Rough Draft

WATER APPLICATION BY SPRINKLER AND FURROW IRRIGATION

by

Gordon Kruse,
Paul Schleusener,
Walter Selby
and
BERT SOMERHALDER

Submitted for Publication in
Agricultural Engineering

Journal of American Society of
Agricultural Engineers

JULY 1961

CER61EGK41

WATER APPLICATION BY SPRINKLER AND FURROW IRRIGATION

by

Gordon Kruse,
Paul Schleusener,
Walter Selby
and
Bert Somerhalder

Irrigation water supplies must be used more efficiently, for reasons of conservation and economy. In order that this might be done, the efficiencies of different irrigation methods must be known at the time systems are designed. High efficiency of water application involves not only the storage of a high percentage of applied water in the soil root zone, but also uniform distribution of the stored water, maximum utilization of the soil zone available for storage, and maximum availability of the stored water to the crop being grown(5).

Field measurements of irrgation efficiencies have been reported by a number of investigators(6, 1, 3, 7, 9, 10, 4, 8, 2). However, topographic and climatic differences between field sites make it difficult to compare the merits of different methods.

A comparative study of irrigation efficiencies of sprinkler and furrow methods is reported in this paper. Irrigations by sprinkler and furrow were conducted simultaneously on a system of paired plots. Thus climatic and soil factors were quite similar for both methods during the course of the study.

The various types of irrigation efficiency have been defined as follows(5).

Water application efficiency, $E_a = \frac{W_s}{W_f}$ (100)

Water distribution efficiency, $E_d = 100 \left[1.0 - \Sigma x/Mn\right]$

Water storage efficiency, $E_s = \frac{W_s}{W_n}$ (100)

Consumptive use efficiency, $CUE = \frac{W_u}{W_d}$ (100)

where:

W_f = water delivered to the farm or, in this study, to the plot.

W_s = water stored in the soil root zone during the irrigation.

x = deviation of the individual depths of water stored from the mean depth M, of water stored in a field or plot.

n = number of individual observations.

W_n = water needed in the root zone prior to irrigation to fill the soil to field capacity.

W_u = normal consumptive use of water.

W_d = net amount of water depleted from the soil root zone.

For the study reported herein, water application and water distribution efficiencies were determined directly with the aid of soil moisture samples taken before and after each irrigation. Soil moisture samples were taken in each of twelve areas within each plot to provide a basis for calculation of E_d.

The water delivered, W_d, was determined by augmenting the water needed according to a constant assumed value of E_a equal to 80 per cent (i.e. $W_f = W_n/0.80$). The values of E_a will be discussed further.

Consumptive use efficiencies were not measured directly. However, comparison of crop yields with the amounts of water applied by each method gave an indication of relative consumptive use efficiency.

Water Application Efficiencies

The water application efficiencies on the sprinkler-irrigated plots averaged 81.9 per cent during the three years of testing. The average efficiency of furrow irrigation was 73.7 per cent.

The occurrence of runoff, deep percolation and evaporation all prevented water from being stored in the soil root zone and thus lowered the application efficiencies. Runoff from each plot was measured. Combined deep percolation and evaporation losses can be estimated indirectly by subtracting runoff and water retained in the root zone from the total amount of water applied.

Runoff measurements are shown in table 1. Average runoff on the sprinkler-irrigated plots was 0.9 per cent of the water applied. On furrow-irrigated plots 8.1 per cent of the applied water was lost as runoff.

The average difference in water application efficiencies of the two methods, 8.2 per cent, is roughly equal to the difference in runoff, 7.2 per cent. This indicates that if runoff on furrow-irrigated fields can be reduced, the efficiencies of furrow and sprinkler irrigation can be made more nearly equal.

Some runoff must be allowed on sloping fields irrigated by gravity methods in order to assure that the lower portion of the field will receive enough water. Adequate irrigation of the lower end of the field can be accomplished with a minimum of runoff loss if water is initially discharged into the furrows at the maximum, non-erosive rate. Then, when runoff begins, the discharge can be reduced to an amount just sufficient to cause the furrow streams to run the entire length of the field.

Another means of preventing furrow runoff is to use level rather than graded furrows. Level furrows can handle large streams of water without erosion. Water distribution is not adversely affected because the large streams of water advance across the field in a short length of time.

Each of the experimental plots was irrigated twice each year. Water application efficiencies averaged 5.5 per cent higher for the first irrigation than for the second. The tendency for the first irrigation of the season to be more efficient than the second was evident for both methods of irrigation. The reduced efficiency for the second irrigation was reflected in increased runoff for both methods. A method of preserving soil intake rate from one irrigation to the next would help to maintain high application efficiencies.

Statistical analysis shows the difference in water application efficiencies of the sprinkler and furrow systems to be highly significant. During the three years of study, an average of 8.0 inches of irrigation water per year was used by the sorghum(excluding pre-season applications). To provide this water, applications of 9.7 inches by sprinklers or 10.8 inches by furrows were necessary. If it had been necessary to supply all water by irrigation, a greater yearly water saving would have been realized by use of sprinklers.

Water Distribution Efficiency

Water distribution efficiency for sprinkler-irrigated plots averaged 76.2 per cent. The value for furrow plots was 74.0.

The value of distribution efficiency alone gives no indication of how the non-uniformity occurred. Table 3 shows the average relative water distribution for each irrigation method as well as the method of division of each plot into sampling areas. Under furrow irrigation, 35 per cent more water was added to the root zone of the upstream fourth of the plots than to the downstream fourth. Repeated irrigations of the same field with this type of distribution will ultimately cause a shortage of water at the lower end even though the rest of the field may receive a sufficiency.

In other words, water storage efficiency on the downstream fourth of the furrow-irrigated plots was low and became lower with each successive irrigation. If storage efficiency becomes low enough, water will not be available to sustain plant growth in this area for the full period between irrigations.

A slight gradient in water distribution occurred across the furrow plots. Discharge from the gated pipe used to supply the plots varied from one end to the other due to head loss in the pipe.

Variations in water distribution over sprinkler plots occurred more or less randomly. Therefore, a series of irrigations over the same area by sprinklers would tend toward uniformity, with subsequent irrigations correcting any deficiencies left by the first irrigation. To illustrate this, the values of E_d given at the first of this section were obtained by averaging the values of E_d calculated for each irrigation of each plot. The difference is 2.2 per cent. If instead the depth of water added to each sampling area is totaled over all irrigations for each method and the distribution efficiencies then calculated, the resulting values of E_d are 95.3 for sprinkler and 90.5 for furrow, a difference of 4.8 per cent. This indicates that the non-uniformities in sprinkler irrigation tended to compensate each other to a greater extent than in furrow irrigation.

Water distribution did vary slightly across the sprinkler plots. The sprinklers tended to apply slightly more water on the west side of the plot than on the east side, due to prevailing easterly winds during the irrigation season. Distribution parallel to the sprinkler laterals was quite uniform.

The effect of changes in intake rate on water application efficiency between the first and second irrigation has already been discussed. These changes also had an effect on water distribution efficiency. E_d increased from 71.3 per cent for the first irrigation to 76.1 for the second on the furrow plots. The change was caused because the reduced infiltration rates allowed the water to advance across the plots in a shorter length of time, thus allowing the upper and lower ends a more nearly equal time of intake.

A slight decrease in E_d was noted for sprinkler plots. Slightly more runoff occurred on the second irrigation. Runoff during sprinkler irrigation tends to decrease uniformity, causing more water to be stored in the down slope end of the plot.

Consumptive use efficiency.

The amounts of water added to the root zone by each irrigation method are shown in Table 1. On the average 3.85 inches were added to the root zone by sprinklers and 3.67 inches by furrows. This difference is not statistically significant. Therefore, growing conditions should have been comparable under both types of irrigation.

Sorghum yield samples were determined each year, Table 2. Yields averaged slightly higher for furrow-irrigated plots but the difference is again not statistically significant. Since the same water application produced the same yield for both irrigation methods, it can be concluded that consumptive use efficiencies were nearly identical.

Limitations.

The study just reported was conducted on a site with fine sandy loam soil and mild slope. Under these conditions a given amount of water was added to the soil with less total application by sprinklers than by furrow irrigation. Furthermore, the distribution of the applied water was more uniform when sprinklers were used. It must be emphasized that on different site conditions, considerably different results might be obtained from such a study. Differences in intake rate would be particularly likely to affect relative efficiencies of sprinkler and furrow methods.

An irrigation system for a given site cannot be selected only on the basis of efficiency. Economics, particularly cost of equipment, land preparation and labor, is a major factor. However, the cost of water saved by more efficient applications and profits from increased crop yields due to more uniform water distribution must be considered.

Conclusions.

Under one set of conditions, conducive to irrigation by either sprinkler or furrow methods, sprinklers applied water more efficiently than did the furrows. High water storage efficiencies can be obtained with either method. Water distribution was slightly better for sprinkler-irrigated plots than for furrow-irrigated plots. Consumptive use efficiencies did not differ between the two methods.

LITERATURE CITED

1. Beckett, S. H. , H.F. Blaney and C.A. Taylor, Irrigation Water Requirements of Citrus and Avocado Trees in San Diego, California, 1926 and 1927, California Agricultural Experiment Station Bulletin 489, 1930.
2. Corey, G.L. and V.I. Myers, Irrigation of Russet Burbank Potatoes in Idaho, Idaho Agricultural Experiment Station Bulletin 246, 1955.
3. Erie, L.J. and N.A. Domick, Soil Moisture Depletion by Irrigated Crops Grown in South Dakota, South Dakota State College Agricultural Experiment Station Circular 104, 1954.
4. Hamilton, F.B. and J.F. Schrunk, Sprinkler vs. Gravity Irrigation A Basis for Choice of the Best System, Agricultural Engineering, Vol. 34, 1953.
5. Hansen, V.E., New Concepts in Irrigation Efficiency, Transactions of the American Society of Agricultural Engineers, Vol. 3, No. 1, 1960.
6. Israelsen, D.W., W.D. Criddle, D.K. Furhiman, and V.E. Hansen, Water Application Efficiencies in Irrigation.
7. Matson, Howard, More Production from Improved Irrigation Practices, Agricultural Engineering, Vol. 24, 1943.
8. Schoenleber, L.H., A Study of Garden Irrigation, Agricultural Engineering, Vol. 24, 1943.
9. Sprinkler Irrigation, United States Bureau of Reclamation, 1949.
10. Walker, A.L. and D.E. Pauls, Comparison of Sprinkler and Surface Irrigation Methods, Washington Agricultural Experiment Station Circular 251, May 1954.

TABLE 1

Water Requirements and Irrigation Efficiencies of Sprinkler and Gravity Irrigation of Sorghum Plots

	Required Water Application, inches	Soil Moisture Increase, Corrected for use, inches	Water Application Efficiency, %	Runoff, % of total water applied
		1955		
›rinkler	14.2	11.8	83.0	1.70
urrow	14.0	11.0	77.0	7.38
		1956		
›rinkler	8.6	7.0	81.8	0.50
urrow	9.2	6.9	74.4	6.67
		1957		
›rinkler	7.6	6.2	81.6	0.65
urrow	8.7	6.0	69.0	10.25

TABLE 2

Yield of Grain Sorghum from Sprinkler and Furrow

Irrigated Plots

Yield, Bushels Per Acre

	Sprinkler	Furrow
1955	65.6	69.0
1956	67.6	69.2
1957	91.6	95.8

TABLE 3

Relative Water Distribution on Sprinkler and Furrow

Irrigated Plots*

Sprinkler			Relative Distribution Along Plot	Furrow			Relative Distribution Along Plot
A_1	A_2	A_3		A_1	A_2	A_3	
100.1	100.1	103.2	101.1	114.3	120.8	113.3	116.1
B_1	B_2	B_3		B_1	B_2	B_3	
87.9	101.5	95.4	94.9	92.8	102.3	102.2	99.1
C_1	C_2	C_3		C_1	C_2	C_3	
95.1	106.6	105.3	102.3	99.6	104.8	100.3	101.6
D_1	D_2	D_3		D_1	D_2	D_3	
96.5	111.6	97.1	101.7	81.9	77.0	92.3	83.7
tive ribution ss Plot							
94.9	105.0	100.2		97.2	101.2	102.0	

Each value represents the depth of water added to a sampling area xpressed as a per cent of the average depth of water added to the oot zone of the plot.