SPRINKLER IRRIGATION SYSTEMS

Introduction

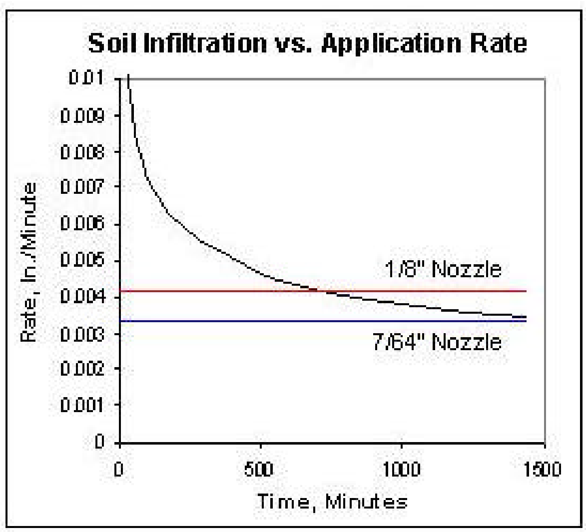
Sprinkler and drip systems have sometimes been categorized as pressurized systems, closed systems, or mechanical systems. Instead of distributing water over a field by allowing it to flow freely across graded land, the water is piped to specific locations and then sprayed or dripped onto the field. In contrast to flood irrigation system types (furrow, border, level basins), the amount of water soaking into the soil with a pressurized system (field sprinklers, drip, spitter, over/under tree sprinklers) depends on two different factors . . .

- The set time.
- The application rate of the system, assuming that the application rate of the system is less than the infiltration rate of the soil.

The system application rate is a measure of how fast water is being applied to the soil. For field sprinklers it is usually measured as a depth of water applied per hour (inches/hour).

The soil's infiltration rate, IR, is a measure of how fast water is soaking into the soil. Infiltration rates are also described in terms of inches/hour. An infiltration rate of one inch/hour means that if you ponded a one-inch depth of water on a soil with that IR, it would take one hour for it to soak in completely. Infiltration rates change constantly during an irrigation.

The figure below shows what can happen if a system is applying water at an incorrect rate, or the set time is too long. At the start of an irrigation, the application rate is less than the infiltration rate(black line) of the soil. All water soaks into the soil. Near the end of the set, the application rate, which remains constant, (red line for 1/8" nozzle) becomes larger than the infiltration rate, which decreases with time. Runoff occurs. Note that the blue line, for a 7/64" nozzle, remains below the soil infiltration throughout the entire 24-hour set. Be aware there are many other factors that affect the soil infiltration rate (http://www.ianr.unl.edu/pubs/irrigation/g1305.htm), and that it will vary even within the irrigation season.



with sprinklers and drip systems, the keys to distribution uniformity are pressure uniformity and device uniformity. Pressures in the system should not vary more than 20 percent. Because of energy and water economics, many engineers are shooting for 10 percent variance. Always have your systems designed and laid out by qualified engineers.

Device uniformity means using all the same size nozzles and sprinkler heads for field sprinklers. For trickle systems, each plant should have the same emitter configuration. That is, you may put more than one type of emitter in the field as long as each plant as one of each. Also, all emitters should have about the same operating pressure range.

With field sprinklers there is one more aspect, overlap uniformity. Wind is the greatest factor in dropping overlap uniformities. Use alternate-set lateral placements whenever possible. Operate in low-wind conditions and use tighter spacings.

With pressurized systems you should know the application rate of the system. This is how fast water is being applied. Then, also knowing the soil moisture depletion, it is a simple matter to calculate required set times.

DISTRIBUTION UNIFORMITY WITH FIELD SPRINKLERS

The three factors to consider in achieving high sprinkler uniformities (http://www.waterright.org/site2/publications/900803.asp) with field sprinklers are . . .

- Pressure uniformity, water is forced out of the sprinkler nozzle due to pressure in the pipes. The amount of water flowing through the nozzle depends on the pressure at the nozzle. The more pressure, the more flow. Uniformity depends on the pressure at each nozzle being as nearly uniform as possible.

  It is virtually (and practically) impossible to design a piping system with 100 percent pressure uniformity. A starting rule of thumb is that pressures in the system should not vary more than 20 percent. (With increasing energy costs, many Growers and Engineers are aiming for 10-15 percent). Thus, if the average pressure in a lateral was 60 PSI, the desired minimum and maximum pressure would be +/- 6 PSI.

  Use a handheld pressure gauge (liquid-filled) and a pitot-tube attachment to measure pressures at sprinkler heads. Hold the gauge so that the pitot tube is just outside the nozzle and directly centered in the flow, as seen below . It is also a good idea to have pressure gauges at the pump and at the head of the mainline.

Gauge-pitot tube being held just in stream of sprinkler to measure pressure.

- Device uniformity - The amount of water flowing through a nozzle depends on the pipe pressure and the nozzle size/condition. You could have 100 percent pressure uniformity in a system and still have bad overall DU if there were two or more nozzle sizes in the field or the nozzles were worn from sand wear. Make sure that all sprinkler heads are similar and that the same size nozzles are being used. Also make sure that they are all high-pressure or low-pressure nozzles.

- Overlap uniformity - Each sprinkler head will cover a certain diameter of the field. However, it does not spray the same amount of water over all that part of the field. Depending on the sprinkler head, nozzle configuration, and pressure, it may spray more or less water closer to the head than farther away. Thus, sprinkler systems are set up so that the spray from one sprinkler will overlap that of another.

  The figure below shows the amount of water applied from adjacent sprinklers on a sprinkler lateral, the dashed lines. The relatively flat, solid line at the top of the figure represents the total water applied at any part of the field. Note that even though the sprays from each sprinkler fall off the farther away from the sprinkler head, the total of both sprays results in a relatively uniform application. The patterns combine differently between the sprinkler laterals, but the effect is the same.

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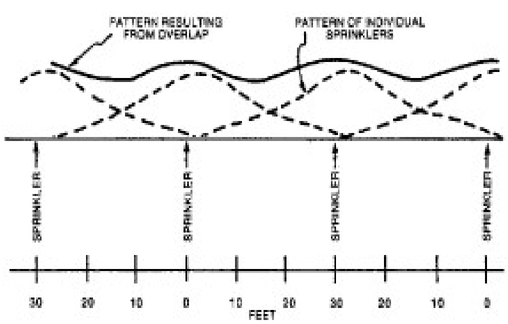
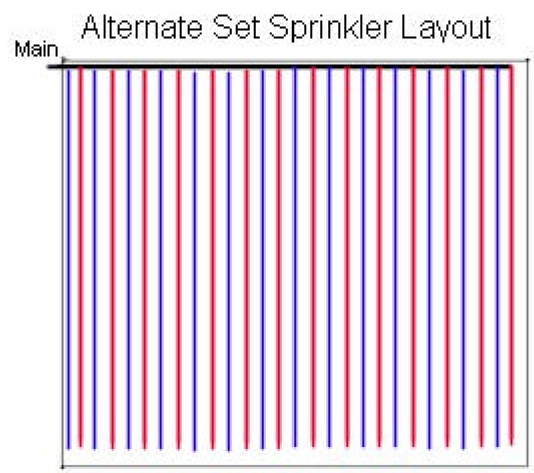


Refer to your irrigation system dealer for the recommended spacing and operating pressure for any combination of sprinkler head and nozzle size. Also, make sure the risers are installed in an upright position and that the heads are turning freely.

FIELD SPRINKLERS AND WIND

Wind effects are critical to field sprinkler distribution uniformity. It is always recommended that "Alternate-set" lateral placement be used. "Alternate-set" lateral placement is illustrated by the figure below. The lateral positions depicted in red are the positions for the first irrigation. The lateral positions for the next irrigation are colored blue. You can see that the same spacing is used for each irrigation. It's just that the laterals are offset by a half-spacing, placed in alternate locations for each irrigation.



Red, first irrigation. Blue, next.
Offset 1/2 lateral move.

This alternate placement of laterals can improve the distribution uniformity by up to 10 percent with no increase in labor costs. Alternate sets are a good idea anytime, but especially important in areas with consistently windy conditions.

Other things you can do to decrease wind effects are . . .

- Irrigate in low wind situations--this seems obvious but if your operations can be modified and you are using electric motors, there might be a double bonus. In many cases, wind picks up in the afternoons. Afternoons are peak use periods for electrical utilities. Modifying your operations to avoid peak wind periods (and peak power use periods) will improve you DU's and possibly allow you to take advantage of "Time-of-Use" power rate schedules.

- Use low-angle sprinklers with closer lateral spacings. This involves a tradeoff between the increase in distribution uniformity and the increased cost of hardware and labor (possibly more laterals in the field, certainly more moves).Another aspect to consider is that application rates increase with tighter spacings (see table this page). If excess runoff occurs with the tighter spacings, try a smaller nozzle size.
- A recent study on field sprinkler performance sponsored by the District also showed that it is best to maintain normal operating pressures. Although it may look like more drift, normal pressures resulted in higher overall uniformities than lower pressures.
- Many times, impact sprinklers are used in under-tree or over-vine systems. In these situations, overlap uniformity may not be as important as in field systems. Trees and vines have extensive rooting systems. Where there is no overlap at all (as in spinner-type undertree systems), it is like a drip system and distribution uniformity is a matter of supplying the same amount of water per each tree. Regardless of the overlap uniformity, always maintain good pressure and device uniformities.

CONTROLLING TOTAL APPLICATIONS WITH FIELD SPRINKLER SYSTEMS

Each sprinkler system applies water at a specific rate that is measured in inches of water applied per hour of opera-tion, or "inches/hour". This "application rate" depends on sprinkler spacing, nozzle size, and system pressure. For example, normal application rates for sprinkler systems with standard 7/64 inch nozzles on 30 x 40 spacings are .20 inches/-hour.

Approximate application rates in inches/hour for sprinkler systems running at 50 psi :

SPRINKLER			NOZZLE			SIZES
SPACING	3/32	7/64	1/8	9/64	5/32	11/64
30 x 30	.19	.27	.34	.44	.54	.65
30 x 40	.14	.20	.26	.33	.41	.49
30 x 45	.13	.18	.23	.29	.36	.43
35 x 40	.12	.17	.22	.28	.35	.42
35 x 45	.11	.15	.20	.25	.31	.37
40 x 40	.11	.15	.19	.25	.31	.37
40 x 45	.10	.13	.17	.22	.27	.32

Knowing the soil moisture deficit (SMD) and the application rate (AR) of the sprinkler system, you can determine the required set time. The soil moisture deficit is the amount of water that is needed to take the soil moisture in the effective root zone from its level at irrigation to field capacity. For additional information refer to the "Soil-Water-Plant Relationships" section of this handbook.

For example, assume you want to apply 2.5 inches using a system with an application rate of .25 inches/hour . . .

RUNTIMEnet = SMD / (APPLICATION RATE)

RUNTIMEnet = 2.5 inches / .25 inches/hour

RUNTIMEnet = 10 hours

However, there are losses from evaporation and also distribution uniformity to consider. The overall irrigation efficiency (IE) may only be 80 percent. Thus, to make sure that 2.5 inches was soaked into all parts of the field you would have to increase the runtime. And . . .

RUNTIMEgross = SMD / (AR * IE)

RUNTIMEgross = 2.5 inches / (.25 in/hr * .8)

RUNTIMEgross = 12.5 hr

Operating in windy conditions can lower DU's drastically. It could easily taking the overall irrigation efficiency to 65 percent. (Remember to use "alternate sets" in windy conditions.)

Now . . .

RUNTIMEgross = 2.5 in / (.25 in/hr * .65)

RUNTIMEgross = 15.4 hr

You may or may not be able to operate a set to that tight of schedule but the calculations will at least tell you what should be done. They might also indicate where a change in operations is needed. For example, the correct set time has been determined to be around 15 1/2 hours. You may not want to take a chance on a 12 hour set but a 24 hour set is too long. Possibly the irrigation scheduling can be shortened up so that irrigations occur more frequently, but with 12 hour sets.

SPRINKLER SYSTEM EVALUATIONS AND RECOMMENDATIONS

The District's Water Conservation Program is constantly looking for better ways to improve irrigation system performance. See this link for those wishing a simplified sprinkler evaluation to evaluate their own systems, developed for Westlands. Check with the District to see if a Mobile Lab program is currently available to district water users. Consultants are also available to do this for you.

Below are explanations of typical recommendations that might improve the performance of sprinkler irrigation systems. Where possible, they are related to the improvement of distribution uniformity and irrigation efficiency.

For General Recommendations . . .

- 1. Replace gaskets on the lateral/main pipes - Pipe leakage in fields can be significant and easy to fix. Leakage reduces the irrigation efficiency. It can also lead to poor pressure uniformity in the field.
- 2. The gross application is much greater than the net required - As previously seen, each system configuration applies water at a specific application rate. This application rate should be compared to the soil moisture depletion at irrigation to determine the set time. Refer to the previous example on preplanning an irrigation. Excessive set times result in excessive deep percolation and/or surface runoff.
- 3. Instruct irrigators how to probe for depth of water penetration - This is another method of determining correct set length. Remember that the top of the root zone will nearly saturate during an irrigation, with the excess redistributing downwards after an irrigation set. Change sets before the wetting front reaches the full depth of the effective root zone.

- 4. The flow rate through a valve opener is too high resulting in excess head loss -This may or may not lead to poor field pressure uniformity. It is certainly costing you money as the head loss is energy that you paid for (through pump and power costs) and did not use.
- 5. Need for more laterals- This considers the "effectiveness" of an irrigation. One side of the field appears to be drying because not enough water is being pumped to the field. An equation to use in determining if the system is large enough is . . .

  Q = 452.5 *ETc *AREA /IE *HROP

  where:
  Q = required system flow in gallons per minute

  ETc = daily crop water use in inches/day

  AREA = area of field in acres

  IE = overall irrigation efficiency as a decimal from 0 to 1.0 (normally in .65 to .8 range)

  HROP = daily hours of operation of the system, from 1 to 24

  452.5 = conversion constant

- 6. There is runoff from the field - This is an efficiency problem, although it may not be as serious if the runoff is being picked up and utilized in a tailwater reuse system. It always represents an excess cost to you as it takes energy to run a system and if the water does not go into the ground, you did not get the full use of your energy dollar. Check the application rate of the system versus the infiltration rate of the soil. Reduce application rates by going to smaller nozzles, lower pressures, or wider spacings. Balance the change against the effects on distribution uniformity.

Explanations for those recommendations concerning Flow Rate Uniformity (these comments address pressure and device uniformity at the same time) are . . .

- 1. Two or more different nozzle sizes in the field - Different nozzle sizes at the same pressure will produce different flows. Do not put larger nozzles in areas of perceived lower pressures. The combination of the large nozzle/low pressure will decrease catch-can uniformity.
- 2. Sand wear in the nozzles - This reduces flow uniformity because the nozzles may not wear at the same rate. But this also affects catch-can uniformity as the droplet size distribution may change. If sand wear is a constant problem check with a qualified agricultural engineer as to the use of a sand separator.
- 3. Poor pressure uniformity - Poor pressure uniformity can be fixed in a number of ways. It may take larger pipe sizes, a different mainline position, or a different pump. In situations with very uneven terrain you may want to investigate using flow-control nozzles. It is always best to consult a qualified agricultural engineer to check your system designs. This only has to be done once.
- 4. Plugged nozzles - This is an obvious problem. Use efficient trash screens where necessary.

Explanations for those recommendations concerning Catch Can Uniformity are . . .

- 1. Change the lateral move distance - Closer spacings will usually result in better catch-can uniformity. Realize that whenever you change the spacing (all other things kept equal) you will change the application rate. Recalculate set times whenever necessary.
- 2. Change the riser height - It is an obvious problem if the crop is high enough to get in the way of the sprinkler spray.
- 3. Use alternate sets - This has been previously discussed. It is always a good idea to use alternate sets but very important in areas with high winds.
- 4. Use a triangular spacing - In some situations a triangular spacing may result in higher uniformity.
- 5. Try to place laterals perpendicular to the wind - This is not as important as previously thought but still a good idea.
- 6. Operate in low wind conditions - If possible, avoid each day's windy period. But remember the equation . . .

  Q = 452.5 * ETc * AREA / IE * HROP

  Operating in less wind will increase IE (because of the higher distribution uniformity) but will also decrease HROP (the daily hours of operation). You may have to increase the system application rate or use more laterals and a larger pump to compensate for the decreased daily hours.
- 7. - 8. Incorrect operating pressures - Check with a qualified agricultural engineer and your system supplier for the recommended operating pressure for each combination of sprinkler head and nozzle. Check for causes of excessive head losses in the system.

See the following link for information on selecting an irrigation method (http://www.wcc.nrcs.usda.gov/nrcsirrig/irrig-handbooks-part652-chapter5.html) from the NRCS National Engineering Handbook, Part 652.