Narrow terraces and alternative training systems for steep sloop viticulture - Douro region.

Banquettes étroites et systèmes de conduite alternatifs dans une viticulture en forte pente - Région du Douro.

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Abstract

In Douro Region, vineyards are usually planted on hillsides with steep sloops. The models currently used for planting those vineyards are, depending on the initial slope of the hillside, vertical planting or terraces. Vertical planting is well adapted when the slope of the hillside is lower than 35-40% and terraces, supported by earthen embankment and one or two rows of vines are the solution for slopes higher than 35 - 40%. Terraces with two planting rows, 3.6 to 4.0m-wide were planted during the 1980s in more than 2500 ha. This solution proved to have disadvantages as to compel the maintenance of the embankment with chemicals for weeds control, high embankment height and consequent problems of instability and erosion.
Due to that in this work it is presented one correct way of constructing narrow terraces 2.5 m wide, using laser systems, and alternatives in control of weeds both in platform and in slope. Because narrow terraces have the disadvantage of a low planting density and yield potential, an experiment was performed with the variety "Touriga Franca", representative of about 20% of vines in the region, grafted in 110R, two training systems and two planting row distances.
The results of the trial, performed in 2006 and 2007, showed that yield in the double cordon system (LYS 2/3) was respectively 62% and 52% higher than in the traditional vertical shoot positioning (VSP) without negative quality effect on quality of the grapes. Concerning planting row distance, 0.80m achieved a higher yield and better quality than planting at 1.20m.
Narrow terraces, constructed with rigor, proved to be an excellent alternative in planting hillside vineyards, 0.80m a better planting distance than 1.20m, both in terms of yield and on quality and double cordon LYS 2/3 a system suitable to improve yield, without quality detriment, as verified in these two years trials.

Key words: Douro**,** narrow terraces, training system, steep slope viticulture (SSV).

Introduction

Alternative Models for Vineyards in Steep Sloops.

In Douro, the Port Wine Region, vineyards are in its greatest majority planted in hillsides with steep sloops. The models currently used for those vineyards are vertical planting or terraces, depending primarily, on the initial slope of the hillside.
Thus, where the initial gradient is below 35-40%, vineyards are planted vertical and where there is a steeper gradient, the hillside is carved into terraces. However, on hillsides where there is little natural depth of the soil and an adverse exposure, according to Guimaraens & Magalhães (2006), vertical planting may not be the best solution even if the slope technically favours vertical planting. On the other hand, many viticulturists consider working conditions as the decisive factor in setting the

maximum acceptable gradient for vertical planting. In that case they only accept vertical planting with slopes up to 20 - 25%.
During the past decades, the method that prevailed in order to solve these problems was that of the *patamares*, 3.6 to 4.0m-wide terraces, planted with two rows of vines. However, these large terraces present inconveniences, in particular the high embankment height and consequent problems of instability and erosion. The use of chemicals for weeds control becomes compulsory. Due to these problems, the alternative is the construction of narrow terraces which, by definition, are up to 2.5 metres wide and contain a single row of vines.
However, in the construction of narrow terraces is not acceptable to maintain the lack of rigor verified in the 1980^s with the *patamares.* For these reason narrow terraces, presented in this paper, had been constructed with bulldozer machines equipped with a rotary laser system (TOPCON RL-H2Sa) (Figure 1) in order to define an exact longitudinal inclination of 3% as referred by Guimaraens & Magalhães (2006). This value for the longitudinal gradient, results from a compromise between a minimum value that allows the excess of water to be drained off the terrace and the maximum speed of it that can lead to erosion on the platform.
Another task in constructing narrow terraces has been the choice of the width of the platform. If in Switzerland, Koblet & Faust (1994) refer terraces with width between 1.2 and 1.8m, depending on the type of machine used in vineyards' work, in former trials in the Douro Region, Félix & Guerra (1998) worked with terraces 1.8 m wide. The narrow terraces width applied here, was chosen having in mind the necessity of using the same tractors as the ones used in other vineyards as the vertical planted (2 metres between rows). Taking that into account, terraces had been constructed with 2.3 metres wide, with a distance of 1.8 metres between the planting row and the base of the embankment (circulation space) (Figure 2). Furthermore, this distance had been considered the minimum adequate to the work with the heavy machines used in mechanical cutting of the grass in the slope of the terrace (Figure 3 and 4). The distance between the vines in the row and the "shoulder" of the embankment, about 0.5m, was chosen considering the necessity of human circulation between the cordon trained upwards and the one trained downwards in the double cordon system, LYS 2/3. Additionally, it is also a way of preventing small erosion's problems, that may occur even if the platform had been constructed laying inwards.

Soil Management in Narrow Terraces

If terraces with two planting rows compel to the chemical control of weeds on the slope, and results in the necessity of keeping it free of grass once it is not possible to control it in another way, in narrow terraces with one planting row, grass ground cover is an additional measure, to those referred before, that can be used to protect hillside vineyards from erosion.
However, there are concerns in Mediterranean mountain viticulture, as that of Douro's, regarding the natural limitations to planting grass due to the lack of, and irregular rainfall that can became a problem, particularly in non-irrigated vineyards.
Regarding this matter, Guimaraens & Magalhães (2006), refer the good behaviour of vines in the hot summer of 2003, observed by Payan & Salançon (2004), on vineyards that were covered with grass. As a consequence, it had been sown a ground cover in the platform, with 1.2 to 1.5 wide, keeping the row free of grass. The type of grass used has been "oats" (*avena sativa*) and "vetch" (*vicia sativa*) (Figure 2), chosen due to the fact that these two species have high efficiency in covering and protecting the soil, due to a rapid growing and consequent colonization, and are considered has being the best to these growing conditions as they have low requirements in soil fertility, and have a relative adaptation capacity to the high stone content and slope (Guimaraens & Magalhães, 2006).
The sown grass had been regularly mowed until at the end of spring, it has been reduced to a mulch that remains, therefore protecting the soil from erosion, and without competing with vines.
The maintenance of slopes of the narrow terraces was achieved through the spontaneous cover of natural grasses (Figure 3) which, in balance with nature, grow naturally and are controlled

Figure 1 Construction of narrow terraces, using a laser system (Adapted from Guimaraens and Magalhães, 2006)

Figure 2 Ground cover in platform composed by sown oats (*avena sativa*) and vetch (*vicia sativa*).

Figure 3 Slopes of the narrow terraces with spontaneous cover of natural grasses (end of March)

Figure 4 Mechanical cutting of spontaneous cover (end of June).

Figure 5 Traditional Vertical Shoot Positioning (VSP).

Figure 6 Double cordon LYS 2/3.

mechanically. Any undesired weeds or bushes had been controlled by spot applications of a systemic herbicide.

Both in the slope and on the platform of the narrow terrace, the growth of the grass cover had been temporary (between November and the end of the Spring), due to the choice of the species sowed or,

in the case of the natural Autumn and Winter grasses, through the mechanical cutting and, above all, due to the natural limitations in water of the Mediterranean climate.

Alternative Training Systems for Steep Sloop Viticulture

Even if several authors studied alternatives for training of vineyards on hillsides (e.g. Koblet & Faust, 1994; Cargnello, 1995; Castro e*t al*. 1998; Félix & Guerra, 1998; Murisier *et al*., 2001) and terraces with one planting row, proved to have great advantages, grape growers in Douro, usually refer to them as having a lower production potential than large terraces due to the low planting density they have.
Due to that fact, a trail had been settled in a vineyard planted in narrow terraces of 2.3 m wide, with alternatives of training, two different planting row distances and two pruning alternatives in the cordon trained downwards of LYS 2/3.

Material and methods

The training system's experiment was conducted in 2006 and 2007, at the private state "Quinta de Santo António", property of "The Fladgate Partnership Vinhos S.A.", located in the central part of Douro Region (Upper-Corgo) - 41º 14' N, 7º 31' W, 300 meters above sea level, with a C1B'3sb'4 climate (Thornthwaite).
The hillside where the vineyard was implanted has an initial slope of 50%, and after systematization in 2.3 m wide horizontal narrow terraces, Touriga Franca, a noble variety that represents 20% of the vines of Douro Region, was planted in 2002 with bench grafted in 110R rootstock. The predominant exposure of the hillside is S-SE, and the soil, of schistose origin, contains a high percentage of stones.
The trial was designed as a split-plot experiment with training system assigned to the main plot and distance in the row assigned to the subplot, with 4 replications and a total number of plants studied of 308.
Treatment consisted of two training systems: i) "Vertical Shoot Positioning" (VSP) - the traditional modality, spur pruned, used as control and ii) a double cordon with part of the canopy trained upwards and part downwards, the LYS 2/3 (Figure 5 and 6), two different distances between plants (0.80 m and 1.20m) (Data about distances on row available only for 2007 harvest). Two pruning alternatives were introduced in 2007 in the cordon trained downwards of LYS 2/3 (spur pruning (*Royat*) and cane pruning). Measurements of leaf water potential and photosynthetic rate had been performed at July 27Th, during the maturation period, with the final daily determination being made at 17h, because of the shadow that affects the trial field after that hour. Foliar Surface Index was assed according methodology proposed by Lopes & Pinto (2005) on the 9th of June, 9th of July (data presented in this paper) and 12th August.
Results of comparison of mean values are expressed as the level of significance. Where differences resulted significant, individual means were compared using the Duncan's multiple range test ($p \leq 0.05$). For statistical analysis, the program SPSS v.15 was used.

Results and discussion

Yield value expressed in kg by linear meter, was, in the double cordon LYS 2/3 62% higher than in the VPS system in 2006, - with yield values of 3.22 and 1.99 kg per linear meter of row, and 52% in 2007, with yield values respectively of 8.10 and 5.32 kg (Figure 7). This difference results from the higher number of bunches per linear meter and from differences at bunch weight. Actually, in 2006 the VSP had 6.6 bunches while the double cordon LYS 2/3 had 13.2 and, in 2007, 12.5 and 23.0 respectively. Concerning the bunch weight (Table 1) the values were statistically different, 0.30 kg for VSP and 0.25 kg for double cordon LYS 2/3 in 2006 and 0.44 k for VSP and 0.36 kg for double cordon LYS 2/3 in 2007. Regarding the quality parameters (Table 1), no significant differences between modalities were detected, with the probable alcohol concentration (converted after fruit sugar concentration) reaching in 2006 a value of 11.5 % (v/v) in VSP and 11.6 % (v/v) in the double cordon LYS 2/3 and in 2007 VSP reached 11.8 % (v/v) and 11.9 % (v/v) in the double cordon LYS 2/3. These values are consistent with those founded in a trail in Douro Region, with Touriga Nacional by Queiroz, *et al.* (2008) and by Murisier *et al*. (2001) where both authors refer increases in yield whilst maintaining quality, in modalities with a double plan of canopy, trained in narrow terraces.

The effect of row distance (data available for 2007 only) shows that planting at 0.80m allowed to reach a higher yield than at 1.20m (Figure 8). This difference results from a higher number of bunches per linear meter in the 0.80 m distance, 16.6 against 13.4 in 1.20m, once the bunch weight were similar (Table 2).
The quality parameters (Table 2), show higher alcohol value in 0.80m with 12.3 % (v/v) than in the 1.20m modality with 11.4 % (v/v) and no differences in the other parameters analysed. These results, similar to that referred by Queiroz *et al.* (2008) with Touriga Nacional, confirm that 0.80m can be considered the best alternative for planting distance between vines on narrow terraces.
In order to optimize the double cordon LYS 2/3, in 2007 winter's pruning, two different pruning systems were introduced in the cordon trained downwards: spur pruning (*Royat*) and cane pruning. Values for yield presented in figure 8 (regarding only the production of the downward cordon) show that spur pruning reached a higher value than cane pruning, due to a higher number of bunches (12.2 for spur and 9.7 for cane pruning) even its weight is similar (Table 3). In terms of quality, both pruning systems reached similar parameters (Table 3). These results are opposite to the verified with Touriga Nacional by the referred authors, due, probably, to different fertility habits in the basal buds of these two varieties.

Modalities	Fruit Sugar Concentration (% v/v)		Titrable Acidity (gr. Tart. Ac./ l)		pH		Berry weight (g)		Bunch weight (kg)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
VSP	11.6	11.8	3.58	4.37	3.84	3.72	2.15	2.55	0.30	0.44
LYS 2/3	11.5	11.9	3.65	4.28	3.87	3.71	2.03	2.31	0.25	0.36
Sig (1)	*n.s*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s*	***.	*

Table 1 Effect of training systems on quality components, berry and bunch weight (Touriga Franca, 2006 and 2007). Note: (1) n.s. – non significant, * - significant at 0.05, *** - significant at 0.001.

Modalities	Fruit Sugar Concentration (% v/v)	Titrable Acidity (gr. Tart. Ac./ l)	pH	Berry weight (g)	Bunch weight (kg)
1.20 m	11.4	4.29	3.72	2.38	0.36
0.80 m	12.3	4.31	3.72	2.37	0.39
Sig (1)	***	*n.s.*	*n.s*	*n.s.*	*n.s.*

Table 2 Effect of distance between plants in the row quality components, berry and bunch weight (Touriga Franca, 2007 Note: (1) n.s. – non significant, *** - significant at 0.001.

Modalities	Fruit Sugar Concentration (% v/v)	Titrable Acidity (gr. Tart. Ac./ l)	pH	Berry weight (g)	Bunch weight (kg)
SPUR	12.0	4.23	3.71	2.15	0.37
CANE	12.2	4.26	3.74	2.38	0.36
Sig (1)	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Table 3 Effect of pruning system (spur or cane pruning) in the cordon trained downwards of double cordon LYS 2/3, in quality components, berry and bunch weight (Touriga Franca, 2007)
Note: (1) n.s. – non significant.

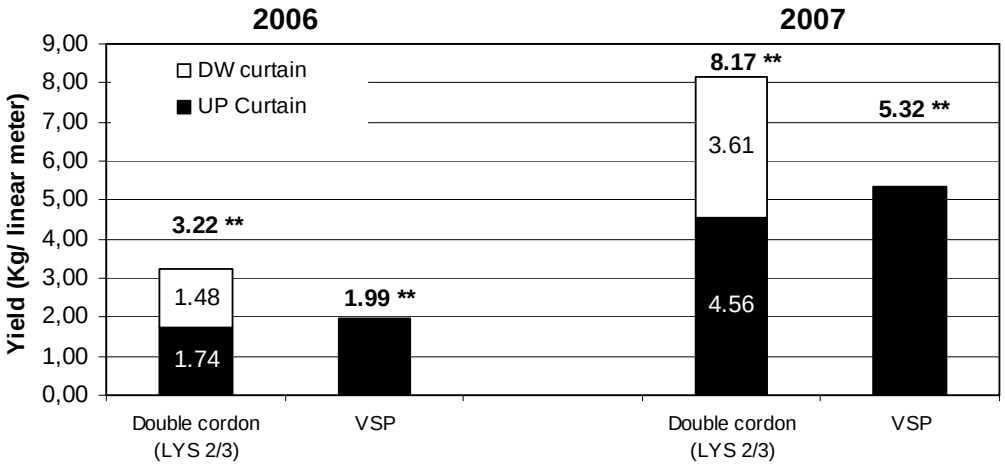

Figure 7 Effect of training system on yield (kg / linear meter of row) (Touriga Franca, 2006 and 2007)

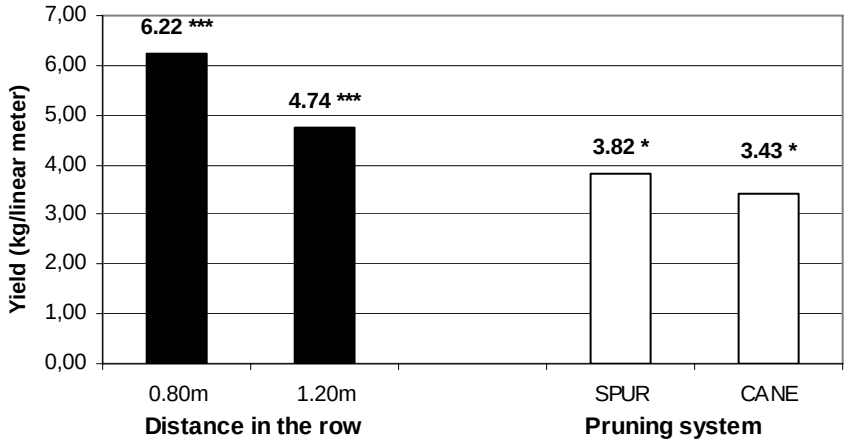

Figure 8- Effect of planting distance and pruning system on yield – for this presented value only of the downward cordon (kg / linear meter of row) (Touriga Franca, 2007).

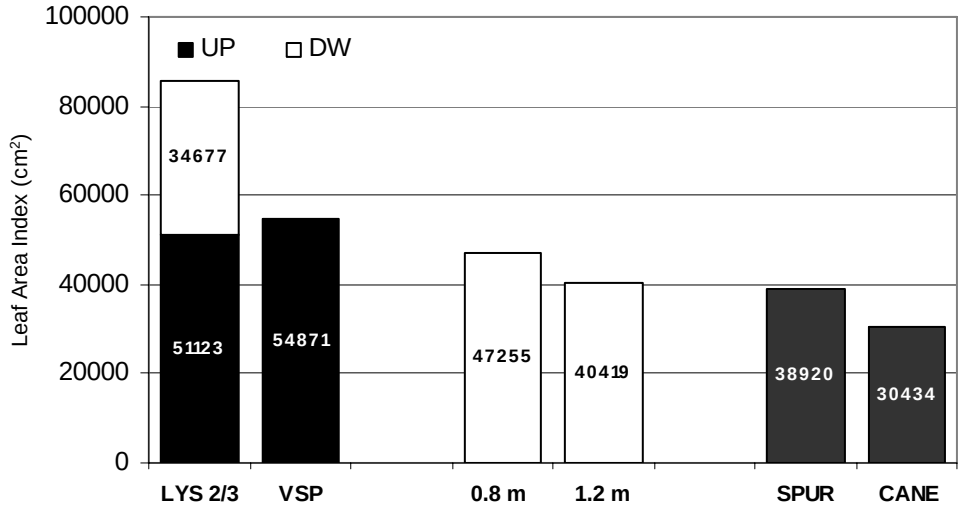

Figure 9 Effect of training system, planting distance along the row and pruning system - presented value only of the downward cordon - on leaf area index (cm^2 / linear meter of row) (Touriga Franca, 9 July, 2007)

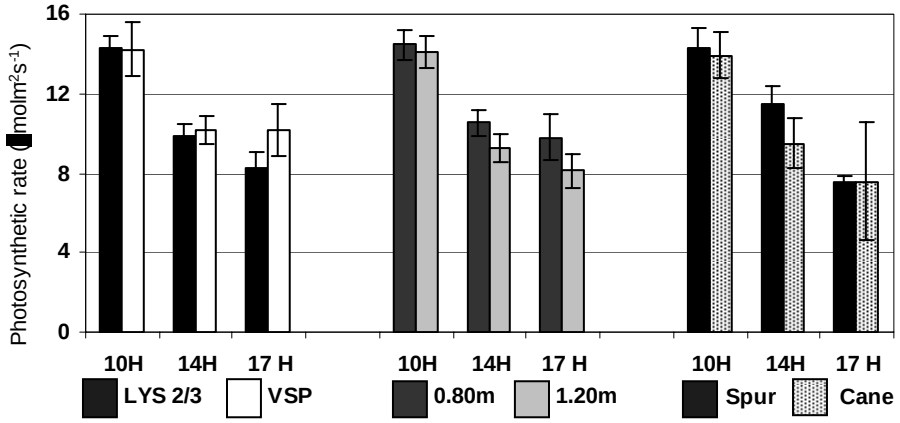

Figure 10 Effect of training system, planting distance in the row and pruning system on photosynthetic rate (µmolm^{-2}s^{-1}), 27TH July, T. Franca, 2007).

Regarding Foliar Area Index (Figure 9), it is substantially higher, as expected, in the double cordon LYS 2/3, than in VSP. Also 0.80m and spur pruning showed higher values than the alternative modalities.

In terms of water leaf potential, the values found were similar in all modalities. The average value measured in predawn – 0.61 MPa can be considered as indicating a strong water deficit. Along the day, values decrease continuously reaching a minimum of – 1.77 MPa, a very negative value, at 17h. These values were lower than those find with Touriga Nacional in the same year in similar conditions (Queiroz *et al*., 2008).

In terms of photosynthetic rate (Figure 10), it was found that the values were high along all day, with no differences between the modalities studied.

Conclusions

Narrow terraces, with one planting row, when constructed with rigor, proved to be an excellent alternative in planting hillside vineyards, allowing the control of weeds mechanically, both in the platform and on the embankment. Due to the fact that oats (*avena sativa*) and vetch (*vicia sativa*) have a rapid growing, under the conditions of this trial, they proved to be a good alternative in platform soil cover. The same applies for natural grasses growing in balance with nature, covering the slope of the terraces, both of them controlled mechanically.

Regarded training systems, the double cordon LYS 2/3 proved to be a good alternative in terms of improvement in yield without negative quality effect on quality of the grapes, even if a longer experimental period is necessary to give support to the results of these two years.

About distance of planting of vines, 0.80 m proved to have a higher yield and quality potential then 1.20m.

In terms of pruning alternatives for the cordon trained downwards of double cordon LYS 2/3, spur pruning appear to be the best alternative, due to higher yield and because it makes easier the work on vegetation.

This way, narrow terraces are an excellent alternative in planting hillside vineyards, being 0.80 m the best planting distance in the row and double cordon LYS 2/3 a system able to reach an important improvement in yield with the maintenance of a satisfactory quality, even if this must be confirmed with next years results.

Acknowledgements

Work financed by "Acção DE&D do Programa AGRO, Projecto 739".

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