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Simulation Model for Integrated Management of Surface Irrigated Palm Trees under New Valley Governorate Conditions

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ABSTRACT

Egypt has the majority of productivity of date palm fruit all over the world due to its nutritional, economic, and social importance to the Egyptians. Therefore, study aimed to apply new technique such as simulation models for improving distribution uniformity and the water application efficiency under different surface irrigation system techniques to raise in order to select the proper decisions of integrated water management. Field experiments had been carried out for two successive growing seasons of (2018-2019and 2019-2020) on date palm (Phoenix dactylifera) at the Experimental Farm in El-Dakhla distinct, New Valley Governorate, Egypt. Modified surface irrigation with gated pips was used with three irrigation water distribution techniques :(Two-side furrows, basin and one side furrow with loop). Results revealed that the statistical indicators of R^2 (> 0.9), RMSE (nearest to 0) and E (> 0.9) between measured and simulated advance time and recession time. However, data analysis indicated high satisfactory to use the software under the Egyptian conditions for furrow irrigation. In addition, data revealed that the highest values of yield, water use efficiency and distribution uniformity were (12288kg/fed, 2.1 kg/m^3 and 90%) for one side furrow with loop treatment comparing with two side furrow and basin (5440 kg/fed, 1.6 kg/m^3 and 87%) and (5760 kg/fed, 0.8 kg/m^3 and 68%).

Keywords: application efficiency; distribution uniformity; gated pips; advance time; and recession time.

INTRODUCTION

Water resources in Egypt are restricted, which considered the principal impediment for crop production in the newly reclaimed lands because of the present intensive agricultural production in the Nile Delta and valley area, as well as agriculture depends mainly on irrigation process. The agricultural sector devours over 84% of the available water resources (El-Beltagy and Abo-Hadeed 2008; El-Noemani *et al* 2015a and El-Noemani *et al* 2015b).

Cultivation of date palms in Egypt returns millennia. The date palm tree has extraordinary socioeconomic significance and nutritional value in Egypt. Its customary use as a primary source of food and by-products and its ecological benefits in oasis agriculture make it an important fruit tree and the best crop to be cultivated. Egypt is the most productive country of date palm fruit in the world. There is a high potential for increasing the production area of date palm to fulfill local consumption in the whole country and to produce date fruits for export purposes. Presently, the Egyptian Government and private sector are convinced of the potential of date production and are striving to establish commercial date plantations and promote viable date production (Bekheet *et al* 2015).

Date palm creation assumes a significant part in the economy of Egypt, especially in the New Valley, Matroh, North and South Sinaa. The annual production of dates in Egypt 1.470000 million tons of elates, contributing 17% of world production (FAO STAT 2012).

Surface irrigation is probably the most seasoned tecuehniq of irrigation in the world, with the lowest application efficiency coverage 50% which led to water logging (Ali and Mohammed 2015). Furrow irrigation system is widespread irrigation system (El-Shafie *et al* 2018). Surface irrigation is considered one of the most common and extensive methods used for irrigation in the old lands of Delta and Nile valley. Although well designed and managed furrow-irrigation systems have the potential to operate at application efficiencies above 90%. To improve the efficiency of surface irrigation methods (border and furrow), the use of gated pipes is claimed to be one of the ways to achieve this goal, since it is considered one of the efficient methods for conveying and distributing irrigation water over the entire field. Therefore, G-Pipe simulation model has been developed to simulate water distribution along the pipeline of the irrigation system for making a decision to select the optimal specification of the irrigation system (Dewedar *et al* 2019). Computer simulation models have the potential to improve the efficiency of irrigation systems and thus deliver significant water savings. This can be achieved by optimising the design and management decisions at the field level (Koech *et al* 2010).

El-Noemani *et al* (2014) mentioned that the validity of using WinSRFR software as a tool of simulation furrow irrigation under clay loam condition. The statistical indicators of correlation coefficient (R^2), the standard error (SE) and the coefficient of efficiency (E) were used for the comparison between measured and simulated advance time, recession time, and distribution uniformity. Indicators of distribution uniformity, advance and recession times were high satisfactory to use WinSRFR simulation model under the Egyptian conditions. Therefore study aimed to apply

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new technique such as simulation models for improving distribution uniformity and the water application efficiency under different surface irrigation system techniques to raise in order to select the proper decisions of integrated water distribution.

MATERIALS AND METHODS

1-The experiment site:

Field experiments were carried out for two successive growing seasons of (2018-2019 and 2019-2020) at the experimental farm in El-Dakhla distinct, New Valley Governorate, Egypt, sandy clay loam soil (latitude 24° 32′ 44″ N, and longitude 27° 10′ 24″ E). The total area of the studied area is (85*55m^2) and it divided into three plots, the area of each plot was (85*18m^2) as shown in Figure (1). In addition, surface irrigation system by gated pipes with three water distribution had been investigated techniques of this study noted: - Two side furrow, basin and one side furrow with loop, as shown in Fig. (1).

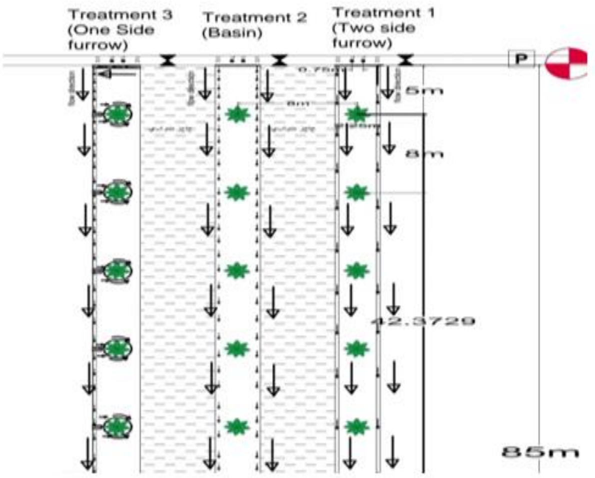


Fig. 1. Description of studied modified surface irrigation system and layout of the experiment

Furrow geometry was measured manually by a locally manufactured furrow profile meter (as an average of cross sections along 6 individual furrows) as shown in Figure (2), a wooden frame was manufactured to measure the furrow geometry, consisted of two vertical legs and steel rods with constant lengths fixed in the horizontal piece with 80 cm length, through holes and a drawing paper was fixed behind the rods on the frame. The furrow shape was measured four times for each furrow and the average for the all furrows was calculated to get the overall furrow shape parameters. Advance and recession times were taken manually using markers at known distances along the furrow during the irrigating process. Cutoff time was determined when the water reaches the last quarter of the furrow length then the recession time was measured at each pointer.

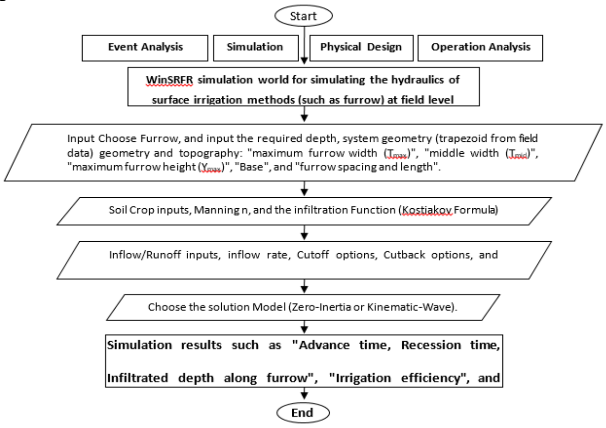


Fig. 2. Components of WinSRFR for simulating the hydraulics of surface irrigation (furrow) at field level

2-Experimental method:

a- Used gated pipe under three techniques of surface irrigation: (two side furrow, basin and one side furrow with loop).

b- Study the effect of using three treatments on determining the most appropriate advance time, recession time and distribution uniformity along furrow irrigation.

c- Study the moisture distribution under the three treatments, soil samples were be taken to measure the moisture content in the soil profile ± (25 and 50 cm) (horizontal direction) around the trunk of the palm tree at depths (10, 30, 60, 90 cm) (vertical direction).

d- Study the effect of using three treatments on determining the most appropriate quantities of the applied water to obtain higher water productivity.

e- Using simulation model to predict appropriate scheduling irrigation, distribution uniformity, energy consumption, and water use efficiency for date palm under study area.

3-Soil and irrigation water analysis:

Soil and irrigation water analysis at the experimental site were conducted according to standard procedures and represented in Table (1 and 2). Samples from irrigation water source were taken for chemical analysis according to Klute and Dirksen (1986). Table (2) shows chemical properties of irrigation water in the experimental site.

Table 1. Some soil physical properties of EI- Dakhla site:

Soil depth, cm	Particle size Distribution, %			F.C.%	W.P.%	A.W.%	Texture class
	Sand	Silt	Clay				
0-30	69	10	21	20	10	10	Sand clay loam
30-60	72	6	22	21	10	11	Sand clay loam
60-100	70.5	8	21.5	21	10	11	Sand clay loam

Table 2. Some chemical data of irrigation water at EI- Dakhla site

pH	EC dS/m	Soluble Cations, meq/L				Soluble Anions, meq/L			SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	SO_4^{--}	CL^-	
6.7	0.4	1.344	0.99	1.52	0.2	0.794	1.63	1.6	1.41

4- WinSRFR simulation model:

Figure (3) shows the inputs and outputs of WinSRFR simulation world. Advance and recession times, as well as distribution uniformity were measured under different hydraulic treatment of surface irrigation for determining the possibility of using WinSRFR as a prediction tool of the furrow irrigation performance under the Egyptian conditions.

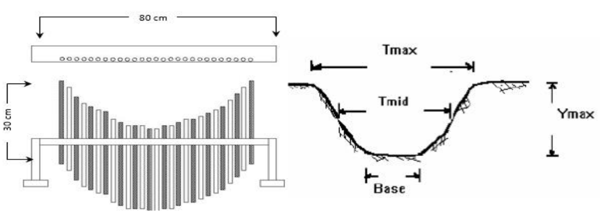


Fig. 3. Locally manufactured furrow profile meter

Data illustrated in Table (3) show the measured field data which used as inputs for WinSRFR to simulate the performance of furrow irrigation under three techniques of surface irrigation system (two side furrow, basin and one side furrow with loop. In addition, WinSRFR was run with different furrow hydraulics using two-field systems for determining the proper function to evaluate and simulate furrow hydraulics under the Egyptian conditions.

Figure (4) shows the screens of WinSRFR which expressed WinSRFR worlds, start simulation world, system geometry, soil crop properties, inflow/runoff, and execution, respectively. After the execution have been done, the results of simulated advance time and recession time will be simulated, and a summary file of all simulated outputs will be gotten as shown in Figure (5). The simulated data of advance and recession times were be compared by the measured data. Moreover; using R^2, *RMSE* and *E* comparisons were high satisfactory for evaluating the possibility of using WinSRFR as a prediction and simulation tool under the Egyptian conditions.

Table 3. Inputs of WinSRFR simulation model

Field Topography/Geometry			
Field Geometry:	Inputs depending on furrow length		
- Field length, m:	85	85	85
- Furrow spacing, m:	3	5.5	5
Field system:	Furrow irrigation and basin		
Downstream boundary;	Blocked		
Slopes:	0.5%		
Manning n values determined from reviews for bare soil:	0.04		
Type of simulation model:	Zero-inertia		
Run parameters:			
- Furrow inflow lit/s:	3.4		
- Time of cutoff depending on furrow length (hr):	1.3	3.5	2.5
Infiltration characteristics of soil type:	Sandy Clay loam soil		

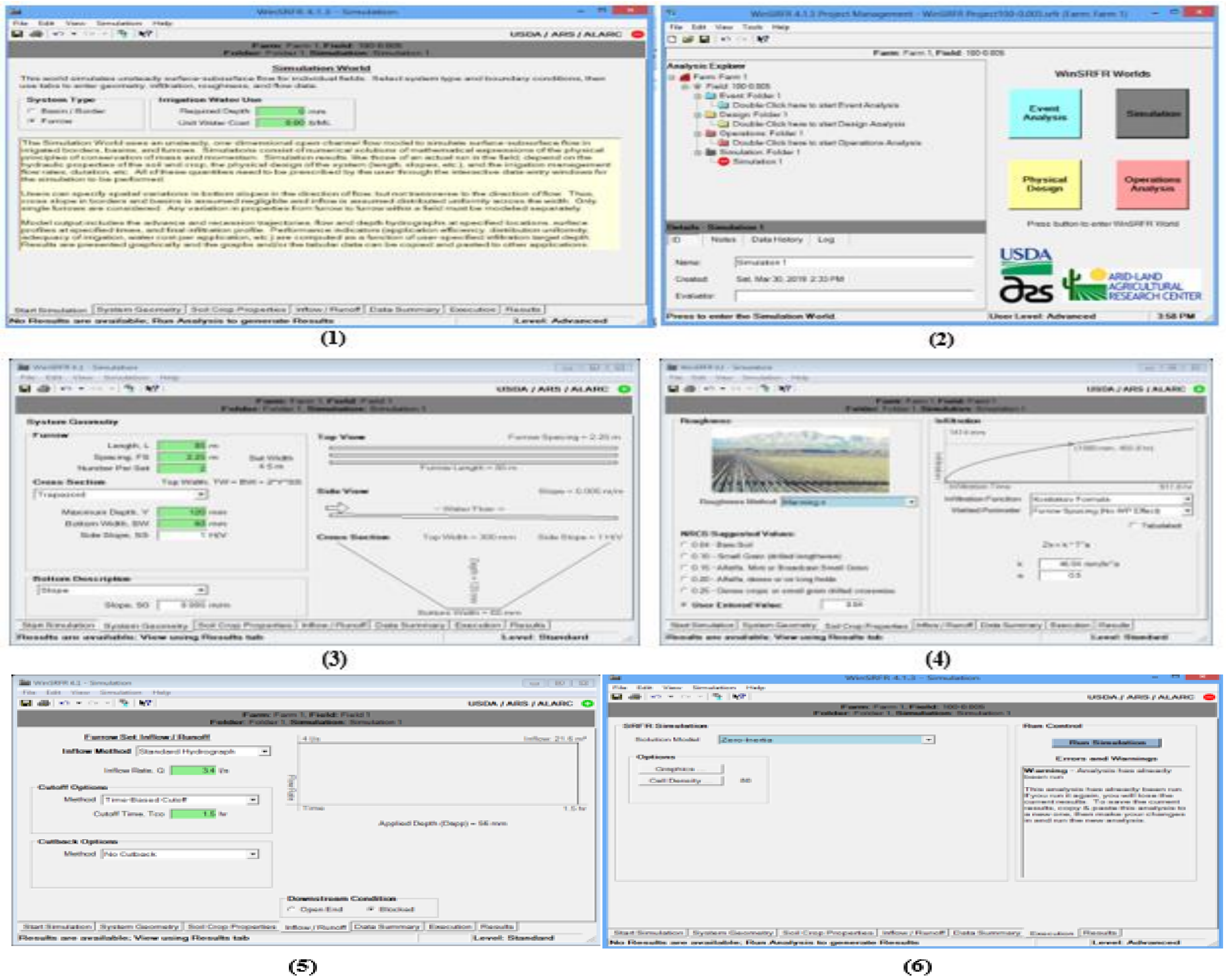
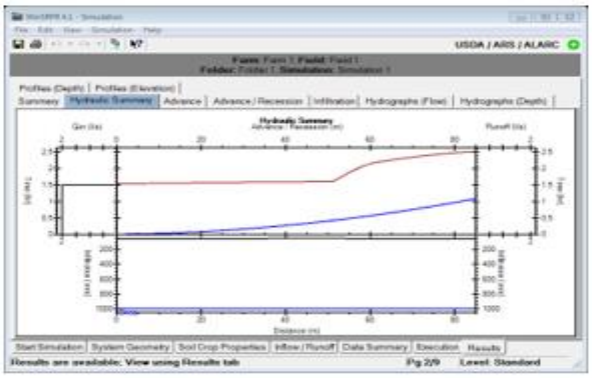
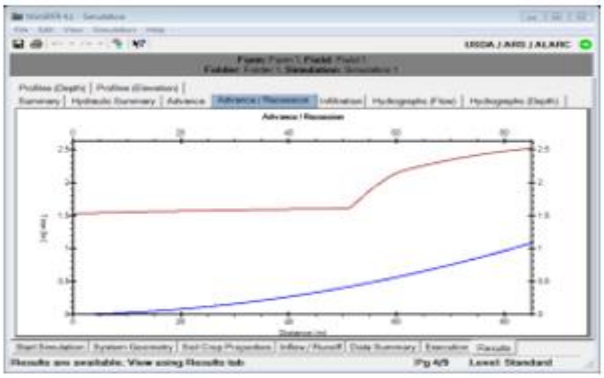


Fig. 4. WinSRFR Screens; (1) WinSRFR Worlds, (2) Start Simulation World, (3) System Geometry, (4) Soil Crop Properties, (5) Inflow/Runoff, and (6) Execution





(1) **(2)**

Fig. 5. WinSRFR Simulation World Results Screens; (1) Advance and Recession Times, (2) Hydraulics Summary

5- Irrigation water requirement calculation:

Irrigation water requirements for date palm were calculated according to the local weather station data at El-Dakhla affiliated to the Central Laboratory for Agricultural Climate (CLAC), Ministry of Agriculture and Land Reclamation.

Irrigation water requirement for date palm crop was calculated from the following equation: (Vermeiren and Jobling, 1980):

$$IR = [(ETo \times Kc / E_i) + LR] \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, IR are irrigation water requirements ($m^3\ h^{-1}$), ETo is reference evapotranspiration (mm day^{-1}), Kc is crop coefficient, E_i is water application efficiency (%) and LR is leaching requirements (%).

6-Outlet discharge:

The following equation was used to estimate outlet discharge of each gate: Smith *et al.*, (1986)

$$Q_0 = C_d A_0 \sqrt{2\ g\ H} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, Q_o is outlet discharge ($m^3\ s^{-1}$), Cd is value for sharp-edged orifice (0.65), A_o is the cross section area of gate (m^2), H is pressure head (m) and g is gravity acceleration (ms^{-2}).

7-Calibration and validation simulated software (WinSRFR):

The coefficient of determination (R^2), root mean square error (RMSE), and model efficiency (E) were used as the error statistics to evaluate both calibration and validation results. These statistical indices were used to compare measured and simulated values. Model performance was assessed using E as follows: (Nash and Sutcliffe, 1970)

$$E = 1 - \frac{\sum_{i=1}^{n}(S_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O}_i)^2} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(S_i - O_i)^2}{n}} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Where, S_i is predicted data, O_i is observed data, $\bar{O}_i$ is mean value of Oi and N is number of observation.

Finally, the data were analyzed using the one way ANOVA with Duncan's HSD test at $p<0.05$ using the COSTAT 3.03 System Software.

8- Measurements and calculations:

Distribution uniformity (DU):

The DU for surface irrigation should be defined as ((Burt *et al.*, 1997) :

$$DU = \frac{Dlq}{Dave} \quad \ldots\ldots\ldots (6)$$

Diq: average depth of water applied in the low quate end of the field.
Dave: average depth of water applied.

Soil moisture:

Measurements of soil moisture distribution pattern in different soil depth around root zone palm were determined by (screw auger). Soil samples had been taken after irrigation to measure the moisture content in the soil profile ± (25 and 50cm) (horizontal direction) around the trunk of the palm tree at depths (10, 30, 60, 90 cm) (vertical direction).in each along the lateral line. Data had been drawn using SURFER 10.

Water productivity (WP):

Water productivity (WP) was determined by using the following equation follows (Molden *et al.*, 2010):

$$WP = Ey/Et \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Where, Ey is the economical yield (kg fed^{-1}) and Et is the applied irrigation water ($m^3 fed^{-1}$).

RESULTS AND DISCUSSION

1-Effect of irrigation treatments on water applied and distribution uniformity:

As shown in Figures (6-A and 6-B), the data represent that there is a significant influence for types of irrigation on applied water consumption especially with two side furrow comparing with the other types (one side or basin) and control. The data recorded (3369 m^3/fed/season) with two side furrow treatment. In addition, this value is a lowest value comparing with control which obtained (9960 m^3/fed/season). Moreover, the other types of irrigation consume (8532 and 5832 m^3/fed/season) with basin and one side furrow, respectively. Consequently; data reflect that there is a significant impact for irrigation types on distribution uniformity (DU). However, there is not a significant effect on (DU) whatever using one side furrow or two side furrow irrigation treatment. Thus, the best values for (DU) were recorded with one side furrow and two side furrows by 90 and 87%, respectively. In contrast; the lowest value for (DU) got with basin by 68% and control by 58%.

2- Effect of irrigation water distribution techniques on soil moisture distribution patterns:

Two side furrows technique:

The results drawn in Figure (7) revealed that the moisture distribution under the first treatment (Two side furrow) was increased on both side furrow and decreased in the middle under the trunk. So, it is clear, that the moisture distribution in the soil was not regular in different soil depth.

Basin technique:

Figure (8) illustrates the moisture distribution in the soil at different soil depths (10, 30, 60 and 90 cm) under basin treatment. The tendency of water distribution and its average content in the soil profile increase relevant to the irrigation under the basin treatment when comparing the average contents of water in the profile for all the cases of irrigation treatment.

One side furrow with loop technique:

The above-mentioned Figure (9) reveal also, the soil under the third treatment (One side furrow with loop) stored water more efficient than under the first and second treatments in soil root zone. So, it is clear that storage capacity of soil water in root zone is better under one side furrow with loop compared with the two-side furrow and basin.

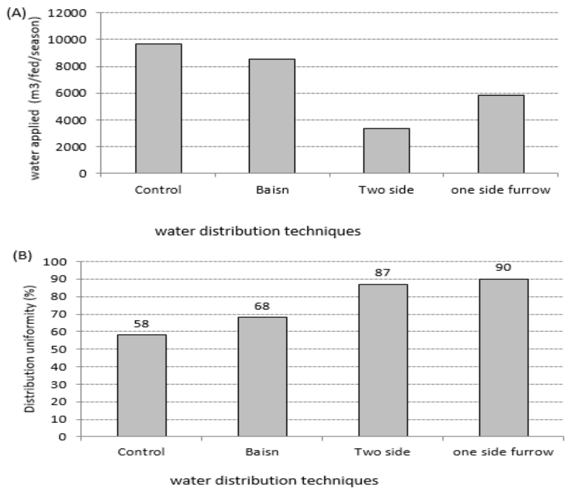


Fig. 6. Impact of irrigation treatments on (A) water consumption, (B) distribution uniformity

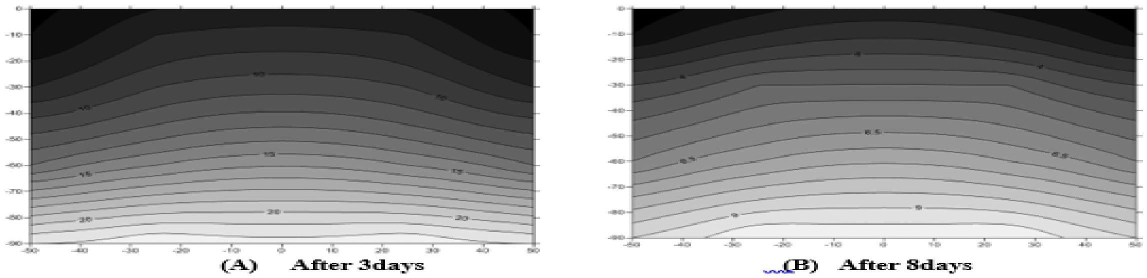


Fig. 7. Soil moisture distribution after irrigation under tow side furrow treatment

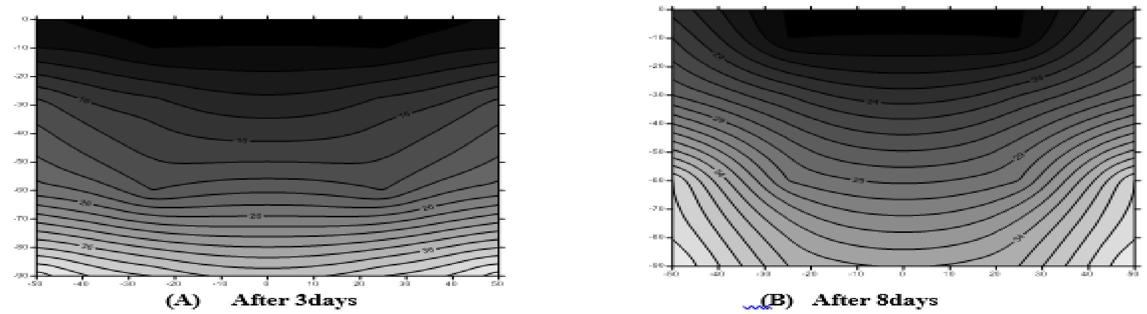


Fig. 8. Soil moisture distribution after irrigation under basin treatment

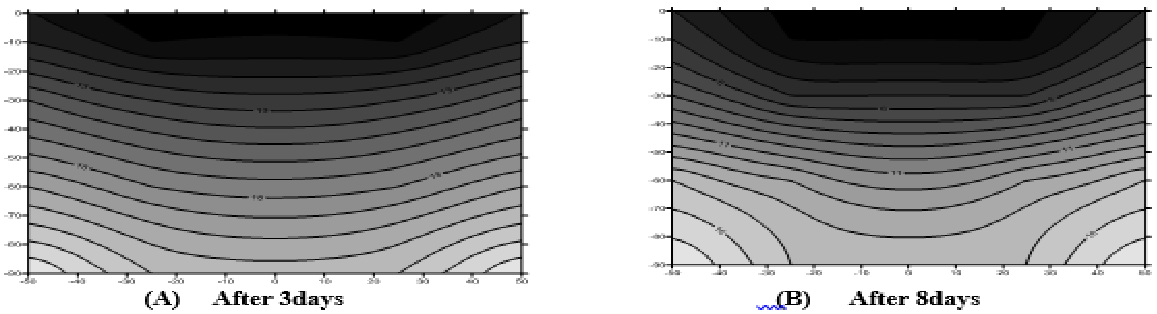


Fig. 9. Soil moisture distribution after irrigation under one side furrow treatment

3-Validation process of the investigated simulation model and different irrigation water distribution technique:

Two side furrows technique:

As shown at Figure (10), the data indicated that there is a strong relationship between a simulated and measured advance time (R^2= 0.93 & E = 0.93 & RMSE = 0.190) for one side furrow irrigation treatment. Moreover, recession time data represented that the relationship between a simulated and measured are still have a good performance for (R^2, E and RMSE) by 0.804, 0.8 and 0.25, respectively at the same type of irrigation treatment. Noticeable; that the higher R^2 and E values and the lower RMSE values indicated a good model performance. However, the best values for R^2, E and RMSE obtained with advanced time. Consequently, these results suggest that the WinSRFR model is useful for simulating advance and recession time under one side furrow irrigation treatment.

Basin technique:

Figure (11) shows the relationship between the measured and simulated advance time expressed by liner equation with high correlation coefficient R^2 (0.9628), E (0.95) and RMSE (0.20064) which indicate the high accuracy of simulating the advance time under basin treatment. Recession time was measured under the field conditions for basin treatment. The statistical indicators obtained from the comparison between simulated and measured recession time were very good which reflects that there were fits between them. The values of R^2, E and RMSE were 0.9363, 0.931 and 0.16192, respectively.

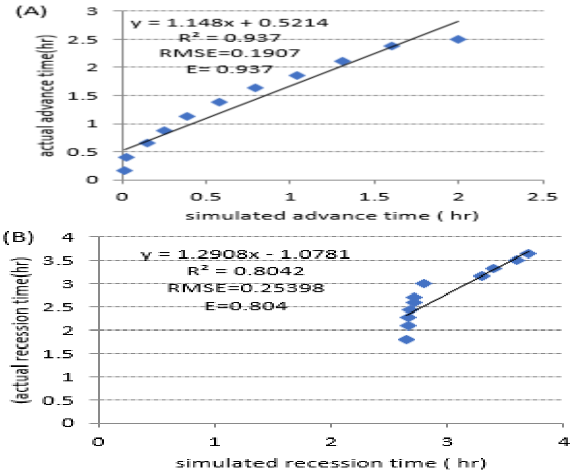


Fig. 10. Relationship between measured and simulated (A) advance time "hr", (B) recession time "hr" under two side furrow treatment.

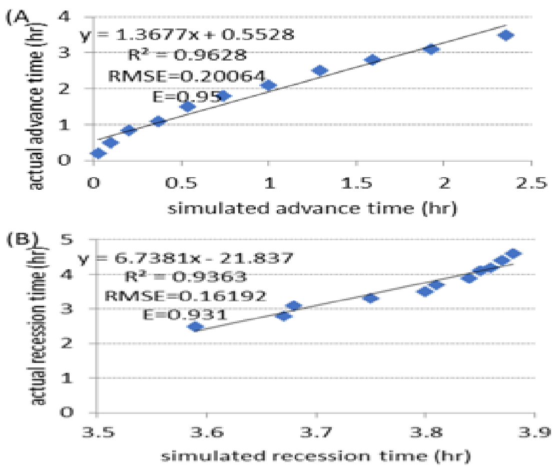


Fig. 11. Relationship between measured and simulated (A) advance time "hr", (B) recession time "hr" under basin treatment

One side furrow with loop technique:

Data illustrated in Figure (12) show the good predictions of the simulated advance time under one side furrow with loop. The simulated and measured advance time under this experimental treatment show a strong correlation with good R^2 values. The average of correlation value was more than 0.9 moreover, the RMSE were close to zero and E nearest to 1. The R^2, E and RMSE were 0.9142, 0.91 and 0.1, respectively. In general, these statistical indicators were very good. Overall measured and simulated recession time were in the same trend with that gained from the comparison of measured and simulated advance time under the experimental conditions where the statistical analysis values o recession time were R^2= 0.9604, E= 0.96 and RMSE= 0.07575.

4-Influence of irrigation treatments on yield and water productivity:

Data are shown in Figures (13-A and 13-B) refer to the effect of treatment (one side Furrow, two side furrow side, basin, and control) of irrigation system on productivity and water use efficiency (WP) of date palm trees.

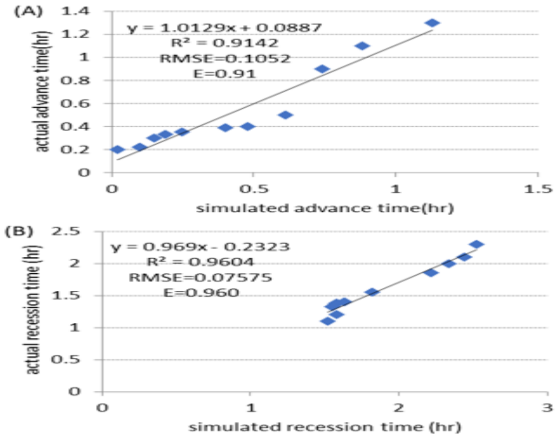


Fig. 12. Relationship between measured and simulated (A) advance time "hr", (B) recession time "hr" under one side furrow with loop treatment

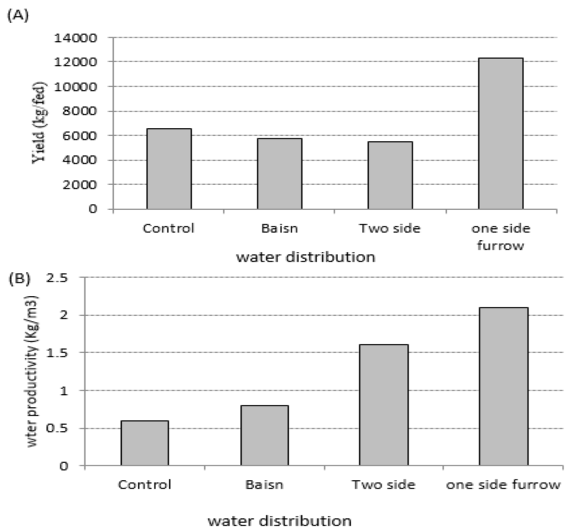


Fig. 13. Impact of irrigation treatments on (A) yield, (B) water productivity (kg/m^3).

It is clear from these figures that there were differences due to variation of irrigation rate in productivity of date palm trees and water use efficiency (WP) in experimental seasons. It is obvious from the data that the highest values of productivity date palm were achieved by applying one side furrow treatment. Moreover, applying two side furrows led to obtaining significantly medium values where basin and control treatments showed the lowest values in the same concern.

CONCLUSION

This study aimed to use simulation models such as WinSRFR to predict distribution uniformity under surface irrigation system for raising the water application efficiency leading to proper decisions. The statistical indicators of R^2, RMSE, and E were used for the comparison between measured and simulated advance time, recession time. The results were sufficiently acceptable to fulfill the objective of this work, this was confirmed by the good agreement between the simulated and measured advance time, recessions time. Gated pipe is used with three techniques of surface irrigation used in this study: (Two side furrow, basin and one side furrow with loop). One side furrow with loop treatment gave the highest values of yield, water use efficiency and distribution uniformity.

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نظام محاكاة للإدارة المتكاملة لأشجار النخيل المروية بالرى السطحي تحت ظروف محافظة الوادى الجديد

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[1]قسم الهندسة الزراعية – كلية الزراعة – جامعة عين شمس – ص . ب 86 – حدائق شبرا 11241 – القاهرة – مصر

[2]المعمل المركزي لأبحاث وتطوير النخيل – مركز البحوث الزراعية – الداخلة – الوادي الجديد – مصر

تم اجراء تجربة حقلية في منطقة الداخلة محافظة الوادي الجديد خلال موسمين (2018-2019) – (2019-2020) على اشجار النخيل. وكان هدف الدراسة تطبيق تقنية جديدة مثل نماذج المحاكاة لتحسين انتظامية التوزيع و كفاءة استخدام المياه باستخدام تقنيات مختلفة لنظام الري السطحي من أجل اختيار افضل القرارات لتحديد التوزيع المتكامل للمياه. وكانت أهم عوامل الدراسة هى استخدام انابيب مبوبة طولها 6م وقطرها 6 بوصة تحت ضاغط تشغيل (0,3 – 0,6 - 0,9 م) و تم قياس الضاغط والتصرف عند كل بوابة و بناءا على الاحتياجات المائية للنخيل طبقا لبيانات المناخ ، وتم اختيار انسب ضاغط تشغيل الذي يعطي التصرف المناسب.وكذلك تم دراسة 3 معاملات من نظام الري السطحي و هما النظام الاول:- نظام الخطوط وكان عدد 2 خط بجانب صف النخل ، النظام الثاني:– نظام الاحواض . النظام الثالث:– نظام خطوط وكان خط بجانب صف النخل متصل بحلقة حول كل نخلة . وتم اجراء القياسات التالية: كفاءة انتظامية التوزيع، زمن التقدم والانحسار، كفاءة اضافة المياه، الانتاجية. وتم التحقق من القيم الحقلية باستخدام نظم المحاكاة ببرنامج WINSERF. أظهرت النتائج أن المؤشرات الإحصائية لـ(R^2 (> 0.9) و RMSE (الأقرب إلى 0) و(E (> 0.9) تم استخدامها للمقارنة بين زمن التقدم المقاس والمحاكي و زمن الانحسار. بشكل عام ، كانت النتائج مقبولة بشكل كافٍ لتحقيق هدف هذا العمل ، وقد تم تأكيد ذلك من خلال الاتفاق الجيد بين زمن التقدم المقاس والمحاكي و زمن الانحسار. أعطى النظام الاول أعلى قيم للمحصول وكفاءة استخدام المياه وانتظام التوزيع (12288 كجم/فدان ، 2,1 كجم/ م^3 و 90٪) مقارنة النظام الثاني والثالث (5440 كجم/فدان، 1,6 كجم/م^3 و 87٪) و (5760 كجم/فدان ، 0,8 كجم/م^3 و 68٪) علي التوالي.