A SINGLE EPISODE OF WATER STRESS REDUCES THE YIELD AND GRADE OF RANGER RUSSET AND UMATILLA RUSSET POTATO

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Introduction

Deficit irrigation is a strategy where crops are allowed to sustain some degree of water deficit in order to reduce costs and potentially increase revenues. English and Raja (1996) described three deficit irrigation case studies where the reductions in irrigation costs are greater than the reductions in revenue due to reduced yields. In these case studies deficit irrigation can lead, in principle, to increased profits when water supplies are limited.

Deficit irrigation has been used successfully with a number of crops. Shock et al. (1998) reported that deficit irrigation of potatoes could be difficult to manage because reductions in tuber yield and quality can result from even brief periods of water stress. However, in some circumstances potatoes can tolerate limited deficit irrigation before tuber set without significant reductions in tuber external and internal quality.

It is generally recognized that some potato varieties are more drought tolerant than others, that is, they give higher yields of tubers in dry years than other varieties (Joyce et al. 1979). Nevertheless, there is not enough information on the effects of slight or moderate water stress on yield of different varieties of potato. The adoption of new potato cultivars by growers and processors makes it desirable to reexamine deficit irrigation, particularly during tuber development.

The objectives of this study were to 1) determine ‘Umatilla Russet’ and ‘Ranger Russet’ potato responses to a single episode of water stress during tuber bulking, and 2) evaluate the potential for deficit irrigation to improve economic efficiency of potato production in the Treasure Valley under a sprinkler-irrigation system.

Materials and Methods

Two potato varieties (Umatilla Russet and Ranger Russet) were grown under sprinkler irrigation on Owyhee silt loam, where winter wheat was the previous crop in a potato, wheat, corn, wheat, and potato rotation. The wheat stubble was flailed and the field was irrigated and disked. A soil test taken on September 16, 2003 showed 37 lb nitrogen (N)/acre in the top 2 ft of soil, and 102 lb available phosphate (P₂O₅), 851 lb soluble potash (K₂O), 29 lb sulfate (SO₄), 1966 ppm
calcium (Ca), 463 ppm magnesium (Mg), 87 ppm sodium (Na), 1.6 ppm zinc (Zn), 18 ppm iron (Fe), 4 ppm manganese (Mn), 0.7 ppm copper (Cu), 0.5 ppm boron (B), 3.5 percent organic matter, and pH 7.4 in the top foot of soil. Fertilizer was spread in the fall to apply 60 lb N/acre, 50 lb P₂O₅/acre, 80 lb K₂O/acre, 57 lb sulfur (S)/acre, 8 lb Zn/acre, 5 lb Cu/acre, and 1 lb B/acre. The field was ripped, Telone II® soil fumigant was injected at 25 gal/acre, and the field was bedded on 36-inch row spacing.

Seed of the 2 varieties was hand cut into 2-oz seed pieces and treated with Tops-MZ+ Gaucho® dust 1-2 weeks before planting and placed in storage to suberize. On March 22 the field was cultivated with a Lilliston rolling cultivator to reshape the hills and to control winter annual weeds and volunteer wheat. On April 2 a soil sample was taken that showed 43 lb N/acre in the top two feet of soil, 83 lb available P₂O₅, 688 lb soluble K₂O, 26 lb SO₄, 1,835 ppm Ca, 353 ppm Mg, 69 ppm Na, 1.1 ppm Zn, 5 ppm Fe, 1 ppm Mn, 0.4 ppm Cu, 1.2 ppm B, pH 7.4, and 3.0 percent organic matter in the top foot of soil.

Potato seed pieces were planted using a 2-row cup planter with 9-inch seed spacing in 36-inch rows. Umatilla Russet was planted on April 19 and Ranger Russet was planted on April 26. After planting, hills were formed over the rows with a Lilliston rolling cultivator. Prowl® at 1 lb/acre plus Dual® at 2 lb/acre herbicide was applied as a tank mix for weed control on May 7 and was incorporated with the Lilliston. Matrix® herbicide was applied at 1.25 oz/acre on May 17 and was incorporated by 0.41 inch of rain on the next day, followed by 0.89-inch additional rain through the end of May 2004.

Under non-water stress conditions irrigation was applied 16 times from June 4 to August 30, with scheduling based on soil water potential (Fig. 1). The average readings of 6 Watermark soil moisture sensors model 200 SS (Irrometer Co. Inc., Riverside, CA) were monitored every 8 hours by a Hansen model AM400 datalogger (M. K. Hansen Co., East Wenatchee, WA). Sensors were installed in the potato row at the seedpiece depth, 10 inches from the top of the hill. The AM400 unit was read daily through the summer to establish when to irrigate, with the objective to apply water before the average soil moisture in the potato root zone at the seedpiece depth exceeded -60 kPa (Fig. 2). Water applied was estimated by recording the sprinkler set duration at 55 psi, and using the nominal sprinkler head output. Crop evapotranspiration (ETc) was estimated by the U.S. Bureau of Reclamation based on data from an AgriMet weather station on the Malheur Experiment Station.

For the water stressed treatment, a single irrigation was skipped on June 28 during tuber bulking (Fig. 1). Eight rain shelters 21 ft long and 10 ft wide were made from clear polyethylene sheets stretched over PVC pipe. These rain shelters were used to prevent sprinkler irrigation on four plots of Umatilla Russet and four plots of Ranger Russet. The area of each plot was 3 potato plant-rows spaced 3 ft apart, 21 ft long, with only the center 15 ft of the middle row
harvested. The statistical design was a randomized complete-block design with four replicates. After the 5-hour, 1.5-inch irrigation, the plastic sheets were removed from the PVC frames.

Fungicide applications to control early blight and prevent late blight infection started with an aerial application of Ridomil Gold® and Bravo® at 1.5 pint/acre on June 12. On June 25, Headline® fungicide was applied; on July 17, Topsin-M® fungicide plus liquid sulfur with 1.5 lb P₂O₅/acre and 0.2 lb Zn/acre was applied by aerial applicator. On August 8, Headline plus 6 lb S/acre was applied to prevent two-spotted spider mite infestation and powdery mildew infection.

Petiole tests were taken every 2 weeks from June 14, and fertilizer was injected into the sprinkler line during irrigation to supply the crop nutrient needs. A total of 103 lb N/acre, 44 lb P₂O₅/acre, 140 lb K₂O/acre, 100 lb SO₄/acre, 0.3 lb Mn/acre, 5 lb Mg/acre, 0.1 lb Cu/acre, 0.1 lb Fe/acre, and 0.5 lb B/acre were applied.

Vines were flailed on September 21 and Umatilla Russet and Ranger Russet tubers were dug on October 5 and 6 with a two-row digger that laid the tubers back onto the soil in each row. Visual evaluations included observations of desirable traits, such as a high yield of large, smooth, uniformly shaped and sized, oblong to long, attractively russetted tubers, with shallow eyes evenly distributed over the tuber length.

Tubers from 15 ft of the middle row of the 3-row plot were picked up. Tubers were placed into burlap sacks and hauled to a barn where they were kept under tarps until grading. Tubers were graded and a 20-tuber sample from each plot was placed into storage. The storage was kept near 90 percent relative humidity and the temperature was gradually reduced to 45°F. Tubers were removed from storage December 7 and evaluated for tuber quality traits, specific gravity, and fry color. Specific gravity was measured using the weight-in-air, weight-in-water method. Ten tubers per plot were cut lengthwise and the center slices were fried for 3.5 min in 375°F soybean oil. Percent light reflectance was measured on the stem and bud ends of each slice using a Photovolt Reflectance Meter model 577 (Seradyn, Inc., Indianapolis, IN) with a green tristimulus filter, calibrated to read 0 percent light reflectance on the black standard cup and 73.6 percent light reflectance on the white porcelain standard plate.

Data were analyzed with the General Linear Models analysis of variance procedure in NCSS (Number Cruncher Statistical Systems, Kaysville, UT) using the Fisher's Protected LSD means separation t-test at the 95 percent confidence level.

Results and Discussion
Precipitation for May 1 through September 30 was 2.55 inches and the crop evapotranspiration ($ET_c$) totaled 26.19 inches. The potato plants received 22.15 inches of irrigation plus precipitation throughout the full growing season, or 84.6 percent of $ET_c$ (Fig. 1). The step increases in the irrigation plus rainfall curve (control) show the 16 sprinkler irrigations applied during the growing season. For the water stress treatment, 15 irrigation episodes were applied, with a single deficit imposed on June 28 as pointed out by the arrow in Figure 1. The previous irrigation was on June 22 and the first irrigation following stress was on July 4. Rainfall during this time interval was 0.07 inch on June 24 and 0.03 inch on June 30.

The trend of soil moisture during the growing season is presented in Figure 2. The data do not show the individual irrigations because the water did not always penetrate the soil to the sensors. The irrigation plus rainfall was less than $ET_c$ for the growing season, and the sensor data show that average root zone soil water potential became drier than -60 kPa at least four times during the growing season.

Soil water potential at the seedpiece depth was allowed to become drier than -60 kPa at the end of the growing season, due to the risk of tuber decay in this field. Frequent sprinkler irrigations of short duration were applied, as shown in Figure 2. This was necessary to avoid swollen lenticels and the associated possibility of rotting the tubers of the early maturity potato varieties planted in the same field, while continuing to apply a portion of the $ET_c$ requirement for the late maturing entries in shallow moisture increments.

Although mean total yield for both cultivars was not influenced by water treatments tested in this preliminary trial, marketable yield and total yield of U.S. No. 1 tubers were significantly affected by a single episode of water stress during tuber bulking (Table 1). Deficit irrigation substantially reduced the percentage of U.S. No. 1 and over-12-oz tubers, with Ranger Russet showing more pronounced response to water stress than Umatilla Russet.

In this preliminary trial, Umatilla Russet responded positively to applied water for total yield and was the most productive cultivar in total yield, besides the non-significant differences among treatments; this agrees with the results obtained by Shock et al. (2003). However, Ranger Russet showed the highest total U.S. No. 1 and marketable yields under a non-limiting water supply.

Production of marketable tubers for processing (which comprises total U.S. No. 1 plus U.S. No. 2 grades) was significantly affected by a single missed irrigation for both potato cultivars. A single episode of water stress during tuber bulking brought about a reduction of 4.5 percent and 26.0 percent on marketable yield of Umatilla Russet and Ranger Russet, respectively.
Shock et al. (2003) reported that well-watered potato subjected to irrigation deficits during tuber bulking responded with reduced specific gravity. Although nonsignificant differences were found between cultivars under both irrigation treatments for specific gravity in this preliminary study, a slight tendency toward reduced specific gravity was observed for Ranger Russet due to a single episode of water stress during tuber bulking. The specific gravity ranged from 1.079 to 1.084 g cm-3, with Ranger Russet showing mean values above 1.080 g cm-3 when water was applied at a rate as close as possible to ETc, a desirable level for processing into frozen potato products.

Length/width ratio was significantly affected by irrigation deficit, with a reduction of about 9 percent for the Ranger Russet potato cultivar.

Acknowledgements

We would like to thank Conselho de Desenvolvimento Científico e Tecnológico (CNPq) of Brazil for providing a Post-Doctoral scholarship and also for the support from Oregon State University that enabled this work.

References


Figure 1. Crop evapotranspiration (ETc), sprinkler irrigation applied plus rainfall (control), and a single episode of water stress (arrow) during tuber bulking of Ranger Russet and Umatilla Russet potato, Malheur Experiment Station, Oregon State University, Ontario, OR, 2004.

Figure 2. Soil moisture data over time for a sprinkler-irrigated potato trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2004.
Table 1. Mean yield and grade of Ranger Russet and Umatilla Russet sprinkler-stressed potato trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2004.

NS = Not significant.