WETTING PATTERN INSPECTION ON STEEP LANDS OF FATH-ALI PLAIN IN, MOQAN

EXAMEN DU SCHEMA D'HUMIDIFICATION SUR LA TERRE RAIDE DE LA PLAINE DE FATH-ALI, MOQAN

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ABSTRACT

The water saving drip irrigation is an appropriate water application system in many parts of Iran due to limitations of water resources. The soil wetting pattern created by a point source such as a drip emitter indicates if the applied irrigation water is able to cover the root zone of the irrigated plant. Wetting pattern depends on soil texture, structure, volume of applied water, emitter discharge rate and land slope. In this research the effect of slope, irrigation time and irrigation water volume with constant discharge of 4 lph on 4 slopes (0, 5, 15 and 25%) on natural terrain with salty-loam texture and three irrigation periods of 2, 4, and 6 hours were investigated. Wetting shape dimensions were measured by digging 24 h after irrigation ended.

From the results, it was observed that the elongation of wetting front below the emitter was more towards the down slope than towards the up slope on steep lands. The reason is that on steeper slopes gravity force is more than capillary force. So in drip irrigation system design on steep lands, using the data from flat slope experiments will induce errors. As a result, for silt loam soil on slopes more than 5%, it is recommended to use double row laterals layout with appropriate distance between emitters as mentioned in the charts for various slopes and irrigation times.

Key words: *Drip irrigation, wetting pattern, capillary force, gravity force, emitters, steep land.*

RESUME

En raison de la pénurie d'eau en Iran, l'utilisation efficace de l'eau est nécessaire pour accroître l'efficience d'utilisation de l'eau. Le système d'irrigation goutte à goutte est approprié pour

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les terres raides de nombreuses régions de l'Iran. A propos de la mise en place d'irrigation goutte à goutte, le schéma d'humidification est très importante. Ce schéma dépend de la texture du sol, de la structure du sol, du volume d'eau d'irrigation, du débit de goutteur et de la pente du terrain. Dans cette recherche, les effets de la pente, la durée d'irrigation et le volume d'eau d'irrigation ont été étudies. Un débit constant de 4 l/h sur 4 pentes naturelles intactes de 0, 5, 15 et 25% sur un sol limon-sableux et avec trois périodes d'irrigation de 2, 4, et 6 heures a été appliqué. Les dimensions du schéma d'humidification ont été mesurées en creusant un profil 24 heures après l'irrigation.

Les résultats montrent que le schéma d'humidification était tendu vers le bas de la pente. En effet, sur une pente, la force de gravite est plus forte que la force capillaire. Donc, pour la meilleure planification du système d'irrigation goutte à goutte sur les terres raides, on ne peut pas utiliser les données concernant les terres plates. En modifiant ces données, on peut améliorer l'efficience d'utilisation d'eau. Pour les sols limoneux-argileux sur les pentes de plus de 5%, en raison de leur faible largeur par rapport aux terrains plats, il est recommandé d'utiliser 2 tuyaux pour chaque rampe d'arbre avec une distance appropriée entre les goutteurs selon les tableaux proposés pour différentes pentes et différentes durées d'irrigation pour optimiser la répartition d'humidité.

Mots clés : *Irrigation goutte à goutte, schéma d'humidification, force capillaire, force gravitaire, goutteur, terre raide.*

1. INTRODUCTION

Drip irrigation is a type of pressurized irrigation system in which irrigation water is applied according to the need of the plant. It has a high efficiency if this system is designed properly It is a good choice for areas with limited water resources and also on steep lands where land leveling may not be feasible. The 'wetting pattern' under a point source of water such as in drip irrigation, plays an important role in drip system design, and reveals if the applied irrigation water is able to cover the root zone of the plant to enable it to uptake water and nutrients. The percentage of wetted area in drip irrigation depends on the discharge of emitters, the amount of water discharged by the emitter, the distance between emitters, the distance between the laterals, soil type, land slope and irrigation duration (Alizade, 1997). In this irrigation method, the wetting pattern dimensions have a significant effect on the quality and quantity of the plant productions. However by changing the arrangement of emitters on steep lands as compared with flat lands it is possible to increase the water use efficiency (Vojdani et al., 2008). There are, however, few studies comparing wetting pattern under drip irrigation on steep lands with flat lands. Field observation is the surest way to determine the percentage of wetted soil in dripping irrigation system (Ekramnia, 1996, Haghighati, 1996, Ziatabar Ahmadi, 1992). Sharifnia et al., (2008) surveyed the effective factors in wetting pattern formation in drip irrigation and suggested some corrections for the position of emitters with respect to the plants on steep lands and presented some charts to correct the arrangement of emitters on steep lands. Vojdani et al., (2008) by measuring the vertical and horizontal dimensions of wetting front progress in Harkale Lali in Khozestan concluded that the distance between emitters of 0.75 m and the mean wetted area around the plant (pw) of 45% gives better results. Sharifnia et al., (2007) inspected the wetting pattern in dripping irrigation on steep lands with silt, clay and loam soil textures and concluded that it is incorrect to use the design charts of flat lands under steep slope lands. Patel & Rajput (2009) inspected the effect of subsurface irrigation effect on onion crop and found that due to predominance of gravity effect over capillary forces in sandy loam soil, water deep percolation loss was high. Tishezan & Mosavi (2006) showed that because both the capillary forces and gravity force are active in the lower part of emitter and gravity is the dominant force in the upper part the wetting pattern extends more towards the down slope. Hoover (1985) examined the wetting pattern on steep lands and noticed that when steep lands are irrigated, the horizontal component of stream was dominant and the vertical component decreased when the slope increased. Feltcher & Wilson (1983) stated that the shape and dimension of wetting pattern was more related to the total water volume discharged by the dripper than its discharge rate. Philip & Knight (1997) presented an analytical relation for stable flow in steep boundaries. They presented for point source on or below soil surface assuming that the progress of moisture occurs more aided by gravity. Schwaterzman & Zur (1986) assumed that the geometry of wetting pattern was related to the soil types, emitter discharge and the volume of water and they expressed the effect of soil type on wetting pattern by hydraulic conductivity. Mostafazade et al., (1998) by examining and comparing of wetting pattern dimensions, wetted area and volume in 4 soil textures on different slops; showed that in heavy texture soil, the wetting pattern dimensions is larger in comparison to the soils with light texture and the wetting front had smaller depth. Zur (1996) assumed that the volume of soil wetted by a single emitter equaled the volume discharged by rotation of a truncated ellipsoid and on this basis he presented an equation to estimate the volume of ellipsoid. Chu (1994) used the three dimensional Green & Ampt model and constant discharge which is equal to mean soil permeability and gave an equation to estimate the depth and diameter of wetted soil which are the functions of wetted zone radius on the soil surface, saturated hydraulic conductivity and time. Hachum (1973) in his investigations on steep lands revealed that the wetted pattern for a single point source has an oval shape at any time.

In this research we tried to determine the wetting pattern on steep lands and compare the results with that in flat lands in order to provide appropriate solutions to reach the increment of dripping irrigation efficiency and optimized use of water in Fath – Ali pressurized irrigation project in Moqan plain.

2. METHODS

The studied area is located in Fath – Ali Plain in Pars – Abad – Moqan which is in the northern part of Ardebil Province in Iran. The area of the project is 4800 ha. It is located around 47°, 32’ E longitude and 39°, 24’ N latitude (Fig. 1).

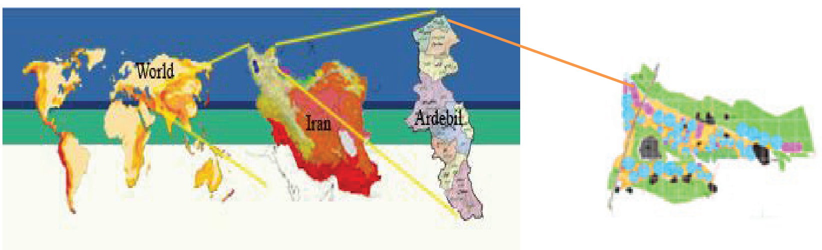

Fig. 1. Geographical location of Moqan Fath Ali – plain (L’emplacement de la plaine de Fathali de Moghan)

The experiments were conducted on undisturbed soils with silt loom texture on slopes of 0, 5, 15 and 25 percent. Drip irrigation system with a constant emitter discharge of 4 lit/hr was adopted with 3 replications in 3 irrigation times of 2, 4 and 6 hours (Irrigation water volume of 8, 12 and 24 liters, respectively). The experimental plot dimensions were 4.5*4.5 meter for each slope and was divided to 9 equal parts with dimensions of 1.5*1.5 meter. By digging the soil in sections parallel to the slope the dimensions of wetted soil were registered 24 hours after irrigation. The soil moisture was measured by a humidity meter device (wettkit) in a network by dimensions of 5*5 cm. The design drawings, volume and area measurements were done by Auto CAD 2010 software; the drawings diagrams and calculation of correlation coefficients were done by Microsoft office Excel 2010 software. The statistical analysis for was done by SPSS software using the LSD criterion for a size of Type I error of 5%. The data was classified by using Duncan method.

3. CONCLUSIONS

Comparison of upstream and downstream components of emitter axis.

On flat lands all components of wetting pattern at upstream and downstream part of emitter were highly zygomorphic. As it is illustrated in Figures 2 and 3, the wetting pattern had a significant difference on steep lands from that of flat lands. It can be explained that it is because of the excessive effect of horizontal component of gravity force and suction (capillarity) at downstream part of the emitter and the of gravity force at upstream part of emitter. These results match with the ones obtained by Tishehzan & Moosavi 2006, when the slope increases. Due to faster saturation of soil pores at downstream part of emitters, the effect of gravity force will be more than suction. Patel & Rajput (2009) and Hoover (1985) achieved the same results. The percentage of wetted pattern area at upstream part and downstream part of the emitter location in various slopes and irrigation times are shown in Table (1).

Fig. 2. The wetting pattern on 0% slope after 2 hours irrigation
(Le bulbe humide sur une pente de 0% pour une durée d'irrigation de 2 heures)

Fig. 3. The wetting pattern on 25% slope after 2 hours irrigation.
(Le bulbe humide sur une pente de 25% pour une durée d'irrigation de 2 heures)

Table1. The wetted area percentage at upstream part and downstream part of emitter axis. (Les pourcentages de deux parties avale et amont de la surface humide totale par rapport à l'emplacement du goutteur)

Irrigation time (hour)	Slope (%)							
	0%		5%		15%		25%	
	Area wetting pattern							
	Up-stream part (%)	Down-stream part (%)	Up-stream part (%)	Down-stream part (%)	Up-stream part (%)	Down-stream part (%)	Up-stream part (%)	Down-stream part (%)
2 h	49.68	50.32	26.12	73.88	24.76	75.24	20.50	79.50
4 h	49.86	50.14	28.79	71.21	23.06	76.94	18.99	81.01
6 h	48.48	51.52	31.97	68.03	23.88	76.12	20.20	79.80

The wetting pattern volume

The volume of wetted zone formed in steep lands is different from that on flat lands. The wetting pattern had a regular geometric shape on flat lands, but on steep lands because of the stretching of wetting front at the downstream part of the emitter along the slope, the wetting front did not have a symmetrical shape and it looked like a half oval (Fig. 4). Therefore it is not correct to use the flat land wetting pattern equations in steep lands. The investigations revealed that when the land slope increases, the wetted zone volume also increases in same irrigation time conditions. In 4 hours irrigation when the slope increases to15% it causes the significant difference between 0% slope and other slopes, but in irrigation times of 6 hours, the 0% slope wetting pattern had a significant difference with only the 25% slope wetting pattern. Theseresults match with Sharif (1997) about the decrease of wetting zone width because of the decrease in hydraulic characteristics as an effect of increasing irrigation time.

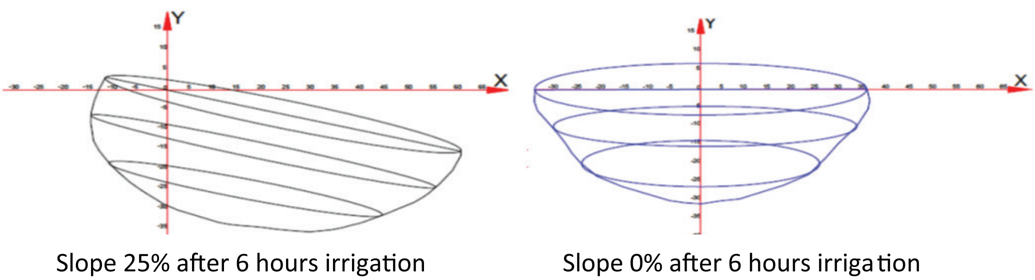

Fig. 4. Schematic view of the wetted soil volume under the emitter on flat and steep lands (Les bulbes humides sur deux pentes de 0% et 25%)

The similarity of wetted pattern on soil surface with geometric shapes

Wetted pattern was circular on the surface of flat lands, but it was elliptical in steep lands. This similarity increases by the increment of slope in steep lands, and we say the wetting pattern on the surface is more elliptical (Fig. 5). The results of this research confirms the results of Clothirer et al., (1985), Vojdani et al,. (2008), and Sharifnia et al., (2008).

Comparing the wetted pattern surface on the soil surface created by the same irrigation water volume showed that the wetted area decreases when the slope increases. The wetting pattern shapes on the surface was like an oval. So the large diameter of oval assumed as the progress front length, and the small diameter was the width of wetted area. According to Fig. 6, because of high correlation coefficient obtained from this comparison (R2=0.958), using the ellipse equation for measuring the wetted pattern area gives a good estimate. By comparing the surface wetted pattern on each slope with the equivalent ellipse the regression coefficient of 0.972, 0.976 and 0.99 were obtained for slopes of 5%, 15% and 25% respectively. As can be seen, in the 25% slope the value of r is almost equal to 1. On this basis, to estimate the dripping arrangements on steep lands, the oval pattern was used instead of circular pattern.

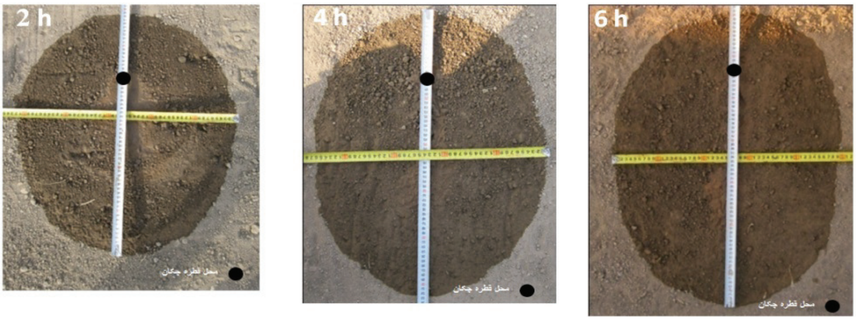

Fig. 5. Slope 25% wetted pattern on the surface (La surface humectée sur une pente de 25%)

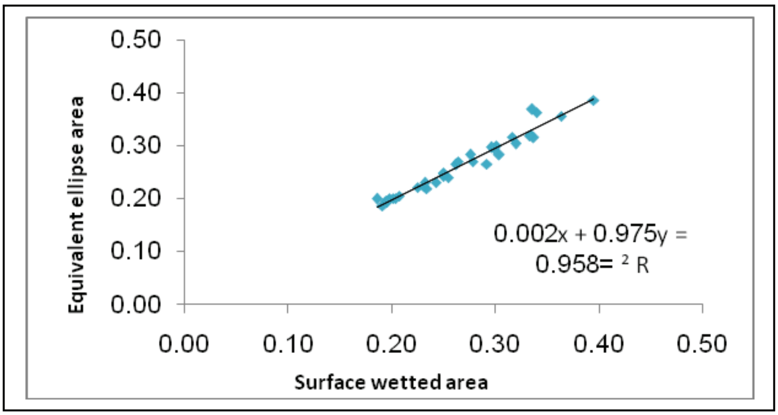

Fig. 6. Wetted area linear regression with equivalent ellipses (La régression linéaire entre la surface humectée et la surface d'un ovale équivalent)

Emitters arrangement on steep lands

Based on investigations and denoting wetted front length by s, width by w and distance between emitters as Se; if on 25 % slope Se = 0 .83s, on 15 % slope Se = 0.82s and on

5% slope Se = 0.82s, then the wetting pattern would have the best overlap on soil surface and depth .

Aaccording to the results of this research it will be erroneous to use the flat land tables for steep lands without correcting for the dimensions of wetting pattern for each slope. This finding is corroborated by Sharifnia et al., (2007). So it is suggested to use Table 2 for designing dripping irrigation on steep lands with silt loam soil texture.

Table 2. Wetted width(w), distance between emitters(s), on 5%, 15%, and 25% slopes) La langueur humectée et l'écartement entre les goutteurs sur les pentes de 5, 15 et 25%)

$W*S_e$ (cm)			
Slope/Irrigation time	**5%**	**15%**	**25%**
2 h	50*45	42*48	42*48
4 h	56*50	45*52	44*56
6 h	57*56	51*62	50*65

According to the results, because of economical reasons in designing dripping irrigation systems on steep lands, it is a good practice to apply irrigation for 6 hours or more. Also due to a decrease in the width of wetted pattern on steep lands as compared to that on flat lands, it is recommended to use the double row lateral arrangements, especially for slopes more than 5%, as it will increase the percent of wetted area (pw) and also the irrigation efficiency.

Determination of crop cultivation suitable distance from point source on steep lands

Considering that in drip irrigation system water is applied near the stem of the plant, it is possible to cultivate shadow giving plants on steep lands. So if drip irrigations system is used for cultivation it is better to plant the crop right at the center of the wetted zone, so it would be possible for the plant roots to have an acceptable progress in both vertical and horizontal directions. Therefore it is preferable when drip irrigation is used in steep lands, with the slops of 5%, 15% and 25%, to plant the crops with the distance of, respectively, 10 , 15 and 25 centimeters away downward from the emitter location on each slope. Also it is possible to determine other suitable cultivation distances for other slopes between 0 to 25 percent, by interpolation among the above mentioned values.

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