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Stream Size Optimization for Furrow Irrigation in Clay Loam Soil

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ABSTRACT

Surface irrigation is most common method of irrigation and most widely used in the world, due to low cost in the initial stage and easy to operate. Realizing the fact that surface irrigation will remain as the most adoptable irrigation method for the farmers of India, a surface irrigation method which is a modification of surge irrigation is proposed in the present study. In the proposed irrigation method irrigation is accomplished by applying inlet stream into furrows intermittently in place of conventional continuous stream application. The hydraulic behavior is studied under intermittent water application. The study involves development of relationship between advance function. The analysis of variance was also carried out for water front advance length, depth of infiltration time and water required under different spells of irrigation The advance under first spell was found similar to continuous application while during second spell and subsequent spells the water front travel fast over the portion which was already wetted by previous spells. Faster advance in intermittent irrigation suggested reduction in infiltration rate relative to continuous application. Stream size significantly affected water front advance time and water utilized. Stream size of 1.5 lps stream in spell irrigation resulted in to maximum saving in time (13.0 %) and water (12.8 %) followed by 1.0 lps stream. However 2.0 lps stream consumed more time and water to cover a targeted furrow length in spell irrigation. Intermittent water application in furrow irrigation saved water front advance time and volume of water. A saving of 11- 23% in time of water front advance and saving of 16-22 % water was obtained when water was applied in 2- spells rather than continuous application for stream size of 1.0 lps and 1.5 lps.

Key words : *Stream size optimization, Furrow irrigation, Clay loam soil*

Introduction

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. Irrigation increases crop productivity. Advances in the field of irrigation management have led to the many water saving techniques such as drip and sprinkler irrigations. These methods are useful for saving water, but all the farmers are not adopting because of their higher cost in the initial stage.

Furrow irrigation is the most commonly used irrigation method used in the world. Simplicity of design and low capital investment have contributed to its popularity. Continuous furrow irrigation usually causes excessive deep percolation at the upper part of the furrows, insufficient irrigation at the lower part and considerable runoff, resulting in low application efficiencies and distribution uniformities. Furthermore, excessive flow rates cause erosion at the soil. To improve its performance, several variations of the method have been developed, among them the technique of surge irrigation.

Surge irrigation is new technology which uses less labour and costs besides saving time and water. It indirectly increases the net income of the farmers. Surge irrigation is a 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. The concept of Surge was first developed by Keller and Stringham of Utah State University (USA, 1979). Surge irrigation is the practice of intermittently starting and stopping the stream flow in the furrow to quickly advance the water across the field. Initial runs down the field help to seal the soil surface, making succeeding runs easier. Surge can reduce tail water runoff at the end of the row and deep percolation at the beginning of the row. As research on surge irrigation has continued (Bishop *et al*.1981) and results have generally confirmed that surge irrigation reduces irrigation advance time, and has the potential to reduce application volumes and improves application efficiency. Coolidge *et al.* (1982), suggested that the intermittent application of water to furrow (surging) decreases the infiltration rate over time. Decrease in the infiltration rate along with changes in the hydrodynamic characteristics of the furrow usually results in quicker advance times and improved application uniformity. After the first surge, the intake rate is significantly reduced resulting in more uniform intake opportunity time over the entire length of the furrow, and a more uniform infiltration profile is expected. Many researchers investigated surge irrigation through studying the infiltration process and the associated hydraulic changes. Forrest *et al*. (1984) concluded that compaction of the soil improves the efficiency of continuous irrigation to a value closer to the efficiency of surge irrigation.

Study Area and Basic Characteristics of the Soil

The area selected for the study was a research field situated at the Demonstration unit of the College of Agricultural Engineering at J.N.K.V.V. Jabalpur, Madhya Pradesh. The texture of soil of experimental area was clay-loam having Bulk density as 1.5 gcc^{-1}, field capacity 32 %, permanent wilting point 15 % and depth of available water per meter of soil depth is 17 cm/m. The soil contains: clay 39.52%, silt 27.82% loam 32.65% and slope of the experimental site is 0.15 %.

Preparation of the Field

The workable plot size was 51 m×42 m with an aggregate size of 55 m×45 m. The field operation was carried out using tractor drawn plough followed by disc harrow and cultivator and then ridge planter was used for making furrows in the field**.** After that manual dressing was done to form furrows. There were total 66 furrows in the field. The width of furrow was 0.45 m and spacing between the furrows was 0.70 m with the length 42 m

The experiment was conducted as per split plot design, with three levels of discharge rates, four water application spells, and four replications.

Experimental Details

Main treatment – 3 discharge rates
Q_1 = 1 lps per m width of furrow
Q_2 = 1.5 lps per m width of furrow
Q_3 = 2 lps per m width of furrow
Sub treatment – 4 water application spells
S1 = 1– spell
S2 = 2– spell
S3 = 3– spell
S4 = 4– spell
Plot size – 42 m×51 m
Replication – 4
Total treatments combination – 48
Water application

Water was applied to the furrow from the upstream end using a tube well; a ball valve assembly is used to control stream size according to the plan of work.

Water front advance under different spells with different stream sizes

Water front advance with respect to time was noted at every 5 m distance along the length of furrow. A representative advance curve for the stream size of 1.0 lps, 1.5 lps and 2.0 lps is shown in Figure 1-3. Water front advance for all other treatment are presented in appendix B.

Water front advance as observed under different treatments revealed that advance under first spell was found similar to continuous stream application and during second spell the water travel fast over the soil which is already wetted during previous spell, but the rate of advance was slowed down as it travelled over the dry portion of furrow; and as in third spell the water travel more faster than 2- spell over the wetted portion and in fourth spell the water travel more faster than 3- spell and as the stream was cut-off, the travelling speed of water lower down.

Analysis of variance

The experimental finding of present investigation undertaken to study the response of various spells and stream size on the water front advance, volume of water used. For this statistics method is employed under which analysis of variance is used for the study.

Three discharge rates; 1.0, 1.5, 2.0 lps were tried on 0.15% land slope in clay loam soil of the experimental field. There were four levels of water application selected on these discharge rates. The whole experiment was replicated four times. An analysis of variance was performed with split plot design.

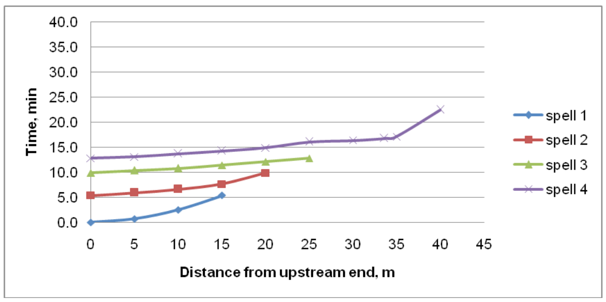

Fig. 1. Water front advance in 4-spell for 1.0 lps

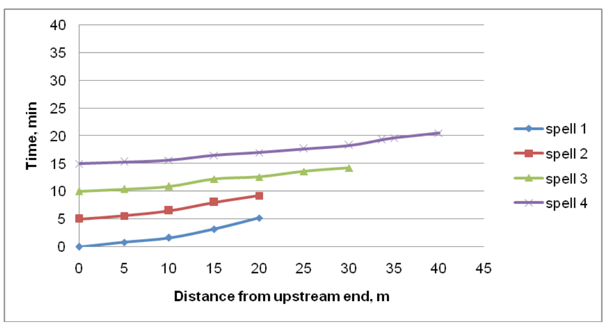

Fig. 2. Water front advance in 4-spell for 1.5 lps

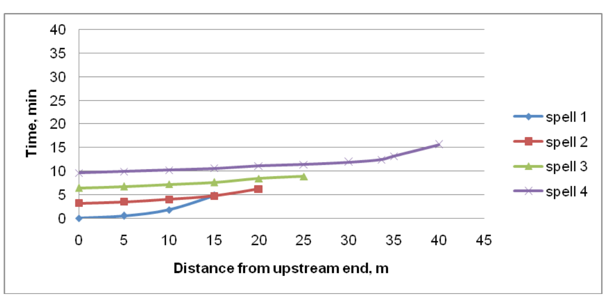

Fig. 3. Water front advance in 4-spell for 2.0 lps

Effect of stream size and application spells on water front advance

The water front advance was measured at every 5 m distance. The cut-off of 80 percent was practiced in all the treatments. The results of the experiment regarding water front advance is shown in Table 1. This table shows the advance time in min. of different spells under different stream size and their replications. In 1 lps stream size, the value ranges from 11 min- 17.6 min. The minimum value of 11 min was found in 3- spell of first replication and found maximum 17.6 min in first spell of fourth replication. In 1.5 lps stream size the value ranges from 11.6 min – 20.8 min. The minimum 11.6 min. was found in 2-spell of fourth replication and maximum 20.8 min was found in 4- spell of second replication. In the same way, in the stream size of 2.0 lps the value ranges from 11.6 min- 21.1 min. The minimum of 11.6 min was found in 2- spell of third replication, and maximum of 21.1 min was found in 4- spell of first replication.

Results showed significant difference among main treatments. Under stream size of 1.0 lps, the advance time of a water front is about 12.7% less than treatment Q_2, i.e. 1.5 lps stream (Table 3). The water front advance time for other treatment, i.e. Q_3 (2.0 lps) was found numerically higher than Q_1 but still about 9.2 % lower than Q_2. It may be seen that the advance time increases with increase of discharge rate of 1.5 lps from 1.0 lps but decrease after 1.5 lps discharge.

The spell time considerably saves time of application though was not found significant. The advance time saving was increasing from continuous spell to double spell but increases in triple spell and in 4 – spell. The advance time was found more than as obtained in continuous water application (S1).

Among different main treatments the water coverage was found fastest with the use of 1.0 lps stream size followed by 2.0 lps and 1.5 lps. The water front advance time was found minimum (14 min.) in 2-spells followed by 3- spell.

Table 1. Water front advance as affected by stream size and spells:

Stream size	Replications Spells	R1	R2	R3	R4	Total
1.0 lps	Q_1S1	17.3	12.8	15.4	17.6	63.1
	Q_1S2	12	12.7	15.2	13.2	53.1
	Q_1S3	11	14.6	13.3	12.8	51.7
	Q_1S4	16.8	16.2	14.6	15.9	63.5
	Total	57.1	56.3	58.5	59.5	231.4
1.5 lps	Q_2S1	20.3	19	14.8	17.2	71.3
	Q_2S2	16.7	14.3	12.9	11.6	55.5
	Q_2S3	17.8	16.4	15.2	15.4	64.8
	Q_2S4	19.3	20.8	13.2	16.2	69.5
	Total	74.1	70.5	56.1	60.4	261.1
2.0 lps	Q_3S1	12.4	12.6	15.8	12.4	53.2
	Q_3S2	17.5	15.8	11.6	14.4	59.3
	Q_3S3	16.2	14.1	15.6	12.2	58.1
	Q_3S4	21.1	12.4	18.6	16.8	68.9
	Total	67.2	54.9	61.6	55.8	239.5
	GT	198.4	181.7	176.2	175.7	732.0

When applying stream size of 1.0 lps, the water front could cover the targeted length at fastest rate in 3- spell followed by 2- spell (Figure 4.15). But under 1.5 lps stream, the targeted length covered at fastest rate in 2- spell followed by 3- spell and 4- spell. The positive effect of spells to save advance time was not obtained for the stream size of 2.0 lps as continuous water application gave maximum saving.

Effect of stream size and application spells on volume of water used

Volume of water is the total amount of water required to completely irrigate the furrow, in all stream size and in all spells.

The Table 4 shows the volume of water required in liter, in different spells under different stream size and their replications. In 1 lps stream size, the value ranges from 660 - 1056 lit, the minimum value 660 was found in 3- spell of first replication and found maximum 1056 lit in first spell of fourth replication. In 1.5 lps stream size the value ranges from 1044 – 1872 lit. The minimum 1044 lit was found in 2- spell of fourth replication, and maximum 1872 lit was found in 4- spell of second replication. In the same way, in the stream size of 2.0 lps the value ranges from 1392 - 2532 lit. The minimum of 1392 lit was found in 2- spell of third replication, and maximum of 2532 lit was found in 4- spell of first replication.

Results showed significant difference among main treatments. Under stream size of 1.0 lps, the

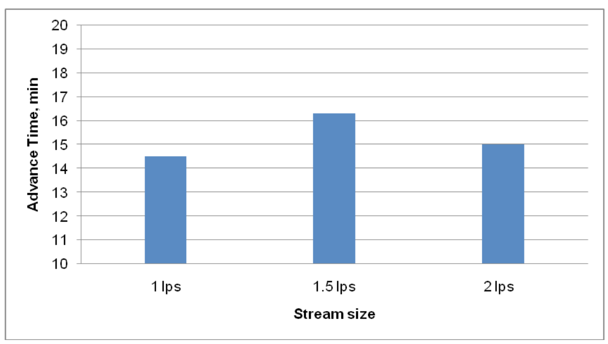

Fig. 4. Water front advances for different stream size

Table 2. ANOVA for Water front advance

Source	Df	Ss	Ms (Ss/Df)	Fcal (Rmss/Emss)	Table 5%	Table 1%
Rep	3	28.2	9.4	1.1	4.8	9.8
MT	2	29.5	14.7	1.7	5.1	10.9
Error A	6	51.1	8.5			
ST	3	56.4	18.8	0.02	3.0	4.6
Int.	6	11541.5	1923.6	2.2	2.5	3.6
Error B	27	23118.9	856.3			
Total	47	11468.6	244.0			

Table 3. Two way table of water front advance

Stream size	Spell					
	S1	S2	S3	S4	Total	Mean
Q_1	63.1	53.1	51.7	63.5	231.4	14.5
Q_2	71.3	55.5	64.8	69.5	261.1	16.3
Q_3	53.2	59.3	58.1	68.9	239.5	15.0
Total	187.6	167.9	174.6	201.9	732.0	45.8
Mean	15.6	14.0	14.6	16.8	61.0	
Sem MT	0.7	Sem ST	8.4			
CD	2.5	CD	24.5			

Table 4. Effect of stream and application spells on volume of water, liter

Stream size	Replications Spells	R1	R2	R3	R4	Total
1.0 lps	Q_1S1	1038	768	924	1056	3786.0
	Q_1S2	720	762	912	792	3186.0
	Q_1S3	660	876	798	768	3102.0
	Q_1S4	1008	972	876	954	3810.0
	Total	3426.0	3378.0	3510.0	3570.0	13884.0
1.5 lps	Q_2S1	1827	1710	1332	1548	6417.0
	Q_2S2	1503	1287	1161	1044	4995.0
	Q_2S3	1602	1476	1368	1386	5832.0
	Q_2S4	1737	1872	1181	1458	6248.0
	Total	6669	6345	5042	5436.0	23492.0
2.0 lps	Q_3S1	1488	1512	1896	1488	6384.0
	Q_3S2	2100	1896	1392	1728	7116.0
	Q_3S3	1944	1692	1872	1464	6972.0
	Q_3S4	2532	1488	2232	2016	8268.0
	Total	8064.0	6588.0	7392.0	6696.0	28740.0
	GT	18159.0	16311.0	15944.0	15702.0	66116.0

Table 5. ANOVA for volume of water required

Source	DF	SS	MS (SS/DF)	Fcal (RMSS/EMSS)	Table 5%	Table 1%
Rep	3	310881.5	103627.2	1.3	4.8	9.8
MT	2	7094914.7	3547457.3	44.2	5.1	10.9
Error A	6	481855.0	80309.2			
ST	3	428210.5	142736.8	0.02	3.0	4.6
Int.	6	108369109.7	18061518.3	2.2	2.5	3.6
Error B	27	216889294.3	8032936.8			
Total	47	100826086.0	2145235.9			

Table 6. Two way table for volume of water required, liter

Stream Size	Spell					
	S1	S2	S3	S4	Total	Mean
Q_1	3786.0	3186.0	3102.0	3810.0	13884.0	867.8
Q_2	6417.0	4995.0	5832.0	6248.0	23492.0	1468.3
Q_3	6384.0	7116.0	6972.0	8268.0	28740.0	1796.3
Total	16587.0	15297.0	15906.0	18326.0	66116.0	4132.3
Mean	1382.3	1274.8	1325.5	1527.2	5509.7	
SEm MT	708	SEm ST	818.2			
CD	245.1	CD	2374			

volume of water required was about 40 % less than treatment Q_2, i.e. 1.5 lps stream (Table 6) and about 50 % less volume of water required when compared to treatment Q_3 of 2.0 lps. It is clearly shown from the table that as stream size increases than volume of water requires also increases.

When compared to spell, spell- 2 and spell-3 takes less volume of water compared to continuous water application (S1). But in spell- 4 it take about 10 % more volume of water as compared to continuous spell (S1).

Among different main treatments the volume of water required was found lowest with the use of 1.0 lps stream size followed by 1.5 lps and 2.0 lps. The volume of water required was found minimum in two spells followed by three spell.

When applying stream size of 1.0 lps, the minimum volume of water required to cover the targeted length in 3- spell followed by 2- spell. But under 1.5 lps stream, the volume of water required to cover the targeted length was found less in 2- spell followed by 3- spell and 4- spell. The positive effect of spells to save water was not obtained for the stream size of 2.0 lps as continuous water application gave maximum saving of water.

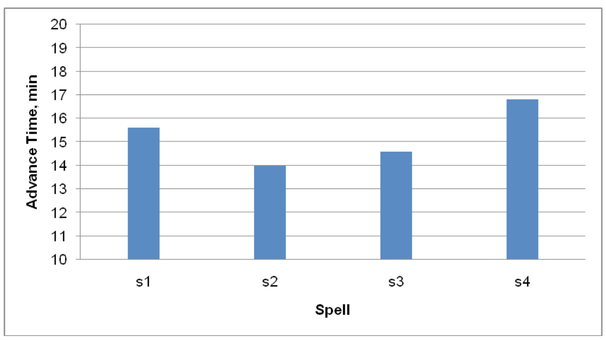

Fig. 5. Water front advances for different spell

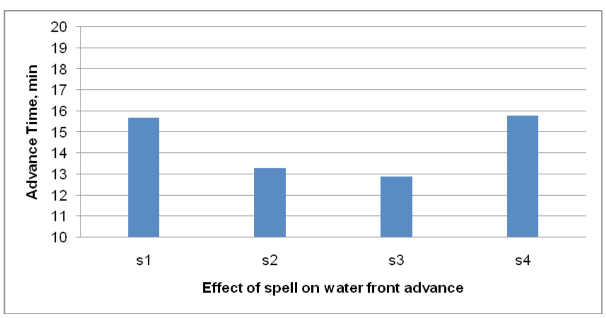

Fig. 6. Water front advances for the stream size of 1.0 lps

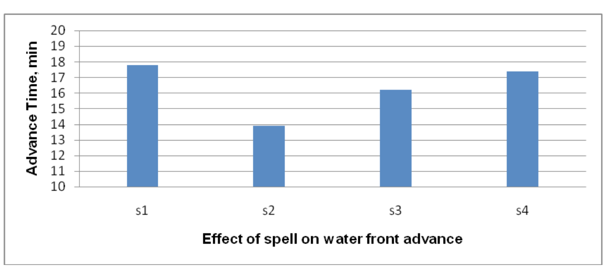

Fig. 7. Water front advances for the stream size of 1.5 lps

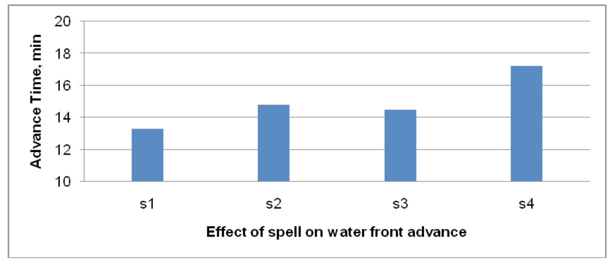

Fig. 8. Water front advances for the stream size of 2.0 lps

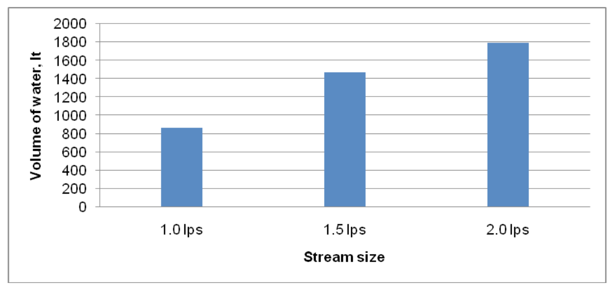

Fig. 9. Volume of water required in different stream size

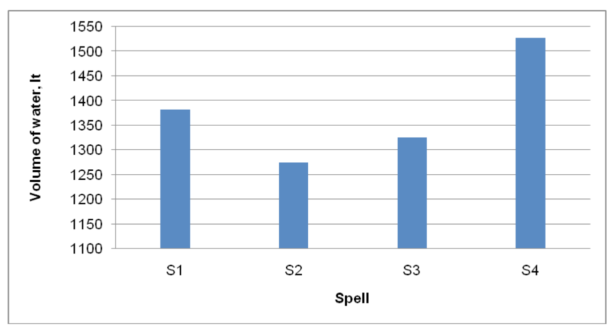

Fig. 10. Volume of water required in different spell

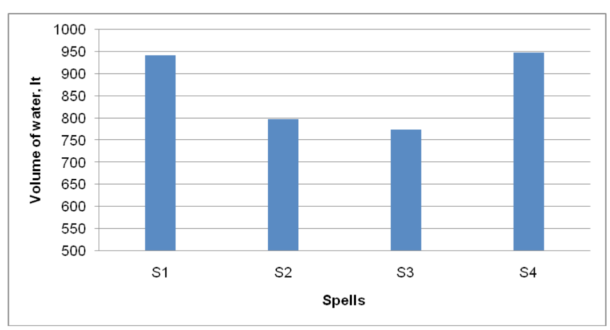

Fig. 11. Volume of water used in stream size of 1.0 lps.

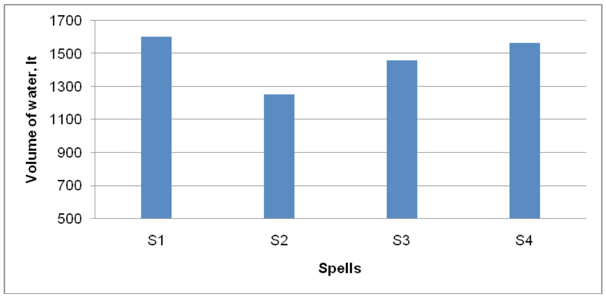

Fig. 12. Volume of water used in stream size of 1.5 lps.

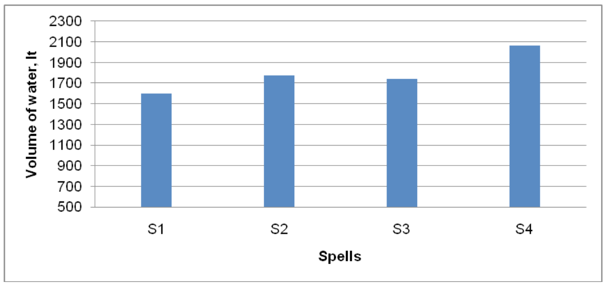

Fig. 13. Volume of water used in stream size of 2.0 lps.

Salient features of the findings of these experiments are presented below.

1. Stream size significantly affected water front advance time and water utilized. Stream size of 1.5 lps stream in spell irrigation resulted in to maximum saving in time (13.0 %) and water (12.8 %) followed by 1.0 lps stream. However 2.0 lps stream consumed more time and water to cover a targeted furrow length in spell irrigation.
2. Intermittent water application in furrow irrigation saved water front advance time and volume of water. A saving of 11- 23% in time of water front advance and saving of 16- 22 % water was obtained when water was applied in 2- spells rather than continuous application for stream size of 1.0 lps and 1.5 lps.

References

Alemi, M.H. and Goldhamer, D.A. 1988. Surge irrigation optimization model. *Trans. ASAE.* 31: 519-126.

Allen, N.L. 1980. *Advance rate in furrow irrigation in cycled flow*. M.S. Thesis, Utah State University, Logan, U.S.A. P: 79.

Bautista, E. and Wallender, W.W. 1985 Spatial variability of infiltration in furrows. *Trans. ASAE.* 15(5): 992-995.

Bishop, A.A., Walker, W.R., Allen N.L. and Poole, G.J. 1981. Furrow advance rate under surge flow systems. *ASCE J. lrrig. Drain.* 107 : 257-259.

Blair, A.W. and Smerdon, E.T. 1987. Modelling surge irrigation infiltration. *ASCE. J Irrigation and Drainage Engineering.* 113 (4) : 497-515.

Blair, A.W. 1984. In: *Proc. on Surge flow Irrigation.* Taxas Agricultural Service, Midland. P: 1-12.

Brown, M.J. 1988. Sediment, erosion and water intake in furrows. *Irrig. Sci.* 9 : 45-55.

Camacho, E., Roldan, J. and Alcaide, M. 1993 Comprision between continuous and surge flow irrigation. *International commission on irrigation and drainage.* 15th Congress university of cordoba, Spain. Pp:1305-1314.

Cavanaugh, P. 1986. Suge irrigation : sealing soil to save water. *California Arizona cotton*. August :4,5,8.

Coolidge, P.S. 1981. *Advance rate under an automated pulsed flow irrigation system.* M.S. Thesis. Utah State University, Logan. P: 152.

Coolidge, P.S., Walker, W.R. and Bishop, A.A. 1982. Advance and runoff surge flow furrow irrigation *ASCE. J. Irrig. Drain.* 108 : 35-42.

Evans, R.G., Girgin, B.N., Chenoweth, J.F. and Kroeger M.W. 1990. Surge irrigation with residues to reduce soil erosion, *Applied Engg. Agric.* 10 : 175-179.

Goldhamer, D.A., Alemi, M.H. and Phane, R.C. 1987. Surge vs continuous flow irrigation. *California Agric.* 41 (9 &10) : 29-32.

Goncalvers, J.M. 1993. In: *Proc. of 15th Cong. of International Commission on Irrigation and Drainage, Athens,* P: 403-415.

Humpherys, A.S. 1978. In: *Proc. of 10th Cong. of International Commission on Irrigation and Drainage, Athens*, P: 90-98.

Humphreys, A.S. 1989. Surge irrigation. 1. An over-view. *ICID Bull.* 2 : 35-48.

Intyre, M.C. 1958. Permeability measurements of soil crust formed by rainfall drop impact. *Soil Sci.,* 85: 185-189.

Israeli, A. 1988. Comparision of surge and cablegation to continuous furrow irrigation. *ASAE Paper No.* 88 : 2014.