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The Performance of Gholam-gardeshy Furrow Irrigation

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ABSTRACT

Gholam-gardeshy (snake shape) furrow irrigation is a modified form of furrow irrigation, which has been used in Iran traditionally for a long time. To measure the performance of this method of irrigation and to compare the results with the furrow irrigation, three experimental fields with different soil textures and field slopes were used to collect data. Field data such as furrow inflow hydrograph, furrow outflow hydrograph and advance were collected for both methods. The results showed higher advance velocity for furrow irrigation and lower water loss as runoff for the Gholam-gardeshy irrigation. The results showed that for the same volume of applied water as the slope of the field increases the application efficiency for Gholam-gardeshy irrigation increases while the application efficiency for furrow irrigation decreases. At higher field slopes, the differences between the infiltrated water along the field for both methods decreases. In heavier texture soils, application efficiency for Gholam-gardeshy irrigation increases as compared to the furrow irrigation. In both methods, the determined advance equations were able to predict the field data with coefficient of determination of more than 90%. The difference between the two methods for longitudinal advance and infiltration along the field was significant at 5% level.

Key Words: Furrow irrigation; Gholam-gardeshy; Runoff; Efficiency

INTRODUCTION

Furrow irrigation is one of the oldest methods of irrigation in which soil surface is used to convey and infiltrate water (Walker & Skogerboe, 1987; Walker, 1989). This method of irrigation as compared with sprinkler or trickle methods is inexpensive. Therefore, more attention is being paid to improve the efficiency of furrow irrigation. For instance runoff recovery, cutback technology and surge irrigation have been studied to reduce losses (Younts *et al*., 2003; Gaton, 1966; Walker, 1989; Mintesiont *et al*., 2004). The field application of these methods of irrigation is usually complicated and also expensive. Also a number of mathematical models of surface irrigation have been developed to simulate different irrigation phases such as, advance, recession, runoff, deep percolation and efficiency. For instance, the Sirmod model can be used to simulate and design surface irrigation including furrow irrigation (Walker, 2003). The efficient application and distribution of water by furrow irrigation is dependent on parameters such as inflow, soil texture, field slope, soil infiltration, plant coverage, roughness coefficient, field shape, irrigation management and ect. These parameters also affect the performance of Gholam-gardeshy. Gholam-gardeshy is a modified form of furrow irrigation which has been used in Iran traditionally for a long time in order to have better distribution of water along the field for sloppy fields where the application efficiency of furrow irrigation is low. However, to date no research has being done about the hydraulic performance of this ancient method of irrigation. In this method of irrigation, water moves in furrows in snaky shape which the result is lower velocity of advance and consequently lower runoff.

To date, none of the above methods or models has considered the Gholam-gardeshy while this method of irrigation can be inexpensive and can be used as an alternative choice for more expensive methods of irrigation such as sprinkler or trickle systems especially for fields with higher slopes where the ordinary furrow irrigation has low efficiency.

The objective of this study was to introduce this method of irrigation and compare its performance with the furrow irrigation for three experimental fields.

MATERIALS AND METHODS

Three experimental fields, Khazaneh and University fields belonged to Isfahan University of Technology and Rudasht field located near the Isfahan were used to collect field data for both Gholam-gardeshy and furrow irrigation (Table I). Soil moisture given in Table 1 is based on dry mass which is the average of three samples taken from depth of zero to 30 cm for before irrigation. At Khazaneh field to study the effects of slope on both methods three plots with different slopes were obtained. The soil and field characteristics for the experimental fields are shown in Tables I and II. A constant head water delivery system to the furrows as shown in Fig. 1 was installed in each field and was used to irrigate the experimental fields. The fields were irrigated for the first time with no plant. Parshall flumes were used to measure inflow and outflow for each furrow. Control valves were used to adjust the furrow inflow rate at desired level. The tests started with non erosive discharge that was delivered to each furrow.

Advance time was measured at different distances along the field for both methods until water reached the end of the furrow. Then, water depth in the outflow flume was recorded with time until no flow accrued at the end. The test was continued until constant outflow hydrograph was achieved. Inflow, outflow, advance, recession and furrow geometry were measured for both methods. Three replications were used for each measurement and the irrigation time and inflow discharge were the same for both methods. The furrow spacing was the same for both methods and was equal to 0.7 m. For the Gholam-gardeshy method the furrow width or the outside distance between two turning points of water was about 2.8 m. The length along the furrow was the same for both methods and it was 30 m for all experiments. A schematic drawing of the experimental fields is shown in Fig. 1. For Gholam-gardeshy irrigation the slope was the same as furrow irrigation but the lateral slope was zero.

The furrow geometry functions were determined after irrigation using furrow profilometer (Mostafazadeh & Walker, 1981):

$$T = a_1 y^{a_2} \quad (1)$$

$$A = \sigma_1 y^{\sigma_2} \quad (2)$$

$$WP = \gamma_1 y^{\gamma_2} \quad (3)$$

Where T = furrow top width, cm; y = depth, cm; A = furrow cross-sectional area, cm^2; WP = furrow wetted perimeter, cm; *and* a_1, a_2, $\sigma_1, \sigma_2, \gamma_1, \gamma_2$ = empirical constants which their values are shown in Table III.

The trajectory of advance of the water front in furrow was determined as follow:

$$x = p t_x^{\,r} \quad (4)$$

Where x = advance distance, m; t_x = advance time, min; and p and r = empirical constants.

The Kostiakove-Lewis infiltration equation (Osman Saleem *et al*., 2003) was used for both methods:

$$Z = Kt^a + f_0 t \quad (5)$$

Where Z = the cumulative infiltration, m^3/min/m; t = the opportunity time, min; and Kand a are empirical constants. The basic infiltration rate (f_0) *of the above equation was* determined using inflow-outflow hydrographs:

$$f_0 = \frac{Q_{in} - Q_{out}}{L} \quad (6)$$

Where f_0 = basic infiltration rate, m^3/min/m; Q_{in} = inflow discharge, m^3/min; Q_{out} = outflow discharge, m^3/min; L is furrow length, m.

To determine the parameters of K and a of the Kostiakove-Lewis equation volume balance method was used. The volume balance equation is as follow (Walker & Skogerboe, 1987):

$$Q_0 t_x = \sigma_y A_0 x + \sigma_z K x t_x^{\,a} + f_0 t_x x/(1+r) \quad (7)$$

Where Q_0 = inflow per furrow at the upstream end of field, m^3/min; t_x = time water advanced to the distance x, min; σ_y = surface flow shape factor, which is between 0.7 and 0.8; A_0 = flow area at the upstream end, m^2; and σ_z = subsurface shape factor, which is defined as:

$$\sigma_z = \frac{a + r(1-a) + 1}{(1+a)(1+a)} \quad (8)$$

To determine the evaluation parameters the following equations were used:

$$E_a = \frac{Z_{req} L}{Q_0 t_{co}} \times 100 \quad (9)$$

$$DPR = \frac{V_Z - Z_{req}}{Q_0 t_{co}} \times 100 \quad (10)$$

$$TWR = 100 - DPR - E_a \quad (11)$$

$$E_r = \frac{Z_{req} x_d + V_{zi}}{Z_{req} L} \times 100 \quad (16)$$

Where E_a= application efficiency, %; Z_{req} = the required infiltrated depth, m^3/m; t_{co}= cutoff time, min*; DPR* = deep percolation*, %; V$_z$* = infiltrated volume, m^3*; TWR* = tail water ratio*,* E_r = water requirement efficiency, %; x_d = the distance along the field which the infiltration is equal to the required infiltration, m*; and* V_{zi} = the volume of infiltration for that portion of the furrow which receives water less than the required water, m^3/m.

RESULTS AND DISCUSSION

Advance. The advance curves and equations were determined for both methods for each of the experimental fields which a sample of these results for Khazaneh field which has irrigation time of 60 minutes is shown in Fig. 2 and 3. For both methods the velocity of advance was determined in longitudinal direction (in field slope direction). These figures and their related equations show that for the same furrow inflow discharge and irrigation time

Fig. 1. Schematic of constant head water delivery system to the furrows

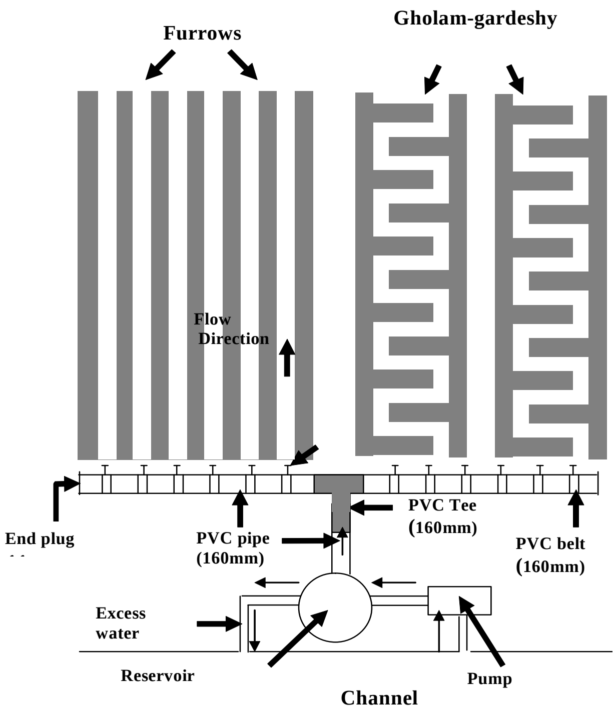


Fig. 2. Advance curves for furrow and Gholam-gardeshy irrigation for Khazaneh field plot 1

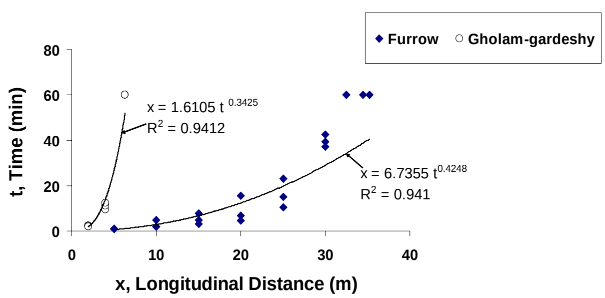
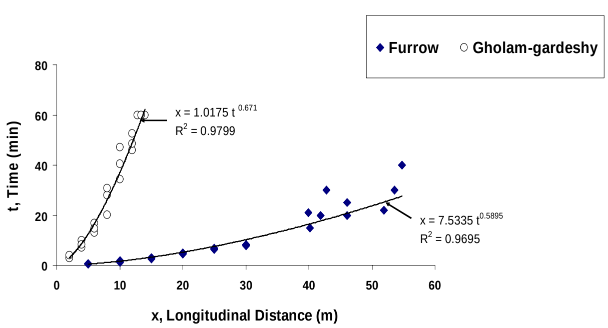


Fig. 3. Advance curves for furrow and Gholam-gardeshy irrigation for Khazaneh field plot 3



the velocity of advance is higher for furrow irrigation as compared to the Gholam-gardeshy irrigation and as the slope of the field increases the advance distance and the difference between two methods increases. Similar results were obtained for other two experimental fields.

Hydrograph and runoff. Sample of inflow and outflow hydrographs for Khazaneh field is shown in Fig. 4 and 5. These figures show as the slope of the field increases runoff increases for furrow irrigation but in the case of Gholam-gardeshy there is no runoff at all three experimental fields and inflow hydrographs are the same for both methods. In Gholam-gardeshy, water moves in snaky shape which causes the velocity of advance and consequently runoff to decrease or even the runoff becomes zero. Table I shows Rudasht field has a soil texture which is heavier as compared to the soil texture of University field and because of this the velocity of advance and consequently runoff (Table IV) is higher at Rudasht field since inflow hydrographs and field slopes are nearly the same for both

Fig. 4. Inflow and outflow hydrographs for furrow irrigation for Khazaneh field plot 1

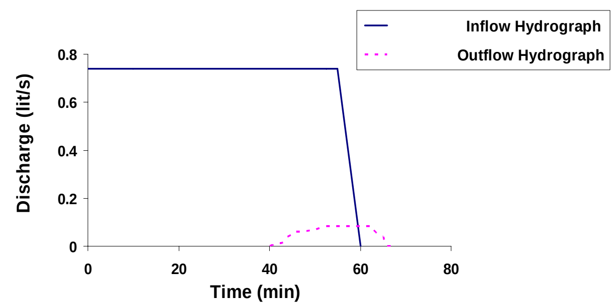


Fig. 5. Inflow and outflow hydrographs for furrow irrigation for Khazaneh field plot 3

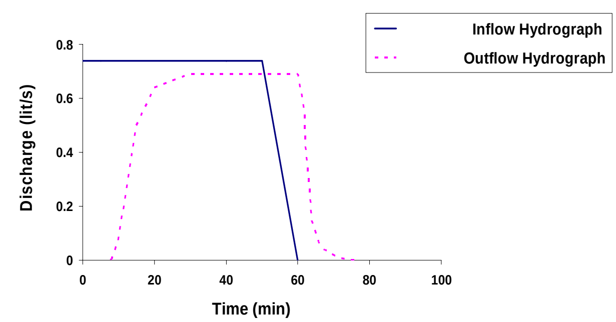


Fig. 6. Furrow cross-section for Khazaneh field

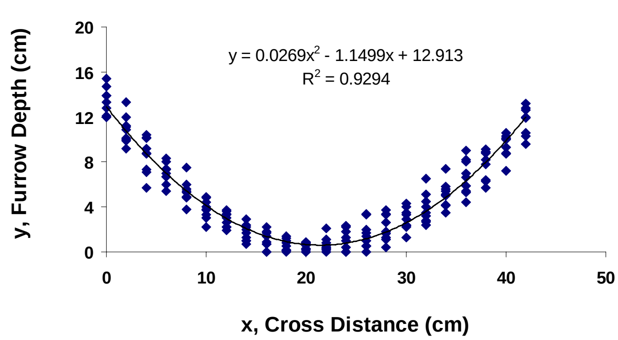


Table I. Soil characteristics for the experimental fields

Field		Bulk density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	Texture	Soil moisture(%)
	Plot 1						
Khazaneh	Plot 2	1.45	48	24	28	Sandy clay loam	11.22
	Plot 3						
University		1.35	40	30.5	29.5	Sandy clay loam	3.2
Rudasht		1.5	18.67	37.4	44	Clay	4.6

Table II. Kostiakov-Lewis infiltration equation parameters for the experimental fields

Field		Slope (%)	Inflow discharge (lit/s)	K (m^3/m/min^a)	a	f_0 (m^3/m/min)
	Plot 1	0.3	0.75	0.005	0.35	0.00119
Khazaneh	Plot 2	1	0.75	0.0043	0.45	0.00048
	Plot 3	2	0.75	0.0042	0.5	0.000108
University		0.29	1.63	0.0004	0.65	0.00323
Rudasht		0.1	1.5	0.0042	0.51	0.00118

Table III. Empirical constants of furrow geometry equations for the experimental fields

Field		Irrigation method	a_1	a_2	σ_1	σ_2	γ_1	γ_2
	Plot 1	Furrow	1.19	0.51	0.79	1.51	1.83	0.63
		Gholam-gardeshy	1.15	0.5	0.77	1.5	2.97	0.79
Khazaneh	Plot 2	Furrow	1.22	0.5	0.81	1.5	1.8	0.61
		Gholam-gardeshy	1.25	0.5	0.83	1.5	1.86	0.61
	Plot 3	Furrow	0.947	0.41	0.67	1.41	1.54	0.55
		Gholam-gardeshy	1.16	0.51	0.77	1.51	1.77	0.62
University		Furrow	1.27	0.49	0.86	1.49	1.88	0.6
		Gholam-gardeshy	1.18	0.46	0.81	1.46	1.83	0.59
Rudasht		Furrow	1.46	0.48	0.99	1.48	1.94	0.56
		Gholam-gardeshy	1.19	0.43	0.83	1.43	1.78	0.55

Table IV. Evaluation parameters for furrow and Gholam-gardeshy irrigation methods for net irrigation depth of 8.4 cm.

Field		Irrigation method	Iinflow volume (m^3)	Z (m^3)	DPR (%)	TWR (%)	E_a (%)	E_r (%)
	Plot 1	Furrow	2.7	2.62	31.89	1.11	67	99.69
		Gholam-gardeshy		2.671	36.36	0	63.4	95.77
Khazaneh	Plot 2	Furrow	2.7	1.75	0.363	52.79	46.85	99
		Gholam-gardeshy		2.63	0.366	0	99.63	89.66
	Plot 3	Furrow	2.7	1.21	0	63.71	36.29	68.59
		Gholam-gardeshy		2.478	0	0	100	59.03
University		Furrow	7.06	6.47	66.66	0.19	33.15	100
		Gholam-gardeshy		6.832	71.78	0	28.22	100
Rudasht		Furrow	7.2	4.97	38.4	46.62	14.98	100
		Gholam-gardeshy		9.88	50.79	0	49.21	99.62

experimental fields.

Furrow geometry. The sample cross-section with its related equation for furrow irrigation for Khazaneh field is shown in Fig. 6. Both furrow and Gholam-gardeshy methods had almost the same furrow cross-section. In Gholam-gardeshy water moves in snaky shape which causes the water depth, wetted perimeter and consequently the infiltrated volume to increase (Table IV). Fig. 7 shows the influence of field slope on furrow wetted perimeter for Khazaneh field. This figure shows as the field slope increases the wetted perimeter decreases. In Table III the furrow geometry parameters are given for three experimental fields for both methods. Table III shows that at each experimental field the furrow geometry parameters are nearly the same for both methods.

Infiltration. The infiltrated depth can be determined using equation 5 which the parameters of this equation are given in Table II. The intake opportunity time required in equation 5 was determined based on advance and recession data. Then, the infiltrated depth along the furrow and along the Gholam-gardeshy was calculated which the results are given in Fig. 8 and 9. The comparison of Fig. 8 with Fig. 9 shows as the slope of the field increases the differences between the infiltrated water along the furrow and along the Gholam-gardeshy decreases. Also as the field slope increases the distribution of water along the field becomes more uniform for Gholam-gardeshy. Table IV shows that for furrow irrigation the infiltration volume at Rudasht field is lower than University field because the soil texture is heavier at Rudasht field which results in higher runoff and less infiltration. The results at Khazaneh field show as the slope of the field increases the basic infiltration rate (f_0) (Table II) and the cumulative infiltration decreases (Table IV).

Efficiency. The efficiency parameters for furrow and

Fig. 7. Furrow wetted perimeter for different field slopes for Khazaneh field

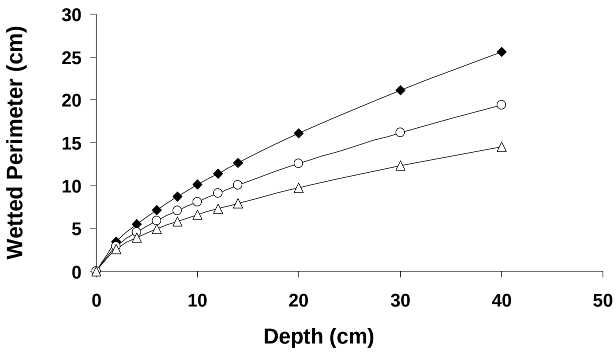
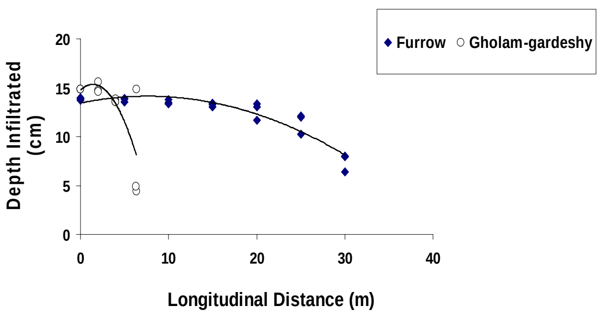


Fig. 8. Infiltrated depth for furrow and Gholam-gardeshy irrigation for Khazaneh field plot 1



Gholam-gardeshy are computed for different assumed root depths of 0.4 m, 0.7 m and 1 m. The sample results of these computations for root depth of 0.7 m which is equivalent to net depth of irrigation equal to 8.4 cm is shown in Table IV. Deep percolation ratio (DPR) is higher for Gholam-gardeshy as compared to furrow irrigation. From plot 1 to plot 3 as the slope of the field increases the furrow runoff (TWR) increases. For Khazaneh field, as the slope of the field increases the application efficiency of furrow decreases due to higher runoff but the application efficiency of Gholam-gardeshy increases. At Rudasht field as compared to University field for the same irrigation time and furrow discharge the application efficiency for Gholam-gardeshy is higher because soil texture is heavier at Rudasht which causes more uniform distribution of water along field. In Fig 10 the application efficiency versus slope for Khazaneh field for net irrigation depth of 8.4 cm is shown. This figure shows that the performance of Gholam-gardeshy improves at higher field slope which is in contrast with furrow irrigation.

CONCLUSION

The results show as the slope of the field increase the application efficiency or the performance of Gholam-gardeshy irrigation increases, while the performance of furrow irrigation reduces. Applying Gholam-gardeshy

Fig. 9. Infiltrated depth for furrow and Gholam-gardeshy irrigation for Khazaneh field plot 3

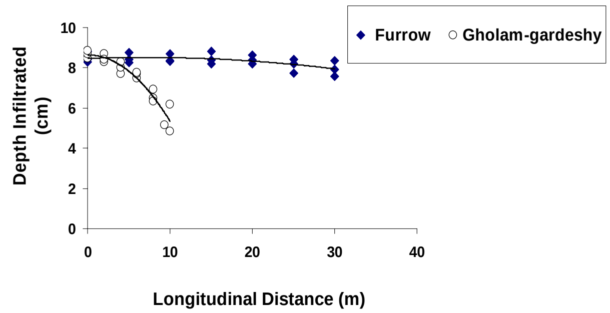
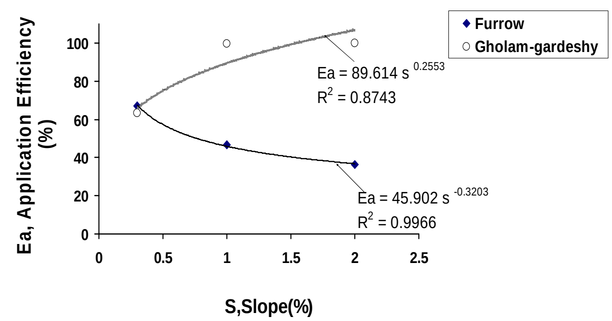


Fig. 10. Application efficiency versus slope for Khazaneh field (for net irrigation depth of 8.4 cm).



method of irrigation to the fields with high slopes reduces the need for more expensive irrigation systems such as sprinkler or trickle system and reduces the energy costs. Further theoretical and practical researches are recommended about the performance of this method of irrigation.

REFERENCES

Gaton, J.E., 1966. Designing an automatic cut–back furrow irrigation system. *Oklahoma Agric. Exp. Sta. Bull.* B–651

Mintesinot, B., H. Verplancke, E. Van Ranst and H. Mitiku, 2004. Examining traditional irrigation methods, irrigation scheduling and alternate furrows irrigation on vertisols in northern Ethiopia. *Agricultural Water Management*, 64: 17–27

Mostafazadeh, B. and W.R. Walker, 1981. Furrow geometry under surge and continuous flow. *Iran Agric. Res.*, 6: 57–71

Osman Saleem, M., A. Muhammad, S. Imran and A. Saqib, 2003. Adoption of Kostiakov model to determine the soil infiltration for surface irrigation methods under local conditions. *Int. J. Agric. Biol.*, 5: 40–2

Walker, W.R. and G.V. Skogerboe, 1987. *Surface Irrigation: Theory and Practice*." p. 386. Prentice–Hall Inc., Englewood Cliffs, New Jersey

Walker, W.R., 1989. *Guidelines for Designing and Evaluating Surface Irrigation Systems*. p. 137. FAO Irrigation and Drainage Paper 45, Food and Agriculture Organization of the United Nations, Rome, Italy

Walker, W.R., 2003. *SirmodIII: Surface irrigation simulation, evaluation and design*. Software Engineering Division, Biological & Irrigation Engineering Department, Utah State University, Logan, Utah, U.S.A.

Younts, C.D., D.E. Eisenhauer and D. Varner, 2003. "Managing furrow irrigation systems."Available at: http://www.ianrpubs.unl.edu/epublic/liver/g1338/build/g1338.pdf

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