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SPRINKLER PACKAGES AND THEIR CONFIGURATIONS FOR CENTER PIVOT IRRIGATION

Dennis C. Kincaid, Bradley A. King and Darrell W. DeBoer[1]

ABSTRACT

The last decade has seen development of some new and innovative sprinkler/spray head designs for use with center pivots and traveling laterals. The impetus behind these devices has been the need to maintain uniformity of water application equivalent to the high pressure overhead sprinklers, while reducing energy requirements, spray drift losses, and controlling potential runoff. Ease of installation, maintenance and long life were also important considerations. Spray head designs have evolved from the simple smooth or grooved fixed-deflector plates to rotating or oscillating plates designed to produce larger patterns or control droplet sizes. Pattern diameters produced with various types of spray plates operating at various nozzle pressures, and nozzle elevations, are given and uniformity attainable on moving laterals is discussed. Peak application rates and droplet size issues are also discussed. Various mounting methods such as adjustable drops or offset booms are available to vary the spray elevation, allow in-canopy spray or to increase the pattern width and reduce application rates.

Keywords: sprinkler irrigation, sprinkler packages, spray irrigation, center-pivot irrigation

INTRODUCTION

The latest irrigation survey (Reaves, 1999) indicates that as of 1998, about 9 million ha (23 million acres) are now sprinkler irrigated in the U. S., and about 47 percent of this area is irrigated by center pivots or traveling laterals (linears). Center pivot acreage is increasing as a replacement for surface systems and handline and side-role laterals. During the last decade many pivots were converted from high pressure (>400 kPa (60 psi)) to low pressure, and most new systems are low pressure. About 80 percent are now low pressure, with nozzle pressures in the 70-140 kPa (10-20 psi) range. The impetus for low pressure has been the desire to minimize energy costs and the desire to maximize application efficiency or overall water use efficiency. Concurrently, sprinkler and pivot manufacturers have developed more sophisticated and reliable equipment, offering a wide range of choices in operating pressure, sprinkler pattern size, and droplet size range. Along with low pressure, the trend has been to reduce the elevation of the spray above the crop canopy or soil surface to reduce spray drift and evaporation losses. Some spray heads are designed to operated within the crop canopy, and some are design to operate either as a spray head or as a Low Energy Precision Application (LEPA) emitter, which drops a stream of water directly onto the soil. More durable and accurate pressure regulators have been developed for use with all types of sprinklers. DeBoer et. al.(1992) field tested spray heads and impact sprinklers on a moving lateral. Although the low pressure sprays produced more runoff than the high pressure sprinklers, there was no difference in crop yields. With careful management of water application depth and tillage systems to control runoff, low pressure center pivots have been highly successful.

SPRINKLER/SPRAY HEAD TYPES

The two main types of sprinklers used on center pivots and moving laterals are: 1) the traditional impact drive sprinklers, and 2) spray heads with fixed or moving deflector plates. The impact

[1]Agricultural Engineers, USDA-ARS, 3793 N 3600 E, Kimberly, ID, 83341, Univ. of Idaho, Aberdeen, ID. and South Dakota State Univ., Brookings, SD, respectively.

sprinklers have been used mainly for high pressures, but can be used for medium pressures (140-280 kPa (20-40 psi)) with square or triangular orifice nozzles. Recent developments in impact sprinklers have included special nozzles and lower jet-trajectory angles to reduce spray drift. They are normally mounted directly on top of the lateral, and offer a low cost hardware package.

Most sprinkler development in the past decade has been in improved spray heads which have some of the characteristics of impact heads. These have evolved from the simple flat plate, to rotating plates, multiple plates and wobble or oscillating plates. Figure 1 shows details of a typical spray head with a pressure regulator. The regulator is designed to maintain a nearly constant pressure to the spray head, provided the upstream pressure is above the nominal pressure (plus the loss through the regulator, which depends on the flow rate). The spray head body provides a receptacle for the nozzle and positions the deflector plate in alignment with the nozzle using 2 or 3 support bars. The circular-orifice nozzle is sized to discharge the design flow rate at the nominal pressure. Nozzle orifice diameters are usually sized in increments of 0.397 mm or 0.198 mm (1/64 or 1/128 inch). Brass nozzles have been replaced with plastic and are color coded for ease of indentification. The water jet impinges on the deflector plate, which is shaped to produce a desired spray pattern and droplet sizes.

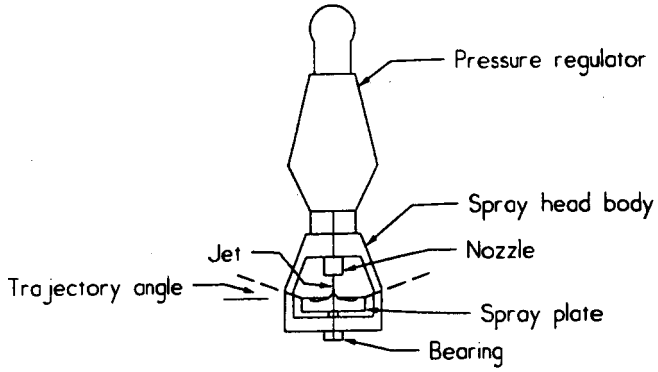

Figure 1. Detail of spray head and pressure regulator

A smooth deflector plate produces a thin sheet of water as it leaves the plate and produces the smallest average drop size at a given pressure and flow rate. Smaller drops are desirable for reducing soil impact energy, but can cause excessive spray drift. This also results in a small pattern radius, which is undesirable from an application rate standpoint. Serrated or grooved plates are used to produce many small jets and larger droplets. The fewer grooves that are used, the larger the jets and the larger the drops, and the larger the pattern radius. Fixed, grooved plates produce stationary jets which can severely impact the soil in localized areas when the lateral is stopped, due to the start-stop motion of most center pivot type laterals. Most fixed groove plates have 15 to 30 grooves. Plates and nozzles are easily changed without tools, allowing in-season conversion from an initial low-flow, small-drop package favoring crop germination and establishment, to a full-flow, large-drop package for the peak water use period with full crop cover. One manufacturer (Senninger, Orlando, FL[2]) uses a stacked 2 or 3 plate arrangement in

[2]Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the products listed by the USDA- ARS.

which the upper plates have a center hole, passing a portion of the water though to the lower plates. This divides the flow into a larger number of grooves, allowing a larger nozzle or lower pressure to be used while maintaining reasonable drop sizes. Each plate may have a different trajectory angle.

In order to increase the pattern radius with spray heads, manufacturers have developed rotating deflector plates (e. g. Nelson Irrigation Corp., Walla Walla, WA). Nelson's Rotator uses 4 or 6 groove plates, and the bearing contains a viscous fluid for slow (approx. 30 sec) rotation. The Nelson Spinner uses the same plates but with a low friction bearing for high speed rotation. Plate rotation is produced by reaction of the water jets in the curved grooves, so rotation speed is affected by pressure and flow rate. Concave plates are available to produce jet trajectory angles from about 6 degrees to 35 degrees. The heads are usually inverted as shown in Figure 1 for use on drops, but can be mounted upright on top of the lateral, where a convex shaped plate would normally be used. Higher trajectory angles produce larger patterns and more uniform application rates, but are more susceptible to wind drift. The four groove Rotator produces the largest pattern radius and larger drops, and can produce high instantaneous application rates due to the slowly rotating jets, while the Spinner produces a slightly reduced pattern radius and a more uniform application rate.

The oscillating plate sprinkler has been a successful alternative to the fixed and rotating plate spray heads. The Senninger Wobbler and Nelson's Nutator use a 6 to 9 groove plate in which the center of the plate moves in a circular motion around the water jet, and the entire jet is channeled through each groove in succession. This produces relatively large drops and a large pattern radius. Versions for low or high trajectory angles (15 and 25 degrees approx.) and upright or inverted positioning (IWOBB) are produced. The oscillation of the plate produces some vibration, and therefore it should be suspended from a short length of flexible hose when mounted on drop tubes.

MOUNTING OPTIONS

Along with different types of sprinklers, various mounting methods have been developed to better suit different climate, crop, soil, and topographic conditions. The lateral pipe elevation on most center pivots varies from 3.5 to 4.5 m above ground, and the minimum crop clearance is about 2.5 m, although low profile systems are available. Sprays mounted on top of the lateral suffer from wind drift problems. Spray heads are most often mounted below the truss level, with a 180 degree gooseneck and rigid pipe (Figure 2). These straight drops are sometimes made flexible to allow the spray head to be operated within a corn crop canopy.

Since sprays have relatively small patterns and consequently high application rates, various types of offset booms have been tried, to increase the overall spray pattern width. In the early 1980's long (12 m) horizontal booms with multiple spray heads were suspended beneath pivot laterals to obtain pattern widths of 20 m or more. These proved to be cumbersome and expensive, however, and have been supplanted by simpler single offset booms as shown in Figures 2 and 3. Offset pipes up to 6 m in length have been used with 19 to 25 mm steel tubing. The simplest method shown in Figure 2 uses support braces attached to the truss rods of the lateral span. This requires braces to be field fabricated or easily adjusted, since the truss rod position varies relative to the lateral. The swivel joint used to connect the spray head-regulator unit to the offset pipe and to level the head consists of two street ells.

The adjustable boom system shown in Figure 3 uses a clamp on the lateral pipe to support the offset, is independent of the truss rods, and the angle can be easily adjusted. A short length of 19 mm hose transfers the water from a lateral outlet to the boom. They can be mounted anywhere

along the lateral with fixed or variable spacing, and alternated on either side of the

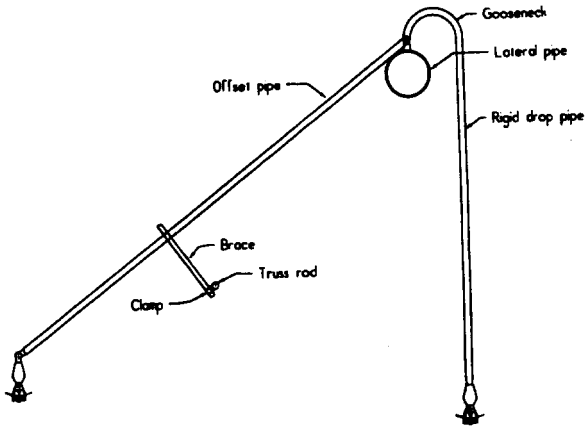

Figure 2. Simple offset supported from a truss rod. and rigid gooseneck drop

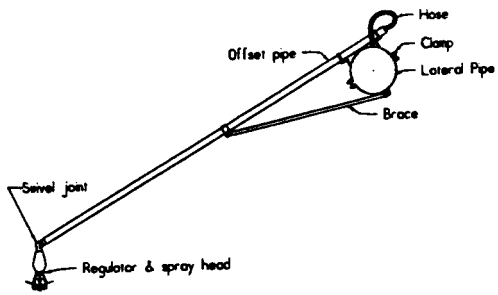

Figure 3. Single adjustable offset boom and spray head assembly.

lateral. They are often used adjacent to pivot towers to apply most of the water behind the wheels to minimize wheeltrack rutting. The adjustable boom allows changing the elevation of the spray head either within season as the crop height increases, or between seasons where different crops are rotated, for example where corn is rotated with grain or other low crops. A minimum crop clearance of about 1 m is recommended for high application uniformity. For low crops, a spray head elevation of about 2 m is convenient for maintenance. In general, offset booms allow use of spray heads producing smaller patterns, and/or lower pressures, while minimizing the elevation of the spray above the surface, and minimizing peak application rates. Disadvantages include increased equipment costs, increased weight on the span and wheels, and susceptibility to wind damage.

PATTERN SIZE AND UNIFORMITY

Uniformity is affected by the size and shape of the pattern, and the spacing of the nozzles. The pattern is in turn affected by nozzle size and pressure, and type of spray plate and elevation of the spray head. Table 1 summarizes approximate pattern diameters for several different spray head and plate combinations at typical operating pressures and nozzle heights, and a flow of about 30 L/min, which is a typical flow rate for the outer portion of a pivot. King and Kincaid (1997)

describe the pattern shapes produced by spray heads, and gave recommended spacing limits for high uniformity. In general, a higher trajectory angle and/or nozzle pressure will produce a larger, more uniform pattern. The oscillating type sprinklers tend to produce a more uniform application rate than fixed-plate or low-angle rotating plates. High uniformity (CU>95%) will usually be obtained if the spacing does not exceed 25 percent of the pattern diameter. This limitation is easy to satisfy in the outer portion of most center pivots where flow requirements per unit length of lateral are high, and it is desirable to limit nozzle sizes and drop sizes. Uniformity problems may occur near the pivot where flow requirements are small.

Table 1. Pattern diameters for sprinklers/sprays at a flow of 30 L/min (8 gpm)

Sprinkler	Plate	Angle	Pressure	Height:1 m	Height: 2 m
		deg	KPa(psi)	Diam., m(ft)	Diam., m(ft)
Fixed plate	Smooth	0	100(15)	7(23)	9(30)
Fixed plate	Serrated	0	100(15)	9(30)	11(36)
Rotator	4 groove	8	200(30)	17(56)	19(62)
Rotator	6 groove	12	100(15)	13(43)	15(49)
Nutator	7 groove	12	100(15)	13(43)	14(46)
Nutator	9 groove	21	100(15)	14(46)	15(49)
Rotator	6 groove	12	200(30)	15(49)	17(56)
Spinner	6 groove	12	100(15)	12(39)	13(43)
Spinner	6 groove	35	100(15)	15(49)	16(52)
Wobbler	Standard	25	100(15)	14(46)	15(49)
Wobbler	Standard	25	200(30)	16(52)	17(56)
Wobbler	Low angle	15	100(15)	13(43)	14(46)
Wobbler	Low angle	15	200(30)	14(46)	15(49)
IWOBB	Standard	20	100(15)	14(46)	16(52)
IWOBB	Low angle	15	100(15)	14(46)	15(49)

APPLICATION RATES

Average application rates are inversely proportional to the width of the spray pattern. Peak application rates are usually about 1.3 to 1.5 times the average rate. Thus, there is a factor of 3 difference in application rates between the smallest and largest pattern sprinklers described here. Using alternating 4 m offset booms can decrease the rates from the fixed plate sprays by a factor of 2, and can decrease the rates from the larger patterns by a factor of about 1.5. Since the application rates under the outer spans of most pivots exceed the infiltration rates of all but sandy soils, the use of offsets can usually be justified on the outer one-third of the lateral. Reducing application rates allows larger application depths, allowing less frequent wetting, thereby reducing excess surface evaporation and minimizing disease problems in some crops.

DROP SIZE CONSIDERATIONS

Drop sizes are an important factor in selection of a sprinkler package. Kincaid, et. al. (1996) and Kincaid (1996) showed how drop size distribution and droplet kinetic energy can be determined for most types of sprinklers given the nozzle and spray plate type, nozzle size and pressure. In general, for a particular type of sprinkler and plate, drop sizes increase as nozzle size increases or nozzle pressure decreases. Mean volumetric drop size ranged from about 1 mm for the smooth plate spray to about 2.5 mm for the 4-groove Rotator and Wobbler at low pressures. Droplet kinetic energy per unit volume of water applied increased by a factor of about five from the smooth plate to the Rotator. Studies by Thompson and James (1985) and Mohammed and Kohl (1987) on silt loam and loam soils showed that as drop energy flux increased, the infiltrated depth prior to runoff decreased by a factor of 2 or 3. Selection of a spray package based on drop sizes must balance the potential for spraydrift losses against the potential for surface sealing and runoff.

CONCLUDING COMMENTS

Current sprinkler packages and associated equipment for center pivots and traveling laterals offer a wide range of options for different climate, soil, crop, topography, water supply, energy cost and economic situations. There is probably no single "optimum" setup for any given situation. Local or regional trends develop based on equipment success.

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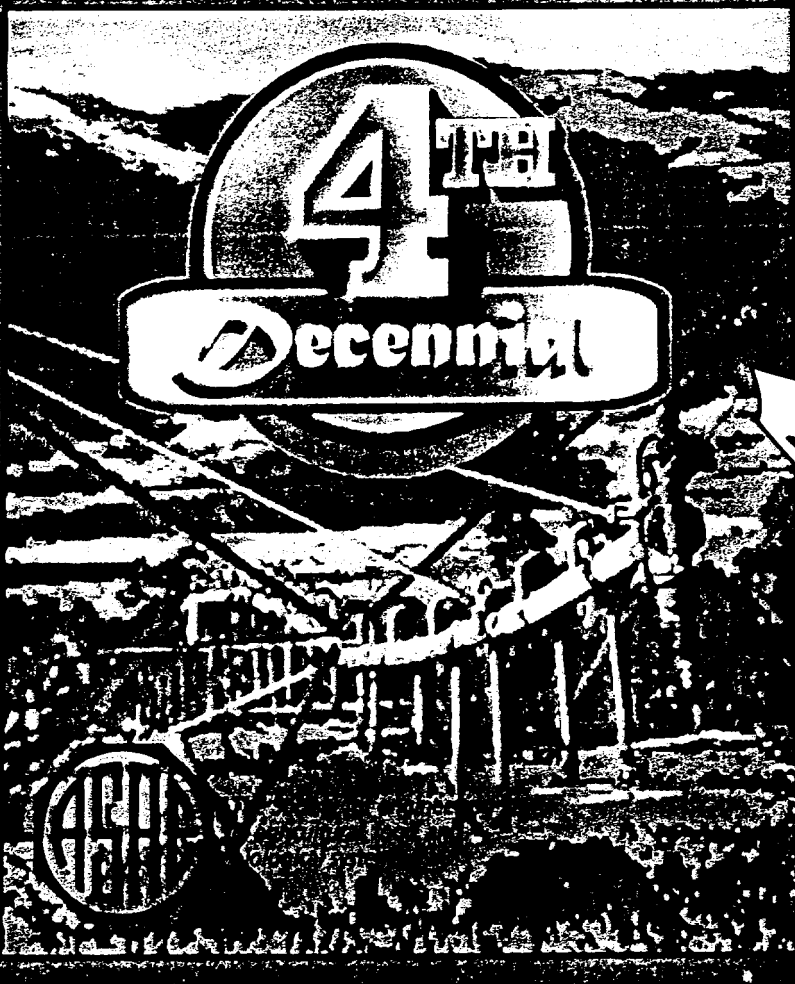

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