Composition of Sauvignon blanc Grapes as Affected by Pre-véraison Canopy Manipulation and Ripeness Level

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The implications of pre-véraison canopy management and ripeness level (19°B and 21°B) on microclimate and grape and must composition were determined on intensively micro-sprinkler irrigated *Vitis vinifera* L. cv. Sauvignon blanc/110 Richter vines, grown on a vertical trellis in the Breede River Valley of South Africa. Rows were east-west orientated and vines spaced 2.75 m x 1.5 m. Spurs were spaced approximately 15 cm apart. Canopy management consisted of different combinations of seasonal practices (suckering, shoot positioning, topping, leaf thinning) during the pre-véraison growth period (just after budding to pea size berry) in order to accommodate foliage and to improve the canopy microclimate. Treatments that included leaf thinning improved the light conditions in the canopy without a noticeable effect on other microclimate parameters as well as bunch and berry sap temperature. The must pH remained relatively stable, with an increase in ripeness level from 19°B to 21°B, whereas the rest of the measured grape composition components followed a decreasing pattern during this period. Treatments that included leaf thinning tended to increase titratable acidity and decrease pH at both ripeness levels. Additional leaf thinning (up to the lower half of the canopy at pea size) increased the glucose and fructose concentrations without changing their ratio. It also decreased the malic acid concentrations of the berries, whereas the free-amino-nitrogen content of the must was stimulated. Furthermore, leaf thinning in general increased the monoterpene content (fruity aroma) and apparently enhanced the 2-methoxy-3-isobutylpyrazine content (grassy/green pepper aroma), thereby increasing the total measured aroma profile. Both palate and flavour profiles were therefore changed by applying pre-véraison seasonal canopy management. The data emphasised the importance of the correct timing and application of canopy management. This seemed to be of great significance in the realisation of an improved grape composition, even for S. blanc subjected to a relatively hot terroir.

It is well known that macro/meso-climate affects grape composition and wine quality (Coombe, 1987, 1989). The sensitivity of the nitrogen-containing 2-methoxy-3-isobutylpyrazine (ibMP) compound, typically occurring in cultivars such as Sauvignon blanc, Cabernet Sauvignon and Sémillon (Lacey *et al.*, 1991) under conditions of high light intensity and/or high temperature, has already been shown (Lacey *et al.*, 1991; Allen & Lacey, 1993; Marais *et al.*, 1999). The resulting reduction in grassy/green pepper-like aroma of the wine is a matter of concern to growers and winemakers, particularly in the case of S. blanc.

The value of canopy management for obtaining and improving grape and wine quality in vineyards where it is required, because of injudicious long- and short-term decisions during establishment and cultivation, has been shown unequivocally (Kliewer *et al.*, 1988; Koblet, 1988; Candolfi-Vasconcelos & Koblet, 1990; Smart *et al.*, 1990; Stapleton & Grant, 1992; Hunter *et al.*, 1995; Hunter, 2000; Volschenk & Hunter, 2001a, 2001b). Since canopy management (along with pruning, training and trellising) is primarily focused on altering canopy components (shoot position and orientation), the microclimate that the grapes are subjected to during development is also changed, mostly in favour of improved light distribution in the canopy. Judicious changing of the physical appearance of the canopy also has physiological implications that virtually always comprise a change in the source:sink relationships in the grapevine and a simultaneous improvement in photosynthetic activity and export of photo-assimilates from leaves to sinks such as the berries (Johnson *et al.*, 1982; Hunter & Visser, 1988a, 1988b, 1988c; Candolfi-Vasconcelos & Koblet, 1990; Hunter *et al.*, 1995; Koblet *et al.*, 1996). Marrying the canopy microclimate required for the improvement of viticulturally-essential parameters – such as bud burst, bud fertility, disease control, the accumulation of well-known quality-determining compounds (e.g. sugars, organic acids, amino acids, phenolics, monoterpenes) and berry pH with a sufficient, quality-contributing occurrence of typical character in the grapes of particularly S. blanc remains a challenge under different environmental and cultivation conditions.

In this study the effect of judicious canopy management as well as ripeness level on the presence of some flavour- and palate-determining compounds in S. blanc grapes produced in a relatively hot terroir was investigated. The study was also aimed at elucidating the importance of creating improved metabolic func-

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tioning of the leaves and grapes during the pre-véraison period. Indications are that events during this period may be critical in the determination of eventual grape and wine quality (Carbonneau & Deloire, 2001; Hunter & Archer, 2001, 2002; Ojeda *et al.*, 2002).

MATERIALS AND METHODS

Vineyard and viticultural practices

A visually vigorous 10-year-old *Vitis vinifera* L. cv. Sauvignon blanc (clone SB10) vineyard, grafted onto 110 Richter (clone RQ28A), and situated in the Robertson region (semi-arid Breede River Valley of the Western Cape – Winkler Region IV) (Hunter & Bonnardot, 2002) on a Hutton soil (Soil Classification Working Group, 1991) was used. Vine rows were orientated approximately north-east to south-west, spaced 2.75 m x 1.5 m and cordon trained to a Lengthened Perold (Vertical Shoot Positioned) System (Zeeman, 1981). Two-bud spurs were spaced 15 cm apart. Intensive micro-sprinkler irrigation was applied.

Treatments

Three treatments comprising different combinations of seasonal canopy management practices were applied: 1) suckering, shoot positioning, topping; 2) suckering, shoot positioning, topping, leaf thinning at berry set; 3) suckering, shoot positioning, topping, leaf thinning at berry set and pea size. Treatments were harvested at ripeness levels of 19°B and 21°B, respectively. Shoot positioning consisted of vertical positioning of shoots in line with corresponding spurs. Suckering consisted of the removal of shoots not located on spurs at approximately 30 cm main shoot length. Topping (30 cm above the top wire) was done twice during the period berry set to pea size and entailed the removal of up to 30 cm of shoots, resulting in a remaining primary shoot length of approximately 1.4 m. Leaf thinning (33%) was done evenly from side to side in the canopy on all leaves, i.e. on primary and secondary shoot leaves (approximately 30% of leaves removed during thinning consisted of leaves situated on lateral shoots), at either berry set or at berry set and pea size berry stages (Hunter *et al.*, 1995). At berry set, leaf thinning was done in the bunch zone and at pea size berry, thinning was done in the bottom half of the canopy above the bunch zone.

Canopy measurements

Light intensity in the bunch zone of the canopy was measured during mid-morning (from 10:00) by means of a LICOR Line Quantum Sensor and expressed as a percentage of ambient light intensity determined in the vine row. Air flow and temperature in the bunch zone were measured using a Kane-May 4003 thermo-anemometer, whereas relative humidity was measured with a Kane-May 8000 humidity meter. Berry sap temperature was determined inside the intact berry and bunch temperature was determined inside the bunch between the berries by using an ETI 2202 thermometer fitted with a probe. Berries and bunches were randomly selected. The probe was inserted into the pulp of the berry. Canopy density was determined after the point quadrat method described by Smart (1982). All measurements were performed immediately before harvest in at least three randomly selected positions per replicate. The percentage canopy gaps and bunch exposure was visually scored for every replicate according to a score card based on that of Smart *et al.* (1990) (Hunter, 1999).

Yield components

Yield values represent total yield from all replications per treatment. Treatments were harvested on the same day and soluble solids (°Balling), titratable acidity (as g/L tartaric acid) and pH were determined from a representative bunch sample consisting of at least seven bunches.

Malic, tartaric and citric acid as well as glucose and fructose extraction from berries and analyses by HPLC were performed as described by Hunter *et al.* (1991). Grape monoterpene and ibMP extractions and analyses by means of GC and GC-MS were done according to Marais *et al.* (1996). Relative individual monoterpene concentrations were summarised as described by Marais *et al.* (1999). Free-amino-nitrogen (FAN) was determined according to an Auto Analyser method using ammonium sulphate as reference (Anonymous, 1974).

Statistical layout and analyses

Treatments were replicated five times with five vines per replicate in a randomised block design and applied for three years. Buffer rows and vines were not included in the experimental layout. Mean values of the last two years of the experiment (1994/95 and 1995/96) are presented. Student's t-LSD test was used to determine significant differences.

RESULTS AND DISCUSSION

Canopy management treatments that included leaf thinning increased light conditions in the canopy (Table 1). In spite of this, other microclimate parameters (temperature, relative humidity, air flow) as well as bunch and berry sap temperature were largely unaffected. The random leaf thinning resulted in a canopy that allowed sunlight to penetrate in such a way that the interior leaves and bunches received diffused (filtered) sunlight, which was recognised in the vineyard by the canopy shadow having small, evenly distributed sun-flecks (Hunter & Visser, 1990a).

Average yield and bunch rot amounted to 15.8 ton/ha and 0.6%, respectively, with no significant differences between treatments. The must titratable acidity as well as FAN content decreased with an increase in ripeness from 19°B to 21°B, whereas pH was not affected during this period (Table 2). Leaf thinning tended to increase the titratable acid content and decrease pH at both ripeness levels. An additional leaf thinning at pea size berry increased the FAN content of the must, resulting in a higher FAN:°B ratio. The presence of amino acids is generally considered to be favourable to fermentation and flavour development in wine (Rapp & Versini, 1996). The glucose and fructose content of the berries decreased with an increase in ripeness (Table 3). This most probably resulted from an increase in berry volume, a possible reduction in sucrose production because of leaf senescence and a reduced sink capacity of the berry (Hunter & Ruffner, 2001). Translocation of sucrose from the leaves to the berries would therefore also have been affected at the later stage of ripeness. An additional leaf thinning at pea size had a stimulating effect on the occurrence of these two hexoses, indicating enhanced leaf function and sucrose translocation from the leaves and/or invertase activity in the berries (Hunter & Ruffner, 2001). The photosynthetic activity of leaves is known to be increased by leaf thinning (Hunter, 2000). Carbohydrates are essential precursors for the formation of secondary compounds and availability is therefore critical. As expected, individual organic acid concentrations decreased with an increase in ripening (Table 3). An additional leaf thinning at pea size reduced the malic acid concentration in the berry, leading to a higher tartaric acid:malic acid ratio.

Given the apparently lower pH in the case of the canopy management treatments that included leaf thinning, this may indicate a reduction in the translocation of potassium to the grapes of these treatments, restricting potassium tartrate formation and a reduction in pH buffering capacity in the berries and must (Ruffner, 1982; Iland, 1987a, 1987b; Gutiérrez-Granda & Morrison, 1992).

The measured aroma profile apparently decreased with an increase in ripening (Table 4). Canopy management that included leaf thinning increased the monoterpene content (fruity/tropical aroma) of the berry (Table 4). Although generally low ibMP values were found [threshold value = 2 ng/L (Allen *et al.*, 1988)], the concentration of this compound was apparently also stimulated by these treatments. The total measured aroma profile therefore seemed to be elevated. The grassy/green pepper-like aroma in grapes and wine is normally maintained at higher levels when canopies are shaded and/or subjected to cooler conditions (Lacey *et al.*, 1991; Allen & Lacey, 1993; Marais *et al.*, 1999). In contrast, the fruity and tropical aroma contribution of monoterpenes to the aroma profile (Sefton *et al.*, 1994) is known to increase upon improved sunlight exposure of the grapes (Marais *et al.*, 1999). Marked changes in grape composition and wine quality, particularly colour intensity and density, total phenolic content, and cultivar character were also induced by additional leaf thinning of a slanting trellised Cabernet Sauvignon vineyard (Hunter *et al.*, 1995).

The relative maintenance of the typical aroma at a rather late berry ripening stage after proper canopy management (and resultant better canopy light microclimate) during the pre-véraison period is noticeable and may be related to a stimulation of the ibMP compound concentration already in the immature, green berry. Hashizume & Samuta (1999) found that light exposure increased both 2-methoxy-3-isopropyl- and 2-methoxy-3-isobutylpyrazine concentrations in immature grapes (up until véraison), but that it had a reducing effect on the levels of these compounds in ripening grapes. The stimulating effect found with canopy management during the pre-véraison period may be related to the increase in leaf photosynthetic activity, availability of higher levels of carbohydrate

TABLE 1

Canopy management effect on canopy appearance and microclimate of Sauvignon blanc/110 Richter during grape ripening.

Canopy management treatment	Canopy appearance				Microclimate				
	Gaps (%)	Density (leaf layer number)	Bunch exposure (%)	Light intensity (μmol/m²/s)	Temp (°C)	Rel Hum (%)	Air flow (m/h)	Bunch Temp (°C)	Berry sap temp (°C)
Suckering, shoot positioning, topping	20	4	10	30.9b*	30.8a	31.1a	18a	30.3a	30.5a
Suckering, shoot positioning, topping, leaf thinning at berry set	20	4	20	52.8ab	30.8a	31.0a	20a	30.5a	31.0a
Suckering, shoot positioning, topping, leaf thinning at berry set & pea size**	30	4	20	59.1a	30.2a	30.8a	21a	29.7a	30.8a

*Values followed by the same letter do not differ significantly ($P \leq 0.05$) for each parameter.

**Suckering entails removal of shoots not located on spurs. Shoot positioning entails vertical positioning of shoots in line with corresponding spurs. Leaf thinning entails random removal of approx. 33% leaves at berry set in the bunch zone and at pea size in the lower half of canopy.

TABLE 2

Ripeness level and canopy management effect on grape and must composition of Sauvignon blanc/110 Richter.

Ripeness level (°B)	Canopy management treatment	Soluble solids (°B)	Titratable acidity (g/L)	pH	Free-amino-nitrogen (mg/L)	FAN: °B ratio
19	Suckering, shoot positioning, topping	19.2b*	11.9a	3.01a	977.5abc	51.0ab
	Suckering, shoot positioning, topping, leaf thinning at berry set	19.3b	12.1a	2.97ab	973.0abc	50.7ab
	Suckering, shoot positioning, topping, leaf thinning at berry set & pea size**	18.9b	12.3a	2.96b	1070.0a	55.8a
21	Suckering, shoot positioning, topping	21.3a	9.7b	3.00ab	895.0c	42.2d
	Suckering, shoot positioning, topping, leaf thinning at berry set	20.7a	9.8b	2.96b	894.6c	43.4cd
	Suckering, shoot positioning, topping, leaf thinning at berry set & pea size	21.3a	10.2ab	2.97ab	1015.0ab	47.8bc

*Values followed by the same letter do not differ significantly ($P \leq 0.05$) for each parameter.

**Suckering entails removal of shoots not located on spurs. Shoot positioning entails vertical positioning of shoots in line with corresponding spurs. Leaf thinning entails random removal of approx. 33% leaves at berry set in the bunch zone and at pea size in the lower half of canopy.

TABLE 3

Ripeness level and canopy management effect on grape composition of Sauvignon blanc/110 Richter.

Ripeness level (°B)	Canopy management treatment	Glucose + Fructose (mg/g dry mass)	Glucose: Fructose ratio	Organic acid (mg/g dry mass)			Tartaric acid: Malic acid ratio
				Citric acid	Tartaric acid	Malic acid	
19	Suckering, shoot positioning, topping	733.02b*	1.04ab	2.18ab	32.65a	20.69a	1.65d
	Suckering, shoot positioning, topping, leaf thinning at berry set	734.43b	1.04ab	1.99bc	33.33a	19.54a	1.76cd
	Suckering, shoot positioning, topping, leaf thinning at berry set & pea size**	768.25a	1.05a	2.25a	31.66ab	14.15b	2.31ab
21	Suckering, shoot positioning, topping	717.85bc	1.02b	1.94bc	29.98ab	14.21b	2.24ab
	Suckering, shoot positioning, topping, leaf thinning at berry set	711.48bc	1.01b	1.92c	28.95ab	13.97b	2.12bc
	Suckering, shoot positioning, topping, leaf thinning at berry set & pea size	735.03b	1.01b	1.94bc	28.73ab	11.48b	2.66a

*Values followed by the same letter do not differ significantly ($P \leq 0.05$) for each parameter.

**Suckering entails removal of shoots not located on spurs. Shoot positioning entails vertical positioning of shoots in line with corresponding spurs. Leaf thinning entails random removal of approx. 33% leaves at berry set in the bunch zone and at pea size in the lower half of canopy.

TABLE 4

Ripeness level and canopy management effect on grape composition of Sauvignon blanc/110 Richter.

Ripeness level (°B)	Canopy management treatment	Total monoterpene (relative conc.)	2-Methoxy-3-isobutylpyrazine (ng/l)
19	Suckering, shoot positioning, topping	15.71bc*	2.43a
	Suckering, shoot positioning, topping, leaf thinning at berry set	19.08a	3.01a
	Suckering, shoot positioning, topping, leaf thinning at berry set & pea size**	19.00a	2.79a
21	Suckering, shoot positioning, topping	14.40c	2.40a
	Suckering, shoot positioning, topping, leaf thinning at berry set	18.39ab	2.56a
	Suckering, shoot positioning, topping, leaf thinning at berry set & pea size	18.78a	3.14a

*Values followed by the same letter do not differ significantly ($P \leq 0.05$) for each parameter.

**Suckering comprised removal of shoots not located on spurs. Shoot positioning entails vertical positioning of shoots in line with corresponding spurs. Leaf thinning entails random removal of approx. 33% leaves at berry set in the bunch zone and at pea size in the lower half of canopy.

Total monoterpene concentration consists of the sum of trans-furanoic linalool oxide, cis-furanoic linalool oxide, linalool, α-terpineol, trans-pyranoic linalool oxide, cis-pyranoic linalool oxide, citronellol, nerol, and diendiol-1.

and a microclimate conducive to higher berry metabolic activity as well as transpiration rate, affecting sink activity and strength. Since ibMP is a nitrogen-containing compound, the increase in leaf nitrate reductase enzyme activity with canopy management during this period as found by Hunter & Ruffner (1997), and which is also evident from the higher FAN content of the must in this study, may also have contributed to an increased formation of this compound. Apart from the obvious reduction in concentration because of an increase in berry volume (which is restricted for a better sunlight-exposed berry – Hunter & Visser, 1990b) during ripening, the ibMP concentration in the ripe grape may therefore represent the result of a balance between the biochemical formation of the compound pre-véraison and its photo/temperature degradation post-véraison. It is thus quite possible that the well-exposed canopy and resultant metabolic, morphological, physical and source:sink ratio changes in both leaves and berries created by canopy management during the pre-véraison period (Hunter & Visser, 1988a, 1988b; Candolfi-Vasconcelos & Koblet, 1990; Hunter *et al.*, 1995; Hunter, 2000; Hunter & Ruffner, 2001) stimulated formation of the compound responsible for the typical green pepper aroma of S. blanc and that the amount formed during this period was greater than the amount degraded by sunlight/temperature during the ripening period. If this is indeed realised, the implications of pre-véraison canopy management for grape composition under cooler conditions than the area (generally classified as Winkler Region IV) in which the experiment was done as well as under conditions that would promote vigorous growth during the active growth phase would be more pronounced. Preferentially, the ripening period should be entered with a homogeneous vineyard in terms of vigour and canopy microclimate and with grapes that are at a similar level of development and having high secondary compound precursor/secondary compound/phenolic compound/flavour compound levels, high acid levels and a low pH (and higher levels of precursors for anthocyanin formation in the case of red grapes). It seems imperative to maintain a well-exposed canopy during both the pre- and post-véraison periods [i.e. to obtain maximum photosynthetic activity of all leaves pre-véraison and to focus on maximum output of younger leaves (in the apical half of the canopy and on lateral shoots) and on stimulating older leaves (especially in the lower half of the canopy) post-véraison] (Hunter, 2000; Hunter & Ruffner, 2001). It is equally important that bunches are subjected to filtered sunlight exposure during both pre- and post-véraison periods in order to obtain maximum activity and strength of these sinks. It seems reasonable to assume that the compositional changes brought about by canopy management in this study would be maintained even when harvesting at a higher ripeness level or when the climatic conditions differ from those under which this study was done.

CONCLUSIONS

It is evident that canopy management during the pre-véraison growth phase of the vine in all probability not only increased the availability of carbohydrate for accumulation in the bunches, but also changed the micro-environment around the bunches to such an extent that metabolic activity and transpiration of the berry were favoured, thereby increasing sink attraction for precursors and eventual formation of primary respiratory compounds and secondary compounds such as those responsible for the greatest part of the final palate and flavour of Sauvignon blanc at harvest. Cultivation practices which may lead to a reduction in the normal physiological performance of the vine and the accumulation of stress-related components in the grape berry should be avoided during both pre- and post-véraison periods.

Judicious selection of long-term practices will to a large extent limit the necessity of short-term, seasonal canopy management. However, the data are evidence that under circumstances where required, seasonal canopy management will greatly contribute to the exploitation of the full potential of a particular vineyard, also in the case of S. blanc. Evidently, the timing of seasonal canopy management and the way in which it is applied are of the utmost importance to create a canopy structure that would allow a favourable canopy microclimate, optimal grapevine physiological activity and an enhancement in grape composition, particularly contributing to the attainment of a specific and sufficient flavour profile and well-structured palate.

It may well be that the pre-véraison growth period of the vine has a determining role in the realisation of the eventual grape composition at harvest. In practice, cultivation during this time should be executed with the greatest care, whereas environmental events with an impact on the grapevine must receive thorough consideration and, where necessary, cultivation practices adapted accordingly.

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