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PAGES: 19-23

ORIGINAL PDF URL: https://dergipark.org.tr/tr/download/article-file/187518

Article
Araştırma

RESPONSES OF GRAIN AND STRAW YIELDS OF WINTER WHEAT (*Cv. Tajan*) TO LIMITED IRRIGATION IN SEMI-ARID ENVIRONMENT

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ABSTRACT: This study was conducted to investigate responses of winter wheat (cv. Tajan) production to limited irrigation under semi-arid environment. The study included four treatments comprising irrigation at cumulative Etc=100 mm (I1), Etc = 100 and 230 mm (I2), Etc = 100, 230 and 350 mm (I3) and Etc = 100, 230, 350 and 400 mm (I4). Results revealed that the applying treatments of I3 and I4 produced similar 1000-grain weight (TGW), harvest index(HI), grain (GY), biological (BY), and straw (SY) yields. Biological yield is evidently affected by grain and straw yields. The findings showed that to obtain optimum production for wheat cv. *Tajan* in Moghan, Iran climate condition, it is recommended to irrigate this crop four times (I3).

Keywords: Winter wheat, Wheat yield, Limited irrigation, Irrigation management

1. INTRODUCTION

The cultivation area of wheat (*Triticum aestivum* L.) in Iran is about 6 million hectares (FAO, 2007). To acquire the potential yield of wheat in the north-west of Iran with average rainfall of 260 mm (Nasseri, 2009), this crop is irrigated. The studies showed that yield and yield components of wheat depend on the proper irrigation management. For example, Abdmishani and Jafari Shabestari (1986) reported that wheat irrigation prior to sowing, at the stem elongation, flowering and milking stages produced the highest yield. While irrigation only prior to sowing produced the lowest yield and 1000-grain weight (TGW). The authors also stated that the highest 1000-grain weight were obtained from the plots irrigated five times. English and Nakamura (1989) reported that under full irrigation with high frequency, did not increase wheat yield. While irrigation with interval of two weeks produced the highest yield. Oweis (1997) showed that one or two times irrigation at the sensitive stages of wheat to water deficit increased grain yield (GY) as 2 to 5 times. In addition, limited irrigation at growing season especially at the critical stages of wheat reduced yield (Musick and Porter,1990; Mahmood et al., 2002).

Hanks and Sorensen (1984) reported that for reduction of seasonal evapotranspiration until one-half, for spring wheat under water stress by line source sprinkler, harvest index was not significantly varied. Musick and Porter (1990) reported that the ranges of harvest index of wheat for high-yielding cultivars are from 0.38 to 0.50. Passioura (1977) concluded that grain filling is the sensitive stage to the limited water that affects harvest index of wheat.

Relationship between crop yield and applied water amount is presented by the water-yield function. This function can be expressed as a second or third order polynomial (Hexem and Heady, 1978). Nasseri and Fallahi (2007) investigated water use efficiency (WUE) of wheat by deficit irrigation and concluded that WUE averaged from 0.6 to 1.9 kg m^{-3}. Also, they proposed a multiple – nonlinear regressional model for grain yield as a function of applied water amount, wheat growth stage, and wheat varieties. Nitrogen fertilization enhances water use efficiency (Fallahi *et al.*, 2008). Doorenbos and Kassam (1979) related percent yield reduction to percent evapotranspiration deficit as a production function. Suitable management for irrigation practices of wheat is not well recognized in the north-west of Iran. The objective of the present study was to investigate responses of grain and straw yields, and harvest index of winter wheat (*cv. Tajan*) to limited irrigation.

2. MATERIAL AND METHODS

The field experiments were conducted at the Agricultural Research Center of Moghan, Iran with latitude 39º 39' N, longitude 47º 55' E, and 31.9 m above mean sea level with a semi-arid climate. The average air temperature during the growing season ranged from 5.4 ºC to16.6 ºC, and cumulative rainfall was 165 mm. The field soil was clay loam with average wilting point (WP), field capacity (FC), and pH of 22.4%, 31.5% (by weight), and 7.2, respectively.

Winter wheat (*Triticum aestivum* L.) cv. *Tajan* was sown on Dec. at seeding rate of 160 kg ha^{-1} on six rows with 8 m long and 20 cm apart (8×1.2 m^2 plots). After seeding, the sown site was uniformly irrigated with 75 mm of water. The experimental treatments were based on long-duration estimated evapotranspiration of wheat (Etc). Four treatments comprising irrigation at cumulative Etc=100 mm (I1), Etc = 100 and 230 mm (I2), Etc = 100, 230 and 350 mm (I3) and Etc = 100, 230, 350 and 400 mm (I4) were laid out in completely randomized blocks with three replications. Applications and measurements of irrigation water in plots were done by siphons from

the ditchs, and by a connected-flow meter to a siphon, respectively. All plots were blocked at their ends. Fertilizer of N as urea was applied to the soil before 2nd and 3th irrigation events as 100, and 200 kg ha^{-1},

respectively. After maturity in the mid-June, the plots were harvested for biological, grain, straw, and 1000-grain weights. Harvest index (HI) was calculated by:

HI (%)= Grain yield (kg ha^{-1}) / Biological yield (kg ha^{-1}) …………………………………………… (1)

3. RESULTS AND DISCUSSION

3.1. 1000-Grain Weight

The effect of experimental treatments on 1000-grain weight was significant (p $\leq$ 0.05, Table 1). Treatments of I2, I3 and I4 produced similar but I1 (35.3 g) produced the lowest TGW values (Fig. 1). This finding agrees with the results of Abdmishani and Jafari Shabestari (1986). Applying five events of irrigation (I4) produced the highest 1000-grain weight (Tables 2 and 3).

3.2. Grain Yield

The effect of irrigation events on grain yield was statistically significant (p $\leq$ 0.05, Table 1). The achieved GY from I1 and I2 were similar (Fig. 1). Also, grain yields from the treatments of I3 and I4 did not vary statistically (Fig. 1). In other words, irrigation

with three events did not increase the grain yield relative to the grain yield with two events (Table 3). It seems that this finding is derived from the effect of experimental treatments on 1000-grain weight. Consequently, irrigation of wheat four times (as I3) is adequate to obtain optimum grain yield of wheat.

3.3. Biological And Straw Yield

The effect of irrigation events on biological yield was also significant (Table 1). Applying I1, and I4 produced the lowest (5800 kg ha^{-1}), and the highest (7058 kg ha^{-1}) straw yields, respectively. The highest (13372 kg ha^{-1}), and the lowest (11166 kg ha^{-1}) biological yields were obtained from the treatments of I4, and I1, respectively (Table 3). The biological yield is eviedently affected by grain and straw yields.

Table 1: Mean squares and significant levels from analysis of variance on wheat production

Source	Df	Mean squares				
		GY	BY	SY	HI	TGW
Replication	2	565146.01	4694852.23	2224427.10	12.96	5.790
Treatments	3	206769.62*	1519417.71[ns]	1001579.86[ns]	16.71[ns]	27.58*
Error	6	850395.73	2520147.27	971163.19	22.15	5.52
Total	11					

* and ns are significantly and insignificantly different at 5% level of probability, respectively. Also, GY, BY, SY, HI and TGW are the grain, biological and straw yields, harvest index and 1000-grain weight, respectively.
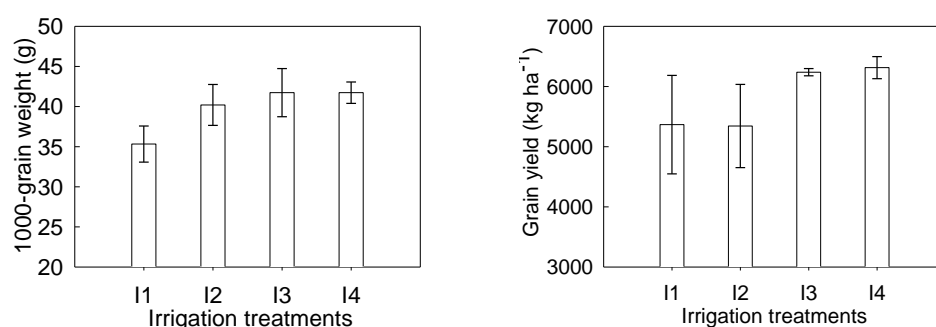

Figure. 1: The 1000-grain weight and grain yield of wheat from limited irrigation treatments

3.4. Harvest Index

In general HI is a function of grain yield and biological yield. In other words, HI is directly related to the grain yield and is inversely related to the biological yield. In this study, the effect of irrigation treatments on harvest index (HI) was insignificant

and all HIs produced by the treatments were statistically identical (Table 1). The highest and lowest HI were 0.51 and 0.45 achieved from the treatments of I3, and I2, respectively (Table 3). The HI values ranged in accordance with those reported by Musick and Porter (1990).

3.5. Applied Water-Yields Models

The 1000-grain weight, grain, straw, and biological yields, and harvest index of wheat model as a function of applied water were acquired by regression analysis (Moghaddam, 1999) and results are presented in Table 2. It could be said that variation of wheat production can be explained by applied water by a polynomial (quadratic) function. The models shapes are in accordance with Hexem and Heady (1978). For grain, biological, and straw yields, harvest index, and 1000-grain weight of wheat, the combined observed and predicted values by acquired models are depicted in Fig. 2. There are well agreements between the measured and predicted values. These models can be applied to predict grain, straw, and biological yields of wheat by available water for irrigation. Based on the models, the highest grain yield (6311 kg ha^{-1}), biological yield (13194 kg ha^{-1}), straw yield (6883 kg ha^{-1}), TGW (43 g), and HI (52%) were produced by applied water of 4257 m^3 ha^{-1} (Fig. 2).

Table 2: Applied water and grain, straw and biological yield; 1000-grain weight and harvest index models

I1 n = 3	GY= 0.00096 W^2 R^2 = 0.99	TGW=0.0000063 W^2 R^2 = 0.99	BY=0.0020 W^2 R^2 = 0.97	SY=0.00104 W^2 R^2 = 0.93	HI= 0.000085 W^2 R^2 = 0.99
I2 n = 3	GY= 0.00048 W^2 R^2 = 0.99	TGW=0.0000036 W^2 R^2 = 0.99	BY= 0.0010 W^2 R^2 = 0.99	SY= 0.00058 W^2 R^2 = 0.99	HI= 0.000004 W^2 R^2 = 0.99
I3 n = 3	GY= 0.00028 W^2 R^2 = 0.97	TGW= 0.0000019 W^2 R^2 = 0.97	BY= 0.0006 W^2 R^2 = 0.94	SY= 0.00027 W^2 R^2 = 0.91	HI= 0.000002 W^2 R^2 = 0.98
I4 n = 3	GY=0.00023 W^2 R^2 = 0.95	TGW= 0.0000015 W^2 R^2 = 0.94	BY= 0.0005 W^2 R^2 = 0.94	SY=0.00026 W^2 R^2 = 0.93	HI=0.000002 W^2 R^2 = 0.96
All treatments n = 12	GY=0.00029 W^2 R^2 = 0.82	TGW=0.0197W+0.000002 W^2 R^2 = 0.99	BY=6.0316W+0. 0007 W^2 R^2 = 0.99	SY=3.2965W-0.0004 W^2 R^2 = 0.97	HI=0.0247W-0.000003 W^2 R^2 = 0.99

GY, W, TGW, BY, SY and HI are the grain yield, applied water, 1000-grain weight, biological yield, straw yield and harvest index, respectively.
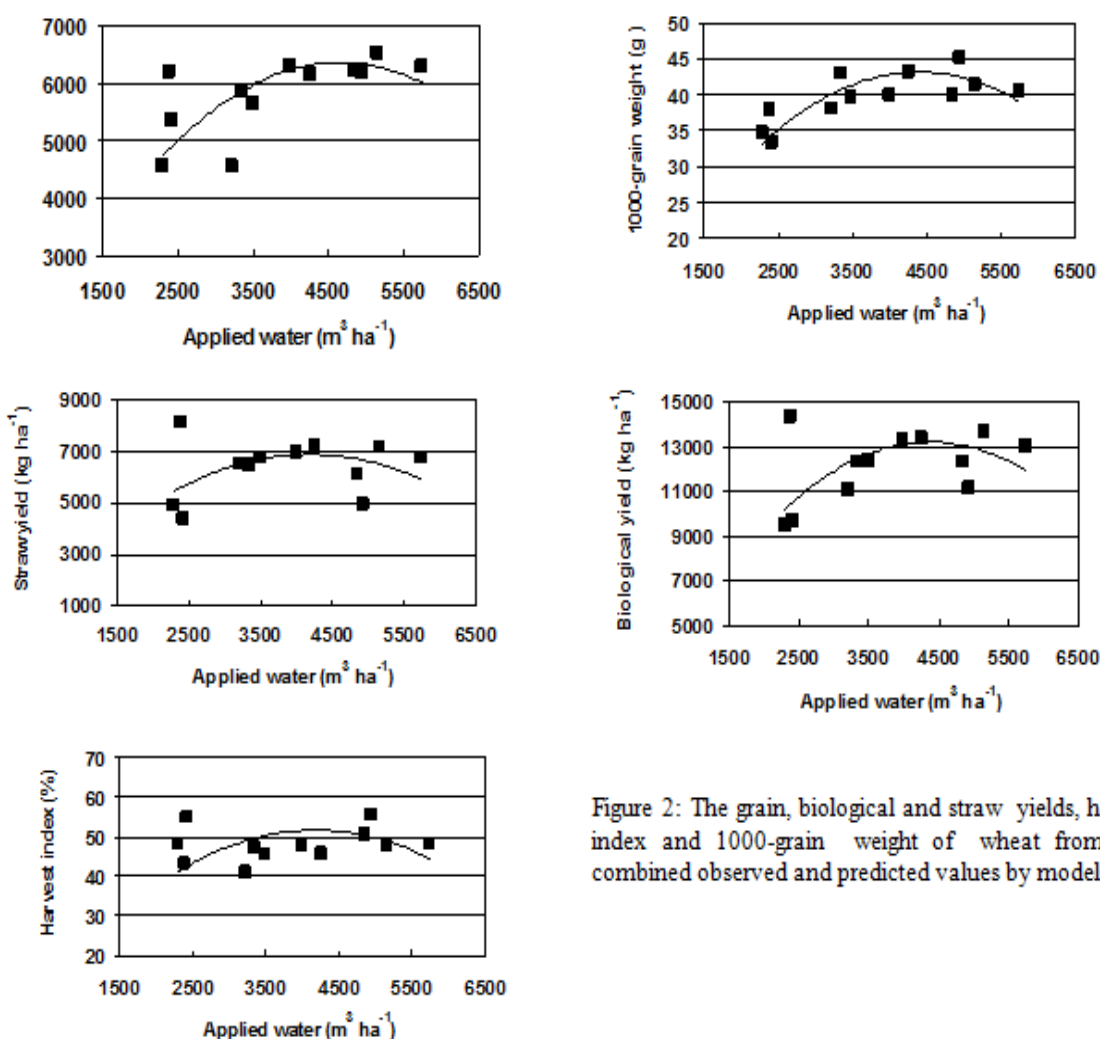

Figure 2: The grain, biological and straw yields, harvest index and 1000-grain weight of wheat from the combined observed and predicted values by models.

21

Table 3: Average values (±standard deviations) of grain, straw and biological yield; harvest index and 1000-grain weight

Treatments	Grain yield	Straw yield (kg ha^{-1})	Biological yield	HI (%)	TGW (g)
I1	5366±818	5800±2031	11166±2732	49±6	35±2
I2	5343±692	6575±152	11918±748	45±3	40±3
I3	6237±60	6008±1005	12246±1060	51±4	42±3
I4	6313±184	7058±270	13372±327	47±1	42±1

4. CONCLUSION

The responses of winter wheat (cv. *Tajan*) productions to limited water condition under a semi-arid environment were investigated. The results support the following conclusions:

Applying irrigation at cumulative Etc = 100, 230 and 350 mm (I3); and Etc = 100, 230, 350 and 400 mm (I4) produced similar production. The highest grain, biological and straw yields were 6313, 13370 and 7058 kg ha^{-1}. To obtain optimum production for wheat cv. *Tajan* in Moghan, Iran climate condition, it is recommended to irrigate this crop at cumulative Etc = 100, 230 and 350 mm. Acquired models in this study could be applied to predict grain, straw and biological yields as a function of applied water in a semi-arid environment. The economic analysis needs to evaluate experimental treatments.

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