WIDE-SPACED FURROW OR BAND IRRIGATION AS A TOOL FOR DEFICIT IRRIGATION

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Wide-spaced furrow irrigation refers to furrow irrigation in which wetted furrows are spaced at least 9 feet apart (2, Note: parenthetical numbers refer to References). Several rows of crops (three or more) would be planted between the irrigation furrows (see Fig. 1). The benefits attributed to wide-spaced furrow irrigation in this paper were derived from studies with furrows at least 9 feet apart. Closer spacings might not be expected to show these benefits. The wide-spaced method does not necessarily refer to the common practice of alternate furrow irrigation unless the furrows are at least 4.5 ft. apart. Consider, for example, furrows 36 inches apart. Alternate furrows would then be 72 inches and not qualify as wide-spaced. In practice, to accomplish the wide-spaced method, one would plant and furrow as for normal irrigation and select the irrigation furrows to give the nine-foot spacing. For example, in a demonstration with 40-inch beds, we irrigated every third furrow to achieve the wide-spaced condition and achieved the benefits of wide-spaced furrow irrigation.

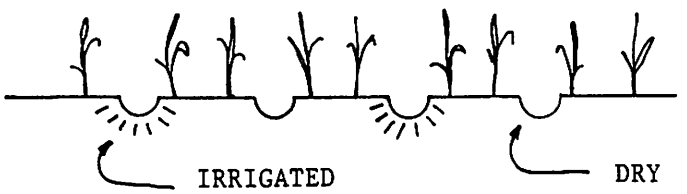

Fig. 1. diagram of wide-spaced furrow irrigation.

The wide-spaced method depends on lateral wetting of the soil to carry the water to roots between the wetted furrows. This can be expected to occur in fine textured soils. In furrow irrigation, fine textured soils wet about as far laterally from the furrow as they do vertically beneath the furrow. Sandy soils are not amenable to the wide-spaced method. They do not wet as far laterally as they do vertically. If the textural descriptor of the soil contains the word "clay," the method should work. For example, clay loam or silty clay loam have worked for us.

The method has been adapted to center pivot sprinkler irrigation. In this approach, water is applied through bubblers on drop tubes spaced at 9 or more

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feet. The bubblers were 18 inches above the ground (5). The field was furrow diked to provide deep basins between beds (4). We have used 56-inch and 60-inch furrow spacings. Water was contained close to the point of application by the basins and the net effect over the field was to have circular bands of irrigation alternating with dry bands. The irrigation effects appear to be similar to wide-spaced furrow irrigation. If low pressure is used, the method saves energy as well as water.

EXPECTATIONS FOR WIDE-SPACED FURROW IRRIGATION

Yield.

The wide-spaced method has been shown (1, 6, 7, and 8) to leave the surface of the soil in a drier condition than for the more common every-furrow irrigation, even though the irrigation was complete. The drier condition reduced evaporation loss, and this saving evidently meant more water available to the plant. This tended to cause the water to be used more efficiently, and in many cases, the wide-spaced method has resulted in no reduction in crop yield when compared to irrigation of every furrow (6). This may be surprising, since the wide-spaced method applies the same amount per furrow, but fewer furrows are watered.

The results of ten years of research on wide-spaced furrow irrigation of cotton in Oklahoma on the relationship between yields of wide-spaced and of every furrow irrigation are shown in Fig. 2 (6, 7). Note that yield is plotted against the amount of irrigation water taken up to get that yield. Also note that the wide-spaced treatments fall on a line above the every-furrow irrigated treatments. To see the significance of this, consider the vertical line on the graph. This line is an example of application of 9-inches of water to the root zone over the season. The point at which this line intersects the sloping lines shows that the wide-spaced treatment gives the higher yield for the water applied. In fact, this would be true for any water amount selected on Fig. 2. The wide-spaced irrigation line shows 60% higher yield at the 9-inch water uptake than the every furrow line. This means water use efficiency is 60% higher for the wide-spaced treatment.

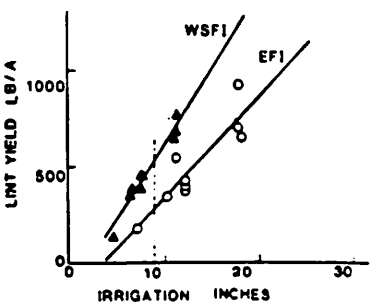

Fig. 2. Yields of cotton for wide-spaced furrow irrigation and every-furrow irrigation.

Grain sorghum studies at 3 locations in Oklahoma (6, 8, 9, and 10) gave results less well defined than cotton in Fig. 2. While the wide-spaced irrigation showed higher yield at any water input, it is only about 7% higher in efficiency. Yields ranged from 5,000 to 10,000 lb/A. This suggests that the sorghum crop is more forgiving of water stress than the cotton in Fig. 2. Nonetheless, we see that the wide-spaced method is more yield efficient than every furrow-irrigation for grain sorghum.

The wide-spaced method was studied in two growing seasons with corn in the Oklahoma Panhandle. The data are insufficient to compose response graphs like Fig. 2, but the wide-spaced method showed no benefit for corn. The study contained no provision to ensure a well-watered condition during the critical period of silking and pollination. In one season, leaves were noted to roll early in the summer in the non-watered furrows. Yield level was 145 bu/A.

Wide-spaced band irrigation produced the following for grain sorghum yields at Goodwell, OK (5): wide-spaced band plots yielded 6880 lb/A, standard LEPA irrigation yielded 6030 lb/A, and application by a uniform spray from drop tubes yielded 7160 lb/A. The same amount of water was applied to each plot. Variation between plots was such that we could not pronounce the yields different with 90% confidence. There is no reason to believe that a long-term study of wide-spaced band irrigation would show results different from the yield rankings obtained from wide-spaced furrow irrigation studies.

Water Application Characteristics of the Wide-Spaced Method

Experience has shown that a given water application rate to a furrow will move water more slowly along the furrow under wide-spaced irrigation than for every-furrow application (1). This appears to be because in a short time the adjacent furrows in every-furrow irrigation will wet across the bed to meet water moving laterally from the adjacent furrow. This essentially terminates lateral movement. From then on, water advances either downward or down field. In wide-spaced application, the lateral wetting movement from the furrows never meets. This gives continuing lateral movement it deducts from the water tending to move down field, so it moves more slowly down field. We have found as a rule of thumb, irrigating wide-spaced furrows at a stream 10% faster than for every furrow will cause equal rates of advance of water down the furrow. Of course, this percentage varies from soil to soil. With tight soils, the difference is less noticeable.

In some years the plants midway between irrigated furrow in wide-spaced application may stress, and yield may be reduced. This has been prevented by watering previously unwatered furrows on successive irrigations. Of course, since wide-spaced furrow irrigation applies half or less the amount of water per

wide-spaced method to apply the same amount of water to the roots. Thus, there is a tradeoff between the benefits of a drier surface and the need to irrigate more frequently. This is a lesser problem with center pivot application of wide-spaced band irrigation because of the lesser labor requirement.

It is sometimes difficult to determine when a furrow has been sufficiently watered when using the wide-spaced method. This is because a dry zone exists on the top of the bed. A useful guide is to apply water to a few furrows as every- furrow irrigation (8). Watering with a 10% greater furrow stream to the wide-spaced furrows should result in water moving down the furrows at the same rate as the every-furrow section. When the every-furrow section has watered through the field, irrigation is stopped in all furrows, wide-spaced and every. The every-furrow section should have watered across the beds (or intervening space), but the wide-spaced application should have a dry zone midway between irrigation furrows. This is normal irrigation for the wide-spaced furrows and must be tolerated.

USE FOR DEFICIT IRRIGATION.

Figure 2 and the results for grain sorghum show the results of actual studies of wide-spaced application of water. In general, if one were to apply water in the extreme, the curve of Fig. 3 would result (3). It shows one can apply water over and above what the plant can use. The region to the right of the "knee" is called luxury application. If water is cheap, it is one way of insuring that yield will not be limited by insufficient water. Persons interested in deficit irrigation certainly have no such luxury. The idea is to stay to the left of the knee but as close as irrigation water availability and yield goal permit.

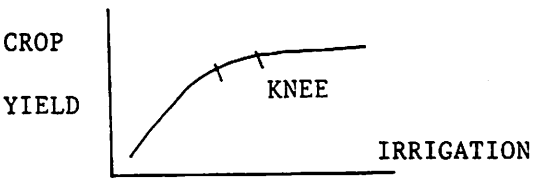

Fig. 3. Example of luxury irrigation.

In fact, with wide-spaced application, it is difficult to over-irrigate. Because lateral movement of water from the furrows proceeds throughout the irrigation set, we tend to approach the application amount of normal every-furrow irrigation at the most. Recall that after a wide-spaced application, we still have a dry zone midway between the irrigated furrows. By its very nature, the wide-spaced method tends to operate at the left of the knee in Fig. 3.

Generally, the yield of an irrigated field is related to the amount of water that passes through the plants (3). This may be different than the amount of water applied (be it irrigation or rain). The wide-spaced method tends to minimize runoff loss as well as deep percolation. More of the water is placed in the root zone than for every-furrow irrigation. This means that if we want the wide-spaced method to give the same

yield as every-furrow irrigation, we must eventually put the same amount of water through the plants. Further, we noted that the wide-spaced method, while more efficient, puts less water in the field than an every-furrow application. As we have noted this means that a wide-spaced irrigator must irrigate more frequently than an every-furrow irrigator to achieve the same yields.

PRACTICAL CONSIDERATIONS

Furrow Irrigation.

Deficit irrigation implies that annual application is below the knee of Fig. 3. If it is only slightly below, little yield is sacrificed and water is used at near maximum efficiency. For deficit irrigation we may try to withhold water during periods of the year when water is not critical for rapid growth, tasseling, pollination, and booting. This may permit even lesser seasonal water applications. However, this can be risky in seasons with low precipitation. Effects of stress may reduce yield because we did not have time to "rescue" the crop with an irrigation when mid-season stress was noted.

If we use wide-spaced application, we apply a reduced amount of water per irrigation, but tend to irrigate more frequently than for every-furrow irrigation. In this manner we can control our operating position on the curve in Fig. 3 without having a great risk of too infrequent irrigation. This is simply taking advantage of the water management characteristics of the wide-spaced technique. The amount of stress we get in deficit irrigation is thus moderated if we use the wide-spaced application; we have the possibility of entering stress with reduced risk of major yield reduction.

We noted above that one disadvantage of the wide-spaced method is that we tend to irrigate more frequently than with every-furrow irrigation, and labor tends to be more costly than for the every-furrow method. Obviously, this cost must be more than offset by the advantages expected from deficit irrigation. It certainly makes a producer think about the value of reduced risk.

Center Pivot Application.

The idea of Fig. 3 and the knee apply completely to center pivot delivery. The positive effect of wide-spaced band irrigation is most nearly realized if one applies water as described above: drop tubes, bubblers and use of beds and basins. In this manner, water is applied in significant amounts in a given basin and significant depth of penetration through the root zone is realized. This enhances the ability of the

irrigation to carry over to the next irrigation. This tends to lend the versatility needed for application to deficit irrigation.

The main control for application amount by center pivot systems is by frequency of irrigation. In principle, one could vary the speed of advance and the output of the bubblers. In practice, neither of these is usually variable except in experimental equipment. In the drop-tube technology, pressures are regulated at the bubblers and amount of water delivered can not be controlled by changing system pressure. A producer in the market for a new center pivot system might be well advised to purchase one that runs at the highest available speed so that a range of speed could be attained through use of a time-proportioning electric drive control. Control of speed can be useful in adjusting the advance to just fill the basins and avoid overtopping. Soil conditions at the time of bedding and diking can determine the capacity of the basins so that a speed of advance that worked well one year might not work as well in a following year.

REFERENCES

1. Hodges, M.E., J.F. Stone, J.E. Garton, and D.L. Weeks. 1989. Variance of water advance in wide spaced furrow irrigation. Agricultural Water Management. 16:5-13.

2. Hodges, M.E., J.F. Stone, and H.E. Reeves. 1989. Yield variability and water use in wide-spaced furrow irrigation. Agricultural Water Management. 16:15-23.

3. Kanemasu, E.T., J.S. Steiner, A.W. Biere, F.D. Worman, and J.F. Stone. 1983. Irrigation in the Great Plains. Agricultural Water Management. 7:157-178.

4. Solomon, S.G., Jr., M.P. Henderson, J.F. Stone, and R.L. Elliott. 1994. Bed and basin tillage practices for LEPA irrigation. Applied Engineering in Agriculture. 10(5):683-686.

5. Stone, J.F. and R.L. Elliott. 1993. An irrigation technology for saving energy and water. Completion report to Oklahoma Center for the Advancement of Science and Technology. Applied Research Project ARO-054. Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, OK.

6. Stone, J. F., J. E. Garton, B. B. Webb, H. E. Reeves, and J. Keflemariam. 1979. Irrigation water conservation using wide-spaced furrows. Soil Science Society of America Journal. 43:407-411.

7. Stone, J.F., and D.L. Nofziger. 1993. Water use and yields of cotton grown under wide-spaced furrow irrigation. Agricultural Water Management. 24:27-38.

8. Stone, J. F., H. E. Reeves, and J. E. Garton. 1982. Irrigation water conservation by using wide-spaced furrows. Agricultural Water Management. 5:309-317.

9. Stone, J. F., H. E. Reeves and T. Tsegaye. 1985. Irrigation water requirements under wide-spaced furrow irrigation. In Developments and Management Aspects of Irrigation and Drainage Systems. IR Div., Amer. Soc. Civil Engrs., New York, p. 462-468.

10. Tsegaye, T., J.F. Stone, and H.E. Reeves. 1993. Water use characteristics of wide-spaced furrow irrigation. Soil Science Society of America Journal. 57:240-245.