OPTIMAL IRRIGATION REGIME UNDER DIFFERENT YIELD OF ORYZA (HASHEMI VARIETY)

REGIME D'IRRIGATION OPTIMAL POUR DIFFERENT RENDEMENT D'ORYZA (VARIETE DE HASHEMI)

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ABSTRACT

Programming and management of water resource assumes importance because of increasing in water demand in municipal, industrial and agricultural sectors and recurrent droughts particularly in the arid and semi-arid regions of the worlds. The primary responsibility of improving water use efficiency goes to the agriculture sector, as it is the largest consumer of water.

Oryza sativa L. is a strategic crop in Guilan province, Iran but its cultivation is restricted by droughts. Intermittent irrigation is useful to reduce water requirement in paddy field with least reduction in yield because mild water stress could be affective in quality and quantity improvement of rice. In this paper we have presented the use of a simulation- optimization tool for optimizing irrigation regime for different acceptable range of rice yields. SWAP model was used for simulating different stages of rice growth under different irrigation regimes (irrigation regime includes irrigation depth, interval and salinity). Linear programming was applied to optimize irrigation regime. Field data of Hashemi variety of Rice Research Inst. of Iran in Rasht in 2007 was selected to SWAP calibration. Soil hydraulic properties (residual and saturated moisture, saturated hydraulic conductivity), climatic data (min and max temperature, relative moisture, sunny hours, precipitation, evaporation), plant parameters (leaf area index, plant high, root depth, reduction factor of plant yield in different stages, plant salinity tolerance) and irrigation management (irrigation water depth and salinity, irrigation interval) are input data to the model. Irrigation depth and interval were pre-assigned values in the SWAP model and were 5-6 cm, 2-3 cm, 2-4 cm, 1-2 cm, respectively, in tiller, vegetative, maturity and harvest stages at 0-8 days range of irrigation interval. At the usual irrigation water salinity in Rasht (0.8 dS/m), acceptable yield reduction of rice is 20% so determining of optimal irrigation regime in 95, 90, 85 and 80% were considered. Optimal irrigation depth 5, 3, 4, 1 cm and 8 days irrigation interval were found to achieve the lowest of the acceptable yield (80%). This

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scenario of irrigation is useful for Sefidroud irrigation and drainage net programming under water resource deficit and drought. Maximum yield of rice was gained 96% under 5, 3, 4, 1 cm irrigation depth and zero day irrigation intervals.

Key words: *irrigation regime, Oryza sativa L., Optimization, water deficit stress.*

RESUME

La programmation et la gestion des ressources en eau revêtent une importance en raison de l'augmentation de la demande d'eau dans les secteurs municipaux, industriels et agricoles, et des sécheresses dans les régions arides et semi-arides du monde. Le secteur agricole est responsable de l'amélioration de l'efficience d'utilisation de l'eau, car il utilise une grande quantité de cette ressource.

L'Oryza sativa L. est une culture stratégique de la province Guilan en Iran, mais la sécheresse pose une contrainte sur cette culture. L'irrigation intermittente est utile pour réduire la demande en eau de la rizière, car le moindre stress hydrique peut affecter la qualité et la quantité du riz. Ce rapport présente l'utilisation d'un outil de simulation et d'optimisation du régime d'irrigation pour une série de rendement acceptable du riz. Le modèle SWAP a été utilisé pour simuler différents stades de croissance du riz pour différents régimes d'irrigation (cela inclut la profondeur d'irrigation, l'intervalle et la salinité). La programmation linéaire a été appliquée pour optimiser le régime d'irrigation.

En 2009, les données suivantes recueillies sur le terrain pour la variété Hashemi par l'Institut de Recherche sur le Riz, à Rasht ont été retenues pour le jaugeage du modèle SWAP : les propriétés hydraulique du sol (humidité résiduelle et saturée, conductivité hydraulique saturée), les données relevant du climat (température minimum et maximale, humidité relative, heures ensoleillées, précipitation, évaporation), les paramètres des plantes (index hydrique de la feuille, hauteur de la plante, profondeur de racine, réduction du rendement de plante dans différents stades, tolérance de la salinité de plante) et la gestion d'irrigation (profondeur d'eau d'irrigation et salinité, intervalle d'irrigation). La profondeur d'irrigation et l'intervalle étaient les valeurs prescrites pour le modèle SWAP et étaient de 5-6 cm, 2-3 cm, 2-4 cm, 1-2 cm, respectivement dans les stades de labourage, végétation, de maturité et de culture, l'intervalle d'irrigation étant de 0-8 jours.

Au niveau de salinité actuelle d'eau d'irrigation à Rasht (0,8 dS/m), la réduction acceptable du rendement de riz est de 20%. Il est ainsi considéré de retenir le régime d'irrigation optimal au niveau de 95, 90, 85 et 80%. Il est constaté qu'à la profondeur optimale d'irrigation de 5, 3, 4, 1 cm et à l'intervalle d'irrigation de 8 jours, il est possible de réaliser un niveau de rendement plus bas (80%). Ce scénario est utile pour la programmation du réseau d'irrigation et de drainage Sefidroud dans la condition de stress hydrique et de sécheresse. Le rendement maximal du riz - 96% - est réalisé à la profondeur d'irrigation de 5, 3, 4, 1 cm et à l'intervalle d'irrigation de zéro jour.

Mots clés : *Régime d'irrigation, Oryza sativa L., optimisation, stress hydrique.*

1. INTRODUCTION

Rice plays a major role in agriculture, economy, occupation and nutrition of the people especially those who live in developing countries. The future of rice production in the world and Iran depends on adopting appropriate management strategy, programming and optimum conservation of water resources. The necessity of sustainable agriculture development and fulfilling self sufficiency in food with revision of irrigation managing systems in paddy fields is an inevitable need for increasing water productivity in Iran, due to her climatic and geographical location, progressive growth of population, low water productivity in farms, outbreak of intermittent drought and inappropriate distribution of annual rains (salahshor et al, 1388).Irrigation is one of the most crucial factors in rice production.

Pimoradian et al., (1382*) found out that constant flooding of rice fields could be dispensed with at no significant loss of productivity and recommended intermittent irrigation in the Fars province of Iran.

8 day alteration period with constant intervals and 5 cm depth is suggested by Rezaei and Nahvi (1382) for Hashemi variety in intermittent irrigation. Irrigation delays of 0, 3 and 6 days were recommended respectively, in water scarcity, medium irrigation and intensified irrigation situations for Binam and Hasani varieties (Rezaei and Nahvi, 1384). In order to investigate the effect of 4 different irrigation system on rice yield, a study was carried out by Ghaemi at Soil and Water Center of Rasht in 1368. The results indicated that 8-9 day alternation period which leads to 8-35% increase in crop yield and 40% saving in water consumption is proper for Binam variety.

Reeducation 32% and 13% was reported, respectively, in irrigation water use and crop yield for Hashemi variety in Rasht (Amiri et al. 1386). According to their results, no further yield increase was seen for rice beyond 800mm of irrigation. Soil saturating led to 23% saving in water use and 6% yield loss in north of India and Philippines (Boman and Tang, 2001). Based on an experiment carried out in 2002, they reported that by 27-37 % economizing in water use, the crop yield would increase around 8-10% compared with permanent flooding in intermittent irrigation. Belder et al., (2004) found intermittent irrigation to cause 15-18% economy in water use. Intermittent irrigation with 6 days intervals and permanent flooding system do not significantly decrease the crop yield in Egypt (Nour et al, 1994). They revealed that Gizal178 variety is able to tolerate lack of irrigation for two times during vegetative and physiological ripening stages and cause 42 % economy in water use with least yield loss.

In Philippines, 5-10 days of drought stress at reproduction phase caused 25-40% yield loss of IR64 variety (Yambao and Ingram, 1988). Based on an investigation on rice yield under different irrigation systems, Aguilar and Borjas (2005) concluded that irrigation treatment of 2 days after disappearance of water from field surface and 5 days intervals were appropriate for getting more yields.

In another experiment, the effect of drought stress on 20 upland varieties of rice was

* Iran calendar year 1382 = Georgian calendar year 2003.

investigated by Jones (1981**). The results showed that drought stress had less effect on grain filling percentage 20 days before and 10 days after flowering. According to Goel and Verma (1998), 4 day interval and 5 cm irrigation water depth led to the highest crop yield.

World wide studies related to rice irrigation are classified into three fields: System of Rice Intensification (SRI), aerobic rice, and intermittent irrigation with proper intervals which has been paid more attention than the others (Asadi et al., 1383). Optimization of depth and intervals of intermittent irrigation in every growth stage could lead to optimum qualitative and quantitative management of irrigation water and decrease in crop yield. Sefidroud River, which is the main water resource of Guilan province agriculture, is encountering downward trend in discharge due to the construction of too many dams upstream of Sefidroud to ward off the ill effects of recent droughts in Guilan province.

Because of rice sensitivity to drought stress, this research tries to determine the ratio of the depth of water and the optimal intermittent irrigation period by using optimization- simulation model to increase rice yield. Agro hydrological SWAP was used to simulate different growth stage of rice, optimize the depth and intermittent rice irrigation period in proportion to different growth stages.

2. MATERIALS AND METHODS

Guilan province with 14030 km^2 area is located in the north of Iran at longitude 48º 34´ to 50 º 48´ E longitude and 36 º 33´ to 38 º 27´N latitude.

Surface water recourses of Guilan province include rivers, lakes and pools. Surface and groundwater resources of Guilan are divided into Sefidroud, east Guilan, Foumanat and talesh basins. Sefidroud basin with 59400 km^2 area is located between 46º 30´ to 51º 15´ east longitude and 34º 45´ to 37º 57´ north latitude. These rivers have been experiencing salinity and water scarcity during recent years. Figure 1 demonstrates the gradual downward trend of discharge in the recent years. Accordingly, intermittent irrigation management and determining the depth and intervals of irrigation at different plant growth stages are very important to save rice from drought stress.

In order to evaluate drought effect on rice growth stages, SWAP agrohydraulic simulation model was used for optimization of depth and intervals of intermittent irrigation. Swap model was set up in Wageningen University by De Wit (1970). This model was developed for simulation of water flow, plant temperature, biomass and salts by van Dam et al., (1997). WOFOST model in which crops growth is simulated based on their eco-physiochemical processes was applied for simulation of plant growth (Amiri et al., 1386). The foundation of this model is physical connection of soil parameters, water, atmosphere and plant that uses different sorts of information such as climate, soil, water and plant (Mansouri and Mostafa zadeh, 1385). This model includes 5 main sub-models of meteorology, plant, soil, irrigation and timing.

** Subtract 621 from Georgian calendar year to get Iran calendar year.

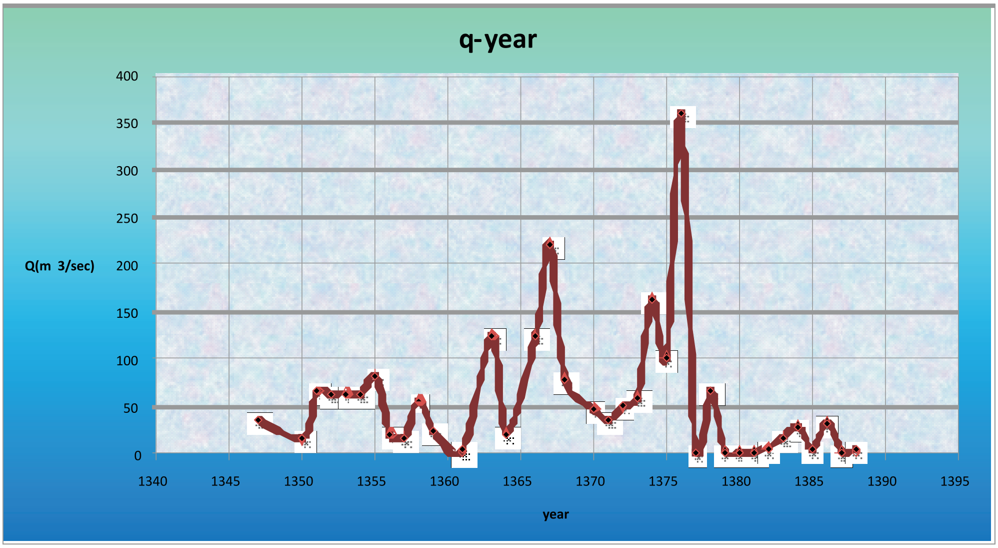

Fig. 1. Gradual downward trend of discharge of Sefidroud River

Characteristics of hashemi variety of Rasht paddy fields were used for calibration of SWAP model. Meteorological sub model data included minimum and maximum temperature, relative humidity, sundial, wind speed; precipitation and evaporation from class a washbasin were obtained from meteorology synoptic station of Rasht agriculture in 1386. Evaporation's washbasin Data with index of 0.78 were changed into potential evapotranspiration.

Plant sub model of SWAP included simple and detailed models and Simple sub model was applied in our project on the basis of available data. Plant parameters of simple model were: leaf area, root penetration depth and yield reaction index in various growth stages. Agronomical data of 1386 was used for Hashemi variety at rice research institute of Rasht rice. Required hydraulic characteristics of soil sub model: residual moisture content, saturated moisture content, saturated hydraulic conductivity and van Genuchten parameters were estimated using clay and silt percentage, organic matter and specific bulk density through transfer function. Irrigation sub model (which contains irrigation management parameters like irrigation method, irrigation water depth and interval) was defined based on rice cultivation conditions and optimization model constraints.

After calibration of simulated model, optimum model determined irrigation interval and water depth in different growth stages aimed at maximization of rice yield. Target function and decision variables are given in equation 1.

$$Maximum\ Y = F(D_1, D_2, D_3, D_4, T) \quad (1)$$

subjectto

$$5 \leq D_1 \leq 6\ cm,\ 2 \leq D_2 \leq 3\ cm,\ 2 \leq D_3 \leq 4\ cm,\ 1 \leq D_4 \leq 2\ cm$$

$$0 \leq T \leq 8\ day$$

D_1 to D_4 are irrigation water depth in establishment steps of tiller, vegetative, maturity, harvest and T period of irrigation Intervals. Connstraints of Optimization model for decision variables were selected according to Mahdavi (1380), Rezaiy and Nahvi (1382).

In this experiment, by inducing 0.8 dS/m salinity, plant yield was simulated by SWAP model and then optimum depths and irrigation intervals were determined using optimization model.

3. RESULTS AND DISCUSSIONS

Current salinity level of Sefidroud river is 0.8dS/m in which the highest crop yield was associated with permanent floating system by irrigation depth of 5,2,4 and1 cm for respectively vegetative, tillering, reproduction and maturity stages was estimated 96%. Figure 2 shows crop yields in different irrigation intervals of 0.8dS/m salinity.

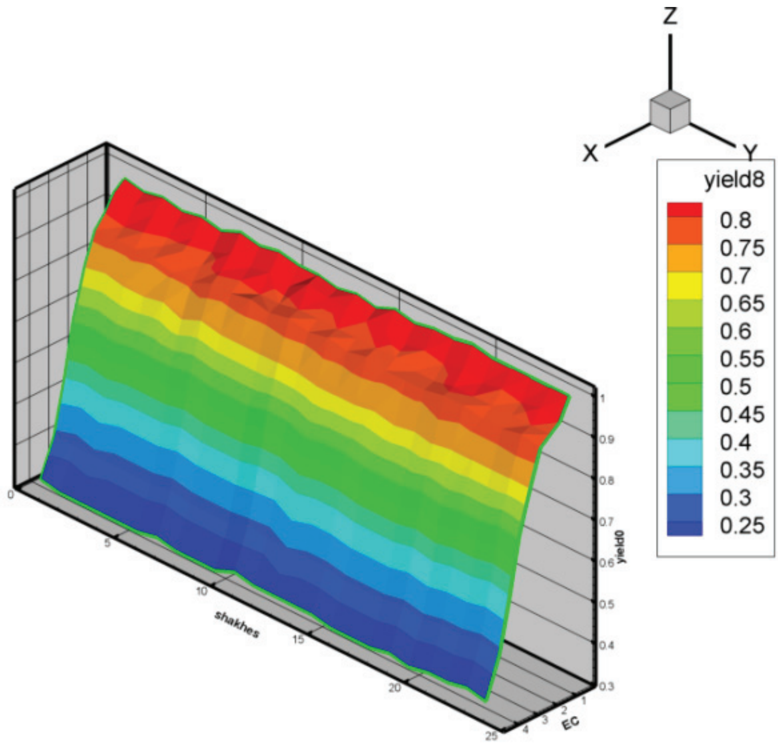

Fig. 2. Yield of rice for salinity of 0.8 dS/m

According to simulation-optimization of different irrigated rice systems and regarding Table1, in 0.8 dS/m salinity, the highest and the lowest crop yield were associated with flooding and 8 day irrigation interval, respectively. In Guilan province, 15-20% rice yield loss is desirable and usual. Based on results of rice yield simulation using SWAP, the best irrigation interval and irrigation depth in different growth stages of rice gave 80-85 % of crop yield in 0.8 dS/m salinity (Table 2).

Table 1. Optimal irrigation regime under different acceptable yield of rice

rrigation interval (day)	Irrigation depth in tiller stage(cm)1	Irrigation depth in vegetative stage(cm)2	Irrigation depth in maturity stage(cm)3	Irrigation depth in harvest stage(cm)4	yeild(%)
0	5	3	4	1	96
1	6	3	4	1	95
3	5	3	3	1	89
3	5	3	3	2	89
3	5	3	4	1	89
3	5	3	4	2	89
3	6	2	4	1	89
3	6	3	4	1	89
5	5	3	2	1	88
5	6	2	4	1	88
5	6	3	4	1	88
5	5	3	2	1	88
7	6	2	3	1	86
7	6	3	4	1	86
8	5	2	2	1	82
8	5	3	4	1	82

Table 2. Optimal irrigation regime under common yield of rice in Guilan

rrigation interval (day)	Irrigation depth in tiller stage(cm)1	Irrigation depth in vegetative stage(cm)2	Irrigation depth in maturity stage(cm)3	Irrigation depth in harvest stage(cm)4	yeild(%)
5	5	2	2	1	86
5	5	2	3	1	86
5	5	3	4	1	86
7	5	2	2	1	84
7	5	2	3	1	84
7	5	2	4	1	84
7	5	3	2	1	85
7	5	3	3	1	84
7	5	3	4	1	86
8	5	2	2	1	82
8	5	2	3	1	81
8	5	2	4	1	81
8	5	3	2	1	81
8	5	3	3	1	81
8	5	3	4	1	82
8	5	3	3	1	81

Table 3. Optimal irrigation for 0.8 ds/m salinity yield of rice

rrigation interval (day)	Irrigation depth in tiller stage(cm)1	Irrigation depth in vegetative stage(cm)2	Irrigation depth in maturity stage(cm)3	Irrigation depth in harvest stage(cm)4	yeild(%)
5	5	3	2	1	88
7	6	2	3	1	86
8	5	2	2	1	82

4. CONCLUSIONS

Regarding derived results in simulation-optimization in rice intermittent irrigation of Guilan province, 8 days irrigation interval and 0.8 ds/m salinity as well as irrigation system of Table 3 was suggested for rice.

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