DOI: 10.1515/cerce-2017-0034 **Original Article**
Available online: www.uaiasi.ro/CERCET_AGROMOLD/
Print ISSN 0379-5837; Electronic ISSN 2067-1865

Cercetări Agronomice în Moldova
Vol. L , No. 4 (172) / 2017: 37-49

ASSESSMENT OF ET-HS MODEL FOR ESTIMATING CROP WATER DEMAND AND ITS EFFECTS ON YIELD AND YIELD COMPONENTS OF BARLEY AND WHEAT IN SEMI-ARID REGION OF IRAN

A. SOLEYMANI[1], M.H. SHAHRAJABIAN[1,*]

*E-mail: a.soleymani444@gmail.com; hesamshahrajabian@gmail.com

Received Apr. 25, 2017. Revised: Aug. 01, 2017. Accepted: Oct. 10, 2017. Published online: Dec. 27, 2017

ABSTRACT. In order to estimate the water requirement of barley and wheat by using of ET-HS model, a research was conducted at Research Farm of Islamic Azad University, Isfahan (Khorasgan) Branch, Iran. ET-HS model is used to determine irrigation water quantity and irrigation schedule for different crop. The study was based on randomized complete block design (RCBD) with three replications and six treatments. The irrigation treatments included irrigation to supply 50, 75, 100, 125 and 150% of crop water demand on the basis of ET-HS model during growing season and control treatment (conventional irrigation), which was irrigation on the basis of 70 mm evaporation from Class A evaporation pan during growing season. In barley experiment, the highest values for number of fertile tiller, maximum LAI, total dry matter in maximum LAI stage, number of grain per spike, a thousand seed weight (35.56 g), grain yield (7877.9 kg/ha), biological yield (17689.7 kg/ha) and harvest index (44.45%) was obtained for irrigation according to 100% of crop water demand on the basis of ET-HS model. In wheat experiment, the highest number of fertile spike, number of grain per spike, 1000 grain weight, grain yield, biological yield was obtained for irrigation treatment on the basis of 100% ET-HS model; moreover, the maximum harvest index was related to control treatment, followed by irrigation on the basis of 100% of ET-HS model. Conclusively, the appropriate irrigation treatment was 100% of crop water demand on the basis of ET-HS model during the growth season for both crops.

Keywords: irrigation schedule; evaporation; LAI; grain yield; harvest index.

INTRODUCTION

Iran is from arid and semi-arid regions and finding ways to overcome water deficiency has been always from research priorities to produce crops for growing population, because

[1] Department of Agronomy and Plant Breeding, Islamic Azad University, Isfahan (Khorasgan) Branch, Iran

in those regions, drough is an important factor limiting crop production (Soleymani *et al.*, 2011; Ghaffari *et al.,* 2012; Soleymani & Shahrajabian, 2012; Esmaeili & Soleymani, 2013; Canavar *et al.,* 2014; Hajiboland *et al.,* 2014; Hajiboland *et al.,* 2015; Ashraf *et al.,* 2016; Soleymani *et al.*, 2016; Shahrajabian & Soleymani, 2017; Shahrajabian *et al.*, 2017; Soleymani & Shahrajabian, 2017). A technique for efficient management of irrigation water is to use new models for determining water demand and scheduling irrigation along with decreasing the susceptibilty of crop to water deficiency and improving their tolerance to drought by breeding (Soleymani *et al.,* 2012), some of these models estimate the yield under water stress condition (Geerts & Raes, 2009), and others are related to climatic changes and evaluate the yearly variations of the yield during drought periods (Jones *et al.,* 2003). These models mostly need a wide range of data and information about climate, which are mainly gathered in research centers and need to be calibrated before use (Soleymani *et al.*, 2012); furthermore, these models, which are used for determining water use efficiency (WUE) that direct evaluation, is very time-consuming and expensive (clearer) (Rajabi *et al.,* 2009). FAO method (Penman-Monteith) was introduced as a standard method, that evaluates potential evapotranspiration (ETp) by software CropWat (Allen *et al.,* 1998). On the other hand, studies in arid and semi-arid regions have shown that temperature and radiation-based equations are highly precise (Allen *et al.,* 1998); among Hargreaves-Samani method has been accepted as an authentic method throughout the world. Hargreaves-Samani equation is more precise than FAO equation for arid and semi-arid regions of Iran. Moreover, given the global validity of Hargreaves-Samani equation in ET-HS model for evaluating evapotranspiration. Indeed, ET-HS model is used to determine irrigation water quantity and irrigation schedule for different crop (Najafi & Tabatabaei, 2007).

After calibration for a certain region, ET-HS model needs a few simple climatic variables, i.e. minimum and maximum daily temperatures, which are readily available to farmers. Indeed, ET-HS model is used to determine irrigation water quantity and irrigation schedule for different crop (Najafi & Mousavi, 2002; Najafi, 2006; Najafi & Tabatabaei, 2007). Barley (*Hordeum vulgare* L.) ranks fifth among crops in grain production in the world after maize, wheat, rice and soybean (Ofosu-Anim & Leitch, 2009; Soleymani & Shahrajabian, 2013; Soleymani *et al.,* 2016). Today, wheat (*Triticum* spp. L.*)* is still a strategically important prodcut in human nutrition; however, wheat yields are limited by the low water availability due to restricted rainfall, high evapotranspiration, heat stress and the short duration of the grain-filling period so irrigation is important for wheat production (Erekul*et al.,* 2012; Shahrajabian *et al.,* 2013;

Shahrajabian *et al.,* 2017). Wheat is also an important staple crop in terms of economy, nutrition and employment (Abdoli *et al.,* 2013). Since sound determination of barley and wheat water demand is very important in planning irrigation management, barley and wheat evapotranspiration models need to be evaluated and if water use is accurately managed, especially during sensitive growth stages, both yield and WUE will be improved. Calculating evapotranspiration, accurate plants water requirement and prediction of irrigation schedule has a great deal of importance for saving water resource (Ghassemi-Golezani*et al.,* 2014).

The aim of this study is conducted to determine the influence on different levels of crop water demand of the basis of ET-HS model on yield and yield components of barley and wheat.

MATERIAL AND METHODS

First experiment on barley

This investigation was conducted at Research Farm, Faculty of Agriculture, Islamic Azad University, Isfahan (Khorasgan) Branch in 2012-2013 (Latitude 32^{o}40'N, longitude 51^{o}58'E and 1570 m elevation). Soil analysis was done before beginning of study at 0-30 cm. Electrical conductivity and pH of soil at 0-30 cm was 3.11 dS/m and 8.1, respectively. The soil of research field was composed of 38% silt, 13% sand, and 49% clay, with a clay texture, which is a sort of Esfahan soils. Changes in mean temperature on the basis of centigrade and relative air humidity during growing season are shown in *Table 1*. The regional climate is classified as arid and very hot with arid summers on the basis of Köppen climate classification, but recommended classification for Iran ranks it as a region with arid and hot climate with relatively cold winter. Long-term average yearly precipitation and temperature of the region are 120 mm and 16^{o}C, respectively. The study was based on randomized complete block design with three replications and six treatments. The irrigation treatments included irrigation to supply 50, 75, 100, 125 and 150% of crop water demand on the basis of ET-HS model during growing season (I_1, I_2, I_3, I_4, I_5, and I_6) was control (conventional irrigation), which was irrigation on the basis of 70 mm evaporation from Class A evaporation pan during growing season. The previous crop on this research farm was rapeseed. The name of barley cultivar in this experiment was Reihan 03, which is appropriate in arid and semi-arid region of Iran. According to planting date (22th Oct.), seed planting was done by skillful workers. In each plot, twenty lines were used. The distance between each plot was 2 m. The length of each line was 5 cm, and the distance between lines were 15 cm. The final plant density on this research field was 400 plants per m^2. Hand weeding was done for controlling of weeds. The first irrigation was done immediately after seed plantation and next irrigations were done on the basis of 70 mm evaporation from Class A evaporation pan. The irrigation treatment began on 22th Feb. In ET-HS model, irrigation schedule was specified by calculating capillary water and available soil water capacity. Therefore, calibrated for research station, this model was designed as a computerized model for the search field that determined irrigation schedule and the amount of required water. To provide appropriate bed for emergence of barley seeds, deep plow, disking and lever was done, respectively. Before sowing, the field was fertilized with 250 kg/ha urea at three stages (30 kg/ha before plantation and other used as top dresser at stem elongation and heading stage) on the basis of soil test. According to soil analysis and high amount of P and K, P and K fertilizers were not used. Insects and pests were controlled with recommended pesticides. To measure the yield and yield components, lines from 1 to 5, and lines from 15 to 20, and sixth rows and 0.5 m from both ends of the rows were removed from the experimental plots at the end of season and the remaining plants were taken as the statistical population of the study. In order to measure the seed yield and dry matter, plants were cut and after drying, dry matter and seed yield were measured. Plants were harvested at physiological maturity stage, when plants turned into yellow. Six plants were randomly selected in each plot to measure plant height. Leaf area index was measured for 10 plants of each plot by leaf area meter (Delta T Device, UK). Harvest index was computed as the ration of the seed yield to aboveground dry matter. Analysis of variance (ANOVA) was used to determine the significant differences. Means were separated by Duncan's Multiple Test at $P \leq 5\%$. Correlation coefficients were calculated for the relationship between parameters. All statistics was performed with MSTAT-C program.

Table 1 - Changes in mean temperature on the basis of centigrade and relative air humidity during growing season

Month	The average of maximum temperature (°C)	The average of minimum temperature (°C)	The average of monthly temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Precipitations (mm)
22th Oct.- 22th Nov.	17	3	10	23	-4	40
22th Nov.- 22th Dec.	10	-4	3	14	-8	12
22th Dec.- 22th Jan.	11	-3	4	17	-10	12
22th Jan.- 22th Feb.	10	-5	3	19	-12	10
22th Feb.- 22th Mar.	12	-3	6	23	-10	2
22th Mar.- 22th Apr.	20	6	13	28	-3	15
22th Apr.- 22th May	30	15	22	33	11	6
22th May- 22th June	32	14	23	36	12	2

Second experiment on wheat

In order to determine crop water requirement and dry matter accumulation of wheat by using of experimental ET-HS model, an experiment was designed at Research farm of Islamic Azad University, Isfahan (Khorasgan) Branch in 2014-2015. The soil research experiment was done before wheat plantation (*Table 2*). A randomized complete block design with three replications and six treatments were used. Changes in mean temperature on the basis of centigrade and relative air humidity during growing season are shown in *Table 3*.

Table 2 - Soil analysis of experimental farm at 0-30 cm, before wheat plantation

EC (dS/m)	pH	$CaCO_3$	OC (%)	Nitrogen (%)	P (ppm)	K (ppm)	Silt (%)	Sand (%)	Clay (%)
3.30	7.04	39	1.12	0.21	53.02	400	40	12	48

Table 3 - Changes in mean temperature on the basis of centigrade during growing season in 2014-2015

Month	The average of maximum temperature (°C)	The average of minimum temperature (°C)	The average of monthly temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)
25th Oct. - 25th Nov.	13.7	1	7.35	22	-3
25th Nov. - 25th Dec.	11.5	-3.3	4.1	15	-6
25th Dec. - 25th Jan.	9.2	-5.3	1.95	16	-6
25th Jan. - 25th Feb.	12.5	-3.7	4.4	18	-5
25th Feb. - 25th Mar.	16.8	0.8	8.8	22	-4
25th Mar. - 25th Apr.	23.5	6.4	14.95	28	1
25th Apr. - 25th May	28.9	10.6	19.75	34	5
25th May - 25th June	37.4	15	26.2	41	11
25th June - 25th July	36.5	17.3	26.9	39	13

In this trial, for estimating plant water requirement ET-HS model was used. This model is designed for semi-arid and arid regions, which is used for measuring ET and crop water requirement (Najafi & Tabatabei, 2007):

$$(1)\ ET_{(ij)} = \alpha j\ (T \max j - T \min j)\ [(T \max j + T \min j)/2 + 17.8],$$

where, ET, α, T max and T min are crop evapotranspiration, calibration coefficient (This parameter is related to climatic condition of research field.), maximum temperature and minimum temperature, respectively. The above equation determines the amount plant water requirement and irrigation interval *via* input data and regional information, namely, crop species, planting date, soil texture, and specially two parameters, which are daily maximum and minimum temperature. Temperature parameter is the most accurate climatic factor, which is forecasted by meteorology organizations; therefore, the model could be very successful to predict irrigation event and crop water requirement through growing season. The amount of crop water requirement (mm) on the basis of ET-HS model and irrigation interval has been shown in *Table 4*.

Table 4 - The amount crop water requirement (mm) on the basis of ET-HS model and irrigation interval

Irrigation interval	100% of water requirement of plant according to the ET-HS model
2008/4/21	mm 35
2008/4/29	mm35
2008/5/4	mm30
2008/5/8	mm30
2008/5/12	mm 30
2008/5/16	mm30
2008/5/20	mm30
2008/5/24	mm30
2008/5/28	mm30
2008/6/1	mm30
2008/6/6	mm33
2008/6/11	mm33
2008/6/16	mm33
2008/6/21	mm33
2008/6/26	mm33

A randomized complete block design with three replications and six treatments were used. Treatments consisted in: I_1 - 50% of water requirement of plant according to ET-HS model during the growth stage; I_2 - 75% of water requirement of plant according to ET-HS model during the growth stage; I_3 - 100% of water requirement of plant according to the ET-HS model during the growth stage; I_4 - 125% of water requirement of plant according to the ET-HS model during the growth stage; I_5 - 150% of water requirement of plant according to the ET-HS model during the growth stage and I_6 - control treatment, that was performed according to evaporation from the basin of the class A during the growth stage. Irrigation treatment was done on the basis of estimation of ET-HS model from spring season to harvesting time. The name of barley cultivar in this experiment was Sepahan, which is appropriate in arid and semi-arid region of Iran. According to planting date (25th Oct.), seed planting was done by skillful workers. In each plot, 20 lines were used. The distance between each plot was 2 m. The length of each line was 5 cm, and the distance between lines were 15 cm. The final plant density on this research field was 400 plants per m^2. Hand weeding was done for controlling of weeds. The first irrigation was done immediately after seed plantation and next irrigations were done on the basis of 70 mm evaporation from Class A evaporation pan. The irrigation treatment began on 30th Feb. To provide appropriate bed for emergence of barley seeds, deep plow, disking and lever was done, respectively. Before sowing, the field was fertilized with 300 kg/ha urea at three stages (30 kg/ha before plantation and other used as top dresser at stem elongation and heading stage) on the basis of soil test. According to soil analysis and high amount of P and K, P and K fertilizers were not used. Insects and pests were controlled with recommended pesticides. To measure the yield and yield components, lines from 1 to 5, and lines from 15 to 20, and sixth rows and 0.5 m from both ends of the rows were removed from the experimental plots at the end of season and the remaining plants were taken as the statistical population of the study. In order to measure the seed yield and dry matter, plants were cut and after drying, dry matter and seed yield were measured. Plants were harvested at physiological maturity stage, when plants turned into yellow. A number of 10 plants were randomly selected in each plot to measure plant height. Harvest index was computed as the ration of the seed yield to aboveground dry matter. The data were statistically analyzed by software MSTAT-C and the means were compared by Duncan's multiple test at 5% probability level.

RESULTS AND DISCUSSION

Barley experiment

Irrigation on the basis of ET-HS model had no significant effect on plant height, number of tiller, number of fertile tiller, number of infertile tiller, number of tillers with infertile spike, spike length and peduncle length. The highest value of plant height was obtained for irrigation based on 100% (91.16 cm) of water demand, followed by control treatment, 125%, 150%, 75% and 50% of irrigation on the basis of ET-HS model. However, no significant differences were found among treatments (*Table 5*). The maximum and the minimum number of tiller were related to 100%, and 50% crop water demand on the basis of ET-HS model, respectively. Like the previous treatment, no significant differences were found among treatments. On the one hand, irrigation on the basis of 100% crop water demand obtained the highest number of fertile tiller. On the other hand, there were no significant differences among treatments; moreover, the lowest number of tiller was related to irrigation under 50% of crop water demand based on ET-HS model. Irrigation on the basis of 50% of crop water demand obtained higher value of both number of infertile tiller and number of tiller with infertile spike than other treatments, in spite the fact that no significant differences were found among treatments. The higher value for spike length was related to 125%, 100% and 50% of crop water demand on the basis of ET-HS model than those of other treatments. Indeed, all differences among treatments were not significant. The maximum and the minimum peduncle length were achieved in 100% and 50% of crop water demand based on ET-HS model, which were 16.03 cm, and 14.14 cm, respectively (*Table 5*).

The impact of irrigation on the basis of ET-HS model were not significant on maximum LAI, total dry matter in maximum LAI stage, the number of grain per spike, biological yield and harvest index. In contrast, number of fertile spike, 1000 seed weight and grain yield were markedly affected by irrigation treatment. Mamnouie *et al.* (2006) also reported that irrigation regime had significant effect on a 1000 seed weight, the number of spikes per m^2 and grain yield. Although, the highest maximum LAI and totally dry matter in maximum LAI stage and the number of grain per spike were achieved in irrigation based on 100% crop water demand, there were not any significant differences among treatments.

Table 5 - Mean comparison for some measured experimental characteristics

Treatment	Plant height (cm)	Number of tiller	Number of fertile tiller	Number of infertile tiller	Number of tillers with infertile spike	Spike length (cm)	Peduncle length (cm)
Crop water demand supplied on the basis of ET-HS model (%)							
50	87.25a	6.65a	4.03a	2.63a	0.46a	13.75a	14.14a
75	88.70a	6.66a	4.80a	1.86a	0.20a	13.83a	14.93a
100	91.16a	7.30a	5.13a	2.16a	0.10a	14.32a	16.03a
125	89.96a	7.20a	4.80a	2.40a	0.23a	14.80a	15.90a
150	89.73a	6.83a	4.63a	2.20a	0.23a	13.33a	15.08a
Control	90.30a	7.06a	4.86a	2.20a	0.16a	13.73a	14.63a

Common letters within each column do not differ significantly.

Plant productivity under drought stress is strongly related to the processes of dry matter partitioning and temporal biomass distribution. The maximum number of grain per spike was obtained in the treatment of irrigation to supply 100% of crop water demand, which had significant differences with the treatments of irrigation to supply 150% of crop water demand. Control treatment did not show significant differences with treatments of irrigation to supply 50%, 75%, 100% and 125% of crop water demand. The higher value of a 1000 seed weight was obtained for the treatment to supply 100% (35.56 g) of crop water demand, which had significant differences with 50%, 75%, and 150% of crop water demand on the basis of ET-HS model. The highest and the lowest grain yield were obtained for the treatment to supply 125% (6285.8 kg/ha) and 50% (4300.5 kg/ha) of crop water demand on the basis of ET-HS model, which had not any significant difference with each other. The adverse effects of water stress on crop yield may be more pronounced at some particular growth stage, may reduce final grain yield (Yilmaz *et al.,* 2010). Nonetheless, the highest biological yield (17689.7 kg/ha) was obtained from the treatment of irrigation to supply 100% of crop water demand and the lowest one (12907.2 kg/ha) from the treatment of irrigation to supply 150% of crop water demand on the basis of ET-HS model. In spite the fact that, the maximum harvest index, which was 44.45%, obtained for 100% of crop water demand, no significant differences were found between this treatment and control treatment, 75%, 125% and 150% of crop water demand. Furthermore, the lowest one was related to 50% of crop water demand on the basis of ET-HS model (31.22%) (*Table 6*). The negative impact of dry periods occurrence was also reported by Maleki Farahani *et al.* (2011).

Table 6 - Mean comparison for some measured experimental characteristics

Treatment	Maximum LAI	Total dry matter in maximum LAI stage (g/m^2)	Number of fertile spike per m^2	The number of grain per spike	A thousand seed weight (g)	Grain yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Crop water demand supplied on the basis of ET-HS model (%)								
50	3.38a	995.9a	617.67ab	25.66a	27.28c	4300.5b	13777.3bc	31.22b
75	3.52a	1184.2a	686.33a	29.00a	29.19bc	5762.5ab	15499.5abc	37.28ab
100	4.02a	1324.6a	730.33a	30.33a	35.56a	7877.9a	17689.7a	44.45a
125	3.63a	1246.2a	657.33a	30.00a	32.35ab	6285.8ab	15867.5abc	39.83ab
150	3.18a	1202.9a	533.67b	28.66a	28.95bc	4395.0b	12907.2c	34.39ab
Control	3.88a	1256.9a	700.00a	28.66a	34.55a	7024.0a	16885.5ab	41.09ab

Common letters within each column do not differ significantly.

Wheat experiment

ET-HS is estimating amount of irrigation water and irrigation period with minimum climatological variable. Irrigation treatment had significant influence on all experimental characteristics, namely, the number of infertile and fertile spike, the number of seed per spike, 1000 seed weight, seed yield, biological yield and harvest index. The highest number of fertile spike, number of seed per spike, 1000 seed weight, seed yield, biological yield was obtained for irrigation treatment on the basis of 100% ET-HS model; moreover, the maximum harvest index was related to control treatment, followed by irrigation on the basis of 100% of ET-HS model. Irrigation on the basis of 50% of ET-HS model had obtained the minimum number of fertile spike, number of seed per spike, one thousand seed weight, seed yield, biological yield and harvest index, but the lowest number of infertile spike was achieved for irrigation on the basis of 100% of ET-HS model (*Table 7*). By increase in stress severity, dry matter accumulation of leaves, stem and other parts of the crop decreased significantly so that 50% irrigation treatment had the lowest characteristics, which shows that irrigation directly influences the yield of barley and practically all the farmers realize its importance. Judicious and timely application of irrigation on the basis of new methods of irrigation increases yield considerable. Productivity of both barley and wheat are grealty affected by drought, however, they are considered moderately tolerant to drought stress.

Table 7 - Mean comparison for some measured experimental characteristics

Treatment	The number of infertile spike	The number of fertile spike	The number of seed per spike	One thousand seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Crop water demand supplied on the basis of ET-HS model (%)							
Control	163.3c	480b	38b	39.50a	7205b	17480d	41.21a
50%	211.7a	382e	29d	37.07c	4107f	15070e	27.25c
75%	186.7b	385e	34c	38.37b	5023e	17470d	28.75c
100%	150d	488a	40a	39.63a	7736a	19200a	40.29a
125%	161.7c	469c	36b	39.42a	6790c	18370b	36.96b
150%	168.3c	460d	35b	39.33a	6455d	17970c	35.92b

Common letters within each column do not differ significantly.

CONCLUSIONS

Determining disasters of water limiting system may be a first way to management practices to enhance barley production by minimizing yield losses through water deficit during critical growth periods of barley and wheat. Irrigation on the basis of ET-HS model effects on number of fertile spike, 1000 grain weight and grain yield were significant. The highest values for plant height, number of tiller, number of fertile tiller, peduncle length, maximum LAI, total dry matter in maximum LAI stage, number of fertile spike per m^2, number of grain per spike, 1000 seed weight (35.56 g), grain yield (7877.9 kg/ha), biological yield (17689.7 kg/ha) and harvest index (44.45%) was obtained for irrigation according to 100% of crop water demand on the basis of ET-HS model. Irrigation directly influences the yield of barley and practically all the farmers realize its importance. Judicious and timely application of irrigation on the basis of new methods of irrigation increases yield considerable. ET-HS is estimating amount of irrigation water and irrigation period with minimum climatological variable. Weather parameters, crop characteristics, management and environmental aspects are factors affecting on evapotranspiration and irrigation water requirement. In ET-HS model, these parameters are constant factors are arrived to the model and after calibrated model, with using daily maximum and minimum temperature as variable factors, it is predicted irrigation even and water requirement for selected crop.

At second experiment, which was survey different irrigation treatments on the basis of ET-HS model on wheat, the higher number of fertile spike, number of seed per spike, 1000 seed weight, seed yield, biological yield was achieved in irrigation treatment on the basis of 100% ET-HS model, followed by other treatments. The highest the number of fertile spike, the number of grain in the spike and 1000 seed weight, which was lead to production of the functional rate of seeds and harvest index, in comparison with irrigation treatments. Thus it could be suggested that in order to combine acceptable agronomical characteristics with the highest grain yield in the region, irrigation on the basis of 100% of crop water demand on the basis of ET-HS model during growth season could be applied.

REFERENCES

Abdoli, M., Saidi, M., Jalali-Honarmand, S., Mansourifar, S., Ghobadi, M.E. & Cheghamirza, K. (2013). Effect of source and sink limitation on yield and some agronomic characteristics in modern bread wheat cultivars under post anthesis water deficiency. *Acta Agric.Slov.,* 101(2): 173-182. DOI: 10.2478/acas-2013-0013

Allen, R.G., Pereira, L.S., Raes, D. & Smith, M. (1998). Crop evapotranspiration - guidelines for computing crop water requirements. *FAO irrigation and drainage paper*. 56: 139-141.

Ashraf, U., Salim, M.N., Sher, A., Sabir, S.R., Khan, A., Shenggang, P. & Tang, X. (2016). Maize growth, yield formation and water-nitrogen usage in response to varied irrigation and nitrogen supply under semi-arid climate. *Turk.J. Field Crops,* 21(1): 88-96. DOI: 10.17557/tjfc.93898

Canavar, Ö., Götz, K.P., Koca, Y.O. & Ellmer, F. (2014). Relationship between water use efficiency and $\delta^{13}C$ isotope discrimination of safflower (*Carthamus tinctorius* L.) under drought stress. *Turk.J. Field Crops,* 19(2): 203-211. DOI: 10.17557/tjfc.28375

Erekul, O., Götz, K.P. & Gurbuz, T. (2012). Effect of supplemental irrigation on yield and bread making quality of wheat (*Triticum aestivum* L.) varieties under the Mediterranean climatical conditions. *Turk.J. Field Crops,* 17(1): 78-86.

Esmaeili, R. & Soleymani, A. (2013). Evaluation of ET-HS model in estimating water requirment of safflower in center of Iran. *Intl.J. Agron Plant Prod.,* 4(12): 3366-3370.

Geerts, S. & Raes, D. (2009). Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agric. Water Manage*., 96:12751284.DOI:10.1016/j.agwat.2009.04.009

Ghaffari, M., Toorchi, M., Valizadeh, M. & Shakiba, M.R. (2012). Morpho-physiological screening of sunflower inbred lines under drought stress condition. *Turk.J. Field Crops,* 17(2): 185-190.

Ghassemi-Golezani, K., Chadordooz-Jeddi, A. & Zehtab-Salmasi, S. (2014). Effects of seed size aging on field performance of lentil (*Lens culinaris* Medik.) under different irrigation treatments. *Acta Agric.Slov.,* 103(2): 158-166.

Jones, P.D., Lister, D.H., Jaggard, K.W. & Pidgeon, J.D. (2003). Future climate changes impact on the productivity of sugar beet (*Beta vulgaris* L.) in Europe. *Climatic change,* 58(1-2): 93-108.

Hajiboland, R., Sadeghzadeh, N. & Sadeghzadeh, B. (2014). Effect of Se application on photosynthesis, osmolytes and water relations in two durum wheat (*Triticum durum L.*) genotypes under drought stress. *Acta Agric.Slov.,* 103(2): 167-179. DOI: 10.14720/aas.2014.103.2.2.

Hajiboland, R., Sadeghzadeh, N., Ebrahimi, N., Sadeghzadeh, B. & Mohammadi, S.A. (2015). Influence of selenium in drought-stressed wheat plants under greenhouse and field conditions. *Acta Agric.Slov.,* 105(2): 175-191. DOI: 10.14720/aas.2015.105.2.01

Maleki Farahani, S., Chaichi, M.R., Mazaheri, D., Tavakol Afshari, R. & Savaghebi, Gh. (2011). Barley *grain* mineral analysis as affected by different fertilizing systems and by drought stress. *J.Agr.Sci.Tech.,* 13: 315-326.

Mamnouie, E., Fotouhi Ghazvini, R., Esfahany, M. & Nakhoda, B. (2006). The effects of water deficit on crop yield and the physiological characteristics of barley (*Hordeum vulgare* L.) varieties. *J.Agric.Sci.Technol.,* 8: 211-219.

Najafi, P. & Mousavi, S.F. (2002). Assessment of CROPWAT and ET-HS models for estimating reference ET in arid and semi-arid regions of Iran. Volume 1A. 18th International Congress on Irrigation and Drainage, Montreal, Canada, pp. 1-9.

Najafi, P. (2006). Effects of using subsurface drip irrigation and treated municipal waste water in irrigation of tomato. *Pak.J.Biol.Sci.,* 9(14): 2672-2676.

Najafi, P. & Tabatabaei, S.H. (2007). Effect of using subsurface drip irrigation and ET-HS model to increase WUE in irrigation of some crops. *Irrig.Drain.,* 56(4): 477-486. DOI: 10.1002/ird.322

Ofosu-Anim, J. & Leitch, M.H. (2009). Relative efficacy of organic manures in spring barley (*Hordeum vulgare* L.) production. *Aust .J. Crop Sci.,* 3(1): 13-19.

Rajabi, A., Ober, E.S. & Griffiths, H. (2009). Genotype variation for water use efficiency, carbon isotope discrimination, and potential surrogate measures in sugar beet. *Field Crops Res.,* 112: 172-181.

Shahrajabian, M.H., Xue, X., Soleymani, A., Ogbaji, P.P. & Hu, Y. (2013). Evaluation of physiological indices of winter wheat under different irrigation treatments using weighing lysimeter. *Intl.J.Farm. & Alli.Sci.*, 2(24): 1192-1197.

Shahrajabian, M.H., Soleymani, A., Ogbaji, P.O. & Xue, X. (2017). Survey on qualitative and quantitative traits of winter wheat under different irrigation treatments using weighing lysimeter in North China Plain. *IJPSS*, 15(4): 1-11.

Shahrajabian, M.H., Soleymani, A., Ogbaji, P., & Xue, X. (2017). Grain yield, seed protein, phosphorus and potassium of winter wheat. Cercetari Agronomice in Moldova. 3(171): 5-13.

Shahrajabian, M.H.,& Soleymani, A. (2017). Responses of physiological indices of forage sorghum under different plant populations in various nitrogen fertilizer treatments. International Journal of Plant & Soil Science. 15(2): 1-8.

Soleymani, A., **Hoodaji, M., Shahrajabian, M.H., & Karimi, A. (2011).** The influence of manganese sulfate and yield components of three wheat cultivars in Abadeh region. Journal of Food, Agriculture & Environment. 9(3&4): 247-248.

Soleymani, A. & Shahrajabian, M.H. (2012). Effect of cut off irrigation in different growth stages on yield and yield components of rapeseed cultivars. *Int.J.Biol.,* 4(4): 75-78.DOI: http://dx.doi.org/10.5539/ijb.v4n4p75

Soleymani, A., Najafi, P., Dehnavi, M. & Shahrajabian, M H. (2012). Evaluation of ET-HS model for estimating water demand and water use efficiency of sugar beet in semi-arid conditions of Isfahan, Iran. *J. Sugar Beet,* 27(2): 29-36.

Soleymani, A. & Shahrajabian, M.H. (2013). Changes in number of seed and seed yield of barley 's genotypes under drought stress and normal irrigation condition. *IJFAS*, 2(12): 325-328.

Soleymani, A., **Shahrajabian, M.H., & Khoshkharam, M. (2016).** The impact of barley residue management and tillage on forage maize. Rom. Agric. Res. 33: 161-167.

Soleymani, A., **& Shahrajabian, M.H. (2017).** Effects of planting dates, root yield and solar radiation absorption in sugar beet at different plant densities. Rom. Agric. Res. 34: 145-155.

Yilmaz, E., Akcay, S., Gurbuz, T., Dagdelen, N. & Sezgin F. (2010). Effect of different water stress on the yield and yield components of second crop corn in semi-arid climate. *JFAE,* 8(3&4): 415-421.