Implications of grapevine row orientation in South Africa
Éffets de l'orientation des rangs des vignes en Afrique du Sud

J.J. Hunter* & C.G. Volschenk

ARC Infruitec-Nietvoorbij, Private Bag X5026, 7599 Stellenbosch, South Africa

***Corresponding author:** hunterk@arc.agric.za

Summary

Row orientation is a critical long-term viticulture practice, which may have a determining effect on grape and wine quality as well as cost efficiency on a specific terroir selected for cultivation. In the Southern Hemisphere in particular, little information is available upon which recommendations on the orientation of rows within a particular terroir, can be based. Shiraz(clone SH 9C)/101-14 Mgt was planted during 2003 to four orientations, i.e. North-South, East-West, North-East-South-West, and North-West-South-East, in the Breede River Region at the Robertson experiment farm of ARC Infruitec-Nietvoorbij, Robertson, South Africa. Vines are spaced 1.8 x 2.7 m. Photosynthetic active radiation patterns showed highest values in January. Largest differences occurred during grape ripening with the EW orientation maintaining stable, low interior canopy interception, the NS orientation displaying two clear peaks each in the morning and in the afternoon, and the NE-SW and NW-SE orientations showing peaks in the afternoon and morning, respectively. The EW orientation induced higher water retention in the canopy. Naturally higher water deficits were induced by the other row orientations, NE-SW and NW-SE orientations resulting in lowest overall leaf water potential. In line with the movement of the sun, W, SW, S, and SE canopy sides displayed lower average photosynthetic activity. Primary shoot lengths of the treatments were similar, reaching approximately 120 cm. Similar leaf area and leaf mass were found. Longer secondary shoots with higher total leaf area were found for the EW row orientation, resulting in highest secondary leaf area as percentage of primary leaf area.

Berry temperatures increased during the day, generally being 3.5 – 6 ^{0}C higher in the afternoon than in the morning. Lowest average berry temperatures for the day were found for EW orientated rows, followed by NS, NW-SE, and NE-SW orientated rows. The latter three treatments had similar berry temperatures that were approximately 1 ^{0}C higher than those of the EW row orientation. No large differences in berry temperature between canopy sides were found for any of the row orientations.

Reproductive growth parameters seem to indicate highest fertility for the NS rows and lowest for the EW rows. The lowest number of berries, but largest berries, per bunch was found for EW rows and highest number of berries, but smallest berries, for NS rows. The NE-SW and NW-SE orientations had similar berry number and size. Rot and sunburn differences were small.

The EW row orientation resulted in must soluble solid contents being higher than those of the other treatments. The pH of the treatments was similar. Highest titratable acidity was found for EW and NW-SE row orientations. Slight differences in grape skin colour occurred. Best ^{0}B:TA ratio was found for NS rows and worst ratios for EW and NW-SE rows. Wines of the different row orientations had similar anthocyanin and phenolic concentrations, although slightly lower phenolic contents seemed to occur for the EW row orientation. Preliminary wine evaluation showed good, medium intensity colour with lively fruit for all wines, but particularly for wines made from NS and NE-SW orientations. Vegetative character was perceived for the EW orientation. Data point to different styles of wine, not only in terms of taste and aroma profiles, but also in terms of alcohol content, that may be expected when a particular row orientation is selected. Results are preliminary.

Key words: Grapevine row orientation, growth, microclimate, grape composition, wine quality

© ACW, Agroscope Changins-Wädenswil 2008

Introduction

Grapevine row orientation, together with plant spacing and trellis system, are critical long-term cultivation practices that may have a determining effect on the optimal utilization of terroir, as manifested in growth, yield, grape composition, wine quality and cost efficiency. However, worldwide little is known about the impact of row orientation on vineyard performance and contributions in this regard are limited to the Northern hemisphere (mainly Switzerland and Italy) on cultivars such as Chasselas (Zufferey *et al*., 1999), Sangiovese (Intrieri *et al*., 1999) and Chardonnay (Intrieri *et al*., 1996). The only extensive research done with regard to grapevines in the Southern hemisphere comprised a numeric model developed by Smart (1973). The available scientific information is insufficient to provide a basis for decision making during establishment.

High, North-South orientated rows have highest seasonal sunlight interception (Smart, 1973). The difference in energy interception between North-South and East-West orientated rows decreases the closer the rows are spaced. North-South orientated rows are advantageous during mid-morning and mid-afternoon, during which periods the East-West orientated rows have the lowest sunlight interception in the canopies. During late morning, photosynthetic activity is high (Hunter *et al*., 1994) and high levels of sunlight interception are therefore preferred during this time. In the Northern hemisphere, Intrieri *et al*. (1996) found that East-West orientated rows of Chardonnay reduced the growth, yield and total dry mass per vine in comparison to North-South, North East-South West and North West-South East orientations. The must soluble solids and pH were not affected. With apples and pears it was found that North-South orientated rows increased the yields in comparison to East-West rows at latitudes of 42^0N and 55.3^0N, respectively (Lombard & Westwood, 1977; Christensen, 1979). However, depending on the cultivar, Devyatov & Gorny (1978) found increases of 16 – 35% in apple productions with East-West, compared to North-South, rows. De Jong & Doyle (1985) also found no differences in the total amount of light interception between North-South and East-West pear rows, at 36.4^0N latitude. According to Zufferey *et al*. (1999), the net diurnal photosynthesis of leaves on South-exposed canopy sides of East-West orientated Chasselas rows was highest during the whole growth season. The outer leaves of North-South canopies showed the highest net photosynthesis until the start of the ripening period, whereas that of the outer leaves of East-West rows was slightly higher at the end of the ripening period.

Row orientation is clearly one of the factors that determine the total amount of sunlight energy being intercepted by the grapevine canopy. However, because of the importance of direct sunlight for photosynthesis and proper exposure of canopy and grapes for yield, grape composition and wine quality, the impact of row orientation on the functioning of both leaves and grapes would also be dependent on other factors, such as the dimensions of the canopy in terms of vigour (density, length and canopy leaf composition), the time of the year, and the latitude (Smart, 1973; Hunter, 1999; Intrieri *et al*., 1999). It therefore follows logical that the terroir *per se* (e.g. soil fertility and water holding capacity, temperature range, prevailing wind, humidity, aspect), plant spacing, and trellis system, would also play a critical role in the final effect of row orientation. Clear guidelines for informed decisions regarding row orientation during establishment are required to ensure an optimal planting strategy for economic viability and top quality grapes and wine. In this study, we are determining the impact of row orientation at fixed row and vine spacing on vine performance and grape and wine quality.

Materials and Methods

Shiraz(clone SH 9C)/101-14 Mgt was planted during 2003 to four row orientations, i.e. North-South, East-West, North-East-South-West, and North-West-South-East, on a flat terroir with clayey loam soil in the Breede River Region at the Robertson experiment farm of ARC Infruitec-Nietvoorbij, Robertson, South Africa. Vines are spaced to a fixed distance of 1.8 x 2.7 m. Vines were pruned to two buds per spur and a uniform vineyard with canopies that filled the allocated space was obtained. A cover crop (rye) was sowed after harvest and killed before budding. The canopies had approximately three to four leaf layers from side to

© ACW, Agroscope Changins-Wädenswil 2008

side. Vines were supplementary irrigated every 7 days, due to this region receiving very low winter rainfall (average 150 – 300 mm per annum).

Photosynthetic active radiation (400 – 700 nm) was measured by means of Li-Cor line quantum sensors, fixed inside the canopy, either on top (measuring 180^0 upwards) or below (measuring 180^0 downwards) the cordon. Ambient radiation was recorded by means of a sensor positioned approximately 3 m above ground level. Data loggers were used to record data during the whole growth season (from October to March). Photosynthesis and water potential of exposed leaves in the bunch zone as well as berry pulp temperature were measured at 09:30, 12:00 and 15:30 on the same day approximately one month post-véraison (one month before harvest) by means of an open system ADC portable photosynthesis meter (The Analytical Development Co., Ltd., England), a Scholander-like pressure chamber (Scholander *et al*., 1965), and an ETI 2202 thermometer, respectively.

Seven shoots (including bunches) per replicate were sampled to determine total leaf area, primary and secondary leaf area, number of lateral shoots, shoot lengths, bunch and berry mass and volume, bunch rot (visual score), and chemical analyses. Total yield was determined from 20 vines per replicate. Leaf area was measured by means of a Li-Cor Model 3100 area meter. Bud fertility (number of bunches/number of shoots originating from buds allocated during pruning) was determined at the end of the season.

Total must soluble solids, titratable acidity, and pH were analysed according to standard methods. Skin anthocyanin (A_{520}) and phenolic (A_{280}) contents were determined as described by Hunter *et al*. (1991).

One wine per replicate was made according to standard techniques. Grapes of all harvests were cooled overnight to the same temperature (20 ^{0}C) before processing. Grapes were de-stemmed, crushed and the pomace inoculated with commercial yeast (VIN 13) in 60 L tanks. Alcoholic fermentation took place at a controlled temperature of 24 ^{0}C (di-ammonium phosphate and SO_2 were added). Skins were pushed through three times per day. Fermentation on the skins averaged four days, after which the pomace was pressed. Wines were analysed spectrophotometrically for anthocyanin (A_{520}) and phenolic (A_{280}) contents after proper dilution. Organoleptic evaluation was done by a trained panel.

The experiment was laid out in a randomized design, comprising four row orientations with five replicates per orientation, each confined to a separate vineyard block with surface area of 714 m^2.

Results and Discussion

Photosynthetic active radiation patterns showed highest radiation in January (data not shown). In general, radiation interception inside the canopy (measured in the bunch zone) decreased with canopy development from October to November/December, where after it increased again. The largest differences occurred during the ripening period with the EW orientation keeping stable at low interior canopy interception values, the NS orientation displaying two clear peaks each in the morning and in the afternoon and the NE-SW and NW-SE orientations showing peaks in the afternoon and morning, respectively. This was also clear from the seasonal interior-canopy radiation interception patterns (Fig. 1). The reflection from the soil (measured in the bunch zone) showed more or less similar trends, but the interception shifted towards the afternoon for the NS and NE-SW orientations, whereas the EW and NW-SE orientations showed uniform trends with optima at mid-day (Fig. 2).

© ACW, Agroscope Changins-Wädenswil 2008

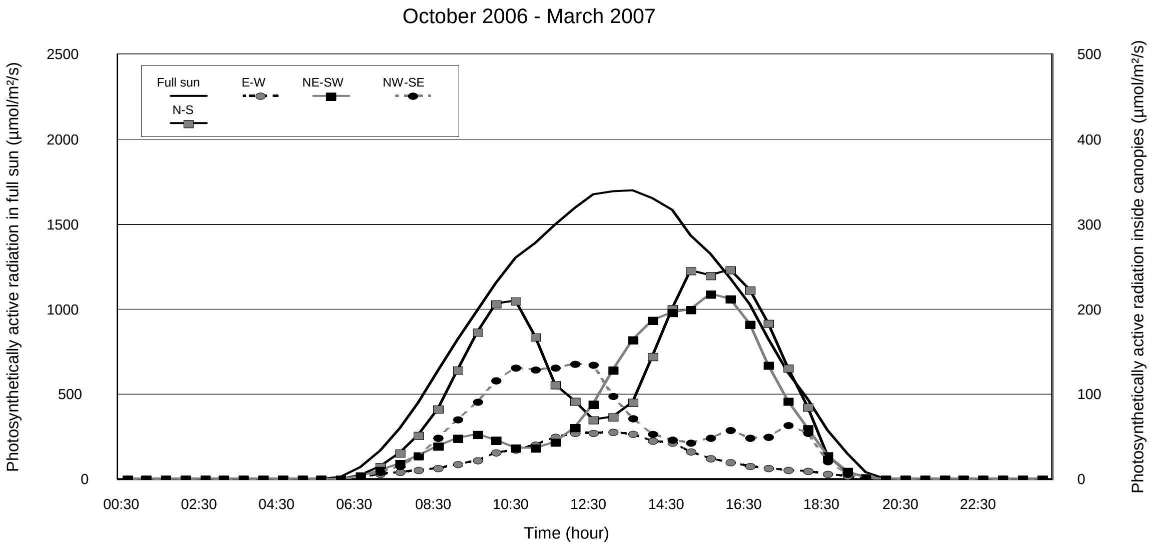

Figure 1 Average seasonal radiation intercepted outside and inside (180 degrees upwards in the bunch zone) the canopies of Shiraz/101-14 Mgt vines planted to different row directions.

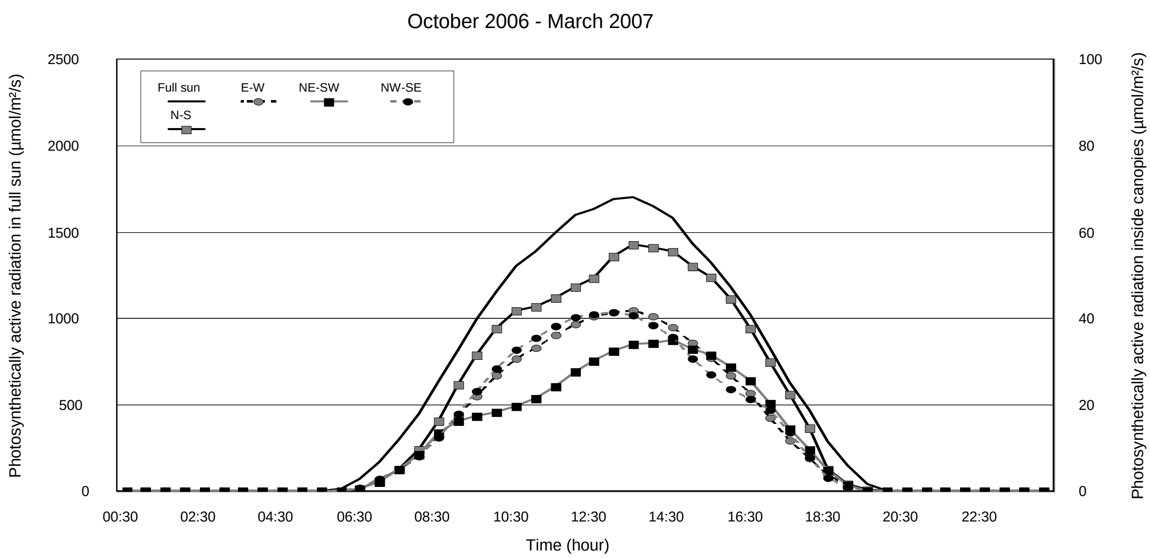

Figure 2 Average seasonal radiation intercepted outside and inside (180 degrees downwards in the bunch zone – soil reflected radiation) the canopies of Shiraz/101-14 Mgt vines planted to different row directions.

The water potential of leaves in the bunch zone noticeably decreased from the morning to noon/afternoon on either side of the canopy and for all row orientations (data not shown). The leaf water potential on either side of the canopy was different, irrespective of treatment; the canopy sides exposed towards the Northern hemisphere apparently showing higher water retention/flow (Table 1). The NE-SW and NW-SE orientations displayed lower overall water potential. The EW orientation led to higher water retention in the canopy, whereas naturally higher water deficits were induced by the other row orientations.

For the E, N and NW sides of the canopies, photosynthesis increased from morning to noon, where after it decreased; for the W, SW, S, SE and NE sides it decreased from the morning to the afternoon (data not shown). In line with the movement of the sun, the W, SW, S, and SE canopy sides displayed lower average photosynthetic activity (parallel to a lower water potential) (Table 1). The EW row orientation had highest overall photosynthetic activity.

Row orientation	Canopy side	Water potential (kPa)		Photosynthesis (mg $CO_2/dm^2/h$)	
		*Per side	Average	*Per side	Average
NS	E	-1531dc		4.66ab	
	W	-1568bc	-1550b	3.51b	4.09ab
EW	N	-1502d		5.61a	
	S	-1483d	-1492c	4.07ab	4.76a
NE-SW	NW	-1653a		4.76ab	
	SE	-1616ab	-1635a	3.41b	4.08ab
NW-SE	NE	-1602ab		3.97b	
	SW	-1593b	-1597ab	3.38b	3.68b

Table 1 Row orientation effect on leaf water potential and photosynthesis of Shiraz/101-14 Mgt.
*Average of Morning, Noon, and Afternoon measurements. Values followed by the same letter or no letter do not differ significantly (p = 0.5).

Primary shoot lengths of the different row orientations were similar, reaching approximately 120 cm (data not shown). Similar leaf area was found for the different treatments (Table 2). Longer secondary shoots (data not shown) with higher total leaf area occurred for the EW row orientation. The latter treatment also had the highest secondary leaf area as percentage of total leaf area. The average (of all treatments) percentage secondary leaf area of 64 % (percentage of total) was slightly lower than the 70 % found previously for Sauvignon blanc, Merlot and older Shiraz (unpublished data).

Row orientation	Primary leaf area/shoot (cm^2)	Secondary leaf area/shoot (cm^2)	Primary:Secondary leaf area (ratio)	Secondary leaf area as % of total leaf area
NS	1414b	2159ab	0.65	60
EW	1508a	2974a	0.51	66
NE-SW	1466ab	2056b	0.71	58
NW-SE	1487a	2225ab	0.67	60

Table 2 Row orientation effect on vegetative growth parameters of Shiraz/101-14 Mgt.
Values followed by the same letter or no letter do not differ significantly (p = 0.5).

Berry temperatures increased during the day, generally being 3.5 – 6 ^{0}C higher in the afternoon than in the morning (Table 3). The lowest increase occurred for NE-SW orientations (with high afternoon exposure) and the highest for NW-SE orientations (with high morning exposure). The lowest average berry temperatures for the day were found for EW orientated rows, followed by NS, NW-SE, and NE-SW orientated rows. The latter three treatments had similar berry temperatures that were approximately 1 ^{0}C higher than those of the EW row orientation. Interestingly, and in contrast to the general believe, no large differences in berry temperature between canopy sides were found for any of the row orientations.

Row orientation	Canopy side	Berry temperature (^{0}C)						Diurnal (Average)	
		Morning		Noon		Afternoon			
NS	E	29.8		32.0b		36.2a		32.7ab	
	W	30.1	30.0ab	32.9ab	32.5	33.7ab	35.0ab	32.2ab	32.5a
EW	N	28.7		32.8ab		33.3b		31.6b	
	S	28.5	28.6b	33.2ab	33.0	32.6b	33.0c	31.4b	31.5b
NE-SW	NW	30.1		32.4b		35.9a		32.8ab	
	SE	28.7	29.4ab	34.1a	32.2	34.9ab	35.4a	32.6ab	32.7a
NW-SE	NE	29.7		32.3b		35.1ab		32.3ab	
	SW	32.4	31.0a	33.1ab	33.7	34.1ab	34.6b	33.2a	32.8a

Table 3 Row orientation effect on berry temperature of Shiraz/101-14 Mgt.
Values followed by the same letter or no letter do not differ significantly (p = 0.5).

© ACW, Agroscope Changins-Wädenswil 2008

The reproductive growth parameters seem to indicate highest fertility for the NS rows and lowest for the EW rows (Table 4). The lowest number of berries, but largest berries, per bunch was found for EW rows and highest number of berries, but smallest berries, for NS rows. The NE-SW and NW-SE orientations had similar berry number and size. Highest yields per vine and per hectare were found for NS orientated rows, followed by NE-SW, NW-SE and EW orientated rows. Rot and sunburn values were low and only slight differences occurred between treatments (data not shown).

Row orientation	Bunches /shoot	Bunch mass (g)	Berries /bunch	Bunch vol. (cm^3)	Berry mass (g)	Berry vol. (cm^3)	Yield /vine (kg)	Yield (ton/ha)
NS	1.98a	256	188a	23.0	1.43b	1.34b	9.3a	19.1a
EW	1.70b	239	142b	224	1.74a	1.61a	6.9b	14.2b
NE-SW	1.84ab	223	158b	202	1.47b	1.41b	8.1ab	16.7ab
NW-SE	1.88ab	227	163b	212	1.52b	1.40b	8.6a	17.6a

Table 4 Row orientation effect on reproductive growth parameters of Shiraz/101-14 Mgt.
Values followed by the same letter or no letter do not differ significantly ($p = 0.5$).

Interesting results were found for grape composition (Table 5). The EW row orientation resulted in soluble solid contents being 1 ^{0}B higher than those of the others. At present, it seems that ripening was enhanced with EW row orientation; this may lead to premature harvesting because of the danger of high alcohol contents in the wine. The pH of the treatments was similar. Highest titratable acidity was found for the EW and NW-SE row orientations. Slight differences in grape skin colour occurred; it seemed not affected by berry size or pattern of sun exposure. Comparison of the ^{0}B:TA ratios with those found previously in a study regarding indicators for optimal ripeness (Hunter *et al*., 2005), showed that all ratios were inside the top category. However, the best ratio was found for NS rows and the worst ratios for EW and NW-SE rows. The results point to style differences.

Row orientation	Soluble solids (^{0}B)	pH	Titratable acid (g/l)	Ratio ^{0}B:TA	Fresh seed mass	A (520)	A (420)	A (280)
NS	23.8b	4.02ab	4.9b	4.83a	5.58b	0.41	0.10	0.47
EW	24.9a	4.02a	5.6a	4.44ab	5.78ab	0.44	0.11	0.49
NE-SW	23.9b	3.91c	5.1ab	4.67ab	6.08a	0.49	0.11	0.54
NW-SE	23.9b	3.93bc	5.5a	4.40b	5.86	0.48	0.11	0.53

Table 5 Row orientation effect on grape composition of Shiraz/101-14 Mgt
A = Absorbancy. Values followed by the same letter or no letter do not differ significantly ($p = 0.5$).

Wines of the different row orientations had similar anthocyanin and phenolic concentrations (Table 6). This may be traced to the berry size differences. Presently, results seem to indicate that EW row orientation may result in higher alcohol wines and that wines at lower alcohol may be made from NS, NE-SW and NW-SE row orientations; from the latter, best wines may be obtained from NS and NE-SW and poorest wines from the NW-SE orientations. Preliminary wine evaluation also showed these tendencies. All wines showed good, medium intensity colour with lively fruit, particularly for NS and NE-SW orientations. Vegetative characters were perceivable for the EW orientation.

Row orientation	A (520)	A (420)	A (280)
NS	0.14	0.10	1.92
EW	0.13	0.11	1.87
NE-SW	0.14	0.11	1.95
NW-SE	0.14	0.11	1.93

Table 6 Row orientation effect on wine composition of Shiraz/101-14 Mgt.
A = Absorbancy. Values followed by the same letter or no letter do not differ significantly ($p = 0.5$).

© ACW, Agroscope Changins-Wädenswil 2008

Conclusions

The data already seem to point to different styles of wine that may be expected when a particular row orientation is selected. For example, more vegetative characteristics may be expected from row orientations receiving less interior canopy radiation (EW) and predominantly morning radiation (NW-SE) during the ripening period; two styles also seem to emerge from this – a low alcohol (NW-SE) and a high alcohol (EW) style. The better wines seem to be obtained from row orientations allowing morning and afternoon grape exposure (NS) as well as predominantly afternoon exposure (NE-SW) *versus* those receiving low light exposure in the interior canopy and those of which the grapes receive predominantly morning exposure, during the grape ripening period.

References

CHRISTENSEN, J.V., 1979. Effects of density, rectangularity and row orientation on apple trees, measured in a multivariated experimental design. *Scientia Horticulturae* **10**, 155 – 165.

DE JONG, T.M. & DOYLE, J.F., 1985. The effect of row orientation on light distribution in hedgerow peach tree canopies. *Acta Horticulturae* **173**, 159 – 166.

DEVYATOV, A.S. & GORNY, A.V., 1978. Effect of espalier orientation on light status and cropping of apple trees. *Fruit Science Reports* **5**, 1 – 8.

HUNTER, J.J., 1999. Present status and prospects of winegrape viticulture in South Africa – focus on canopy related aspects/practices and relationships with grape and wine quality. In : *Proc. 11^th Meeting of the Study Group for Vine Training Systems*, 6 – 12 June 1999, Sicily, Italy, pp. 70 – 85.

HUNTER J.J., PISCIOTTA A., VOLSCHENK C.G., ARCHER E., NOVELLO V., KRAEVA E., DELOIRE A., NADAL M., 2005. Role of harvesting time/optimal ripeness in zone/terroir expression. *Proc. Joint OIV, GESCO, SASEV Intl Conference on Viticultural Zoning*, 15–19 November 2004, Cape Town, South Africa, p 466–78.

HUNTER, J.J., SKRIVAN, R. & RUFFNER, H.P., 1994. Diurnal and seasonal physiological changes in leaves of *Vitis vinifera* L. : CO_2 assimilation rates, sugar levels and sucrolytic enzyme activity. *Vitis* **33**, 189 – 195.

INTRIERI, C., SILVESTRONI, O., REBUCCI, B., PONI, S. & FILIPPETTI, I., 1996. The effects of row orientation on growth, yield, quality and dry matter partitioning in Chardonnay vines trained to Simple Curtain and Spur-pruned Cordon. In : *Proc. 4^th International Symposium on Cool Climate Viticulture and Enology*, 16 – 20 July 1996, Rochester, USA, pp. 10 – 15.

INTRIERI, C., SILVESTRONI, O., REBUCCI, B., PONI, S. & FILIPPETTI, I., 1999. The effects of row orientation on growth, yield, quality and dry matter partitioning in "Sangiovese" vines trained to free cordon and spur-pruned cordon. In : *Proc. 11^th Meeting of the Study Group for Vine Training Systems*, 6 – 12 June 1999, Sicily, Italy, pp. 254 – 262.

LOMBARD, P.B. & WESTWOOD, M.N., 1977. Effect of hedgerow orientation on pear fruiting. *Acta Horticulturae* **69**, 175 – 182.

SCHOLANDER P.F., HAMMEL H.T., BRADSTREET E.D., HEMMINGSEN E.A., 1965. Sap flow in vascular plants. *Science* **148**, 339 - 346.

SMART, R., 1973. Sunlight interception by vineyards. *Am. J. Enol. Vitic*. **24**, 141 – 147.

ZUFFEREY, V., MURISIER, F., AERNY, J. & GINDROZ, V., 1999. Bilans journaliers de CO_2 chez la vigne (cv. Chasselas) a vec des rangs orientes Nord-Sud et Est-Ouest. In : *Proc. 11^th Meeting of the Study Group for Vine Training Systems*, 6 – 12 June 1999, Sicily, Italy, pp. 235 – 244.

© ACW, Agroscope Changins-Wädenswil 2008