CONTINUOUS SOIL MOISTURE MONITORING FOR IRRIGATION SCHEDULING OF DRIP-IRRIGATED VEGETABLES GROWN IN GREENHOUSES

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Introduction

Approximately 24,000 ha of plastic greenhouses are used for intensive horticultural production in the coastal region of Almeria, in SE Spain. Tomato, pepper, cucumber, aubergine, and zuccini are grown in autumn-spring, and melon, watermelon and tomato in spring-summer. 80% of cropping is in soil, the rest in hydroponics. Most of the soil used is an artificial soil system ("enarenado"), in which 20–30 cm of imported loam soil is placed over the indigenous gravely soil, and 8–12 cm of coarse sand mulch over the loam soil.

Drip irrigation (above-ground tape) is used. Irrigation management is mostly based on experience of farmers and/or technical advisors. Considerable variation in water use occurs for similar levels of production. Most irrigation water is obtained from local aquifers, extraction exceeds replenishment. There is scope for improved crop irrigation management. Soil moisture monitoring (SMM) enables irrigation to be "tailored" to the characteristics of individual crops.

An applied research program was conducted to adapt continuous monitoring of volumetric soil moisture content, for practical irrigation management in this horticultural system. Recommendations for the use of SMM, in this system, were developed.

Methods

Four successive crops were grown in a (28 by 23 m) plastic greenhouse at the Estación Experimental "Las Palmerillas", in El Ejido, Almeria province, Spain. The soil was 10 cm of coarse sand mulch over 20 cm of imported silty-loam soil over the natural soil (loam texture, high gravel content). For comparing irrigation treatments, there were 3 separate irrigation sectors, each formed from four randomly-selected plots (10 by 4.5 m). Adjoining plots were separated by plastic sheeting to 30 cm depth.. The above-ground drip irrigation system had 50 cm linear spacing between drippers and 1.5 m between laterals (3 laterals per plot).

All crops (see Table), excluding pepper were grown with one plant per dripper (6-8 cm separation); in pepper, there was one plant either side of the dripper (20 cm separation).

Crop/year	Period	Access tube installation	Probe location	Method for "lower" limit
Tomato99	Aug-Feb	Excavated hole, refill	Behind dripper, opp. side to plant	reduced uptake
Melon00	Mar-July	Excavated hole, refill	Behind dripper, opp. side to plant	reduced uptake
Tomato00	Aug-April	Narrow hole, slurry	B/w & to side of dripper/plant	Uptake at depth
Pepper01	July-Nov	Narrow hole, slurry	B/w & to side of dripper/plant, & at edge of bulb behind/to side of plant	"wet cylinder"

The EnviroSCAN (ES) capacitance sensor (Sentek, Australia; Paltinaeu and Starr, 1997) was used to continuously monitor volumetric soil moisture. Each probe consisted of sensors at 15, 25, 35 and 45 cm soil depth, which was placed vertically within a 5.5 cm outside dia. access tube. Irrigation management, using the ES, is usually based on maintaining soil moisture, of a depth of soil, within defined upper and lower limits. In this work, the limits were developed for the 20 cm layer of imported silty-loam soil, using the 15 and 25 cm deep sensors.

A series of crops were grown (Table). In each, one irrigation treatment was managed with data from the ES, and another with manual tensiometers (10–30 kPa). Fruit production, crop growth (height) and soil matric potential (tensiometers) were measured. During the trials, protocols for ES probe installation, location and management strategy were developed.

Review of work and findings

Access tube installation

The manufacturer's procedure of augering inside the 5.5 cm dia access tube and forcing the tube down was ineffective on account of the high gravel content. For the initial installation (for tomato99, melon00), a 20 cm dia., 65 cm deep hole was excavated, the access tube positioned, and the hole manually re-filled. This method considerably alters soil physical conditions.

For subsequent installations (tomato00, melon01), a 7–9 cm dia. hole was augered and partially filled with a thick soil slurry (from 4-mm sieved, silty-loam soil), and the access tube pushed in. This method greatly reduced soil disturbance. At depth, the slurry could take as long as 8 weeks to dry. If slurries were too thin, cracks apparently developed in the dried slurry, and if too thick, air pockets formed; both could cause channelling of water. Correct consistency was determined experientially, and assessed subjectively. This reinforced the subsequent requirement for replication and regular perusal of data.

Probe location and management strategy

These issues were assessed within the context of limiting the number of probes &sensors required (*i.e.* cost) and to simplify management, to increase the likelihood of farmer adoption.

The initial probe location (tomato99, melon00) was 1 probe per dripper, 4 cm from the dripper, on the opposite side to the plant. Initial management strategy, based on the manufacturer's recommendations had an "upper" limit that avoided drainage to 45 cm depth, and a "lower" limit where water content (combined 15 & 25 cm depths) limited the rate of water and amount of crop water uptake. To assess the latter, irrigation is withhold for several days; also, periodic re-evaluation is recommended to consider changes in crop growth and development.

Withholding water from the very rapidly growing melon crop was detrimental to growth and production. For very fast-growing spring-summer greenhouse crops, and crops with daily requirements for water, withholding water risks negatively affecting production.

In the melon crop, water uptake at 35 cm depth clearly occurred only when water availability declined in the overlying 20 cm layer of imported loam soil. A simplified management strategy was subsequently tried in the tomato00 crop; the "upper limit" was defined by drainage to 35 cm depth, and the "lower limit" by uptake from the 35 cm depth. One probe was located mid-way between dripper and plant, and 6 cm to the side, to better measure root uptake. In this crop, there was excessive irrigation on account of apparent horizontal drainage.

To control horizontal drainage, a second sensor per dripper/plant was installed, for pepper01, located 5 cm behind the plant, 6 cm to side, on the presumed edge of the "irrigation bulb". The management strategy adopted was to maintain a "moist cylinder of soil", with no drainage at 45 cm depth, and with irrigation applications sufficient to both just reach and to maintain a long-term horizontal trend at the "edge of bulb" position. This method was simple to apply, enabled daily irrigation, had the same production and water use as the tensiometer treatment.

Recommendations

Final recommendations for commercial application in Almeria are: installation using slurry method, and two probes per plant using the "moist soil cylinder" management approach. For each crop, it is suggested there be 3 replicate probes close to plant, with sensors at 15, 25, 35 and 45 cm, and 2 replicate probes at edge of bulb with a sensor at 15 cm. Additional suggestions are: having option of GSM to download, monitoring of soil salinity (e.g. using soil suction lysimeters and hand-held EC meters), and regular perusal of SMM data to verify validity of data.

Reference

Paltineanu, I.C. y Starr, J.L. 1997. Soil Science Society of America Journal, 61: 1576-1585