HORTSCIENCE 33(7):1188–1191. 1998.

Onion Yield and Quality Affected by Soil Water Potential as Irrigation Threshold

C.C. Shock[1], **E.B.G. Feibert**[2], **and L.D. Saunders**[3]
Malheur Experiment Station, Oregon State University, 595 Onion Avenue, Ontario, OR 97914

Additional index words. Allium cepa, profit

Abstract. **Onion (*Allium cepa* L., 'Great Scott') was grown on silt loam soils and submitted to four irrigation thresholds (–25, –50, –75, and –100 kPa) in 1992 and six irrigation thresholds (–12.5, –25, –37.5, –50, –75, and –100 kPa) in 1993 and 1994. Irrigation thresholds (soil water potential measured at 0.2-m depth) were used as criteria to initiate furrow irrigations. Onions were evaluated for yield and grade after 70 days of storage. In 1992 and 1994, total yield, marketable yield, and profit increased with increasing irrigation threshold. In 1993, total yield increased with increasing irrigation threshold, but marketable yield and profit were maximized by a calculated threshold of –27 kPa due to a substantial increase of decomposition during storage with increasing threshold.**

The Treasure Valley of eastern Oregon and southwestern Idaho produces Sweet Spanish onions on ≈9000 ha annually. Onions grown in the Treasure Valley can be classified as long-day, and medium- to long-term storage. Onions are marketed starting at harvest in August and then out of storage through April, so quality out of storage is very important. Onions are almost exclusively furrow irrigated in the Treasure Valley, where high evapotranspiration (average of 669 mm of onion Et_c in 1992–94) and low precipitation (average of 61 mm in 1992–94) during the growing season make irrigation essential.

Irrigation scheduling using soil water potential could provide an accurate method of maintaining optimum soil moisture. All attempts to determine onion yield and quality response to soil water potential as an irrigation threshold have been done in the winter with short-day onions (Abreu et al., 1980; Coelho et al., 1996; Hegde, 1986; Klar et al., 1976; Narang and Dastane, 1969). The objective of this study was to determine yield and quality response of long-day Sweet Spanish onions to soil water potentials as irrigation thresholds in the Treasure Valley.

Materials and Methods

The trials were conducted in three successive years on Owyhee silt loam (coarse-silty, mixed, mesic, Xerollic Camborthid) at the Malheur Experiment Station, Oregon State Univ., Ontario, Ore. Onions followed winter squash, potatoes, and wheat in 1992, 1993, and 1994, respectively. Seed of the yellow onion 'Great Scott' (Scottseed, Vale, Ore.) was planted in late April at 2.5-cm depth in two double rows on 1.12-m beds. Each double row consisted of two rows spaced 6 cm apart with one seed per 10 cm of row. The two double rows were spaced 0.56 m apart on the bed. Plots were eight double rows wide (4.5 m) × 24 m long. The field was sprinkler irrigated until seedling emergence.

The treatments were arranged in a randomized complete-block design with six replicates. The treatments consisted of four soil water potential levels in 1992, and six levels in 1993 and 1994 as thresholds for initiating irrigations. When the average of all the soil water potential readings from all plots in a treatment reached the threshold, they were all irrigated. Plots were irrigated long enough for the lateral wetting front to reach just beyond the row of onions. Lateral wetting was achieved by irrigation durations of 24, 12, and 24 h in 1992, 1993, and 1994, respectively. The 1993 field had higher water infiltration and lateral water movement. The 1992 field had less topsoil due to previous leveling operations and the 1994 field had a higher slope. The irrigation treatments were started in late May and terminated on 7 Sept. each year. The plots were furrow irrigated using gated pipe. A gated pipe and tail ditch allowed for individual plot irrigations.

Soil water potential was measured with two granular matrix sensors (GMS; Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, Calif.) at 0.2-m depth below one onion row in each plot (12 GMS per treatment). Sensors were previously calibrated to soil water potential (Eldredge et al., 1993). The GMS were read at 8:00 AM daily starting 1 d before the treatments were initiated. To corroborate the GMS calibration, tensiometers (Irrometer Moisture Indicator, Irrometer Co.) were installed 1 m from each GMS in two replicates of treatments 1 through 4 during August. The tensiometers were located in the same position relative to the furrow and the onions and at the same depth as the GMS.

Residual soil nitrate-N plus ammonium-N in the upper 0.3 m in late March was 76 , 67, and 47 $kg \cdot ha^{-1}$ in 1992, 1993, and 1994, respectively. In 1992, a total of 280 $kg \cdot ha^{-1}$ N as sulfur-coated urea was banded before planting in all plots. In 1993 and 1994, all plots received a total of 112 $kg \cdot ha^{-1}$ N in two applications of 56 $kg \cdot ha^{-1}$ N during the month of June. The nitrogen was applied as urea to the furrow bottoms immediately before an irrigation.

The onion bulbs were undercut with a rod weeder in late September to allow field curing. Onions from the central 9.2 m of the middle two double rows in each plot were topped and stored in early October. Onions were graded out of storage in mid-December. Rotten and split bulbs were separated before grading. The bulbs were graded according to diameter: small (<57 mm), medium (57–76 mm), jumbo (77–102 mm), and colossal (>102 mm). Marketable onions were mediums, jumbos, and colossals. Total yield included rotten 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 onion prices for each year were calculated from data prepared by the U.S. Dept. of Agriculture Agricultural Marketing Service, Idaho Falls, Idaho. Production costs were based on data prepared by Malheur County Extension (Oregon State Univ., Ontario, Ore.). Fertilization costs were calculated by assuming two custom sidedressing operations for the –12.5, –25, –37.5, and –50 kPa treatments and one operation for the –75 and –100 kPa treatments. Irrigation costs were calculated based on the number of irrigations applied to each treatment. Onion loading, hauling, and storage costs were calculated based on the yield for each treatment. All other production costs were considered to be identical for all treatments. Onion grade data were analyzed by regression and by analysis of variance (NCSS 6.0, Number Cruncher Statistical Systems, Kaysville, Utah). The irrigation threshold for maximum yield and profit responses in 1993 was calculated using the first derivative of the regression equation using the formula $x = -b/2c$, where x is the irrigation threshold and b and c are the regression equation coefficients for the first and second order terms, respectively.

Results and Discussion

The furrow irrigation scheduling using the threshold soil water potential values resulted

---

Received for publication 17 Feb. 1998. Accepted for publication 20 July 1998. Oregon State Univ. technical paper no. 11292. Support for this study was provided by the Oregon Dept. of Agriculture, Oregon Dept. of Environmental Quality, and the Idaho–Eastern Oregon Onion Committee. Use of trade names does not imply endorsement of the products named or criticism of similar ones not named. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1] Professor.

[2] Senior Faculty Research Assistant.

[3] Biological Sciences Research Technician.

Table 1. Season-long average soil water potential (–kPa) and average maximum and minimum soil water potential between irrigations, at Ontario, Ore., 1992–94.

Irrigation threshold	1992 Avg	1992 Avg max.	1992 Avg min.	1993 Avg	1993 Avg max.	1993 Avg min.	1994 Avg	1994 Avg max.	1994 Avg min.
–12.5				6.3	13.2	2.0	7.9	9.7	6.6
–25	15.0	26.7	6.1	11.5	24.2	3.3	11.3	16.4	7.2
–37.5				16.6	36.9	4.6	15.6	25.7	6.4
–50	27.5	44.3	15.0	20.9	49.9	3.3	20.4	36.7	8.2
–75	39.3	65.0	8.5	30.9	76.5	6.2	39.2	61.2	7.6
–100	60.2	94.8	8.3	40.8	98.4	5.2	58.1	95.6	19.1

Table 2. Effect of using different thresholds on the total number of irrigations for furrow irrigated onions, at Ontario, Ore., 1992–94.

Irrigation threshold	1992	1993	1994
–12.5		18	22
–25	20	11	13
–37.5		9	6
–50	12	6	5
–75	6	4	2
–100	2	3	0

in a regular oscillation of soil water potential between the threshold values and soil saturation, when the soil water potential came close to 0 kPa (Table 1).

The average irrigation frequencies (d between irrigations) for the highest irrigation thresholds (–25 kPa in 1992, and –12.5 kPa in 1993 and 1994) during the months of July and August were 4.5, 3.8, and 3.5 in 1992, 1993, and 1994, respectively. The total number of irrigations for the highest thresholds (–25 kPa in 1992, and –12.5 kPa in 1993 and 1994) were 20, 18, and 22 in 1992, 1993, and 1994, respectively (Table 2).

Soil water potential measured with the GMS showed a strong correlation with the soil water potential measured with the tensiometers. The equation for the regression line is $Y = -2.12 + 1.015X$, ($R^2 = 0.69$, $P = 0.001$) where Y is the tensiometer soil water potential reading and X is the soil water potential from GMS measurements based on Eldredge et al. (1993).

Onion total yield and marketable yield in 1992 and 1994 increased with increasing irrigation threshold, showing a positive quadratic response (Fig. 1). Similar results were obtained in 1993, but marketable yield was maximized at a threshold of –27 kPa. The lower optimum threshold for marketable than for total yield in 1993 was the result of substantially higher amount of decomposition during storage. This decomposition increased with increasing irrigation threshold, as indicated by the increasing separation between total yield and marketable yield. Decomposition was, in general, higher in 1993 than in 1992 and 1994, probably because of to the cooler growing season and greater rainfall in 1993. The growing degree days (base 10 to 30 °C) from May through September were 1547, 1210, and 1601 in 1992, 1993, and 1994, respectively. Cool weather during the growing season delayed maturity and increased susceptibility to *Botrytis allii* resulting in decomposition during storage. In addition, cool, wet weather during the growing season promotes disease development in the field and can hinder curing of the onions after lifting. There was no measurable onion decomposition in 1992. Combined over the 3 years, total and marketable yields increased linearly with increasing irrigation threshold.

Onion bulb size increased with increasing irrigation threshold each year. The highest yield of colossal onions was obtained with the highest threshold (Fig. 2).

Profits showed a quadratic response to irrigation threshold in 1992 and 1994 with greatest profits achieved with the highest irrigation threshold of –25 kPa in 1992 and of –12.5 kPa in 1994 (Fig. 3). A quadratic response was also evident in 1993, but maximum returns, predicted from the equation, were obtained with a threshold of –27 kPa because of decomposition during storage. Combined over the 3 years, profit increased linearly with increasing threshold.

These results suggest that in years with warm, dry growing conditions, as in 1992 and 1994, onion yields and profits could be maximized by an irrigation threshold higher than –12.5 kPa. Other studies with short-day

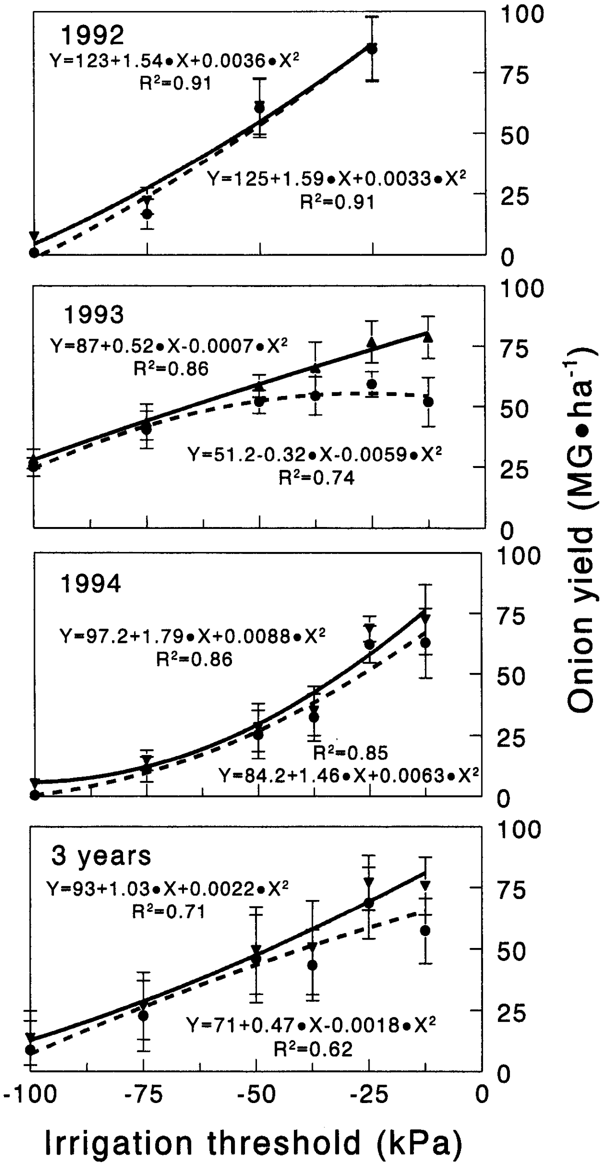

Fig. 1. Effect of irrigation threshold on total (—▲—) and marketable (— ● —) yield of 'Great Scott' onions over three seasons. Each data point represents the average of six replicates. Error bars represent SD. All equations were significant at $P = 0.001$.

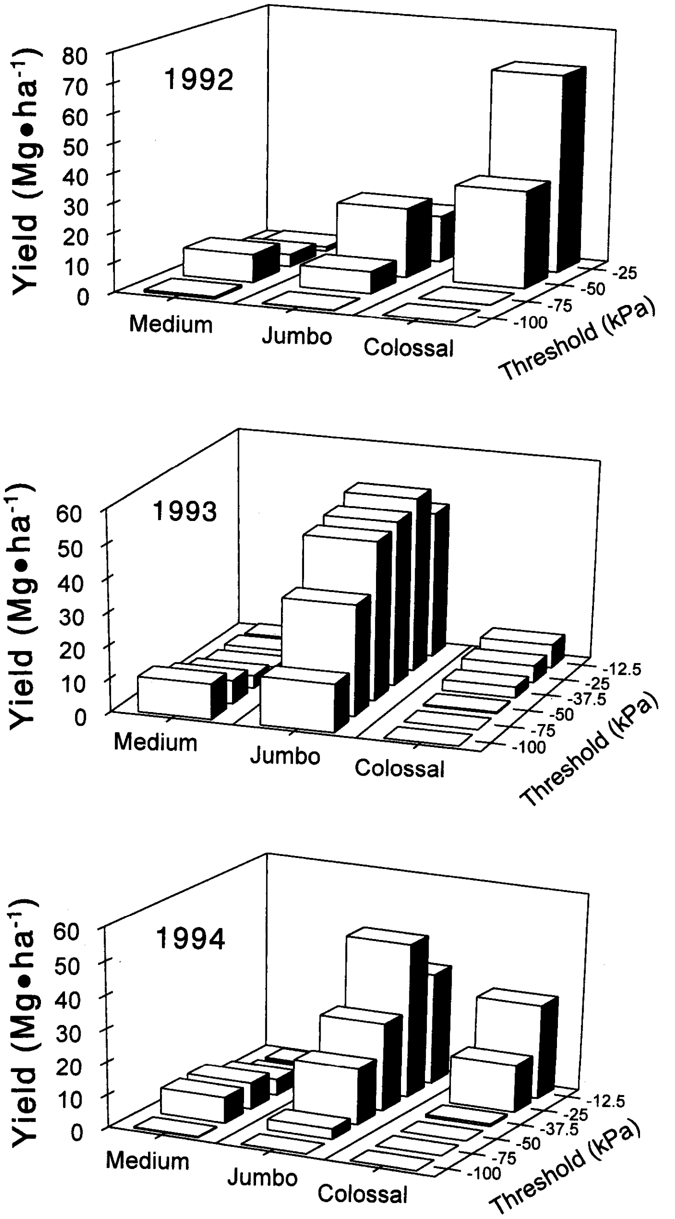

Fig. 2. Effect of irrigation threshold on 'Great Scott' onion market-size class. Each bar represents the average of six replicates. Least squares difference values according to Fisher's LSD at $P = 0.05$ were 1.5, 3.9, and 6.6 in 1992; 2.7, 5.8, and 2.0 in 1993; and 1.9, 5.7, and 2.5 in 1994 for medium, jumbo, and colossal onions, respectively.

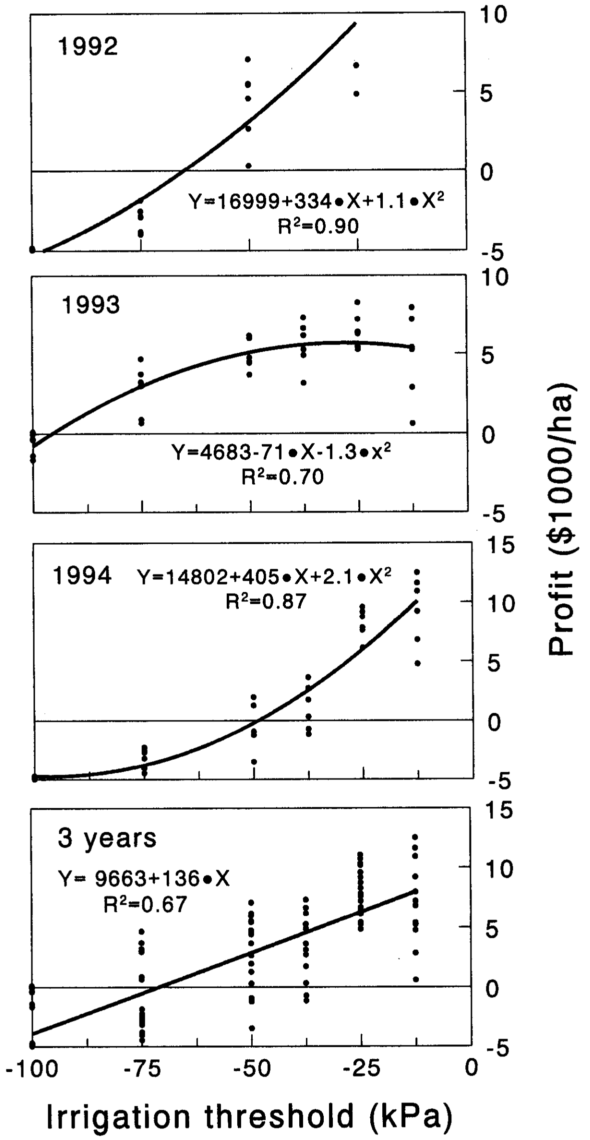

Fig. 3. Effect of irrigation threshold on onion profit. All equations were significant at $P = 0.001$.

onions have reported onion yield responses to higher irrigation thresholds. Coelho et al. (1996) and Abreu et al. (1980) reported onion yield responses to thresholds of –8.5 kPa and –10 kPa, respectively. Klar et al. (1976) reported that onion yields were highest with the lowest threshold tested of –15 kPa, also indicating the possibility of a higher optimum threshold.

According to the data for number of irrigations (Table 2), for every increase in irrigation threshold there was an additional number of irrigations required. Based on these figures, to increase the irrigation threshold from –12.5 kPa to a hypothetical –6.25 kPa may have required 25 to 30 irrigations in 1993 and 1994. An average of 15 irrigations are applied to onions in Malheur County from late May to early September based on a survey of nitrogen and water use practices conducted by the Malheur County Extension office. An irrigation threshold higher than –12.5 kPa would probably require a highly uniform and efficient irrigation system, such as drip irrigation, to be practical in Malheur County. Furrow irrigation even at –12.5 kPa on 400-m furrow irrigation runs would be difficult because of field disuniformity and problems with cultivation and spraying. Areas of soil with greater water infiltration and water retention place bulbs at risk of decomposition.

Other studies report lower optimum irrigation thresholds for short-day onions. Narang and Dastane (1969) tested three thresholds (–30, –60, and –80 kPa) and reported –60 kPa to be optimum. However, their study was done with red onions and the soil water potential was not measured directly, but calculated from soil moisture content determined gravimetrically. Their method is subject to error due to hysteresis and variations in the relationship between soil moisture content and soil water potential caused by variations in soil texture and structure within a given site (Warrick, 1990). Hegde (1986) measured soil water potential with tensiometers and tested four thresholds (–45, –65, –85, and –105 kPa); the optimum threshold was either –45 or –65 kPa. However, Hegde did not evaluate thresholds higher than –45 kPa.

Literature Cited

Abreu, T.A.S., A.A. Millar, E.N. Choudhury, and M.M. Choudhury. 1980. Analise da produção de cebola sob differentes regimes de irrigação. Pesquisa Agropecuaria Brasileira 15:233–236.

Coelho, E.F., V.A.B. de Souza, and M.A.F. Conceição. 1996. Comportamento da cultura da cebola em tres regimes de irrigação e cinco espacamentos. Pesquisa Agropecuaria Brasileira 31:585–591.

Eldredge, E.P., C.C. Shock, and T.D. Stieber. 1993. Calibration of granular matrix sensors for irrigation management. Agron. J. 85:1228–1232.

Hegde, D.M. 1986. Effect of irrigation regimes on dry matter production, yield, nutrient uptake and water use of onion. Indian J. Agron. 31:343–348.

Klar, E.A., J.F. Pedras, and J.D. Rodrigues. 1976. A influencia de differentes condições de solo e microclima no uso de água da cultura de cebola, I. Produção de bulbos e precocidade. Phyton 34:9–25.

Narang, R.S. and N.G. Dastane. 1969. Water use by *Allium cepa* L. (bulb onions) grown under different soil moisture regimes. Indian J. Hort. 26:176–180.

Warrick, A.W. 1990. Nature and dynamics of soil water, p. 69–92. In: B.A. Stewart and D.R. Nielsen (eds.). Irrigation of agricultural crops. Agronomy monograph 30. ASA, CSSA, and SSSA publishers, Madison Wis.