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Consumptive water use and irrigation performance of strawberries

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ABSTRACT

In south-west of Spain, the strawberry crop generates high economic value goods and high rate of employments. However, strawberry is cultivated in the vicinity of the Doñana National Park, a wetland with the maximum European environmental protection. Hence, minimize agricultural water use is of considerable interest in this area. Two experiments were conducted in order to determine strawberry (*Fragaria* × *ananassa*) irrigation requirements. The experiments were carried out with *Sabrina* and *Antilla* cultivars without deficit irrigation. Three irrigations amounts were applied with different water volumes. Drainage lysimeters were installed in order to measure crop evapotranspiration. In *Sabrina* trial, seasonal crop evapotranspiration ranged from 430 to 453 mm, whereas in *Antilla* it reached 352 mm. The crop coefficient reached maximum values of 1.1 and 0.8 in *Sabrina* and in *Antilla*, respectively. In *Sabrina* trial, irrigation efficiency of 81% was achieved when an irrigation volume of 5500 m^3 ha^{-1} was applied. In all *Sabrina* trial treatments, marketable fruit production exceeded 1000 g $plant^{-1}$ and crop productivities were above 74 t ha^{-1}, with no significant differences among treatments ($P < 0.05$). In *Antilla* trial, the maximum irrigation efficiency reached was 58%. The yield was around 750 g $plant^{-1}$, whereas land productivity was above 48 t ha^{-1}, with no significant differences between treatments. Water productivity was higher in *Sabrina* trial. The results suggest that following an irrigation schedule based on meteorological data and estimated crop coefficients, can result in significant water savings without losses in yield.

1. Introduction

Spain is the main strawberry growing area in Europe and the fourth worldwide after the United States, Mexico and Turkey (FAOSTAT, 2014). An area of 7500 ha was dedicated to strawberry (*Fragaria* × *ananassa*) cultivation in the province of Huelva (southern Spain) in the 2012/2013 season. This figure represents a 10% increase compared to the average in the 2004–2007 period, when the average annual production was 300,000 metric tons (Consejería de Agricultura y Pesca, 2012). The strawberry crop is cultivated under plastic tunnels and generates high economic value goods and employment (around 55,000 jobs). Montesinos et al. (2011) described a high economic water productivity of 21.4 € m^{-3}. However, the fact that it is cultivated in the vicinity of the Doñana National Park, the most important wetland in Europe, requires the reconciliation of environmental conservation and productive activity (Fig. 1). In fact, agricultural withdrawals for irrigation have caused a general decline in groundwater and piezometric levels (Custodio et al., 2008). The Spanish Geological and Mining Institute (IGME) also highlights that during the last 30 years the average summer flows recorded in the main streams that flow into the Doñana marshes has suffered a 50% reduction (García Morillo et al., 2015a). Furthermore, the cation exchange capacity of these sandy soils is low and there can be significant leaching of crop nutrients from excess water (Albregts and Howard, 1984). Consequently, finding ways to reduce agricultural water use is of considerable interest in this area.

Despite the widespread use of drip irrigation in strawberry, there is still uncertainty about the precise amount of water needed. In previous works, a wide range of consumptive water use has been reported, between 300 mm (Trout and Gartung, 2004) and 797 mm (Strand, 2008). Likewise, crop yield ranged from 179 g $plant^{-1}$ (Rolbiecki et al., 2001) to 1704 g $plant^{-1}$ (Larson and Shaw, 1996). Moreover, in terms of land productivity, values ranging from 6 t ha^{1} (Stevens et al., 2011) to 83 t ha^{-1} (Serrano et al., 1992) were found. Even in water productivity there is a wide range of values between 4.0 kg m^{-3} (Kirschbaum et al., 2003) and 14.67 kg m^{-3} (Serrano et al., 1992). In our study area there is also a similar situation with water applied between 4071 and 15,214 m^3 ha^{-1} (García

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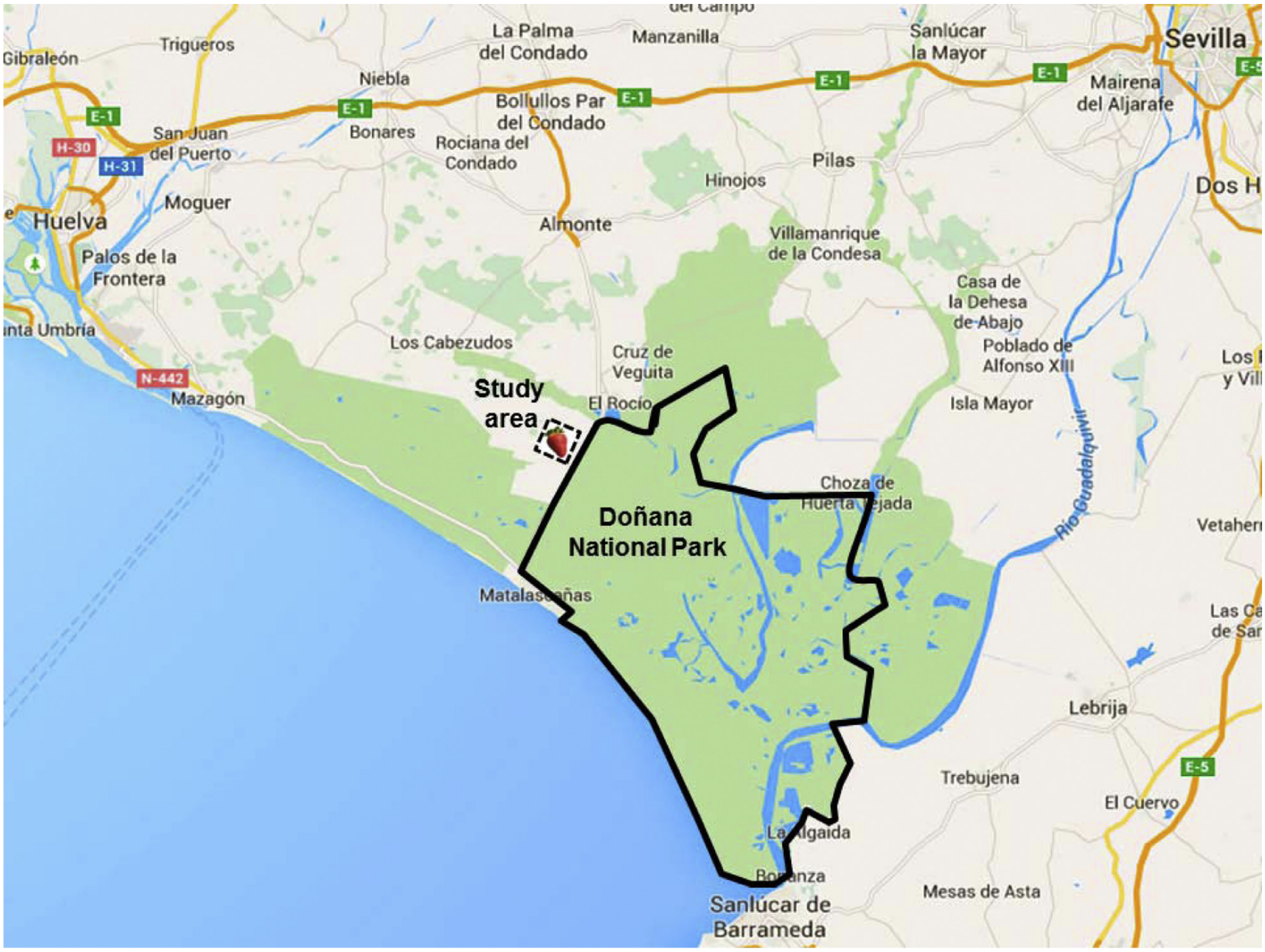

Fig. 1. Location of the Doñana National Park and the study area.

Morillo et al., 2015a). In Huelva, strawberry farmers schedule their irrigations in order to obtain maximum production. They based on past experience, observation of weather conditions and visual plant indicators of stress. Therefore, over-irrigation easily occurs. This involves not only a problem of irrigation efficiency, but also of water pollution.

To improve their irrigation practices farmers need tools to calculate the strawberry irrigation requirements. In this sense, FAO developed a methodology based on crop coefficient (K_c) and reference evapotranspiration (ET_o) (Doorenbos and Pruitt, 1977). This methodology has been used worldwide to determine crop water requirements. FAO-56 Irrigation and Drainage Paper (Allen et al., 1998) manual suggests some general values of K_c for growing strawberries. However, there are differences between cultivars, length of growing season, weather conditions and farming systems. These differences raise questions about the applicability of these general values in any system. Likewise, a standardized method for estimating ET_o has been defined in the FAO-56 manual. Nevertheless, there is no standardized method under plastic tunnel conditions. This fact is important because strawberries are grown in plastic tunnels in most parts of the world.

In Europe they have been grown successfully since the early 1970s. In China, there are also thousands of hectares of strawberries grown over the winter in energy-saving plastic tunnels. However, most of the researches on strawberry irrigation have been carried out in California and Florida (USA), where open-field cultivation is the standard strawberry production method. McNiesh et al. (1985) estimated crop coefficients reporting values from 0.45 to 0.7 during the summer production period. Clark et al. (1996), using water balance lysimeters in Florida, measured maximum K_c values of around 0.8 when the 60 cm-wide beds had nearly full cover. Grattan et al. (1998) measured strawberry ET_c using a Bowen ratio system in California. They estimated K_c as nearly equal to canopy cover, when there was 100% coverage on the bed. For the State of California, Hanson and Bendixen (2004) reported maximum K_c estimated values of 0.7, when the maximum coverage of the crop was no higher than 75%. However, these last authors did not measure ET_c. They estimated ET_c by first establishing the relationships between canopy coverage and days after planting (DAP). In this study, seasonal ET_c ranged from 310 to 396 mm. Jackson (1992) also reported maximum K_c values of 0.7 for final crop coverage of 75%. Finally, the FAO-56 Irrigation and Drainage Paper (Allen et al., 1998) lists basal crop coefficient values for strawberry as 0.15 early in the season, 0.85 midseason, and 0.7 late season.

In Spain almost all strawberries are grown under tunnels, but there are no studies that have attempted to estimate irrigation requirements in these conditions. Hence, since 2011, the Andalusian Institute of Agricultural Research and Training (IFAPA in Spanish) has conducted studies on drip irrigation of strawberries in Huelva. The aim is to help strawberry growers to obtain irrigation requirement values for their local crop system (Gavilán et al., 2014).

This study was conducted in Huelva coast to: (1) measure crop evapotranspiration of two commonly used strawberry cultivars using drainage lysimeters; (2) estimate their crop coefficients; (3)