VINE RESPONSE TO THE IMPLEMENTATION OF PARTIAL ROOTZONE DRYING (PRD)

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INTRODUCTION

Growing vines for wine production presents a special challenge because of the effects of water supplied by irrigation. While necessary to obtain good yields, they should be moderate to avoid negatively affecting the final wine quality by excessive irrigation. This assertion is a reality with regards to the management of grape vines used for winemaking. However, on a more scientific level, the meaning of the word moderation is poorly defined.

Numerous studies have explained the effects of water deficiencies during different stages of the annual vine cycle, and its consequences on the production, vegetative growth and must composition (Matthews, et al., 1987 et 1990; Matthews et Anderson, 1988 et 1989; McCarthy, 1997 et 2000), which were reviewed by Goodwin (2002).

Besides providing pertinent scientific information, these studies also showed the possible practical advantage of applying moderate stress at certain stages of the annual cycle. With this in mind, various irrigation strategies have been proposed, and regulated deficit irrigation (RDI) (Chalmers et al., 1981; Mitchell et al., 1984), sustained deficit irrigation (SDI) (Girona et al., 2002a) and partial rootzone drying (PRD) (Loveys et al., 2000) appear to be noteworthy representatives.

All of these strategies aim at reducing the vegetative growth, improving the production and the quality of the musts, and at decreasing the consumption of irrigation water.

This current work reviews the existing information on PRD, and analyses the possible factors involved in the responses obtained.

REVIEW OF EXISTING INFORMATION

Irrigation systems

Figure 1 shows different localized irrigation system methods, namely the traditional and the partial root drying (PRD) methods, with their respective elements.

The traditional localized irrigation (the most frequent in viticulture) with one or two laterals per vine row, leads to a large degree of wet soil when using two laterals. All drippers and laterals are maintained open and supplied with water during system operation.

The PRD system utilizes two laterals per vine row but alternates their water supply twice per month, thus maintaining part of the root system in wet soil and the other part in dry or drying soil.

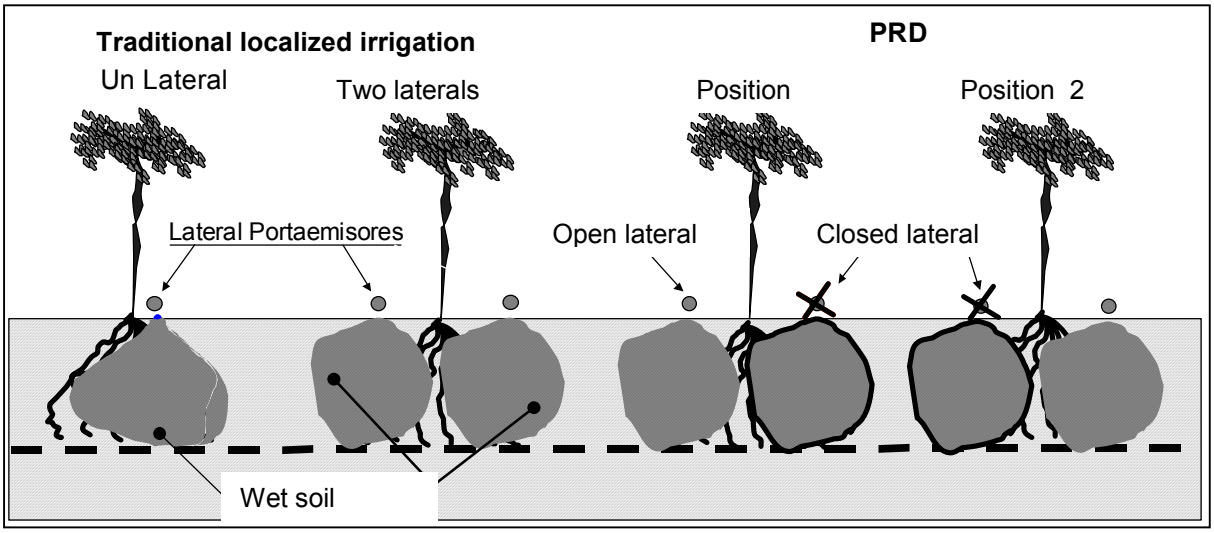

Figure 1. Illustration of traditional and PRD localized irrigation systems.

First studies with PRD

In order to obtain the specific conditions desired for PRD, that is, alternation of wet soil and dry soil, the first trials were carried out by dividing the roots in tow parts and putting each one in different pots (Figure 2A) (Stoll et al., 2000). When the trials were transferred to the field, the use of plastic planks allowed to separate the two parts of the roots (Figure 2B) (Dry et al., 1996; Stoll et al., 2000).

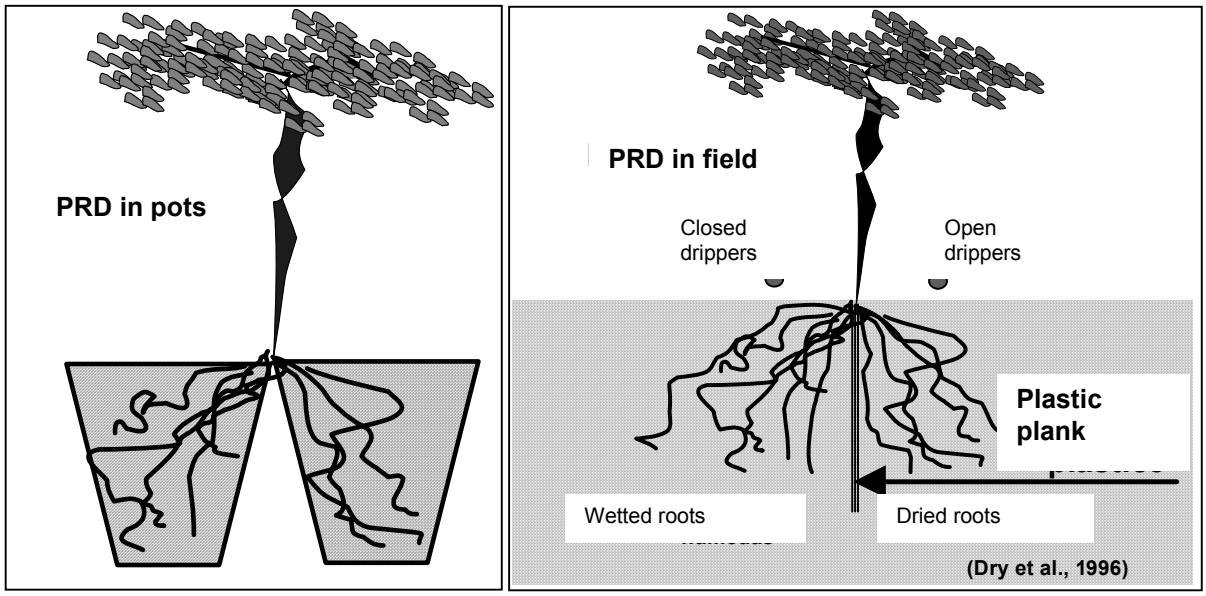

Figure 2. Experimental protocols for PRD in pots (A) and in the field (B) according to Dry et al., (1996).

The first results from physiological studies analyzing the plant response to PRD, showed that by changing the irrigated side (or pot) a rapid decrease of the water content in the non-irrigated soil could be observed, which was accompanied by a punctual increase of abscisic acid (ABA) and an equally punctual reduction of stomatal conductance (g_s) (Stoll et al., 2000).

Finally, a punctual decrease of the vegetative growth (Dry et al., 2000) could also be observed. All these parameters reverted to normal values few days later. The leaf water potential (Ψ_h) was not affected by these changes. (Dry et al., 2000) (Table 1).

Parameter	Behaviour
Soil water availability (**SWA**)	⇩
Stomatal conductance (**g_s**)	⇩⇧
Abscisic acid (**ABA**)	⇧⇩
Plant growth (**Pl-Grth**)	⇩⇧
Leaf water potential (**Ψ_h**)	=

Explanation of symbols: Large arrow = significant unidirectional change in the direction of arrow; small double arrows = change in one direction followed by a change in the opposite direction of an approximately equivalent magnitude; Equal = no significant change.

Table 1. Comparison of the change of physiological parameters of vines exposed to PRD with a total irrigation strategy in pots or fields with root confinement (Stoll et al., 2000; Dry et al., 2000)

These results are in agreement with the work of Zhang and Davis (1989) showing that ABA regulates stomatal closure and vegetative growth during partial soil drying.

However, it is important to indicate that ABA levels peaked for 4 to 5 days, as well as all the other parameters indicated by a double arrow in Table 1. The parameters returned to normal values after a few days in potted vines. During field trials, this response was much smaller and occurred over the course of few hours (Stoll et al., 2000).

Effects of PRD on Production

The analysis of the effect of different PRD applications on vine production (Table 2) showed that by decreasing water contributions by 50% the production remained stable. On the other hand, maintaining the water supply significantly increased production. The consequences on must quality were minimal, or even absent.

Parameter	Cultivar →	CS[1]	Sh[1]	CS[2]	Mon[3]
Irrigation (mm)		⇩ 50%	=	⇩ 50%	=
Production		=	⇧	=	⇧
Quality		=	=	=	⇩
Plant growth (**Pl-Grth**)		⇩		⇩	⇧
Stomatal conductance (g_s)		⇩		⇩	=
Leaf water potential (**Ψ_h**)					

CS = Cabernet Sauvignon; Sh = Shiraz; Mon = Monastrell; (1) Dry et al., 2000; (2) Dry et al., 1996; (3); De La Hera et al., 2002.

Table 2. Comparison of vine production with PRD and traditional localized irrigation

These trials were carried out in the field and included different grape varieties and geographical locations. However, there was no explicit mention of the fact that the ABA increases, and reductions of g_s and vegetative growth occurred in accordance with the results obtained with pot trials. Only the work by Stoll et al. (2000) mentioned that it was also possible to detect changes of ABA levels in the field, even though these were smaller compared with experiments in pots.

It should be remembered that the PRD protocol introduces some important variations concerning water management, such as the significant increase of wetted soil volume and the sometimes drastic decrease of irrigation water supplied.

Under these conditions, it is legitimate to ask whether the effect of PRD would not rather be attributable to the more significant volume of wetted soil and the more efficient application of irrigation water. In fact, this would concur with the results shown in Table 2.

Other PRD trials in vineyards

The original PRD protocols with two laterals separated from the vine row can present problems with regards to vineyard management and vehicle movements. Thus, alternative solutions have been proposed, such as positioning the laterals side by side, with drippers positioned alternatingly between vines (Fig.3) in order to ensure that PRD occurs in the direction of the rows instead of perpendicularly to the vine row (such as is shown in Fig.3).

In a PRD trial carried out with Merlot (Girona et al., 2002b) a 60% diminution of the irrigation did not affect the production, must quality was slightly improved and the vegetative growth decreased (Table 3).

On a physiological level, there was a slight but permanent decrease of the leaf water potential over the entire duration of the annual cycle, and a marginal impact on stomatal conductance. The same type of results could be expected at least during the first year of trials with a sustained deficit irrigation (Girona et al., 2002a).

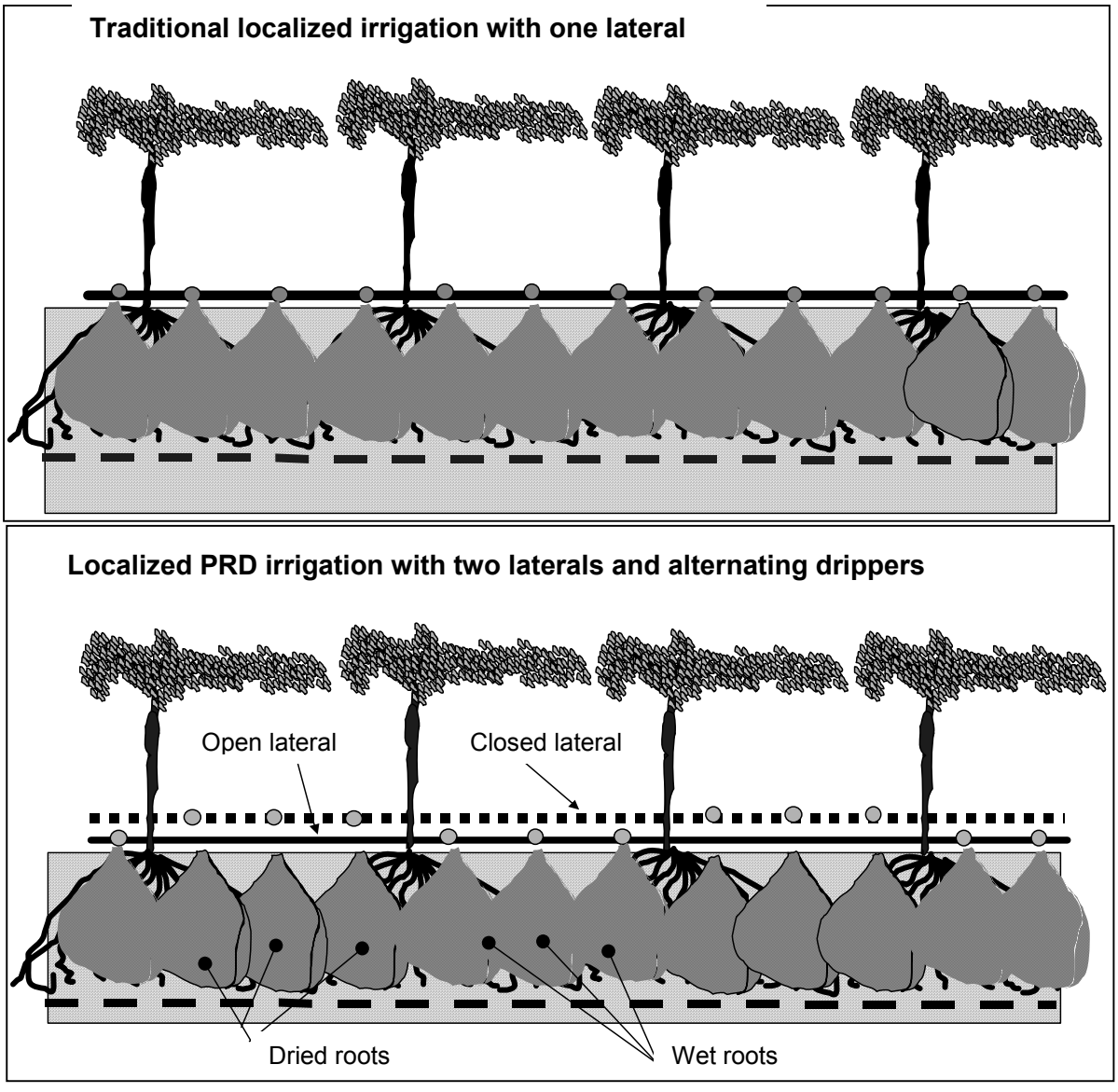

Figure 3. Localized irrigation systems A) traditional with one lateral; B) PRD with two laterals and alternating drippers between the vines.

These doubts concerning the real causes of the vine response to PRD have been underlined in a study by Santos et al. (2002) who obtained essentially identical results with the "Castelao" variety with PRD and SDI, where the water supply was decreased by 50% with regards to the control treatment in both cases. There was also a very clear effect compared with the non-irrigated treatment (NR) (Table 3).

Cultivar →	Merlot[1]	Castelao[2]		
Parameter	PRD	PRD	SDI	NR
Irrigation (mm)	⇩ 60%	⇩ 50%	⇩ 50%	0
Production	=	⇩	⇩	⇩
Quality	⇧	⇧	⇧	=
Plant growth (**PI-Grth**)	⇩	⇩	⇩	⇩
Stomatal conductance (g_s)	=			
Leaf water potential (Ψ_h)	⇩			

Table 3. Comparison of the productive response after application of PRD and traditional irrigation with Merlot, as well as with SDI and a non-irrigated control with the Castelao variety.

DISCUSSION

In the initial studies on PRD, it was suggested that the advantage of this technique consisted in inducing an increase of ABA leading to stomatal closure (g_s ↓) and limiting vegetative growth while not affecting the water potential of the leaf (Ψ_h). These results, which are only weakly supported in the trials carried out by the proponents of this technique, have not been confirmed in other field trials, and were obtained under soil conditions that were less "controlled" compared with precedent trials. However, a common feature of all experiments was that even important reductions of irrigation water still allowed to obtain the same results as with the control irrigation. It was even possible to increase the production while using the same amount of water. Thus, PRD effectively leads to a substantial improvement of water efficiency, but this improvement is not associated with the physiological variations of the plant, or more specifically, with its level of ABA. Possible explanations for these results could be:

- The increased irrigation water efficiency (due to a larger volume of wet soil).
- The augmentation of active roots ensuring a better radicular activity, which is favourable to the water supply of the plant above the soil.
- An over-irrigation considering the real need of the vine, either because of a very small vegetative surface, or because of a fruit load low enough to eliminate the water needs and the competition for water between the two.
- The scarcity of information available to explain these results, specifically the interactions possible among the precedent scenarios.

In order to find an answer to the last scenario, we analyzed all the possible situations by combining the differential factors observed between PRD and traditional irrigation:

- Volume of wet soil.
- Volume of irrigation water.

- Alternance of soil wetted by irrigation.

This analysis (Table 4) allows us to notice that the comparison between PRD ((2) in Table 4) and traditional irrigation ((7) in Table 4), such as carried out in the first trials (in pots as well as in the field), is a multifaceted comparison. The factors which may vary are the three listed above and thus, it is difficult to attribute the benefits of PRD to a single cause. In addition, it can be observed that among all the possible combinations of factors, more than 50% remain to be studied.

	Volume of wet soil			
	Normal		Double	
	PRD	Traditional	PRD	Traditional
Total Irrigation [z]	? [1]	**REF** [2]	✓ [3]	? [4]
Insufficient irrigation	✓ [5]	? [6]	✓ [7]	? [8]

[z] Total irrigation based on the application of 100% evaporative transpiration
ETc.; the ✓ symbol identifies the cases studied and compared with the control treatment (REF). ? designates the cases to be studied. [1], [2], .. The number of each case is used in the text as explicit reference.

Table 4. Factor combinations potentially affecting the comparison of PRD and traditional irrigation

It would be interesting to have sufficient information in order to compare the results of all the cases presented in Table 4. This information should come from a study carried out under the same conditions (geographical location, type and depth of soil, grape variety, vineyard age, vine density, vine training, fruit load (clusters, grapes,), etc.). Indeed, these conditions can be more important for the results than the cases presented in Table 4. Among all the possible situations, some correspond to more common cases such as SDI (which would correspond to the case [6] in Table 4) and irrigation by micro-aspersion (which would correspond to the case [4] in Table 4).

From a practical point of view, it could be concluded that PRD has improved the production efficiency of the water supplied by irrigation in the majority of the cases studied, even though the various reasons for the efficiency of PRD in the different situations (and conditions of cultivation) analyzed do not coincide. However, from a more scientific and technical point of view, the biggest advantage of PRD could be to simply demonstrate that a water management adapted to the water status of the vines is vital to control the production, as known for other cultures. PRD, such as once SDI, constitutes a small advance in vine control by playing with the vine water stress to obtain specific results. Though, with regards to the practical agronomical knowledge, a large gap remains.

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