RELATION BETWEEN ROW AND LEAF ORIENTATION OF SYRAH/101-14 MGT

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Summary

Row orientation may have a determining effect on terroir valorization, mainly because of its effect on the total amount of sunlight energy being intercepted. Impact of row orientation on functioning of leaves and grapes would also depend on other factors, such as growth dimensions, plant spacing, trellis and latitude. Orientation of a vineyard row is critical for energy distribution and sunlight and heating effects on leaves and grapes at vineyard level. Row orientation may be a management tool to manipulate the impact of environmental stress in practice. The aim of this study was to determine the relationship between row and leaf orientation of Syrah/101-14 Mgt, planted to four different row orientations in the Robertson region of South Africa. In general, row orientation showed a clear impact on the orientation of leaves in a horizontal plane, with a significant change in the direction of primary leaf dorsal surface exposure from a early to a late ripening stage. Specific leaf weight was also affected. It is envisaged that the study will contribute to understanding the effect that row orientation may have on energy balances in the grapevine canopy and how this may impact on the seasonal dynamics of physiological parameters, such as carbon assimilation and water potential. In addition, it would provide further insight into orientating vineyard rows for a specific product objective focused on a preferred wine style.

INTRODUCTION

The orientation of grapevine rows is decisive during the establishment of a vineyard. It may have a determining effect on terroir valorization, mainly because of its effect on the total amount of sunlight energy being intercepted (Intrieri *et al.*, 1996; Zufferey *et al.*, 1999; Hunter *et al.*, 2008; Hunter *et al.*, 2010a). The impact of row orientation on the functioning of leaves and grapes would also depend on other factors, such as growth dimensions, plant spacing, trellis, canopy management, latitude, wind conditions, etc. (Smart, 1973; Intrieri *et al.*, 1999; Tarara *et al.*, 2005; Nadal *et al.*, 2009; Hunter *et al.*, 2010b).

Orientation of a vineyard row is critical for energy distribution and sunlight and heating effects on leaves and grapes at vineyard level. The initial planting decision about row orientation, and subsequent training and trellising, determine the efficiency of sunlight interception (Smart, 2010). Row orientation affects canopy photosynthetically active radiation distribution (Grifoni *et al.*, 2008) as well as berry temperature during ripening, with diurnal differences between canopy sides being more pronounced under higher ambient temperature (Hunter *et al.*, 2010). A number of mechanisms may be used by the grapevine to deal with environmental conditions and cultural practices in an effort to satisfy source and sink requirements during different stages of the growth season. Over the years, physiological changes in grapevine canopies received much attention. However, morphological contributions to physiological processes have not been systematically investigated in complex configurations such as grapevine canopies. It is generally accepted that shoot orientation, spatial distribution of leaves, leaf age, leaf exposure and environmental conditions such as light and temperature would all impact on carbon allocation and water fluxes, generally contributing to canopy function at different stages of the growth season. However, leaf orientation, being an integral factor that would impact on light interception and reflectance, light and temperature balances, and thus physiological processes (Jiang *et al.*, 2006), have not been studied to any appreciable level.

Light and temperature are the main factors impacting on sugar content, anthocyanin formation and the level and composition of aroma during grape maturation (Crippen and Morrison, 1986; Dokoozlian and Kliewer, 1996; Marais *et al.*, 1999; Spayd *et al.*, 2002; Hunter *et al.*, 2004; Chorti *et al.*, 2010). However, a combination of high irradiance and high fruit temperature can compromise berry colour and phenolic composition (Bergqvist *et al.*, 2001). Full bunch exposure leads to lower quality (Haselgrove *et al.*, 2000; Spayd *et al.*, 2002; Barbagallo *et al.*, 2007; Tarara *et al.*, 2008).

The aim of this study was to determine the relationship between row and leaf orientation in a vineyard of Syrah/101-14 Mgt, planted to four different row orientations in the Robertson region of South Africa. It is envisaged that the study will contribute to understanding the effect that row orientation may have on energy balances in the grapevine canopy and how this may impact on the seasonal dynamics of physiological parameters, such as carbon assimilation and water potential. In addition, it would provide further insight into orientating vineyard rows for a specific product objective focused on a preferred wine style.

MATERIAL AND METHODS

Vineyard: The study was done in 2009 in a Syrah(clone SH 9C)/101-14 Mgt vineyard that was planted during 2003 to four row orientations, i.e. North-South, East-West, North-East-South-West, and North-West-South-East, replicated five times on a flat terroir with clayey loam soil at the Robertson experiment farm of ARC Infruitec-Nietvoorbij in the Breede River Region, Robertson (33°5'S/19°54'E/159m), South Africa. Vines were spaced to a fixed distance of 1.8 x 2.7 m and pruned to two buds per spur. A VSP trellis with four sets of movable wires was used. Canopies had approximately four leaf layers (side to side) and were uniformly managed by means of suckering, vertical shoot orientation, shoot positioning and apical topping. Suckering consisted of the removal of shoots not located on spurs at approximately 30 cm primary shoot length. Topping was done twice during the period berry set to véraison and comprised the removal of up to 30 cm of shoots at a time. Vines were irrigated every seven days due to the region receiving low winter rainfall (average 150–300 mm per annum). Since vines were harvested at three ripeness levels (commonly at 1, 15 and 30 March), water restrictions were introduced from the last week in February.

Sampling: Sampling was replicated three times for each of the four row orientations at two dates in 2009, namely 30 January (approx. 13 °Brix – two weeks post-véraison) and 17 March (approx. 25 °Brix). Leaves were sampled from a canopy volume of 1 m width, 1.2 m high and approximately 40 cm wide and were separated according to the orientation of the dorsal side of the leaf lamina. Leaves of each group were counted and the leaf area determined by means of a LICOR Model 3100 area meter. Specific leaf mass (expressed as mg/cm^2) was determined by drying in an oven at 60 °C until constant weight.

Statistics: Data were subjected to a one-way analysis of variance (ANOVA) using Systat 10 software.

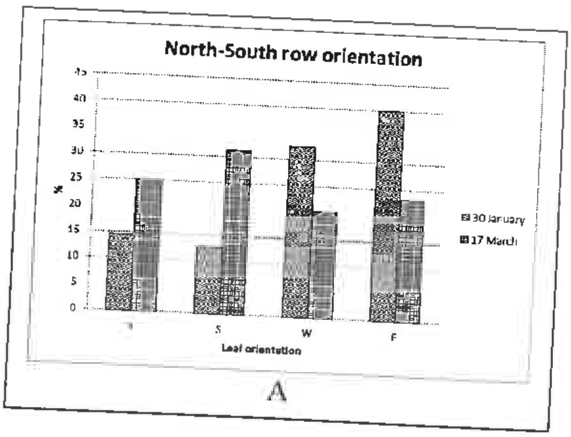
RESULTS AND DISCUSSION

The change in total surface area of primary leaves per canopy sampling volume and for each row orientation from 30 January to 17 March is shown in Table 1. Changes were most pronounced for NW-SE and NE-SW orientations, decreasing and increasing, respectively. Re-growth and a loss of leaves with ageing during the late ripening stage may be reasons for this phenomenon.

Table 1. Total surface area of primary leaves per canopy volume and per row orientation for two dates during the growth season.

Row orientation	Measuring stage	
	30 January cm^2	17 March cm^2
N-S	32 126	32 408
E-W	30 123	28 185
NW-SE	32 215	27 593
NE-SW	30 770	35 811

In general, row orientation showed a clear impact on the orientation of primary leaves in a horizontal plane (Fig. 1). At the first measuring stage, leaves were predominantly orientated with the dorsal sides of the leaf laminae perpendicular to the relevant row orientation. This orientation changed drastically after 1.5 months (from 30 January - 17 March). At the second measuring stage, a more uniform distribution was evident (Fig. 1).



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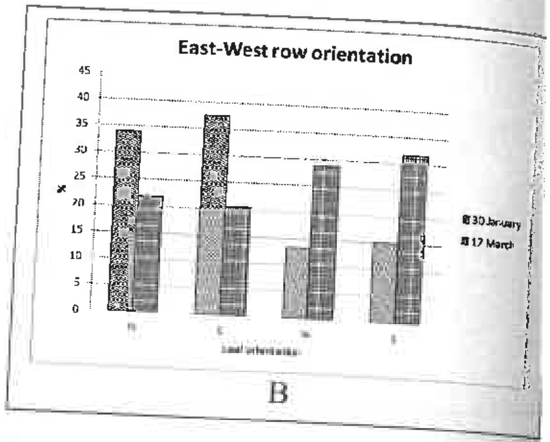

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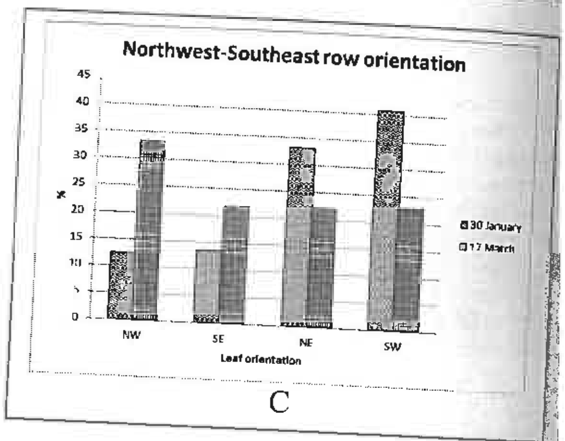

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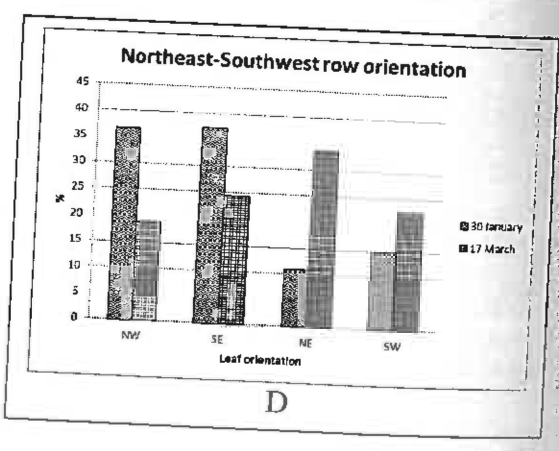

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Figure 1. Effect of row orientation on the surface of primar[y] leaves (%) orientated to different sides of the canopy.

The initial orientation of leaves in the canopy (up to the first measuring stage) may have been primarily steered by factors such as the physical restriction to leaf orientation by adjacent shoots and the impact of interior-canopy shade. Up to full canopy development, leaves of adjacent shoots would force each other outwards because of a physical lack of space. Interior shade during canopy development would result in leaves orientating themselves towards the outside of the canopy because of photo-morphogenesis and phytochrome effects and to increase photosynthetic capacity.

The orientation of the primary leaves and the changes that are observed from the first to the second measuring stage may be attributed to many factors, such as:

- *The change in the azimuth of the sun, leading to a more direct exposure of the leaf lamina to* *sunlight*. This change may have resulted in the leaves turning/rolling with their dorsal surfaces perpendicular to the rays of the sun in order to avoid photo-destruction of light absorbing compounds (chlorophyll and carotenoids) and excessive photo-chemical quenching/inhibition of photosynthesis. It is, however, unlikely that photo-damage protection would have been a high priority for the vine at this stage of the growth season.

- *The late ripening conditions that are normally associated with the introduction of drier conditions in order to concentrate the berry contents.* Under such conditions, grapevine leaves tend to turn to avoid excessive water loss through transpiration and an increase in leaf temperature, especially at high mid-day temperatures. However, the elasticity of the leaves and petiole would have been low at this stage of the growth season and re-orientation of the leaves may have been difficult, also because of the physical restriction by adjacent leaves in a fully developed canopy.
- *The berry as a sink would be highly demanding regarding source supply during the early stages of berry ripening (first measurement stage).* The vines were well-watered during this time and the canopy highly functional without any obvious restrictions on photosynthetic activity and transpiration (Hunter *et al.*, 2008). However, during the last stages of ripening, the functioning of the canopy would decrease due to leaf senescence (Hunter *et al.*, 1994); at the same time, drier conditions due to water restrictions may result in the triggering of protective mechanisms.

Table 2. Specific primary leaf weight (mg/cm^2) per row and leaf orientation at two dates during the growth season.

Row orientation	Measuring stage: 30 January				Measuring stage: 17 March			
	Leaf orientation				Leaf orientation			
	N	**S**	**W**	**E**	**N**	**S**	**W**	**E**
E-W	6.6	6.3	5.7	5.9	6.0	5.6	5.7	5.7
N-S	6.6	6.3	6.9	6.7	6.3	6.0	6.3	6.3
	NW	**SE**	**NE**	**SW**	**NW**	**SE**	**NE**	**SW**
NW-SE	6.1	6.3	7.2	6.7	6.3	5.8	6.4	5.9
NE-SW	6.7	6.9	6.0	6.1	6.0	5.8	5.9	5.7

Although re-orientation as a result of photo-damage protection and low water potential may be argued as unlikely at a late stage of the growth season, high irradiance and low water availability, may lead to thermal dissipation being insufficient to protect the physiological processes, including the photosynthetic apparatus, in the leaf from thermal- and photo-destruction (Feng *et al.*, 2002). A physical process such as leaf rolling would therefore effectively reduce the light interception, especially during high temperature and evaporative demand conditions over mid-day.

The decrease in the activity of the canopy from the first to the second measuring stage seems to be supported by the specific leaf mass data showed in Table 2. It is clear that the specific leaf mass of the groups of leaves that were orientated perpendicular to the row orientation decreased from the first to the second measuring stage. This may have been related to the physiological activity of the leaves and may indicate reduced photosynthetic activity.

Although the obvious occurrence of leaf turning/rolling is not easily explicable during such relatively late stage of the growth season, it most likely resulted from a combination of the factors mentioned. Further research into this phenomenon is underway.

LITERATURE

BERGQVIST J., DOKOOZLIAN N., EBISUDA N., 2001. Sunlight exposure and temperature effects on berry growth and composition of Cabernet Sauvignon and Grenache in the central San Joaquin Valley of California. *Am. J. Enol. Vitic.*, 52, 1-7.

CHORTI E., GUIDONI S., FERRANDINO A., NOVELLO V., 2010. Condizioni microclimatiche e profilo antocianico della cv Nebbiolo. *ITALUS Hortus*, 17,3, 54-60.

CRIPPEN D.D., MORRISON J.C.,1986. The effects of sun exposure on the phenolic content of 'Cabernet Sauvignon' berries during development. *Am. J. Enol. Vitic.*, 37, 243-247.

DOKOOZLIAN N., KLIEWER. W.M., 1996. Influence of light on grape berry growth and composition varies during fruit development. *J. Am. Soc. Hort. Sci.*, 121, 869-874.

FENG Y.L., CAO K.F., FRNG Z.L., 2002. Thermal dissipation, leaf rolling and inactivation of PSII reaction centres in Amomum villosum. *Journal of Tropical Ecology*, 18, 865-876.

GRIFONI D., CARRERAS G., ZIPOLI G., SABATINI F., DALLA MARTA A., ORLANDINI S., 2008. Row orientation effect on UV-B, UV-A and PAR solar irradiation components in vineyards at Tuscany, Italy. *Int. J. Biometeteorol*, 52, 755-763.

HASELGROVE L., BOTTING D., VAN HEESWIJCK R., HØJ P.B., DRY P.R., FORD C., ILAND P.G., 2000. Canopy microclimate and berry composition: the effect of bunch exposure on the phenolic composition of *Vitis vinifera* L. cv. Shiraz grape berries. *Aust. J. Grape Wine Res.*, 6, 141 – 149.

HUNTER J.J., SKRIVAN R., RUFFNER H.P., 1994. Diurnal and seasonal physiological changes in leaves of *Vitis vinifera* L.: CO2 assimilation rates, sugar levels and sucrolytic enzyme activity. *Vitis*, 33, 189-195.

HUNTER J.J., VOLSCHENK C.G., MARAIS, J. & FOUCHÉ G.W., 2004. Composition of Sauvignon blanc grapes as affected by pre-véraison canopy manipulation and ripeness level. *S. Afr. J. Enol. Vitic.*, 25, 13 – 18.

HUNTER J.J., VOLSCHENK C.G., 2008. Implications of grapevine row orientation in South Africa. Proc. VIIth International Terroir Congress, 19 – 23 May 2008, *Agroscope Changins-Wädenswil, Switzerland, pp. 336 – 342.*

HUNTER J.J., ARCHER E., VOLSCHENK C.G., 2010a. Vineyard management valorisation. *Proc. VIIIth International Zoning Congress, 14 – 18 June 2010, Soave. 7 pp. 3 – 15.*

HUNTER J.J., VOLSCHENK C.G., BONNARDOT V., 2010b. Linking grapevine row orientation to a changing climate in South Africa. *Proc. Intervitis Interfructa Conf.,24 – 28 March 2010, Stuttgart. 60 – 70.*

INTRIERI C., SILVESTRONI O., REBUCCI B., PONI S., FILIPPETTI I., 1996. The effect of roe orientation on growth, yield, quality and dry matter partitioning in Chardonnay vines trained to Simple Curtain and Spur-Pruned Cordon. *Proc. 4th Symp. Cool Climate Viticulture and Enology, 16-20 July 1996, Rochester, USA: 10-15.*

INTRIERI C., SILVESTRONI O., REBUCCI B., PONI S., FILIPPETTI I., 1999. The effect of roe orientation on growth, yield, quality and dry matter partitioning in Sangiovese vines trained to Free Cordon and Spur-Pruned Cordon. *Proc. 11th GESCO Symp., 6-12 June 1999, Sicily, 235-244.*

JIANG C.D., GAO H.Y., ZOU Q., JIANG G.M., LI L.H., 2006. Leaf orientation, photorespiration and xanthophyll cicle protect young soybean leaves against high irradiance in field. *Environmental and Experimental Botany*,55,87-96.

LINO T., SCAFIDI P., BARBAGALLO M.G., 2007. Effetti dell'altitudine e dell'orientamento dei filari sulla qualità dell'uva ed in particolare sulla componente polifenolica della cv Pinot nero. *Quad. Vitic. Enol. Univ. Torino*, 29, 113-124.

MARAIS, J., HUNTER J.J., HAASBROEK P.D., 1999. Effect of canopy microclimate, season and region on Sauvignon blanc grape composition and wine quality. *S. Afr. J. Enol. Vitic.*, 20, 19 – 30.

NADAL M., ROZÈS N., HUNTER J.J., 2009. Canopy side sun exposure effects on bunches during ripening of Syrah/R99. *Proc.'s 16th GESCO Conference, July 2009, Davis, California, pp. 171 – 176.*

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

SMART R., 2010. Row orientation and sunburn. *Practical winery and vineyards. Nov-Dec. 42-49.*

SPAYD S.E., TARARA J.M., MEE D.L., FERGUSON J.C., 2002. Separation of sunlight and temperature effects on the berry composition of Vitis vinifera cv Merlot berries. *Am. J. Enol. Vitic.*, 53, 171-182.

TARARA J.M., FERGUSON J.C., HOHEISEL G.A., PEREZ PENA J.E., 2005. Asymmetrical canopy architecture due to prevailing wind direction and row orientation creates an imbalance in irradiance at the fruiting zone of grapevines. *Agricultural and forest meteorology*, 135, 144-155.

ZUFFEREY V., MURISIER F., AERNY J., GENDROZ V., 1999b. Bilans journaliers de CO_2 chez la vigne (cv. Chasselas) avec des rangs orientes Nord-Sud et Est-Ouest. *Proc. 11th GESCO Symp., 6-12 June 1999, Sicily, 235-244.*

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