On-Farm Volumetric Measurement of Irrigation Water Use As A Best Management Practice Tool For Water Conservation In Drip Irrigated Vegetables

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Project Goal

To use affordable totalizing water meters to accurately measure irrigation water inputs and get a better estimate of the amount of water that can be saved through the use of drip irrigation compared to furrow irrigation. This project is part of a wider effort to improve on-farm water conservation and crop water use efficiency (WUE) in vegetable production systems in the Lower Rio Grande Valley through site-specific irrigation scheduling approaches.

Project Location

Sullivan City, Hidalgo County, TX: Cooperator: Valley Onions, Inc, Duda Farms: 2004
Edinburg, Hidalgo County, TX: Cooperator: Valley Onions, Inc, Duda Farms: 2005
Rio Grande City, Starr County, TX: Cooperator: Tetra Fruit & Vegetable Company: 2005
Weslaco - Hidalgo County, TX - Texas Agricultural Experiment Station: 2004, 2005

Summary

Information on how much water can be saved by adopting on-farm water conservation technologies is scarce due to a lack of accurate records of crop water use. In this study, we used portable, reusable and affordable totalizing water meters to estimate crop water use and the amounts of water that can be conserved by switching from furrow- to sub-surface irrigation of onions in the lower Rio Grande region of Texas. Results obtained from commercial onion fields in Sullivan City (Hidalgo County), indicate that about 0.9 acre-feet of water could be saved by using subsurface drip irrigation instead of furrow irrigation. We estimated that the current practice of furrow irrigation uses about 2.2 acre-feet of water for onion production. These water savings were obtained without compromising productivity. This translates to nearly 8,000 acre-feet of potential water savings in onion production for the Lower Rio Grande Valley given that only about 10 percent of the 11,000 acres of onions currently grown in the Valley are drip irrigated. Volumetric monitoring of on-farm water use provides the most accurate means for documenting on-farm water use, fine-tuning irrigation scheduling, and quantifying the success of water conservation when best management practices are implemented. Volumetric flow-metering, when used in conjunction with other water conserving strategies, can increase growers' profit margins by reducing production costs. Converting from furrow to drip irrigation of major vegetables grown in the Valley could conserve a significant amount of water and actually increase productivity.

Furrow irrigation is used on onion crops at Sullivan City in Hidalgo County, Texas.

Introduction

The adequacy of water supplies continues to be a major concern for agricultural production in most of Texas particularly in the Lower Rio Grande Valley, which is the most important vegetable production region in the state. Drought vulnerability is particularly high for vegetable crops because they are harvested, marketed and consumed fresh. A uniform supply of moisture throughout the growing season is therefore essential for vegetable production. Major Valley vegetable crops such as muskmelons, onions, and cabbages can require up to 20-30 inches of water depending on weather, soil, and management factors (Dainello, 1996). With less water available for irrigation, improved water management techniques are needed to optimize yields. Irrigation scheduling for vegetable production in the Valley is largely based on empirical assessments of factors such as days since the last irrigation or crop and soil symptoms. Such approaches can cause drought stress during periods between irrigations and anoxia due to excessive irrigation. Water requirements for major vegetable crops grown in the Valley are highly variable, partly because accurate records of water used in irrigation are not available. Compared to furrow irrigation, subsurface drip irrigation is an efficient means of delivering water to the crop root zone with minimal losses. It is also ideally suited for monitoring irrigation water input by use of various measuring devices. In order to quantify the potential water savings and water use efficiency of drip compared to furrow irrigation, it is essential to obtain accurate data on the amount of water supplied.

Objectives

The main objective of this project was to determine the potential water savings in drip- compared to furrow-irrigated onions. Affordable totalizing water meters were used to accurately measure irrigation water inputs. Total water use was compared with crop evapotranspiration for the season. We also compared water use in a typical commercial production field with results from fields that were irrigated based on crop evapotranspiration.

Procedures

The first phase of this study was conducted during the 2004-2005 onion growing season in commercial-scale onion fields in Sullivan City (Hidalgo County; soil type, Reynosa silty clay loam; about 32 acres) and Weslaco (Hidalgo County; Raymondville clay loam soil; about 5 acres). The cooperating grower in Starr County was Duda Farms.

The second phase was planted in the fall (October) of 2005 at three locations: Rio Grande City (Starr County; Lagloria silt loam), Edinburg (Hidalgo County; Hidalgo sandy clay loam) and Weslaco. This report includes data from the first phase only.

Onions (cv. Texas Grano 1015Y) were direct-seeded in double rows, spaced 10 inches apart on 40-inch wide raised beds with drip tape (T-Tape, T-Systems Int. Inc., San Diego, CA) installed at a depth of 6 inches. The drip tape had emitters spaced 12 inches apart and a flow rate of 0.45 gal/minute/100 ft. At Sullivan City and Weslaco, furrow-irrigated plots were also established.

This subsurface drip-irrigated commercial onion field is in Sullivan City in Hidalgo County.

Irrigation scheduling in the commercial fields (Sullivan City, Rio Grande City and Edinburg) was managed entirely by the grower and was based largely on empirical assessments such as days since the last irrigation or crop and soil symptoms. Weather conditions were also monitored and recorded at these sites. At the Weslaco sites, irrigation scheduling was based on soil moisture monitoring and crop evapotranspiration (ET_c) using crop coefficients from the United Nations Food and Agriculture Organization (FAO) and reference ET_o data from a local weather station. At one of the Weslaco sites (Center), irrigation was managed so the drip- and furrow-irrigated plots would receive roughly the same total amount of irrigation water. At the other site (Annex), irrigation decision making was independent for drip- and furrow irrigation plots. In general, irrigation was managed to match crop evapotranspiration demand and maintain the moisture at field capacity level. Soil moisture was monitored at 15-cm and 45-cm depths using Watermark soil moisture sensors connected to portable data loggers (WatchDog, Model 200, Spectrum Tech. Inc.). The amount of water applied to each plot through irrigation was recorded with ½-inch diameter totalizing water meters (Model DLJSJ50, Daniel L. Jerman Co., Inc. Hackensack, NJ) connected to the irrigation system. Water meters were installed at the junction between the main water delivery tube and the drip tape. Several water meters were installed in each field and data were averaged based on the total land area that was planted and irrigated. Prior to installation, each water meter was calibrated at typical drip tape flow rates (Max. 0.45 gal/minute/100 ft) by connecting it in series with a flow monitor (Model Eggs Delta FLM21-10NCW, Sparling Instruments, Inc. El Monte CA). Cumulative water inputs from rainfall and irrigation were calculated at the end of the irrigation treatments.

Onions were harvested on April 21, 2005, at Sullivan City and on April 25, 2005, at Weslaco. Yield was calculated on a unit area basis and onions were further classified by size as small (less than 5 cm in diameter), medium (between 5 and 7.5 cm), large (between 7.5 and 10 cm), and colossal (greater than 10 cm). Additionally, the quality parameters – pungency (measured as the pyruvic acid concentration, µmoles/mL) and soluble solids content (°Brix) were measured following standard procedures (Randle and Bussard, 1993). Water use and yield data were used to calculate crop water use efficiencies (crop yield/water applied).

This photo provides a close-up view of economical totalizing water meters that were installed to record water inputs on onion fields. At each site, a sensor (inset) was installed to record irrigation data

Results and Discussion

Sullivan City Site: Cumulative onion evapotranspiration (ETc) calculated from weather station data was 16.0 inches. Reference ET values at and shortly after planting were fairly low (0.01 – 0.25 inches), hence crop water use was also low. Total rainfall throughout the study duration (2004-2005 growing season) was 6 inches and an additional 16.1 inches of irrigation water was applied to the crop. Thus, the amount of water supplied throughout the growing season from rain and irrigation exceeded crop water demands (ETc) by nearly 35 percent (5.6 inches). This may be due, in part, to the fact that on a few occasions there was a heavy rainfall event following irrigation. However, the total amount of water supplied by irrigation alone was similar to the calculated crop ETc. As expected, more water was applied to furrow-irrigated fields (66 percent of crop ETc or 11 inches) compared to drip-irrigated fields. However, average onion yields from drip-irrigated fields were more than double (125 percent) those from furrow-irrigated fields. Long intervals between irrigations in the furrow-irrigated fields probably predisposed plants to water deficit stress and poor stand establishment, ultimately contributing to the diminished yields. Switching from furrow to drip irrigation saved 10.6 inches of irrigation water and increased yields and water use efficiency.

Table 1: Weather parameters and water use of sweet onion grown at two locations in the Lower Rio Grande Valley using two irrigation types (sub-surface drip, SDI or furrow).

Site	Irrigation method	Season ET_c, in	Irrigation (inches)	Combined irrigation & rain (inches)
Sullivan City	Drip	16.0	16.1	21.6
	Furrow	16.0	26.7	32.2
Weslaco	Drip	20.2	14.9	18.6
	Furrow	20.2	13.0	16.7

Weslaco Site: Crop water demand as calculated from cumulative ETc throughout the growing season was 20.2 inches. Total rainfall received during the growing season was 3.7 inches and irrigation water inputs totaled 14.9 inches. The amount of water supplied (18.6 inches of rain + irrigation) throughout the growing season was 8 percent less than the crop water demand (Etc) of 20.2 inches. The total amount of water supplied by subsurface drip irrigation alone was 26 percent less than crop ETc. Even though ETc was greater in Weslaco than in Sullivan City, significantly less irrigation water was applied (compared to ETc) in Weslaco, but average yield from the SDI fields were similar (65 $t \cdot ha^{-1}$) at both sites. The higher water savings at the Weslaco site may reflect the improved irrigation scheduling approach which was based on a combination of soil moisture monitoring, weather-based irrigation scheduling and volumetric measurement of irrigation water. This resulted in reduced water use without compromising yield and quality. The amount of water used in furrow-irrigated onions was similar (13 inches) to the amount of water used in drip-irrigated fields. However, the furrow-irrigated fields probably experienced water deficit stress which resulted in significantly reduced yields compared to the drip-irrigated fields. Yields from drip-irrigated fields were 70 percent greater than those from furrow-irrigated fields.

Table 2: Yield and quality (pyruvic acid development, PA; total soluble solids content TSS) of sweet onion as influenced by irrigation type (sub-surface drip, SDI or furrow) at two locations in the Lower Rio Grande Valley.

Site	Irrigation method	Yield, $t \cdot ha^{-1}$ Small	Medium	Large	Colossal	Total	PA $\mu mole \cdot ml^{-1}$	TSS %
Sullivan City	Drip	0.67	13.2	43.1	7.5	64.5	4.1	8.1
	Furrow	-	-	-	-	28.7	4.9	8.8
Weslaco	Drip	0.40	10.8	42.3	10.9	64.5	3.1	7.1
	Furrow	0.38	19.3	17.9	0.24	37.9	3.7	6.5

At a second field site in Weslaco (Annex), water use of drip- and furrow-irrigated onions and cabbage were compared. As expected, more water was applied to furrow-irrigated fields compared to drip-irrigated plots (68 percent for cabbage and 46 percent for onion plots) during each irrigation event. Compared with cumulative ETc for the study period, drip-irrigated plots saved about 4.5 inches of water whereas furrow-irrigated plots were over-irrigated by about 0.75 inches. The lower water savings (of drip vs. furrow irrigation) at the Weslaco sites compared to the Sullivan City site are an indication of improved irrigation scheduling techniques (weather + soil based) used at the Weslaco sites. Notwithstanding the lower water application rates under drip- compared to furrow-irrigated plots, yields were significantly higher in drip-irrigated fields. The yield difference between drip- and furrow-irrigated plots was much greater in onions (103 percent) than in cabbages (11 percent). The shallow rooting habit of onions, together with greater water loss from exposed soil in onion plots, may account for the much of the difference.

Table 3: Yield and water use efficiency of 'sweet onions' (Texas Grano 1015Y) and cabbage (Blue Vantage) as a function of irrigation method.

Crop	Irrigation method	Irrigation (inches)	Combined irrigation & rain (inches)	Yield, $t \cdot ha^{-1}$	WUE $t \cdot in^{-1}$
Onion	Drip	9.5	18	34.5	1.92
	Furrow	13.9	22.5	17.0	0.76
Cabbage	Drip	8.8	17.4	56.8	3.27
	Furrow	14.8	23.3	51.0	2.19

Conclusions

Significant water savings were obtained by switching from furrow to drip irrigation without compromising productivity. Portable, reusable and affordable totalizing water meters enabled precise monitoring and measurement of irrigation water inputs. When used in conjunction with soil moisture monitoring and improved irrigation scheduling techniques, these methods resulted in observed water savings and increased water use efficiency. Volumetric water measurement will give growers a more precise idea of crop water requirements and may reduce wasteful water applications. This technique could potentially increase growers' profit margins by reducing production costs. The current total acreage of major vegetables (onions, muskmelons, cabbages, watermelons, and peppers) grown in the Lower Rio Grande Valley is approximately 30,000 acres. With the exception of muskmelons, most of these vegetables are still grown with furrow irrigation. Converting from furrow to drip irrigation could conserve a significant amount of water and reduce production costs. For shallow-rooted crops such as onions, supplying water directly to the root zone where it is most needed can lead to improved crop water use efficiency.

Future Research

The second year of this research was established in October 2005 in two additional field sites in Edinburg (Hidalgo County) and Rio Grande City (Starr County). This research is expected to provide the basis for development of best management practices for on-farm water conservation in vegetable production systems in the Lower Rio Grande Valley.

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