SITE-SPECIFIC WATER AND NUTRIENT MANAGEMENT IN POTATO

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ABSTRACT

Center pivots are the most commonly used irrigation system for potato production in the Pacific Northwest and Intermountain West. Conventional irrigation management treats the field as a homogeneous unit in regards to water requirements. However, differences in water requirements often develop throughout the season within center pivot irrigated fields that can reduce field scale tuber yield and quality. This study investigated the potential increase in gross return from increased tuber yield and quality under site-specific versus conventional uniform irrigation management with center pivot irrigation. In 2001 and 2002, one quadrant of an 11.5 ha center pivot irrigated field was divided into eighteen arbitrary irrigation management zones. One-half of the management zones received site-specific irrigation management and the remainder received equal irrigation based on the average irrigation requirement for the nine zones. The difference between mean seasonal irrigation amounts for the treatments was less than 13 mm for both years. Total tuber yield was not significantly different ($p<0.05$) for both years. However, based on a tuber quality adjusted price structure for processing potatoes, the trend in gross receipts was approximately \$159 ha^{-1} (\$64 ac^{-1}) greater under site-specific water management compared to conventional uniform irrigation management for the field site. In 2004, the potential increase in gross return from conjunctive site-specific water and in-season nitrogen management was investigated. Total tuber yield was not significantly different ($p<0.05$) between treatments. The trend in gross receipts was approximately \$324 ha^{-1} (\$131 ac^{-1}) greater under conjunctive site-specific water and nitrogen management compared to conventional uniform water and nitrogen management.

INTRODUCTION

Interest in site-specific irrigation management has emerged over the past decade in response to successful commercialization of other site-specific application technologies in irrigated agriculture. This interest is due partially to the desire to improve water use efficiency as well as to complement site-specific management of other crop inputs such as nitrogen for groundwater protection. A holistic approach to site-specific crop management in irrigated agriculture includes water as one of the primary inputs. Extension of the site-specific crop management concept to irrigation follows from the fact that excessive and deficient water availability greatly impacts crop yield and quality.

Continuous-move irrigation systems provide a natural platform upon which to develop site-specific irrigation management technologies due to their current and increasing usage and high degree of automation. Control systems and hardware to implement site-specific irrigation management have been reported in the literature (e.g. Fraisse et al., 1995; King et al., 1996;

Sadler et al., 1996; Evans et al., 1996; Harting, 1999; and Perry et al., 2003). In each case, spatially variable water application was successfully achieved on a limited scale. However, many issues relating to reliability, management and economic viability need to be addressed before commercialization and producer adoption can be expected.

Site-specific irrigation management will not likely be an economically viable practice for all crops and all growing conditions. However, it may likely be universally advantageous in regards to reducing the impact of irrigated agriculture on regional water resources through improved water use efficiency and reduced leaching of nitrogen from the crop root zone. Site-specific irrigation management will most likely be economical on crops such as potato where yield and quality are highly water sensitive and crop price structure is heavily dependent upon crop quality.

From an economic prospective, site-specific irrigation management has the potential to increase gross return with potatoes, but this has not yet been demonstrated in the field. The objective of the field study was to determine if site-specific irrigation management for potatoes could actually improve potato yield and quality relative to conventional uniform irrigation and provide an increase in gross return.

METHODS AND MATERIALS

This field study was conducted at the University of Idaho Aberdeen Research and Extension Center in 2001, 2002, and 2004 using a center pivot irrigation system equipped with the variable rate irrigation control system described by King et al. (2000). Briefly, variable rate water application along the center pivot lateral is achieved using two sprinkler packages sized with application rates of 1X and 2X. Solenoid valves on each sprinkler provide ON/OFF control of each sprinkler resulting in application rates of 0X, 1X, 2X, and 3X using ON/OFF sequencing. Valve control is provided by a supervisory control and data acquisition (SCADA) system that utilizes RS-232, power line carrier, and radio frequency communication media to link system-mounted controls and in-field stationary data loggers to a master computer. The SCADA system is designed to upload logged soil moisture, water application, and environmental data from in-field sensors when the center pivot lateral is within low-power radio frequency range. The data is stored in the master computer located at the pivot point and downloaded to a portable computer for analysis and site-specific irrigation scheduling decisions. In 2003, the center pivot system was modified to include a separate low volume chemical application system to allow independent site-specific water and nitrogen application.

Each year one 2.9 ha (7.1 ac) quadrant of the center pivot irrigation system was divided into eighteen arbitrary irrigation management zones. Different quadrants were used in 2001 and 2002, with 2001 and 2004 being the same quadrant. Soil texture in the upper 60 cm (2 ft) of the soil profile was determined in the laboratory using the hydrometer method based on soil sampling of the field on a 30.5 m (100 ft) hexagonal grid. Soil texture ranged from loamy sand to silty clay loam, resulting in a two-fold variation in water holding capacity for the field site, which is representative of many commercial potato fields in the region. The eighteen arbitrary management zones were blocked into nine groups of two according to most similar soil texture in the top 30 cm (1 ft) of the soil profile. Irrigation treatments of site-specific irrigation management (SSIM) and conventional uniform irrigation management (CUIM) were randomly assigned to the experimental units in each block. The resulting experimental design is a randomized complete block with two treatments and nine replications.

An experimental plot was established near the center of each irrigation management zone. A custom data logger with a unique assigned identification number was installed in each experimental plot. The data logger recorded soil moisture at two depths, soil and air temperature, relative humidity, and precipitation at 30-minute intervals. The soil moisture sensors (CS615, Campbell Scientific, Logan, UT) were installed in the crop row at 45° inclines to measure soil moisture at depths 2-23 cm (1-9 in) and 20-41 cm (8-16 in). An installation jig was used to ensure that the soil moisture sensors were installed identically in all experimental plots.

A site-specific irrigation decision support model was used to determine the irrigation requirement in each irrigation management zone (Reeder 2002). The decision support model used a soil water balance along with soil moisture data and forecast evapotranspiration to compute the irrigation requirement in each irrigation management zone. The irrigation requirement was computed as the minimum irrigation amount needed to maintain 65% available soil water in the crop root zone until the next scheduled irrigation. In 2004, nitrogen was applied through the independent chemical application system to maintain 15,000 mg/kg N in potato petioles. Nitrogen was applied weekly over a six-week period from 28 June through 13 Aug.

Russet Burbank potato crops were planted on 9 May 2001, 1 May 2002, and 6 May 2004 with a seed piece spacing of 30 cm (12 in) and row spacing of 91 cm (36 in). Fertilizer, herbicide and fungicide were applied following University of Idaho potato production guidelines. Fertilizer, herbicide, and fungicide applications through the irrigation system were done uniformly using the 3X application rate with a minimum amount of water application according to label recommendations. At harvest, tuber samples from three 9.1m (30 ft) sections of crop row from each experimental unit were collected on 5 Oct. 2001, 10 Oct. 2002, and 15 Oct. 2004. Tuber samples were weighed, sized and graded within 30 days of harvest. Specific gravity was determined with the standard weight-in-air/weight-in-water method using a sub sample of U.S. No. 1 grade tubers weighing 0.170 to 0.283 kg (6 to 10 oz).

RESULTS AND DISCUSSION

In 2001, the average seasonal irrigation depth for the SSIM treatment was 503 mm (19.8 in), which is essentially equivalent to the 500 mm (19.7 in) applied to the CUIM treatment. The minimum seasonal irrigation depth applied under the SSIM treatment was 437 mm (17.2 in) and the maximum depth was 597 mm (23.5 in). In 2002, the average seasonal irrigation depth for the SSIM treatment was 432 mm (17.8 in), which is slightly less (3%) than the 445 mm (17.5 in) applied to the CUIM treatment. The minimum seasonal irrigation depth applied under the SSIM treatment was 372 mm (14.6 in) and the maximum depth was 498 mm (19.6 in). In 2004 the average seasonal irrigation depth applied to the SSIM treatment was 384 mm (15.2 in.), which was 8% less than the 416 mm (16.4 in.) applied to the CUIM treatment. The minimum seasonal irrigation depth applied under the SSIM treatment was 331 mm (13.0 in.) and the maximum was 452 mm (17.8 in.). Over the three study years, the variation in seasonal irrigation depth under the SSIM treatment ranged from 82 to 119% of the average application depth, which is within the 61 to 120% spatial variation in optimum irrigation depth reported by Sadler et al. (2002) for corn.

In 2004, average seasonal N application was 210 kg/ha (187 lb/ac) for the SSIM treatment and 216 kg ha^{-1} (193 lb/ac) for the CUIM treatment. The minimum seasonal N application under the SSIM treatment was 168 kg/ha (150 lb ac^{-1}) and the maximum was 247 kg ha^{-1} (220 lb ac^{-1}).

Total tuber yields for both irrigation treatments for each block in 2001, 2002, and 2004 are shown in Figs. 1, 2 and 3, respectively. In 2001, total tuber yield was greater under the SSIM treatment in 6 of the 9 blocks. Only in block 2 was total tuber yield substantially greater under the CUIM treatment. Total tuber yield averaged across the field site was 37.4 Mg ha^{-1} (334 cwt ac^{-1}) for the CUIM treatment and 39.0 Mg ha^{-1} (348 cwt ac^{-1}) for the SSIM treatment. Total tuber yield was not significantly different ($p \leq 0.10$) between treatments at the 95% confidence level. In 2002, total tuber yield was again greater under the SSIM treatment in 6 of the 9 blocks. Total tuber yield averaged across the field site was 33.1 Mg ha^{-1} (296 cwt ac^{-1}) for the CUIM treatment and 34.3 Mg ha^{-1} (306 cwt ac^{-1}) for the SSIM treatment. However, again total tuber yield was not significantly different ($p \leq 0.16$) between treatments at the 95% confidence level. In 2004, total tuber yield was greater under the SSIM treatment in 6 of the 9 blocks. Total tuber yield averaged across the field site was 39.4 Mg ha^{-1} (351 cwt ac^{-1}) for the CUIM treatment and 41.0 Mg ha^{-1} (374 cwt ac^{-1}) for the SSIM treatment. Total tuber yield was not significantly different between ($p \leq 0.16$) treatments at the 95% confidence level.

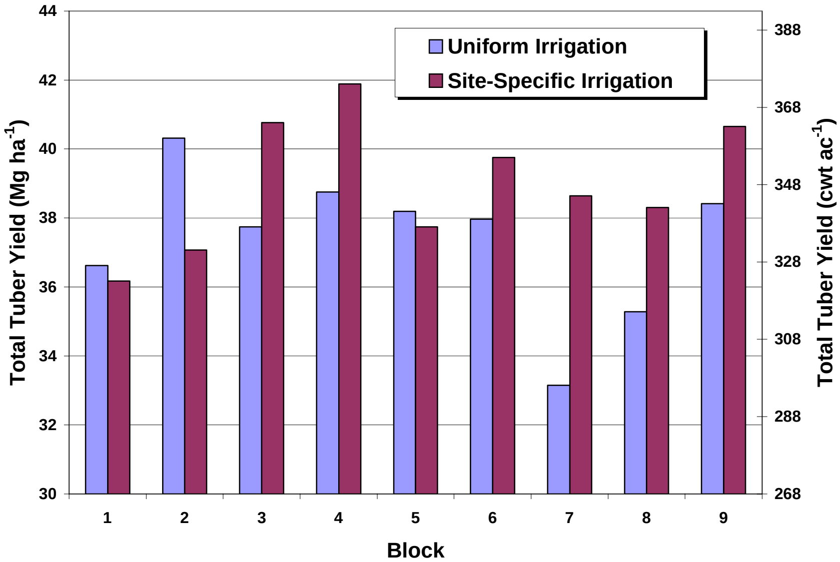

Fig. 1. Total tuber yields measured in each block of the 2001 field study.

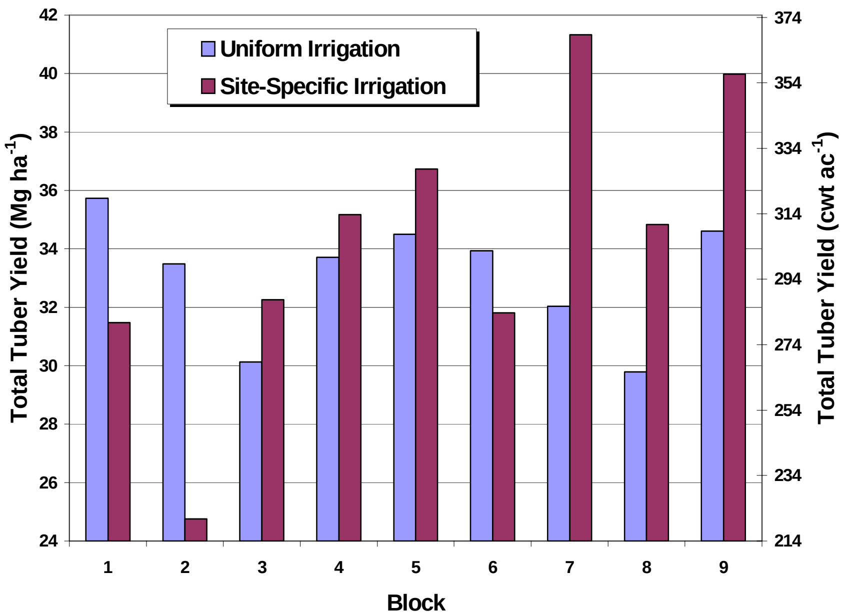

Fig. 2. Total tuber yields measured in each block of the 2002 field study.

Computed gross income was calculated using a local tuber quality incentive based potato processing contract price structure. In 2001, gross income averaged across the field site was \$3690 ha^{-1} (\$1494 ac^{-1}) for the CUIM treatment and \$3856 ha^{-1} (\$1561 ac^{-1}) for the SSIM treatment, a non-significant trend difference of \$165 ha^{-1} (\$67 ac^{-1}) greater under SSIM. In 2002, gross income averaged across the field site was \$3283 ha^{-1} (\$1329 ac^{-1}) for the CUIM treatment and \$3435 ha^{-1} (\$1391 ac^{-1})) for the SSIM treatment, a non-significant trend difference of \$152 ha^{-1} (\$62 ac^{-1}) greater under SSIM. While non-significant, demonstration of a trend showing an average increase in gross return of \$159 ha^{-1} (\$65 ac^{-1}) under the SSIM in the field experiment is encouraging. In 2004, gross income average across the field site was \$3544 ha^{-1} (\$1435 ac^{-1}) for the CUIM treatment and \$3867 ha^{-1} (\$1566 ac^{-1}) for a non-significant trend difference of \$324 ha^{-1} (\$131 ac^{-1}) in the one-year study.

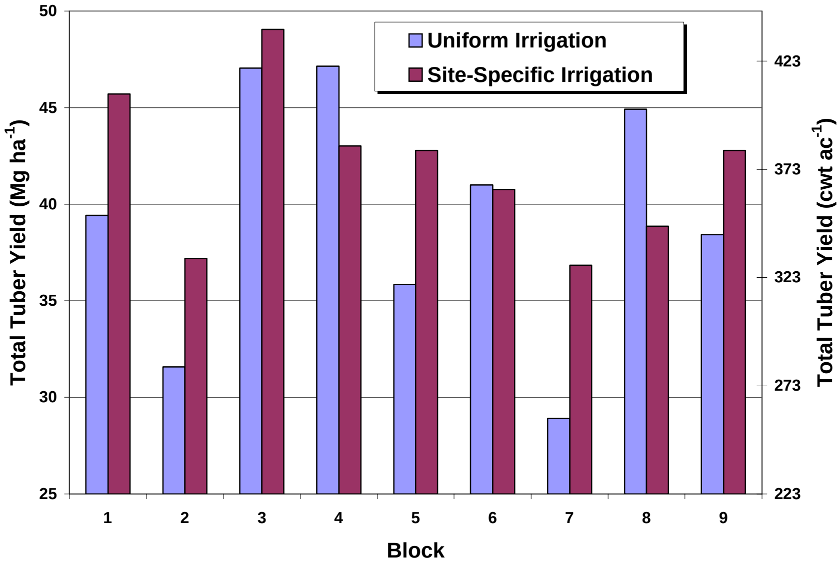

Fig. 3. Total tuber yields measured in each block of the 2004 field study.

CONCLUSION

Potato total yield was not significantly different ($p \leq 0.05$) under site-specific irrigation management relative to conventional uniform irrigation management for the study field site. However, total yield was significantly greater under site-specific irrigation management at the 90% confidence level in 2001. Based on a local tuber quality adjusted potato processing contract price structure, the trend in gross income averaged across the field site for study years 2001 and 2002 was \$159 ha^{-1} (\$65 ac^{-1}) greater under site-specific irrigation management compared to conventional uniform irrigation management. In 2004, the non-significant trend in gross income averaged over the field site was \$324 ha^{-1} (\$131 ac^{-1}) greater under conjunctive site-specific water and in-season nitrogen management compared to conventional uniform water and nitrogen management. The non-significant trend in increased gross return under site-specific irrigation management and conjunctive in-season nitrogen management is encouraging. Continued research and development is needed to reduce the capital and operational costs of site-specific irrigation and nitrogen management and realize an increase in net return.

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