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# SPRINKLERS, CROP WATER USE, AND IRRIGATION TIME

## CARBON AND EMERY COUNTIES

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Sprinkler irrigation has been an important part of Utah's agricultural production since the early 1950's. About 40% of Utah's 1.3 million irrigated acres are watered with sprinklers, including hand move, wheel move, center pivot and other types. Sprinklers can be a good investment when properly designed, installed, maintained and managed. For every acre-foot of water supplied to an efficient sprinkler system a farmer can expect to harvest about 1-3/4 ton of alfalfa and 46 bushels of wheat. In contrast, the expected harvest with a typical surface irrigation system (flood or furrow) is less than 1-1/4 ton of alfalfa or about 30 bushels of wheat for each acre-foot of water supply to the farm. Sprinklers produce more yield than typical surface irrigation systems per acre-foot because sprinklers apply water more efficiently.

Not all water applied by an irrigation system is used by the crop. Some water is lost to deep percolation, evaporation, or runoff. Application efficiency (Ea) is a term that tells how much of the water applied by the system is actually stored in the root zone for crop use. In Utah a typical sprinkler system has an Ea of 70% which means that 70% of the water applied by the sprinkler heads is actually stored in the soil for crop use. The actual Ea depends upon how evenly the sprinklers distribute water and other factors such as operating pressure, nozzle size and spacing, wind, air temperature and humidity (day versus night), irrigation scheduling and maintenance condition. The average efficiency of surface irrigation in Utah is about 50% as compared to the higher sprinkler efficiency of 70%.

## SPRINKLER IRRIGATION MANAGEMENT

An efficient sprinkler system is the result of good system design, proper irrigation scheduling and careful operation and timely maintenance.

**Table 1. Sprinkler Pressure and Flowrate.**

| Nozzle size | Nozzle Pressure, psi | | | | |
|---|---|---|---|---|---|
| | **30** | **40** | **50** | **60** | **70** |
| inch | Nozzle flow rate, gallons per minute (gpm) | | | | |
| 5/32 | 3.9 | 4.5 | 5.0 | 5.4 | 5.8 |
| 11/64 | 4.7 | 5.4 | 6.0 | 6.6 | 7.1 |
| 3/16 | 5.5 | 6.3 | 7.0 | 7.7 | 8.3 |
| 13/64 | 6.4 | 7.4 | 8.2 | 9.0 | 9.7 |
| 7/32 | 7.4 | 8.6 | 9.6 | 10.5 | 11.3 |

Note: Flowrates are for agricultural sprinkler heads with brass nozzles. Sprinkler nozzle flowrate is proportional to the square root of the water pressure at the base of the nozzle.

## DESIGN

A well designed sprinkler system applies water uniformly to the soil surface, and is capable of applying enough water to meet the peak demands of the crop without producing excess runoff. Good design considers such factors as pressure; nozzle size and spacing; wind, air temperature and humidity (day versus night); soil intake rate; crop rooting depth and water use rates.

The flow rate from a sprinkler nozzle depends upon nozzle size and water pressure. Flow rates for selected nozzle sizes and pressures are given in Table 1. Typical sprinkler flow rates may vary from 4 gallons per minute (gpm) from a 5/32-inch nozzle at 30 pounds pressure to over 11 gpm from a 7/32-inch nozzle at 70 pounds pressure. The nozzle size is usually stamped on the nozzle. Wheelmove systems typically have 3/16-inch nozzles.

On sloping fields there may be considerable pressure differences between sprinkler heads on high and low ends of the line. In this situation, flow control nozzles may be used to improve the uniformity of water application. Flow control nozzles apply water at the same rate, regardless of water pressure.

**Precipitation Rate (How hard is it raining?):**

The Precipitation Rate (Pr) is the rate at which water is delivered from the nozzle, averaged as inches per hour, over the area covered by one nozzle. It is important to consider the Precipitation Rate when designing a sprinkler system, since water will run off if applied faster than the soil can absorb it. Precipitation rate can be calculated using the following formula:

$$\text{Pr (inches/hr)} = 96.3 \text{ x nozzle flow rate (gpm)/area covered (ft}^2\text{)} \quad (1)$$

Precipitation Rate can be calculated as follows: In a typical wheelmove system, each sprinkler covers 2400 square feet. This is based on a spacing of 40 feet between sprinklers on the line, and a 60 foot move (40' x 60' = 2400 square feet). If we have 3/16 inch nozzles that are operating at 50 pounds pressure, the nozzle flowrate is 7.0 gpm (from Table 1). The Precipitation rate would be:

$Pr = 96.3$ (7.0 gpm)/2400 ft$^2$ = 0.28 inches per hour

**Application Rate (How much of the rain stays in the soil?):**

The Application Rate (Ar) is the average rate at which water is stored in the soil, in inches per hour.

Ar = Application Efficiency (Ea) x Precipitation rate (Pr) (2)

Typical sprinkler application efficiency values vary from 60% to 80%, 70% is a reasonable average.

*Example*:

Ar = (70/100) x 0.28 $\cong$ 0.20 inches per hour

**How Long to Irrigate (Duration):**

The duration of irrigation needed to store the crop irrigation requirements in the root zone is:

Irrigation Duration (hours) = Crop Irrigation requirements (inches)/Ar (3)

*Example*:

Determine how many hours to irrigate in July with a crop irrigation requirement of 8.5 inches, 3/16 inch diameter nozzles at 50 psi and 40' x 60' spacing (use results of previous examples).

Hours to irrigate in July = 8.5 inches/ 0.20 inches/hour $\cong$ 43 hours

Assuming that the sprinklers were moved twice per day, about 11 ½ hour sets, then about four irrigations (4 $\cong$ 43/11.5) are needed in July. This is equivalent to one 11 ½ hour irrigation about every 8 days [8 $\cong$ 31/(43/11.5)].

Calculated irrigation duration for nozzle sizes of 5/32 to 7/32 and pressures of 50 and 60 psi are given in Table 2. The durations shown in Table 2 were obtained from the use of Table 1 and Equations 1, 2, and 3, assuming sprinkler spacing of 40' by 60' and 70% application efficiency. The Table 2 duration value corresponding to the above examples is 43.2 hours, which is found at the intersection under the 3/16, 50 psi column and the 8.5 inch row.

## IRRIGATION SCHEDULING

Irrigation scheduling is the process of determining when to irrigate and how much water to apply. It depends upon design, maintenance, and operation of the irrigation system and the availability of water. The objective of irrigation scheduling is to apply only the water that the crop needs, taking into account seepage, runoff losses, and leaching requirements. Scheduling is especially important to pump irrigators if power costs are high. Common irrigation scheduling approaches include the following:

1. Irrigation on fixed intervals or following a simple calendar, i.e., when a water turn occurs or according to a predetermined schedule.
2. Irrigating when the neighbor irrigates.

3. Observation of visual plant stress indicators.
4. Measuring (or estimating) soil water by use of instruments or sampling techniques such as probes.
5. By following a soil-water budget based on weather data and/or pan evaporation.
6. Some combination of the above.

For irrigation scheduling to be most useful at a specific location, the following should be done:

1. Evaluate the irrigation system. Determine application depth, efficiency, and operating capabilities and constraints.
2. Select an appropriate irrigation scheduling method.
3. Monitor performance at intervals during the growing season.
4. Perform a post-season evaluation and determine changes for next year.

## Operation and Maintenance

To realize the full benefit of the sprinkler system, it must be operated according to design and properly maintained throughout the irrigation season. This may involve special operating techniques such as using an offset hose or alternating between day and night on successive irrigation cycles to improve distribution uniformity. Where pressure differences within a sprinkler system result in low uniformity of water application, special hardware such as flow control nozzles or pressure regulators may be required.

An audit or evaluation of the irrigation system is recommended if you suspect that the system is not as efficient as it might be. An audit determines application depth, distribution uniformity, and hydraulic performance of the supply system. If a pump is used, it is tested to determine fuel or energy use efficiency. An audit may also identify steps to improve system operation and maintenance.

Good operation also includes matching the set time (or rotation time with a center pivot) with the applied water depth and application rate to maximize the fraction of water stored in the root zone. Field irrigation (application) efficiency is the water stored in the root zone divided by the water delivered to the field. If a field is under-irrigated, a high irrigation efficiency could result with a low uniformity. Conversely, an over-irrigated field will have a low irrigation efficiency even with a high uniformity because of the deep percolation. Thus, a knowledge of the soil moisture content prior to irrigation is essential to maintaining a high application efficiency while providing for optimum crop water use and growth.

## Crop Water Use

The single most important factor that influences plant growth and crop yields from one location to another, or from one year to the next, is moisture availability. A better understanding of how water influences crop growth is essential for good water management practices. Water is the most massive of the inputs to crop yield. It takes 120 pounds of water (evapotranspiration only) to produce 1 pound of Idaho potatoes, 560 pounds of water for 1 pound of alfalfa hay and 790 pounds of water for 1 pound of wheat.

Soil water availability is affected by infiltrated irrigation water and rainfall, drainage and evapotranspiration. Evapotranspiration (Et) is the combination of transpiration from plant leaves plus evaporation from adjacent soil surfaces. While crop Et can be measured, it is most often estimated with equations from weather data collected locally. Estimated average monthly crop water use (Et) for alfalfa, spring grain, pasture, turf, and garden at Castle Dale and Ferron are given in Table 3. Seasonal Et is higher at Castle Dale than at Ferron for all crops. However, Et for all crops in July is higher at Ferron.

Assuming that the soil water depletion is completely replenished with each irrigation, the irrigation requirement is equal to Et minus effective rainfall. As a general rule, field crops should be irrigated whenever the soil water depletion approaches 50% of the available water in the root zone (see Appendix). In the peak crop water use period in an arid area, the occurrence of rain is often neglected in determining an irrigation schedule as in the example following Table 3.

**Table 2. Required Irrigation Duration for Selected Irrigation Water Requirement Values**

| Irrigation. Water Req'd, inches | **Nozzle size, inches** 5/32 | | 11/64 | | 3/16 | | 13/64 | | 7/32 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pressure psi | | | | | | | | | |
| | 50 | 60 | 50 | 60 | 50 | 60 | 50 | 60 | 50 | 60 |
| | Irrigation Duration, Hours | | | | | | | | | |
| 0.5 | 3.6 | 3.3 | 3.0 | 2.7 | 2.5 | 2.3 | 2.2 | 2.0 | 1.9 | 1.7 |
| 1.0 | 7.1 | 6.6 | 5.9 | 5.4 | 5.1 | 4.6 | 4.3 | 4.0 | 3.7 | 3.4 |
| 1.5 | 10.7 | 9.9 | 8.9 | 8.1 | 7.6 | 6.9 | 6.5 | 5.9 | 5.6 | 5.1 |
| 2.0 | 14.2 | 13.2 | 11.9 | 10.8 | 10.2 | 9.2 | 8.7 | 7.9 | 7.4 | 6.8 |
| 2.5 | 17.8 | 16.5 | 14.8 | 13.5 | 12.7 | 11.6 | 10.9 | 9.9 | 9.3 | 8.5 |
| 3.0 | 21.4 | 19.8 | 17.8 | 16.2 | 15.3 | 13.9 | 13.0 | 11.9 | 11.1 | 10.2 |
| 3.5 | 24.9 | 23.1 | 20.8 | 18.9 | 17.8 | 16.2 | 15.2 | 13.8 | 13.0 | 11.9 |
| 4.0 | 28.5 | 26.4 | 23.7 | 21.6 | 20.3 | 18.5 | 17.4 | 15.8 | 14.8 | 13.6 |
| 4.5 | 32.0 | 29.7 | 26.7 | 24.3 | 22.9 | 20.8 | 19.5 | 17.8 | 16.7 | 15.3 |
| 5.0 | 35.6 | 33.0 | 29.7 | 27.0 | 25.4 | 23.1 | 21.7 | 19.8 | 18.5 | 17.0 |
| 5.5 | 39.2 | 36.3 | 32.6 | 29.7 | 28.0 | 25.4 | 23.9 | 21.8 | 20.4 | 18.6 |
| 6.0 | 42.7 | 39.6 | 35.6 | 32.4 | 30.5 | 27.7 | 26.1 | 23.7 | 22.3 | 20.3 |
| 6.5 | 46.3 | 42.9 | 38.6 | 35.1 | 33.1 | 30.1 | 28.2 | 25.7 | 24.1 | 22.0 |
| 7.0 | 49.8 | 46.2 | 41.5 | 37.8 | 35.6 | 32.4 | 30.4 | 27.7 | 26.0 | 23.7 |
| 7.5 | 53.4 | 49.4 | 44.5 | 40.5 | 38.1 | 34.7 | 32.6 | 29.7 | 27.8 | 25.4 |
| 8.0 | 57.0 | 52.7 | 47.5 | 43.2 | 40.7 | 37.0 | 34.7 | 31.6 | 29.7 | 27.1 |
| 8.5 | 60.5 | 56.0 | 50.4 | 45.9 | 43.2 | 39.3 | 36.9 | 33.6 | 31.5 | 28.8 |
| 9.0 | 64.1 | 59.3 | 53.4 | 48.5 | 45.8 | 41.6 | 39.1 | 35.6 | 33.4 | 30.5 |
| 9.5 | 67.6 | 62.6 | 56.4 | 51.2 | 48.3 | 43.9 | 41.2 | 37.6 | 35.2 | 32.2 |

Note: Irrigation duration, hours, calculated from flowrate in Table 1 and from Equations (1), (2), and (3) assuming sprinkler spacing of 40' by 60' and 70% application efficiency.

**Table 3. Monthly Crop Evapotranspiration for Castle Dale and Ferron**

| Site | Apr | May | Jun | Jul | Aug | Sep | Oct | Season Total |
|---|---|---|---|---|---|---|---|---|
| | | | | **Alfalfa Water Use, Inches** | | | | |
| Castle Dale | 0.48 | 5.49 | 6.95 | 8.47 | 7.04 | 4.52 | 1.30 | 34.24 |
| Ferron | 0.44 | 5.45 | 6.57 | 8.66 | 6.89 | 4.21 | 1.31 | 33.54 |
| | | | | **Pasture Water Use, Inches** | | | | |
| Castle Dale | 1.44 | 3.35 | 6.04 | 6.53 | 5.23 | 3.99 | 1.44 | 28.01 |
| Ferron | 1.34 | 3.33 | 5.72 | 6.72 | 5.10 | 3.75 | 1.48 | 27.43 |
| | | | | **Sp Grain Water Use, Inches** | | | | |
| Castle Dale | 0.58 | 3.83 | 9.29 | 8.78 | 0.60 | | | 23.08 |
| Ferron | 0.55 | 3.82 | 8.79 | 9.02 | 0.55 | | | 22.74 |
| | | | | **Turf Water Use, Inches** | | | | |
| Castle Dale | 1.77 | 3.42 | 5.21 | 5.62 | 4.50 | 3.44 | 1.23 | 25.21 |
| Ferron | 1.66 | 3.39 | 4.94 | 5.78 | 4.39 | 3.23 | 1.28 | 24.67 |
| | | | | **Garden Water Use, Inches** | | | | |
| Castle Dale | | 1.38 | 3.62 | 6.62 | 6.00 | 1.82 | 0.26 | 19.71 |
| Ferron | | 1.38 | 3.42 | 6.84 | 5.84 | 1.74 | 0.26 | 19.48 |

Adapted from: Consumptive Use of Irrigated Crops in Utah, Utah Agricultural Experiment Station Research Report No. 145. Oct. 1994.

**Example:** Simple Irrigation Calendar for Alfalfa at Castle Dale, July $E_t$ = 8.47 in.

A. Irrigate at 50% management allowed depletion (MAD).
Soil water holding capacity (sandy loam) is 1.5 inches/ft (from Appendix)
Root zone available water = 5 ft x 1.5 in/ft = 7.5 inches
MAD of 50%, irrigation amount = 7.5 x .5 = 3.8 inches depletion between irrigations..
Irrigation interval = Amount/daily $E_t$ rate = 3.8 inches/(8.47 inches/31 days)
= 3.8 inches/0.27 in. per day
= 14 days

B. Alternate schedule from sprinkler net irrigation.
Net irrigation of 2.3 inches stored in the soil (2.3 = 0.20 inches per hour x 11.5 hours per set). Irrigation Interval = 2.3 inches/0.27 inches per day = about 8 ½ days.

## SUMMARY

Good sprinkle irrigation requires:

- Understanding of Soil-Water-Plant Relationships
- Irrigation timing and amount depends on soil water holding capacity, weather, and crop growth progress.
- Adequate Design and Installation
- Proper Operation and Maintenance
- Dedication and Commitment of Resources to Manage (i.e., the ***WILL*** to manage)

## WHERE CAN YOU GET HELP?

**Utah State University - Extension Service**


| | | |
|---|---|---|
| USU Extension, Biological and Irrigation Engineering<br>4105 Old Main Hill<br>Logan, UT 84322-4105<br>bobh@ext.usu.edu<br>(435) 797-2791 | Carbon County<br>120 East Main<br>Price, UT 84501<br>marlonw@ext.usu.edu<br>(435) 636-3233 | Emery County<br>P.O. Box 847<br>Castle Dale, UT 84513<br>dennisw@ext.usu.edu<br>(435) 381-2381 |

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Hill, R.W. , R.J. Hanks, and J.L. Wright. 1984. Crop Yield Models Adapted to Irrigation Scheduling Programs. Utah Agr. Exp. Stn. Res. Report 99.

**For additional reading/resource material see:**

Larsen, D.C. and T.S. Longley. "Nozzle Management and Leak Prevention for Sprinkler Irrigation." Current Info. Series No. 569. University of Idaho Coop. Extension Service, Moscow, ID 83843.

MSU Agronomy Notes Series numbers 44, 47, 49, 53, 102, and 122. J.W. Bauder. Soil and Water Specialist; Plant, Soils and Environmental Science Department, Montana State University, Bozeman, MT 59717. Telephone (406) 944-5685; email: jbauder@montana.edu.

Pacific Northwest Extension Publication, PNW Series numbers 286-292. Jan. 1986. Available from University of Idaho Cooperative Extension Service, Moscow, ID 83843. Titles in this series include: *Pumping Plant Efficiencies, Offsets for Stationary Sprinkler Systems, Irrigation Runoff Control Strategies, Irrigation Scheduling, Converting Sprinkler Systems to Lower Pressure, Sizing Irrigation Mainlines and Fittings, Electrical Demand Charges-How to Keep them Low, Extending Electric Motor Life.*

# APPENDIX

**Available Water-holding Capacity of Soils** / **Typical Crop Rooting Depths**

| Soil Texture | Inches of available water per foot of moist soil | Crop | Typical active root Zone depth, feet |
|---|---|---|---|
| Sands and fine sands | 0.5 - 0.75 | Alfalfa | 5 |
| Very fine sands, loamy sand | 0.8 - 1.0 | Corn | 4 - 5 |
| Sandy Loam | 1.2 - 1.5 | Small Grains | 3 - 4 |
| Loam | 1.9 - 2.0 | Dry Beans | 3 |
| Silt loam, silt | 2.0 | Pasture | 1.5 - 2.5 |
| Silty clay loam | 1.9 - 2.0 | | |
| | | Potatoes | 2 - 3 |
| Sandy clay loam, Clay loam | 1.7 - 2.0 | Turf | 1 - 2 |
| | | Vegetables | 1.5 - 3 |

Allowable depletion to avoid crop water stress is usually about 50% of available water holding capacity for most field crops.

The web site address for UAES Research Report #145 data tables used in Table 3 herein is found by going to the Utah Division of Water Rights home page at:

http://nrwrtl.nr.state.ut.us/

Then select "Publications" and then select "Consumptive Use Tables"

The direct URL is:

http://nrwrt1.nr.state.ut.us/techinfo/consumpt/default.htm



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