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Transpiration and evaporation of grapevine, two components related to irrigation strategy

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ABSTRACT

The quantification of evaporation is crucial for the appropriate use of water, especially in arid areas where rainfall is scarce. An experiment was carried out in a semiarid area of Spain (Albacete) with the objective of quantifying the evaporation and transpiration of grapevine cv. Tempranillo and the effects of irrigation frequency on the evaporation. Measurements of transpiration and crop evapotranspiration of grapevine cv. Tempranillo without soil water limitations were conducted in a weighing lysimeter covered with a waterproof canvas during different periods from 2011 to 2014. The transpiration rates measured on the days after irrigation were higher than those measured when irrigation was not applied or when there were no precipitation events. Evaporation, calculated as the difference between the days on which the lysimeter surface was covered or not covered, ranged from 81% of evapotranspiration in the first phenological stages to 30% close to the time of full canopy cover. Under similar canopy cover and reference evapotranspiration, transpiration measured on the days when irrigation was applied was greater than transpiration measured on the days when the vines were not irrigated. Different irrigation strategies were applied to determine the effect of the quantity of water applied on the evaporation, and the results showed that the greater the amount of irrigation applied, the higher the efficiency, when the irrigation frequency is reduced; in fact, three times more water was applied during each irrigation event and the evaporation percentage was 7% lower. Therefore, a high irrigation frequency should be questioned in semiarid areas.

1. Introduction

Numerous studies have concluded that climate change has globally altered hydrological regimes. This has affected the availability of fresh water, and will therefore impact rainfall and irrigated agriculture (UN-Water, 2009). In this context, the semiarid areas of the entire Mediterranean basin, southern Africa, Australia and the Americas have shown a decrease in rainfall and a severe reduction in river runoff and aquifer recharge (IPCC, 2008; FAO 38, 2012). Knowledge of the inputs and losses of water is necessary for understanding ecosystem processes under current and climate change conditions, especially in dry regions (Schwinning et al., 2004).

The region of La Mancha, in central Spain, belongs to the Mediterranean basin, and its climate is semiarid continental. It is one of the largest irrigated areas in the country. Groundwater from aquifers is used as a source of irrigation water in this area and unfortunately, water table reservoirs have declined since the beginning of their exploitation (Montoro et al., 2011a). This depletion could chanllenge the sustainability of the aquifers and, in an effort to avoid this, the water authority does not allow extractions to exceed 7000 m^3 per year and ha, and for a maximum surface area of 7 ha for grapevine.

With this background, it is necessary to seek alternative practices that can increase water productivity, among which irrigation scheduling is priority. Water losses in agricultural systems can be attributed to runoff, deep drainage or evaporation from the soil (E), although there is controversy regarding the definition of E as a water loss (Agam et al., 2012). Although Zhang et al. (2005) considered E as a water loss; Burt et al. (2005) claimed that E provides a benefit for maintaining a micro-climate around the crop, mainly under conditions of high irrigation levels. In FAO 38 (2012), E is considered as a loss, which indicates that a clear understanding is needed to ensure good management strategies because E varies with local conditions.

Grapevine is the largest cultivated crop in La Mancha. Moreover, this is a sparse crop for which the soil usually consititutes

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an important and variable source of water for E. This results in some difficulties in modeling evapotranspiration (ET_c) fluxes. Some authors consider that grapevines and soil should be treated as independent systems (Oliver and Sene, 1992; Trambouze and Voltz, 2001). However, Hicks (1973) and Heilman et al. (1994) speculated that sensible heat transport from the soil surface in vineyards contributed to vineyard crop evapotranspiration.

To achieve optimal grapevine production in drip-irrigated vineyards, it is necessary to estimate the ET_c components to assess vineyard water requirements (Trambouze et al., 1998; Yunusa et al., 2004). Different methods and techniques have been applied to estimate total ET_c in vineyards; based either on a simplified bulk formulation of the sensible heat flux (Miglietta et al., 2009), or on the Shutteworth and Wallace model (Ortega-Farias et al., 2010), on the Bowen ratio-energy balance (Zhang et al., 2010), or on the Two-Source Energy Balance model (González-Dugo et al., 2010), and surface renewal analysis (Shapland et al., 2012). However, there are few studies where direct measurement of ETc has been conducted using lysimeters. López-Urrea et al. (2012b) conducted one of the few studies that used a weighing lysimeter, from which the present work was developed. Additionally, some efforts have been made to estimate E and transpiration (T) separately, e.g., T has been estimated using micrometeorological methods (Oliver and Sene, 1992; Yunusa et al., 2004), or using satellite images and deriving T from vegetation indices (Campos et al., 2010) and measuring directly on the crop, using sap flow sensors (Trambouze and Voltz, 2001; Intrigliolo et al., 2009), among others. Different results have been found mainly because the crop is trained on a vertical shoot positioned system, which varies the fractional canopy cover (f_c) from 20% to 80% (Heilman et al., 1994; Williams and Ayars, 2005; López-Urrea et al., 2012b). In addition, the fraction of the soil surface exposed to solar radiation varies; Lascano et al. (1992), working with vineyard that was flood irrigated, measured 77% of evaporation of total ET, however, the crop is irrigated by drip irrigation in most cases, and some authors have considered the fraction of the soil surface wetted by the dripper to be low (3%) and consequently, soil evaporation should be minimal (Ortega-Farias et al., 2010).

Irrigation frequency is one of the most important factors in drip irrigation scheduling. Due to the differences in soil moisture and wetting pattern, crop yields may be different when the same quantity of water is applied under different irrigation frequencies (Wang et al., 2006; Sebastián et al., 2015). Many experiments have shown positive responses in some crops under high drip irrigation frequency (Freeman et al., 1976). However, inconsistencies regard to the optimum frequency are found in the literature and could depend on the crop. Meshkat et al. (2000) went one step further by pointing out that an irrigation regime with excessively high frequency could cause the soil surface to remain wet with first stage of evaporation persisting most of the time, resulting in a maximum rate of water loss. In this sense, FAO (2012) suggests agronomic practices in irrigated systems that maximize the amount of water that is put to beneficial use through crop transpiration, and to minimize the amount of water lost through non-beneficial evaporation.

The objective of this research was to know the T and the E of grapevine cv. Tempranillo in a weighing lysimeter under semiarid conditions before and after irrigations events and to evaluate the importance of the evaporation component of ET_c as a function of irrigation frequency.

Fig. 1. View of the lysimeter with the waterproof canvas installed.

2. Materials and methods

2.1. Experimental site and design

The study was carried out over four years, from 2011 to 2014, at the Las Tiesas farm, Albacete, Spain (lat. 39°3′31″N; long. 2°6′04″W) at an altitude of 695 m above sea level. The climate is semiarid continental with an average annual rainfall of 320 mm, which is mostly concentrated in spring and fall. The soil is classified as a Petrocalcic Calcixerept (Soil Survey Staff, 2006).

Two vines (*Vitis vinifera* cv. Tempranillo) grafted to 110 Richter rootstock were planted in 1999 in the lysimeter, described in Montoro et al. (2008) and López-Urrea et al. (2012b). The spacing between the vines and rows was 1.5 and 3 m, respectively. The plants were trained to a bilateral cordon. Eight weeks prior to bud break, the plants were pruned to five spurs per cordon and two buds per spur. The shoots were maintained on a vertical plane by three wires, the highest of which was located 1.40 m above the soil surface. Nutrient, pest, and disease management practices were applied each year according to standard commercial practice. Further descriptions of the experimental site and vines are presented in Montoro et al. (2008) and López-Urrea et al. (2012b).

The T was measured in the lysimeter by covering the soil surface with a waterproof canvas that had a color similar to the soil to prevent modification of the albedo, thereby eliminating evaporation (Fig. 1). The lysimeter was covered for only a few days in 2011. The soil was covered for 95 days in 2012 and 119 days in 2013, with a few days in the middle of the cycle when the soil was exposed to areate the soil surface and prevent fungal growth. In 2014, the lysimeter was covered for 15 days during grape maturation (Table 1).

Table 1
Main phenological stages of grapevine during the 2011, 2012, 2013 and 2014 growing seasons and period which the surface soil was covered with waterproof canvas.

	Day of year									
Year	Bud break		Flowering			Veraison			Harvest	
2011	98		154	(199	202)	213			246	
2012	110		161	(195		222			258	290)
2013	106	(129	161			227		248)	260	
2014	108		154			217	(231	246)	255	

The gray frame corresponds to period which the surface soil was covered with waterproof canvas.