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# Evaluation of Aqua Crop computer model in the potato under irrigation management of continuity plan of Jiroft region, Kerman, Iran.

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## ABSTRACT

The agricultural regions are running into difficulties, which are restrictive availability of water, successive appearing draughts, and overuse of ground water resources for supplemental water requirements. As a sample which is got from the farm is sent to the laboratory for testing and the laboratory works need devices. Hence, conducting farm experiments are expensive and time consuming to optimize the amount of water use, and desirable plant performance.Therefore, aqua crop computer model was used to determine water use efficiency, performance and evaluation of potato. This research project was completed in the form of random complete blockdesign in the strip plot model with three times in the farm experiment which was located in VakilAbad of Jiroft in 2010. In this study, the effect of three irrigation level i.e.100, 75 and 50 percent plant water requirement was assessed on the performance and water use efficiency of potato. The results of this study suggested that the amount of water requirement, behavior and water use efficiency simulated by Aqua crop computer model had well adaptation and correlation with field measures.

**Key words**: Aqua crop model, Under irrigation, Water use efficiency, Yield of potato

## INTRODUCTION

Software and simulated models can be valuable devices for exact assessment of agronomical crops under deficit irrigation conditions (Farahbakhsh et al., 2011; Garsiavila et al., 2009; Samarzadeh et al 2011). The Aqua crop model imitates the crop behavior in the base of use able water under different conditions of full irrigation, dry farming, supplement irrigation, and under irrigation (Hsiao et al., 2009). Improving water use efficiency (WUE) based on more production instead of consuming water unit is so important. Therefore, precise knowledge of relationship between water use and crop behavior is necessary. As the impacts of water deficit is different in the base ofintensity, period, and time of application, modelingofthe reaction crop to water deficit is hard and complicated (Alsuhaibani, 2011). The first attempts to comprehend these relations causedresulted inexperienced equations between water and behavior that is called function of water production (Olarinde et al., 2011; Vaux et al., 1983). Many efforts were made to optimize the allocation of water recourses, for the production functions are extensively used in economic

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analysis of crop behavior changes to water. As the plant has complicated responses to the water deficit, it has tempted the users to use experienced functions for crop reaction as the most applied choice (Khordebin and Landi, 2011). Some researchers have concluded that the model is proper for estimating the efficiency of wheat. Estimating the ratio of wheat performance by aqua crop computer model has an acceptable ability in estimating the ratio of wheat performance by aqua crop computer model (Alizadeh et al., 2011). The aim of this paper was to evaluate of Aqua crop model in the reaction simulation, determination of potato performance and water use efficiency.

## MATERIAL AND METHODS

This research was conducted at Jiroft-Bandarabas road VakilAbad in 2010. Jiroft has 235 km distance from Kerman and it is located in the southern east of Iran. Moreover, it has 57°. 25′ N., 27°.30′E. , 140mm average annual rainfall , and 3000mm annual evaporation. The irrigation treatments include 50, 75 and 100 percent plant water requirement. The requirement and ratio of water which plant needs were calculated by evaporation pan and FAO methods. In this research the output evaporation data was collected from pan evaporation that was located in the experimental farm for estimating the amount of irrigation water.

$$ET_C=K_P*K_C*E_P \quad (1)$$

Where

$ET_C$: evaporation and transpiration of crop, mm per day.

$K_P$: evaporation pan factor.

$K_C$: crop factor (Farshi et al., 1999).

$E_P$: evaporation from surface Pan Mm per day (Alizadeh, 2005).

The drip irrigation system was used to irrigate in the strips type with a discharge of 4 L $hr^{-1}$ for 3 days. The amount of water and evaporation for 3 days period to 100 percent water requirement was presented in (Table1). Depth of irrigation water was estimated for 75 and 50 percent water treatment and it was used as input data for Aqua crop model.

Table1: The amount of discharged irrigation water to the potato farm for treatment of 100 percent water requirement with three periods of irrigation

| The day after cultivation | Depth of water irrigation (mm) | The day after cultivation | Depth of water irrigation (mm) | The day after cultivation | Depth of water irrigation (mm) | The day after cultivation | Depth of water irrigation (mm) | The day after cultivation | Depth of water irrigation (mm) | The day after cultivation | Depth of water irrigation (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 22 | 8 | 43 | 6 | 64 | 6 | 85 | 7 | 106 | 12 |
| 4 | 14 | 25 | 8 | 46 | 7 | 67 | 4 | 88 | 8 | 109 | 12 |
| 7 | 15 | 28 | 10 | 49 | 7 | 70 | 5 | 91 | 8 | 112 | 12 |
| 10 | 15 | 31 | 9 | 52 | 6 | 73 | 7 | 94 | 7 | 115 | 13 |
| 13 | 12 | 34 | 8 | 55 | 10 | 76 | 5 | 97 | 8 | 118 | 14 |
| 16 | 11 | 37 | 7 | 58 | 8 | 79 | 7 | 100 | 8 | 121 | 11 |
| 19 | 8 | 40 | 6 | 61 | 9 | 82 | 8 | 103 | 12 | 124 | 12 |

The reaction of performance response of water can be assessed using the following equation at the farms (Dorenbos and Kassam, 1979).

$$\left(\frac{Y_x - Y_a}{Y_x}\right) = K_Y \left(\frac{ET_x - ET_a}{ET_x}\right) \quad (2)$$

Where

$Y_X$: maximum performance .

$Y_a$: real performance.

$ET_X$: maximum evaporation and transpiration.

$ET_a$: real evaporation and transpiration.

$K_Y$ : proportion factor between decreasing of ratio performance and evaporation separation .

This cause to unconsidered the in effective section of water in the production of crop with separating evaporation and tramps rationing to transpiration of crop surface (Tr) and evaporation of soil surface (E).This issue is important when the cover plant is not completed the following equation explains the arithmetic description(Bradford and Hsiao, 1982).

$$B_i = WP^* \left(\frac{Tr_i}{ET_{o,i}}\right) \quad (3)$$

In this equation, the amount of daily transpiration ($T_{ri}$) by daily $ET_0$ and Water Productivity (WP)are constant in the same climate conditions. Water productivity is called water use efficiency (Hanks, 1983; Tanner and Sinclair, 1983), so moving from the first equation to the second one introduces the correction of common of model. The other advantage of the second equation, which was used in the Aqua crop model, was simulating the process of growth plant on daily- basis, while the simulation was performed in the season or month format for equation 1. The soil component of Aqua crop can be considered as a dispersed system up to five layers with different textures .The model consider the all of soil texture classifications of the soil angular which is used in the United States Department of Agriculture.However, the user canenter its favorable texture so that the model determine the hydraulic characteristics such as drainage factor (T), saturated hydraulic conduction ($k_{sat}$), saturated ratio volume ($\Theta_{vsat}$), saturated farm capacity ($\Theta_{VFC}$), the ratio volume of wilting point ($\Theta_{VPWP}$) for per classification soil texture in the region (Singh et al., 2008; Steduto et al., 2009).

The sensitive analysis of Aqua crop computer model

The sensitive analysis is a technique to evaluate and reevaluate the impression of a model, described the method for this analysis(Heng et al., 2009; Hsiao and kxu, 2000).

$$S_c = \frac{\frac{\Delta W}{\overline{W}}}{\frac{\Delta P}{\overline{P}}} \quad (4)$$

Where

$S_c$: sensitive factor.

ΔW: the difference of output parameter amount before and after changing of input parameter.

W: the average ofoutput parameter before and after changing of input parameter.

ΔP: the difference of input amounts of base band changed input.

P: the average of input amounts of a parameter into a model.

The range of suggested sensitive changes was presented by (Heng et al., 2009; Hsiao and Kxu, 2009) (Table2).

Table2: The sensitivity classification of input parameters with sensitivity factors

| $S_c$>1.5 | 0.3<$S_c$<1.5 | 0<$S_c$<0.3 | $S_c$=0 | he ratio of changes |
|---|---|---|---|---|
| High sensitivity | SensitivityAverage | Low sensitivity | Without sensitivity | The intensity of sensitivity |

The standards of evaluating results.

The efficiency of model is evaluated by Root Mean square Error (RMSE). coefficient of efficiency (E), index of agreement (d), Maximum Error (ME), and coefficient of Residual Moss (CRM) which were calculated in the following form :

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - M_i)^2} \times 100 / \overline{M} \qquad (5)$$

Where Si and Mi. are the simulated and measured values, respectively, and n is the number of observations. The unit for RMSE is the same as that for $S_i$ and $M_i$, and M is the mean of the n measured values.

$$E = 1 - \frac{\sum_{i=1}^{n}(M_i - S_i)^2}{\sum_{i=1}^{n}(M_i - \overline{M})^2} \qquad (6)$$

The parameters are defined in the equation (Eitzinger et al., 2004).

$$d = 1 - \frac{\sum_{i=1}^{n}(S_i - M_i)^2}{\sum_{i=1}^{n}(\left|S_i - \overline{M}\right| + \left|M_i - \overline{M}\right|)^2} \qquad (7)$$

The parameters are defined in the equation (Eitzinger et al., 2004; Singh et al., 2008).

$$ME = Max\left|S_i - M_i\right| \times 100 / \overline{M} \qquad (8)$$

The parameters are defined in the equation (Eitzinger et al., 2004).

$$CRM = \frac{\sum_{i=1}^{n} M_i - \sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} M_i} \qquad (9)$$

The parameters are defined in the equation (Eitzinger et al., 2004).

## RESULTS

Aqua crop computer models were performed by cultivation calendar, after entering the necessary information.The model has ability to simulate root development, the growth of crop chlorophyll and transpiration in the period of growth season. The ratio of performance, the amount of required water plant, and water use efficiency were added to the model. The soil texture was Loamy-sandy, and depth of agronomical soil was measured between 70 to 100 Cm. The saturated hydraulic conduction of soil was 700 mm $d^{-1}$.

The Water balance model includes run off, percolation, redistribution, deep percolation, capillary rise, absorption, evaporation and transpiration. The soil water balance, input and output streams from boarders of the root and supplied water in the soil were simulated.

The analysis of model sensitivity

The calculated sensitivity factor amounts for some of the input parameters of Aqua Crop model are presented in the table (Table3).The results illustrate that model has a little sensitivity to the time of recovered, the period of yield formation, cultivation calendar to the maximum growth of root, the density of cultivation, and calendar of cultivation to the beginning of yield formation, so the errors which included from parameters in the farm is inconsiderable. The results of sensitivity showed that the model is more sensitive to evaporation factor ($K_{cb}$), water productivity normalized (WP), and harvest index. The manual of model considers transpiration safety 1.1 for potato, and this factor changed to the 1.12 for this region. Normal water use efficiency was located between 13 to 18 for $C_3$ plants which first produce a $C_3$ sugar that is called 3PGAL in the photosynthes is process such as potato. Also, it is located between 28 to 32 for $C_4$ plants which first produce Malt in the photosynthes is process.The manual of model considered 18 to 20 for normalized water use for potato, and with paying attention to the especial climate condition, water efficiency was normalized to 23 in order to produce a good balance between the performances of model and farm. Normalized water productivity provides this opportunity for climate to have good efficiency in the different weather, and climate scenarios in the future. The ratio harvest index was considered 70 to 85 percent in the Jiroft region which is considered 87% for jiroft as with increasing or decreasing the harvest index, the water use efficiency changed sharply (Farahani, 2009; Geerts et al., 2009; Raes et al., 2009). Evaporation safety ($K_{cb}$),crest growth cover (CGC),water productivity normalized (WP), harvesting Index ($HI_0$), senescence, and the first humidity were the changes to which the model was more sensitive under irrigation treatment (the treatments of 75 and 50 percent water requirement).These parameters should be measured carefully, or a sensitive error will happen in the predicting of model performance (Table 2&3). The model sensitivity to the depth of irrigation water was different for all the treatments. With decreasing depth of irrigation water, the sensitivity of model to the changes of irrigation water depth will increase, for water use efficiency decrease with going up of irrigation water depth.

Table 3: The sensitivity factors of input parameters of model

| The degree of sensitivity | The amount of Sc in - %25 | The amount of Sc in +%25 | Input parameters | |
|---|---|---|---|---|
| Average | 1.03 | 0.84 | $K_{cb}$ | Agronomical Parameters |
| Low | 0.10 | 0.08 | Density of cultivation | |
| Average | 0.51 | 0.27 | Cover Growth Crest(CGC) | |
| Average | 1 | 1 | water productivity Normalized(WP) | |
| Average | 0.99 | 1 | Harvest Index($HI_0$) | |
| No-Low | 0.00 | 0.17 | Recovered | |
| Average-High | 1.46 | 0.3 | Senescence | |
| No-Low | 0.05 | 0.00 | yield formation The period of | |
| No | 0.00 | 0.00 | The days from cultivation to the maximum of depth root | |

| | | | | |
|---|---|---|---|---|
| No-Low | 0.00 | 0.01 | The time from cultivation to yield formation | |
| No | 0.00 | 0.00 | In the treatment of $a_3$ | The first humidity of soil |
| No-Low | 0.04 | 0.00 | In the treatment of $a_2$ | |
| No-Low | 0.17 | 0.00 | In the treatment of $a_1$ | |
| No | 0.00 | 0.00 | The hydraulic conduction of soil | The first conditions of soil |
| No-Low | 0.28 | 0.00 | A3 | Irrigation |
| Low-Average | 0.63 | 0.28 | $A_2$ | |
| Average | 1.11 | 0.63 | $A_1$ | |

## DISCUSSION

The results indicated that the simulated amounts by this model were close to the measured amounts (Table4). Root mean square error (RMSE), coefficient of efficiency (E), index of agreement (d), maximum error (ME), and coefficient of residual mass (CRM) were calculated to identify the model performance (Table5). The results showed that the model has ability to simulate $ET_c$ with relatively good care. The results which were included from that comparison of the measured yield formation performance in the farm and simulated by computer model have good correlation. The maximum performance that is 29.65 Tons per hectare belongs to treatment of 100 percent requirement, and the minimum one with 16.95 Tons per hectare belongs to treatment of 50 percent water requirement in the field experiment. The maximum performance that was 25.31Tons per hectare belongs to treatment of 100 percent water requirement, and the minimum one with 18.14 Tons per hectare belongs to the treatment of 50 percent water requirement in the aqua crop computer model. The results of aqua crop computer model illustrated that the ratio of plant performance goes up with increasing water irrigation like field measurements. The simulated performance results of model less than field results in the 100 and 75 percent irrigation treatment, and it was more in the 50 percent treatment. However, in the both of field experiment and simulated by aqua crop computer model, the ratio of performance goes down with decreasing irrigation water. Generally, all of the statistical indexes showed that the model has good efficiency in the estimating the performance ratio of potato (Table5).

Table 4: The simulated and measured amounts of water use in the period of potato growth.

| The amount of simulated used water($m^3$/ Hectare ) | The amount of measured used water($m^3$/Hectare) | Treatment |
|---|---|---|
| 2795 | 3542.13 | 100 percent water requirement |
| 2471 | 2655.09 | 75 percent water requirement |
| 1984 | 1770.23 | 50 percent water requirement |

Table 5: The evaluation of assessing parameters of aquacrop model in estimating of used water and performance of potato.

| CRM | ME | d | E | RMSE | Treatment |
|---|---|---|---|---|---|
| 0.09 | 28.132 | 0.61 | 0.123 | 12.27 | The ratio of $ET_C$ |
| 0.086 | 17.8 | 0.871 | 0.654 | 9.213 | The ratio of performance |

Regression analysis (figure l) showed that there was a significant linear relation between simulated and measured amounts. With considering the correlation factor ($R^2$=0.999) Aqua crop computer model can simulate the ratio of crop performance with relatively high care.

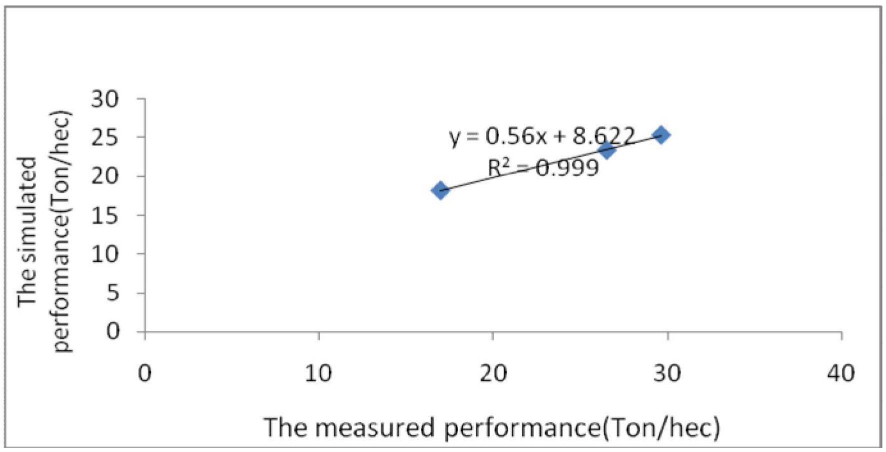


Figure 1: The comparison of ratio measured performance and simulated one by computer model.

Water use efficiency is one of the most important indexes in the designating of optimized irrigation level in irrigation conditions. The results of field measurements showed that with putting water stresses, water use efficiency increased, and if it had gone up, the water use efficiency would decrease. Seventy five percent was concluded the maximum water use efficiency in the field experiments, but the computer model shows the maximum water use efficiency in the water level of one hundred percent water requirement because evaporation section was separated from transpiration, and the model does not consider in effective water section evaporation in the water use efficiency calculation. Hence, the model is capable of calculating the real water use efficiency for plants. The statistics show that aqua crop model can estimate carefully the water use efficiency with a small standard deviation. The maximum errors of model occurred in the water use efficiency of 19.4 percent. The amount of RMSE is lower than 7 percent which shows the high care of model in predicting water use efficiency. The amount of CRM was close to zero and negative indicating the high care of model in simulating water use efficiency. Also, the simulated values were close to the measured amounts. The negative amount of CRM illustrated that the model simulate water use efficiency more than measured amounts as model calculate just transpiration of plant in estimating water use efficiency, but both of transpiration and evaporation are interfered for estimating plant water use efficiency in the farm experiment.The maximum temperature is 48° c and its minimum is

1$^{\circ}$c; furthermore, it has 55 to 65 percent ratio humidity .The rainfalls usually occur in the winter and spring in this region. The experiment was done in the strip plot form in the complete random blocks plan model with three replications in 36 checks and per secondary check had four cultivated line with 6 m light and 3m weight.

## Conclusions

1. Aqua crop computer model is the comparison of achievable and real performances in the farm and this model cause recognition of restrictive factors of crop production and exploitation of water. Also, it assists the economists, executors, and water manager of region to program the aims.
2. The evaluation of aqua crop model shows that the performance of yield formation potato depends on factors such as crest cover growth, crop transpiration factor, water normal use, beginning of old time, index of harvesting. Moreover, the amount of water irrigation was more sensitive than other factors.
3. The assessment of aqua crop model shows that model has good ability in predicting and estimating of evaporation and transpiration of crops ($ET_c$), performance, and water use efficiency.

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