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Exploring the genetic variability in water use efficiency: Evaluation of inter and intra cultivar genetic diversity in grapevines☆

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ABSTRACT

Genetic improvement of crop Water Use Efficiency (WUE) is a general goal because the increasing water scarcity and the trend to a more sustainable agriculture. For grapevines, this subject is relevant and need an urgent response because their wide distribution in semi-arid areas. New cultivars are difficult to introduce in viticulture due to the narrow dependency of consumer appreciation often linked to a certain particular wine taste. Clones of reputed cultivars would presumably be more accepted but little is known on the intra-cultivar genetic variability of the WUE. The present work compares, on the basis of two field assays, the variability of intrinsic water use efficiency (WUE_i) in a large collection of cultivars in contrast with a collection of clones of Tempranillo cultivar. The results show that clonal variability of WUE_i was around 80% of the inter-cultivar, thus providing a first assessment on the opportunity for clonal selection by WUE. Plotting the WUE_i data against stem water potential or stomatal conductance it was possible to identify cultivars and clones out of the confidence intervals of this linear regression thus with significantly higher and lower WUE_i values. The present results contribute to open the expectative for a genetic improvement of grapevine WUE

1. Introduction

Water use efficiency issue is becoming an important subject for environmental sustainability of crops because of growing necessity of food production and increasing needs of irrigation to enhance crop productivity [1–3].

Viticulture is mainly located in semi-arid areas [3,4]. High water requirements are common because the growth cycle of grapevines coincides with the driest months, making irrigation a convenient practice. That means an important consume of water which sometimes enter into conflict with the economic and environmental viability of this crop, particularly in dry prone areas. Water use by irrigation is therefore limiting the sustainability of the vineyards and sometimes also enters in competition with other critical human uses [5–7]. Stressing even more the conflict, the climate change forecasts and last year's climatic data show increasing drought and heat waves frequency joined with higher unpredictability of rainfall [8,9]. According to climate change predictions, episodes of extreme drought will be from 3 to 8 times more frequent than at the present [10]. It means that, for most of the Mediterranean and semi-arid regions of grapevine production, high irrigation volumes will be required to obtain a reasonable harvest.

In consequence, the optimization of water use for vineyards, by improving water use efficiency (WUE), is one of the highest interest subjects. As a response to this social claim, an important volume of applied and fundamental research has been focused into the exploration of the capacity to optimize grapevine water use. Such optimization is explored directly adjusting the irrigation timing and schedule introducing new technologies to reduce water consumption [11–14] looking for a compromise between reasonable crop yield and quality and reduction of irrigation dosage.

However, the successful results of genetic selection and the advances in genomics and phenotyping [15,16] also impulse to exploit the *Vitis* genetic diversity to enhance the stress resistance and the improvement of WUE [17]. The impressive world-wide amount of grapevine cultivars used in viticulture and already properly described [18,19] provides wide genetic variability of the grapevine genome which constitute invaluable genetic resource to reach with crop adaptation to the different environmental conditions and potentially to climate change.

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Since, little is known about the WUE as a selection criteria in grapevines, even though some cultivars are reputed as more adapted to drought-prone conditions, thus, presumably showing, in some way higher WUE.

Genetic variability in WUE in grapevines was early demonstrated in our group [20] measuring intrinsic leaf water use efficiency (WUE_i) as the quotient of photosynthesis rate versus stomatal conductance (A_N/g_s) in a collection of old Majorcan cultivars, and by Gaudillere et al. [21], estimating WUE as the surrogate character isotope ^{13}C discrimination in biomass ($\delta^{13}C$). After these early works, significant differences in different physiological parameters closely related to the WUE such as A_N and g_s as well as WUE_i were published by Souza et al. [22]; Soar et al. [23]; Pou et al. [24]; Prieto et al. [25]; Costa et al. [26]; Tomás et al. [27]; Tomás et al. [28]; Bota et al. [29] showing interesting variability in WUE_i, in leaf or grape $\delta^{13}C$, or whole plant WUE among different cultivars. A wide range of A_N/g_s among genotypes under high soil water availability and soil water stress conditions was demonstrated also for field growing plants [29].

However, it has been shown that within a single plant, there is a large variation of A_N/g_s clearly dependent on prevailing environmental conditions [30,31]. The high environmentally-induced variation on intercepted light, and other parameters was always present limiting the capacity to evaluate the genetic variability among cultivars. Moreover, most of the measurements of WUE in grapevines were performed at the leaf level and the comparisons with the measurements at whole-plant level showed to be sometimes good but poor in other experiments [3,27,28]. The lack of correlation was related to the complexity of the grapevines canopy structure [32], night transpiration [33], and the important role of plant respiration [34,35]. Nevertheless, the necessity to evaluate the WUE genetic variation previous to any breeding program obligates to explore it on the basis of single, rapid measurements parameters (as A_N/gs) as selection criteria.

The end goals of those genetic variability assessments were also to identify some cultivar with higher WUE which could help to reduce the watering necessities thus improving the WUE at the vineyards. Furthermore, for commercial viticulture, the agricultural behavior, the fruit quality characteristics and particular wine taste of a certain cultivar are crucial for the final wine production. Therefore to change current cultivars for others with higher WUE would be matter of wide discussions likely reducing the applicability of new obtentions. In such a way, there is a large tradition of clonal selection inside a certain cultivar which was matter of wide research for more adjusted productivity, higher diseases resistance or particular adaptation to limiting environmental characteristics [36–38]. Different grapevine clonal selection programs were already made at the regional level for public research as for private nurseries with reasonable successful results [39,40]. Particularly, inside the Tempranillo, a Spanish cultivar widespread in Spain and around the world, a wide effort was done in different Spanish regions to select clones better adapted to different characteristics, with results recently analyzed by Ibáñez et al. [39].

In the light of these results, it seems interesting to look for the variability of the WUE among clone collections already shown as a source of important variability for agronomic and quality characters in grapevine [38].

Tempranillo cultivar has also been mater of wide studies on its agronomic behavior, physiological performance and genetic background [39,41], and moreover there is a large collection of Tempranillo commercial clones available at public research and nurseries. The wide differentiation among grapevine clones in productivity, quality and other complex characters reinforces the interest to explore such variability for the WUE parameters.

On these grounds, the present work shows a particular insight on the variability of the WUE among different cultivars as well as among different clones of Tempranillo cultivar. The results open a new field of research for high-WUE addressed selection inside elite cultivars of grapevine.

Table 1
List of plant material.

Tempranillo clones		
	Name	Plot
Accession	86	+
	232	+
	260	+
	280	+
	518	+
	560	+
	807	+
	814	+
	843	+
	1041	+
	1048	+
	1052	+
	1084	+
	1089	+
Selection	RJ26	+++
	RJ43	+++
	RJ51	++
	RJ78	+++
	RJ79	+
	VN1	+
	VN3	+
	VN31	+
	VN32	+
	VN33	+
	VN69	+
	VP8	+
	VP11	+
	VP24	+
	VP25	+
	VP28	+
Grapevine cultivars		
Berry color	Cultivar	
Red	Cabernet Sauvignon	
	Callet	
	Escursac	
	Esperó de Gall	
	Galmeter	
	Garnacha	
	Gorgollasa	
	Manto Negro	
	Merlot	
	Sabater	
	Syrah	
	Tempranillo	
	Valent Negre	
	Vinater Negre	
White	Argamusa	
	Callet Blanc	
	Chardonnay	
	Giró Ros	
	Macabeo	
	Malvasia de Banyalbufar	
	Moll	
	Valent Blanc	
	Vinater Blanc	

2. Material and methods

2.1. Plant material

Twenty three grapevine cultivars (Table 1) were studied during August 2011 in an experimental vineyard located in Palma de Mallorca (39° 35′N, 2°39′E) (Balearic Islands, Spain). Plants were 12 year old, grafted onto 99-Richter rootstock, trained as doubled cordon