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Sprinkler Pattern Analysis for Center Pivot Irrigation

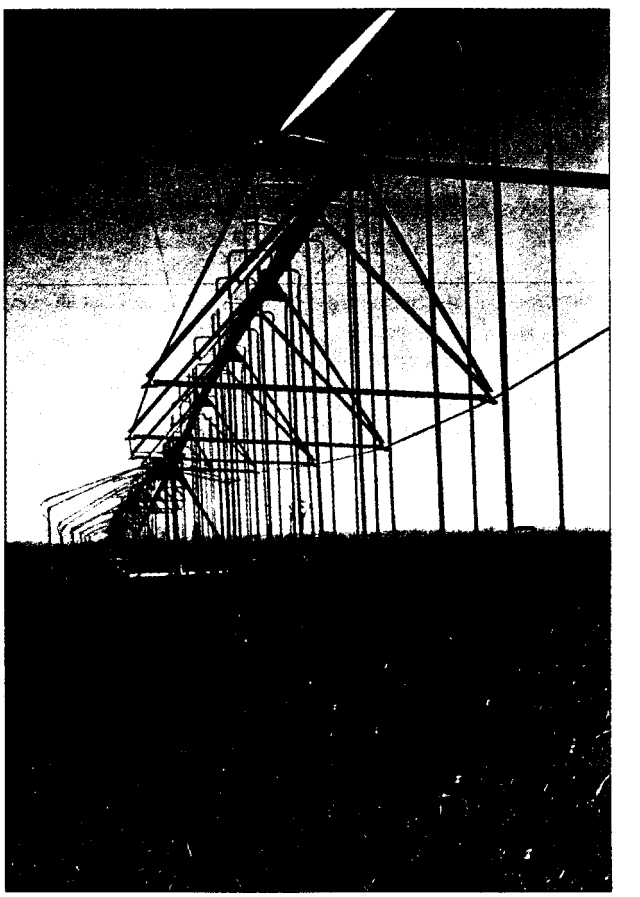
By Dennis C. Kincaid

Users of center pivot and lateral-move irrigation systems now have a wide array of sprinkler packages from which to choose, including the traditional overhead impact sprinklers, various types of spray heads and the LEPA-type furrow emitters. The original spray heads used simple, smooth or serrated fixed deflection plates. Recently, rotating plate or wobble-plate spray heads have been developed, combining the advantages of spray heads and rotating sprinklers — medium-size pattern radius, good pattern shape and medium-size droplets at medium to low pressures (10 to 30 psi).

An automated sprinkler test grid was developed at the Northwest Soils and Research Laboratory in Kimberly, ID, to measure sprinkler patterns in wind. The site was developed primarily for stationary sprinkler systems, but spray devices used on traveling laterals also can be tested. The test hardware consists of a 16 x 16 square grid of tipping bucket rain gages. The gages are wired to a portable computer that controls the tests and collects the data. Hourly tests are run continuously. Wind speed and direction are monitored continuously and averaged for each test period. Tests are run for a range of nozzle sizes, pressures and elevations for a given type of spray device and plate combination, for a range of wind-speed conditions. The grid was spaced for the test referred here at one meter.

The individual spray patterns are overlapped by computer on a specified sprinkler spacing to simulate different wind directions relative to the lateral. The lateral application rate patterns are plotted on a one-meter grid. Various parameters are calculated, including the average and peak application rates, application depths along the lateral, application uniformity coefficient for a representative section and flow rate per unit length of lateral.

The average application depth is inversely proportional to the travel speed of the lateral and proportional to the unit flow rate. To realistically simulate a section of a pivot lateral, the unit flow rate should approximate that found on a pivot at a particular location.



Spray head spacing, height and operating pressure all affect application uniformity, particularly under windy conditions or on rolling terrain.

Uniformity of Application

The trend in recent years has been toward low-pressure spray heads mounted at relatively low elevations less than 2 meters to reduce wind drift. The lower elevation spray reduces wind effects but can cause problems with spray-pattern shape. The shape of the spray pattern is affected by several factors: the design of the deflection or diffusion plate; nozzle size; nozzle pressure; nozzle or spray elevation; and wind effects. Application patterns from low-pressure spray heads tend to be annular, or doughnut-shaped, and this tendency is accentuated as pressure or nozzle elevation is reduced.

Table 1 gives the approximate spacing at which the uniformity coefficient (CU) values dropped below 0.95 for a nozzle elevation of approximately 2 meters. Actual field uniformities will be slightly lower for several reasons. Moderate wind speeds of about 2 meters per second or less did not appear to reduce the CU value significantly. Nozzle pressure had a significant effect on the pattern. Higher pressure produces a smoother pattern, allowing larger spacings. Also, at 70 kPa (10 psi) most types of spray heads produce a pronounced doughnut pattern with spikes or high instantaneous application rates that can cause spot ponding. This tendency is greatly reduced at 103 kPa (15 psi) nozzle pressure.

The fixed-plate sprays require closer spacing because of the similar pattern radius. The spinners produce results similar to the rotators. The wobblers tend to produce smoother patterns, due to their higher spray trajectory angle (10 to 25 degrees). The rotators could be mounted slightly higher to compensate for the lower trajectory angle (12 degrees).

Table 1
Recommended maximum nozzle spacings m (ft) for low-elevation spray heads.

Type of Spray Head	Pressure, kPa (psi)			
	70 (10)	104 (15)	140 (20)	210 (30)
Fixed plate sprays	1.8 (6)	2.4 (8)	2.4 (8)	3 (10)
Rotator 6 groove	2.4 (8)	3 (10)	3.7 (12)	4.3 (14)
Rotator 4 groove	2.4 (8)	3 (10)	3.7 (12)	4.3 (14)
Wobbler Low Angle	3.7 (12)	4.3 (14)	4.3 (14)	4.9 (16)
Wobber High Angle	4.3 (14)	4.9 (16)	4.9 (16)	5.5 (18)

Drag socks apply water directly on or very near the soil surface to minimize evaporation.

Factors Affecting Overall Water Distribution

Two types of nonuniformity can occur with traveling laterals: 1.) random effects, such as wind-speed variation and travel-speed variation; 2.) cumulative effects due to topography, insufficient overlap of the sprinkler patterns, improper nozzle sizes and/or malfunctioning sprinklers.

Random effects are not usually a serious problem, because they tend to average out over several passes of the system. However, when applying chemicals in a single pass, random effects can cause serious nonuniformity in the chemical distribution after a single pass of the system. Sprinkler problems show up as dry rings around the pivot or wet areas with excessive ponding or runoff. Topographic effects appear gradually in specific areas of the field , particularly if runoff occurs. Field topography can affect uniformity in two ways: pressure variation due to elevation differences, and differences in uphill and downhill travel speed of the outer controlling tower due to resistance or wheel slippage.

Pressure variations can be greatly reduced by using pressure regulators on individual spray heads. In general, pressure regulators should be used if the maximum elevation difference (in feet) across the field is greater than about half of the nozzle pressure (in psi).

At present there is no reasonably good way to correct for the effects of wheel slippage. However, this should not be a problem with good management to minimize wheel-track depth. Variation in travel speed of the lateral due to the stop/start motion of the electric drive mechanisms and lateral alignment controls causes random variability similar to that due to wind. A wider spray pattern will help to reduce these effects.

The traditional high-pressure, high-elevation sprinkler packages can produce very high uniformity but can have problems in high-wind conditions. Wind blowing toward the pivot will increase the application depth along the lateral, while leaving a dry outer edge; wind blowing outward from the pivot will reduce the application with a resulting drift loss from the outer edge. Wind blowing perpendicular to the lateral can cause skips or dry strips when the wind speed changes suddenly.

General Recommendations

Recommendations follow for maintaining high uniformities with low-pressure center pivots, while minimizing peak application rates.

- Observe maximum space limits shown in the table.
- Maintain at least one meter (3 feet) of crop clearance (0.3m with high-trajectory angle).
- Use nozzle pressures between 100 and 300 kPa (15-30 psi).
- Use nozzle offsets with low-elevation sprays.
- Regularly check for worn nozzles or malfunctioning pressure regulators.
- Use a pressure gage with a pitot tube to check nozzle pressure at the high and low points of the field.
- Set pivot rotation speed not equal to 24-hour multiples, to help average out evaporation and wind effects.

Dennis Kincaid is an agricultural engineer with the USDA-Agricultural Research Service Northwest Irrigation and Soils Research Laboratory in Kimberly, ID.