Grapevine row orientation: a factor in microclimate, physiology, growth and yield

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A South African trial has shed further light on the effects of row orientation on various viticultural parameters such as canopy microclimate, vine growth and yield over a seven-year period.

INTRODUCTION

Terroir factors (e.g. soil, climate) and viticulture practices have layered and integrated effects on growth, yield, grape and wine quality, and cost efficiency. Inappropriate choices or mistaken execution of practices may lead to or enhance erratic behaviour in grapevines, compromising sustainability and product consistency. Generally, climatic conditions and landscape topography dictate the selection of a row orientation. Mechanisation of cultivation activities adds another layer of complexity to decision-making and expected outcomes.

The angle of incidence of the sun may affect light and temperature profiles in rows and inside canopies. Further, within a chosen trellis system, horizontal and vertical canopy dimensions (architecture) and their relation to spacing and shoot orientation/positioning also affect climatic profiles. The macro and meso-climatic and orographic conditions of a vineyard site naturally impose their influence on canopies. Climatic (e.g. temperature, wind velocity and direction, humidity) and valley floor/edaphic (e.g. soil water availability, soil fertility, drainage) conditions often force vineyard establishment towards geo-morphologically complex terroirs where aspect, slope, relief, erosion potential and the ease of practices are determining factors in row orientation. This may lead to single or multiple (contoured, curved) row orientation in the same block.

These factors can become more complex by the practicalities of production, particularly in complex terrains, which can often lead to opposing/sub-optimal row orientation decisions for specific cultivars and product objectives. Despite the importance of row orientation as a basic consideration in grapevine cultivation, sustainable production and the quality/style of grapes and wine, scientific evidence on its implications is scarce.

VINEYARD AND MEASUREMENTS

A trial was carried out in the Breede River Valley of South Africa where the effects of row orientation (north-south, NS; east-west, EW; north-east-south-west, NE-SW and north-west-south-east, NW-SE) were compared. Each row orientation was replicated five times on a flat site at fixed row (2.7m) and vine (1.8m) spacings. The vines were spur pruned (two buds), vertically-trellised Shiraz/101-14 Mgt, which were irrigated weekly at a volume of 14mm during the high season. A cover crop (rye) was sowed after harvest and killed before budding. Vines were only vertically shoot positioned and topped. Meso- and microclimate profiles were continuously monitored during three consecutive seasons by means of sensors. Meso photosynthetic active radiation (PAR) (400-700nm) was recorded approximately 0.5m on top of vineyard rows. Micro canopy filtered radiation and temperature (°C) were measured in the bunch zone. Physiological measurements were carried out during three consecutive seasons approximately six weeks after véraison (last week of February) on all treatments and replications. Average data of mid-morning (10:00), mid-day (13:00) and afternoon (16:00) leaf water potential and photosynthesis are discussed. Shoots (including bunches) were sampled at three grape ripeness levels (approximating 23°B, 25°B and 27°B) from each canopy side per treatment replicate and used for determining vegetative and reproductive growth; cane mass was measured in winter. These measurements were carried out for seven consecutive years. ▸

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RESULTS

Regional macroclimate

The Breede River Valley experiences semi-arid conditions. The pre-véraison period (from September/October to the first half of January) is warm (max. temperature 27-30°C) and the ripening period (from the middle of January to the end of March) is hot (max. temperature >30°C). The average macro temperature normally increases from approximately mid-December (around pea berry size) while maximum temperatures frequently reach more than 30°C from there on. High temperatures are unfavourable for optimal photosynthetic activity (25-30°C under field conditions) and the supply of precursors for various compounds associated with quality grape and wine composition. Under high temperatures (especially >35°C), the risk of organic acid respiration, high pH and poor colour and flavour development and maintenance is high. High photosynthetic activity (sucrose availability for transport to grapes) during the pre-véraison period would contribute to primary and secondary compound pools present in berries at the start of ripening, whereas it would largely restrict a decrease in organic acid and an increase in pH during ripening.

Vineyard mesoclimate and canopy microclimate

In line with macroclimate, ambient (mesoclimatic) photosynthetic active radiation (on top of canopies) was highest during November to January (Figure 2). Seasonal patterns of photosynthetic active radiation in bunch zones at microclimate level showed that EW-orientated rows maintained

Figure 1. Complete layout and close-up view at the treatment level of the experiment at Robertson Experiment Farm of ARC Infruitec-Nietvoorbij, Breede River Valley, Robertson, South Africa.

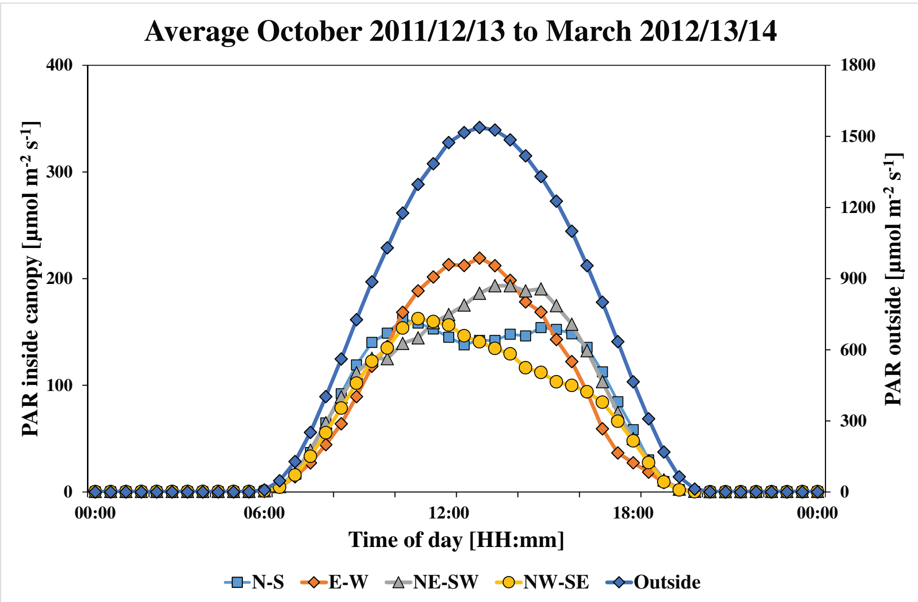

Figure 2. Micro hourly mean photosynthetic active radiation of a Shiraz/101-14 Mgt vineyard planted to four different row orientations at Robertson Experiment Farm of ARC Infruitec-Nietvoorbij, South Africa.

lower interior canopy interception than the other row orientations (Figure 2), decreasing during the season as canopies developed and peaking just after midday. The NS orientation displayed the highest values, peaking in the morning and afternoon, respectively, whereas NE-SW and NW-SE orientations showed peaks primarily in the afternoon and morning, respectively. Average soil surface reflected radiation during the grape-ripening period showed more or less similar trends, but canopy interception shifted towards the afternoon for NS and NE-SW orientations, whereas EW and NW-SE orientations showed uniform trends with optima at midday (data not shown). Reflected radiation quantities may change with different soil types (e.g. clay versus calcareous versus stony versus sandy soils) and different soil covers/mulches. The contribution of soil-reflected light to the total light component captured in vine canopies may have significant effects on the composition (e.g. far-red:red ratio) of the total light spectrum received by leaves and berries. It may also affect the enzyme activity involved in primary and secondary metabolism in these organs. Canopy porosity would, however, play a large role in this regard. Changes in soil type may also result in changes in radiant heat, which may further affect berry temperature and berry composition. Bunch zone humidity may be affected, especially with frequent irrigation during summer. Except for generally slightly lower and higher morning temperatures of EW and NS row orientations, respectively, canopy interior temperature profiles did not show marked differences between row orientation treatments (data not shown). Since the characteristics of canopy vegetation between treatments were relatively uniformly controlled, canopy interior temperature seemed primarily masked and driven by diurnal ambient air temperature.

Although the quantity (and likely quality) of light is very different between EW and NS orientations, these treatments may generally be considered as causing the most uniform canopy light distribution. However, the implications for canopy disease occurrence may be different between orientations as an inverse relationship between polyphenolics produced when leaves are exposed and the severity of downy mildew was shown; this may equally apply to grape bunches and the presence of botrytis. Berry phenolic composition reacts positively to judiciously controlled sun exposure. Row orientation may, therefore, be a natural way to enhance defence mechanisms against invading phytopathogens. This is especially critical during pre-véraison canopy development stages when pathogen infection should be prevented to secure a healthy, efficient and sufficient canopy during grape ripening. Leaves should, however, be managed in such a way that grapes are not over-exposed; if so, the positive effects may likely be nullified, even reversed.

Canopy physiology

The EW orientation displayed the highest (approx. 1250kPa) and NW-SE orientation lowest (approx. -1500kPa) leaf water potential in the morning. The other two orientations were similar at -1430kPa. Water potential of the EW orientation stayed higher, but in the other orientations it decreased to similar values in the afternoon. Diurnally, NS, NE-SW and NW-SE orientations displayed lower water potential (approx. -150kPa) than the EW orientation. The EW row orientation had the highest average photosynthesis in accordance with high stomatal conductance and transpiration (data not shown). The most uniform canopy photosynthesis occurred in the NS and NW-SE orientations. The photosynthesis trends in the sides of the various canopies paralleled diurnal light profile trends, practically following the sun movement over rows. Sides facing W, S, SE and SW displayed a lower average photosynthesis and photosynthetic efficiency (photosynthesis:transpiration ratio/carbon assimilated/water loss). A higher overall photosynthesis in the EW row orientation corresponded with a higher canopy water retention. Measurements were done during the ripening period when the sun azimuth mostly favoured the northerly-exposed canopy side. Considering the seasonal sun path, the canopy density of the EW orientated rows would be critical during the entire season and should be well managed in order to favour photosynthesis and other viticulturally important factors (e.g. bud fertility, shoot lignification for spur and cane pruning, grape ripening).

Growth characteristics

Primary and secondary shoot characteristics showed minor differences between row orientations and canopy sides. Primary shoot lengths and primary leaf area:secondary leaf area ratios averaged 110-120cm and 0.80-0.90cm, respectively, indicating good canopy height and leaf age composition. Each primary shoot had approximately 11 primary leaves and nine secondary shoots. Since vines were topped pre-véraison, primary growth was controlled and secondary shoot growth stimulated as a compensation mechanism for excess vigour. The secondary leaf area of the primary shoots on the S and SW sides tended to be lower. The SW canopy side displayed generally lower values for most characteristics. The EW-orientated vines showed a higher total leaf area/leaf mass, mainly attributed to the significantly higher secondary leaf area/leaf mass. The NS and EW orientations had higher cane mass, i.e., an average of 3.84 tonnes/ha versus 3.57 tonnes/ha for the NE-SW and NW-SE orientations. The average cane mass/vine was approximately 1.8kg.

Although bud fertility, berry set and general bunch morphology were largely unaffected by row orientation, less than two bunches per shoot were generally found for EW-orientated vines. Canopies were clearly not fully developed during the period of inflorescence primordia formation, initiation and differentiation, and vines were also already suckered during this time. Row orientation (and concomitant light intensity and quality), therefore, may not have had a pronounced impact on these processes. Bunch and berry mass and volume progressively decreased during ripening for all row orientations. Over the period of increasing grape ripeness, rachis mass (average of all orientations = 9.7g) decreased by only 5%, whereas bunch mass (average of all orientations = 196g) decreased by 15%. Berry mass at approximately 23°B, 25°B and 27°B was 1.51g, 1.38g and 1.27g, respectively. The berry mass of the EW orientation was, respectively, 5%, 7% and 6% higher than the average for the rest of the row orientation treatments at the different ripeness levels. The EW row orientation (south side in particular) resulted in consistently higher berry mass and volume. Canopy radiation profiles at critical times during the day (and season) were most likely impacting factors on berry size and for EW, more favourable whole vine water relation status may have been a primary causal factor. Total leaf area (10-12cm^2/g) fresh mass values showed equal balance for the differently orientated vines, aligned with generally acknowledged viticulture criteria; secondary leaf area was the largest contributor to the ratio. Primary, secondary and total leaf area values/g of fresh berry mass confirmed the significant role that secondary leaves may play in overall canopy capacity, in extending the harvesting window and in the build-up of reserves after harvest, irrespective of row orientation.

Yields

Overall average yields (over ripeness levels) of NS, EW, NE-SW and NW-SE orientations were 18.2, 17.1, 17.1 and 17.4 tonnes/ha, respectively (Table 1, see page 45). Average yields (over treatments) for the seven-year monitoring period varied from 19.2t/ha at ripeness level 1 (approx. 23°B) and 17.4t/ha at ripeness level 2 (approx. 25°B), to 15.9t/ha at ripeness level 3 (approx. 27°B). Total yield losses (over treatments) from ripeness level 1-2 and from ripeness level 2-3 averaged 9.5% and 8.6%, respectively, whereas from ripeness level 1-3 it averaged 17.3%. This yield loss with time appeared to be mainly attributed to a decrease in berry mass. Changes in berry mass:rachis mass ratio predominantly appeared from the second ripeness level, showing an almost 5% higher average over ripeness levels and a more than 6% higher average at the final ripeness level for EW orientated vines. The ratio of the NE-SW orientation seemed lowest overall.

These trends have high economic impact as producers (income mostly based on bunch yield) and wineries (income depending on berry yield) alike would gain or suffer losses depending on the timing of harvest and the yield price point, especially in regions where environmental factors (such as dry and hot conditions) favour high plant water deficits. Yields would decrease with longer bunch hang time and harvesting at lower ripeness levels would yield higher berry mass/total bunch mass; this would progressively decrease with an increase in ripeness level. The timing of harvesting is therefore critical for crop quantity and quality and overall sustainability.

Table 1. Row orientation and ripeness level effect on the yield of Shiraz/101-14 Mgt [at ripeness levels 1 (approx. 23°B), 2 (approx. 25°B) and 3 (approx. 27°B)].

Row orientation	Avg. yield (2007/08 – 2013/14)					
	Ripeness 1 (tonne/ha)	Ripeness 2 (tonne/ha)	Ripeness 3 (tonne/ha)	% Yield loss Ripe 1–Ripe 2	% Yield loss Ripe 2–Ripe 3	Total % yield loss Ripe 1–Ripe 3
NS	19.99	18.22	16.50	8.87	9.40	17.44
EW	18.37	17.05	15.87	7.18	6.91	13.60
NE-SW	19.41	16.75	15.19	13.73	9.30	21.75
NW-SE	18.95	17.39	15.86	8.23	8.78	16.29
Avg.	19.18	17.35	15.86	9.50	8.60	17.27

Yield consistency

The statistics across seven vintages from each row orientation treatment showed that for ripeness levels 1, 2 and 3, the NS row orientation consistently yielded above average, while the EW row orientation performed below average at ripeness levels 1 and 2 and on average at ripeness level 3. The NE-SW orientation had above average yield at ripeness level 1, whereas it performed below average at ripeness levels 2 and 3. The NW-SE orientation showed roughly average yields for all ripeness levels. Producers rather prefer predictable production and income and stability is, therefore, crucial in addition to the specific yield quantity of a row orientation; the NS orientation was stable as well as producing the highest yield. Conversely, NW-SE was stable at an average level and EW and NE-SW were variable.

Generally, the highest yields over the different seasonal time periods, and at all ripeness levels, were obtained with NS orientated rows. The yields of the other row orientation treatments varied according to seasons and ripeness level; at ripeness level 1, NE-SW was followed by NW-SE and EW; at ripeness level 2, NW-SE was followed by EW and NE-SW; and at ripeness level 3, EW was followed by NW-SE and NE-SW. Yields from the canopy sides of the different row orientations showed minor differences that progressively diminished the higher the grape ripeness level. In line with berry mass and berry mass:rachis mass findings, EW-orientated vines showed the lowest overall yield losses from low to high ripeness levels. Considering cane mass, the lowest ratio of yield:cane mass was found in the EW row orientation treatment (4.48), increasing for NW-SE (4.82), NS (4.90), and NE-SW (4.91).

General

Trellising (e.g. bush/goblet, vertical or horizontal architecture) may mitigate or magnify the positive and negative viticultural (and potential oenological) effects of row orientation. Microclimatic-efficient, uniform canopies within practical norms of trellising systems are necessary to supply primary compounds (sucrose, amino acids, minerals, etc.) and hormones to bunches and reserve compartments (roots, trunk, cordon, shoots/canes). The capacity for sustained and predictable yields and protection from extreme environmental/climatic events that may be detrimental to berries at physical/morphological, sanitory and physiological/biochemical levels, should be maintained. Sunlight exposure and ambient temperature have differential effects under field conditions and are well-known regulating drivers of the whole plant and berry size (along with water availability, evapotranspiration, transpiration, etc.) and the myriad of biochemical/physiological processes taking place pre- and post-véraison in canopies and grapes. The oenological quality potential of grapes is largely determined by these environmental factors that have already been linked to the matrix of sugars, anthocyanins, flavonols, flavanols/tannins, terpenes, carotenoids and methoxypyrazines in red and white grapes.

Different cultivars may vary in their vegetative and reproductive response to vineyard row orientation. Reaction may depend primarily on the sensitivity of the cultivar to the main factor influenced by row orientation, that is, the meso-/microclimate (especially diffused and direct radiation, according to altitude and solar path at any given latitude). Energy/heat balances and concomitant canopy and grape physiological processes would naturally respond. If cultivar sensitivity to direct radiation and temperature is high, yields may be lower. Management practices leading to overly-exposed canopies and grapes may enhance the quantitative losses with further grape ripening, while the eventual taste and flavour

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profiles of grapes and wine of both red and white cultivars may change, most likely negatively. Row orientation as a viticulture practice therefore has a critical role in the quest for grape and wine quality/style.

CONCLUSIONS

Row orientation is crucial in determining canopy microclimate and it affects grapevine behaviour at levels of leaf function, bud fertility, yield, berry development, berry temperature, berry composition, shoot lignification and whole plant health, thus driving sustainable yields and grape composition.

Summer and winter parameters indicate a change in growth balances/ carbon partitioning (between photosynthesising, reproductive and perennial storage tissue) with row orientation.

The ideal row orientation depends on yield and grape and wine style objectives/targets and thorough consideration of relevant terroir conditions, including soil, climate, topography and cultivation practices; haphazard choices would increase production costs and are expensive to modify/reverse.

Row orientation complements other viticulture practices and a judicious, intelligent best practice strategy involving all practices is required to avoid a diminished impact and obtain the true reflection of a chosen row orientation in final products.

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