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Assessment of water use efficiency in related to yield and yield components of corn in deficit irrigation condition

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ABSTRACT

To assessment of water use efficiency in related to yield and yield components of corn in deficit irrigation condition, this field experimental was conducted in 2008 and 2009 cropping seasons in the under semi-warm climate condition in south west of Iran. The treatments were consisted three irrigation levels (based on 100, 80, 60 percent of full irrigation) and water stress in five levels (full irrigation and irrigation-off at the 8-leaf, the 12 leaf, the tasselling and grain milky stages) applied in factorial experiment, using randomize complete block design with three replications. Results showed that the effect of deficit irrigation and water stress were significant on grain yield. Both grain and biological yields reduced in response to stress intensity.. The highest grain and biological yields were obtained in full irrigation. The combination treatment of 60 percent of full irrigation with irrigation-off at the tasselling stage reduced the grain yield by 93% compared to the optimum irrigation condition. The highest rates of harvest index (HI) and water use efficiency (WUE) were obtained in full irrigation treatment. According to the results of this study to achieve simultaneously higher water use efficiency and lower grain yield reduction, irrigation based on 80% of full demand of the plant is recommended.

Key words: Grain yield, water stress, tasselling stage

INTRODUCTION

Water deficit is one of the main causes of yield reduction in arid and semi-arid areas. Nowadays deficit irrigation technique is a practical and effective method to justify the minimum use of water with economic and acceptable yield.

The main purpose of deficit irrigation is to increase water use efficiency by reducing the volume of consumed water. Lak [15] reported that grain yield and dry matter of corn reduced. In response to the severe drought stress compared to optimal irrigation. Alizadeh *et al.*, [2] showed that water stress reduced the accumulation of dry matter in corn stress during the reproduction stage reduced the grain growth period while stress at pre-pollination stage and 50 percent flowering, post pollination stage and grain filling was due to disorder in pollination and the creation of grains hallow and also due to disorder in transferring photosynthesis matters to the corn grains, so stress that the accumulation of dry matter reduced in corn. Khodarahmpour and Hamidi [14] showed that the grain yield reduced 15, 40, and 60 percent respectively due to stress during at the vegetative growth, pollination and grain filling.

Mojadam [17] concluded that biological yield, grain yield, dry matter of ear, cob, stem, leaves, plant height, and ear length significantly reduced in response to water deficit stress. Olaoye [21] reported that biological yield reduced 61 to 71 percent due to water stress. Alavi Fazel and Lak [1] reported that the highest grain yield was obtained at the optimum irrigation and grain yield reduced up to 35 percent due to stress at the pollination. Jonghanko and Pikini [11] reported that grain yield increased with irrigation increasing grain yield increased. The results of the research conducted by Payero *et al*., [23] indicated that there was a linear relationship between irrigation and grain yield. Kalantar Ahmadi *et al*., [12] stated that delay in irrigation up to 120mm evaporation was recommendable with little reduction in the yield. Higher Corn grain yield is attributed to higher number of rows and number of grains per row. El-Hendawy et al., [6] reported that grain yield, yield components and water use efficiency increased with increasing irrigation increment, yield, yield components and water use efficiency increased. Mansouri-far *et al*., [16] showed that the optimum irrigation efficiency obtained once the water stress was enforced during the vegetative stage . They also reported that water stress during the reproduction stage reduced the grain yield more than the stress during vegetative stage in comparison to control treatment and the grain weight was more sensitive to deficit irrigation than any other yield components. Fatemi *et al*., [7] and Khalili *et al*., [13] reported that yield more decline under stress condition at the reproductive stage than that of vegetative stage and grain filling. Moser *et al*., [18] examined the effect of pre-anthesis drought on the yield, yield components and the corn's harvest index. They showed that water stress at vegetative stage reduced the grain yield as much as 32, 13, and 21 percent respectively comparison to optimal irrigation. Under semi-warm climate condition of Iran, water resources is going to be limited for crops such as corn mainly due to farm area increment. Under such a condition, in order to achieve less grain yield reduction with lower water usage, deficit irrigation might be a beneficial water management. To practice water deficit management it is necessary to determine the sensitive stages of plant growth and favorable water management due to evaporation potential. The main objective of this research is to determine the sensitivity of corn stages to water deficit stress and design deficit irrigation program. This research was aimed to study the effects of water stress and deficit irrigation on corn.

MATERIALS AND METHODS

This field experimental was conducted in 2008 and 2009 cropping seasons in under semi-warm climate condition in south west of Iran(48°:20'E and 32°:20'N). Treatments were consisted of three irrigation levels (based on 100, 80, 60 percent of full irrigation) and water stress in five levels (full irrigation and irrigation-off at the 8-leaf, the 12 leaf, the tasselling and grain milky stages) which were applied in factorial experiment consisted of a factorial experiment, using randomize complete block design with three replications.

Fertilizer were used based on the soil test analysis. Planting was carried out in early July.

According to Saremi and Siadat [26] and Kalantar Ahmadi et al., [12] and based on corn crop coefficient, water requirement was calculated as follow:

$$ET_O = ET_P \times K_P$$

ET_O = potential evapotranspiration (mm)

ET_P = evaporation from class A pan (mm)

K_P = pan coefficient

$$ET_C = ET_O \times K_C$$

ETc = crop evapotranspiration (mm)

ET_O = potential evapotranspiration (mm)

K_C = crop coefficient

$$I_n = ET_C - P_e$$

I_n = total water requirements

ET_C = crop evapotranspiration (mm)

P_e = effective rain (Effective rain with %80 confidence) (mm)

Irrigation treatments was carried out evenly by means of pump, contour, and tubes. During final harvest , biological yield and the grains of each plot were weighed. Dry weight of stem , leaves , tassel , corn-cob , corn baseline , corn sheat were measured. To measure dry weight, the samples were placed in oven with 72° for 48 hours. Harvest index was calculated based on the Ratio of grain yield to biological yield. Water use efficiency was calculated based on the grain yield and the volume of consumed water. Data were analyzed using Advanced Statistical Software.

RESULTS

The analysis variance of data showed that the effect of deficit irrigation and water stress were significant for traits which were studied in this research (Table 1). Except two traits including ear diameter and number of rows per ear interaction effect of water stress and deficit irrigation was significant all other traits. Means comparison (Table 2) showed that grain yield reduced 53, 67, 78, and 43 percent in response to water stress, at 8-leaf, 12-leaf, pollination and grain milky stages respectively, comparing to full irrigation. The results of this research was consistent with the results reported by Alavi Fazel and Lak [1] , El-Hendawy *et al*.,[6] , Alizadeh *et al.*, [2]. Setter *et al.*,[28] stated that water stress at pollination stage affected grain formation process in the corn through reducing leaves photosynthesis and reduced the number of grains per ear due to increasing the production of sterile pollen which was resulted from assimilate deficiency. The lowest number of grains per row was obtained under irrigation-off at 12-leaf and pollination stages (Table 2) which was consistent with the results of Alavi Fazel and Lak [1] and Jazayeri [10]. Nesmith and Ritchie [19] stated that drought stress at the grain filling stage leads to the reduction of dry matter accumulation in the grain which results from the shortening of effective vegetative period. Considering the results of this research which are consistent with those of Oktam [20], deficit irrigation reduced the yield, so that deficit irrigation and supplying 80 and 60 percent of full irrigation. Decline of grain yield was mainly due to number of grains per ear and the number of grains per row reduction. Both drought stress and deficit irrigation affected the total biomass. Maximum reduction of biological yield was obtained to drought stress at 8-leaf and 12-leaf stages with 25 and 28 percent respectively reduction comparing to full irrigation. In deficit irrigation treatment of 60 percent of required irrigation grain yield declined up to 70 percent compare to full irrigation. Gardner *et al.,* [8] stated that stress during at the vegetative growth stage resulted smaller leaves and reduced the leaf area index at plant maturity and also reduced the light absorption by the plant. In severe stress, stomata were closed which in turn reduced the uptake of carbon dioxide and the dry matter production, and the continuance of stress led to drastic reduction of photosynthesis. It seems that the reason of dry matter reduction under deficit irrigation, is mainly due to less leaf area expansion which did not provide a sufficient physiological source for absorbing more light and dry matter producing. These findings confirmed the researches of other researchers who reported that drought stress reduceed the biological yield (Classen and Shaw [5], Alizadeh *et al*., [2], Alavi Fazel and Lak [1]).

The highest number of grains per row and number of grains per ear were belonged to full irrigation and drought stress at milky stage. The lowest number of grains per row and per ear were obtained from drought stress at vegetative growth stage and pollination. Alizadeh *et al.*,[2] pointed out that that the most important cause of biological yield reduction was the reduction of the ear's length and diameter. The results of this research showed that stress at vegetative growth stage and pollination reduced the grain yield by reducing the number of grains, while water stress at milky stage reduced the grain yield by reducing the weight of the grain. These results were consistent Alizadeh *et al.*,[2].

The results of this research showed that the ear diameter reduced In response to drought stress at vegetative growth and pollination stages, but the effect of drought stress on diameter of the ear at milky stage was not significant. It seems that water stress causes the reduction of the ear diameter through reducing the supply of assimilate for the growth of corn. The findings Of this research terms of the reduction of the ear diameter due to water stress were in consistent with the findings of Imam and Ranjbar [9]. On the other hand , as Rashidi [24] reported , reduced growth of grain as a result of current photosynthesis reduction in stress treatments due to irrigation-off , reduced the ear (source) demand to receive assimilate and therefore less dry matter was stored in the ear. Irrigation-off at vegetative growth stage resulted in the reduction of the plant size and photosynthesizing areas , which in turn ultimately led to the reduction of produced assimilate during the ear growth and thus reduced the weight of the ear components.

Table 1. Results of the analysis of variance for studied traits based on square mean

S. O. V.	df	ear baldness length	ear diameter	ear length	No. rows per ear	No. grains in row	No. grains	Grain yield	Biological yield	Harvest index	Water use efficiency
Y	1	86.32 **	7.05 **	2549.55 **	0.07 ^{ns}	93.27 **	9060.1**	1.52 **	189.77**	470.92**	0.0054 ^{ns}
D	2	35.92 **	5.51 **	104.39 **	12.61 **	221.98 **	50890.2 **	37.86 **	100.62 **	1123.37 **	0.34 **
D * y	2	1.17 ^{ns}	1.09 **	6.01 **	0.584 *	0.52 ^{ns}	103.33 ^{ns}	0.07 ^{ns}	5.66 **	32.38 **	0.0098 ^{ns}
R (Y)	4	0.22 ^{ns}	1.37 **	0.41 ^{ns}	1.24 **	24.78 **	3338.2 **	0.15 ^{ns}	1.84 **	8.43 ^{ns}	0.0053 ^{ns}
S	4	48.56 **	3.74 **	41.77 **	6.13 **	588.25 **	100683.6 **	48.31 **	37.09 **	2147.64 **	1.34 **
D * S	8	2.83 *	0.06 ^{ns}	1.46 *	0.19 ^{ns}	10.04 **	2554.9 **	3.33 **	1.37 **	62.9 **	0.037 **
S * Y	4	15.56 **	0.09 ^{ns}	4.87 **	0.65 **	7.18 *	1101.57 *	1.2 **	1.2**	46.98 *	0.03 **
Y * S * D	8	0.84 ^{ns}	0.03 ^{ns}	0.28 ^{ns}	0.108 ^{ns}	2.24 ^{ns}	265.7 ^{ns}	0.22 ^{ns}	0.16 ^{ns}	14.62 ^{ns}	0.013 *
Ec	56	1.03	0.08	0.64	0.18	2.07	317.33	0.138	0.23	13.46	0.0041
CV(%)		16.68	8.44	4.7	12.81	3.57	13.1	13.33	4.64	14.23	13.7

ns, * and **; Non significant, Significant at the 0.05 and 0.01 probability level, respectively
Y= Year, D= Deficit irrigation, R=Replication, S=Drought stress.

Table 2: Comparing 2-year average of studied traits affected by treatments

Treatment	ear baldness length (cm)	Ear diameter (cm)	ear length (cm)	No. rows per ear	No. grains in row	No. grains	Grain Yield (ton/ha)	Biological yield (ton/ha)	Harvest Index (%)	Water use Efficiency (kg/m^3)
Drought stress*										
Without stage stress	4.45	4.05	19.18	12.53	19.3	243	5.4	12.7	40.88	0.9
Stress at 8-leaf stage	5.92	3.16	16.46	11.12	10.5	120	2.51	9.5	26.32	0.42
Stress at 12-leaf stage	6.54	3.22	15.58	11.55	7.19	86	1.79	9.1	20.08	0.3
Stress at tasselling stage	8.62	3.04	15.59	11.4	4.9	55	1.16	10.16	11.47	0.18
Stress at milky stage	4.45	3.86	17.55	12.09	14.16	176	3.09	10.48	29.25	0.52
LSD	3.65	0.28	2.04	0.75	2.47	30.7	1.02	1.02	6.34	0.16
Deficit irrigation **										
100% full irrigation	5.13	3.93	18.77	12.36	13.47	170.87	3.7	12.2	29.72	0.53
80% of full irrigation	5.84	3.39	16.79	11.83	11.98	146.33	3.03	10.47	28.51	0.52
60% of full irrigation	7.28	3.08	15.05	11.06	8.2	90.5	1.56	8.5	18.57	0.34
LSD	1.2	1.16	2.7	0.84	0.79	11.28	0.29	2.64	6.32	0.11

**The average of each drought stress was obtained from the average of rate of each drought stress in deficit irrigation*
*** The average of each deficit irrigation was obtained from the average of rate of each deficit irrigation in drought stress*

Table 3: comparing two-year average of interactive effects of deficit irrigation and drought stress on studied traits

Irrigation and drought stress treatment		ear baldness length (cm)	ear length (cm)	No. grains in row	No. grains	Grain Yield (ton/ha)	Biological yield (ton/ha)	Harvest index (%)	Water use Efficiency (kg/m^3)
Deficit irrigation	Drought stress								
	Without stage drought*	3.12	21.98	22.8	299.83	7.5	15.8	49.18	1.07
100% supply of	Stress at 8-leaf stage	5.16	17.99	12.35	144.5	3.2	11.15	29.15	0.45
Water for the	Stress at 12-leaf stage	6.22	17.19	8.63	105.8	2.3	10.34	22.75	0.32
plant	Stress at tasselling stage	7.8	17.17	6.56	79.3	1.6	11.79	13.89	0.23
	Stress at milky stage	3.3	19.55	17.03	224.83	4.5	12.36	33.63	0.58
	Without stage stress*	3.9	18.87	21.03	265.5	5.87	12.76	45.86	1
80% supply of	Stress at 8-leaf stage	5.8	16.67	11.03	128.33	2.85	9.7	30.06	0.49
Water for the	Stress at 12-leaf stage	6.03	15.47	7.73	93.5	2.03	9.4	22.56	0.35
plant	Stress at tasselling stage	9.05	15.68	4.98	59	1.34	10.14	13.82	0.23
	Stress at milky stage	4.4	17.25	15.15	185.3	3.09	10.32	30.3	0.53
	Without stage stress*	6.3	16.68	14.1	163.66	2.83	10.21	27.59	0.62
60% supply of	Stress at 8-leaf stage	6.7	14.7	8.23	87.66	1.46	7.64	19.78	0.32
Water for the	Stress at 12-leaf stage	7.3	14.06	5.21	57.33	1.03	7.56	14.94	0.22
plant	Stress at tasselling stage	9	13.93	3.15	26.83	0.49	8.53	6.7	0.1
	Stress at milky stage	6.92	15.87	10.3	117	2.02	8.78	23.83	0.44
LSD		1.17	0.92	1.66	20.6	0.43	0.55	4.24	0.07

By “without stage stress” at each irrigation level, it is meant that there hasn’t been irrigation-off at different growth stages in mentioned level

The effect of irrigation treatments on biological yield was significant, irrigation-off at the tasseling stage had the highest influence on the reduction of biological yield (Table 2 and 3 and figures 1 and 2). It seems that the reduction of vegetative growth in such conditions was because of sensitivity to the processes of cell division and growth in drought stress. These results were in agreement with the findings of cakir [4] and Alavi Fazel and Lak [1]. Compare to grain yield in full irrigation (7.5 t/ha), grain yield reduced to 5.87 t/ha and 2.83 t/ha in deficit irrigation at a rate of 60 and 80 percent respectively (table3). This finding indicates that the effect of deficit irrigation on economic yield was significant. Drought stress at 8-leaf, 12-leaf, pollination, and milky stage, reduced grain yield at the rate of 57, 69, 78, and 44 percent respectively. Therefore both deficit irrigation and drought stress severely affect the grain yield (Table 2 and figures 3 and 4).

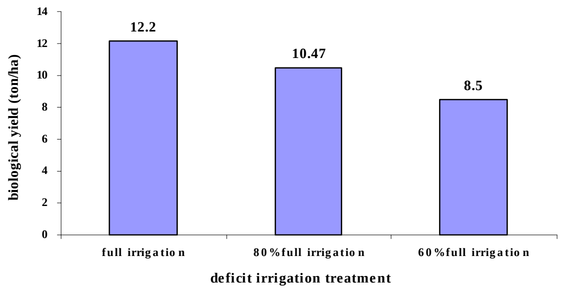

Figure 1: Means of biological yield in deficit water treatment

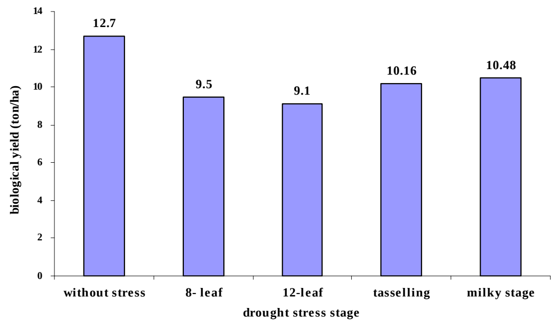

Figure 2: Means of biological yield in drought stress at some stages of corn growth

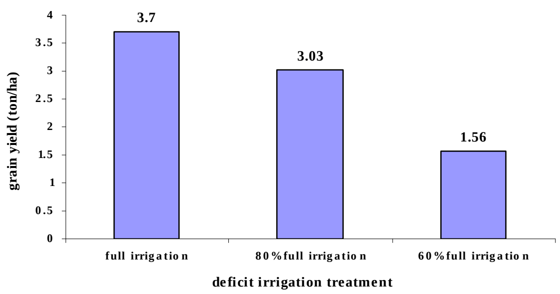

Figure 3: Means of grain yield in deficit water treatment

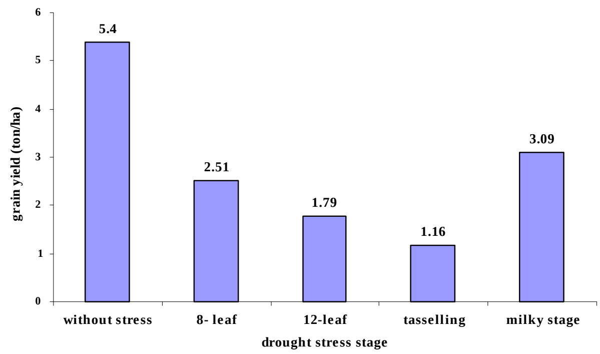

Figure 4: Means of grain yield in drought stress at some stages of corn growth

Both drought stress and deficit irrigation had significant effect on harvest index (Table 3 and figures 5 and 6), so that by increasing the stress intensity or by decreasing the volume of consumed water, the harvest index reduced. Water deficiency is a limiting factor in plant growth which not only reduces dry matter, but also disturbs the distribution of carbohydrates to the grain and thus reduces the harvest index. Imam and Ranjbar [9] reported that stress at corn vegetative growth stages was associated with the significant increase of the harvest index in comparison to the stress at 12-leaf stage and tasselling. Since the plant had more access to water during grain filling and redistribution of stored photosynthesis matters from vegetative parts to the grain, therefore the grain yield didn't change a lot. These findings are consistent with Pandey *et al.*, [22] Who reported that compare with vegetative growth; reproductive growth is more sensitive to adverse conditions.

Means comparison of water use efficiency in different treatments showed that the highest water use efficiency (1.07 kg/m³) was belonged to full irrigation (Table 3 and figures 7 and 8). According to the result of this research deficit irrigation with 80 percent of full irrigation can be recommended. These results are consistent with those of Salemi and L. Mosharaf [25] and El-Hendawy *et al.*, [6].

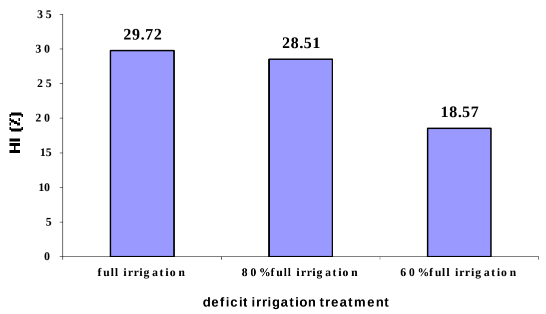

Figure 5: Means of harvest index in deficit water treatment

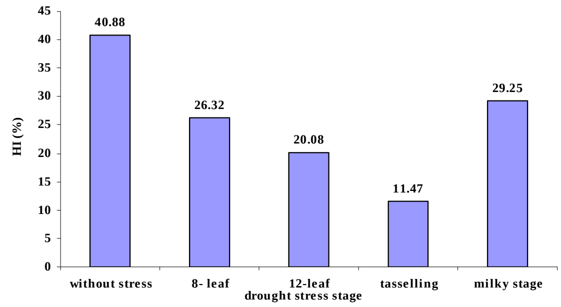

Figure 6: Means of harvest index in drought stress at some stages of corn growth

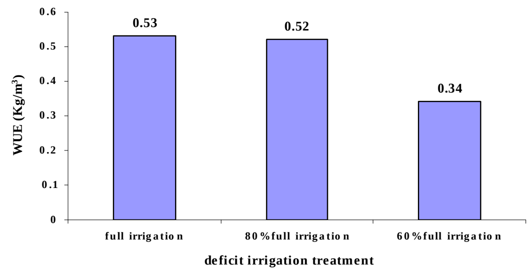

Figure7: Means of water use efficiency in deficit water treatment

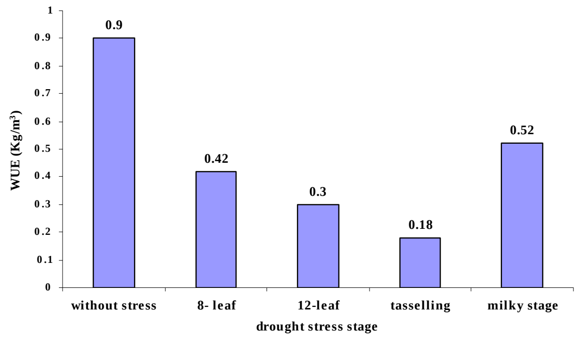

Figure8: Means of water use efficiency in drought stress at some stages of corn growth

DISCUSSION

According to the results of this research deficit irrigation based on 80% of full corn water requirement could be recommended under dry years condition with lower grain yield reduction. Since anthesis was found as the highest sensitive stage to water stress, to avoid high grain yield reduction, favorable soil water condition must be provided in irrigation schedual.

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