USE OF IRRIGAS® FOR IRRIGATION SCHEDULING FOR ONION UNDER FURROW IRRIGATION

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Introduction

Irrigation scheduling consists of applying the right amount of water at the right time. Incentives to onion (*Allium cepa* L.) growers for precise irrigation scheduling are based on the fact that underirrigation leads to a loss in market grade, bulb quality, and contract price, whereas overirrigation leads to a loss in water, electricity for pumping, leaching of nitrogen, and it may favor weeds and wastes labor. Overirrigation results in soil erosion, increases the potential for contamination of surface and groundwater, and requires additional chemicals and fertilizers. One of the several tools growers can use to schedule irrigation is based on the monitoring of soil water potential (SWP) and a criterion has been established at –27 kPa for furrow-irrigated onion grown on silt loam (Shock et al. 1998b). The SWP is of direct importance to plants because it reflects the force necessary to remove water from the soil.

This trial had the following objectives: 1) to evaluate the performance of six different kinds of soil moisture sensors in a furrow-irrigated onion field; 2) to compare the irrigation criterion of the Irrigas® to that defined by previous research carried out at the Malheur Experiment Station for onions under furrow irrigation; and 3) to verify if the nominal functioning pressure of the Irrigas performs reliably through wetting and drying cycles on silt loam in eastern Oregon, and observe onion yield and quality.

Materials and Methods

Six types of soil moisture sensors were compared by their response to wetting and drying in furrow-irrigated onion grown on Owyhee silt loam at the Malheur Experiment Station. Seeds were planted on 17 March 2004 in double rows on 22-inch beds. The double onion rows were spaced 3 inches apart. The sensors were tensiometers with pressure transducers (Irrometers, Irrometer Co. Inc., Riverside, CA, Model RA), ECH_2O dielectric aquameter (Decagon Devices, Inc., Pullman, WA), granular matrix sensors (GMS, Watermark soil moisture sensors Model 200SS, Irrometer Co., Inc.), Irrigas (National Center for Horticultural Research of EMBRAPA, Brasilia, DF, Brazil), and two experimental granular matrix sensors not described further here. Sensors were installed at 8-inch depth below the double row of onions on 15 July 2004 and replicates were spread 60 ft apart down an irrigation furrow in a 3-acre field. The statistical design was a randomized complete block with four replicates.

Tensiometers, GMS, and ECH_2O dielectric aquameters were attached to three AM416 multiplexers (Campbell Scientific, Logan, UT) that in turn were wired to a CR 10X datalogger (Campbell Scientific), which was programmed to make readings once an hour. Two temperature sensors were installed at 8-inch depth to allow for temperature corrections of GMS readings. Data were collected from the datalogger using a laptop computer. Each replicate contained two tensiometers, two GMS, one ECH_2O dielectric aquameter, and two Irrigas. The ECH_2O dielectric aquameters were calibrated against volumetric soil water content by taking two soil samples near each probe centered at 8-inch depth, once when the soil was relatively wet, and once when the soil was relatively dry, and by preparing oven-dry soil and placing the probes in the oven-dry soil at the end of the trial. Gravimetric data were converted to volumetric water contents using soil bulk density. Irrigas operates on the principle of air permeability of porous ceramics explained below. Data were collected from all sensors from July 15 to September 30, 2004.

Air permeability of porous ceramics has been used to estimate SWP (Kemper and Amemiya 1958). Air permeability of a specific porous ceramic is a function of its water content. As water dries from the ceramic, the pores allow the passage of air. The "initial bubbling pressure" (IBP) of a water-saturated porous ceramic is the lowest applied pressure at which air permeability is observed.

The IBP of a specific porous ceramic can be used to estimate whether a soil has reached a specific SWP used as an irrigation criterion. The National Center for Horticultural Research of EMBRAPA, Brazil used IBP to develop a SWP indicator, Irrigas (Calbo 2004; Calbo and Silva 2001). Irrigas consists of a porous ceramic cup, a flexible tube, a transparent barrel, a rigid thin plastic support, and a moveable container of water. The porous ceramic cup is installed in the effective rooting zone of the crop and connected to a small transparent barrel by means of the flexible tube. The porous ceramic cup is designed to retard free air movement out of the cup until the soil and cup reach a predetermined water potential. To make a reading, the barrel is immersed in the container of water. The free air passage through the porous ceramic cup gets blocked whenever the soil water saturates the pores in the ceramic. As the soil dries, its moisture drops below a critical tension value, and the porous cup becomes permeable to air passage. In dry soils when the barrel is immersed into the water, the meniscus (air-water boundary) rapidly moves upwards in the barrel to equalize it to the water level in the container. Whenever water enters the barrel, the soil is at least as dry as the calibration of the porous ceramic cup. The soil moisture is evaluated once a day to determine the moment to irrigate. In sandy soils the evaluation is made twice a day.

The Irrigas had a nominal calibration of -25 kPa and when we subjected Irrigas to progressive amounts of suction, the porous ceramic freely bubbled air at -25 kPa. Irrigas readings were taken every day at 9:00 AM.

The onion crop was irrigated at -25 kPa throughout the season based on average GMS readings (Shock et al. 1998b). With the establishment of this experiment in an onion field, the onions in the entire sensor calibration trial were irrigated when the average

GMS reading reached -25 kPa on July 17 and 22. Since the Irrigas had not provided positive readings, the next five irrigations were delayed until at least half of the eight Irrigas sensors indicated the need for irrigation.

The onions were lifted on September 8 to field cure. Onions from the middle two rows in each replicate were topped by hand and bagged on September 15. Onions were graded on September 16. During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small (<2.25 inches), medium (2.25-3 inches), jumbo (3-4 inches), colossal (4-4.25 inches), and supercolossal (>4.25 inches). Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading.

Results and Discussion

All the sensors used in this study had advantages of low unit cost and simple installation procedures. Both tensiometers and GMS demonstrated similar responsiveness to wetting and drying of the soil (Fig. 1). In this trial, there were two episodes of irrigation based on GMS readings at –25 kPa and five irrigation events based on the Irrigas criterion (Fig. 1). It took the same amount of time (4 hours) for all the tensiometers and all GMS to indicate that the soil at 8-inch had reached saturation after the onset of each irrigation episode. The relative similarity in responsiveness between tensiometers with pressure transducers and granular matrix sensors (GMS) was statistically confirmed by regression with a coefficient of determination of 0.92 (Fig. 2). The Irrigas indicated free air permeability close to -35 kPa for Owyhee silt loam in this trial (Fig. 1).

Large changes in tensiometer readings from -10 to -40 kPa translated into small changes in water content readings for the ECH_2O dielectric aquameter (Fig. 3). The exact responsiveness of the ECH_2O dielectric aquameter to the soil water content was beyond the scope of this work. A comparison of the ECH_2O dielectric aquameter readings with soil volumetric water content from this field indicated that the readings were relatively flat and nonlinear in response to changes in volumetric soil water content (Fig. 4). The relatively small changes in volumetric soil water content as read by the ECH_2O dielectric aquameter occurred across the critical range of SWP for onion irrigation decisions.

The ECH_2O dielectric aquameter was relatively easy to automate. The ECH_2O dielectric aquameter was used in only one experiment and the readings were relatively unresponsive to changes in soil water potential in the range of -10 to -40 kPa (Fig. 3) and relatively unresponsive to changes in volumetric soil water content in the range of 23 to 38 percent (Fig. 4). The need for site specific calibrations noted here for the ECH_2O dielectric aquameter is consistent with the work of Evett et al. (2002), who tested a variety of capacitance probes in widely divergent soils and recommended site specific calibrations.

The tensiometers with pressure transducers were easily automated. The tensiometers required servicing twice during the 76 days of the trial. More frequent servicing to replace lost water should be expected when soils are not maintained as wet as in the present experiment. The GMS have limitations in reading SWP in soils wetter than –10 kPa (Fig. 2), as has been described previously (Shock et al. 1998a), and in responding in coarse texture soils (Shock 2003).

The model of Irrigas was only tested in one comparison experiment, where it appeared to be promising for irrigation scheduling at –35 kPa in silt loam, not the nominal specifications of –25 kPa. Kemper and Amemiya (1958) pointed out that soil particles which surround and are in contact with a porous ceramic could cut down on air permeability to some extent. From the limited experience of this trial, the interference of the soil with air permeability of porous ceramics is a possibility for further study. We would expect greater interference in fine textured soils at relatively high (wetter) SWP and less interference with coarse textured soils and at relatively low (drier) SWP.

Scheduling furrow irrigations at a criterion near -27 kPa has been shown to optimize long-day onion yield and grade (Shock et al. 1998b). However, perhaps the Irrigas irrigation threshold of -35 kPa for August through the end of growing season may not have been detrimental and may bring about a convenient reduction in irrigation frequencies. An Irrigas type instrument could probably be manufactured with porosity designed specifically for measurements at -25 kPa in silt loam.

The irrigation scheduling used in this field trial appeared to be adequate, since there was an average onion marketable yield of 993 cwt/acre. Average marketable onion yield for 2000 through 2002 from commercial production in the Treasure Valley was 633 cwt/acre.

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Figure 1. Soil water potential over time for tensiometers with pressure transducers and granular matrix sensors in a furrow-irrigated onion trial. Arrows denote furrow irrigations with 75 mm of water applied. The last five irrigations started based on Irrigas. Malheur Experiment Station, Oregon State University, Ontario, OR 2004.

Figure 2. Soil water potential measured in a furrow-irrigated onion trial by a tensiometer with transducers (X axis) regressed against soil moisture suction measured by a

granular matrix sensor (Y axis). Data points are the average of eight instruments. Malheur Experiment Station, Oregon State University, Ontario, OR 2004.

Figure 3. Soil water potential measured in a furrow-irrigated onion trial by a tensiometer with transducers (X axis) regressed against volumetric soil water content measured by an ECH_2O dielectric aquameter (Y axis). Data points for soil water potential are the average of eight tensiometers. Data points for the ECH_2O dielectric aquameter are the average of four sensors. Malheur Experiment Station, Oregon State University, Ontario, OR 2004.

Figure 4. Regression of the volumetric soil water content measured by an ECH_2O dielectric aquameter (X axis) against the classical gravimetric method (Y axis). Data

points from each of four ECH_2O dielectric aquameters were compared with two soil samples in each of three soil moisture ranges. Malheur Experiment Station, Oregon State University, Ontario, OR 2004.