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Water distribution under sprinkler systems used in the united states

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Many factors affect the distribution of water to the soil or crop. These can be grouped under sprinkler head, distribution system, climatic, and management factors. Sprinkler head factors include size, pressure, number and type of nozzle, and speed of rotating sprinklers. Distribution system factors include sprinkler head spacing on the lateral, spacing of laterals along the main pipeline, height of sprinkler above soil or crop, stability of the sprinkler riser, and pressure variation in the sprinkler system. Climatic factors are primarily relative humidity, windspeed, and wind direction. Management and other system factors are duration of system operation, velocity of lateral or sprinkler movement over the land in self-propelled moving laterals and sprinkler machines, alignment of laterals, and alignment of sprinkler risers with the vertical.

The application of chemicals through sprinkler systems has been practiced for many years in parts of the United States. Fertilizers, pesticides, and herbicides are being applied to turf, ornamentals, food and fibre crops, with fertilizer applications having the greatest volume and longest history of use. Much experimentation is being done with insecticides, fungicides, and herbicides to obtain better and safer results with the wide variety of chemicals available for use (1), (2), (3), (5), (6), (7), (8), (9), and (10). Both liquid and dry fertilizers are applied through sprinkler irrigation systems in the U. S. A. The distribution of chemicals over the field is only as good as the water distribution from the sprinkler system.

The United States farmer has a choice of eight major types of sprinkler systems and many versions of each type. These are handmove (Figure 1), tow line (Figure 2), side roll (Figure 3), side move with and

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without trailer lines (Figure 4), center pivot self-propelled moving lateral (Figure 5), straight lateral self-propelled (Figure 6), giant sprinkler (Figure 7), and solid set systems (Figure 8).

The uniformity of water distribution over the field by several types of sprinkler systems was determined on field installations in southern Idaho. To determine the water distribution, quart oil cans used as rain gages were set on a 10-foot square grid over the area to be irrigated by a sprinkler lateral. The sprinkler lateral was operated for a normal irrigation period and the amount of water caught in each can was measured. The coefficient of uniformity of water distribution was calculated using Christiansen's (4) formula:

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

where Σd 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 85 is acceptable.

Systems tested

Four series of water distribution tests were made on various types of sprinkler systems:

1. A handmove system for three individual irrigations and the cumulative distribution after the third irrigation.
2. Individually operated side roll, sequencing solid set, and center-pivot self-propelled moving lateral systems for one irrigation.
3. Handmove, straight self-propelled moving lateral, and side move with trailer lines systems operating simultaneously with the same pressure, spacing, nozzle size, and wind conditions.
4. A side roll system under low, medium, and high windspeeds.

The handmove system used in the first test was a 440-foot length of 3-inch-diameter aluminum lateral pipe with sprinklers on 2-foot risers spaced 40 feet apart on the lateral. The lateral move was 60 feet on the main pipeline. Sprinkler nozzle size was 5/32-inch and water pressure at the sprinkler nozzle was 35 p. s. i.

The side roll system had laterals 1/4 mile long, 4-inch-diameter aluminum pipe, and 76-inch-diameter wheels mounted every 40 feet along each lateral. The lateral was moved 60 feet on the main pipeline. Sprinkler heads were single-nozzle type with a 5/32-inch nozzle diameter and operated at 55 pounds per square inch nozzle pressure. Sprinkler spacing on the lateral was 40 feet. The sprinklers were attached to the lateral with a balanced head mechanism that maintained the sprinkler in the correct operating position regardless of the sprinkler riser pipe outlet positions around the lateral pipe.

The sequencing solid set system had a buried steel main line with 1-1/4-inch-diameter portable aluminum laterals. Laterals were 310 feet long, with five sprinklers on each lateral. Sprinkler heads were the two-nozzle type with 7/32-inch and 3/32-inch nozzles operating at a nozzle pressure of 76 p. s. i. Sprinklers on alternate laterals were offset to give a triangular spacing of 70 feet between sprinklers.

The center-pivot self-propelled moving lateral system had a 1485-foot, 5-inch-diameter lateral pipe supported by 15 wheeled supports. Sprinklers were both single-nozzle and double-nozzle types with nozzle sizes varying from 1/8 to 1/2 inch in diameter. Sprinkler spacing along the lateral was variable; operating pressure was 80 p. s. i. at the pivot point; travel speed of lateral was one revolution in 48 hours.

The handmove lateral used in the simultaneous water distribution test of three systems was 300 feet long, 3 inches in diameter, and sprinklers were spaced 40 feet apart on the lateral. Nozzles were 5/32-inch in diameter and operating pressure was 50 p. s. i. The lateral was moved 50 feet on the main pipeline.

The straight self-propelled moving lateral was 300 feet in length, 4 inches in diameter with wheeled supports every 40 feet along the lateral. Sprinklers had the same spacing, nozzle size, and operating pressures as the above handmove lateral. Velocity of lateral movement was 25 feet per hour.

The side move with trailer line lateral had a 300-foot length of 5-inch lateral pipe with a 150-foot length of 1-1/4-inch trailer line spaced every 40 feet along the lateral. Two-wheeled carriage-type supports were spaced every 60 feet along the lateral. Three sprinklers were spaced 50 feet apart on each trailer line, and sprinklers were spaced every 40 feet along the 5-inch lateral pipeline. Sprinklers had the same spacing, nozzle size, and operating pressures as the handmove and straight self-propelled moving laterals.

The side roll system used in the three windspeed tests was similar to the one used in the single sprinkler system tests, but had 11/64-inch-diameter sprinkler nozzles and a 40 p. s. i. sprinkler operation pressure at the nozzle. Sprinkler lateral move on the main line pipe was 60 feet. Windspeeds during the tests were 1. 8, 4. 5, and 13 miles per hour.

Results

The handmove sprinkler system had individual irrigation Christiansen's coefficients of uniformity of 56, 90 and 77 for the three irrigations. The coefficient of uniformity for the cumulated pattern after the third irrigation was 89. Figure 9 shows the water distribution patterns.

The side roll, sequencing solid set, and circular self-propelled systems had uniformity coefficients of 84, 78, and 86 respectively. Water distribution patterns are shown in Figure 10.

Where three laterals were operated simultaneously, the handmove lateral had a coefficient of uniformity of 92, straight lateral self-propelled - 95, and side move with trailer lines - 89. See Figure 11 for water distribution patterns.

The effect of wind on the water distribution pattern of a side roll sprinkler lateral resulted in a coefficient of uniformity of 91 for a 1. 8 m. p. h. wind, 86 for a 4. 5 m. p. h. wind, and 58 for a 13 m. p. h. wind. See Figure 12 for the distribution pattern.

Discussion

The distribution of water was good for all types of systems tested under low windspeeds (0-5 m. p. h.) except the sequencing solid set system. The sequencing solid set system tested gave less than satisfactory water distribution because of poor system design. Observations showed that the sprinklers were spaced too far apart, risers were not tall enough to eliminate crop interference with sprinkler operation, and the small diameter, lightweight riser permitted sprinkler head vibration which caused erratic sprinkler head rotation, thus giving poor water distribution.

The effect of wind on the distribution of water, and consequently, on fertilizers and other chemicals had they been in the water, is shown in Figure 12. This poor distribution could be partially overcome by changing to a 50-foot lateral move. Also, multiple applications would help give a better water and consequent fertilizer distribution as is shown by the uniformity of the cumulative handmove system distribution shown in Figure 9. The better water distribution from multiple irrigations is due to the random nature of the water distribution from a sprinkler. Changing wind patterns shift the high and low water application points in the pattern each irrigation, so that a better coefficient of uniformity is obtained for the cumulative pattern.

Conclusion

All types of well-designed systems tested gave good water distribution patterns under low wind conditions. Increased windspeeds caused poorer water distribution. Best fertilizer and chemical distribution would be obtained when the applications were made during the part of the day having the least wind. If fertilizers must be applied under windy conditions, better distribution will be obtained by putting it on in two or more applications.

Self-propelled, moving lateral sprinkler systems gave better water distribution than most other types of systems under windy conditions.

Properly designed and operated sprinkler systems are a necessity where fertilizers and chemicals are to be applied through the irrigation system for best distribution.

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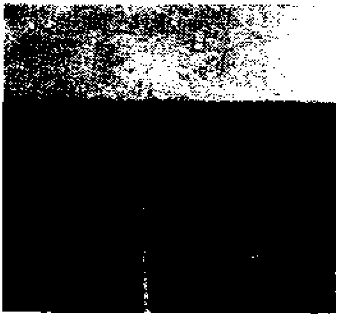

Figure 1. Handmove

Figure 2. Tow line

Figure 3. Side roll

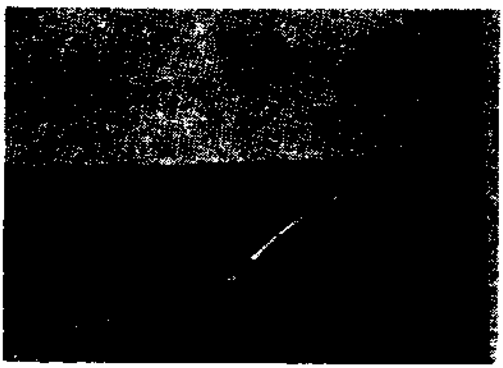

Figure 4. Side move with trailer lines

Figure 5. Center-pivot self-propelled moving lateral

Straight lateral self-propelled

Figure 7. Giant sprinkler

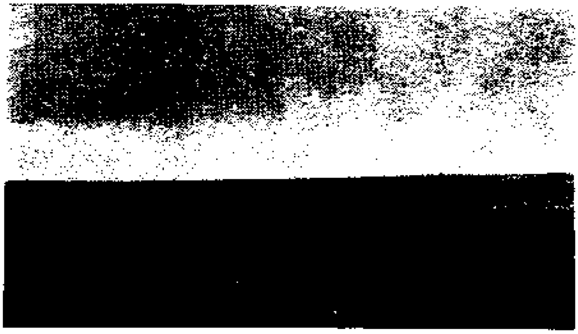

Figure 8. Solid set

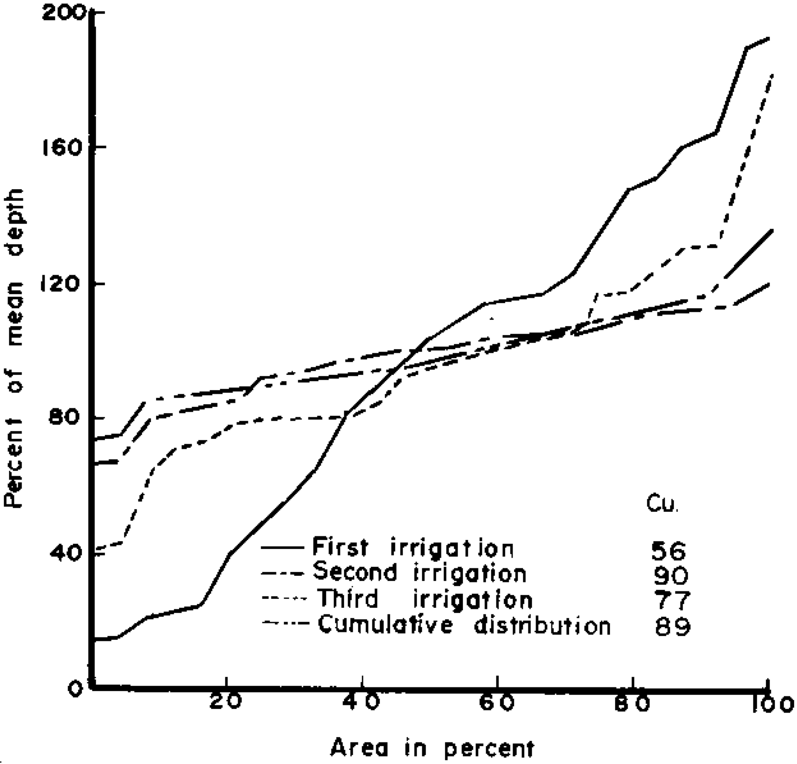

Figure 9. Water distribution under handmove system for three irrigations and cumulative water distribution after third irrigation.

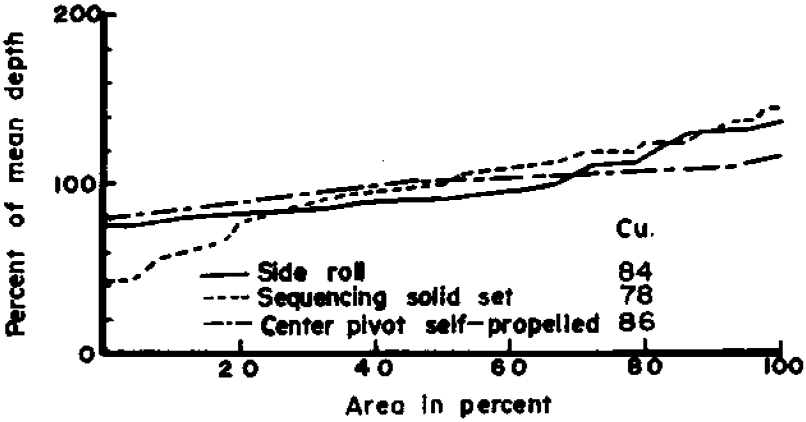

Figure 10. Water distribution under side roll, sequencing solid set, and circular self-propelled sprinkler systems.

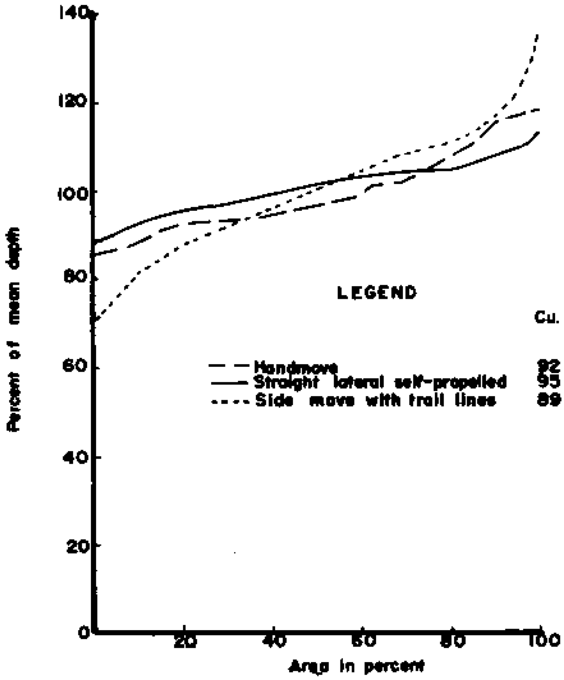

Figure 11. Water distribution under three sprinkler systems with same operating conditions.

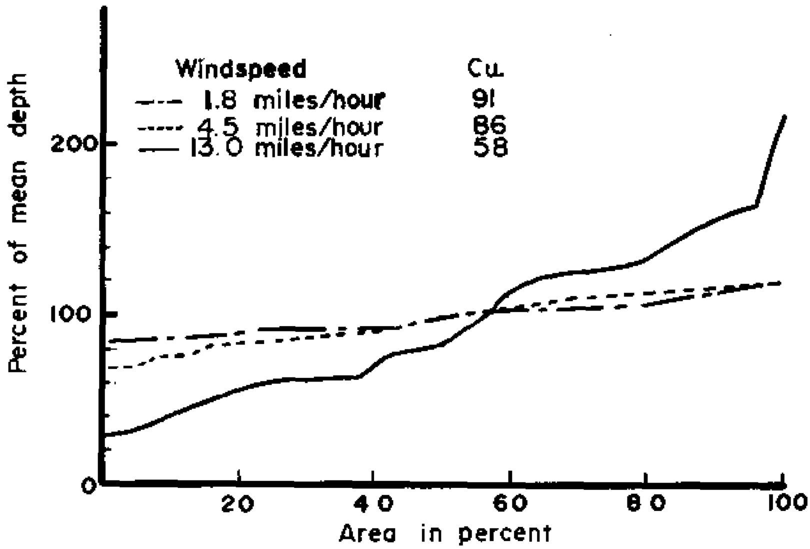

Figure 12. Water distribution for a side roll system under various windspeeds.