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STUDY OF ALTERNATIVE DESIGN PARAMETERS OF FURROW IRRIGATION SYSTEM USING WINSRFR

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ABSTRACT

Surface irrigation is the oldest and most widely used method for irrigating agricultural lands across the world. Surface irrigation systems are characterized by their operational simplicity and their complicated analysis and design. Furrow irrigation is widely used because of its low cost and energy requirement. The pressurized irrigation systems i.e. sprinkler and drip irrigation systems, are usually more efficient than the furrow irrigation Therefore, the furrow irrigation system should be designed in such a way to ensure an adequate and uniform water application over the fields and to minimize the potential water losses. The aim of this study is to simulate furrow irrigation systems using the WinSRFR. Based on WinSRFR simulation results, in furrow irrigation of wheat crop in the field near padra village, different optimum design alternatives which can achieve reasonable water application efficiency, even more than 70%, could be selected. Choosing selected length and spacing of field could be selected in the range of 300-400 m and 0.1-0.4 m respectively. The furrow design alternatives number of furrows 90-130, Inflow rate from 25-35 l/s, cutoff time 6-10 hr , and slope of 0.001-0.005 m/m. The furrow design alternative of length 315 m, spacing 0.2 m, number of furrows as 100, field slope as 0.002 m/m, Inflow rate as 30 l/s and cutoff time as 8 hr are good alternative. The result shows that adequate and efficient irrigations can be obtained using furrow irrigation with maximised distribution uniformity and application efficiency through a proper selection of alternatives.

Keywords: *Application efficiency, Distribution uniformity, Furrow irrigation, Optimum length, wheat*

INTRODUCTION

Surface irrigation systems have the largest share in irrigated agriculture all over the world. The performance of surface irrigation systems highly depends upon the design process, which is related to the appropriateness and precision of land levelling, field shape and dimensions, and inflow discharge. Surface irrigation is mainly divided in basin, border, and furrow systems. It is widely utilised and therefore a well-known system, which can be operated without any high-tech applications. In general, it is more labour intensive than other irrigation methods.

Furrow irrigation avoids flooding the entire field surface by channelling the flow along the primary direction of the field using 'furrows,' 'creases,' or 'corrugations'. Water infiltrates through the wetted perimeter and spreads vertically and horizontally to refill the soil reservoir. Furrows are often employed in basins and borders to reduce the effects of topographical variation and crusting. Furrow irrigation is widely used because of its low cost and energy requirement. The pressurized irrigation systems i.e. sprinkler and drip irrigation systems, are usually more efficient than the furrow irrigation

Therefore, the furrow irrigation system should be designed in such a way to ensure an adequate and uniform water application over the fields and to minimize the potential water losses.

Simulation in surface systems is the process of mathematically describing the hydraulic characteristics of water as it flows from one end of the field to the other. This is achieved by use of computer models based on mathematical equations known as Saint Venant equations. SIRMOD (Walker 1997) and WinSRFR (Bautista et al. 2009) appear to be the most widely used simulation models. Appropriate design of surface irrigation systems requires a complex manipulation of data, models, and decisions. Gonçalves et al. 2009 suggested that The multicriteria approach integrated in a DSS enables to solve that complexity while creating and ranking a large number of design alternatives.

Mohsen A. El-Adl 2010 evaluated improvement of surface irrigation efficiency using COMPUTER SIMULATION model. The objective of the model is to evaluate the actual irrigation performance parameters with those calculated by the program and increase the efficiency of furrow irrigation system under different factors that affecting the system design. Prajapati and Suryanarayana 2014 used Computer simulation modelling for irrigation of water in surface irrigation system. Simulation models help irrigators make informed decisions concerning that irrigation practices. Shah and Suryanarayana 2017 concluded that Simulation is used for modification of field size and prevalent for irrigation in surface irrigation system using best possible alternatives like field length and field width.

STUDY AREA AND METHODOLOGY

Fig.1 shows Study area of present study Padra, Vadodara district in Gujarat, India. For infiltration rate infiltrometer test is performed on field and for type of soil, Sedimentation analysis is performed.

For the area taken under study, as per sedimentation analysis soil is loamy and as per infiltrometer test infiltration rate is 10 mm/hr. Here type of crop is Wheat. Following data were collected for simulation of furrow irrigation system, Max. depth (100 mm), Bottom width (100 mm), and side slope (1 m/m). Manning's Roughness coefficient is 0.03.

For simulation, various data are collected from the field, such as Maximum Depth (mm), Bottom width (mm), side slope (m/m), and Manning's roughness coefficient. Where,

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application efficiency (%), Low-quarter adequacy, Tail water ratio (%) and Deep percolation loss (%) are determined in the

Fig.1. Study area at Padra

furrow irrigation system. It is necessary to keep field slope not more than 0.5% in wheat crop. For the area under study cutoff time, depending upon electricity available between 6 hr and 10 hr, in the present study, six alternatives have been used, i.e.: change in Length (L) from 300 m-400 m, change in furrow Spacing (FS) from 0.1m -0.4 m, change in Number of furrows per set from 90-130, change in Field slope(S_0) from 0.001m/m -0.005 m/m, change in Inflow rate(Q) from 25l/s - 35 l/s, and cutoff Time(Tco) from 6 hr-10 hr. First four alternatives related to field parameter and remaining two alternatives related to water application.

RESULTS AND DISCUSSION

Here, the area under study get less Application efficiency than 70 % that's why it is necessary to increase the application efficiency more than 70 % and also low quarter adequacy should be equal to 1 so field under study is fully irrigated. If low quarter adequacy should be greater 1 so field under study is over irrigated. For better crop production, there have been six alternatives used.

They are given as:

Alternative-1: change in Length (300-400 m)

Alternative-2: change in spacing (0.1-0.4 m)

Alternative-3: Change in number of furrows per set (90-130)

Alternative-4: Change in field slope (0.001-0.005 m/m)

Alternative-5: Change in inflow rate (25-35 l/s)

Alternative-6: Change in cutoff time (6-10 hr)

Alternative-1: change in Length (L)

Table 1: application efficiency (%), low quarter adequacy, deep percolation loss (%) and tail water loss (%) for a various changes in length

Length (m)	300	310	315	320	340	350	370	380	400
Application Efficiency (%)	69	71	72	73	77	79	82	83	85
Deep Percolation loss (%)	15	15	15	15	15	15	15	15	15
Low quarter adequacy	1.04	1.01	1	0.98	0.92	0.89	0.82	0.77	0.67
Tail water Loss (%)	15	13	12	11	8	6	3	2	0

As shown in Table 1, as Length increases from 300 to 400 m, Application efficiency increases from 69 to 85% as per fig.2, Deep percolation loss remain constant as per fig.3, Low quarter adequacy decreases from 1.04 to 0.67 as per fig.4, and tail water loss decreases from 15 % to zero as per fig.5.

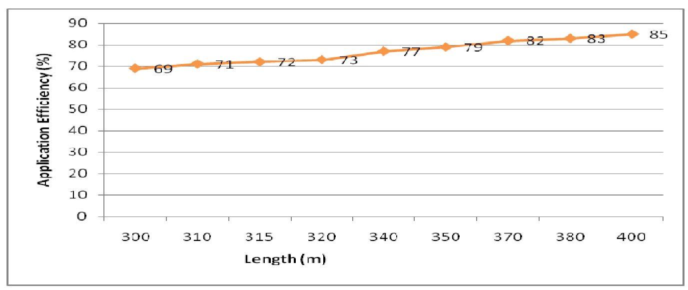

Fig.2 Application Efficiency at various Lengths

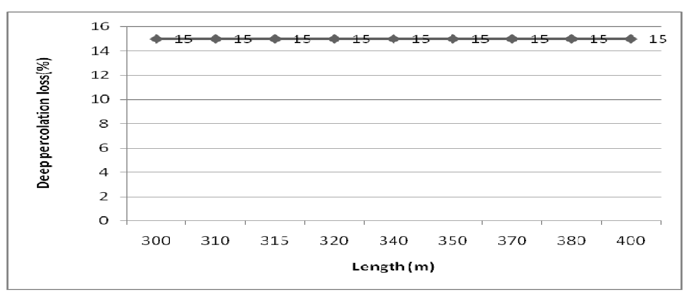

Fig.3 Deep percolation loss at various Lengths

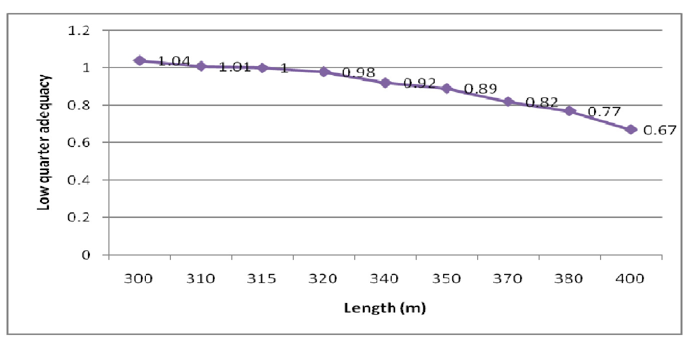

Fig.4 Low quarter adequacy at various Lengths

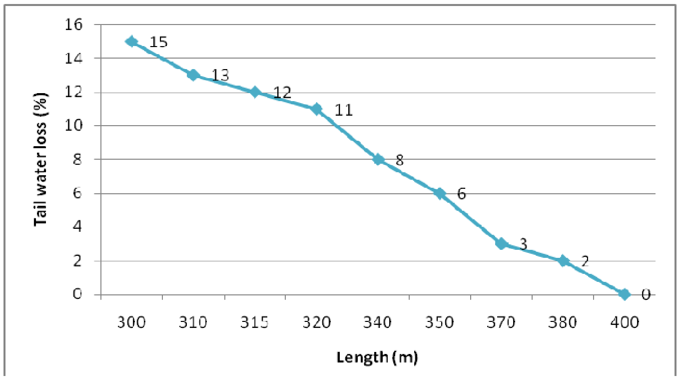

Fig.5 Tail water loss at various Lengths

The results obtained from various changes in length reveals that for the length of 400 m, Application efficiency, Deep percolation loss, and Tail water loss are obtained as 85%, 15%, and 0% respectively. Similarly for length of 300 m, Application efficiency, Deep percolation loss, and Tail water loss are obtained as 69%, 15%, and 15% respectively. But, for the above said both scenarios, low quarter adequacy is 0.67 in case of 400 m length and 1.04 in case of 300 m length, which suggests that 400 m should not be preferred as the criteria of low quarter adequacy says that it should be equal to 1. Therefore the optimum length is determined by varying the length from 300 m -400 m as given in Table 1, and the optimum values are obtained for length of 315 m with Application efficiency, Deep percolation loss, Low quarter adequacy and Tail water loss of 72%, 15%, 1.00, and 12% respectively.

Alternative-2: change in Spacing (m)

Table 2: Application efficiency (%), low quarter adequacy, deep percolation loss (%) and tail water loss (%) for a various changes in Spacing(m)

Spacing(m)	0.1	0.2	0.25	0.3	0.35	0.4
Application Efficiency (%)	36	72	84	85	85	85
Deep percolation loss (%)	12	15	15	15	15	15
Low quarter adequacy	1.29	1	0.71	0.21	0	0
Tail water loss (%)	52	12	1	0	0	0

As shown in Table 2, as Spacing increases from 0.1 to 0.4 m, Application efficiency increases from 36 to 85% as per fig.6, Deep percolation loss increases from 12 to 15 as per fig.7, Low quarter adequacy decreases from 1.29 to zero as per fig.8, and tail water loss decreases from 52 % to zero as per fig.9.

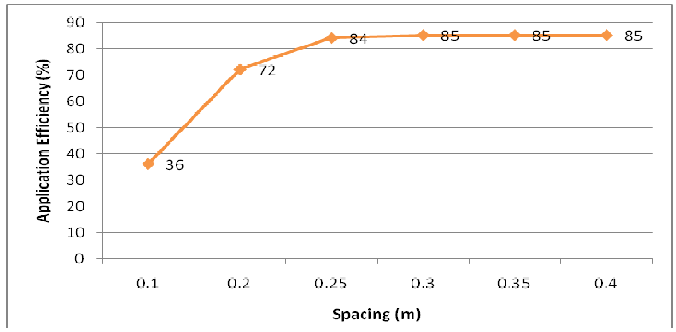

Fig.6 Application Efficiency at various spacing

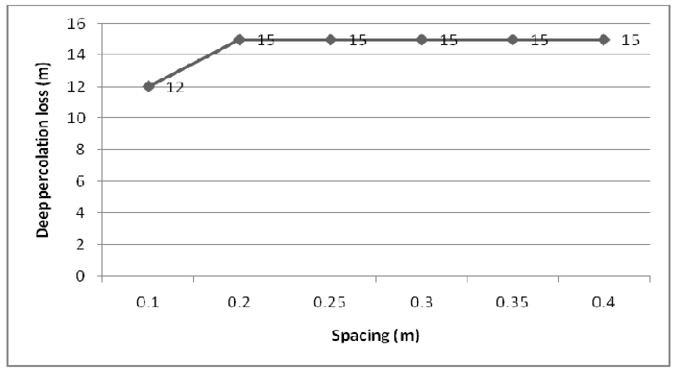

Fig.7 Deep percolation loss at various spacing

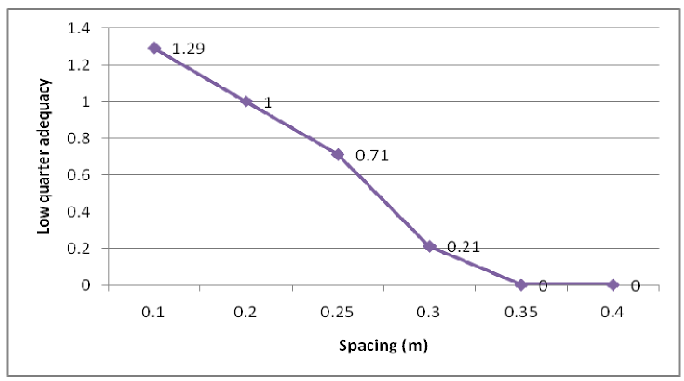

Fig.8 Low quarter adequacy at various spacing

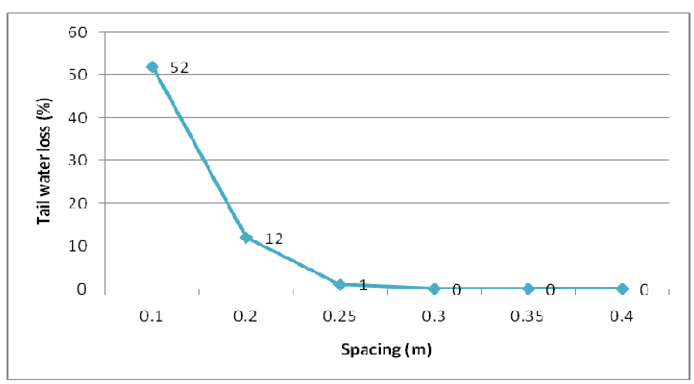

Fig.9 Tail water loss at various spacing

The results obtained from various changes in spacing reveals that for the spacing of 0.4 m, Application efficiency, Deep percolation loss, and Tail water loss obtained as 85%, 15%, and 0% respectively. Similarly for the spacing of 0.1 m, Application efficiency, Deep percolation loss, and Tail water loss obtained as 36%, 12%, and 52% respectively. But, for the above said both scenarios, low quarter adequacy zero in case of 0.4 m spacing, and 1.29 in case of 0.1 m spacing, which suggests that 0.4 m should not be preferred as the criteria of low quarter adequacy says that it should be equal to 1. Therefore the optimum spacing is determined by varying the spacing from 0.1m -0.4 m as given in Table 2, and the optimum values are obtained for spacing of 0.2 m with Application efficiency, Deep percolation loss, Low quarter adequacy and Tail water loss of 72%,15%, 1.00, 12% respectively.

Alternative-3: change in number of furrows

Table 3: application efficiency (%), low quarter adequacy, deep percolation loss (%) and tail water loss (%) for a various changes in Number of furrows

number of furrow per set	90	**100**	110	120	130
Application Efficiency (%)	66	**72**	78	83	85
Deep percolation loss(%)	15	**15**	15	15	15
Low quarter adequacy	1.08	**1**	0.9	0.78	0.6
Tail water loss (%)	19	**12**	7	2	0

As shown in Table 3, as no. of furrows increases from 90 to 130 m, Application efficiency increases from 66 to 85% as per fig.10, Deep percolation loss remain constant as per fig.11, Low quarter adequacy decreases from 1.08 to 0.6 as per fig.12, and tail water loss decreases from 19 % to zero as per fig.13.

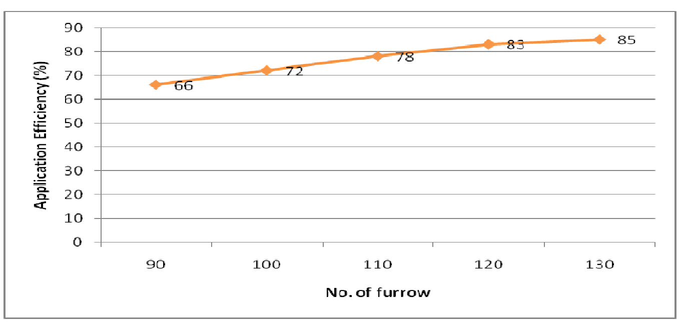

Fig.10 Application Efficiency at various no. of number of furrows

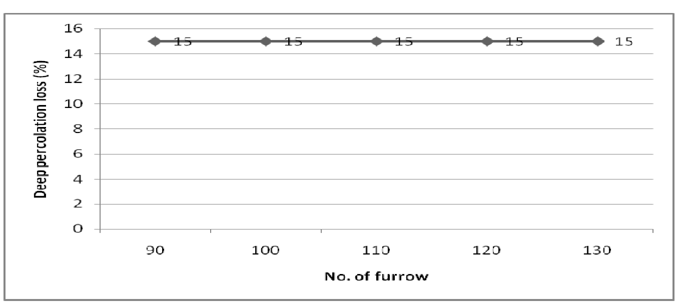

Fig.11 Deep percolation loss at various numbers of furrows

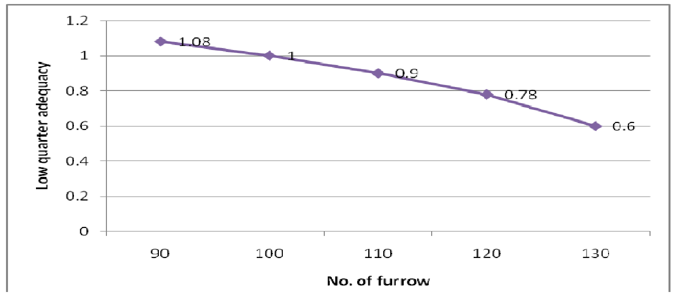

Fig.12 Low quarter adequacy at various numbers of furrows

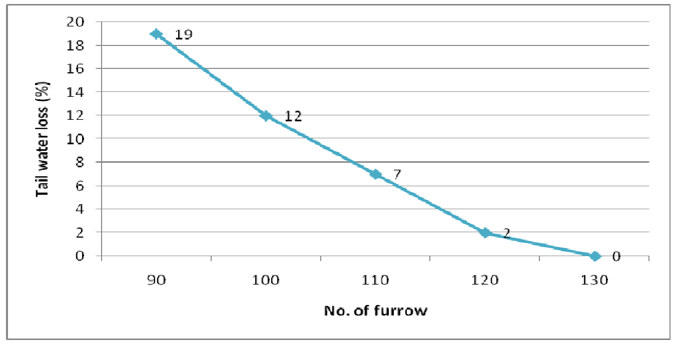

Fig.13 Tail water loss at various numbers of furrows

The results obtained from various changes in number of furrows reveals that for the number of furrows 130, Application efficiency, Deep percolation loss, and Tail water loss obtained as 85%, 15%, and zero respectively. Similarly for the number of furrows 90, Application efficiency, Deep percolation loss, and Tail water loss obtained as 66%, 15%, and 19% respectively. But, for the above said both scenarios, low quarter adequacy 0.6 in case of 130 number of furrows, and 1.08 in case of 90 number of furrows, which suggests that 130 should not be preferred as the criteria of low quarter adequacy says that it should be equal to 1. Therefore the optimum number of furrows is determined by varying the number of furrows from 90-130 as given in Table 3, and the optimum values are obtained for number of furrows 100 with Application efficiency, Deep percolation loss, Low quarter adequacy and Tail water loss of 72%,15%, 1.00, 12% respectively.

Alternative-4: change in field slope (m/m)

Table 4: application efficiency (%), low quarter adequacy, deep percolation loss (%) and tail water loss (%) for a various changes in field slope (m/m)

field slope (m/m)	0.001	**0.002**	0.003	0.004	0.005
Application Efficiency (%)	72	**72**	72	72	72
Deep percolation loss (%)	16	**15**	15	15	15
Low quarter adequacy	1	**1**	0.99	0.99	1
Tail water loss (%)	12	**12**	13	13	13

As shown in Table 4, as field slope increases from 0.001 to 0.005 m/m, Application efficiency remain constant as per fig.14, Deep percolation loss decreases from16 to 15% as per fig.15, Low quarter adequacy decreases from 1 to 0.99 and then 1 as per fig.16, and tail water loss increases from 12 to 13 % as per fig.17.

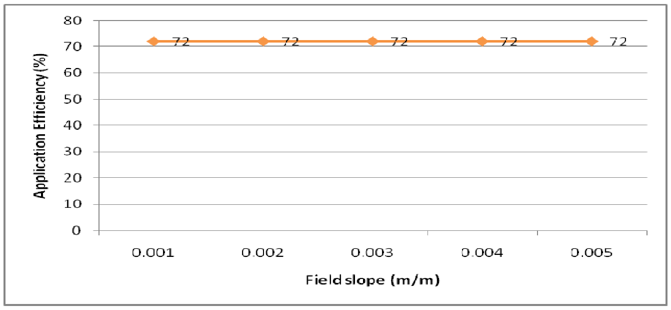

Fig.14 Application Efficiency at various field slope

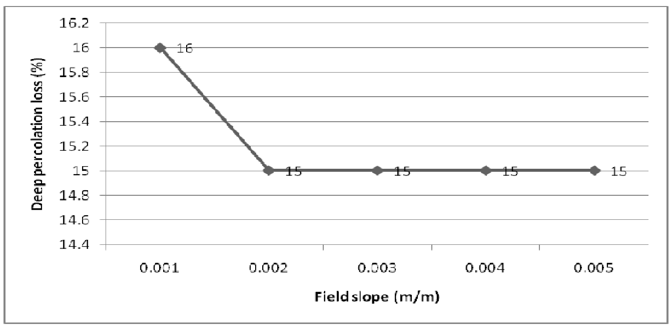

Fig.15 Deep percolation loss at various field slope

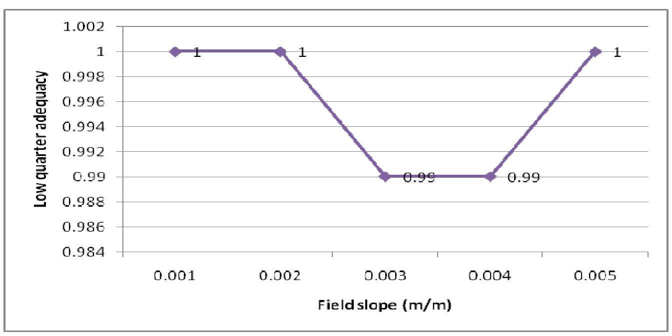

Fig.16 Low quarter adequacy at various field slope

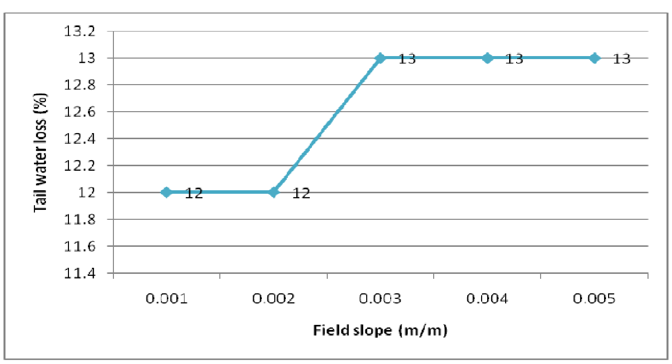

Fig.17 Tail water loss at various field slope

The results obtained from various changes in field slope reveals that for the field slope 0.005 m/m, Application efficiency, Deep percolation loss, and Tail water loss obtained as 72%, 15%, and 13% respectively. Similarly for the field slope 0.001 m/m , Application efficiency, Deep percolation loss, and Tail water loss obtained as 72%, 16%, and 12% respectively. But, for the above said both scenarios low quarter adequacy 1 in case of 0.005 m/m field slope, as well as in case of 0.001 m/m field slope, which suggests that it is necessary to check other efficiency also. Therefore the optimum field slope is determined by varying the field slope from 0.001 m/m-0.005m/m as given in Table 4, and the optimum values are obtained for field slope 0.002 m/m with Application efficiency, Deep percolation loss, Low quarter adequacy and Tail water loss of 72%,15%, 1.00, 12% respectively.

Alternative-5: change in inflow rate (l/s)

Table 5: application efficiency (%), low quarter adequacy, deep percolation loss (%) and tail water loss (%) for a various changes in inflow rate (l/s)

Inflow rate (l/s)	25	28	**30**	32	35
Application Efficiency (%)	83	77	**72**	68	63
Deep percolation loss (%)	15	15	**15**	15	15
Low quarter adequacy	0.78	0.93	**1**	1.05	1.1
Tail water loss (%)	2	8	**12**	16	22

As shown in Table 5, as inflow rate increases from 25 to 35 l/s, Application efficiency decreases from 83 to 63% as per fig.18, Deep percolation loss remain constant as per fig.19, Low quarter adequacy increases from 0.78 to 1.1 as per fig.20, and tail water loss increases from 2 to 22 % as per fig.21.

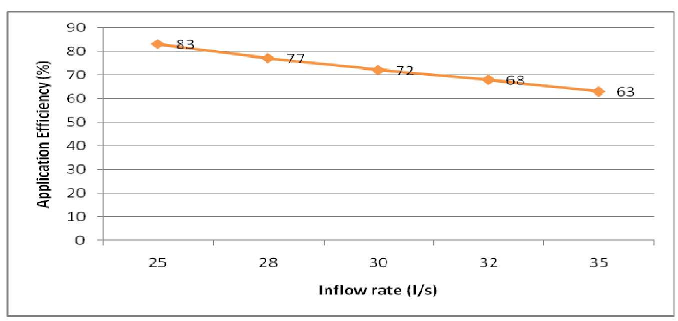

Fig.18 Application Efficiency at various Inflow rate (l/s)

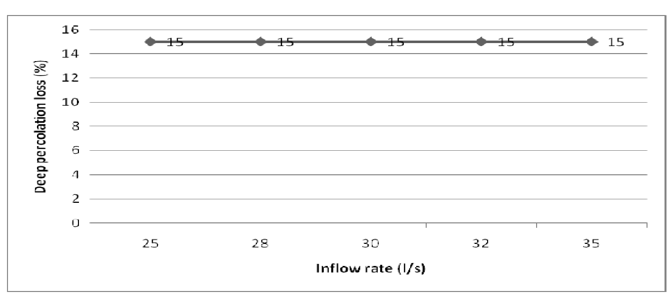

Fig.19 Deep percolation loss at various Inflow rate (l/s)

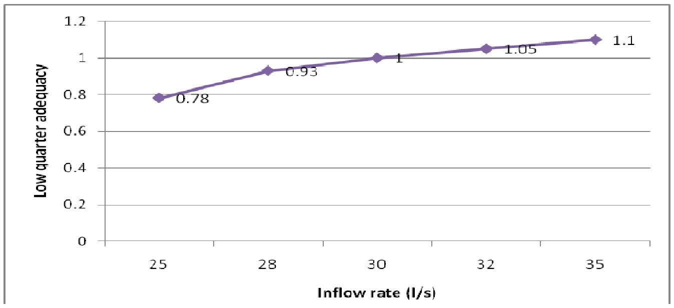

Fig.20 Low quarter adequacy at various Inflow rate (l/s)

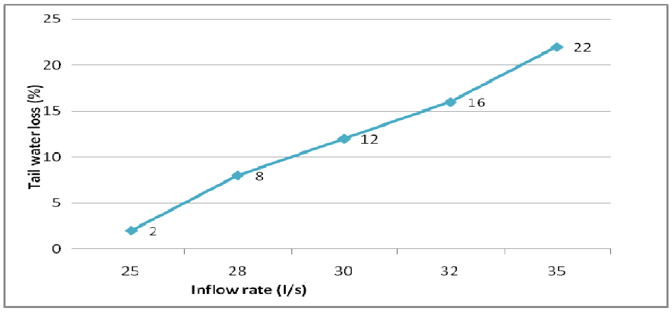

Fig.21 Tail water loss at various Inflow rate (l/s)

The results obtained from various changes in Inflow rate reveals that for the Inflow rate 35 l/s, Application efficiency, Deep percolation loss, and Tail water loss obtained as 63%, 15%, and 22 % respectively. Similarly for the Inflow rate 25 l/s, Application efficiency, Deep percolation loss, and Tail water loss obtained as 83%, 15 %, and 2 % respectively. But, for the above said both scenarios low quarter adequacy 1.1 in case of 35 l/s Inflow rate, and 0.78 in case of 25 l/s Inflow rate, which suggests that 35 l/s should not be preferred as the criteria of low quarter adequacy says that it should be equal to 1. Therefore the optimum Inflow rate is determined by varying the Inflow rate from 25 l/s-35 l/s as given in Table 5, and the optimum values are obtained for Inflow rate 30 l/s with Application efficiency, Deep percolation loss, Low quarter adequacy and Tail water loss of 72%,15%, 1.00, 12% respectively.

Alternative-6: change in cutoff time (hr)

Table 6: application efficiency (%), low quarter adequacy, deep percolation loss (%) and tail water loss (%) for a various changes in cutoff time (hr)

cut-off time (hr)	6	7	**8**	9	10
Application Efficiency (%)	86	77	**72**	61	55
Deep percolation loss (%)	7	11	**15**	19	22
Low quarter adequacy	0.8	0.93	**1**	1.15	1.24
Tail water loss (%)	7	12	**12**	20	24

As shown in Table 6, as cutoff time increases from 6 to 10 hr, Application efficiency decreases from 86 to 55 % as per fig.22, Deep percolation loss increases from 7 to 22 % as per fig.23, Low quarter adequacy increases from 0.8 to 1.24 as per fig.24, and tail water loss increases from 7 to 24 % as per fig.25.

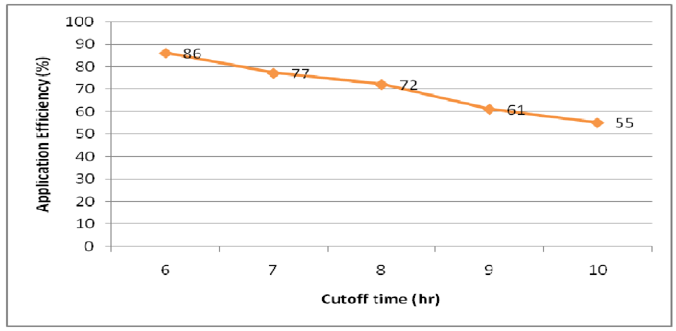

Fig.22 Application Efficiency at various cutoff time (hr)

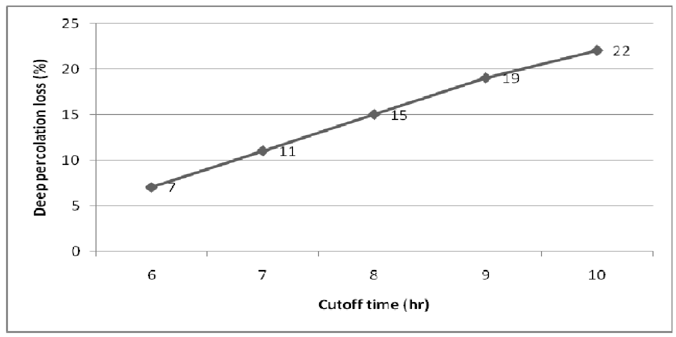

Fig.23 Deep percolation loss at various cut-off time (hr)

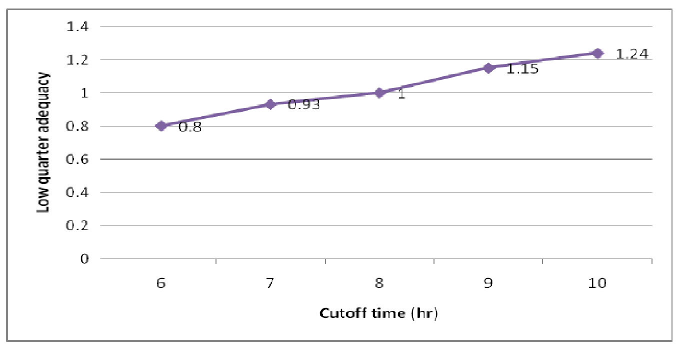

Fig.24 Low quarter adequacy at various cutoff time (hr)

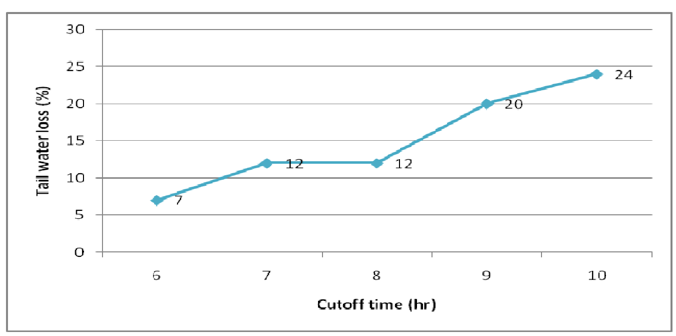

Fig.25 Tail water loss at various cutoff time (hr)

The results obtained from various changes in cutoff time reveals that for the cutoff time 10 hr, Application efficiency, Deep percolation loss, and Tail water loss obtained as 55%, 22%, and 24 % respectively. Similarly for the cutoff time 6 hr, Application efficiency, Deep percolation loss, and Tail water loss obtained as 86%, 7 %, and 7 % respectively. But, for the above said both scenarios low quarter adequacy 1.24 in case of 10 hr cutoff time, and 0.8 in case of 6 hr cutoff time, which suggests that 10 hr should not be preferred as the criteria of low quarter adequacy says that it should be equal to 1. Therefore the optimum cutoff time is determined by varying the cutoff time from 6 hr-10 hr as given in Table 6, and the optimum values are obtained for cutoff time 8 hr with Application efficiency, Deep percolation loss, Low quarter adequacy and Tail water loss of 72%,15%, 1.00, 12% respectively.

CONCLUSIONS

Simulation analysis of furrow irrigation system is carried out for determining optimum parameters of field. For the area taken under study and for changes in length, spacing between furrows, numbers of furrows, field slope, inflow rate, cutoff time, the optimum parameters obtained are the best possible length of 315 m, spacing as 0.2 m, Numbers of furrows as 100, Field slope as 0.002 m/m, Inflow rate as 30 l/s, and cutoff time as 8 hr. The Application efficiency, Deep percolation loss, Low quarter adequacy, and Tail water loss for the obtained parameters came out to be 72%, 15%, 1.00 and 12% respectively.

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