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Analysis of on-farm irrigation performance in Mediterranean greenhouses

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ABSTRACT

A comprehensive irrigation assessment was conducted using on-farm water use information and simulated crop water requirements in a Mediterranean greenhouse area, mainly dedicated to horticultural crops, located on the Almería coast.

The mean irrigation water supply (IWS) for the main greenhouse crop cycles was 228 mm and ranged from 158 mm (autumn green bean) to 362 mm (autumn–spring sweet pepper). Besides, the mean AIWS value for the main crop rotations was 444 mm and ranged between 363 mm for autumn–spring sweet pepper and 502 mm for autumn–winter pepper and spring melon.

Mean relative irrigation supply (RIS) values were close to 1 for most greenhouse vegetable crops, indicating that, on average, the irrigation supply matched the maximum water requirements of these crops. By contrast, the mean RIS value of autumn–winter cucumber was 1.6, indicating that, on average, the irrigation supply clearly exceeded the calculated optima. However, for most crops, the high CV values observed for RIS and the analysis of the RIS dynamics throughout the cycles indicate that there are greenhouse crops and crop cycle periods for which the IWS clearly does not match the crop water requirements. Greenhouse irrigation water use in the Almería coastal region can, therefore, be improved.

Mean irrigation water use efficiency (IWUE) values for greenhouse horticultural crops ranged from 15.3 kg m^{-3} (autumn–winter green bean) to 35.6 kg m^{-3} (spring watermelon). They were, in general, higher than those found when these crops were grown outdoors in similar climatic regions. Water productivity (WP) varied from 7.8 to 15.9 € m^{-3} and were highest for green bean crops. WP values of greenhouse crops were generally much higher than those found in other irrigation districts around the world, including Mediterranean areas, due to the low IWS and, especially, to the high value of the vegetable crops grown off-season.

1. Introduction

Greenhouse vegetable production is expanding in many world regions (Enoch and Enoch, 1999) and in particular throughout Mediterranean coastal areas (Pardossi et al., 2004). The Mediterranean greenhouse vegetable system is mostly based on simple low technology plastic greenhouses located in mild winter areas, which enables the production of high-value vegetables from autumn to spring (Castilla and Hernández, 2005).

Growing populations and an expected higher standard of living will increase water demand dramatically in the near

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future. Irrigation worldwide (including Spain) accounts for about two thirds of all water usage, and so there are increasing societal demands for a more productive use of this resource (Howell, 2001) and for an effective accountability of irrigation water use (Seckler, 1996). Therefore, performance evaluation of irrigation areas is needed to propose improvements in irrigation management, to assess water productivity and to preserve the environment (Molden and Sakthivadivel, 1999; Lorite et al., 2004a). In semiarid Mediterranean coastal areas with increasing water demands, such as the Almería coast, where intensive agriculture, tourism and other sectors are competing for scarce water resources, evaluation of irrigation performance including water productivity is going to be a prerequisite for any future water policy.

The analysis of irrigation performance is usually conducted with a set of indicators (Molden and Gates, 1990; Malano and Burton, 2000), which could be locally adapted to account for the idiosyncrasies of each irrigation area, so that meaningful assessments may be carried out (Lorite et al., 2004b). Scheme-level assessments, producing performance indicators based on average values for the whole irrigation area (Molden et al., 1998), are the only feasible approach when information at sub-scheme-levels (usually farmers) is not available. However, this procedure may not reflect accurately the current irrigation practices in the area, since it does not measure the degree of variation in irrigation management among farmers. The availability of water-use information at the individual plot or farmer level allows in-depth assessment of irrigation performance by characterising average performance indicators on each of the main crops in the area and the variation among farmers for any of these indicators. High variability in performance among farmers would indicate a substantial potential for improvement, even if average performance values are reasonable. In a further step, a more detailed study could be focussed on farmers with performance values outside the reasonable range.

Irrigation performance studies have already been conducted in several semiarid areas dedicated to open field crops (Faci et al., 2000; Dechmi et al., 2003; Lorite et al., 2004a,b; Lecina et al., 2005), but not in greenhouse areas, which usually present rather different characteristics in soils (artificial soils), crops (intensive crops), irrigation practices and socio-economic conditions (high water cost, high-value crops, etc.). The greenhouse area located on the Almería coast, one of the largest in the world, is drip irrigated and mainly dedicated to horticultural crops. Despite the relatively high irrigation water prices, current irrigation practices are generally based on local growers' experience (soil or plant water sensors are not normally used) and high variations in irrigation water supplies to each of the main vegetable crops have recently been detected (Caja Rural de Almería, 1997; González, 2003). Additionally, some water contamination problems of the underlying aquifers have been already detected (Pulido-Bosch et al., 2000). The aim of this work was to conduct a comprehensive assessment of the irrigation performance in this area using on-farm water use information and simulated crop water requirements in order to improve the irrigation water management and minimise percolation losses.

2. Materials and methods

2.1. Area description

The study area was located within the Campo de Dalías, on the west coast of the Almería province, in southeast Spain (Fig. 1). This is the largest and oldest greenhouse area on the Mediterranean Spanish coast with approximately 20,500 ha of plastic greenhouses (Sanjuán, 2004), mainly dedicated to vegetable production. The climate is Mediterranean with mild winters and low annual precipitation: average annual temperature and rainfall are 18 °C and 220 mm, respectively. Artificial layered soils, locally called "enarenados" (Wittwer and Castilla, 1995), are mostly used by greenhouse farmers, although inert substrates (perlite and rockwool) in plastic bags are being used increasingly. Greenhouses are mostly low-cost structures covered with plastic film, called "Parral" (Pérez Parra et al., 2004), located on practically flat plots. On average, they are 10 years old and have a surface of 7300 m^2. The main crops in the Campo de Dalías area were pepper, cucumber, green bean, melon and watermelon.

There are more than 100 water irrigation districts in the Campo de Dalías (Caja Rural de Almería, 1997). The evaluation study was conducted in the two main irrigation districts, called Sol y Arena (SAID) and Sol-Poniente (SPID), respectively, and in a representative group of greenhouses supplied from small irrigation districts (SID). Water of relatively good irrigation quality [electrical conductivity (EC) values usually about 1 dS m^{-1}, but always lower than 2 dS m^{-1}] and provided by deep wells and a nearby reservoir was mostly used. The water distribution system in the SAID and SID consisted of a gravity-fed branched network, mostly concrete irrigation ditches, from which water is diverted weekly to farmers' irrigation ponds (Caja Rural de Almería, 1997). In the SPID the water was distributed by a pressurized irrigation system, which allows flexibility of frequency and duration of water delivery to each greenhouse. Most farmers have small reservoirs or ponds close to the greenhouses for ensuring

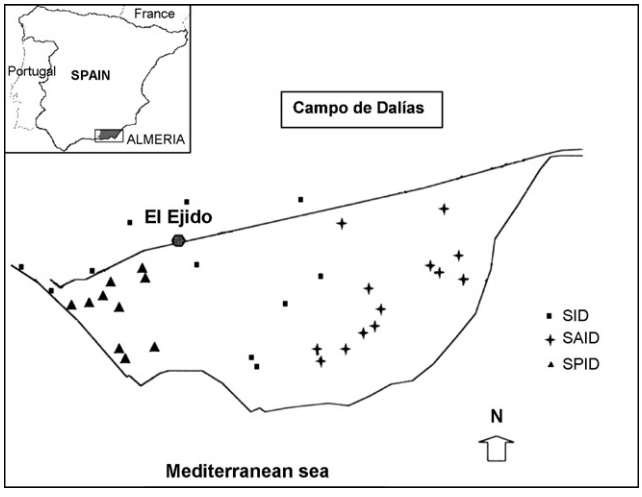

Fig. 1 – Distribution of the monitored greenhouses in the Sol y Arena (SAID) and the Sol-Poniente irrigation districts (SPID), and from small irrigation districts (SID) located on the Almería coast, southeast Spain.