‘Umatilla Russet’ and ‘Russet Legend’ Potato Yield and Quality Response to Irrigation

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Abstract. ‘Umatilla Russet’ and ‘Russet Legend’, two newly released potato (Solanum tuberosum L.) cultivars were compared with four established cultivars (‘Russet Burbank’, ‘Shepody’, ‘Frontier Russet’, and ‘Ranger Russet’). Potatoes were grown under four, season-long, sprinkler irrigation treatments in three successive years (1992–94) on silt loam soil in eastern Oregon. At each irrigation, the full irrigation treatment received up to the accumulated evapotranspiration (ETc) since the last irrigation. Three deficit irrigation treatments had progressively less water. The new cultivars ‘Umatilla Russet’ and ‘Russet Legend’ performed as well as or better than the other cultivars in the full irrigation treatment, with ‘Umatilla Russet’ showing a higher yield potential at the higher water application rates than ‘Russet Legend’. All cultivars produced more U.S. No. 1 tubers than ‘Russet Burbank’, except in 1993, an unusually cool and wet year. ‘Russet Legend’ was the only cultivar showing a tolerance to deficit irrigation. In two out of the three years, ‘Russet Legend’ was as productive of U.S. No. 1 yield over most of the range of applied water as ‘Shepody’, ‘Frontier Russet’, and ‘Ranger Russet’ were at the higher end of the applied water range. Chemical names used: 0,4-dimethyl S-[(ethylthio) methyl] phosphorodithioate (phorate); N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine (pendimethalin); and 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methyl-ethyl) acetamide (metalochlor).

The release of new cultivars and their adoption by growers and processors makes it desirable to determine cultivar tolerance to deficit irrigation. ‘Umatilla Russet’ and ‘Russet Legend’ have recently been released by the Agricultural Experiment Stations of Oregon, Idaho, and Washington and the U.S. Dept. of Agriculture in 1998 (Mosley et al., 2000a, b). Potato cultivars can differ in their tolerance to water stress (Jeffries and MacKerron, 1993a, 1993b; Lynch and Tai, 1989; Lynch et al., 1995; Martin and Miller, 1983; Miller and Martin, 1987a, b; Shock et al., 1993). Western U.S. agriculture is under increased pressure to reduce irrigation water use and to reduce groundwater pollution (Schalte, 1995). Deficit irrigation, which can be defined as the deliberate under irrigation of a crop, is a strategy that could optimize crop production under scarce or costly water situations. However, deficit irrigation of potato could be difficult to manage without loss of profitability. Potato is sensitive to water stress and reductions in tuber yield and quality can result from even brief periods of water stress (Eldredge et al., 1992, 1996; Lynch et al., 1995; Shock et al., 1992, 1993; Wright and Stark, 1990).

By carefully reducing the irrigation rate for the full season, water stress levels that result in losses in potato yield and quality could be avoided. Irrigation management using sprinkler irrigation with scheduling by soil water potential could provide the level of precision necessary to successfully deficit irrigate potato.

The objective of this research was to compare two new cultivars, ‘Umatilla Russet’ and ‘Russet Legend’, with four commercial processing cultivars to determine the tuber yield and quality response to deficit irrigation. The commercial cultivars tested were ‘Russet Burbank’, ‘Shepody’, ‘Frontier Russet’, and ‘Ranger Russet’.

Materials and Methods

The trials were conducted in three successive years on an Owyhee silt loam (coarse-silty, mixed, mesic, Xerollic Camborthids) at the Oregon State Univ. Malheur Experiment Station, in Ontario, Oregon. Potatoes followed alfalfa in 1992, and spring wheat in 1993 and 1994. Fields were bedded into 0.9 m wide hills in the fall of each year. In late April, tuber seed pieces (60g) were planted at 0.23 m spacing. Residual soil nitrate-N plus ammonium-N in the upper 0.3 m in late March was 62 kg·ha⁻¹, 45 kg·ha⁻¹, and 30 kg·ha⁻¹ in 1992, 1993, and 1994, respectively. Nitrogen fertilizer was applied uniformly to all plots at 22 kg·ha⁻¹, 174 kg·ha⁻¹, and 134 kg·ha⁻¹ in 1992, 1993, and 1994, respectively. Because of adequate residual soil N following alfalfa in 1992, the N fertilizer was applied as a single post-emergence application. In 1993 and 1994, the N fertilizer was applied as a combination of pre-emergence and post-emergence applications. Pre-emergence applications were made within one week after planting by banding urea in both sides of the potato hill at the same level as the seed piece and offset 0.23 m to the side. N fertilizer for post-emergence applications was applied to the plots as broadcast urea immediately before an irrigation or as urea-ammonium nitrate solution injected through the sprinkler system.

In the experimental design, the four irrigation treatments were the main plots, replicated five times, and cultivars were split-plots within the main plots. Irrigation treatments were arranged in randomized complete blocks and consisted of an adequately irrigated check and three deficit irrigation treatments (Table 1). At each irrigation, the check treatment had

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Table 1. Actual water applied plus precipitation and average soil water potential at two depths in response to four irrigation treatments. Crop evapotranspiration, ETc was estimated to be 666, 491, and 622 mm in 1992, 1993, and 1994, respectively.

| Treatment irrigation criteria | 1992 | 1993 | 1994 |
|-----------------------------|-----|-----|-----|
| Irrigation intensity (%)    | 0.2 m | 0.5 m | 0.2 m | 0.5 m | 0.2 m | 0.5 m |
| water applied               | kPa  | kPa  | kPa  | kPa  | kPa  | kPa  |
| Total water potential       | 589 | 566 | 411 | 368 | 46 | 22 |
| Avg soil water potential    | 50 | 64 | 64 | 64 | 39 | 14 |
| % of ET                     | 50 | 64 | 64 | 64 | 39 | 14 |
| LSD             | 50 | 64 | 64 | 64 | 39 | 14 |

Average of daily 8:00 AM measurements from 5 plots, recorded a few days before tuber set through 7 Sept. each year.

150% of accumulated ET replaced until tuber set, then 70% of ET replaced for six weeks, then 50% of ET replaced until last irrigation.

Nonsignificant.
no more water applied than the accumulated evapotranspiration (ET) since the last irrigation. The deficit irrigation treatments had a percentage of the accumulated ET, applied at each irrigation: 1) nearly 100%; 2) 70%; and 3) 50% until tuber set, then 70% for six weeks, and 50% thereafter. To reduce the risk of water movement below the top 0.3 m of soil, water applications at each irrigation were limited to avoid exceeding the water holding capacity of the soil to a 0.3 m depth. Individual water applications did not exceed 30 mm for the check treatment and 35 mm for the other treatments.

Irrigation scheduling was by soil water potential at a 0.2 m depth. When the average soil water potential reached –60 kPa for the check treatment and –80 kPa for the other treatments, all plots in the respective treatment were irrigated. Plots were irrigated individually as necessary. The level of –60 kPa for the check treatment was based upon previous research (Eldredge et al., 1992; Holder and Cary, 1984; Shock et al., 1992; van Loon, 1981). The level of –80 kPa for the other treatments was based on previous research showing that even a brief exposure to this soil water potential during tuber bulking could reduce ‘Russet Burbank’ tuber grade and quality (Eldredge et al., 1992, 1996).

Soil water potential was measured in each plot by two granular matrix sensors (GMS; Watermark Soil Moisture Sensors model 200SS; Irrometer Co., Riverside, Calif.) at the 0.2 m depth and two GMS at the 0.5 m depth. The GMS were offset 0.15 m from the hill center (Steiber and Shock, 1995). Sensor readings were calibrated to soil water potential (Eldredge et al., 1993). The GMS were read at 8:00 AM daily starting a few days before tuber set each year. Irrigation treatments were initiated no sooner than one week before tuber set each year (Cappaert et al., 1994; Shock et al., 1992).

Crop ET$_c$ was estimated using a modified Penman equation (Wright, 1982) with data from an AgriMet (U.S. Bureau of Reclamation, Boise, Idaho) weather station at the experimental site. Crop ET$_c$ was recorded from crop emergence until the final irrigation. Growing degree days (10 to 30 °C) were measured by a model TA 51 Omnidata experimental site. Crop ET$_c$ was estimated and evapotranspiration (ETc) since the last irrigation. The deficit irrigation treatments had a percentage of the accumulated ET$_c$ applied across the treatments and 3 years.

Data for 1993 and 1994 were similar.

### Table 2. Tuber yield, tuber size distribution and tuber internal quality for six cultivars averaged over four irrigation treatments and 3 years.

| Cultivar    | Total yield | No. 1 yield | U.S. No. 1 and U.S. No. 2 by tuber size | Fry color | Specific gravity |
|-------------|-------------|-------------|----------------------------------------|-----------|------------------|
|             | Mg·ha$^{-1}$ | ---         | Small (<113 g) | Medium (113–283 g) | Large (>283 g) | % reflectance g/cm$^3$ |
|              |             | ---         | ---         | ---         | ---         | --- |
|              | 1992        | 1993        | 1994        | All years   | 1992        | 1993        | 1994        | All years   |
| Russet Burbank | 64.3        | 57.5        | 54.5        | 58.8        | 32.3        | 39.3        | 39.8        | 37.5        | 21.1        | 29.8        | 28.0        | 26.3        | 26.3        |
| Shapody      | 62.9        | 45.8        | 48.7        | 52.5        | 50.0        | 35.0        | 27.5        | 37.5        | 10.9        | 21.1        | 22.0        | 14.6        | 14.6        |
| Frontier Russet | 51.6        | 64.5        | 47.9        | 58.8        | 41.6        | 35.0        | 28.0        | 28.0        | 17.2        | 31.3        | 22.3        | 25.4        | 25.4        |
| Ranger Russet | 59.6        | 48.7        | 45.8        | 63.2        | 45.6        | 34.0        | 24.0        | 24.0        | 13.5        | 31.3        | 22.3        | 25.4        | 25.4        |
| Umatilla Russet | 69.3        | 48.7        | 51.6        | 71.0        | 56.4        | 34.0        | 24.0        | 24.0        | 17.7        | 32.9        | 22.3        | 25.4        | 25.4        |
| Russet Legend | 58.9        | 47.1        | 51.2        | 61.0        | 48.2        | 37.5        | 26.2        | 26.2        | 10.5        | 25.4        | 19.7        | 15.2        | 15.2        |
| Mean         | 61.0        | 57.5        | 54.5        | 58.8        | 45.7        | 39.3        | 31.2        | 31.2        | 15.2        | 29.5        | 27.3        | 23.1        | 23.1        |

**P** < 0.05, 0.01, or 0.001, respectively.

Data for 1992, Treatment 1 was irrigated at –60 kPa and had a target of 100% of ET$_c$ applied. Treatments 2, 3, and 4 were irrigated at –80 kPa and had targets of 100%, 70%, and <70% of ET$_c$ applied, respectively.

Fig. 1. Cumulative ET$_c$ and water applied plus rainfall for potatoes submitted to four irrigation treatments in 1992. Treatment 1 was irrigated at –60 kPa and had a target of 100% of ET$_c$ applied. Treatments 2, 3, and 4 were irrigated at –80 kPa and had targets of 100%, 70%, and <70% of ET$_c$ applied, respectively.
The insecticide phorate at 3.4 kg·ha⁻¹ was applied together with the pre-emergence urea in early May. The herbicides pendimethalin and metolachlor were broadcast at 1.12 kg·ha⁻¹ and 2.24 kg·ha⁻¹, respectively, in mid May, and incorporated immediately with a Liliston Rolling Cultivator (Bigham Brothers, Lubbock, Texas).

Tubers were harvested from the middle 9 m of one 12-m long row for each cultivar in each main plot in early October each year. Tubers were graded by market class (U.S. No. 1 and U.S. No. 2) and size (small: 113 to 170 g, medium: 170 to 283 g, and large: >283 g). Tubers were graded as U.S. No. 2 if any of the following conditions existed: growth cracks, bottleneck shape, abnormally curved shape, or two or more knobs.

A representative 20-tuber subsample from every cultivar in every main plot was put in storage (8 °C, 90% relative humidity) until early November when tuber specific gravity and stem-end fry color were determined. Tuber fry color was determined according to the methodology described by Shock et al. (1994).

The response of tuber yield, tuber size distribution, and tuber internal quality to cultivars and years were evaluated by analysis of variance with the general linear model procedure (NCSS, Kaysville, Utah). The response of tuber yield and U.S. No. 1 yield to total water applied (irrigation plus precipitation) were evaluated by regression analysis with the response surface regression procedure (NCSS).

Results and Discussion

Water applications over time for all treatments were close to and less than the target ETc values each year (Table 1; Fig. 1). In every year of the study, the average soil water potential at 0.5 m depth was lower than at 0.2 m depth for all treatments and total water applied was less or slightly less than the estimated ETc (Table 1), suggesting that nitrate leaching potential was minimal. Irrigation scheduling, using both a target soil water potential and controlled water applications that did not exceed the water holding capacity of the top 0.3 m of soil, resulted in total seasonal applied water being slightly less than estimated ETc, even when the crop was irrigated at ~60 kPa. The water deficit can be partly supplied from stored soil water at lower depths. In addition, water savings were accrued by initiating irrigations only after full emergence and early vegetative growth (Shock et al., 1992).

Year, cultivar, and the interaction of year by cultivar significantly influenced total yield and U.S. No. 1 yield (Table 2). ‘Russet Burbank’ was the least productive cultivar in U.S. No. 1 yield in 1992 and 1994 and the most productive of U.S. No. 1 yield in 1993.

In 1993, ‘Umatilla Russet’ had a strong positive response to applied water for total and U.S. No. 1 yield and was the most productive cultivar in U.S. No. 1 yield (Table 2). In 1992, ‘Shepody’ and ‘Umatilla Russet’ were similar to maximum yields for ‘Frontier Russet’, ‘Ranger Russet’, and ‘Umatilla Russet’ at slightly higher levels of applied water.

Total yields of all the other cultivars except ‘Russet Legend’ were nonsignificant. ‘Russet Legend’ was as productive of U.S. No. 1 yield over most of the range of applied water as ‘Shepody’, ‘Frontier Russet’, and ‘Ranger Russet’ were at the higher end of the applied water range.

In 1993, only ‘Russet Burbank’ showed a positive response for total yield to the range of applied water (Fig. 3) and was the most productive of total yield (Table 2). ‘Russet Burbank’, ‘Shepody’, ‘Umatilla Russet’ and ‘Russet Legend’ had similar productivity of U.S. No. 1 tubers. The lack of tuber yield responsiveness to applied water in 1993 was probably related to the unusual cool and wet weather during the tuber bulking period (10 June to 24 Aug.), cooler and wetter than in either 1992 or 1994 or the historic average for that period.

In 1994, all cultivars showed linear increases in both total and U.S. No. 1 yield with increases in water applied except ‘Russet Burbank’ and ‘Russet Legend’ (Fig. 4). ‘Russet Burbank’: U.S. No. 1 yield was maximized at 27 Mg·ha⁻¹ by 565 mm of applied water. ‘Russet Legend’ total and U.S. No. 1 yield were maximized at 61 and 52 Mg·ha⁻¹ by 539 and 540 mm of applied water, respectively. These maximum yields for ‘Russet Legend’ were similar to maximum yields for ‘Frontier Russet’, ‘Ranger Russet’, and ‘Umatilla Russet’ at slightly higher levels of applied water.

Total yields of all the other cultivars except ‘Russet Legend’, increased at the higher water application rates. ‘Umatilla Russet’ had a high regression coefficient for applied water vs. total yield.

![Fig. 2. Potato cultivar yield response to irrigation plus precipitation in 1992. Total yield (•) solid line, U.S. No. 1 yield (+) dashed line.](image)

![Fig. 3. Potato cultivar yield response to irrigation plus precipitation in 1993. Total yield (•) solid line, U.S. No. 1 yield (+) dashed line.](image)
Averaged over the three years, ‘Umatilla Russet’ had a high regression coefficient for applied water vs. U.S. No. 1 yield and was the most productive of U.S. No. 1 yield. ‘Russet Burbank’ and ‘Umatilla Russet’ were the most productive in total yield when irrigated at full ET. Averaged over the three years, total yields of all cultivars except ‘Russet Burbank’ and ‘Russet Legend’ increased with increases in applied water (Fig. 5). ‘Russet Burbank’ produced relatively few U.S. No. 1 tubers in applied water (Fig. 5). ‘Russet Legend’ was as productive of U.S. No. 1 yield as ‘Russet Burbank’ when irrigated at full applied water. Both total and U.S. No. 1 yield response to applied water for ‘Russet Legend’ was in the very high category (>1.089 g·cm⁻³) according to Mosley and Chase (1993). Neither tuber stem-end fry color nor tuber specific gravity were responsive to applied water in this study.

Short term deficit irrigation intensities (percent of ETc replaced) in this study were within the ranges that resulted in dark stem-end fry color and losses in tuber specific gravity in other studies (Eldredge et al., 1996; Shock, et al., 1993). The lack of stem-end fry color response or consistent losses in tuber specific gravity to the season-long deficit irrigation in this study indicates that the potato plants could have become somewhat drought hardened in this study. Well watered potato subjected to irrigation in an unusually cool and wet year.

These results indicate that ‘Russet Legend’ was the only cultivar showing a tolerance to deficit irrigation. In 2 out of the 3 years, ‘Russet Legend’ was as productive of U.S. No. 1 yield over most of the range of applied water when compared to ‘Shepody’, ‘Frontier Russet’, and ‘Ranger Russet’ at the higher end of the applied water range. The new cultivars ‘Umatilla Russet’ and ‘Russet Legend’ performed as well or better than the established commercial cultivars at full irrigation, with ‘Umatilla Russet’ showing a higher yield potential at the higher water application rates than ‘Russet Legend’. All cultivars produced more U.S. No. 1 tubers than ‘Russet Burbank’ in 1992 and 1994. ‘Russet Burbank’ performed well in 1993, an unusually cool and wet year.

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Fig. 4. Potato cultivar yield response to irrigation plus precipitation in 1994.

Fig. 5. Potato cultivar yield response to irrigation plus precipitation averaged over three years. Total yield (•) solid line, U.S. No. 1 yield (+) dashed line.
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