IRRIGATION WATER MANAGEMENT TO MINIMIZE DISEASE POTENTIAL IN SUGARBEETS

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Sugarbeet yield and sugar content can be significantly reduced by both under and over-irrigation. For example, under-irrigation reduces beet tonnage and total sugar yield, while over-irrigation can leach water-soluble plant nutrients and increase disease potential. Therefore, to minimize disease potential and achieve sugar yield, irrigation equipment must be designed, maintained, and operated to uniformly apply the correct amount of water at the proper time.

SUGARBEET IRRIGATION WATER MANAGEMENT NEEDS

Establishment (seed to 4-leaf; the first 30 days after emergence): Because beets are planted less than 1-inch deep, frequent, light irrigations may be needed to provide adequate soil moisture for germination and emergence under high ET or low water-holding soil conditions. On soils that tend to crust (high-silt or other), if irrigation during this period is needed, it should be light and frequent. Irrigation system components should be selected to deliver small, low energy droplets continuously over all parts of a large-diameter wetted pattern. The goal is to minimize the kinetic energy applied to the soil and minimize development of a surface crust. If a crust is formed by a rainfall event, irrigations should be light and frequent to keep the soil surface moist until the seedlings emerge.

One practice that is helpful in minimizing crusting under center pivots during this period is the use of a dual-nozzle clip which allows a second set of nozzles to be stored on the pivot drops. About 1 hour is usually required to change from one nozzle set to the other on a typical ¼ mile machine. The second set of nozzles is designed to apply about 2/3 of the mid-season design application rate. The lower application rate reduces the potential for crusting and runoff. After the crop establishes adequate cover, the nozzles can be quickly changed to allow the system to meet the mid-season irrigation demand.

Beet roots advance slowly downward, requiring about a month to reach a 1-foot root depth. Moist, non-compacted soil is essential for root development. During the first month, frequent irrigations on light, low water holding soils may be needed to maintain adequate soil moisture in this shallow root zone. This may also be true during periods of early-season hot, windy weather.

Excess water during this period can increase the potential for Rhyzomania development. Irrigation should be the minimum required to promote good crop emergence and then reduced to keep soil moisture dryer, but still above 50% available soil moisture in the active root zone (top 1 foot).

Sugarbeet diseases require a minimum soil temperature for initial development. Several also require moist soil conditions. For example, Rhyzomania requires temperatures above 70 deg F in the top 4 inches for disease development. As shown in Figure 1, adequate soil temperatures occur between early June and mid September. It also requires moist soil conditions, with soil matric potential between zero (saturation) and -40 centibars (cb), as shown in Figure 2.

Irrigation system design and operation can determine the percentage of time that soil moisture falls in the optimum range for disease development. Figures 3-6 show the seasonal soil moisture variation for different management strategies. All figures assume 7 gpm/ac center pivot design and a silt loam soil

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at Kimberly. Data are for the 2004 crop year. Similar data could be shown for a number of other years such as 2003, 2006, etc., but the trends are clearest for the 2004 data.

When the maximum root zone depth is filled to field capacity before June 1, an adequately-designed center pivot can be managed to maintain relatively constant soil moisture during the growing season. If soil moisture starts out dry (in this case at 50% available moisture), soil moisture drops off as the season progresses (Figure 3). In Figure 3, the center pivot was operated to re-fill the soil to field capacity with early season irrigations, and on a 2.5 day interval during mid-season. Under this management strategy, soil moisture was favorable for disease development early in the season. However, with adequate early-season moisture, the profile could be dried out somewhat and soil moisture maintained at a less favorable moisture content for disease while still in a near-optimum moisture range for plant growth (Figure 4). Note that this would not be possible at less than 7 gpm/ac – soil would dry excessively as discussed later. Similar results are shown in Figures 5 and 6 for a set-move system.

Vegetative and yield formation (4-16 leaf; about 3 months): Water stress during this period reduces root and top growth. Yield reduction is about 7-11% for each 10% of ET deficit. ET during the June 1 – September 1 period averages about 23.5 inches at Kimberly, so a 10% deficit would be about 2.4 inches. If soil moisture in the second and third foot is below field capacity, additional irrigation to fill the deeper root zone should occur after establishment and before lay-by (typically late June to early July). Because soil temperatures reach the disease threshold by early June, it may be desirable to add extra water to fill the root zone before then if farming schedules allow. Dry surface soil moisture at lay-by is necessary since throwing moist soil into the crown at lay-by is a major way to move Rhyzoctonia root rot pathogens into the beet plant.

To minimize disease problems in this period due to excess water:

- Monitor soil moisture to avoid over-watering
    - Irrigate for the majority of the field
    - Optimum growth is in the -40 to -60 centibar (cb) range
    - Keep slightly dryer (-60 to -80 cb) when Rhizoctonia is a problem on silt loam soils
- Fix leaks in lines
- Reservoir till or otherwise eliminate surface runoff
- Minimize time of wet foliage (slower pivot speed but without runoff)

Excess irrigation during this period may also move N from the upper to lower portions of the root zone. This produces a nutrient deficiency followed by excess N later in the season when lower nitrate values are needed to maximize sugar extraction.

ASSURING ADEQUATE SYSTEM CAPACITY

An irrigation system with adequate capacity gives a grower more management options to both meet crop water needs and minimize conditions for disease development. In contrast, an under-designed system minimizes grower options and requires wet soil conditions during portions of the growing season to help meet ET needs during mid season. For optimum beet growth, the combination of soil moisture storage and system capacity must be able to provide sufficient water during the highest water use parts of the season. Most hand line, wheel line or solid-set systems are designed to meet peak ET. However, to reduce equipment costs, most center pivot systems in Idaho are designed to meet only 80-90% of peak ET (Figure 7). This means that the remainder of the mid-season crop water demand must come from soil moisture stored in the crop root zone. If a grower enters the peak use period with very little soil moisture storage, and the system is unable to meet daily water use, the crop will become progressively more water stressed until the system can begin to catch up after the peak use period is over. A similar situation occurs if the crop root zone is nearly filled to field capacity at the start of the peak use period but system capacity is inadequate. To avoid either situation, the grower should assure that the system has sufficient capacity and the 2-3 foot deep root zone is filled to field capacity before the peak use period.

Only a portion of the water applied by the sprinkler system ends up in the crop root zone. The rest is lost to evaporation, wind drift, leaks, and non-uniformity. Application efficiency for a well-maintained pivot is about 85%, and can drop to as low as 70% for a poorly-maintained system. Application efficiencies are about 70% for solid set or set move systems under low to moderate wind conditions, and drop to 65% in higher wind conditions. Another way of looking at application efficiencies is that to place 1 inch of water in the crop root zone, the amount of water applied by the system (gross irrigation) would be 1/0.8 or 1.25 inches for 80% AE, 1.4 inches for 70% AE, and 1.5 inches for 65% AE.

Most center pivot systems are designed to deliver gross irrigation of 6.5 gpm/ac in Eastern Idaho, 6.5-7 gpm/ac in the Magic Valley, and 7-7.5 gpm/ac in Western Idaho. Using an application efficiency of 80%, net application rates are then 0.28, 0.30, and 0.32 inches/day (in/d) in Eastern, South-central, and Western Idaho, for rates of 6.5, 7, and 7.5 gpm/ac, respectively.

The impact of center pivot system capacity on the ability to maintain adequate root zone moisture throughout the growing season is shown in Figure 8 for rates of 6.5, 7 and 7.5 gpm/ac using Kimberly ET. Initial soil moisture was 50% available in the entire root zone. Early-season irrigation timing and amount were selected to keep soil moisture drier than -40 cb. The 6.5 gpm/ac design rate was unable to maintain adequate moisture in the crop root zone, with mid-season levels dropping to about 30-35% available. Water stress (below 50% available) occurs over about an 8-week period, from about July 1 to September 1. Total ET deficit is about 13%. With yield penalty of about 10% per 10% ET deficit, estimated yield reduction would be about 13% less than under no-stress conditions. Figure 8 indicates that at 7.5 gpm/ac, a system could be operated to minimize early season disease and maintain adequate moisture throughout the peak ET portion of the season. This is not true for the 6.5 or 7 gpm/ac system capacity. Other simulations show that the 7 gpm/ac system could meet mid-season demands without crop stress if some water were “banked” in late May to early June, filling the entire root zone to Field capacity. However, the 6.5 gpm/ac system would not meet mid-season demands even with early season “water banking”.

In areas where canal company delivery is less than that required to operate a pivot at the desired rate, additional irrigation water supply is required. If additional water is not available, consider one of two options: 1) reduce acreage and re-nozzle to meet peak ET by using water from corners or the end gun area, or 2) plant half the pivot to grain and half to beets. Although this is less convenient, grain irrigation can usually be curtailed by the time the beets need extra water.

POOR APPLICATION UNIFORMITY

As indicated in UI Bulletin 824 “Irrigation Uniformity” (King, et al., 2000), in a system with poor application uniformity, about 34% of the field area will be over-watered by more than 3 inches, with an equal area under-watered by the same amount. Only 10% of the field area will receive optimum irrigation. In contrast, a system with high uniformity will over or under-water only 9% of the field area by more than 3 inches, while 34% of the field will receive optimum irrigation. Disease potential is greatest in the areas of over-irrigation (34% of the field for poor uniformity vs. 9% for good uniformity).

Poor system uniformity in pivots and linear move systems can be caused by plugged or sticking pressure regulators (Figure 9A) or by nozzles placed in the wrong location (Figure 9B). In general, pressure regulators on low-pressure systems have a useful life of about 10,000-14,000 hours (about 5-7 years), depending on the quality of the irrigation water. As they age, the moving parts within the regulator tend to stick in one position, particularly in water with high levels of dissolved minerals. As a result, the output of a 15 psi regulator may range from 5 to 25 psi, creating bands of over or under-watering.

Surprisingly, a significant number of pivots have had nozzles installed in the wrong location. This also produces bands of over or under-watering (Figure 9B). Therefore, taking the time to double-check the location of nozzles on a new or re-nozzled system is certainly worthwhile.

Correct system operating pressure is essential for good water application uniformity under solid set or set-move systems. Poor uniformity can be produced by either insufficient or excessive system pressure (Figure 10). The optimum pressure for brass nozzles is about 40-60 psi. When water applied by nozzles operating in this pressure range (Figure 11, center) is combined by overlapping patterns, the result is a relatively uniform irrigation depth across the field. At lower pressures, more large water droplets are formed, producing the pattern shown in Figure 11 (top) and Figure 12. Excess pressure produces more small droplets which are prone to wind drift and evaporation and produce the pattern shown in Figure 11 (bottom). Water application uniformity resulting from overlapping patterns shown in the top or bottom part of Figure 11 will be lower than that from overlapping the distribution shown for proper nozzle pressure. This poor distribution can result in areas of significantly higher or lower than average water application depths and corresponding increase in disease potential.

SURFACE RUNOFF PROBLEMS UNDER SPRINKLER SYSTEMS

Ideally, irrigation systems are designed to uniformly apply the correct depth of water. Surface runoff occurs when water is applied at a rate high enough to exceed water movement into the soil (infiltration rate) and fill water storage due to surface roughness. Presence of surface runoff means that some areas are not receiving the intended water, and other areas where the water ponds are receiving excess. As mentioned previously, both insufficient and excessive irrigation can reduce crop yield and quality.

In addition, areas of excess water tend to be “hot spots” for disease development. Runoff from center pivots tends to collect in pivot tracks. Diseases that favor wet soil conditions tend to start near pivot tracks, and in the chronically over-watered area under the first span. If conditions are favorable, disease then spreads to the rest of the field. Pesticides and fertilizers applied through the irrigation system are also non-uniform if the water uniformity is less than optimal. Water lost to runoff under sprinkler systems is truly “wasted water,” something no one can afford this year.

Runoff can be reduced or eliminated by reducing water application per irrigation to match available surface water storage, using reservoir tillage to increase surface storage, and by proper selection of water application packages on pivots and linear-move systems. Reservoir tillage (or dammer diking) increases surface storage by formation of miniature ponds between crop rows. These “mini-ponds” can store up to 0.75 inch on 0-2% slopes, 0.5 inch on 2-5% slopes and about 0.25 inches on slopes >5%. Applying water in excess of infiltration plus surface storage will cause the “mini ponds” to overtop and destroy the future effectiveness of the treatment.

On soils prone to surface sealing and runoff, water should be applied in a manner that produces the lowest droplet kinetic energy per unit area. This means applying smaller droplets over a larger area. Some application packages (Wobblers[2], Iwobs, Spinners) apply water in all areas of a wetted circle at once. Application resembles a gentle rainfall. Others, such as rotators, apply water in a few slowly-rotating high-intensity streams which apply more kinetic energy per unit area and produce more severe crusting and runoff.

Within the "continuous, gentle rainfall" group, Spinners will produce smaller droplets. Drop size for the Wobblers or Iwobs can be reduced by increasing pressure (higher pressure = smaller drops). Although spray nozzles are inexpensive and can produce small droplets at the correct pressure, the wetted diameter is only about 20 feet, or only 20% of the area covered by all the application packages listed above. As a result, the application rate is about 5 times higher under the spray nozzles, making them more prone to surface runoff on the outer pivot spans.

SUMMARY

Proper irrigation water management is essential for minimizing the potential for disease and for optimum sugar production. In general, this means applying the correct amount of water to the crop at the correct time and applying it as uniformly as possible. Specifically, this means:

- Assuring that the irrigation system is designed to meet peak season water requirements, considering any root zone water storage that may be possible
- Early season management to ensure that soil water storage in the crop root zone is filled before peak ET occurs
- System maintenance to assure best water application uniformity
- System design and management to minimize surface runoff

REFERENCES

King, B.A., J.C. Stark and D.C. Kincaid. 2000. Irrigation Uniformity. University of Idaho Bulletin 824. 11pp.

[2] Product names are included for reader benefit and do not imply endorsement by the University of Idaho.

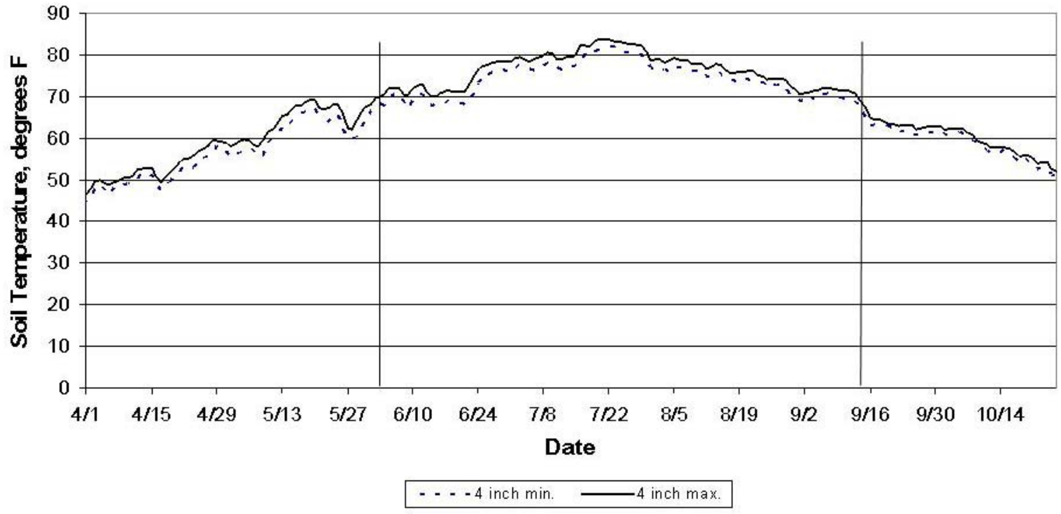

Figure 1. 2006 soil temperature at the 4-inch depth. Data are from the Kimberly, ID AGRIMET weather station.

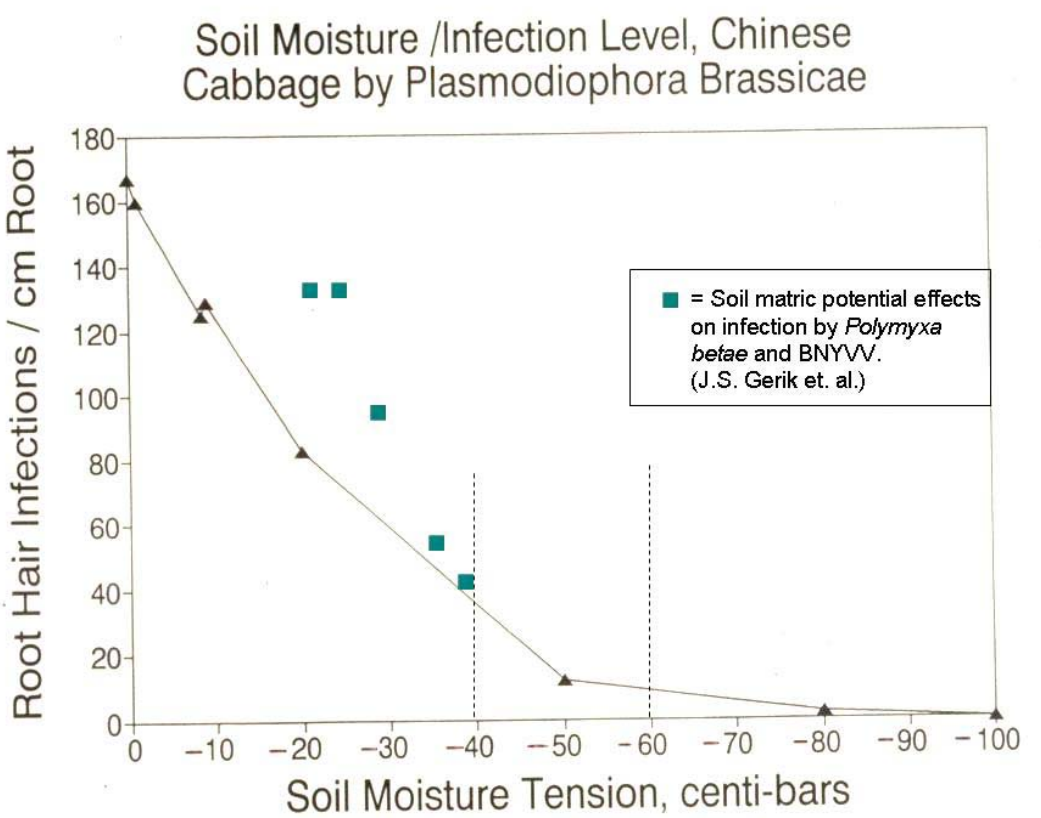

Figure 2. Root hair infections of Chinese cabbage by Plasmodiophora Brassicae and Polymyxa betae and BNYYVV (Gerik et at., 19)

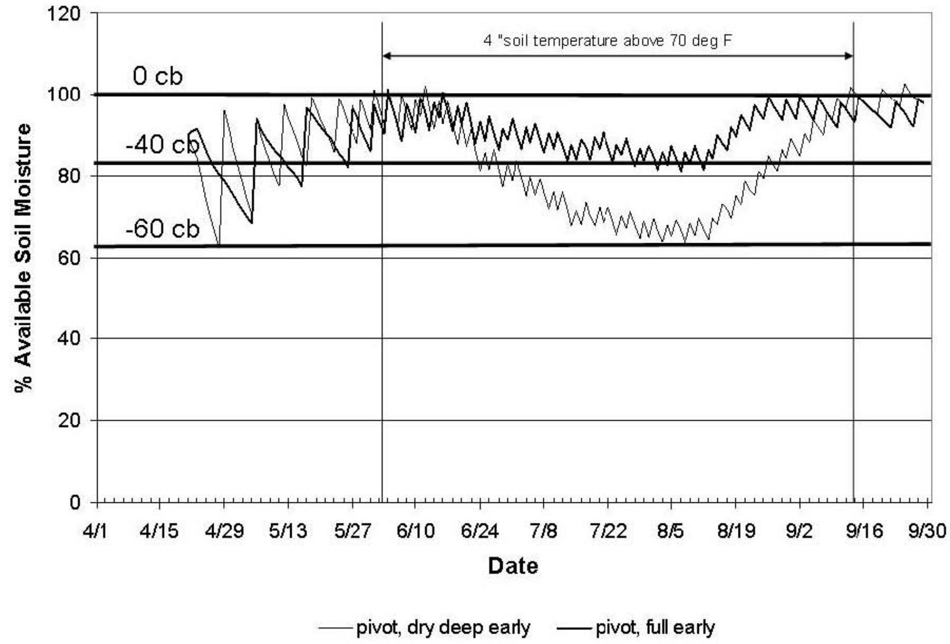

Figure 3. Seasonal variation in crop root zone soil moisture for a 7 gpm/ac center pivot operating under early season initially dry and moist soil moisture conditions.

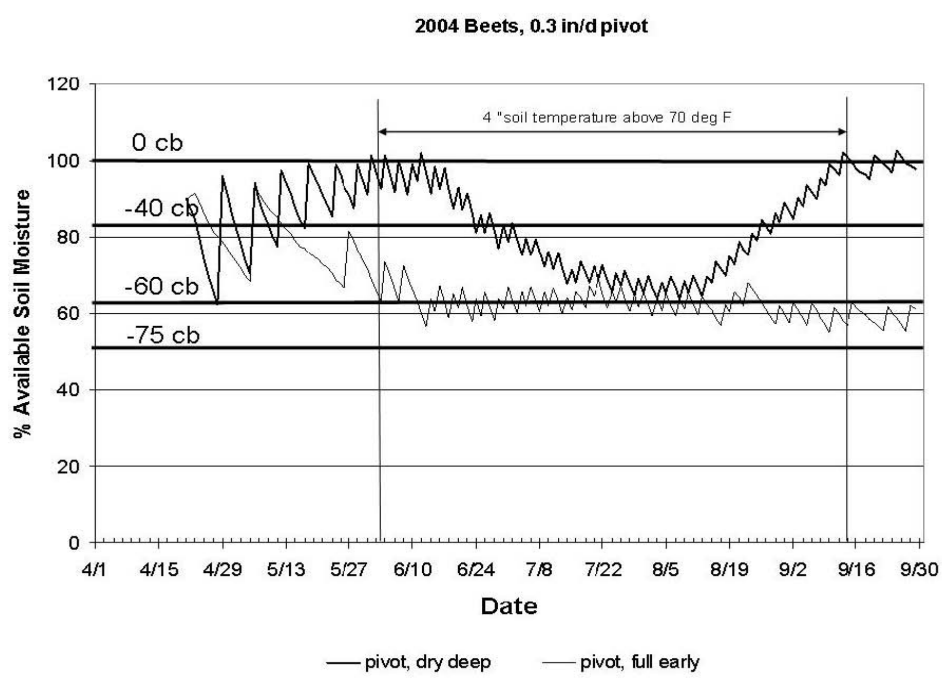

Figure 4. Seasonal variation in crop root zone soil moisture for a 7 gpm/ac center pivot operating under early season initially dry and moist soil moisture conditions. For a moist root zone, the pivot could be operated to maintain average soil moisture in the 50-70 cb range.

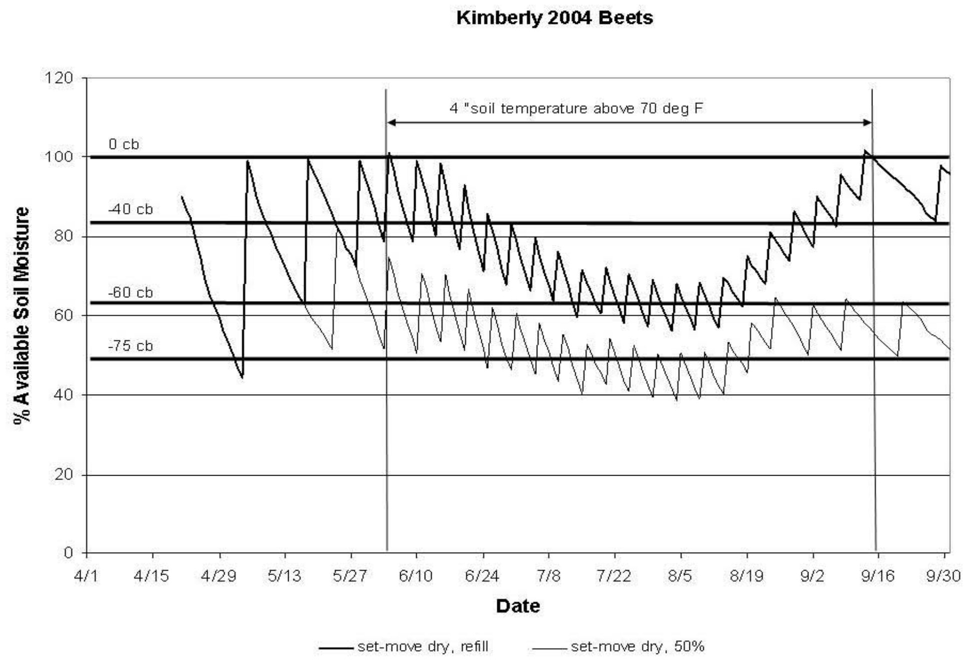

Figure 5. Seasonal variation in crop root zone soil moisture for a 7 gpm/ac center pivot operating under early season initially dry and moist soil moisture conditions.

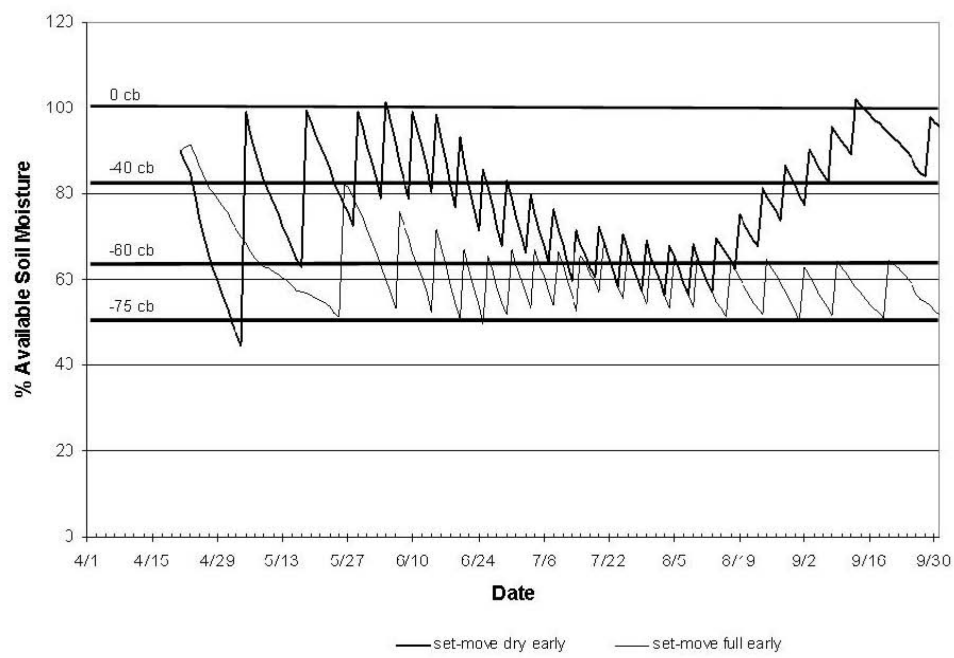

Figure 6. Seasonal variation in crop root zone soil moisture for a 7 gpm/ac center pivot operating under early season initially dry and moist soil moisture conditions. For a moist root zone, the pivot could be operated to maintain average soil moisture in the 50-70 cb range.

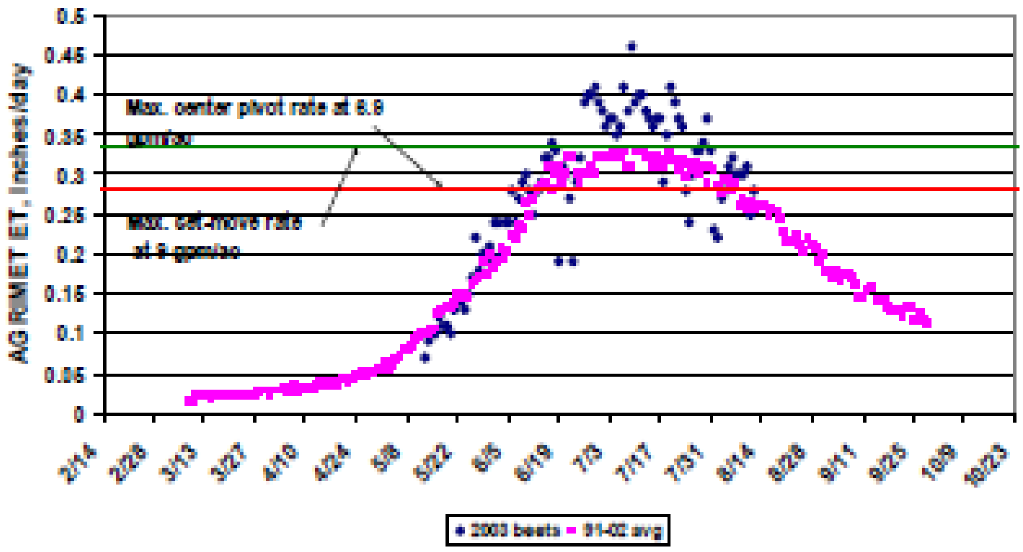

Figure 7. 12-year average and 2003 AGRIMET estimated ET for sugarbeets at Kimberly, ID. Pivot capacity is 7 gpm/ac (0.3 in/d net irrigation)

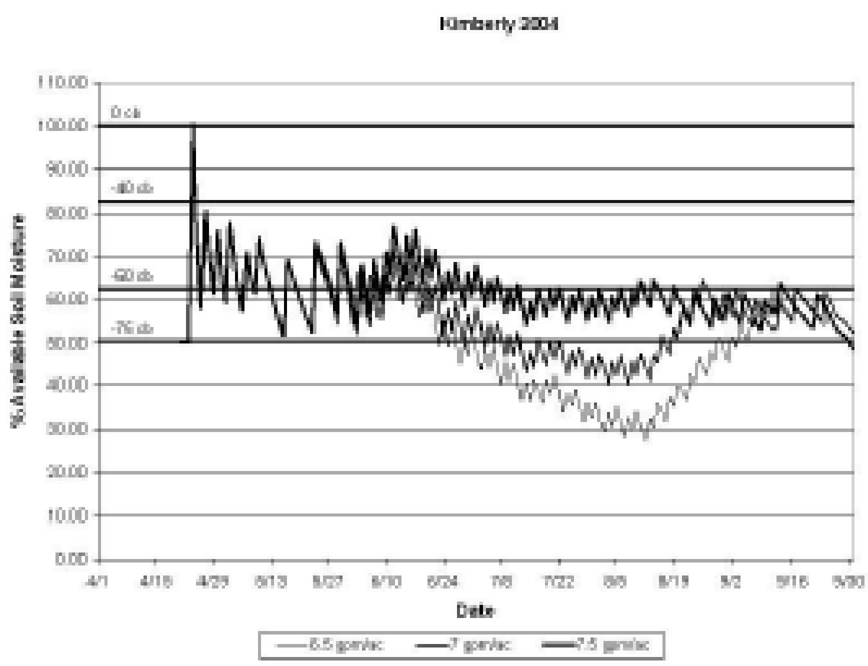

Figure 8. Seasonal variation in soil moisture for center pivot design capacities of 6.5, 7.0, and 7.5 gpm/ac. ET conditions are 2004 Kimberly AGRIMET data.

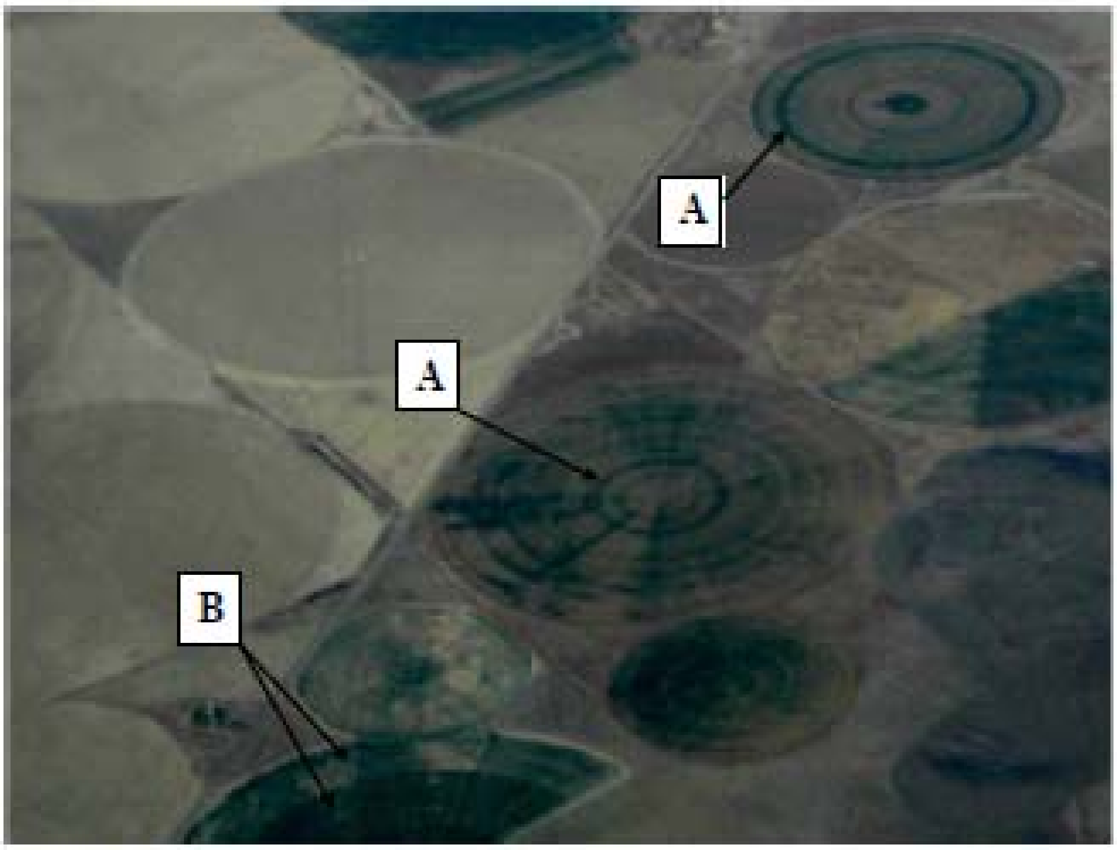

Figure 9. Poor center pivot uniformity due to malfunctioning pressure regulators (A) or incorrect nozzles on spans (B)

Figure 10. Poor uniformity on wheel line irrigated field.

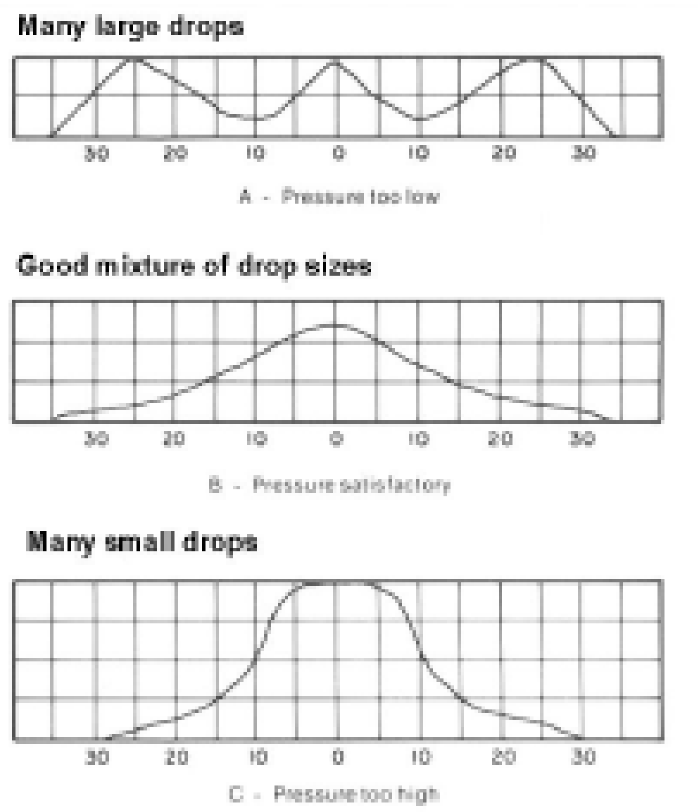

Figure 11. Variation in water application rate with horizontal distance (in feet) to the left and right of the sprinkler riser. The riser is located at distance "0".

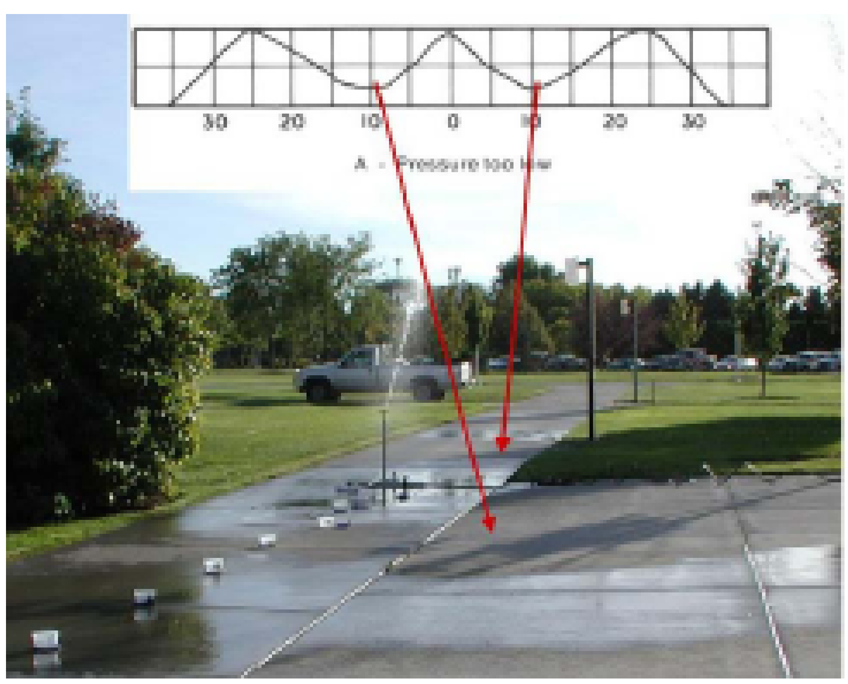

Figure 12. Water distribution from a sprinkler test using a brass nozzle at 20 psi system pressure for 20 minutes. Note the dry areas on the pavement corresponding to low areas in the theoretical distribution shown above.