Optimal Performance from Center Pivot Sprinkler Systems

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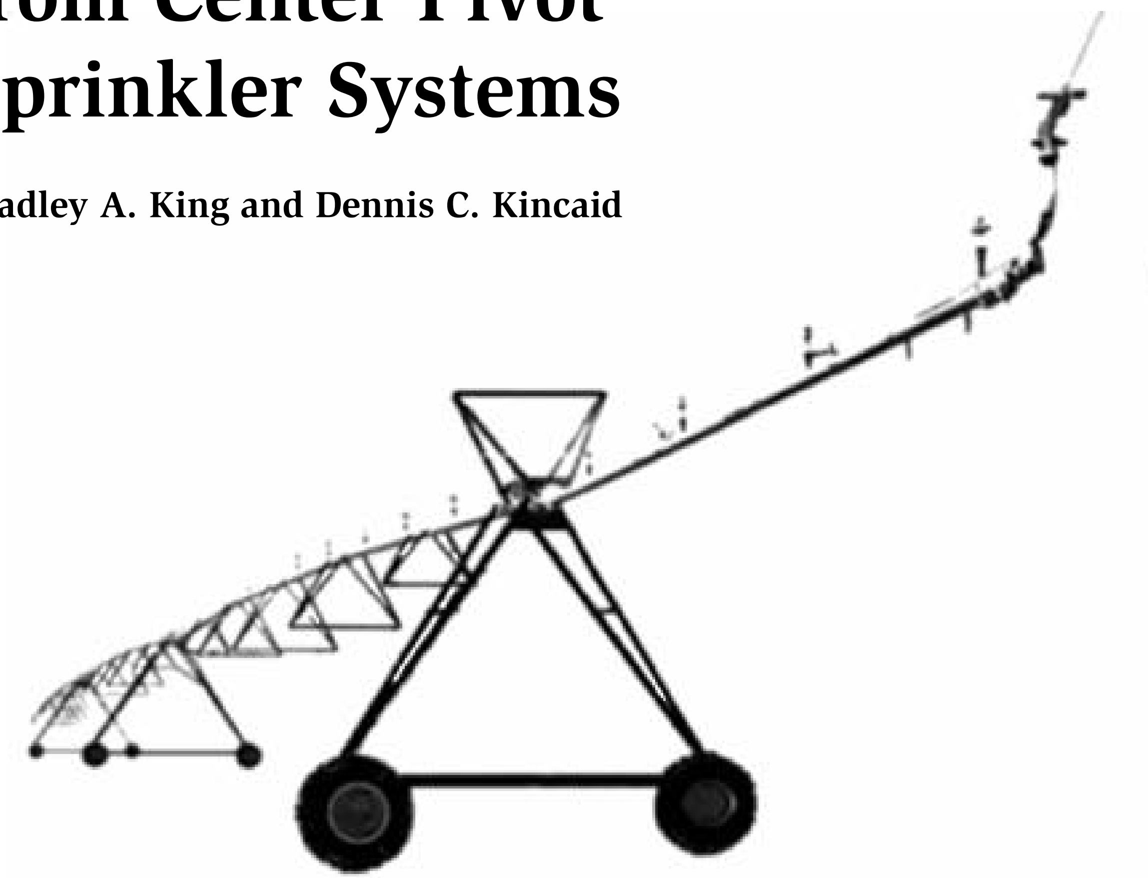

A good supply of groundwater and the commercial development of center pivot irrigation systems significantly increased sprinkler-irrigated acreage in southern Idaho during the late 1960s and early 1970s. Today, center pivot systems, with their automation, large areal coverage, reliability, high application uniformity, and ability to operate on relatively rough topography, are replacing surface, handline, and wheelline systems.

The irrigated area under a center pivot system expands substantially with increasing system length. To accommodate the increased area, the application rate increases linearly along the center pivot lateral through one of two methods: increased flow rates through equally spaced sprinklers or gradually decreased spacing of equal-flow sprinklers along the center pivot lateral. The most common approach is to have equally spaced sprinklers with increasing flow rates (nozzle sizes) along the center pivot lateral.

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High-Pressure Sprinklers

In the 1960s, center pivot irrigation systems had standard high-pressure (greater than 50 pounds per square inch) impact sprinklers. These sprinkler packages provided good application uniformity when the system nozzles were properly sized and pressure variation along the lateral was within recommended limits. However, losses from wind drift and evaporation under the dry, windy conditions often encountered in arid and semi-arid environments were excessive. The sprinkler irrigation industry addressed this problem by developing low angle and low pressure (25 to 40 pounds per square inch) impact sprinklers. These effectively reduced wind drift and evaporation losses, but flow rate variation caused by undulating topography continued to be a significant problem. In the mid 1970s, flow control sprinkler nozzles and fixed-pressure regulators were developed. They reduce the flow rate variation due to topography to within tolerable limits. As a result, reduced-pressure impact sprinklers could be used on center pivots.

Low-Pressure Spray Sprinklers

In the mid 1970s, escalating energy costs made the high energy requirement of impact sprinklers a major concern among producers. The sprinkler irrigation industry responded by developing low-pressure spray sprinklers (less than 30 pounds per square inch) for center pivots. These have a fixed-head and a part or full-circle application pattern. A deflection plate creates spray by deflecting the water jet exiting the nozzle. The deflection plate can be smooth or grooved with a concave, convex, or flat shape. Water leaves the smooth plates as a mist-like spray and leaves grooved plates as tiny streamlets. The sprinklers are either mounted upright on the top of the lateral or mounted upsidedown on drop tubes or booms that extend below the lateral. On undulating topography, pressure regulators are required to minimize flow rate variations and are commonly used to minimize the influence of pressure loss along the lateral.

Spray sprinklers have a smaller wetted area than impact sprinklers and require closer sprinkler spacing. The smaller wetted area greatly increases application rates along the center pivot system. This can intensify runoff problems, particularly on loam and silt-loam soils. Various types of sprinkler booms have been developed to reduce application rates by increasing the wetted area under the center pivot lateral. Today, the most popular type is an offset boom with a horizontal length of 10 to 20 feet perpendicular to the center pivot lateral. These offset booms are commonly used on the outer one-half to one-third of a center pivot lateral.

Recently developed moving-plate spray sprinklers also decrease application rates by increasing wetted area. These sprinklers, such as Rotators, Spinners, and Wobblers, reduce the number of water streamlets which increasing drop size and water throw distance. At the same time, they maintain good application uniformity. Moving-plate spray sprinklers combined with offset booms along the outer spans of the center pivot provide efficient irrigation.

LEPA Systems

In the early 1980s, a low pressure application package for center pivot systems known as LEPA (Low Energy Precision Application) was developed for the southern plains states. A LEPA package has very-low-pressure (6 to 10 pounds per square inch) bubblers or furrow drag socks suspended on drop tubes at a height of 1 to 3 feet above the soil surface. Crop rows are planted to follow the circular path of the center pivot system, and alternate furrows are wetted. LEPA systems have characteristically high application rates that usually exceed the water infiltration rate. Basin tillage is required to provide soil-surface storage until the water infiltrates. Some LEPA applicators can be converted to spray heads having wetted areas on the order of 10 to 25 feet in diameter. These have good sprinkler pattern overlap and apply water uniformly. When used in the crop canopy, the heads are usually spaced to match alternate crop rows.

Irrigation application efficiencies of 90 to 95 percent have been measured using LEPA sprinkler packages. This efficiency is the result of reduced evaporation. By locating the applicators within the crop canopy and near the soil surface, the amount of wetted soil and wetted plant surface area is minimized. Wind drift and spray evaporation are also eliminated. However, their high application rates and their limited clearance of the applicators make the LEPA packages unsuitable for slopes. They can not be transferred directly to the agricultural production systems of Idaho where undulating topography is common. One study in idaho on a silt loam soil with 1 percent slope that compared a LEPA sprinkler package against low-pressure sprinklers mounted on offset booms found no significant difference in crop yield. The increase in application efficiency of the LEPA system was offset by increased runoff (Kincaid, 1994.)

Application Rate

The main disadvantage of center pivot irrigation systems is the high water application rates under their outer spans. Since sprinkler flow rate increases linearly along the system lateral, application rates at the outer end also increase with the length of the system. Application rates under the outer spans of the standard quarter-mile-long low-pressure center pivot normally exceed infiltration rate and result in runoff. Runoff, the lateral redistribution of applied water, causes areas of excessive and deficient soil water content in the field, reducing crop yield and quality in these regions. The potential for localized chemical leaching from the crop root zone also increases in places where runoff collects. Soil-surface water storage in small, natural depressions decreases the actual volume of runoff. Surface storage can be enhanced by tillage practices, such as basin or reservoir tillage.

Infiltration rate, which determines the potential for runoff, is dynamic. Infiltration rate decreases during irrigation (figure 1). The initial soil water content also affects the infiltration rate; an increase in the initial soil water content decreases the infiltration rate. In addition, infiltration rates normally decrease over the season due to soil-surface sealing from sprinkler droplet impact. As a result, in row crops such as potatoes, runoff may increase throughout the season. Decreasing infiltration rates combined with high water application rates make runoff a near certainty for standard quarter-mile-long center pivots on all but sandy soils. Optimal center pivot system performance requires the use of both proper sprinkler packages to minimize water application rates and basin or reservoir tillage to minimize runoff.

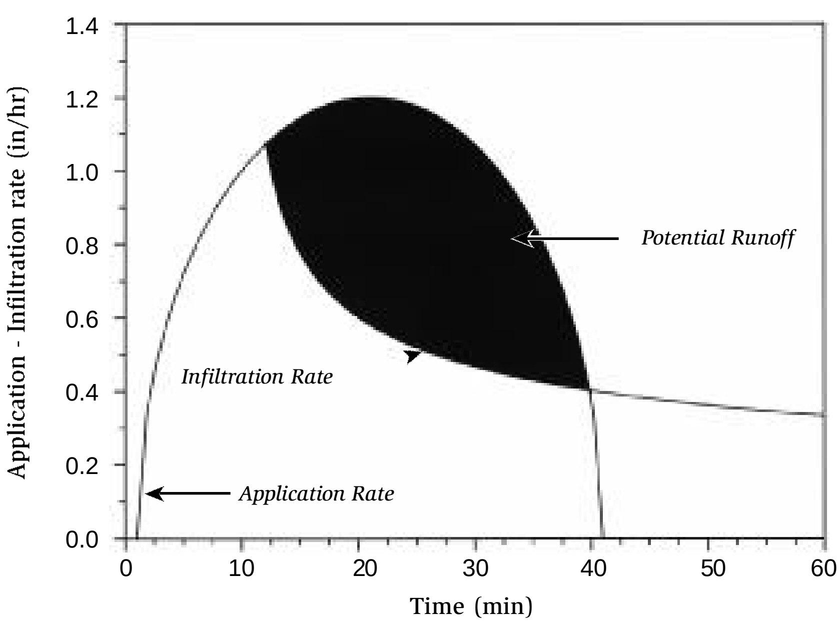


Figure 1.
Graphical representation of how water application rates under a center pivot exceed infiltration rate. Potential runoff is represented by the shaded area.

Typical relative water application rate patterns for various center pivot sprinkler packages are shown in figure 2. High-pressure impact sprinklers have the lowest application rates followed by low-pressure impact sprinklers. Low-pressure spray sprinkler packages, listed from lowest application rate to highest, are offset booms with rotators, offset booms with sprays, drop tubes with rotators, drop tubes with sprays, and in-canopy sprays.

The peak application rate along the outer spans of a standard quarter-mile-long center pivot system for all the sprinkler packages exceeds the infiltration rate of most soils. Booms are an effective means for increasing sprinkler wetted area while decreasing water application rate. Since application rates are lower nearer the center pivot point, booms are usually only used on the outer one-half to one-third of a quarter-mile-long center pivot system.

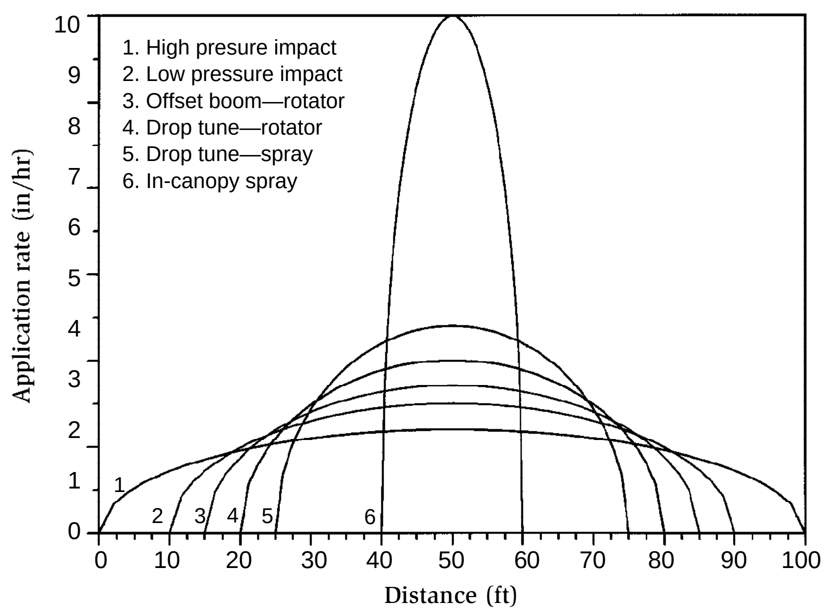


Figure 2.
Comparison of relative application rates under various center pivot sprinkler packages.

Low–Pressure Sprinkler Patterns

For a low-pressure center pivot sprinkler package, the shape of the application rate pattern is defined by pressure, nozzle size, plate configuration, sprinkler height, and wind speed. Sprinkler application rate pattern and spacing determine application uniformity.

Pressure and nozzle size

Pressure and nozzle size control the drop size distribution from a sprinkler and drop size influences the application rate pattern. Higher pressure creates smaller drops while bigger nozzles produce larger drops. Drop size also influences the trajectory of a given sprinkler droplet. When initial velocities are equal, large droplets will travel farther from the sprinkler than small droplets. Consequently, high pressure or small nozzle sizes, which tend to produce smaller droplets, increase application rates near the sprinkler while low pressure or large nozzle sizes, which tend to produce larger droplets, increase application rates farther from the sprinkler.

Obtaining suitable application rate patterns is dependent on following the manufacturer's nozzle size and pressure range recommendations. However, donut application rate patterns may be accentuated at the lowest recommended pressure, reducing application uniformity. At the highest pressure recommendation, droplet size is smaller and wind drift losses will increase. The best results are often found near the middle of the manufacturer's recommended pressure range.

Deflection plate configuration

Sprinkler deflection plate configuration has a large effect on the sprinkler application rate pattern. In general, smooth deflection plates produce small drop sizes, which are highly susceptible to wind drift losses, except at lower pressures (10 to 15 pounds per square inch). Serrated deflection plates have many small grooves and are used with fixed-plate sprinklers. Grooved deflection plates have four to six large grooves and are used on moving-plate sprinklers.

Moving-plate sprinklers are the most common type in Idaho. They maximize wetted sprinkler area while minimizing operating pressure. The application rate pattern depends on the number of grooves, trajectory angle, and speed of motion. The number of grooves in the plates affects the drop size distribution. Fewer grooves produce larger streamlets and larger drop sizes, which travel farther from the sprinkler and maximize wetted area. Within limits, greater trajectory angles produce more uniform application rate patterns. The primary disadvantage of higher trajectory angles is a greater susceptibility to wind drift. Lowering the sprinkler elevation will reduce wind drift.

The effect of plate configuration and motion on sprinkler application rate pattern is shown in figures 3 through 7.

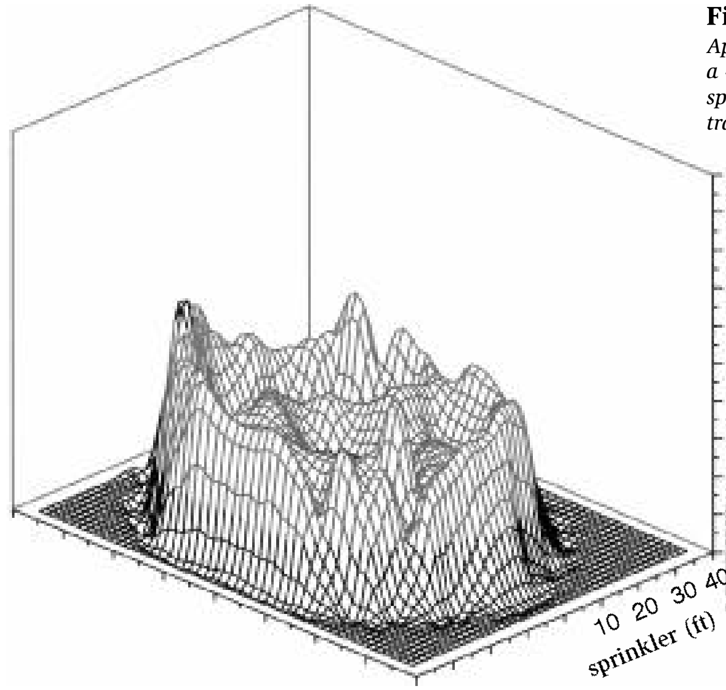


Figure 3.
Application rate pattern from a 4-groove rotating-plate spray sprinkler with an 8° trajectory angle.

A 4-groove plate with an 8 degree trajectory (figure 3) produces a concentrated application of water near the outer spans of the wetted pattern, creating a donut-shaped application rate pattern. The application rate pattern for the same sprinkler with a 6-groove plate and a 12 degree trajectory angle (figure 4) creates smaller droplet sizes and increases water application near the sprinkler. The smaller droplet sizes combined with the higher trajectory angle reduce the wetted area slightly. The donut-shaped application rate pattern remains but to a lesser degree because a larger percentage of the water is applied near the sprinkler.

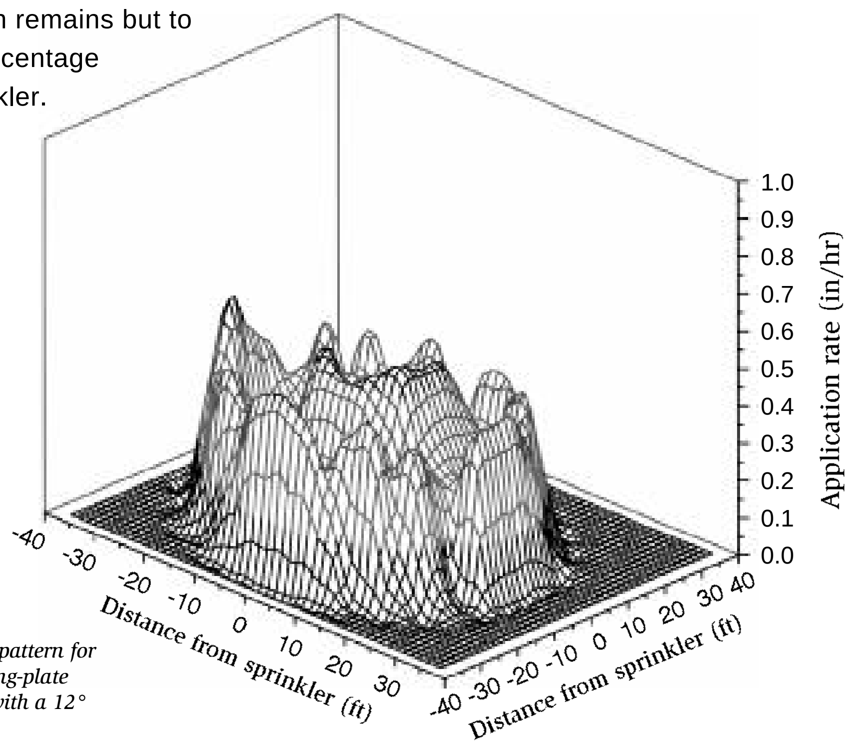
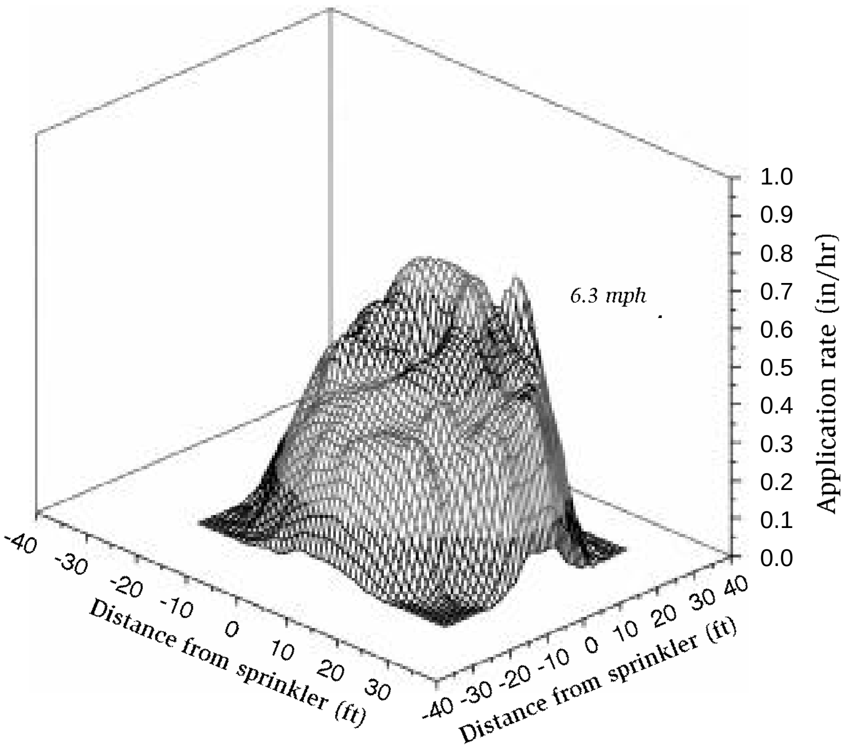
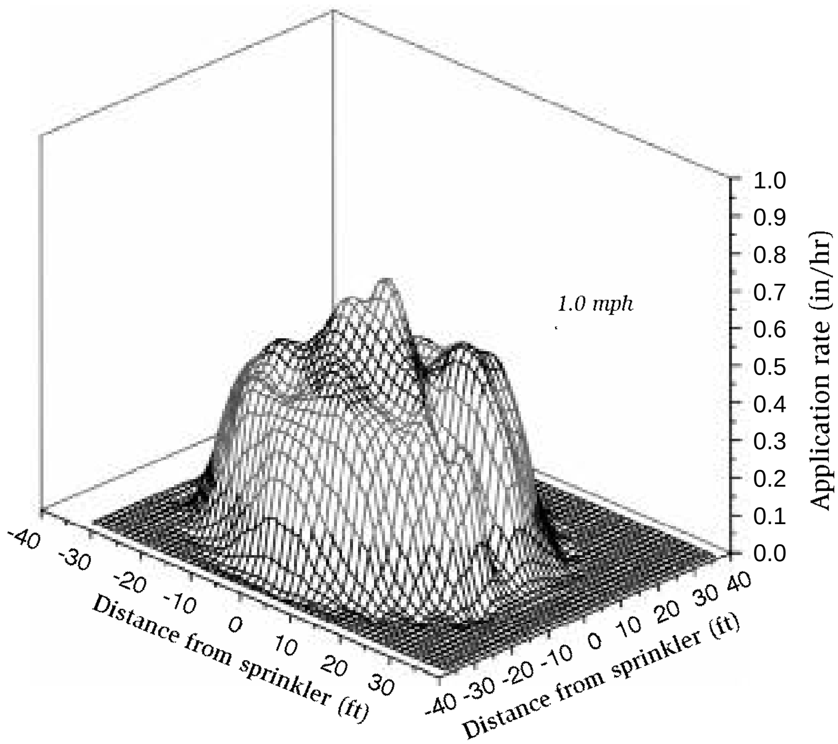


Figure 4.
Application rate pattern for a 6-groove rotating-plate spray sprinkler with a 12° trajectory angle.



The application rate pattern for a fast rotating-plate (spinner) with 6 grooves and 12 degree trajectory angle is shown in figure 5. The faster rotation of the plate provides a more uniform application rate pattern of elliptical shape with the highest application rate near the sprinkler. The application rate pattern for the same sprinkler with a 20 degree trajectory angle is shown in figure 6. The greater trajectory angle slightly increases the wetted area of the sprinkler, reducing the application rate near the sprinkler.

Figure 6.
Application rate pattern from a 6-groove spinning-plate spray sprinkler with a 20° trajectory angle.



The application rate pattern from a wobbling-plate type sprinkler having 9 grooves and a 15–degree trajectory angle is shown in figure 7. This application rate pattern resembles a truncated cone with an additional elliptical shaped peak near the sprinkler. The application rate pattern is very uniform except near the sprinkler.

For donut-shaped application rate patterns, such as those illustrated in figures 3 and 4, the cumulative application rate pattern produced by multiple sprinkler overlap is reasonably uniform. This, combined with the effect of averaging the cumulative application rate pattern as a center pivot passes over a point on the soil surface, provides excellent application uniformity. Application rate patterns that are more uniform in shape, such as those in figures 6 and 7, provide excellent application uniformity with less sprinkler overlap. However, the individual sprinkler wetted areas are usually smaller so the required sprinkler spacing is about the same as that of sprinklers with larger donut-shaped application rate patterns.

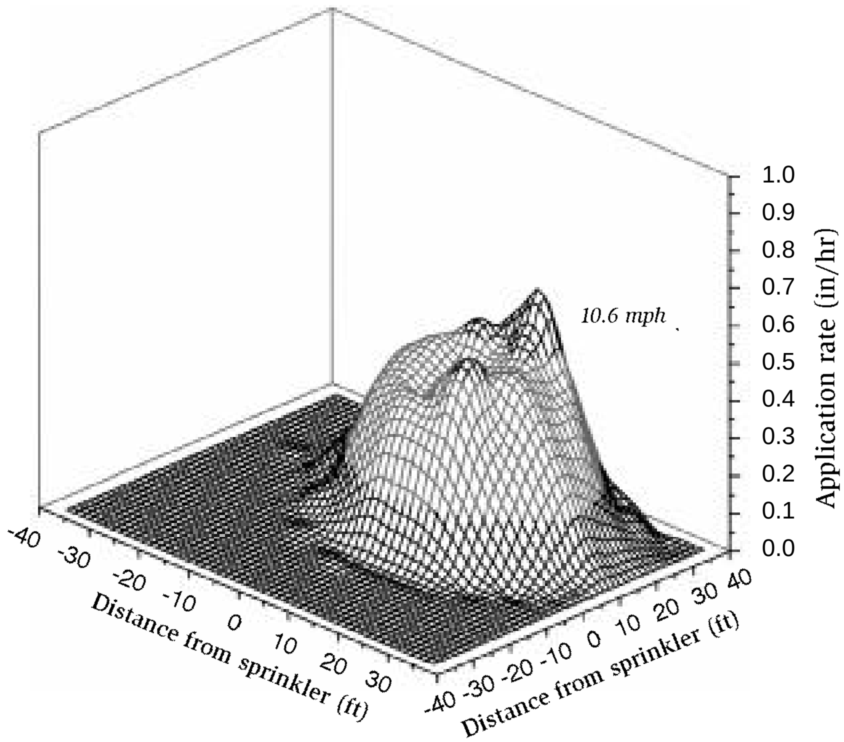
Sprinkler height

Sprinkler height influences the size of the sprinkler wetted area and wind drift losses. Increasing sprinkler height increases sprinkler wetted area slightly with no significant effect over the practical heights of 6 to 10 feet. Sprinkler heights greater than 6 feet on short crops (height less than 3 feet) do not significantly increase application uniformity. However, sprinkler heights less than 6 feet significantly decrease application uniformity, particularly for sprinklers having deflection plates with low trajectory angles. With taller crops, the optimal sprinkler height is the maximum canopy height.

Sprinkler heights greater than 6 feet significantly increase spray losses due to wind drift and evaporation. Spray losses average about 3 and 5 percent for sprinkler heights of 3 and 6 feet, respectively. Spray losses increase to 10 percent for sprinklers (spray and impacts) mounted on the top of the center pivot at heights of 12 to 15 feet. Spray losses can double as wind speed increases from 0 to 5 miles per hour to 5 to 10 miles per hour. For short crops, sprinkler heights near 6 feet provide good application uniformity while maintaining reasonable spray losses.

Wind speed

Wind distorts the application rate pattern from spray sprinklers and affects application uniformity. The effects of wind on the application rate patterns for a Spinner and a Wobbler type spray sprinkler are depicted in figures 8 and 9, respectively. Comparing these patterns with those of figures 6 and 7 for the same sprinklers under lower wind speeds reveals that the application rate patterns are largely shifted downwind. Distortion of the application rate pattern is most pronounced near the sprinkler where the smallest droplets occur. Computer simulation of composite wind-affected application rate patterns under a center pivot indicates that application uniformity is not significantly reduced for wind speeds up to 10 miles per hour. This favorable result is largely due to the multiple sprinkler overlap required to obtain good uniformity with low-pressure sprinklers and to limiting sprinkler height to about 6 feet.


10.6 mph
Application rate (in/hr)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-40 -30 -20 -10 0 10 20 30
Distance from sprinkler (ft)
-40 -30 -20 -10 0 10 20 30 40
Distance from sprinkler (ft)

Sprinkler Droplet Kinetic Energy

Many soils, particularly those containing significant silt fractions, are susceptible to soil-surface sealing from sprinkler droplet impact. The force of the droplets hitting the ground breaks down the surface soil structure, forming a thin compacted layer that greatly reduces infiltration rate. The application rate and the kinetic energy of sprinkler droplets at impact are the major factors affecting soil-surface seal formation. The infiltration rate reduction is a function of the particular soil and the energy flux density. Energy flux density combines the effects of sprinkler droplet kinetic energy and water application rate into a single parameter that is expressed as power per unit area (feet-pounds per minute per square foot or watts per square meter). It correlates very well with infiltration rate.

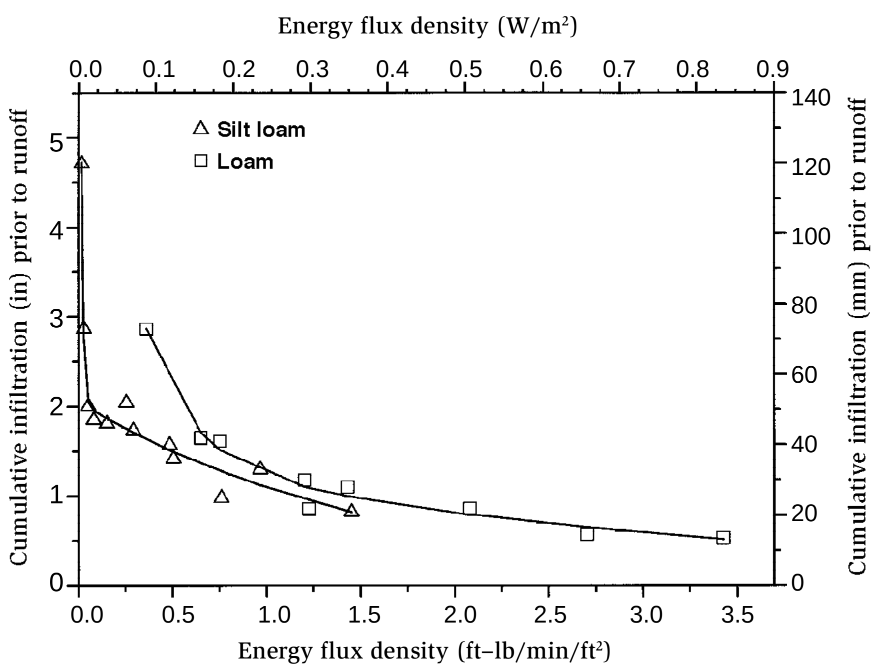


Figure 10.
Infiltration rate reduction by energy density flux of sprinkler droplets for two soils. Adapted from Thompson and James (1985) and Mohammed and Kohl (1987).

The relationship between energy flux density and depth of infiltration prior to runoff is illustrated in figure 10 for two different soils under dry, bare conditions. The silt loam soil is very susceptible to soil-surface sealing. The infiltration depth prior to ponding decreases very rapidly with a minimal increase in energy flux density. The loam soil is less susceptible to soil-surface sealing, but the depth of infiltration prior to runoff still decreases significantly as energy flux density increases.

The effect of sprinkler droplet impact on the infiltration rate of a particular soil must be measured to develop a quantitative relationship similar to that of figure 10. This is difficult because the results depend on soil surface conditions, soil structure, and soil water content. However, the general trend shown in figure 10 is applicable to any soil and useful in the selection of sprinklers for a center pivot irrigation system.

Studies of runoff under center pivot irrigation systems indicate that soil-surface sealing continues to develop with each additional irrigation. The only way to recover from soil-surface seal formation is to physically destroy it with a tillage operation. The best approach for limiting soil-surface seal formation is to protect the soil surface through residue management and to exclude water application from bare soil conditions.

When water applications must be made on bare soils, the energy flux density should be reduced to delay formation of the soil-surface seal. This can be accomplished by either using sprinklers with reduced droplet kinetic energy, reducing application rate, or both. Reducing the application rate is easiest and can be done by renozzling the center pivot system to reduce flow rate. The application rate under a center pivot is independent of system speed, so adjusting the system speed does not affect formation of a soil-surface seal.

The kinetic energy of a sprinkler droplet depends on droplet size (mass) and velocity at impact with the soil surface. Droplet velocity is also a function of drop size. Drop size distribution is determined by sprinkler nozzle size, pressure, and deflection plate configuration.

Figure 11 shows the kinetic energy per unit volume of water applied (foot-pounds per cubic foot or joules per kilogram) versus the dimensionless ratio (ft/ft, m/m) of nozzle size to pressure head for several types of sprinklers. Droplet kinetic energy is highest for sprinklers producing the largest drop sizes, such as standard impact sprinklers and rotator type sprinklers having deflection plates with few grooves. Droplet kinetic energy is the lowest for sprinklers producing small drop sizes such as those using fixed sprays with flat or serrated plates. There is little difference in droplet kinetic energy between the various spray sprinklers, except for the 4-groove rotating-plate sprinkler. Overall, droplet kinetic energy varies only by a factor of three across all sprinkler types.

Despite this limited range in droplet kinetic energy, a study of sugar beet emergence comparing sprinklers with 105 ft-lb/ft^3 and 315 ft-lb/ft^3 of drop- let kinetic energy found a 13 percent increase in sugar beet emergence under the sprinkler with two thirds less droplet kinetic energy (Lehrsch et al.)

Sprinkler selection does influence soil-surface seal formation. This not only affects infiltration rate, but has other agronomic implications such as soil erosion, water application efficiency, and nutrient distribution in the soil profile.

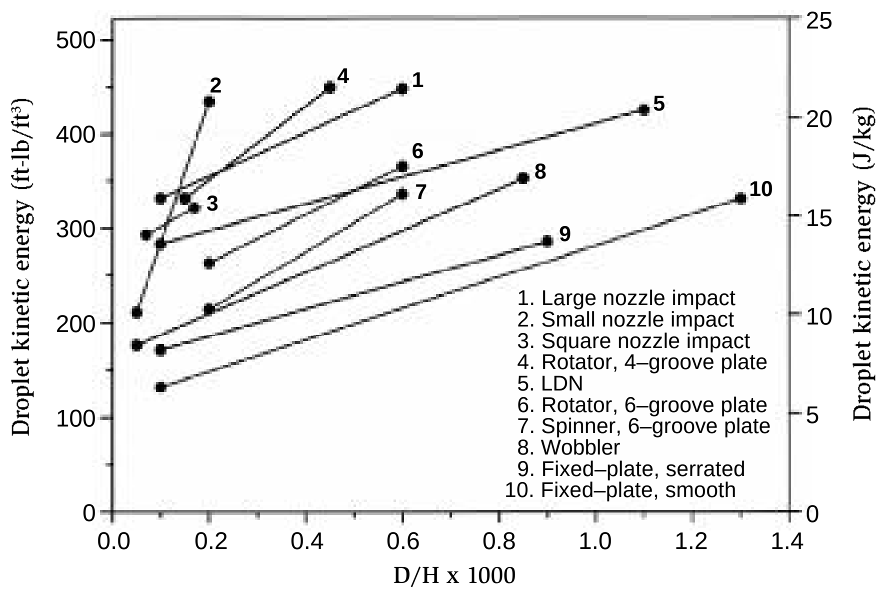


Figure 11.
Sprinkler droplet kinetic energy for various sprinkler types as a function of the dimensionless ratio of sprinkler nozzle diameter to sprinkler pressure head. Adapted from Kincaid (1996).

Optimal Sprinkler Package Selection and Installation

Sprinkler selection and installation have a significant effect on the performance of a center pivot irrigation system. Both application rate relative to infiltration rate and the susceptibility of the soil to surface sealing need to be considered in the system design. The application rate of low-pressure spray sprinklers can be reduced by using offset booms on alternate sides of the center pivot lateral. On soils with extremely low infiltration rates or with a high susceptibility to soil-surface sealing, offset booms on both sides of the center pivot lateral can be used at each sprinkler outlet to further reduce application rate. The effectiveness of offset booms for reducing application rate is shown in figures 12, 13, and 14.

The composite application rate for 6-groove rotating-plate sprinklers on drop tubes is shown in figure 12.

Figure 13 shows the composite application rate under the same sprinkler conditions with offset booms on alternate sides of the center pivot lateral. The average application rate is reduced about 30 percent by offset booms.

The composite application rate with two offset booms at each sprinkler location and each sprinkler nozzle providing one-half the flow rate is shown in figure 14. The application rate is reduced 5 percent compared to the single offset boom. The major advantage of the double offset boom is that it uses smaller nozzles, which reduces the kinetic energy of the droplets.

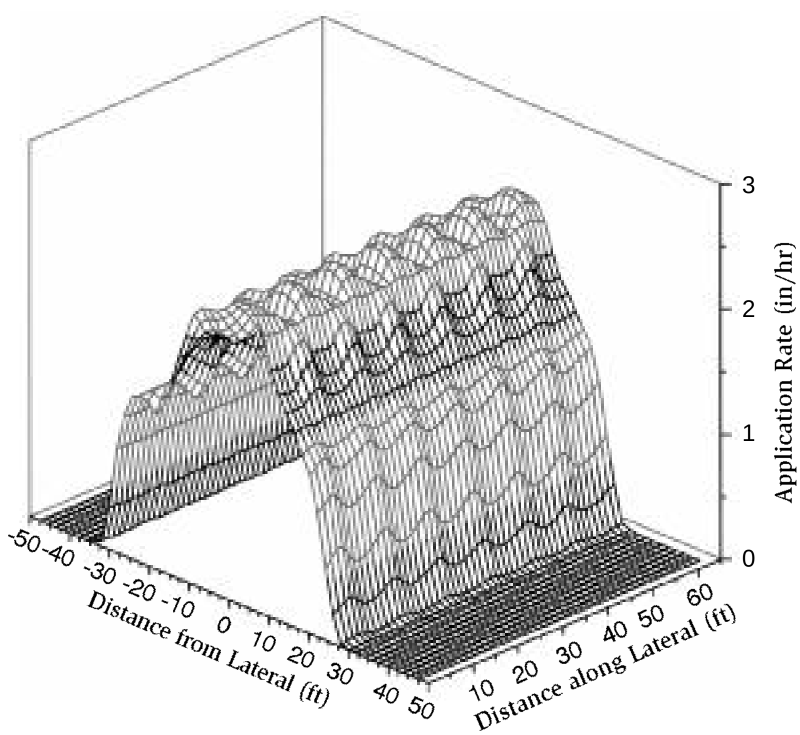


Figure 12.
Composite application rate pattern under a center pivot from 6-groove rotating-plate sprinklers on drop tubes with 10-foot sprinkler spacing and 10 gallons-per-minute flow rate.

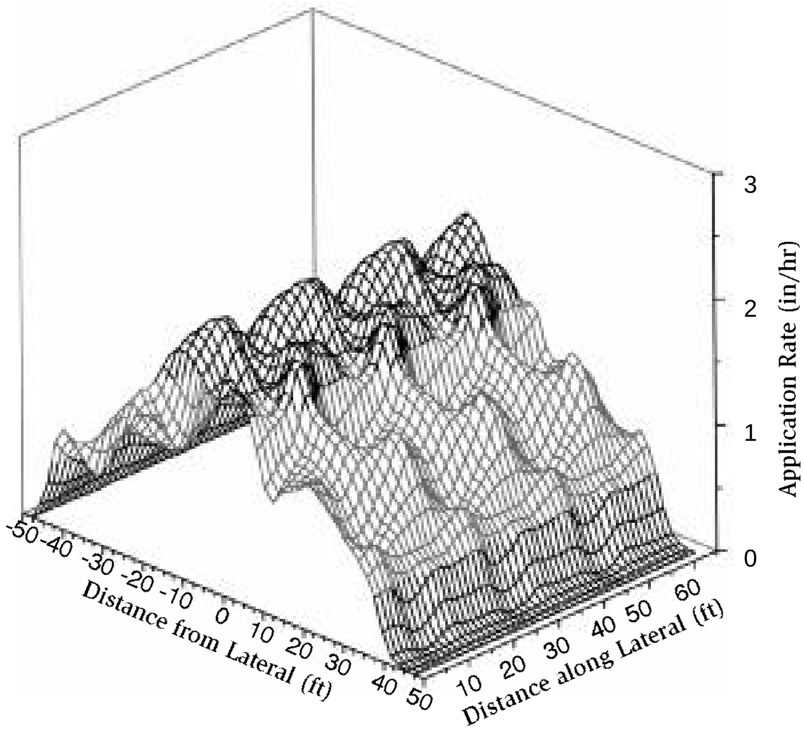


Figure 13.
Composite application rate pattern under a center pivot from rotating-plate sprinklers on offset booms having a 15-foot horizontal projection on alternate sides of the center pivot lateral with 10-foot sprinkler spacing and 10 gallons-per-minute flow rate.

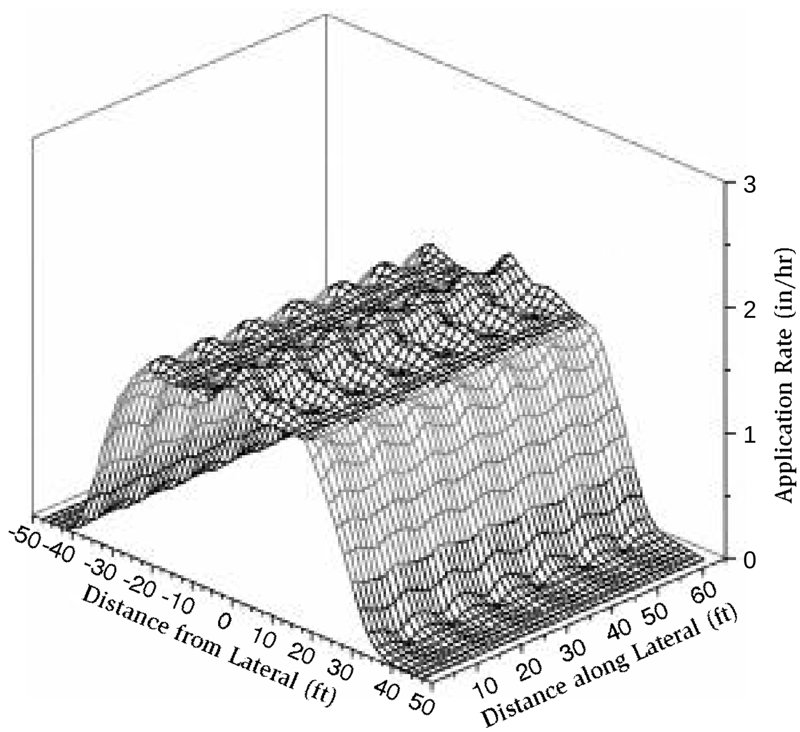


Figure 14.
Composite application rate pattern under a center pivot from rotating-type sprinklers on an offset boom having a 15-foot horizontal projection on both sides of the center pivot lateral with 10-foot sprinkler spacing and 10 gallon-per-hour flow rate.

The highest ten percent application rate is the rate for which ten percent of the wetted area exceeds this value. It provides a better measure for comparing peak application rates than the absolute highest rate.

Table 1.
Application rates and application rate reduction provided by offset booms of various lengths with a 10-foot sprinkler spacing and flow rate of 10 gallons per minute.

Sprinkler type	Offset distance (ft)	Application rate		Application rate reduction		Application uniformity (%)
		Average (in/hr)	High 10% (in/hr)	Average (%)	High 10% (%)	
Fixed-plate smooth	0	2.03	3.84	—	—	97
	10	1.45	3.31	71	86	97
	15	1.28	2.56	62	67	97
	20	1.11	2.52	55	66	97
Fixed-plate serrated	0	2.13	4.35	—	—	98
	10	1.52	3.51	71	81	98
	15	1.32	2.87	62	66	98
	20	1.15	2.75	54	63	98
Rotator 4-groove	0	1.44	2.37	—	—	98
	10	1.12	2.24	78	95	98
	15	1.00	2.21	70	93	99
	20	0.91	1.82	63	77	98
Rotator 6-groove	0	1.54	2.47	—	—	97
	10	1.17	2.27	76	92	97
	15	1.04	2.12	67	86	97
	20	0.94	1.65	61	67	97
Spinner 6-groove	0	1.58	2.76	—	—	97
	10	1.22	2.49	78	90	97
	15	1.09	1.97	69	72	97
	20	0.97	1.50	62	54	97
Wobbler low angle	0	1.42	2.41	—	—	100
	10	1.11	2.27	79	94	100
	15	1.00	1.94	70	80	100
	20	0.90	1.41	64	58	100

Table 1 lists the average and highest 10 percent application rates for various types of spray sprinklers on offset booms installed on alternate sides of a center pivot lateral. The same information for two offset booms is listed in table 2. The exact application rates will change with sprinkler flow rate, but the relative reductions will remain nearly the same. Offset booms are relatively inexpensive and very effective in reducing the application rate.

Since the application rate under low-pressure spray sprinklers can be minimized by using offset booms, sprinkler selection should be based on drop size distribution. Small drop sizes have the least droplet kinetic energy but are the most susceptible to wind drift losses. Large drop sizes have the highest droplet kinetic energy but are the least susceptible to wind drift losses. Sprinklers that provide a compromise between these two extremes are best. Most moving-plate sprinklers have medium drop sizes and maximum wetted area. Because they all have about the same droplet kinetic energy, the final selection of the brand rests on personal preference.

The significant differences in the application rate patterns of the various moving-plate sprinklers influence the spacing of the sprinkler heads (table 3). Fixed-plate spray sprinklers with their smaller wetted area require closer spacing than the moving plate spray sprinklers. Wobbler type sprinklers with their more uniform application rate pattern allow for larger spacing.

Table 2.
Application rates and reduction provided by double offset booms of various lengths with a 10-foot sprinkler spacing and flow rate of 5 gallons per minute.

Sprinkler type	Offset distance (ft)	Application rate Average (in/hr)	Application rate High 10% (in/hr)	Application rate Reduction Average (%)	Application rate Reduction High 10% (%)	Application uniformity (%)
Fixed-plate smooth	0	2.03	4.02	—	—	98
	10	1.42	2.76	70	69	98
	15	1.24	2.05	61	51	98
	20	1.09	2.01	54	50	98
Fixed-plate serrated	0	2.24	3.93	—	—	99
	10	1.52	3.23	68	82	99
	15	1.33	1.96	59	50	99
	20	1.15	1.96	51	50	99
Rotator 4-groove	0	1.63	3.04	—	—	99
	10	1.21	2.27	74	75	99
	15	1.06	2.30	65	76	99
	20	0.96	2.06	59	68	99
Rotator 6-groove	0	1.90	3.37	—	—	97
	10	1.35	2.65	71	79	97
	15	1.19	1.80	62	54	96
	20	1.05	1.69	55	50	97
Spinner 6-groove	0	2.02	3.42	—	—	96
	10	1.42	2.82	70	82	96
	15	1.25	1.77	62	52	96
	20	1.09	1.72	54	50	96
Wobbler low angle	0	1.55	2.58	—	—	98
	10	1.17	2.19	75	85	98
	15	1.02	1.80	66	70	98
	20	0.94	1.33	61	52	98

Pressure also has a significant effect on the required spacing. Higher pressure allows wider spacing because of the resulting smoother application rate pattern and slight increase in the wetted area. With most spray sprinklers, low pressure produces a donut-shaped application rate pattern. As a result, closer spacing is needed in order to maintain application uniformity. Due to the high flow rates required on the outer portion of center pivots, large spacings require large nozzle sizes, which may result in excessively large drops, particularly at low pressures.

Center pivot sprinkler outlets are normally spaced about 8 to 10 feet apart. This spacing is adequate for all but fixed-plate spray sprinklers and rotators at 10 pounds per square inch. Since every sprinkler outlet is normally used along the outer half of a standard quarter-mile-long center pivot, all the moving-plate type spray sprinklers provide good application uniformity. The difference between sprinklers occurs when spacing exceeds 10 feet, such as along the inner portion of the center pivot where alternate sprinkler outlets are commonly used and flow rates are small. There may be a slight increase in application uniformity with sprinklers that allow larger spacings. The actual application uniformity under field conditions will likely be less than 95 percent due to wind effects and actual sprinkler height. In general, all moving-plate type sprinklers provide good application uniformity with spacings normally encountered on center pivots.

Table 3.
Recommended maximum sprinkler spacings for low pressure spray sprinklers at a 6-foot height.

Sprinkler type	Pressure (psi) 10	15	20	30
Fixed-plate	6	8	8	10
Rotator 4-groove	8	10	12	14
Rotator 6-groove	8	10	12	14
Spinner 6-groove	8	10	12	14
Wobbler low angle	12	14	14	16
Wobble high angle	14	16	16	18

Table 4.
Advantages and disadvantages of spray sprinkler deflection plate features and sprinkler mounting.

Feature	Advantages	Disadvantages
Deflection plate configuration		
Fixed-plate, smooth	Minimum droplet kinetic energy	High application rate, high wind drift loss, close sprinkler spacing required for high application uniformity
Fixed-plate, serrated	Low droplet kinetic energy	High application rate, high wind drift loss, close sprinkler spacing required for high application uniformity
Moving-plate, 4-groove	Lowest average application rate, low wind drift loss, larger sprinkler spacing allowable	Highest droplet kinetic energy
Moving-plate, 6-groove & 9-groove	Low average application rate, low wind drift loss, larger sprinkler spacing allowable	Moderate droplet kinetic energy
Trajectory angle		
Less than 15 degrees	Reduced wind drift loss	Donut application rate pattern requiring closer sprinkler spacing to maintain high application uniformity
More than 15 degrees	More uniform application rate pattern allowing larger sprinkler spacing	Increased wind drift loss
Mounting configuration		
Overhead	Low cost, higher uniformity with larger sprinkler spacing	High wind drift loss
Drops	Reduced wind drift loss	Increased cost, slightly increased application rate, spacing more critical for high application uniformity
Offsets	Reduced application rate	High cost

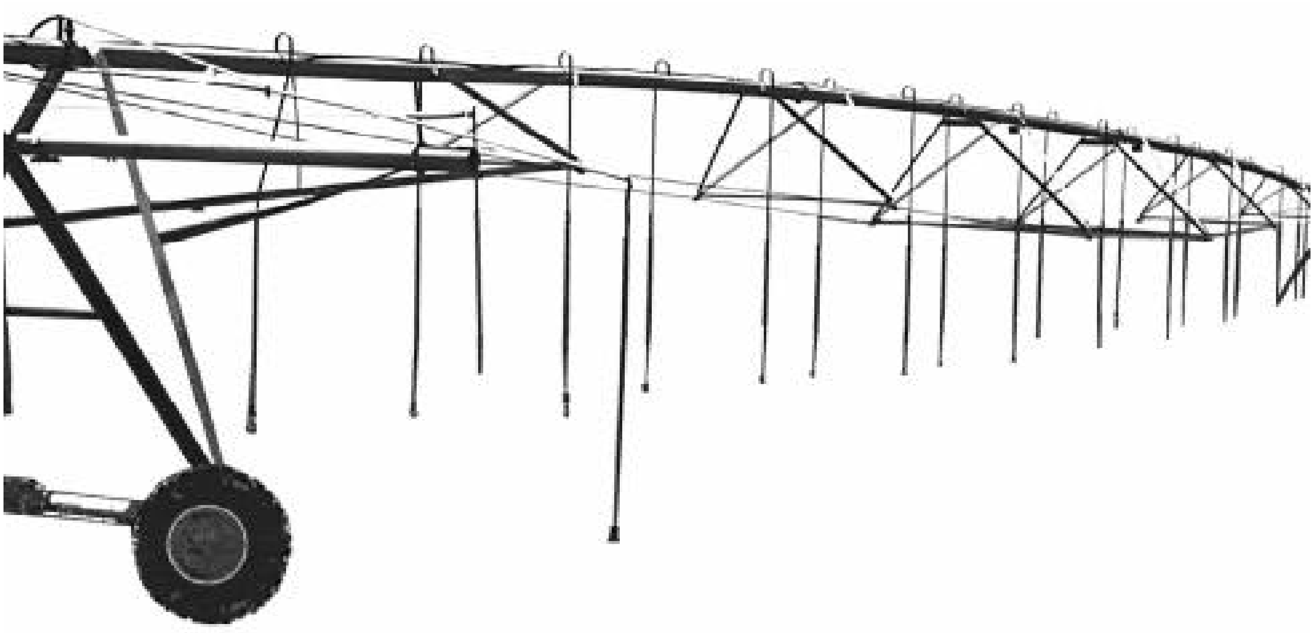
Summary

Center pivot sprinkler packages have changed significantly since they were first introduced. The original high-pressure impact sprinklers have been largely replaced by low-pressure spray sprinklers. The current moving-plate spray sprinklers, the result of years of development by the sprinkler industry, minimize operating pressure while increasing application uniformity. When properly selected and installed, these sprinklers provide an efficient center pivot irrigation system.

In general, there is very little difference in application uniformity and irrigation efficiency between the common low-pressure moving-plate spray sprinklers available today. The primary advantages and disadvantages of the various low-pressure spray sprinkler features are listed in table 4. Offset booms are usually required on the outer spans of a center pivot to reduce application rates to acceptable levels to minimize runoff potential, especially on silt loam soils.

Soils susceptible to soil-surface sealing can be protected by reducing application rates and droplet kinetic energy via the use of two offset booms at each sprinkler outlet, temporarily renozzling the sprinkler package to reduce the system flow rate, and managing residue through conservation tillage practices. Even with the use of offset booms, application rates from low pressure spray sprinklers exceed the infiltration rate of most soils. Basin or reservoir tillage can increase surface storage and significantly reduce actual runoff.

Low pressure spray sprinklers should be installed at a height of about 6 feet for low growing crops. This height maintains good application uniformity, limits wind drift, and reduces droplet evaporation losses to acceptable levels. LEPA packages should only be used on near level topography. The increase in application efficiency of LEPA systems from reduced evaporative and wind drift losses is easily overcome by increased runoff on silt loam soils. The increased cost of LEPA sprinkler packages relative to low pressure sprinkler packages and the additional effort needed to plant crop rows to follow the circular travel of the center pivot system are not justified by the marginal increase in application efficiency.



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