EVALUATION OF MECHANIZED SPRINKLER EQUIPMENT[1]

By

Claude H. Pair[2]

The growth of sprinkler irrigation has been steady since the end of World War II. The 1949 United States Census showed 639,987 acres sprinkled out of 25,787,455 total irrigated acres. 1968 estimates show 6,750,000 acres sprinkled and 45,000,000 acres irrigated. The sprinkled acreage of the United States is equivalent to all the irrigated acreage in Oregon, Washington, and Idaho. Oregon ranks sixth among the fifty states in the acreage irrigated by agricultural sprinkler systems. Only California, Texas, Florida, Idaho and Washington have more sprinkled agricultural acreage than the 450,000 acres sprinkler irrigated in Oregon.

The early sprinkler systems were handmove, portable lateral types that required a minimum of capital and maximum of labor for irrigation. The availability and reliability of present day farm labor has caused the Oregon farmer to look to mechanization as a method of reducing irrigation labor requirements. The sprinkler industry responded to this demand by introducing a large number of mechanical move systems.

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2 Research Engineer (Irrigation), Snake River Conservation Research Center, Kimberly, Idaho - 83341.

This paper presents a brief description of the various mechanized sprinkler systems and a summary of an evaluation of the field performance of some of the systems. Tests were made on systems operating in the Boise and Twin Falls, Idaho areas.

TYPES OF SYSTEM

Today's farmer has a choice of eight major types of sprinkler systems and many versions of each type. These are handmove, tow line, side roll, side move with and without trailer lines, center pivot self-propelled, straight lateral self-propelled, giant sprinklers and solid set systems.

The handmove, portable lateral system is used to irrigate more acres in Oregon than any other system. These systems cost from $100 to $125 per acre to install. Labor requirement is about one man-hour per irrigation to move one-quarter mile of lateral. No major changes in this type of sprinkling equipment have been made in the last decade.

The tow line lateral system has fixed or swivelled two-wheeled carriages attached to the pipe at intervals of 40 to 60 feet. These hold the sprinkler pipe a foot or more above the ground. This lateral is then end-towed by truck or tractor from one set to the next. Skid pans have replaced the wheels in some versions of this system. Only a very small acreage is irrigated with this system in Oregon.

The side roll system was developed during the late 1940's. Wheels were clamped around the coupler end of each joint of handmove sprinkler lateral to develop this system. Hand-operated bicycle pedals were first used to power the mover mechanism. One to two small gasoline engine-powered movers are used today to move a quarter-mile of a side roll lateral. The mover marketed by one manufacturer is an engine-driven hydraulic powered unit. These mover units require the irrigator to walk considerable distances to start the gasoline engines. To further reduce the labor requirement, equipment has been developed to operate the mover units from the mainline end of the side roll lateral. These end-move devices include a gasoline engine-driven shaft, tractor-driven shaft, and an electric motor mover unit driven and controlled from a tractor-powered electric generator. The manufacturer of the engine-driven hydraulic powered mover unit installed an electric starter on the gasoline motor. Remote starting and hydraulic controls allowed starting the engine and control of the mover unit from the mainline end of the lateral.

The side move sprinkler system was developed to place the sprinkler above tall crops such as corn. The main lateral pipeline is supported at 50- to 60-foot intervals with a two-wheeled carriage arrangement. Each wheel is powered from a line shaft by a belt, chain-drive, or gear mechanism. The line shaft is powered at the middle of the lateral by a small 6- to 10-horsepower gasoline engine. One system uses electric motors to power sections of the line shaft. Quick opening automatic valves are installed along the lateral to drain water from the system before moving. Trailing pipelines varying in diameter from 1 to 2 inches are used on some systems. The lateral and trailer lines are moved by the power unit at one time. From 1 to 7 sprinklers are mounted on each trailer line, making the 7-sprinkler trailer line system equivalent to 8 handmove quarter-mile laterals. Outrigger stabilizers are used on the trailer lines to increase the stability of the sprinkler riser and improve water distribution. Stabilizers may be placed on each riser, on the end riser, or on the trailer line itself. Adjustable carriage wheels, or an extra set of wheels, allows the side move lateral to be end-towed from one field to another using a truck or tractor. The trailer pipelines are loaded on a rack attached to the lateral pipeline carriage mechanism during this moving process.

The lateral pipeline of a center pivot, self-propelled system is anchored at the center of the irrigated area. Water is introduced into the lateral at the center pivot through a pipeline from a well, irrigation canal, or stream. Sprinklers varying in type, nozzle size, and discharge capacity are spaced at intervals along the lateral with the largest discharge farthest from the pivot point. Spacings of sprinklers are designed to give uniform water distribution along the lateral. Speed of lateral travel can be varied so that from 15 hours to 7 days are required to complete one revolution. The slower the lateral rotation, the greater the depth of water applied. The total depth of water application is a function of sprinkler nozzle size, nozzle pressure, spacing of sprinklers on the lateral, and speed of travel.

The center pivot, self-propelled lateral systems are moved on wheels, crawler tractor tracks, or skids. The wheeled versions are powered by water-driven, hydraulic cylinders, rotating arm type sprinklers, or electric motors. The track type lateral is powered by electric motors. The skid type is pushed forward by a walking foot powered by a hydraulic cylinder drive mechanism. The lateral pipeline in most center pivot, self-propelled systems is rigid pipe, but one system has flexible joints at each track or wheel support which permits satisfactory operation on uneven terrain. All systems have built-in safety devices that stop the lateral if a section gets out of alignment. Center pivot, self-propelled systems are available to irrigate 40-acre, or larger tracts. Laterals vary in length from a few hundred feet to 1600 feet. The most common lateral length is 1285 feet, which will irrigate a circular 130-acre area out of a square 160-acre field.

The straight, self-propelled lateral is a continuously moving system powered by a hydraulic ram driver operated by water pressure. Each 40-foot section of pipe is supported on a two-wheeled "A" frame. A chain drive powers each wheel from a power drive shaft. A high pressure flexible hose connects the lateral to the mainline. Speed of lateral movement varies from 7 to 25 feet per hour. Speed is adjusted by changing the nozzle size in the sprinkler that discharges water from the hydraulic drive mechanism.

Self-propelled lateral systems have been more highly advertised than usual this year because of the shortage of irrigation labor. A recent count showed 19 manufacturers of center pivot, self-propelled laterals. Only one straight self-propelled lateral was marketed in 1967.

The giant sprinkler system may consist of one or more sprinklers discharging from 100 to several hundred gallons per minute over an area 200 feet or more in diameter. Originally this system was an enlarged version of the ordinary field sprinkler, but now they may involve a rotating boom with multiple nozzles. Boom arms up to 125 feet in length on each side of the pivot point were developed for use in tall growing crops. The giant sprinkler systems have been mechanized by mounting on a trailer for easy movement by tractor or truck. A high pressure flexible hose is used in combination with a gasoline-driven winch to convert to a moving sprinkler system that is pulled back and forth across a field. The flexible pipe is abrasion-resistant and can be dragged around guides to the new location or rolled on a reel and transported to the next setting.

Solid set systems have been used in bean fields in Oregon for several years. The labor problems encountered with handmove laterals have caused some farmers and ranchers to purchase solid set systems. These systems may have either portable surface, or permanent buried pipelines. The solid set portable pipelines are moved only to allow cultivating and harvesting. Systems may be operated in blocks of laterals with all sprinklers on a lateral operating simultaneously. Some systems have pressure-operated sequencing valves that allow the operation of one or more sprinklers on each lateral at one time. With this type, a momentary interruption of the water pressure shuts off the operating sprinkler heads and turns on the next sprinkler on each lateral. A time clock is used to control the momentary pressure interruption by closing an electric valve or shutting off a pump. Thus, irrigation can be completely automated on these systems. The solid set systems also may be used for frost protection, application of fertilizers, insecticides and crop cooling.

EVALUATION OF SYSTEMS

Each type of system has its advantages and disadvantages. Some systems can be designed for use on almost all lands in Oregon, whereas others have limited applications. Regardless of the type of system used, it should meet certain requirements:

1. The application rate should not exceed the ability of the soil to absorb water. Runoff water is evidence of too high an application rate.
2. The amount of water applied during an irrigation should not exceed that which can be held within the root zone of the crop unless leaching to remove harmful salts is necessary.

3. The system should be of such a size and capacity that it is able to replenish the soil moisture at a rate equal to the peak rate of water use by the crops irrigated.
4. Water should be applied as uniformly as practical over the field. The point of lightest application should receive at least 80 percent as much water as the average for the field.
5. Distribution pipes should be large enough so that there is an economic balance between pipe cost and power cost.
6. Water must be applied in a way that will not physically damage the crop.

The uniformity of water distribution and maximum application rates of various types of systems were evaluated on several field installations in the Boise and Twin Falls, Idaho area. Quart oil cans were set on a 10-foot square grid over the area wetted by a sprinkler lateral to determine the water distribution. The sprinkler lateral was operated for several hours and the amount of water caught in each can was measured. The coefficient of uniformity of water distribution was calculated using Christiansen's formula:

$$Cu = 100 \left(1 - \frac{\Sigma d}{nm} \right)$$

where d is the sum of the deviation of individual water depths from the mean depth m caught in all cans, and n is the number of cans. In this formula, a Cu of 100 means the same amount of water was caught in all cans in the test area. A coefficient of uniformity of 80 is acceptable. The maximum application rate for the systems was calculated by dividing the maximum depth of water caught in a single can in the water distribution pattern by the time of water application.

Coefficients of uniformity and maximum average application rates were determined for individual irrigations with five types of systems: the side roll, sequencing solid set, center pivot self-propelled, straight lateral self-propelled, and side move with trailer lines.

The side roll system had a 1/4-mile lateral length and a nozzle pressure of 40 p.s.i. Sprinkler heads were spaced 40 feet on the lateral, and the lateral move was 50 feet on the main pipeline. Sprinkler nozzle sizes were 5/32-inch for one series of tests, and 11/64-inch for the second series. Windspeed averaged 1.9 miles per hour for the first series, and 13 miles per hour for the second series.

The sequencing solid set system was portable with 2-nozzle sprinklers spaced at 70-foot intervals along the lateral. Sprinklers on alternate laterals were offset to give a triangular spacing of 70 feet between sprinklers. Sprinkler heads had two nozzle sizes, 7/32 inch and 3/32 inch, operating at a pressure of 76 p.s.i.

The center pivot, self-propelled system had a 1485-foot lateral length. Nozzle pressure at the pivot point was 80 p.s.i. Sprinkler nozzle sizes on this system varied from 1/8 to 1/2 inch in diameter. The travel speed was 1 revolution in 48 hours.

The straight self-propelled continuously moving system had single-nozzle sprinkler heads with 5/32 inch nozzles operated at 50 p.s.i. Sprinklers were spaced 40 feet apart along the lateral. Lateral speed was varied from 8.3 to 12.8 feet per hour for the various tests.

The side move with trailer line system had trailer lines spaced 40 feet apart on the 5 inch diameter carriage lateral. Each trailer line had three sprinkler heads spaced 50 feet apart. Sprinkler heads were the 2-nozzle type with 1/8 inch and 3/32 inch nozzles. Nozzle pressure was 50 p.s.i.

Three types of sprinkler systems operating simultaneously were compared for water distribution and maximum average application rates. The systems were handmove portable lateral, straight self-propelled lateral, and side move with trailer lines. For these tests, all systems had the same type of sprinkler heads, sprinkler nozzle size, nozzle pressure, and wind pattern. Sprinkler heads were single-nozzle, medium pressure type with 5/32-inch nozzles operated at 50 pounds per square inch. Travel speed of the self-propelled lateral was 25 feet per hour.

RESULTS

The side roll system had a coefficient of uniformity of 71 and 76 under high windspeed and 86 and 89 under low windspeed. The sequencing solid set system coefficients were 75, 75, and 78. The center pivot, self-propelled system coefficients were 81 and 86. The straight lateral self-propelled coefficients were 89, 89, and 90, and the side move with trailer lines coefficients were 84, 86, 87, and 88. Table 1 gives a tabulation of the results obtained, together with average windspeed during the test.

The maximum application rate in a sprinkler lateral pattern is of interest because if this rate exceeds the intake rate of the soil, the water distribution pattern of the sprinkler will be altered by the resulting runoff.

With the side roll lateral, the maximum application rate exceeded 0.32 inch per hour at high winds, while the maximum application rate was less than 0.20 inch per hour at low winds. The sequencing solid set had a maximum rate of 0.24 inch per hour, the straight self-propelled 0.18 inch per hour, and the side move with trailer lines 0.42 inch per hour.

The center pivot, self-propelled system had a variable application rate (Table 2), the smallest being at the pivot point (0.21-inch/hour) and the highest at the last tower (1.0-inch/hour). Many soils do not have such high intake rates, so on those soils there would be runoff. This is one limitation to using this type of system.

When the handmove, straight self-propelled and side move with trailer lines were tested simultaneously (Table 3), the water distribution uniformity was best for the straight lateral self-propelled, the handmove was second, and the side move with trailer lines was third.

DISCUSSION

All systems tested gave good water distribution under low windspeeds except the sequencing solid set system. The sequencing solid set gave less than satisfactory water distribution in moderate winds because the sprinklers were spaced too far apart, risers were not tall enough to eliminate interference with the sprinklers by the crop, and insufficient support for the riser permitted vibration of the sprinkler head

The high application rate of the center pivot self-propelled systems limits their use to soils with high intake rates. Also, high wind can cause runoff because of increased localized application rate, whereas no runoff would occur with the more uniform rate under low wind conditions.

CONCLUSION

The trend in irrigation methods is toward more sprinkler systems. The trend in sprinkler systems is toward more mechanization, with many solid set systems being installed. The use of solid set systems to apply fertilizers, insecticides, fungicides, and to control climate will reduce the charges to irrigation for this most expensive type of sprinkler system. All sprinkler systems tested except the sequencing solid set showed acceptable uniformity of water distribution under low winds. Continuously moving laterals give better water distribution in high winds.

Table 1. System coefficients of uniformity, maximum average application rates and windspeeds.

Type System	Christiansen's Coefficient of Uniformity	Maximum Pattern Application rate (in/hr)	Average Wind-speed during Test (mi/hr)	Speed of Lateral Travel
Side roll	71	0.38	13.0	--
	76	0.32	13.0	--
	86	0.19	1.9	--
	89	0.18	1.9	--
Sequencing	75	0.22	6.0	--
solid set	75	0.22	5.5	--
	78	0.24	4.3	--
Center pivot	81	(See Table 2)	7.1	1 rev/48-hr
self-propelled	86	~~0.17~~	6.0	"
Straight lateral	89	0.17	6.0	11.7 ft/hr
self-propelled	89	0.18	3.2	8.3 "
	90	0.16	2.9	12.8 "
Side ~~roll~~ move with three	84	0.31	2.8	--
sprinklers on	86	0.37	3.9	--
each trailer line	87	0.42	4.1	--
	88	0.38	2.9	---

Table 2. Average water application rates from pivot point to outer end of a center pivot self-propelled sprinkler lateral.

Distance from pivot (in feet)	Average Application rate (inches/hr)
0 + 95	0.21
1 + 85	0.22
2 + 75	0.25
3 + 65	0.35
4 + 55	0.35
5 + 45	0.43
6 + 35	0.39
7 + 25	0.45
8 + 15	0.45
9 + 05	0.53
9 + 95	0.65
10 + 85	0.72
11 + 75	0.81
12 + 65	0.83
13 + 55	0.73
14 + 45	1.01

Table 3. Christiansen's coefficients of uniformity and maximum application rates for straight self-propelled, side move with three sprinkler trailer lines, and handmove sprinkler laterals operated under the same conditions.

Type System	Christiansen's Coefficient of Uniformity	Maximum Average Application Rate (in/hr)	Average Windspeed during Test (mi/hr)
Handmove 40' x 50'	79	0.26	4.9
	92	0.26	5.2
Straight lateral self-propelled	90	0.14	4.9
	95	0.14	5.2
Side move with three trailer lines	77	0.34	4.9
	89	0.34	5.2