

SURGE IRRIGATION : A NEW SURFACE IRRIGATION METHOD - A REVIEW

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ABSTRACT

Water is a basic need of any life. The "liquid gold" (water) is becoming scarce due to the demands from various quarters such as agriculture, industries and households. Advances in the field of irrigation management have led to the many water saving techniques such as furrow irrigation, drip and sprinkler irrigations. No doubt, these methods are useful for saving water, but all the farmers are not adopting because of their higher cost in the initial stage. Surge irrigation is another technology which uses less labour and costs besides saving water. It indirectly increases the net income of the farmers. Therefore, through this review an attempt has been made to compile the research on surge irrigation for advancing the surge science.

Surge irrigation is a new technique of irrigation where water is applied in a series of relatively short "ON" and "OFF" modes of constant or variable time spans. It will reduce infiltration as a result of which water front advance along the furrow is quickened and uniform wetting throughout the furrow is obtained. Surge irrigation was first introduced in Utah State University (USA) by Stringham and Keller (1979).

Surge flow Vs continuous flow irrigation

There was a significant difference between continuous flow and surge irrigation. Among the surface flow treatments with different cycle times and cycle ratio, differences were not observed (Bishop *et al.*, 1981; Podmore and Duke, 1982; Podmore *et al.*, 1983). Velocity of advancement under surge flow irrigation was higher than continuous flow with the same amount of water delivered to the furrow (Mostafazadeh, 1990). Surge flow irrigation was more efficient than continuous flow irrigation and it reduced both amount of water used and irrigation time by 30% (Shih and Chang, 1990).

Mechanism for reducing infiltration rate

Water front advances faster with surge flow due to reduction in infiltration rate compared to continuous irrigation (Stringham and Keller, 1979). Soil particles were oriented

in a plate like structure during 'OFF' time (Allen, 1980). The reductions in infiltration rate occurred during dewatering period following the initial wetting (Coolidge *et al.*, 1982). Surge irrigation required less opportunity time to produce an equivalent reduction in the filtration rate than continuous irrigation (Malano, 1982). Infiltration rate declined to steady state after one surge cycle (Izuno *et al.*, 1985). Surge flow recorded steady state infiltration rate of one and half of those measured under continuous flow irrigation (Podmore and Duke, 1982). Mechanisms by which surge irrigation reduced infiltration include the following as stated by various researchers (Malano, 1982; Blair, 1984; Samani *et al.*, 1985; Kemper *et al.*, 1988).

- * Surface soil consolidation due to negative hydraulic gradients developed in the soil water during flow interruption.
- * Filling of cracks, which formed in the furrow bed when flow is interrupted by bed load when re-enters the furrow.
- * Water remaining in the furrow after each flow interruption infiltrates and deposits leading to sealing of the furrow bed.
- * As a result of wetting by the advancing water front more complete disintegration of soil particles occur in the wetted perimeter.

- * Hydration and swelling of clay particles.
- * Air entrapment.

In clay loam soil, compacting of furrows during 'OFF' time of first irrigation cycle did not produce a corresponding reduction in infiltration occurred end of first 'ON' time (Izadi and Wallender, 1985). Intermittent application of water increased the instantaneous intake rate of the soil if the soil's bulk density did not change during the 'OFF' time. If the soil's bulk density change is high enough to off set the effect of the increased hydraulic gradient during the 'OFF' time then the intermittent application of water will reduce instantaneous intake rate of the soil (Samani *et al.*, 1985). Intermittent flow increased the degree of soil aggregates breakdown and amount of sediment erosion and deposition in furrows and thus the formation of surface seals. However, this effect reversed if the erosiveness of the flow reached a level such that the surface seal erodes away (Kemper *et al.*, 1988).

Air entrapment

If the air is entrapped in the soil profile, the entrapped air compresses and increases the air pressure, reduces the hydraulic gradient and thus reduced the infiltration rates. The pressure of trapped air within the soil profile increased until other internal pressure reached a certain value thereafter the air escapes through a surface via large pores (Jarette and Fritton, 1978). This reduced air pressure allows infiltration to continue at an increased rate. Surface layer soil is consolidated due to increase in soil water suction during the 'OFF' time of surge flow which reduced infiltration rates. This reduction in infiltration rate was due to both vertical consolidation and lateral shrinkage (Jalali *et al.*, 1990).

Surface sealing

A major portion of the fine sediment is carried to the tail end of the furrow under continuous irrigation whereas in surge flow irrigation the suspended sediment is deposited

on the furrow bed when the water supply is interrupted before water reaches the end of the furrows. Soil surface sealing produced a 2000 fold decrease in hydraulic conductivity of the soil surface layer in fine sandy loam (Intyre, 1958). Surface seal significantly decreased the soil permeability (Falayl and Bouma, 1975).

Field evaluation parameters of surge irrigation

a. Stream size

Furrow irrigation guidelines for continuous flow can be used to obtain maximum non-erosive stream size and length of run for surge flow (Jenson, 1981; USDA-SCS, 1986). Larger stream size produced faster advancement even though cycle 'ON' times were reduced to give equal volume water during surge flow treatment. Even after 5 surge cycles the stream size below 0.95 lps did not reach to field end (Izuno and Podmore, 1986). A stream size of 1.5 lps was optimum for 150 m length and 60 cm wide furrow. There was no difference between 1 and 1.5 lps and again between 1.5 and 2 lps (Dhanapal, 1996).

b. 'ON' and 'OFF' time

The 'ON' and 'OFF' time in surge flow irrigation is important because it decides the number of surge cycles required for an irrigation. This depends on furrow length, soil type, infiltration rate etc. Either too long or too short cycle of 'ON' and 'OFF' time will not produce desired surge effect. Surge cycles of 4 to 6 was optimum for advancing the water to the end of the furrow with 'ON' time equals of 'OFF' time with cycle ratio of 0.5 (Humpherys, 1978). The 'ON' time of about 1.3 times the field wet advance time is recommended for the last surge for high intake rate soils whereas only 0.75 times the wet advance time is sufficient for low intake rate soils (Izuno and Podmore, 1986). Four surge cycles were recommended for furrows upto 400 m and 4 to 6 surge cycles were recommended for over 400 m. The 'ON' time for the second surge

can be determined from the field trial by measuring the time required for water to advance already wetted furrow length and an additional 100 to 150 m of dry furrow or alternatively add to the initial 'ON' time required for water to advance the already wetted furrow length of first surge (USDA-SCS, 1986). The 'ON' time should be long enough to allow the irrigator to adjust for uniform advance in all furrows (Cornick *et al.*, 1986). For relatively short field length either constant 'ON' time or variable distance method is recommended (Alemi and Goldhamer, 1988). The initial 'ON' time can be approximately time required by advance to reach 20 to 30 % of the total furrow length (Israeli, 1988). There was no significant difference in advance rate between continuous flow and surge flow irrigation (Goncalves *et al.*, 1993). Surge flow with 'ON' time of 10 and 15 minutes were better for 150 m furrow length with a flow rate of 1.5 lps over the surge flow treatment with 'ON' time of 20 minutes (Dhanapal, 1996).

c. Quantity of water needed to complete advance

In surge irrigation, quantity of water needed to complete advance is less compared to continuous irrigation. The volume ratio (volume of water used to complete surging is divided by volume required with continuous flow) is used to compare the volume required under surge and continuous flow. For non-wheel track furrow on a silt loam soil, the advance time for surge flow was 3 to 4 times faster than continuous flow irrigation (Bishop *et al.*, 1981). The volume ratio ranged from 0.38 to 0.95 for a clay loam soil with 0.4% slope (Coolidge, 1981; Walker and Schlegal, 1984; Testezlaf, 1985). Volume of water applied during the advance phase surged non-wheel track furrow was 36% of that required for continuous stream while for surged wheel track furrow was 60% (Izuno *et al.*, 1985). The volume ratio for three soil types *viz.*, sandy

loam, clay loam and silty clay soils was 0.61 and during advance phase of surge and continuous irrigation significantly differed volume of water applied (Goldhamer *et al.*, 1987). The volume of water applied during a season with surge irrigation was 31% lesser than continuous flow irrigation and average reduction in cumulative water intake was 24% (Musick *et al.*, 1987). Surge irrigation required a volume ratio of 0.53 and 0.73 for the stream size of 0.433 and 0.483 lps respectively (Humpherys, 1989). Total elapse time required to complete the irrigation was higher in the continuous flow irrigation than surge irrigation. The irrigation time to complete the irrigation was higher in farmer's method (basin furrow) and continuous flow than surge flow irrigation (Dhanapal, 1996).

d. Infiltration under surge irrigation

The major benefit from surge irrigation is reduction in infiltration rate (Malano, 1982). Coarse textured sandy loam soil have show greater reduction in intake rate in response to surge irrigation than fine textured soils such as silt and clay loam (Walker *et al.*, 1982; Testezlaf *et al.*, 1987). Surge irrigation reduced cumulative intake by 17% during the next four irrigation following the first (Musick *et al.*, 1987). Infiltration rate at the beginning of the second surge was 58% of the rate at the end of the first surge (Purkey and Wallender, 1989).

e. Surge irrigation on soil properties

Bulk density and saturated hydraulic conductivity of soil were significantly changed after intermittent wetting and drying under laboratory conditions (Samani *et al.*, 1989). Due to soil consolidation, water suction increased from 0 to 100 cm of water and consolidated soil by 1.4 mm and 5.1 mm for powdered sand and greely soil respectively under surge irrigation (Jalali *et al.*, 1990). Flow interruption in surge irrigation increased bulk density by 100 kg m⁻³ and decreased infiltration by 25% compared to continuous flow (Trout,

1991).

f. Irrigation efficiency

Surge irrigation during advance phase have the highest application efficiency (Izuno and Podmore, 1986; Almei and Goldhamer, 1988). An irrigation efficiency of 85% for surge flow irrigation compared to 55% for continuous irrigation (Israeli, 1988). Application efficiency was 80% under surge irrigation (Evans *et al.*, 1990).

g. Advance phase

A rapid furrow stream advance was the main effect of surge irrigation (Bishop *et al.*, 1981). There was no increase in application efficiency in surge irrigation if there was no cut back during the post advance phase (Podmore and Duke, 1982). Water advance rate was higher with the surge flow system than continuous flow irrigation (Vega, 1988). Velocity of advance under surge irrigation was higher than continuous flow with the same amount of water delivered to the furrow and this higher advance rate reduced the difference in intake opportunity time (Mostafazadeh, 1990).

h. Run off

The runoff in surge irrigation can be minimized by irrigating in two phase such as advance phase and post advance phase. To give the water requirement of continuous flow, a flow rate that would minimize runoff is recommended (Izuno and Podmore, 1986). Runoff rate of about 75% of continuous flow was recorded in surge flow. Well managed surge flow irrigation reduced runoff and increased uniformity of water distribution in furrows (Humpherys, 1989).

i. Labour requirement

Due to high water advance rate and higher irrigation efficiency of surge irrigation, it requires less labour for irrigation management than continuous irrigation. Two sets of furrows irrigated simultaneously under surge flow irrigation and thus it required less labour than

continuous irrigation (Israel and Leibrock, 1993). More labour was required under farmers practice of irrigation (Basin furrow) than continuous flow irrigation whereas surge irrigation needed the lowest man hours for irrigation (Dhanapal, 1996; Sathyamoorthy, 1997).

j. Organic residues

Substantial amounts (25 g of wheat straw/metre length) of crop residue increased roughness, decreased the flow velocity and resulted slower rates of advance and slower rates of wetting of the soil (Miller *et al.*, 1986). Infiltration rates were higher in furrows with crop residues than clean furrows. Furrows that contain grown crop residues were more effective in reducing erosion than furrows without crop residues (Brown *et al.*, 1988). In general, coconut fibre waste applied @ 10 t/ha took one more surge cycle to complete the irrigation as compared to FYM applied @ 12.5 t/ha (Dhanapal, 1996; Sathyamoorthy, 1997).

Yield response to method of irrigation

Yield reduction of 6.5% in corn with surge irrigation was recorded than continuous irrigation (Musick *et al.*, 1987). Surge irrigation produced yields similar to that of cablegation but was higher than continuous flow irrigation (Israeli, 1988). Seven per cent more corn yield was obtained under surge irrigation than continuous flow irrigation (Israel and Leibrock, 1993). However in sunflower there was no significant difference in yield between surge irrigation and continuous flow irrigation (Rajagopal and Dhanapal, 1994). While in maize, surge irrigation produced yield similar to that of farmers method of irrigation (Basin furrow) (Rajagopal and Lalitha, 1994; Dhanapal, 1996). Similarly in sunflower, yield from surge irrigation was comparable to continuous irrigation and farmers method of irrigation (Sathyamoorthy, 1997).

Penultimate depression

In sunflower, the yield progressively

increased as the distance advances in surge and parameters and yield were obtained in sector continuous irrigation except at the third 1 (0-25 m) and gradually reduced upto sector distance (50 - 75 m) (Rajagopal and Dhanapal, 3 (50-75 m) and again increased in the sector 1994). In maize, higher growth, yield 4 (75-100 m) (Dhanapal, 1996).

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