Irrigation Criteria for Drip-irrigated Onions

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Abstract. Long-day onion (*Allium cepa* L. 'Vision') was subjected to five soil water potential (SWP) treatments (–10, –20, –30, –50, and –70 kPa) using subsurface drip irrigation in 1997 and 1998. Onions were grown on 1.1-m beds with two double rows spaced 0.56 m apart and a drip tape buried 13 cm deep in the bed center. Soil water potential was maintained at the five levels by automated, high-frequency irrigations based on SWP measurements at 0.2-m depth. Onions were evaluated for yield and grade after 70 days of storage. In 1997, total and colossal (bulb diameter ≥ 102 mm) yield increased with increasing SWP, but marketable yield was highest at a calculated –21 kPa because of greater decomposition in storage in wetter treatments. In 1998 total, marketable, and colossal-grade onion yield increased with increasing SWP. Onion profits were highest with a calculated SWP of –17 kPa in 1997, and at the wettest level tested in 1998. Storage decomposition was not affected by SWP in 1998. Maintenance of SWP at –10 and –20 kPa required, respectively, 912 and 691 mm of water in 1997 and 935 and 589 mm of water in 1998. Onion crop evapotranspiration from emergence to the last irrigation totaled 681 mm in 1997 and 716 mm in 1998.

The Treasure Valley of eastern Oregon and southwestern Idaho annually produces 9000 ha of Sweet Spanish onions, classified as long day and medium-to-long storage. Onions are marketed starting at harvest in August and out of storage through April, so maintaining quality during storage is indispensable. Growing season weather is characterized by high evapotranspiration (average of 699 mm of onion E_t in 1997 and 1998) and low precipitation (average of 122 mm in 1997 and 1998), making irrigation essential.

Previous research with furrow-irrigated onions at the Malheur Experiment Station has shown that onions are sensitive to small water deficits. Frequent irrigations are needed to maintain a high soil water potential (SWP) for optimum yield and size (Shock et al., 1998b). Optimizing onion yields with furrow irrigation can be difficult because of low application efficiency and a low distribution uniformity. Furrow irrigation can also result in excessive erosion and nitrate leaching. Reduction of nitrate leaching is important since Malheur County was declared a Groundwater Management Area (Oregon Dept. of Environmental Quality, 1991) because of groundwater nitrate-N levels above the U.S. Environmental Protection Agency standard for drinking water.

Although the majority of onions in the Treasure Valley are furrow irrigated, drip irrigation is increasing in popularity because of superior water application efficiency and more precise irrigation management. Automated drip irrigation allows for high-frequency irrigations, thus maintaining the SWP relatively constant compared with furrow irrigation. There are no studies, which we are aware of, that investigate the constant optimum SWP for onions using high-frequency drip irrigation. The objective of this trial was to evaluate the effects of several SWPs on onion yield and quality with subsurface drip irrigation.

Materials and Methods

Trials were conducted in 1997 and 1998 at the Malheur Experiment Station on Owyhee silt loam (coarse-silty, mixed, mesic, Xerollic Camborthid) previously planted to wheat (*Triticum aestivum* L.) each year. Seed of the yellow onion 'Vision' (Petoseed, Payette, Idaho) was planted at 2.5-cm depth in two double rows 0.56 m apart on 1.1-m beds in mid-April. Each double row consisted of two onion rows spaced 6 cm apart with one seed per 10 cm of row (346,000 seeds/ha). Drip tape (Nelson Pathfinder, Nelson Irrigation Corp., Walla Walla, Wash.) was laid at the same time as planting at 13-cm depth between the two double rows. The tape had emitters spaced 30 cm apart and a flow rate of 3.65 L·h^{–1}·m^{–1} in 1997 and 1.60 L·h^{–1}·m^{–1} in 1998. The field was sprinkler irrigated until seedling emergence, which began on 1 May 1997 and on 29 Apr. 1998.

Irrigation treatments consisted of five SWP levels: –10, –20, –30, –50, and –70 kPa. The SWP was maintained relatively constant by automatically applying 1.5 mm of water up to eight times a day based on SWP readings

every 3 h. The irrigation treatments began in early June and were replicated five times in a randomized complete-block design. Plots were four double rows wide (2.2 m) $\times$ 15 m long. Irrigations were terminated on 29 Aug. 1997 and on 10 Sept. 1998.

Soil water potential was measured with four granular matrix sensors (GMS; Watermark Soil Moisture Sensors Model 200SS, Irrrometer Co., Riverside, Calif.) at 0.2-m depth below one onion row in each plot. Sensors were calibrated to SWP (Shock et al., 1998a). The GMS were connected to a datalogger (CR 10 datalogger, Campbell Scientific, Logan, Utah) via five multiplexers (AM 410 multiplexer, Campbell Scientific). The datalogger was programmed to read the GMS in each plot every 3 h and, if necessary, irrigate the plots individually. The irrigations were controlled by the datalogger using a controller (SDM CD16AC controller, Campbell Scientific) connected to solenoid valves in each plot. The pressure in the drip lines was maintained at 69 kPa by pressure regulators in each plot and the amount of water applied to each plot was recorded daily at 8:00 AM from a water meter installed between the solenoid valve and the drip tape.

Onion evapotranspiration (E_t) was calculated with a modified Penman equation (Wright, 1982) and onion crop coefficients using data collected at the Malheur Experiment Station by an AgriMet weather station (U.S. Bureau of Reclamation, Boise, Idaho). The E_t was estimated and recorded from crop emergence until the final irrigation.

A total of 112 kg·ha^{–1} N was applied to all plots as urea-ammonium nitrate solution injected through the drip tape in 1997. In 1998, an additional 56 kg·ha^{–1} was applied after a hail storm for a total of 168 kg·ha^{–1}.

The onions were undercut with a rod weeder on 23 Sept. each year to allow field curing. The onions in the central 12 m of the middle two double rows in each plot were topped and placed in storage. After separating and weighing decomposed and split bulbs, the onions were graded out of storage on 15 Dec. 1997 and on 2 Dec. 1998 according to diameter: small (<57 mm), medium (57–76 mm), jumbo (77–101 mm), and colossal (≥ 102 mm). Marketable onions were mediums, jumbos, and colossals. Total yield included small, decomposed, and split bulbs.

Gross economic returns were calculated by crediting each marketable onion class with the average price of onions paid to the grower from the beginning of the marketing season in early August through January for each year. Average prices for each year were calculated from data prepared by the U.S. Dept. of Agriculture Agricultural Marketing Service, Idaho Falls, Idaho. Average prices reflecting adjustments for packing and shipping costs in U.S. dollars·Mg^{–1} in 1997 and 1998, respectively, were: 63.88 and 77.53 for medium-grade bulbs, 97.36 and 219.38 for jumbo-grade bulbs, and 136.56 and 302.64 for colossal-grade bulbs. Production costs were based on data prepared by the Malheur County Extension Service. Drip irrigation system costs were based on

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those for a typical 16-ha field. Fertilization costs were calculated by assuming that 168 kg·ha⁻¹ N would be needed by the -10, -20, -30 kPa treatments and 84 kg·ha⁻¹ N by the -50 and -70 kPa treatments. Irrigation costs were the same for all treatments except for the diesel fuel for the pump. Onion loading, hauling, and storage costs were calculated based on the yield for each treatment. All other production costs were considered identical for all treatments.

Data was analyzed by regression (NCSS 6.0, Number Cruncher Statistical Systems, Kaysville, Utah). The SWP for maximum yield and profit responses in 1997 was calculated from the first derivative of the regression equation using the formula $x = -b/2c$, where x is the SWP and b and c are the regression equation coefficients for the first and second order terms, respectively, of the response equation $Y = a + b \cdot x + c \cdot x^2$.

Results and Discussion

The automated drip irrigation system maintained the SWP at 0.2-m depth relatively constant for the -10 and -20 kPa treatments (Fig. 1), whereas the SWP for the -30, -50, and -70 kPa treatments oscillated more, and the oscillations appeared to increase as SWP decreased. The soil dried rapidly following the termination of irrigations each year.

Onion yield and grade were far lower in 1998 than in 1997 because of a severe hail storm 4 July that totally defoliated the plants and reduced them to short stubs. Total yields were about half those of 1997.

In both years, total and colossal onion yield increased with increasing SWP, with the highest yields attained with the highest SWP tested, -10 kPa (Fig. 2). Marketable yield in 1997 was maximized at SWP of -21 kPa because of an increase in decomposition during storage with increasing SWP. In 1998 marketable onion yields increased with increasing SWP, with the highest yields attained with the highest SWP tested, -10 kPa (Fig. 3).

Storage decomposition was not affected by SWP in 1998. The difference in optimum SWP between years might suggest the influence of the hail in 1998. However, the difference in decomposition did not seem to be related to the hail. Hail would be expected to enhance the effect of SWP on storage decomposition, by promoting disease development and by delaying plant maturity (Bartolo et al., 1994), which could hinder bulb curing in the field. However, Thornton et al. (1991) found that simulated hail did not influence storage decomposition of onions at two sites in the Treasure Valley. The most severe simulated hail treatment resulted in 73% defoliation and a 30% yield reduction, comparable to our hail damage with 100% defoliation and 50% yield reduction. In addition, a fungicide was applied at the Malheur Experiment Station on the morning of 5 July 1998 to control disease development on the injured plants. Hail was followed by dry weather and hotter than normal temperatures over several weeks.

The lack of effect of SWP on storage de-

Fig. 1. Seasonal profile of soil water potential at 0.2-m depth for onions drip-irrigated at five levels (-10, -20, -30, -50, and -70 kPa) using high frequency automated irrigations.

Fig. 2. Effect of soil water potential on onion yield components in 1997.

composition in 1998 is in agreement with previous research with furrow-irrigated onions at the Malheur Experiment Station. Storage decomposition increased in response to wetter SWP threshold in only 1 of 3 years, when weather was unusually cool and wet (Shock et al., 1998b). El-Gizawy et al. (1993) also observed no effect of soil moisture level on decomposition during storage, but Chung (1989) and Drinkwater and Janes (1955) reported increases in storage decomposition with increasing irrigation intensity. However, Chung (1989) suggested that this could be attributed to higher than average precipitation during the harvest and field curing stages and, in Drinkwater and Janes's study (1955), precipitation during the two seasons totaled 224 and 363 mm. This is considerably higher than in our experiment and could have favored decomposition.

Profits showed a quadratic response to SWP in 1997, with the maximum profit, predicted from the equation, obtained with a SWP of -17 kPa (Fig. 4). The higher optimum SWP for profit than for marketable yield (-21 kPa) is a reflection of the higher monetary value placed on the larger bulbs. In 1998 profits increased with increasing SWP.

These results are similar to those of Shock et al. (1998b), who found that, with furrow-irrigated long-day onions at the Malheur Experiment Station, the optimum soil water potential at 0.2-m depth as an irrigation threshold ranged from the highest tested level (-12.5 kPa) down to -27 kPa, depending on the level of storage decomposition each year. However, with automated, high-frequency, drip irrigation, the optimum SWP could be higher than with furrow irrigation. With furrow irrigation, large oscillations of SWP are difficult to avoid and could lead to longer periods of excessively wet soil, which could promote disease. Research with short-day onions has also shown similar results. Coelho et al. (1996) reported a yield response to a threshold of -8.5 kPa, and Abreu et al. (1980) reported a yield response to a threshold of -10 kPa. Klar et al. (1976) report onion yields to be highest with the lowest threshold tested (-15 kPa). However, comparison of the present study with others using less frequent irrigations (Abreu et al., 1980; Klar et al., 1976; Shock et al., 1998b) is complicated because of the different irrigation frequencies, environments, and cultivars. In addition, none of the studies with short-day onions considered the possibility of bulb decomposition in storage, which can be increased by high SWP (Shock et al., 1998b).

The total amount of water applied to the -10 kPa treatment was higher than E_t and the total amount of water applied to the -20 kPa treatment was close to E_t in both years (Table 1). The optimum irrigation treatment, based on economic returns, would be $\approx 100\%$ E_t in 1997 and 153% E_t in 1998. The actual amount of water used by the crop at the highest yield measured (153% E_t) in 1998 was less than the amount applied because of deep percolation. Abu-Awwad (1994) compared drip irrigation rates of 0.25, 0.5, 1, and 1.5 times pan evaporation; a rate equivalent to pan evaporation

Fig. 3. Effect of soil water potential on onion yield components in 1998.

Fig. 4. Effect of soil water potential on onion profit.

Table 1. Total water applied to onions drip-irrigated at different soil water potentials. Precipitation totaled 81 mm in 1997 and 163 mm in 1998, and E_t totaled 681 mm in 1997 and 716 mm in 1998.

Soil water potential (kPa)	Total water applied			
	Irrigation (mm)		Irrigation plus precipitation (mm)	
	1997	1998	1997	1998
-10	912	935	993	1098
-20	691	589	772	752
-30	544	523	625	686
-50	445	345	526	508
-70	356	302	437	465
LSD _{0.05}	199	173	199	173

was optimum for onions. In our study, irrigating at pan evaporation would have resulted in 1041 mm of applied water each year—about the same as the water applied, plus precipitation, in the -10 kPa treatment, which was optimum in 1998. However, the large increment between 0.5 and 1 times pan evaporation leaves unanswered whether the optimum rate in Abu-Awad's study could have been between these two values. Our results are consistent with those of Bucks et al. (1981), who found that the highest irrigation rate tested (100% E_t) was optimum for drip-irrigated onions. Both Bucks et al. and Abu-Awad used drip irrigation systems with higher capital costs than ours (one drip line per two double rows on a 1.1-m bed). Bucks et al. (1981) used three drip lines on a 1-m bed and Abu-Awad (1994) used one drip line per row. We sought to test irrigation rates for a commercial drip irrigation system, where reducing costs by installing one drip line per two double rows is standard planting configuration in the Treasure Valley. We have used other drip tape configurations, such as three tapes on a 2.2-m

bed. These configurations are effective, but increase costs to growers because of more tape per hectare of onions.

Our results show that, depending on the year, the optimum SWP for maximizing profits of drip-irrigated onions in the Treasure Valley is in the range of -10 to -17 kPa. Considering the added environmental benefit of less leaching with a SWP closer to -20 kPa and the difficulty of predicting the storage quality of the crop, the use of a SWP closer to -17 kPa for drip-irrigated onions is suggested.

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