Effect of Drip Irrigation on the Growth and Yield of Russet Burbank Potato

Gary Deziel and David Curwen

Summary

Drip irrigation may be a viable alternative to traditional sprinkler irrigation in Central Wisconsin potato production because of more efficient water and fertilizer use. In this study we tested three irrigation scheduling approaches and two drip tape placements.

Total, US#1, and 6-13-ounce tuber yields were significantly higher when plots were irrigated every day or every other day compared to irrigation initiated at soil water tension levels of 18-20-centibars (measured with tensiometers). No differences in yield or growth were found between every day and every other day irrigation treatments.

Total, US#1, and other yield factors were significantly higher when the drip tape was placed on top of the hill prior to final hilling than when placed in the hill with the seed piece at planting. Stolon number, tuber set, and petiole nitrate levels 45 days after emergence were also significantly higher.

Introduction

Agricultural production and irrigation practices have been identified as potential sources of ground water contamination in the Central Sands of Wisconsin. Pesticide and fertilizer use is coming under increasing public scrutiny and regulatory control. Because of this, area farmers, particularly potato growers, may see increasing pressure to justify their use of ground water resources, especially related to nitrogen fertilizer use. Drip irrigation may be a viable alternative to conventional overhead irrigation. This type of irrigation system would enable farmers to more precisely manage fertilizer and water inputs, thus improving their ability to protect ground water resources.

With drip irrigation, water is applied through emitters (small holes) spaced along thin-walled (4-15 mil), narrow (i.e., 5/8") tubes or tapes (one emitter every 12 or 18 inches, etc.). Drip tapes are placed in or on top of the soil close to the root zone of the plant. Water is applied in low volume and under low pressure. Fertilizer is commonly applied through the drip irrigation system for optimal crop production.

Drip irrigation is not a new technology. First developed in the 1960's, drip irrigation has since enjoyed a steady increase in acreage and importance, especially where competition for water resources is...
keen. Responses to a 1993 drip irrigation survey for the southeastern and mid-Atlantic states showed that Florida had 40,100 acres of commercial vegetables under drip irrigation, about 10% of Florida's total commercial vegetable acreage. Tomatoes accounted for the greatest number of acres in the survey. Peppers, strawberries, watermelons, muskmelons, cucumbers and squash followed in importance (Hochmuth, 1994).

Although research with potato has shown mixed results under drip (Burt, 1994), researchers in Idaho have shown positive results (Neibling and Brooks, 1994). They found yield and quality of Russet Norkotah potato were maintained and probably improved under drip irrigation. In addition, water use was only 60% as great with the drip system and nitrogen use only 50 to 60% as great.

Drip irrigation has many advantages over traditional overhead irrigation, including the following:

- Precise and uniform water application
- Precise application of fertilizer nutrients
- Energy, water and fertilizer conservation
- Reduced disease pressure due to dry foliage conditions

And, as you may expect, drip irrigation has many disadvantages, including the following:

- High installation costs
- Water quality and water filtration concerns
- Emitter clogging
- Drip tape disposal problems

However, if drip irrigation is to become a viable cultural alternative for potato growers in Wisconsin, many questions must be answered. These include irrigation scheduling, drip tape placement, fertigation practices, and drip tape handling (at planting and harvest) and disposal.

Two Wisconsin growers, Brian Bowen, Superintendent, UW-Madison Agricultural Research Station, Rhinelander, and Bob Guenther, an Antigo, Wisconsin, grower, have produced potatoes under drip irrigation. They have both built drip tape "applicators" which install the drip tape at planting with the seed piece, and Bowen has invented an innovative reel-retrieval system to wind up the tape at harvest. Both have had good success with drip. Guenther has disposed of the drip tape after every season. Bowen uses a costlier, thicker-walled tape which he intends to use up to three seasons. In both cases, acreage under drip is small. Additionally, soils are heavier there than found in the central Wisconsin potato production area. Management of drip irrigation in the Central Sands may require different approaches than in Antigo or Rhinelander, Wisconsin.

Objectives of 1995 Study

With this in mind, in 1995 we undertook a study of drip irrigation of potatoes at the Hancock Agricultural Research Station. Our study was primarily concerned with answering questions about
irrigation scheduling and drip tape placement. Objectives of the 1995 study included the following:

- Evaluate the effect of drip irrigation scheduling on Russet Burbank plant growth and tuber yield.
- Evaluate the effect of drip tape placement on Russet Burbank plant growth and tuber yield.
- Estimate drip irrigation costs and compare these costs to conventional irrigation methods.

**The irrigation treatments were as follows:**

- **Treatment 1:** Irrigate when Allowable Depletion (AD) balance dropped into the range of 0.5 to 0.6" -- Irrigation was then applied to bring AD balance back up to 0.7". (essentially daily irrigation).
- **Treatment 2:** Irrigate when AD balance dropped into the range of 0.3 to 0.4" -- AD balance returned to 0.7". (Approximately every other day irrigation).
- **Treatment 3:** Initiate irrigation when average tensiometer (at 8" depth) readings reached 18-20 centibars.

Each of the above treatments were split into the following drip tube placement treatments:

- **Drip tape placed at seed piece during planting** (5 to 6" below top of hill).
- **Drip tape placed on hill prior to hilling** (0 to 1" below top of hill).

**Methods**

This experiment was designed to evaluate three methods of irrigation scheduling and two drip tape placements. Treatments 1 and 2, listed in the table above, are based on the Wisconsin Irrigation Scheduling Program (WISP). AD refers to Allowable soil water Depletion before plant stress occurs. In potatoes grown on sandy soils, WISP considers the AD value to be 0.7". Thus, 0.7" of evapotranspiration can occur without causing stress to the crop (approximately 3 days with an ET rate of 0.25"").

Each irrigation treatment was split into two sub-treatments: drip tape placed on top of the hill prior to hilling and drip tape placed in the hill next to the seed piece at planting.

The experiment was conducted at the University of Wisconsin Agricultural Research Station in Hancock, Wisconsin on a Plainfield Sand (pH 6.3; ppm P 59; ppm K 150). Russet Burbank potatoes were planted in rows three feet apart at the rate of approximately 18 cwt. per acre on May 3, 1995. There was approximately 12 inches between seed pieces. Netafim Typhoon 10 mil drip tape with 12-inch emitter spacing was installed at planting (with seed piece) and prior to hilling (on top of hill) (Drawing 1, next page). Fifty percent emergence occurred May 29, 1995. The first irrigation application was applied June 2, 1995.

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1 Dripper tube rated at 0.4 gallons per hour per emitter, approximately 0.19" per acre per hour application rate.
Two Irrometer®-brand tensiometers were placed in each "tensiometer-based" irrigation plot (treatment three, previous page). One was inserted 8 inches below the top of the hill and the other inserted 15 inches below the top of the hill. Both were offset from the center of the hill by 6 inches (Drawing 2).

Three hundred pounds of 0-0-60 per acre was applied April 3, 1995, to the plot area. Thirty pounds of actual N per acre was applied at planting with the starter fertilizer (500 lbs. per acre of 6-24-24 with Admire® Insecticide). Sidedress nitrogen applications of 30, 60, and 60 lbs N/a were made on June 7, June 15, and July 7, respectively, through the irrigation system using 28% UAN solution. A petiole nitrate test was taken on July 10, 1995, to assess plant nitrogen status of each plot.

On August 2, 1995, two hills from each plot were dug, and measurements were made. These included plant height, above-ground plant weight (fresh and dry), number of stems per hill, number of stolons per hill, average stolon length, number of tubers, average tuber length, tuber fresh weight, and average tuber fresh weight.

Plots were killed on August 22 and harvested on September 26, 1995. Harvest from all plots was graded and sized, and specific gravities were taken.

Results and Comments

The summer of 1995 was well suited for irrigation research. Evapotranspiration rates of as high as 0.35 inches were reached, and several dry periods (up to 16 days without rainfall) occurred in June and July. Over half the growing season rainfall fell in the first 20 days of August. Thus, soil moisture differences between treatments were at their highest during the critical periods of tuber initiation, and during early and mid tuber bulking.

Due to unusually high day and nighttime temperatures, average yield of Russet Burbank potatoes in central Wisconsin was reduced ten to twenty percent and specific gravities were low (avg. 1.073)¹. This experiment reflects this regional trend.

Yield was reduced further by an apparent nitrogen deficiency in all the plots. Only 150 pounds per acre of supplemental nitrogen was applied -- 75% of our conventional application. This was done because of the expected increase in fertilizer efficiency under drip and to match the N rate in a related drip irrigation study done elsewhere on

the farm. The average petiole nitrate-nitrogen level across treatments was 0.9 percent, far below the 1.5 percent concentration deemed adequate for Russet Burbank 45 days after emergence. Thus, plots died early (average of 21% cover 8/18/95), and the decision to kill the plots was made in late August.

The results as related to each objective are discussed in the following sections.

Objective 1: Effect of Irrigation Scheduling

Total seasonal irrigation differed markedly between treatments (Table 1). It should be noted that application times were kept to a maximum of 1.5 hours. This was done to lessen the likelihood of water leaching beyond the potato root zone. If crop need was determined to be greater than the amount which could be irrigated in 1.5 hours, an additional irrigation period was scheduled for later in the day.

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<th>Table 1. Irrigation Treatment Seasonal Summary</th>
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<td>Trt 1</td>
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<td>0.5 to 0.6&quot; AD</td>
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<td>Number of Irrigation Applications</td>
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<td>Total Irrigation in Inches</td>
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<td>Average Amount per Application</td>
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Significant total yield differences were found between irrigation scheduling treatments (Table 2). Average total yield for treatment 1 (daily irrigation) was 307 cwt/a, which did not significantly differ from that for treatment 2 (every other day), which yielded 294 cwt/a. Treatment 3 (tensiometer-based) yield, however, was significantly lower at 244 cwt/a.

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<th>Table 2. Yield Summary, Irrigation scheduling.</th>
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<tr>
<td>Total Yield</td>
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<td>Treatment 1, 0.5 to 0.6 AD</td>
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<td>Treatment 2, 0.3 to 0.4 AD</td>
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<td>Treatment 3, (Tensiometers)</td>
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*Values with different letters are statistically different \( (p=0.05) \).

Significant differences were also found in US#1 yield. Treatments 1, 2, and 3 produced an average of 223, 216, and 156 cwt./acre. Again, yields were somewhat limited by nitrogen deficiency. However,
there was no difference in petiole nitrate nitrogen levels between treatments.

Experience and research document that moisture stress during tuber initiation and tuber bulking reduces yield and causes increased incidence of scab and off-shapes. This was true in the "tensiometer-based" treatment. The soil moisture status of the sandy soils was often adequate in the morning when tensiometer measurements were taken, but the status quickly changed as the day wore on, especially given high ET rates. This caused moisture stress and subsequent yield reductions, notably in the greater than 6 ounce size category, in which treatment 3 yield was significantly lower than treatments 1 and 2. We did not use the newer 'Model LT' tensiometers made by Irrometer. These are made specifically for sands and may have improved our ability to manage irrigation in these plots.

Pitted scab was more prevalent, and knobby, misshapen tubers were more numerous in the tensiometer-based treatment, which is consistent with potatoes grown under moisture deficit conditions at tuber initiation and during tuber bulking.

There were no significant differences between irrigation scheduling treatments with regard to mid-season measurements: plant height, above-ground plant weight (fresh and dry), number of stems per hill, number of stolons per hill, average stolon length, number of tubers, average tuber length, tuber fresh weight, or average tuber fresh weight. Tuber specific gravity at harvest was also unaffected.

Objective 2: Effect of Drip Tape Placement

Yield was significantly higher when the drip tape was placed on top of the hill prior to hilling than when the tape was placed with the seed piece at planting (both total and US#1 yield) (Table 3).

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<th>Table 3. Yield Summary, Drip tape placement.</th>
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<tr>
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<tr>
<td>Total Yield</td>
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<td>cwt/a</td>
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<td>Drip tape placed prior to hilling</td>
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<tr>
<td>Drip tape at Seed Piece</td>
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Generally, almost all vegetable and row crop growers in the major drip irrigation states (California, Florida, Arizona) place the drip tape four to ten inches below the top of the soil surface. However, in sandy soils the drip tape is often placed near or on the soil surface because of reduced lateral and upward water flow in sands (Burt, 1994). Thus, the wetted volume of the hill appeared to be greater when the drip tape was placed on top of the hill. This may have improved root growth and, ultimately, yield. For instance, we found that numbers of stolons per hill were significantly higher when the drip tape was placed on the hill prior to hilling than when placed with the seed piece at planting and there was a trend towards
increased tuber set when the tape was placed near the top of the hill. Also, petiole NO, nitrogen levels were significantly higher (P=0.10) when the drip tape was placed on top of the hill than at the seed piece, substantiating the belief that the crop was better able to utilize water when it was applied from the top of the hill.

Drip tape yield differences are reflected in tuber size. Again, tape placed on top of the hill prior to hilling produced greater yields per acre of 4-6-ounce and 6-13-ounce tubers.

However, there was an interaction between drip tape placement and irrigation scheduling method with regard to total yield. With treatment 2 (irrigation when AD balance dropped to 0.3 to 0.4 inches), there was no total yield difference between drip tape placement (see graph below).

![Graph of Interaction of Irrigation Method and Drip Tape Placement](image)

There was no significant difference between drip tape placement treatments with regard to mid-season plant height, above-ground plant weight (fresh and dry), number of stems per hill, number of stolons per hill, average stolon length, number of tubers, average tuber length, tuber fresh weight, or average tuber fresh weight. Drip tape placement had no effect on tuber specific gravity.

**Economic Notes**

Given a 160-acre center pivot (131 acres irrigated) at the initial cost of $65,000 with an expected life of 20 years, average annual ownership costs are $25 per acre per year. A 75-horsepower well motor will cost approximately $3.30 per hour to run at $ 0.06 per kwh. Given 700 hours of operation to apply approximately 12 acre-inches of water, annual operating cost is $2,350, or $18 per acre per year. Thus, annual cost of irrigation would be near $50 per acre per year (Mary Hopp, Roberts Irrigation, Stevens Point, Wisconsin, personal communication).

Drip irrigation cost is highly dependent on water quality because filtration needs (and costs) increase with increasing levels of dissolved minerals, suspended particles, etc. Thus, there seems to be no "rule of thumb" for fixed costs. However, drip irrigation systems
require a well, filtration system, and motor plus a permanent distribution system (underground pipe, risers, manifolds, etc.). Growers in California and Arizona estimate costs per acre ranging from $400 to $2,100 per acre.

Regardless of fixed costs, annual costs are of concern and can be quite high. In this experiment, the drip tape cost $412 for a 7,500 foot roll. At three foot spacing, a total of 14,520 feet of drip tape is required per acre. If the drip tape is used for only one season, drip tape alone would cost nearly $800 per acre per year. The drip tape might be used more than season, which would significantly reduce annual costs (but may increase labor costs associated with fixing tape damaged at harvest). Workers in Idaho estimated that buried drip tape costs ranged from $160 to $320 per acre, depending on tape brand and thickness used (Neibling and Brooks, 1994).

Conclusions

Total and US#1 yields of Russet Burbank potato were significantly higher when the drip tape was placed on top of the hill prior to hilling than when placed at the seed piece during planting. This did not hold true, however, with irrigation treatment 2, irrigation when the soil AD balance fell to 0.3 to 0.4 inches, where no differences between drip tape placement were observed.

Stolon number per hill was significantly higher when drip tape was placed on top of the hill prior to hilling as were petiole nitrate-nitrogen values 45 days after emergence. This may indicate improved potato health status because of greater soil wetting volumes when the drip tape is placed on top of the hill prior to hilling.

Irrigation treatments 1 and 2 showed higher yields, both in terms of total yield and US#1 yield, than treatment 3, where irrigation scheduling was based on tensiometer readings. Irrigation treatments 1 and 2, essentially every-day irrigation and every-other-day irrigation, respectively, did not show significant differences in yield.

Because this data is from the first year of a multiple-year study, no certain conclusions can be made for Wisconsin growers. However, from a cultural standpoint, we feel that high quality, high yield potatoes can be grow using drip irrigation. From a profitability standpoint, more research needs to be done examining lower cost materials to make this type of system more competitive with conventional methods of irrigation.

Literature Cited

