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Improvement of Irrigation Efficiency and Water Productivity By Surge Flow Irrigation in Short Furrows

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Résumé

Des essais au champ ont été conduits dans la station expérimentale de l'Université d'Assuit sur des sols argileux et sableux en vue d'évaluer l'efficacité et la productivité de l'irrigation gravitaire par vague. La longueur et la largeur des raies étaient respectivement de 70 et 0.70 m. Les débits étaient de 0.74 l/s pour le sol argileux et de 1.0 l/s pour le sol sableux. Deux cycles avec trois ratios chacun ont été appliqués. L'humidité du sol a été mesurée au début, milieu et fin de raie. Le rendement a été simulé à l'aide du modèle CROPWAT en fonction du volume d'eau appliqué pour les deux types de sol. L'irrigation gravitaire par vague a augmenté l'uniformité de la distribution d'eau et a réduit la vitesse de progression en comparaison à l'irrigation en continue. Le cycle de 24 minutes était meilleur à celui de 16 minutes. Plusieurs ratios de cycle pourraient être utilisés mais celui de 1/3 était le meilleur. La simulation a montré que des rendements élevés pourraient être obtenus avec l'irrigation par vague en comparaison à celle en continue. Avec la même quantité d'eau d'irrigation, l'irrigation gravitaire par vague s'avère un moyen plus efficace pour obtenir des rendements élevés que l'irrigation en continue.

1. Introduction

The main objective of surge flow irrigation is to improve the application efficiency by reducing deep percolation and runoff losses and to obtain a uniform wetting of the root zone, with minor differences in the infiltration depth at the beginning and the end of a furrow. The combined effects of the reduced infiltration during the advance phase plus the more rapid advance with surge flow, lead to a more uniform distribution of water along the furrow. In some soils, the same quantity of water normally required to reach the end of one furrow can be spread out over two furrows with surge flow. Crop yield is improved by uniformity of water application. Over-watering at the head of the field and under-watering at the end are almost eliminated under surge flow irrigation. Amer (1998) found that surge flow irrigation increased the cotton yield by about 4% - 9% and irrigation requirements were reduced by about 20 - 22% compared to continuous flow. The aim of this study was to investigate the applicability of surge flow irrigation for water saving and productivity under short furrows.

2. Materials and Methods

Field experiment was carried out in clay and sandy soils at the Agriculture experimental station, Assiut University, Assiut, Egypt. The length of the blocked end furrows in both soils was 70 m and the width was 0.70 m. The advance time was monitored at five points along the furrows, at 0 L, ¼ L ½ L, ¾ L, and 1 L. Soil water content was measured at the beginning, at the middle and at the end of the furrows at 3 depths: 0 - 0.1 m, 0.1 - 0.3 m and 0.3 - 0.7 m with gravimetric method. The recommended discharge to be used was 0.74 l/s for clay soil and were conveyed to the furrows from an open channel with a constant head via siphons, while it was 1.0 l/s for sandy soil and supplied via special orifices made in A 10 cm diameter PVC pipeline to obtain the required discharge (Ismail, 2004). Cycle times were 16 and 24 minutes. Three cycle ratios have been chosen for each cycle time, 1/4, 1/2 and 3/4 for 16 min cycle time and 1/3, 1/2, and 2/3 for 24 min cycle time. The water supply was cut-off at the end of the first surge that advanced the water to the end of the furrow. The cropwat model developed by FAO (Allen et al., 1998) was used to simulate cotton yield in relation to the available soil moisture in the root zone area, which obtained from the filed experiment. The meteorological data used to calculate ET_0 were taken for the year 1999 from the Assiut University station. The cotton data used in the simulation were taken from FAO (table 1).

Table 1 Cotton simulation data with a planting date of 22 March and a harvest date of 2 October (FAO, 1998)

Stage	Initial	Develop	Mid	Late	Total
Length in day	30	50	60	55	195
kc values	0.35	---→	1.20	0.70	
Critical depletion	0.60	0.60	0.60	0.90	
Yield response f	0.40	0.40	0.40	0.40	0.40

3. Results and discussion

3.1.Water content distribution, cycle time and cycle ratio

The distribution uniformity (DU) is defined at the present wok as the minimum infiltrated depth divided by the average infiltrated depth over the whole field. Three levels of water distribution were given in table 2, homogenous (H), which means that distribution uniformity is more than 80%, slightly homogenous (SH) which means that the distribution uniformity ranged from 70% to 80% and not homogenous (NH) which means that the distribution uniformity is less than 70%. The results showed a better water distribution along the furrow in most of the cases with surge flow compared with continuous flow for both textures, but the improvement was less in sandy soil than in clay soil due to the higher infiltration rate of sandy soil. The results clearly indicate that the 24 minutes cycle time was better than 16 minutes because with 24 minutes cycle time the water advanced rapidly to the furrows end in both soil types compared to 16 minutes cycle time (table 2).

Table 2 Results of the both soil textures treatments related to continuous and surge flow irrigation.

Soil type	Q l/s	Cycle time in min	Cycle ratio	Initial water content in vol. %	Adv. time in min	Total inflow time in min	Diff. in inflow time in cont. and surge flow in min	Diff in water supply in cont. and surge flow in m^3	Change in water content in vol. %	DU % and moisture distrib. Along the furrow
Clay soil	0.74		Cont.	29.7	75	75			11.3	68.0 - NH
		16	1/4	35.8	62	52	-23	1.0	8.3	88.9 - H
			1/2	30.8	56	48	-27	1.2	9.1	84.6 - H
			3/4	34.0	54	48	-27	1.2	9.2	82.2 - H
		24	1/3	35.8	37	32	-43	1.9	4.1	87.3 - H
			1/2	37.0	62	60	-15	0.66	9.6	98.4 - H
			2/3	38.7	56	48	-23	1.0	8.0	91.0 - H
Sandy soil	1.0		Cont.	0.3	55	55			11.1	77.3 - SH
		16	1/2	0.3	50	40	-15	0.9	9.9	70.0 - SH
			3/4	0.3	70	72	**+17**	**-1.0**	14.3	78.3 - SH
		24	1/3	0.3	44	40	-15	0.90	9.0	77.1 - SH
			1/2	0.3	39	36	-19	1.1	7.4	65.3 - NH
			2/3	0.3	48	48	-7	0.42	10.3	76.5 - SH

The highest reduction in advance time was obtained from 1/3 and 1/2 cycle ratio for both cycle times in clay and sandy soils, however the Non-Parametric test evaluation " Kruskal-

Wallist" presented in Devore (1982) and used to evaluate this study revealed that the best cycle ratios to be applied were 2/3 and 1/3 for 24 minutes cycle time in clay and sandy soils, respectively because the evaluation in the Non-Parametric test based on several factors not only the reduction in advance time.

The improvement in water content distribution along the furrows in surge treatments resulted from the interrupted water flow because intermittent water flow reduce the infiltration capacity resulted in a faster water advance, which distributed the water more uniformly along the furrow than in continuous flow (Tabuada et al., 1995). The reduction in advance time can be explained by the off-time. For some conditions and within limits an increase of off-time decreased the infiltration rate and the advance time, which may be due to two mechanisms: a) the redistribution and development of the negative pressure in the soil slows down as the off-time continues; b) the consolidation rate of the soil decreases as the negative pressure increases. The intake rate decreased as off-time increased. This does not mean that increasing the off-time will result in a faster advance in surge flow irrigation because the advance time does not only depend on the reduction in intake rate of the wetted section, but also depends on the length of the dry advance for each surge (Samani et al., 1985). A suitable off time is at least the time required to infiltrate the water completely before the next surge starts. The increase in advance time of 3/4 treatment in sandy soil may be due to a gravel layer or holes made by animals, which led to increase infiltration rate in the subsurface layers in the monitored furrow of this treatment.

3.2.Crop production

The evaluation of the experiment by the Non-Parametric test indicated that the best surge treatments, which can be applied were 2/3 and 1/3 cycle ratio for 24 minutes cycle time in clay and sandy soil, respectively (Ismail, 2004). These two cases together beside the continuous flow have been used in the cropwat model to simulate cotton yield in relation to the net stored water depth available in the root zone area (table 3).

Table 3 Net stored water depth and application efficiency for the treatments of 2/3 and 1/3 of clay and sandy soils

Soil type	Sandy soil		Clay soil	
Irrigation method	Continuous	Surge	Continuous	Surge
Net stored water depth mm	50	42	50	36
Application efficiency %	74	82	75	83

Two criteria have been used to reach the best irrigation interval for each growth stage to obtain the minimum yield reduction in relation to the net stored water depth without any irrigation loss. The first criterion was based on net stored water depth along the furrow for continuous flow (optimal continuous). Based on this amount of water the best intervals between subsequent irrigations with a minimum yield reduction of about 5%, and without water losses have been obtained by the model. Then these intervals have been applied to surge flow irrigation to study the effect of the water supplied according to this schedule on the yield reduction and water saving. The second criterion was exactly the same as the first one, except that in this case the best intervals were obtained from the average net stored water depth for surge flow irrigation, which gives the same yield reduction as in continuous flow (optimal surge). The simulation results of the two criteria are presented in figure 1.

The results indicated that the yield reduction in continuous flow was higher than in surge flow for both soils under both criteria (Fig.1A). Comparing the results of continuous and surge flow irrigation for the same yield reduction with different irrigation intervals in clay soil based on the average net stored water depth indicate that producing 95% of the maximum yield under continuous flow requires 1,733 mm and it requires 1,475 mm under surge flow irrigation. That means that the same yield can be produced under surge flow irrigation with less water leading to 15% water saving (Fig.1B). The same results were obtained in sandy soil but with less water savings than in clay soil. Producing 95% of the maximum yield requires 1,689 mm for continuous flow and 1,485 mm for surge flow irrigation leading to 12% water saving.

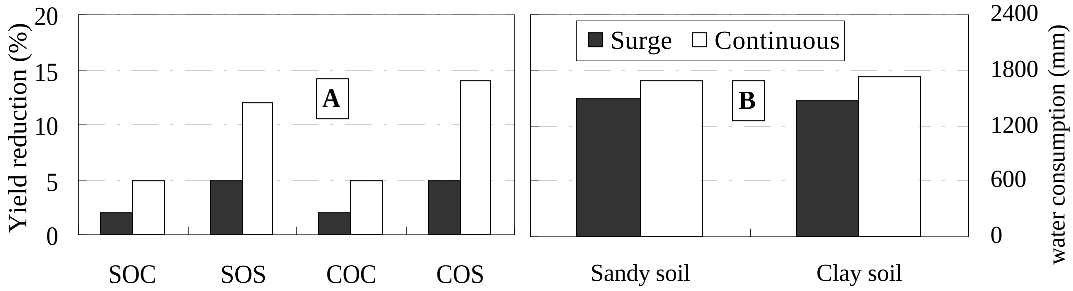

Figure 1 Simulated yield reduction (A) and water consumption (B) in relation to net stored water depth for clay and sandy soil (SOC is sand soil with optimal continuous, SOS is sand soil with optimal surge, COC is clay soil with optimal continuous and COS is clay soil with optimal surge).

4. Conclusions

Surge flow irrigation under short furrow conditions led to a more uniform water distribution than continuous flow. This uniformity is more pronounced in clay soil than in sandy soil. The 24 minute cycle time led to more reduction in advance time than the 16 minute cycle time. Different cycle ratios can be used. The simulation results revealed that the surge flow irrigation is an efficient tool to produce the maximum yield with less water than in continuous flow or to produce higher yield than continuous flow by using the same gross irrigation supply. Surge flow irrigation is an effective tool for water saving under short field condition. It may save 15% to 35% of irrigation water compared to continuous flow.

References

Allen, R.G., Pereira, L.S., Raes D., and Smith M. (1998) Crop evapotranspiration: guidelines for computing crop water requirements. FAO Irrigation and Drainage paper No. 56.

Amer, M.H. (1998) Surge flow irrigation as a farm practice for cotton production. Zagazig Journal of Agriculture Research 25: 659–669.

Devore, J.L.(1982) Probability and statistics for engineering and the sciences. Brook/Cole Publishing Company, CA, pp. 596-598.

Ismail, S.M. (2004) Effectiveness of surge flow irrigation in Egypt: Water use efficiency in field crop production. Ph.D. Thesis, Wageningen Agricultural University and UNESCO-IHE institute for water Education, the Netherlands.

Samani, Z.A., Walker, W.R and Willardson, L.S. (1985) Infiltration under surge flow irrigation. Transaction of ASAE 28: 1539–1542.

Tabuada, M.A., Rego, Z.J.C., Vachaud, G. and Pereira, L.S. (1995). Modelling of furrow irrigation: advance with two-dimensional infiltration. Agricultural Water Management 28: 201-221.