A few thoughts on grapevine training systems

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Which criteria should decide the choice of a training system? Why use the Lyre instead of the Vertical Shoot Positioning (V.S.P.)? What are the advantages (if any) of the Smart-Dyson over the Goblet (bush vine)?

This article will try to give some information and guidelines on how to make a decision regarding the choice of training and pruning systems and will give some information regarding the ratio leaf to fruit. The article is presented using a Q&A format to simplify the reading and to help promote discussions and experimentation on training systems.

What is vine architecture?

Vine architecture is the result of the training system which includes the pruning and the trellis system. The geometry of plantation (distance between vines and rows represents the density of plantation) is part of vine architecture. The way a cultivar will grow, the capacity of the soil, the rootstock if we include the subterranean architecture, will influence the vine architecture.

How does a pruning system work?

Pruning is necessary to maintain the health and to control the productivity of the vine on a long term basis. A pruning system is chosen according to a) the number of latent buds per vine or m^2, which will determine the yield per vine or m^2; b) the number of primary shoots per surface unit which will be according to the number of buds per spur (cordon) or per cane (Guyot) (Figures 1 and 2). The Guyot is known to increase the fertility for some cultivars. The bud fertility is related to the position of the latent buds on a cane and there is a gradient from bottom to top. The buds' fertility along a primary shoot follows a Gaussian pattern.

What does a training system do?

A training system helps to control and regulate canopy growth and exposure of the leaves and grapes to light, wind and humidity (Figure 3). The growth of the laterals will depend on the vigour of the terroir unit (Figure 4). The laterals are responsible of the width of the canopy. A good training system will optimise:

a) a ratio exposed leaf area /yield (per vine or m^2) ;
b) a ratio exposed leaf area/shaded leaf area;
c) a ratio primary and secondary shoots;
d) the bunch microclimate.

How the yield per bud/vine is determined?

The yield per bud/vine is determined over two seasons (two years in area with real winter or two seasons the same year in tropical climate). It is cultivar and climate (light, temperature, wind) related. The vine's bud fertility/productivity occurs over two years with the following main phonological stages:

Year n

- Differentiation of inflorescence's primordia (= first step of inflorescences formation) in the new latent bud.

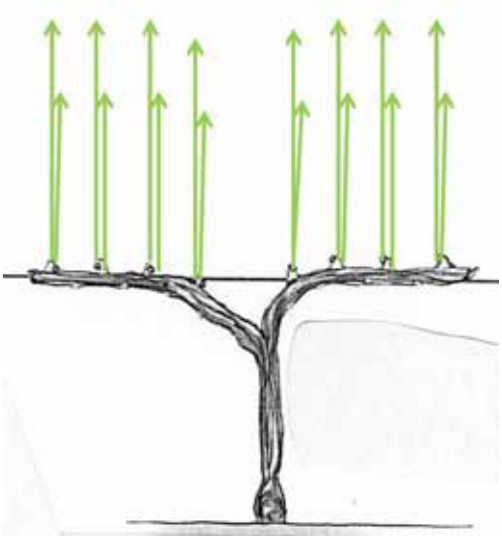

FIGURE 1: Pruning system named cordon de Royat. The number of primary shoots will be determined by the number of latent buds per spur. The density of the vegetation will depend on the distance between spurs.

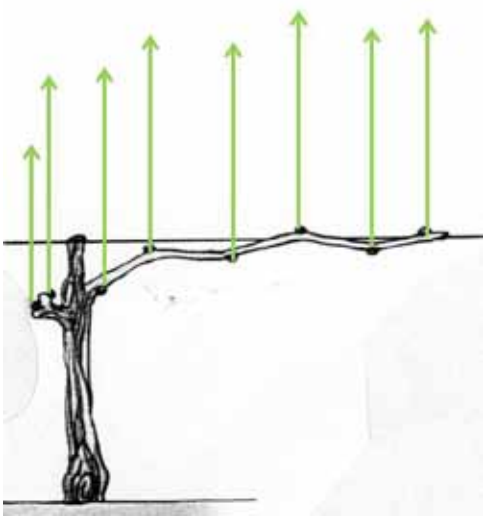

FIGURE 2: Pruning system named Guyot. The number of primary shoots will be determined by the number of latent buds per cane. The density of the vegetation will depend on the length of internodes. The cane is positioned horizontally (or bended and twisted) to avoid the acrotony (named as well cane's apical dominance).

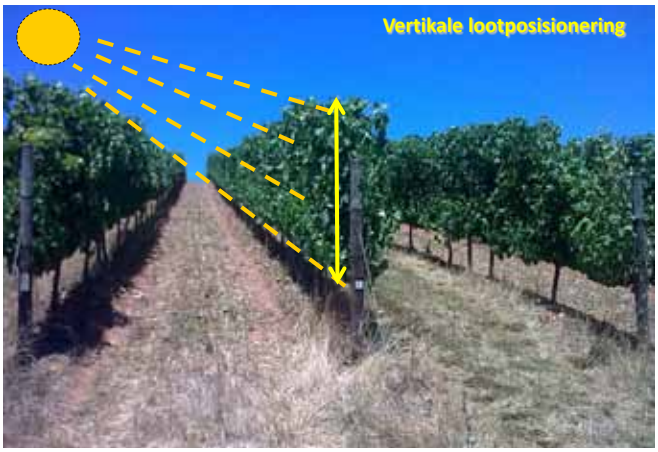

FIGURE 3: Example of Vertical Shoot Positioning, V.S.P. The width of the canopy is due to the growth of the secondary shoots (named the laterals). The growth of the laterals depends on the vigour of the terroir unit (temperature, water and nitrogen mainly) and the choice of the rootstock.

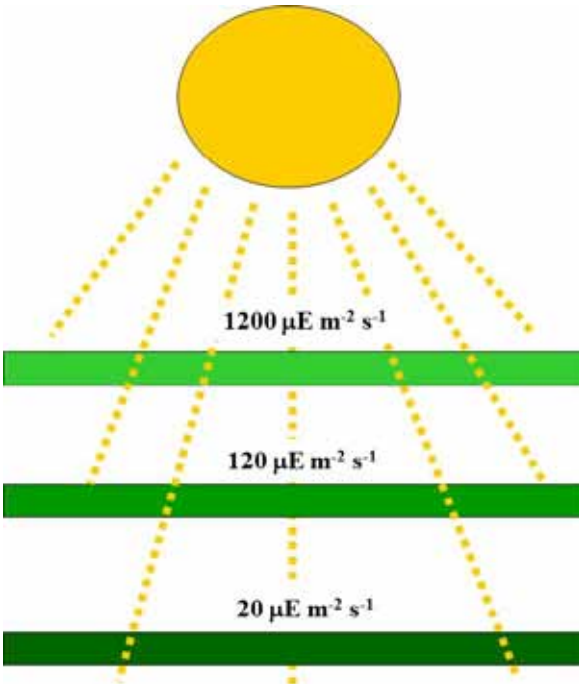

FIGURE 5: Decrease in transmission of solar light intensity according to the leaf layer number (i.e. thickness of the canopy). This figure illustrates the importance of both canopy width and density. To get less shaded leaves as possible, it is recommended to avoid canopy width > 0.40 m (Smart and Robinson, 1991; Carbonneau *et al.*, 2007).

Year n+1

- Differentiation of flowers' primordia (= first step of flowers formation) in the latent bud during bud break and beginning of inflorescence growth,
- Inflorescence growth (elongation) and flowers differentiation from bud break to flowering,
- Flowering and opening of the stamens (pollen release),
- Flower fertilisation (depends on climate and vine physiology),
- Ovary/young berry's cell multiplication (after ovule fertilisation only. At this stage the elongation of the inflorescence is finished and the number of berries is determined),
- Cell enlargement during berry green growth and ripening stages (determines the berry's volume).

Deloire, 2008

FIGURE 4: The growth of the laterals on a primary shoot (PS) will depend on the apical dominance which is due to the apex and will depend mainly on the vigour of the terroir unit (water and nitrogen). By removing the apex, one allows the growth of the laterals immediately underneath the apex and along the primary shoot.

How are yield per vine and per hectare determined?

This part of the yield production is dependent on:

i) the pruning system (number of buds per vine);
ii) the training system (number of arms, cordons, canes: the result is the number of buds per vine);
iii) the plantation density (number of vines and buds per hectare);
iv) and on the various cultural practices (irrigation, soil or leaf fertilisation) and canopy manipulation.

One should remember that:

- The training system x pruning system will determine the canopy architecture,
- The pruning system will determine the number of buds per vine or m^2,
- The plantation density (distance between vines and rows) will determine the number of vines and buds per hectare,
- The various cultural practices (mainly irrigation and fertilisation) will affect the vine physiology and indirectly bud fertility and berry growth, volume and composition.
- The canopy manipulation x canopy architecture will determine the leaf and bunch microclimate,
- The climatic conditions of a "terroir unit" (soil x climate) will affect as well the vine physiology and indirectly bud fertility, berry growth and composition at the meso- and micro- climatic levels,
- The soil capacity versus soil type, depth, and water content will affect (depending on the rootstock), root development and morphology, root type, anatomy and functioning, which in turn will influence vine vigour and yield, and indirectly berry growth and composition.
- Rootstocks are genetically controlling cultivars transpiration, and thus vine water use efficiency (WUE, i.e. biomass gain as a function of water use).

How do we estimate the potential yield per vine and per hectare?

Crop estimation per vine and per hectare could be done using the following formula:

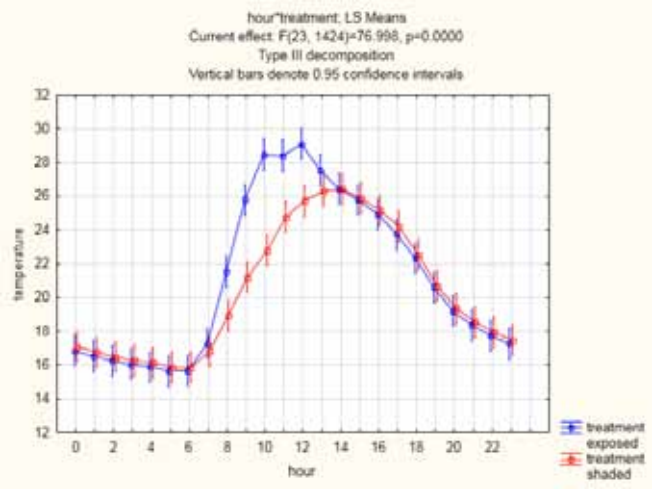

FIGURE 6: Example of daily temperature evolution at the berry level over the ripening period of Sauvignon blanc. The leaves and the laterals have been totally removed at the bunch zone (at berry pea size stage), morning side of the canopy. Because of the influence of the sea breeze, the temperature of the exposed bunches (blue curve) never increases above 30°C. No sunburn or berry dehydration has been observed over three years (2010, 2011 and 2012; Elgin). This allows for an increase in the diversity of wine styles and reduce the berry and wine pyrazines' level responsible of aromatic profiles as asparagus, green bean and green pepper.

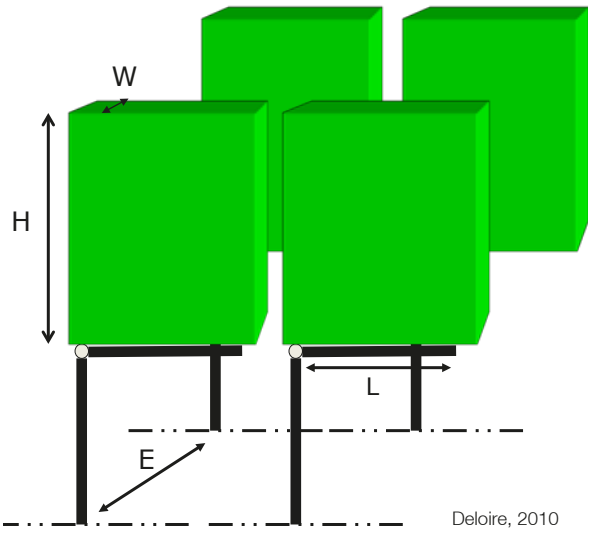

FIGURE 8: The Canopy External Leaf Area Perimeter (CELAP) represents the very first photosynthetic leaf layers. CELAP allows for the estimation of the ratio of CELAP to kg of grapes produced by the grapevine.

FIGURE 7: Example of total leaf and lateral removal (at berry pea size stage), on Merlot in the Stellenbosch area. The row orientation (East-West) allows such canopy manipulation. No sunburn or berry dehydration has been observed. The level of pyrazine in the wine has been decreased due to the effect of the light at the berry skin level (Eikendal vineyard).

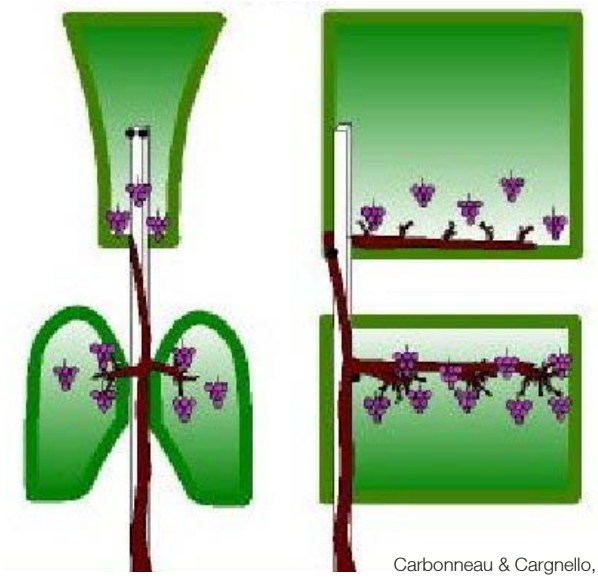

FIGURE 9: Training system called "Lys", with two levels of cordon (origin from Portugal). It is an example of a training system which allows for the increase in the number of buds per vine (need some adaptation for South Africa).

Yield = (vines/hectare) x (number of clusters/vine) x (average cluster weight)

- Vines per hectare: determined by the vines and rows spacing.
- Number of clusters/vine: will depend on latent bud fertility, on the number of primary shoots/vine and on the cultivar.
- Average cluster weight: will depend on the number of berry/cluster and the average berry fresh mass at harvest.

Canopy manipulation: possible benefit of leaf and lateral removal at the bunch zone

Light interception. Light is important for leaf photosynthesis (Figure 5) and leaf stomata density. In most C3 plants photosynthesis is saturated at approximately 25% of full sunlight. This is why in most terroir units in South Africa there is enough light. Sunlight within the canopy (avoiding shade) will increase latent bud fertility by 10 to 20%.

Bunch microclimate. To bring direct or indirect light to the bunch level is always favourable for grape quality (versus berry composition). More anthocyanins and lower levels of pyrazines (green characteristics) will be formed in the presence of more light at the bunch zone. Higher light and temperature exposure could also reduce the berry's level of organic acids such as malic acid. An increase in light at the bunch level doesn't always mean an increase in temperature. It will depend on the wind (sea breeze) and humidity effect (figure 6).

TABLE 1: Examples of global reasoning regarding to specific training systems. All parameters could be changed if the exposed leaf area on yield ratio is respected. The length of the single cordon is 1 meter for these examples (except for the Goblet). For each example of training system, this table is presenting the best yield per vine value for a thin canopy (w ≤ 30 cm), and considering that the exposed leaf area is mainly due to the primary shoot leaves without contribution of laterals. The Goblet "échalassé » falls apart.

Training system	CELAP (m^2/vine)	Yield / vine (Kg.)	Distance vines x rows (m.) Vines per hectare	Estimated yield / hectare (Kg)
V.S.P.	[(1.2x2) + 0.3] x 1 = 2.7	2.7	1 x 2.5 (4000)	10,800
Smart-Dyson	[[(1.2x2) + 0.3] + 1] x 1 = 3.7	3.7	1 x 2.5 (4000)	14800
Lyre	[[(1.2x2) + 0.3] x 2] x 1 = 5.4	5.4	1 x 3 (3333)	17998.
Goblet "échalassé »	1.5	1.5	1.2 x 1.2 (6944)	10416.

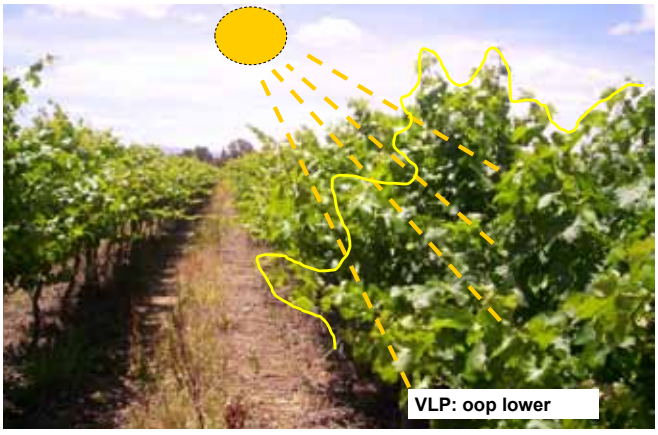

FIGURE 10: Example of a 3 wire Perold system (V.S.P.) which allows opening the canopy. This type of trellising system has to be reasoned in relationship with the vigour of the vineyard or the irrigation program to control the vigour.

FIGURE 11: Example of Smart-Dyson. It is easy to transform a V.S.P. in Smart-Dyson and it is recommended to do it for situations within the width of the canopy is ≥ 40 cm. The distance between the cordon and the soil has to be a minimum of 0.8 to 1.2 meter if possible, to allow bending half of the primary shoots, preferably at flowering. The Smart-Dyson will be preferably used in vigorous situation for which the bunch and canopy microclimate needs to be improved by reducing the width of the canopy and increasing the exposed leaf area.

It is sometimes difficult to choose the correct canopy manipulation to apply, as there is no single recipe for all varieties and climates. For example, light at the bunch level could help to reduce the berry skin pyrazine level but it could also, in some situations, reduce the titratable acidity. Choices of canopy manipulations (figure 7) have to be made according to the desired wine style, the row orientation and the macro-mesoclimate (warm/hot versus cool/temperate). It is always a compromise: at the berry level each, chemical compound follows its own pathway, thus one cannot rely on one compound (example sugar) to predict the evolution of another compound (example malic acid).

What is the desired yield per vine according to wine quality/style?

The basis for reasoning is at the vine level, and the ratio of leaf to fruit has to be considered.

Ratio exposed leaf area on yield. The first important ratio is the exposed leaf area on yield per vine or m^2 (table 1). The Canopy External Leaf Area Perimeter (CELAP) represents the very first photosynthetic leaf layers. CELAP allows for the estimation of the ratio of CELAP to kg of grapes produced by the grapevine (Figure 8). This indicator can be used at véraison and during the berry ripening period.

For a classical vertical shoot positioning training system, the formula is: CELAP (in m^2/vine)= {(2H + W)}. L

Where H = height of the canopy from the bottom of the primary shoots on a cordon (m); W = width of the canopy in the middle of the canopy (m); L = length of the canopy, usually cordon or Guyot cane length (*Murisier, 1996; Zufferey, 2000).*

If we assume a ratio of one: one m^2 of exposed leaf area for 1 Kg of grape. Thus, table 1 gives examples of CELAP to fruit ratios versus few training systems.

From this we can see that alternative training systems which will allow increasing the number of buds per vine or m^2 (examples: Geneva Double-Curtain, T-trellis, Lys (figure 9) or the Lyre) will give us a crop of 4/5 Kg per vine, allowing to crop 15 to 20 tons (or more) per hectare, respecting the bunch and wine quality. There are also solutions which allow the increase of exposed leaf area and therefore proportionately the yield per vine (for example: transforming a V.S.P. in Smart-Dyson or using a 3 wires Perold system (V.S.P.) which allows to open the canopy letting the shoots partially hanging in the row) (See respectively figures 10 and 11). The laterals can contribute to increase the exposed leaf area but their growth as with any vegetative growth has to stop preferably at véraison. A young leaf formed at véraison will be adult and source of carbohydrate only 40 days after having acquired its definitive size.

As can also be seen from Table 1, Goblet (bushvine) training systems could give high yields/hectare because of the high density plantation. These systems are used either for quality purpose in steep slope situations (figure 12) or in dry land (figure 13), and usually for specific cultivars as Syrah (Goblet with posts), Grenache, Carignan, Pinotage or Chenin (goblet without post).

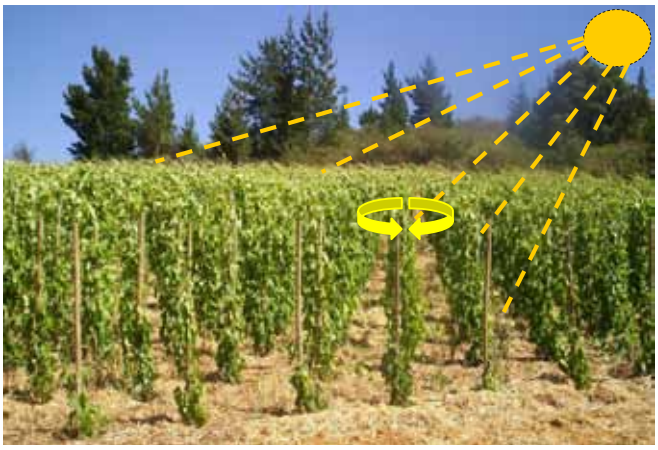

FIGURE 12: Example of Goblet "échalassé" from L'Ormarins vineyard (Syrah). This training system allows to get a 360° light penetration at the leaf and bunch zones. It is interesting in a situation where there are steep slopes and for high quality wine for specific cultivars as Syrah, Grenache noir or Viognier.

FIGURE 13: Example of non-trellised Goblet, which has to be used for cultivars with raised shoots.

How do we correlate the wine style to the leaf to fruit ratio per vine, or the wine style to the yield per vine?

To achieve the matching between wine style/quality and yield per vine, the following information needs to be provided:

- The ratio exposed leaf area to yield (as a minimum)
- The ratio total leaf area to yield

The matching of yield per vine and wine style/quality has to be defined in the context of terroir units (climate and soil), cultural practices such as irrigation and canopy manipulation (bunch microclimate) and clones. In other words, the leaf to fruit ratio is not the only criteria which impacts on the berry composition and wine style. The climate (temperature, light, wind, humidity) and the soil (water and minerals restitution to the plant) in interaction with the bunch microclimate play a major role in berry composition and wine styles. Rootstocks, by controlling vine transpiration, will play a role on vine carbohydrates production.

Why do we practice bunch thinning (green harvest)?

The bunch thinning (green harvest) method is practiced when the yield per vine is estimated too high or when the ratio of exposed leaf area/yield is estimated to be unbalanced. This means that one has to be able to know/estimate when a vine is balanced or not. It is not simple because it will depend on numerous factors: leaf to fruit ratio, vine water status, terroir unit (climate and soil), bunch microclimate and minerals.

When do we carry out bunch thinning?

In most vineyards, bunch thinning is done at véraison, when it is possible to select the most-ripe, promising bunches. In a young vineyard, it is a current practice in Europe to remove the inflorescences at flowering, and during the first three years after plantation, to limit carbohydrates competition.

An alternative/ additional practice is to remove inflorescences at flowering/berry set to fit the yield per vine and the yield per hectare according to a specific crop target (6, 8, 10, 12…tons/hectare). This has to be considered in the light of the correct leaf to fruit ratio per vine in interaction with the terroir unit, cultural practices and expected wine style.

It is difficult to conclude on the real effect of bunch thinning on grape quality from the literature as the results are different from one situation to another. Bunch thinning has to be considered as a backup solution, and mainly be used to remove the non promising bunches (green bunches or bunches carrying green berries after véraison), the shoulders of big bunches, to homogenise the bunch ripening level from véraison onwards.

New or adapted training systems?

It is important to keep in mind that it is always possible to adapt/transform a particular training system to the conditions of a specific vineyard and again considering yield/vine or hectare, wine style and profitability.

The decision to use or transform a particular training system should be according to physiological principles in the context of specific terroir units instead of using recipes. Recommendations should always be proposed/discussed in the light of the production targets which often depend on the terroir units, the market demands and the farm profitability (see for review Eben Archer, 2011. Technical yearbook, Wynboer). At least one has to keep in mind that vines are cultivated for the quality of the crop and not only for the quality of the leaves, even if leaves are important pre- and post-harvest for carbohydrates reserve.

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