, i.e. 1997, total monoterpene concentrations were also higher in the cooler Elgin region than in the warmer Stellenbosch and Robertson regions (Figs. 1 to 3). This tendency was, however, not repeated in the total bound aroma concentrations during the 1997 season. In fact, the Robertson levels were apparently slightly higher than the other values (Figs. 4 to 6). During the 1998 season, total monoterpene levels were also much higher in the cooler Elgin than in the warmer Robertson region (Figs. 1,3,4 and 6).

Generally, the ibMP levels were higher during the cooler 1997season, compared to the other season in each region, as well as higher in the cooler Elgin than in the two warmer regions, i.e. during the 1997 season (Figs. 7 to 9). This is in general agreement with monoterpene levels in the same grapes (Figs. 1 to 3). Similarly, ibMP levels were shown to be highest in grapes from cooler climatic regions (Lacey *et al.*, 1991; Allen & Lacey, 1993). However, during the warm 1998 season, small differences in ibMP levels occurred between the warmer Robertson and cooler Elgin regions, although the values of the latter region tended to be higher at ripeness. The sugar concentration of the Elgin grapes at ripeness was about 1°B higher than that of the Robertson grapes, which could also explain the relatively small difference in ibMP levels. In both cases, the end ibMP levels were still above the threshold value of 2 ng/*l* (Buttery *et al.*, 1969). The relatively high ibMP levels at ripeness in the Stellenbosch region (1996 season), and the gradual decrease in concentrations thereof during ripening (Fig. 8), in contrast to relatively prominent decreases in the other cases, is difficult to explain, but could probably be ascribed to dense canopies, caused by rainfall prior to veraison. On the other hand, solar radiation values in the same vineyard and season (Fig. 12) were much higher than all the other values concerned, which seems contradictory in the light of the extreme light-sensitivity of ibMP (Heymann, Noble & Boulton, 1986). It

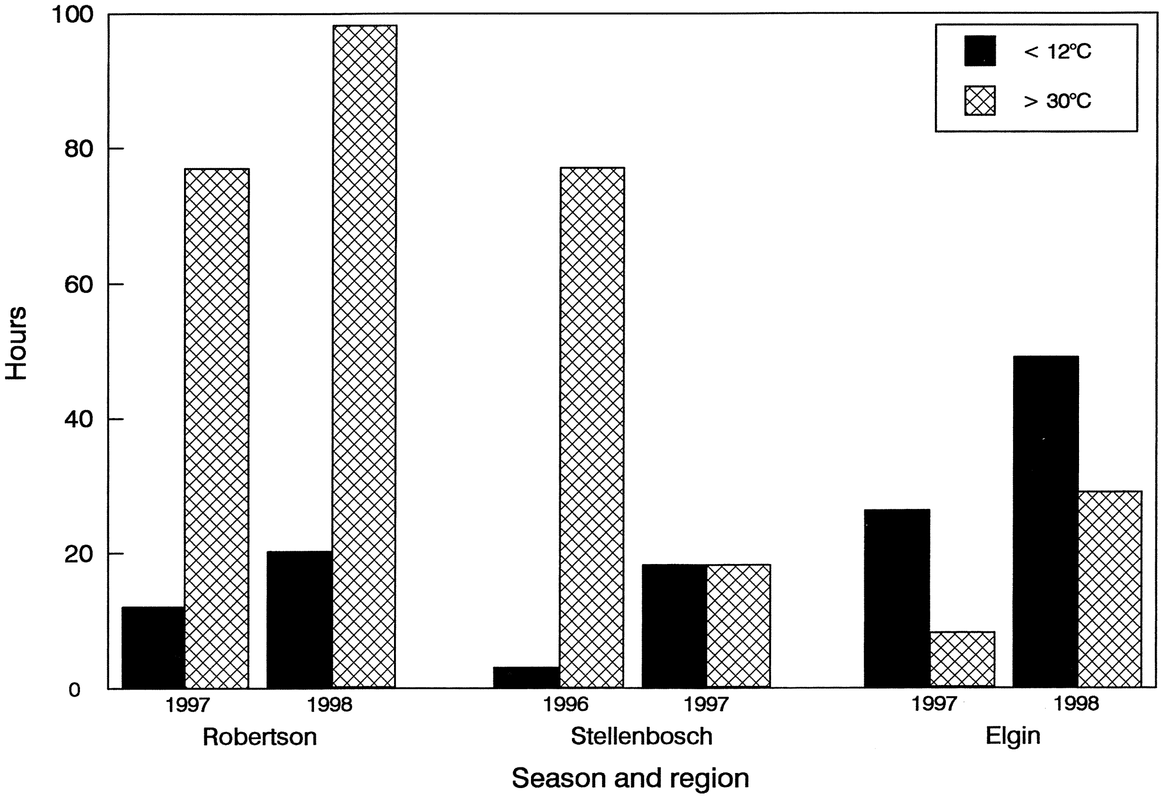

FIGURE 11

Average outlier temperatures (hours) in three regions and over two seasons. Values represent averages for three months (December, January and February) for each respective region and season.

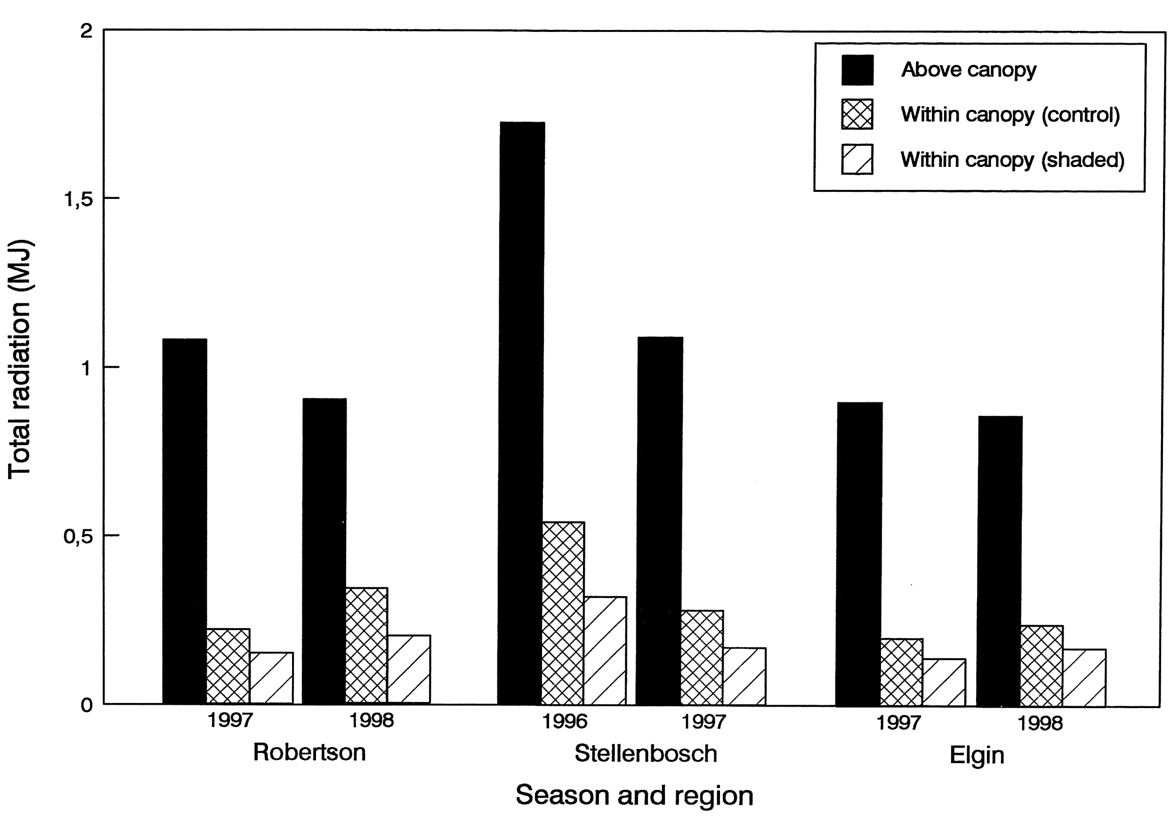

FIGURE 12

Average total radiation above and within differently manipulated Sauvignon blanc canopies in three regions and over two seasons. Values represent averages for three months (December, January and February) for each respective region and season.

is evident that the interaction between solar radiation and temperature and the effect thereof on grape aroma development, is a complex phenomenon. Furthermore, other factors such as soil water supply and nutrient status may also affect vine vigour, which in turn affects light exposure of grapes and subsequently wine aroma composition (Noble, Elliot-Fisk & Allen, 1995).

It appears that there is a relationship between solar radiation, temperature, monoterpene, C_{13}-norisoprenoid and ibMP concentrations within each region and season. Higher monoterpene and norisoprenoid, and lower ibMP concentrations coincided with higher light intensity within the canopy, while higher monoterpene, norisoprenoid and ibMP concentrations coincided with lower environmental temperatures. It also appears that within a region and season, solar radiation, as manipulated by canopy management, has a more prominent effect on aroma component levels than temperature (Figs. 1 to 9). Morrison & Noble (1990) also suggested that changes in the composition of the berry as a result of shading of the leaf and cluster were affected more by light than by temperature. However, when regions or seasons are compared, it appears that the effect of temperature on aroma component levels becomes much more prominent. Although it is not possible to single out solar radiation and temperature as the most inportant parameters affecting aroma component concentrations, it is well known that chemical and, within limits, enzymatic reaction rates, are temperature and light dependent. Therefore the role of temperature and light in the development and/or degradation of aroma components appears to be of particular importance. In general, it can be stated that cooler conditions, i.e. a cooler region and/or a cooler season, benefitted the development and retention of monoterpenes and ibMP in the local study.

It is generally accepted that monoterpenes and C_{13}-norisoprenoids contribute to the fruity and tropical nuances and ibMP to the vegetative/green pepper/asparagus aroma of Sauvignon blanc wines (Sefton, Francis & Williams, 1994; Lacey *et al.*, 1991). These contributions to wine quality are affected by, amongst others, temperature and solar radiation in each region and season. The variation in green pepper/asparagus aroma intensity of the 1997 wines between warm and cool regions (Fig. 13) corresponds to the respective grape ibMP levels (Figs. 7 to 9). A highly significant correlation between ibMP concentration and vegetative aroma intensity of Sauvignon blanc was found by Allen *et al.*, (1991). Differences in 1997 ibMP levels at harvest between regions (Figs. 7 to 9) were, however, not of the same magnitude as differences between the perceived "green" nuances (Fig. 13). When the monoterpene levels at harvest (Figs. 1 to 3) and respective fruity aroma intensities are compared, the Robertson values do not follow the expected trend, although the bound component levels tended to be higher in this region (Figs. 4 to 6). When the sensory data of the wines of the relatively warm and short 1998 season (Fig. 14), and the respective aroma component levels at harvest (Figs. 1 to 9) were considered, a number of trends were observed. Generally, differences in fruitiness and green pepper/asparagus intensities between the cooler Elgin and the warmer Robertson region were small, which coincide with the

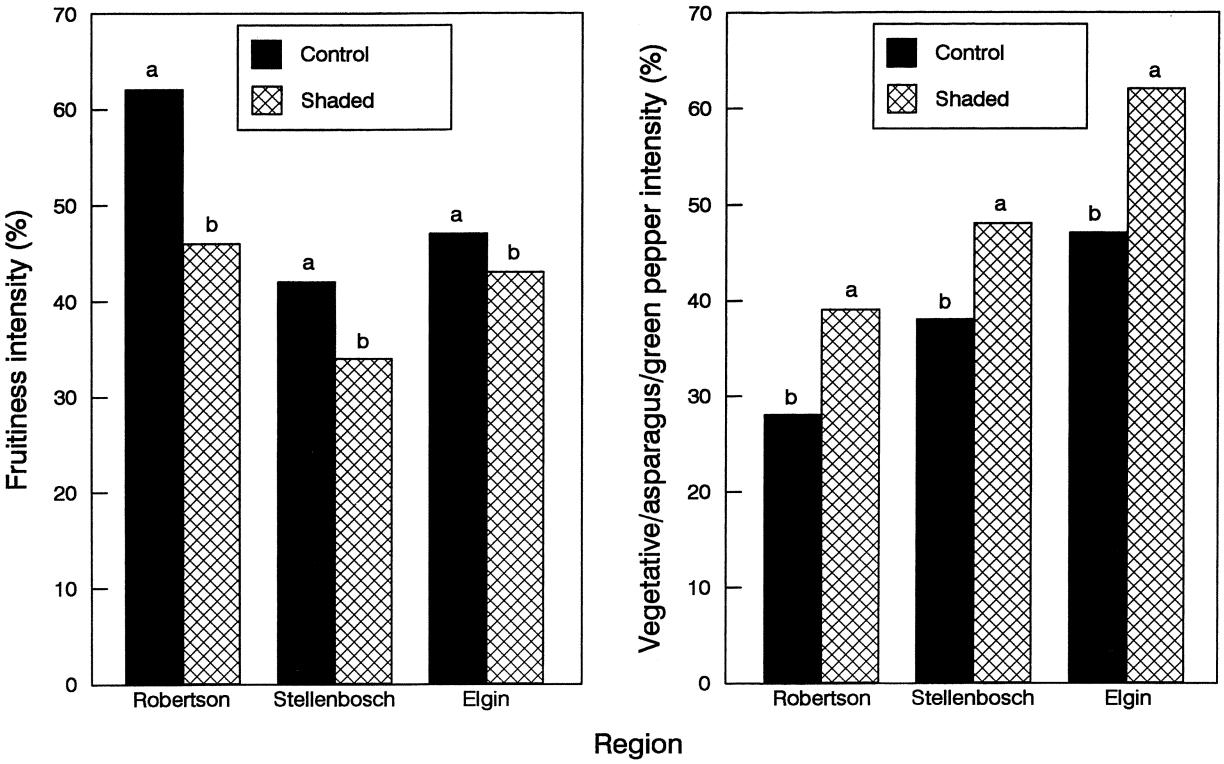

FIGURE 13

Effect of canopy microclimate on aroma intensities of Sauvignon blanc wines from the Robertson, Stellenbosch and Elgin regions (1997 season). Treatments in each region designated by the same letter do not differ significantly (p≤0,05).

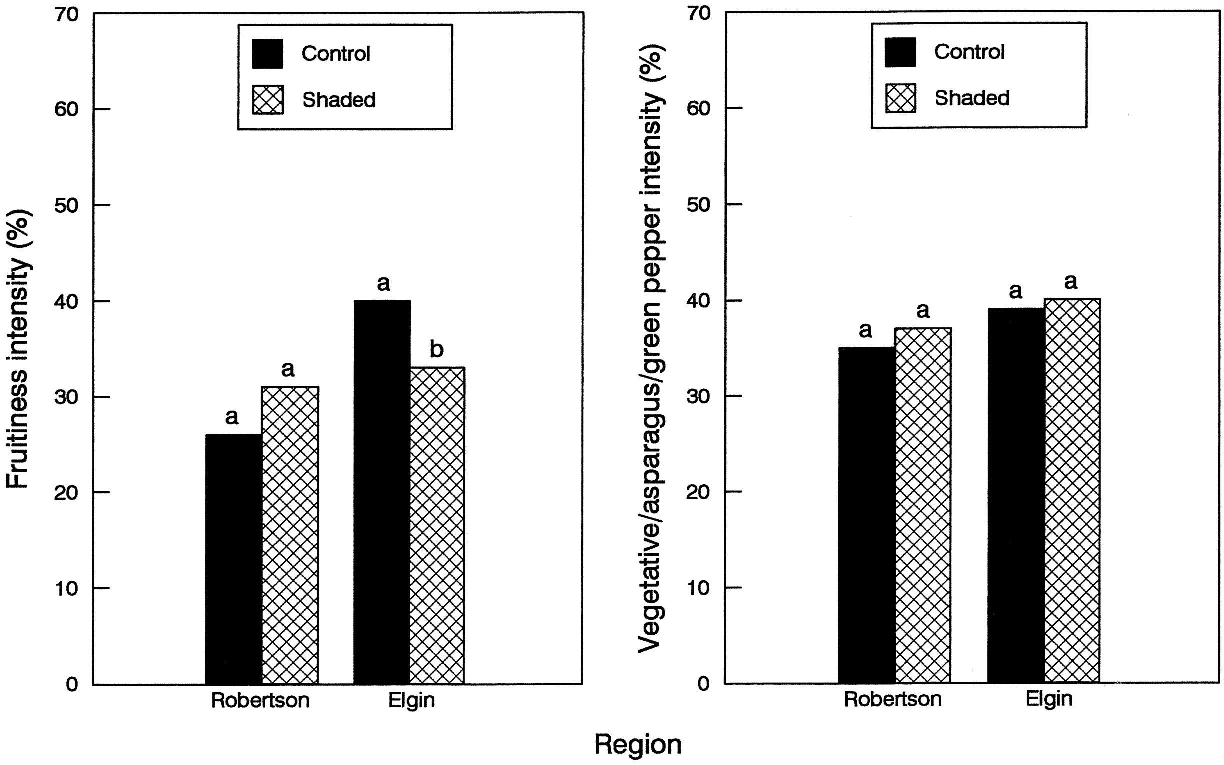

FIGURE 14

Effect of canopy microclimate on aroma intensities of Sauvignon blanc wines from the Robertson and Elgin regions (1998 season). Treatments in each region designated by the same letter do not differ significantly (p≤0,05).

respective grape norisoprenoid and ibMP levels at ripeness. The 1998 Sauvignon blanc wines lacked prominent cultivar-typical characteristics and virtually no differences in green pepper/-asparagus intensities between treatments occurred, which is in agreement with the relatively low ibMP concentrations of the respective grapes at ripeness (Figs. 7 and 9). In a ranking evaluation of the 1998 wines, however, the panel indicated that the wines produced from the shaded treatments had more intense green pepper/grassy aromas and higher quality than the control wines in 100% of the cases. Wine composition can differ markedly between wines from climatically-different regions (Marais *et al.*, 1992), and a large number of aroma components are involved. Therefore it is not suggested that the measured components are the only ones involved in Sauvignon blanc characteristics. Futhermore, it is common knowledge that aroma components manifest differently in different media, depending on the presence of other aroma-enhancing components. Therefore the perceived aroma nuances in this study could have been masked or enhanced by the synergistic action of different aromas present.

Considering the above-mentioned results, it can be expected that prominent differences in aroma component concentrations and wine sensory characteristics may be possible between climatically-different regions during a cool season, but not necessarily in a warm season. It is clear that basically two different wine styles, i.e. the typical green pepper/asparagus style and the more tropical/fruity style were produced in the three regions in the cooler 1997 season. The results indicate that cooler regions and/or more shade are needed for the first, and warmer regions and/or more sunlight exposure for the second style. Wines of both styles can be of high quality and it remains the choice of the winegrower to manipulate, within the limits of his region, light exposure of the grapes (and to a certain extent also temperature), in order to obtain the style that is preferred. Whatever the choice, the following basic principle should be taken into account. Optimum ripeness, yielding maximum Sauvignon blanc wine quality, would be that stage where a sufficient level of ibMP is still present in the grapes, i.e. above its threshold value (2 ng/*l*) to obtain the typical green pepper/asparagus nuances, and where it is complemented by a sufficiently developed level of other herbaceous, fruity and tropical aromas.

CONCLUSIONS

There appears to be a definite relationship between the concentrations of aroma components in grapes, such as monoterpenes, C_{13}-norisoprenoids and ibMP, and microclimatic parameters such as within canopy temperature and solar radiation. Macro- and microclimatic differences between regions and seasons manifested in Sauvignon blanc grape aroma composition and could explain most of the observed tendencies. It is not suggested that solar radiation and temperature are the only parameters that affect the development or degradation of the above-mentioned components, since too many factors are involved. Nevertheless, from the present and previous studies they appear to be of particular significance.

Canopy microclimate can, to a certain degree, be manipulated by viticultural practices to obtain grapes that will produce wine with the desired aroma composition, character and quality. This appears to be easier in a cooler than in a warmer season. Two Sauvignon blanc wine styles, i.e. the green pepper/asparagus style and the tropical/fruity style, can be obtained by the selection of appropriate cultivation localities and canopy management practices. The ideal is that each style should have nuances of the other. Generally, grapes in cooler regions would benefit from more sunlight exposure, while those in warmer regions would benefit from more shade. Negative effects of too high temperatures and too much sunlight exposure, or too low temperatures and lack of sunlight exposure on grape and wine quality should be borne in mind. Depending on the macro- and mesoclimate, certain localities would naturally not be suited for the cultivation of a climatically-sensitive cultivar such as Sauvignon blanc. It is, however, possible that most wine regions in South Africa have specific locations, where Sauvignon blanc could be cultivated successfully and investigations are in progress to locate such "cooler" areas in the warmer regions.

The possibility exists of using microclimatic parameters as indicators or predictors of grape and wine quality, instead of less-easily measurable aroma components, and is the subject of ongoing research. It would also make more sense to apply parameters that would give more representative information of the whole ripening process, rather than monitoring quality at harvest only. Additional data have to be collected during forthcoming vintages from different regions in order to better understand the complex interaction between light, temperature and aroma development, and to further refine existing guidelines for optimum canopy management for the production of maximum quality grapes and wines in all suitable regions.

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