IRRIGATION WATER MANAGEMENT IN POTATOES: DROUGHT CHALLENGES

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Potato yield and quality can be significantly reduced by both under and over-irrigation. For example, under-irrigation can reduce the number of tubers, produce undesirable tuber shapes, and increase potential for disease infection. Over-irrigation can leach water-soluble plant nutrients and increase disease potential. Therefore, to minimize disease potential and achieve maximum yield and quality, irrigation equipment must be designed, maintained, and operated to uniformly apply the correct amount of water at the proper time.

Growers faced several irrigation-related challenges during drought growing seasons. The following problems may be encountered:

- Capacity of center pivot systems plus insufficient soil moisture storage to meet peak ET needs.
- Continuing irrigation continued at the peak rate after crop water use drops off.
- Poor application uniformity.
- Surface runoff under pivots and set-move systems.

RESULTS OF IMPROPER IRRIGATION WATER MANAGEMENT

Potatoes are a water-sensitive crop and require a season-long assured water supply. Water stress reduces crop yield and quality and also makes the plants more susceptible to a number of diseases. Stark and Love (2003) describe potato diseases with a connection to irrigation water management. Some of these diseases and tuber shape problems are:

- Water stress during stolonization and tuber set reduces the number of tubers and increases susceptibility to Common Scab (*Streptomyces scabies*)
- Water stress also increases disease potential for:
    - Potato early dying (*Verticillium dahlia*)
    - Early blight (*Alternaria solani*)
    - Black dot (*Colletotrichum coccodes*)

- Continuous water stress produces small or cucumber-shaped potatoes
- Periodic water stress produces knobby or bottlenecked potatoes
- Excess water can also be detrimental, increasing disease potential for the following diseases:
    - Blackleg (*Erwinia carotovora, subsp. atroseptica*)
    - Dry rot (*Fusarium sambucinum* or *Fusarium coeruleum*)
    - Early blight (*Alternaria solani*)
    - Pink rot, water rot (*Phytophthora erythroseptica*)
- To minimize problems due to excess water:
    - Monitor soil moisture to avoid over-watering
    - Fix leaks in lines
    - Reservoir till or otherwise eliminate surface runoff
    - Minimize time of wet foliage (slower pivot speed but without runoff)

ASSURING ADEQUATE SYSTEM CAPACITY

Because potatoes are sensitive to water stress, 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. 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 1.5 to 2 foot deep root zone is filled to field capacity before the peak use period.

Presented at Idaho Potato Conference on January 17 and 18, 2007

Several factors must be considered when evaluating the adequacy of system capacity. These include system application efficiency, long-term average evapotranspiration (ET), and seasonal ET for higher than normal ET years.

System Application Efficiency (AE): 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.

Long-term average ET: Average Russet Burbank ET for a 30-year period and 2004 ET for Kimberly are shown in **Figure 1**. At 7.0 gpm/ac, a center pivot operating continuously in mid-season could meet the long-term average peak ET. However, long-term averages tend to under-state the peak needs in any one year, since they average across high and low ET's for each date. Therefore, individual year ET data such as that shown in **Figure 1** for 2004 are more useful in determining the capability for an irrigation system to deliver adequate water throughout the growing season.

2006 ET (high peak ET year): Estimated 2006 crop water use for Russet Burbank potatoes at Aberdeen is shown in **Figure 2**. Since many center pivots are operated to complete one revolution in 2-3 days, a 3-day moving average of 2006 ET is shown in **Figure 3** to simulate this operation. **Figure 3** shows that when averaging over 3 days of consecutive ET values, the system still operates at a deficit in mid-season. For a 1-month period (July 13- August 13), ET is generally greater than the system application rate. The cumulative mid-season water deficit for a 7 gpm/ac system (0.3 inch/day net irrigation) is 0.93 inches, while for 6.5 gpm/ac (0.28 in/d) it is 1.49 inches. That deficit must come from soil moisture storage in the crop root zone. For a silt loam soil with an 18 inch root zone, an allowable depletion of 30% would translate to about 1 inch of maximum soil moisture storage. Corresponding numbers for sandy loam and light sandy loam soils are 0.72 and 0.45 inches. This would suggest that a center pivot system on a sandy or sandy loam soil in the Aberdeen area should be designed to apply about 7 gpm/ac, while 6.5 gpm/ac with soil moisture storage would meet ET on silt loam soil. Similar analyses can be done for the Magic Valley or Western Idaho, showing that on sandy or sandy loam soils, the irrigation system should be designed to meet an expected ET of about 0.02 to 0.03 in/d larger than the long-term average.

Additional irrigation water supply is required to increase the system capacity. For an existing system,

this may mean re-nozzling to a higher application rate (if surface runoff is not a problem) with additional water supplied from another source. 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 potatoes. Although this is less convenient, grain irrigation can usually be curtailed by the time the potatoes need extra water. This option can also be less than convenient for pivots without programmable panels, but it can prevent water stress and assure a higher quality crop.

IRRIGATION CONTINUED TOO LONG AT THE PEAK RATE

As shown in **Figure 4**, ET rates can drop quickly during late season as the plants begin to senesce. Since this period follows the period of peak water use, it is imperative to monitor soil moisture conditions carefully to detect the drop off in ET and avoid excess soil moisture. Excessively wet soils can produce enlarged, open lenticels that allow soft rot bacteria to enter the tubers. Excessive late-season soil moisture can also increase pink rot and Pythium leak infections (Nolte et al., 2003).

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. The difference in potato crop value between these two situations was estimated to be about $140/acre (King et al., 2000).

Poor system uniformity in pivots and linear move systems can be caused by plugged or sticking pressure regulators (**Figure 5A**) or by nozzles placed in the wrong location (**Figure 5B**). 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 5B**). 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 6**). The optimum pressure for brass nozzles is about 40-60 psi. When water applied by nozzles operating in this pressure range (**Figure 7**, 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 7** (top) and **Figure 8**. Excess pressure produces more small droplets which are prone to wind drift and evaporation and produce the pattern shown in **Figure 7** (bottom). Water application uniformity resulting from overlapping patterns shown in the top or bottom part of **Figure 7** 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.

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.

The 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. Potato 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 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[1] , 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.

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

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 potato yield and quality. 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 assure that soil water storage in the crop root zone is filled before peak ET occurs
- Carefully matching water application to ET in mid-late season to avoid over-irrigation as ET drops off due to crop senescence
- 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.

Nolte, P., J.S. Miller, B.D. Geary and D.L. Corsini. 2003. “Disease Management”, Chapter 10. In: Potato Production Systems. J.C. Stark and S.L. Love, ed. Agricultural Communications, University of Idaho. Moscow, ID. 426 pp.

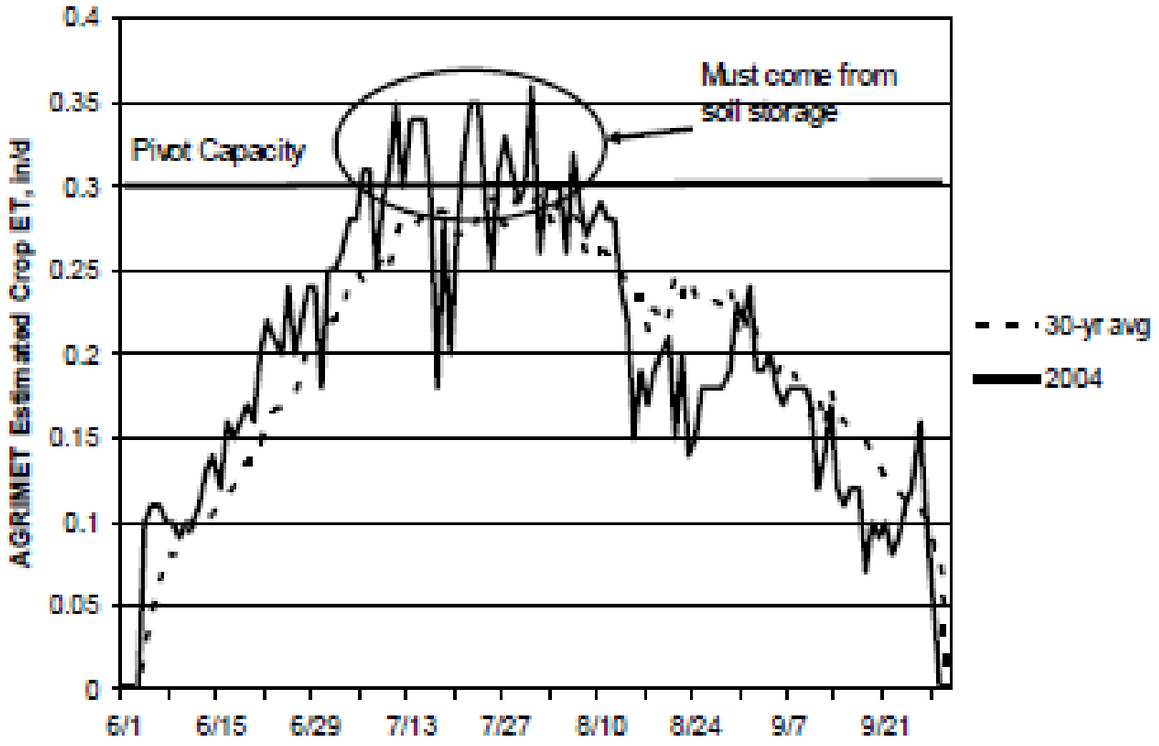

Figure 1. 30-year average and 2004 estimated ET for Russet Burbank potatoes at Kimberly, ID. Pivot capacity is 7 gpm/ac (0.3 in/d net irrigation)

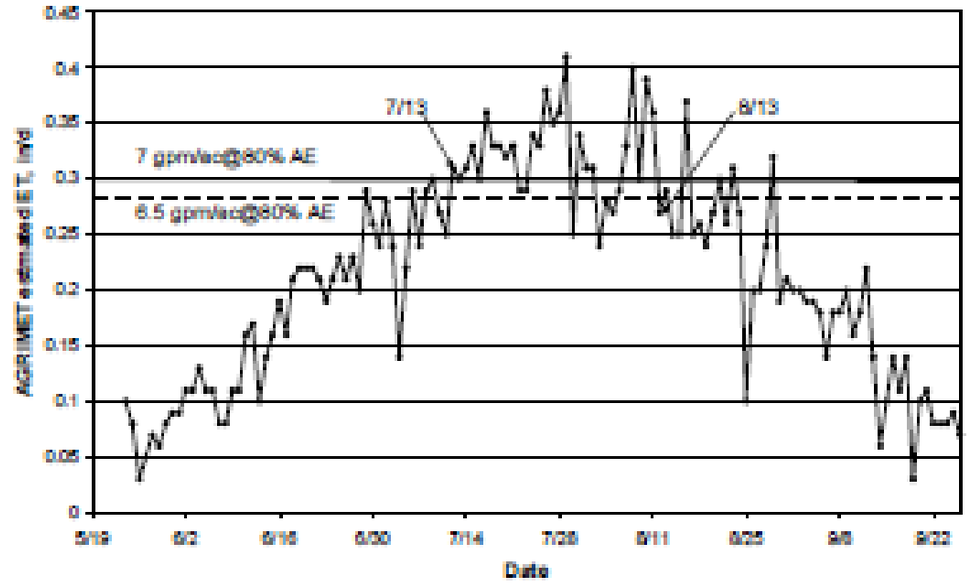

Figure 2. 2006 AGRIMET estimated Russet Burbank ET at Aberdeen, ID.

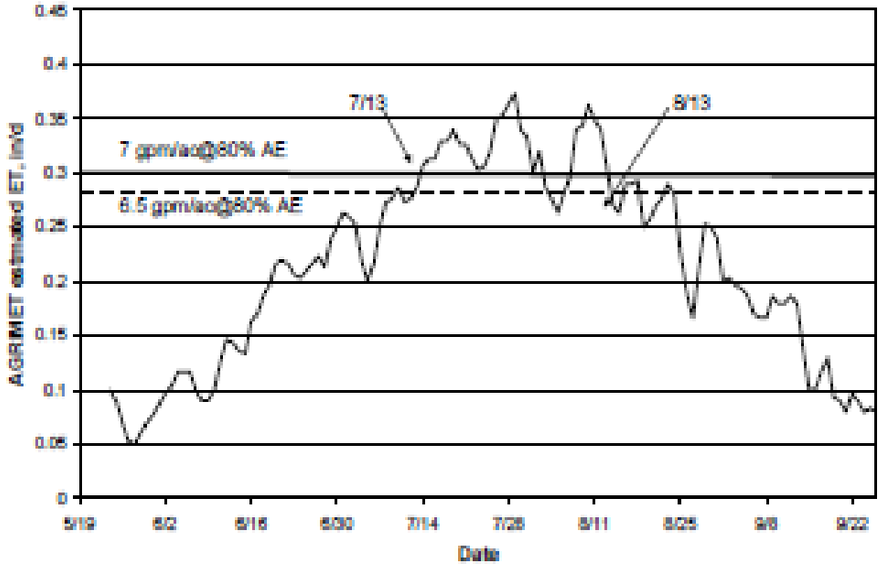

Figure 3. 3-day moving average of 2006 AGRIMET estimated Russet Burbank ET at Aberdeen, ID.

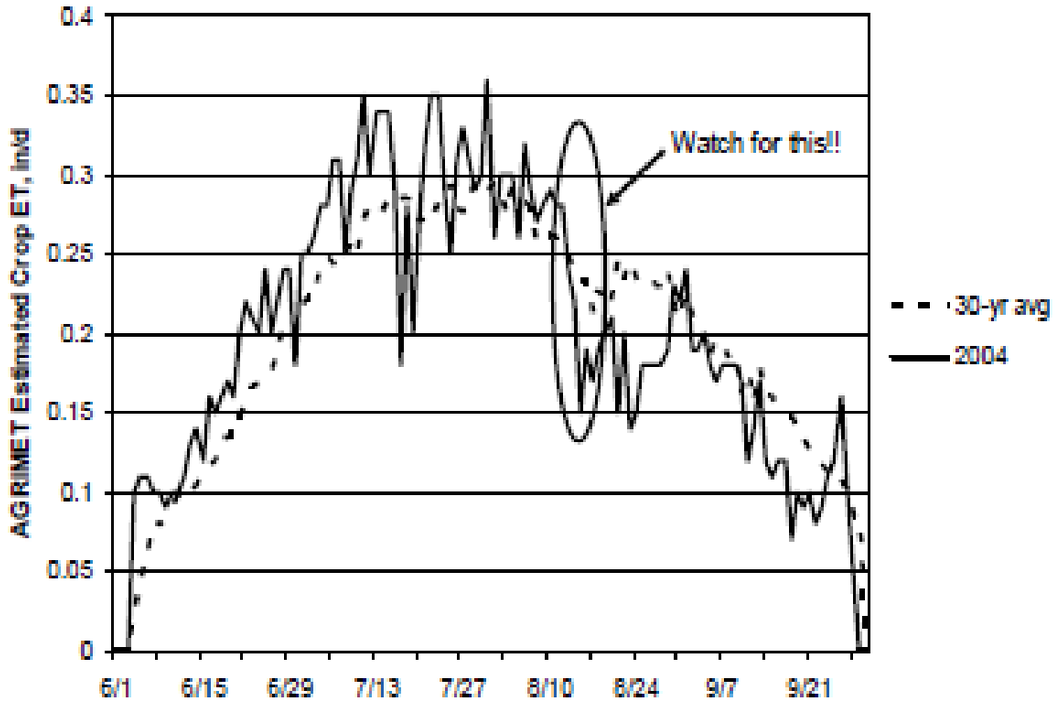

Figure 4. 30-year average and 2004 estimated ET for Russet Burbank potatoes at Kimberly, ID. Pivot capacity is 7 gpm/ac (0.3 in/d net irrigation)

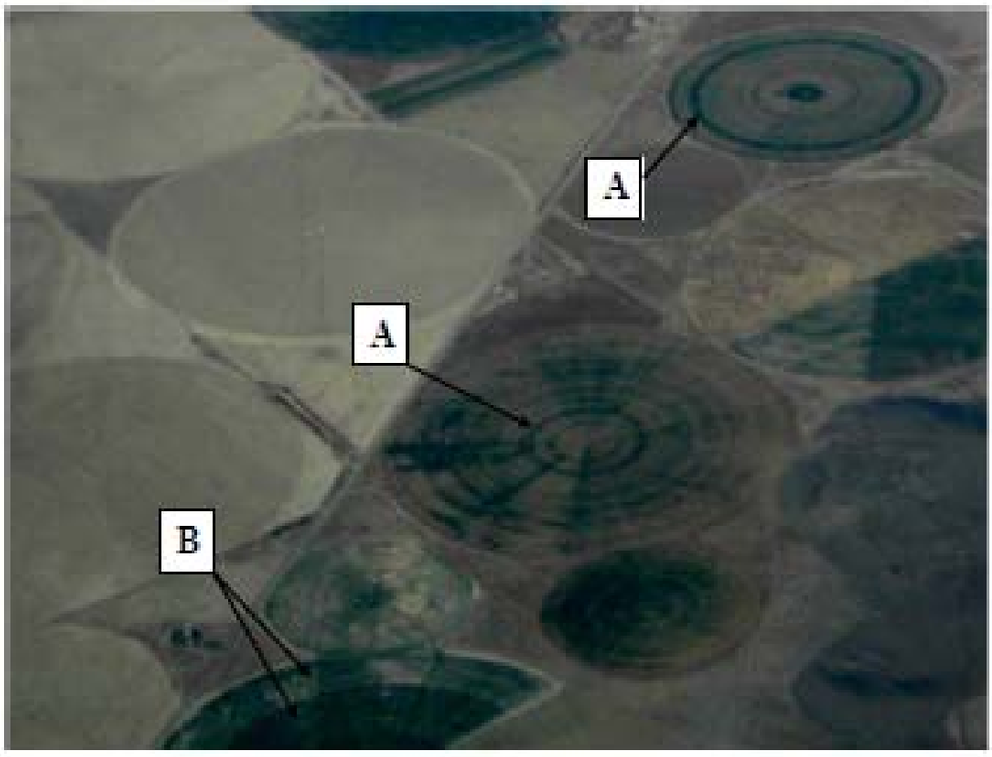

Figure 5. Poor center pivot uniformity due to malfunctioning pressure regulators (A) or incorrect nozzles on spans (B)

Figure 6. Poor uniformity on wheel line irrigated field.

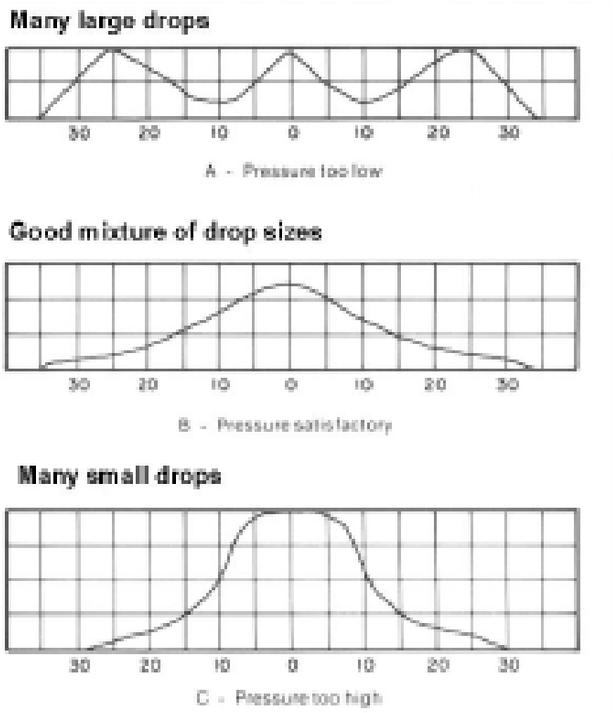

Figure 7. Variation in water application rate with horizontal distance (in feet) to the left and right of the sprinkler riser. The riser is located at distance "0".

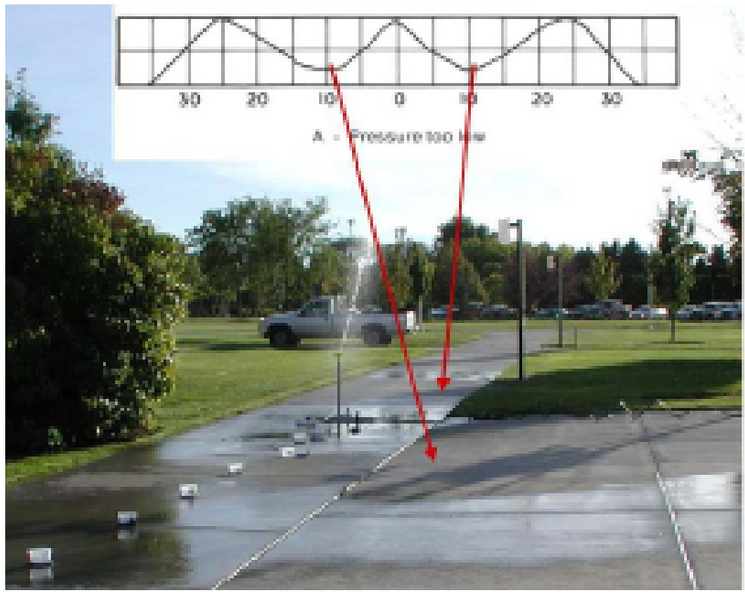

Figure 8. Water distribution from a sprinkler test using a brass nozzle at 20 psi system pressure for 20 minutes. Note the dry areas on the pavement corresponding to low areas in the theoretical distribution shown above.