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Surge Flow Irrigation

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Furrow irrigation is the application of irrigation water in the furrows between crop rows. The water soaks into the soil as it runs down the furrow, spreading downward and laterally into the crop root area between the furrows. Since the furrow is the carrier for the irrigation water, the pump must produce only enough head to deliver the water to the high point of the field. Thus, the pumping cost per unit of water is lower for furrow irrigation (and other surface or gravity flow methods of irrigation) than for sprinkler irrigation methods.

The objective with any method is to apply the same amount of water to all of the irrigated area. With furrow irrigation, soil at the upper end of the furrow begins to absorb water when irrigation is started and may absorb a considerable amount of water before the flow reaches the lower end. Although the lower end of the furrow may contain water long after the flow is stopped at the upper end, it is very difficult to provide equal "opportunity time" for water absorption along all parts of the furrow and achieve uniform and efficient water application.

Seven factors (length of run, slope of the furrow, water intake rate of the soil, furrow shape, furrow roughness, furrow stream size and total application time) affect the amount of water absorbed in the soil, the uniformity of water absorption along the furrow and water losses through runoff and percolation beyond the crop root zone. Several practices and techniques are used to obtain uniform application of an appropriate amount of water to all parts of the field and minimize water losses.

Land Leveling or Grading

Moving soil in the field to establish a specific grade or slope along the furrows improves water distribution and makes irrigating easier. However, balancing the furrow stream size to the slope, length of run and water intake rate of the soil is still necessary. Excessive runoff from the lower ends of the furrows and deep percolation of water beyond the crop root zone will continue unless water application is carefully managed.

Cut-Back Furrow Streams

To achieve uniform absorption of water along the entire length of a furrow requires a large furrow stream to move water quickly to the lower end of the furrow. Excessive runoff occurs, however, if the large furrow stream is continued after water reaches the lower end of the furrow. Ideally, the furrow stream should be just large enough to maintain water in the furrow throughout its length after water reaches the lower end. The lower rate of flow, or cut-back furrow stream, is continued until the desired amount of water is applied. The cut-back furrow stream technique can produce reasonably uniform and efficient irrigation. This practice requires extra labor and is somewhat difficult to manage.

Short Runs-Level Slopes

Use of short rows and level fields allows a furrow to be filled quickly with a measured amount of water. The area irrigated is bordered with a ridge to contain the water until it is absorbed by the soil. The system achieves uniform water distribution and high application efficiency, but short rows are more difficult to farm mechanically and excess rainfall may present drainage problems.

Runoff Recovery-Reuse Systems

A furrow stream size which moves water quickly through the total length of run (but does not cause soil erosion) provides reasonably equal "opportunity time" for water absorption. However, excessive runoff is produced if continued after water reaches the lower end of the furrow. Runoff recovery-reuse systems collect and recirculate runoff to prevent water loss and achieve relatively high application efficiency in the sense that

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water loss is minimized. Installation of the water recovery system and pumping costs to recirculate the water add to the cost of irrigation.

Surge Flow Irrigation

Researchers and irrigators have been searching for ways to overcome some of the problems associated with furrow irrigation. Irrigators have frequently experienced difficulty in getting furrows to "water through" in preplant irrigation and in the first irrigation following major cultivation. Some irrigators discovered that water could be moved to the lower end of the furrow with less total irrigation time by interrupting furrow flow temporarily and then reapplying it later, a practice called "bumping". Surge flow irrigation, the intermittent application of irrigation water to furrows or borders in a series of on-off watering periods, was developed from this practice. After the water reaches the end of the furrows, on-off times can be adjusted to minimize runoff.

Reduced Water Intake Rate

Higher advance rates (water reaches the end of the furrow more quickly) with surge flow irrigation are caused by a reduction of the water intake rate of the soil during the off-time. The infiltration rate reduction is likely due to a combination of several of the following factors:

1. Swelling of clay particles.
2. Reduced soil matrix potential (distribution of infiltrated water).
3. Consolidation of top layer of soil.
4. Sediment deposition and downward movement.
5. Air re-entry in pore space of top layer of soil.

Benefits of Surge Flow Irrigation

The natural soil surface sealing that occurs following the first surge cycle aids irrigation efficiency by increasing the rate of water advance down the furrow, reducing variability in furrow stream advance and reducing deep percolation losses.

Cycling the furrow stream on and off gives an average furrow flow rate less than the instantaneous flow rate. Therefore, more furrows can be watered to the end of the field within a given time period and with a given water supply.

Surge flow irrigation allows light irrigations to be applied. As little as 2 to 3 inches of water can be applied uniformly providing some of the management flexibility afforded by sprinkler systems. Heavy water applications may take longer and result in greater runoff loss than with continuous flow, especially on slowly permeable soils and soils with plow-pans. Surge irrigation requires greater operator skill, record keeping and adjustments between irrigations to realize the potential for increased efficiency.

Surge Flow Equipment

The current practical application of surge flow irrigation consists of a surge valve controller and valve in a tee directly downstream of a main pipeline riser or outlet valve. Downstream from each side of the tee is a setting of gated pipe at the end of a "set" of furrows. The surge valve directs water alternately to one set of furrows and then to the other. The duration of flow to each set of furrows is regulated by the surge valve controller. Surge valves can be adapted easily to existing gated pipe systems.

Since its inception, surge flow methods and equipment have undergone significant development and refinement. Several valves and controllers are available varying from basic low cost units which offer few operating options to more sophisticated units. Select a valve controller with the capability to set two or more cycle times in an irrigation set.

Presently, there are two main types of surge flow valves: the bladder valve and the mechanical valve. The bladder valve contains an inflatable bladder in each branch of the tee that inflates to block flow and deflates to pass flow. The bladders are inflated by water pressure from the main pipeline or with air pressure. The mechanical valve is a butterfly disk valve either across the tee junction (single butterfly) or in each branch of the tee (double butterfly). The disk valves are powered by electricity (storage batteries or solar cells), air pumps, or water pressure.

Surge flow irrigation can be accomplished by manually changing the flow from one set of furrows to another set and then reversing the process some time later. For gated pipe systems, surge flow can also be created by shutting the pump on and off (manually or with a timer) provided crop water needs could still be met. Most irrigators would soon find it advantageous to purchase a surge valve to automate the process; however, either of these techniques would allow the use of surge flow on a trial basis.

Surge Flow Irrigation Management

Operators of surge flow systems have two primary objectives: advance water to the end of the furrows as quickly as possible and minimize runoff during the remaining portion of the irrigation application. Major variables that can be controlled are furrow stream size and surge cycle time.

The cycle time for surge flow is the length of time used for a complete on-off cycle (the water on-time plus the off-time). Proper cycle times may vary from 30 minutes to several hours depending on soils, length of furrow, furrow stream size and other variables. An excessive on-time would be similar to continuous flow irrigation and could cause excess deep percolation. The off-time for each cycle during the advance stage must be long enough to allow the furrow to become dewatered before the next surge.

The cycle ratio is defined as the surge on-time divided by the cycle time. Theoretically, cycle ratio can be controlled. In normal practice, however, two equal sets of furrows are irrigated, the furrow on-time equals the off-time and the cycle ratio is 0.5.

Appropriate furrow stream size and surge on-time depends on field length, furrow size and shape, soil infiltration characteristics and surface debris. Furrow stream size and cycle time should be relatively large for coarse-textured soils, long furrows, large furrows and abundant crop residues. On the other hand, smaller furrow streams and shorter cycle times are more appropriate for fine-textured soils and short, small, clean furrows.

An initial estimate of furrow stream size can be computed with the formula: Furrow stream, gpm = 0.02 x Furrow length, feet. For example, for a furrow 1000 feet long, use a 20 gpm furrow stream. Using the calculated furrow stream size as a starting point, set the appropriate number of furrows based on total flow rate available, Try different combinations of furrow stream size and on-time. The best combination is the one which moves water to the end of the furrow in the shortest time.

After water reaches the ends of the furrows, cycle time should be reduced to minimize runoff while irrigation continues until the desired amount of water is applied. Surge flow applications may need to run longer than continuous flow to obtain adequate moisture penetration. On soils with low intake rates, minimizing runoff while getting adequate water into the soil at the downstream end of furrows may be difficult. Two alternate management strategies are suggested for use after water has reached the end of furrows. Reduce cycle time until individual surges combine, creating steady flow at a cutback rate, or open both sides of the surge valve and irrigate furrow sets on both sides at a reduced (cutback) rate.

Surge flow does not reduce the actual water required by the crop. It may improve irrigation efficiency and allow a field to be covered more quickly when properly used. The application of adequate water to meet crop requirements is very important. Surge flow should be continued until the appropriate amount of water is applied.

Field Tests With Surge Irrigation

Satisfactory results have been obtained with surge flow irrigation on sandy soils (0.5 inch/hour water intake rate) and on finer-textured soils (0.3 and 0.1 inch/hour water intake rate) under certain conditions. Cycle times of 1 to 2 hours for sandy soils and 2 to 4 hours for fine-textured soils have worked well. The cycle time can be reduced to 30 to 60 minutes after water reaches the end of the field.

On a clay loam soil in the High Plains, total seasonal water intake was reduced 28 percent with surge flow. Intake was reduced 32 percent with surge in the first irrigation but only 16 percent for the next four irrigations. By reducing soil intake, surge flow reduces wetting of the deep soil profile (below the root zone) and results in more uniform soil water contents along the furrow as compared with steady flow irrigation.

In another test on clay loam soil, water applied with surge for pre-plant irrigation of corn was reduced 60 percent from 15.4 inches with steady flow irrigation to 6.3 inches with surge flow. Watering time was reduced from 570 minutes per acre with steady flow to 230 minutes per acre with surge flow. In similar tests on the same soil type however, surge flow increased application efficiency, but actually reduced distribution efficiency. Differences in soil preparation, soil compaction and management can produce radically different results.

Will Surge Flow Work for You?

Surge flow works in many, but not all, soils. Results are also subject to change over time. Experience with continuous flow irrigation will usually indicate if surge flow would be beneficial. For example, if there is a noticeable difference in how rapidly water moves down furrows for the first irrigation compared to subsequent irrigations, surge flow could be beneficial. Also, if conventional (steady) flow has been interrupted before a set was completed and the furrow stream advanced quickly past the previous wetting front when irrigation was resumed, surge flow should work on your soils. You can conduct a simple test by running two furrows of continuous flow irrigation alongside two furrows in which flow is interrupted and reapplied in successive surges. If the rate of advance is greater with the interrupted streams, surge flow would work on your soils.

Surge flow usually works best during pre-plant irrigation and the first seasonal irrigation following cultivation. Subsequent irrigations usually show less difference between continuous and surge flow irrigation methods. Surge flow has less effect on tire-compacted furrows than on non-wheel track furrows resulting in less variation in the rate of advance in compacted and non-compacted furrows. Surge flow may not improve irrigation efficiency in short, level furrows where irrigation efficiency is already relatively high.

Economics

The cost of surge flow valves per acre are low when the price is annualized over their useful life and divided over the acres on which they are used. The total annualized cost, shown in Table l, of surge flow irrigation must be tested against savings from reduced water requirement per acre or per unit of yield. Water savings required to break even on surge flow equipment is minimal, only 0.2 to 0.6 inches per year, according to the analysis. In addition, labor requirement may be reduced because two sets of furrows are made at a time.

However, better-trained labor might be required to work with surge flow compared to conventional irrigation.

Summary

Surge flow irrigation reduces deep percolation losses in many soils through a large decrease in infiltration rate during the off-time of the first surge cycle. Therefore, surge gives farmers an opportunity to apply lighter applications than with continuous flow irrigation. However, runoff losses may not be reduced. Lower crop yields due to lighter applications during high crop water use periods may be a problem if the system is not managed properly. The beneficial effects of surge are most dramatic on pre-plant irrigation and the first irrigation following cultivation, especially in non-wheel compacted furrows. It may be best to use surge for pre-plant irrigation or the first seasonal irrigation and use continuous flow irrigation, in some cases, for later seasonal irrigations.

Table 1. Annualized cost of surge flow equipment and required efficiency increase to break even.

Parameter	Surge Valve Diameter, inches			
	4	6	8	10
Flowrate handled, gpm	196	440	780	1220
Acres irrigated[1]	49	110	196	306
Initial cost, $[2]	1200	1400	1700	2000
Annualized cost, $/acre/yr[3]	10.90	5.65	2.70	2.90
Annualized cost, $/inch of water[4]	0.78	0.40	0.19	0.21
Cotton yield needed to break even, lbs[4,5]	22	11	5	6
Water savings needed, inches/yr[6]	0.6	0.3	0.2	0.2
Efficiency increase necessary to justify cost, %[7]	3	1	1	1

Assumptions:
1. Irrigation water supply is 4 gpm/acre.
2. Includes $500 flow controller and $700-$1500 valves, depending on size.
3. Annualized for 3 years @ 10% per year.
4. Assuming surge flow is used only on first of two seasonal irrigations of 7 inches each.
5. Cotton price of $0.50 per lb.
6. Cotton lint yield of 35 lbs/acre-inch.
7. Total irrigation water, including pre-plant, is 22 inches/yr.

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