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Effect of different irrigation treatments and mulch on water use efficiency of lentil (*Lens culinaris* Medick.)

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Abstract

In order to investigate the effect of water limitation on water use efficiency of lentil (*Lens culinaris* Medik.) an experiment was carried out as split plot based on randomized complete block design with three replications at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran in 2012. Irrigation treatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) were assigned to main plots and two mulch levels including 0 (control) and 2 ton/ha wheat straw were allocated to the sub plots. The results of this study showed that among irrigation treatments, the highest grain and biological yield and harvest index was observed in I_1 treatment. The biological and grain yield of lentil in 2 ton/ha mulch were greater than that of control treatment. The irrigation and mulch had significant effects on water use efficiency (WUE) of lentil. The highest biological and grain WUE obtained in I_2 treatment with application of 2 ton/ha straw mulch. Consequently irrigation with low volume and short intervals could be more suitable for lentil production.

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Introduction

Drought stress (water deficit or low water availability) is a major problem at over 1.2 billion ha in rain fed agricultural land (Passioura, 2007). In dry areas, the major factor limiting agricultural production is water. The most effective measure for evaluating crop-and water-management systems is the crop production or yield per unit of water used, also known as water use efficiency (WUE) (Oweiset *et al.,* 2004). Reducing water use in agriculture and increasing irrigation water use efficiency (IWUE) can reduce water shortages and increase water availability for other purposes while decreasing input costs. Insufficient water supply during the growing period may reduce crop production and quality (Debaeke and Aboudrare, 2004), while excess irrigation not only wastes water and increases nutrient leaching (Pang *et al.,* 1997), but can also reduce crop yield (Sezen *et al.,* 2006). These reasons emphasis on developing methods of irrigation that minimize water use or maximize the water use efficiency. This has led to irrigation scheduling which is conventionally aimed to achieve an optimum water supply for productivity, with soil water content being maintained close to field capacity (Boamah *et al.*, 2011).

Direct evaporation from soil is often a major loss of available water because it is not contributing to biomass production. Reducing evaporation can help conserve soil moisture, save irrigation water, and reduce salt accumulation in surface layer of the soil (Yamanaka, 2004).The relationship between WUE and evapotranspiration or irrigation water use also shows large spatial and temporal variability. Aggarwal *et al.* (1986) reported that WUE decreased with increasing evapotranspiration. Mulching is an efficient way to reduce evaporation, improve WUE (Hartkamp*et al.*, 2004) and maintain soil under stable temperature (Lal, 1974; Ji and Unger, 2001; Kar and Kumar, 2007). Plastic or straw mulch is an efficient practice, which can alter water distribution between soil evaporation and plant transpiration (Raeini-Sarjaz and Barthakur, 1997). Zhang *et al.*, (2005) observed that mulching with straw reduced soil evaporation loss and increased water use efficiency of winter wheat in northern China.

The lentil (*Lens culinaris* Medick.) is a lens-shaped grain legume well known as a nutritious food. It grows as an annual bushy leguminous plant typically 20-45 cm tall. Lentil seed is a rich source of protein, minerals (K, P, Fe, and Zn) and vitamins (Bhatty, 1988). In Iran and many other countries, most people rely on such pulses as peas, lentil, beans and vetch for meeting their protein requirement (Soltani *et al.*, 2001). With a total cultivation area of 271000 ha, lentil ranks second in pulse production after peas in Iran. It is an important food and forage crop so that nowadays, organic farming development has created new advantages for lentil cultivation in various climates (Hornburg, 2000).Thus, having a high WUE is necessary for economic produce of lentil. This research was aimed to evaluate the effects of irrigation and straw mulch on water use efficiency and grain yield of lentil under well and limited irrigation conditions.

Materials and methods

Site description and experimental design

A field experiment was conducted in 2012 at the Research Farm of the University of Tabriz, Iran (latitude 38°05_N, longitude 46°17_E, altitude 1360 m above sea level). The climate of research area is characterized by mean annual precipitation of 285 mm, mean annual temperature of 10°C, mean annual maximum temperature of 16.6°C and mean annual minimum temperature of 4.2°C. The experiment was arranged as split plot design with three replications. Irrigation treatments (I_1, I_2, I_3 and I_4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) and mulch treatments (0 (Control) and 2 ton/ha wheat straw mulch) were allocated to the sub plots. Seeds of lentil were obtained from Agricultural Research Center of Ahar, Iran. Seeds were inoculated with *Rhizobium* and treated with 2 g/kg Benomyl and then were sown with a density of 80 seeds/m^2. Each plot was included 5 rows of 4 m long, 25 cm apart. All plots were irrigated immediately after sowing. Irrigation treatments were applied after seedling establishment. Hand weeding of the experimental area was performed as required.

Measurement of lentil grain and biological yield

To specify grain yield and biological yield of lentil an area equal to 1 m^2 was harvested from middle rows of each plot by considering marginal effect. The harvested plants were dried in 25 °C and under shadow and air flow and then grains were separated from their remains by threshing.

Measurement of water use efficiency

Water use efficiency was calculated as (Hussain and Al-Jaloud, 1995):

$$WUE_G = Grain\ Yield / Used\ Water \quad (1)$$

$$WUE_B = Biologhical\ Yield / Used\ Water \quad (2)$$

where WUE_G is water-use efficiency for the grain yield (kg/m^3), WUE_B the water-use efficiency for the biomass yield (kg/m^3).

The volume of used water was calculated as:

$$v = (\theta_{FC} - \theta_{SM}).\rho b.A.d \quad (3)$$

where *v* is volume of used water (Lit), θ_{FC} the soil humidity in the field capacity level (%), θ_{SM} the soil humidity before exerting treatment(%), ρb soil bulk density (gr/m3), A plot area (m^2), d root penetrate depth (m).

Harvest index was calculated by the following equation:

Harvest index = (Grain yield / Biological yield) × 100 (4)

Statistical analysis

Statistical analysis of the data was performed with SAS software ver. 6.12. Duncan multiple range test was applied to compare means of each trait at 5% probability.

Results and discussion

Irrigation treatment and wheat straw mulch had significant effect on lentil grain yield (Table 1). Also the irrigation treatments had a significant effect on biological and grain WUE, biological and grain yield and harvest index. The grain and biological yield of lentil at I_1 treatment was higher than that in other treatments (Table 2) which was in agreement with the results of Albright *et al.*, (1989). The lentil grain yield between I_1 and I_2 treatments was not significantly different. Salisbury and Ross (1992) reported that low water availability adversely affects plant development and assimilate translocation. Silvius *et al.*, (1977) stated that the effects of water stress on soybean yield appeared to be related to limited availability of photosynthate and nitrogen for translocation to developing seed. In the case of the effect of mulch levels on grain yield, results showed that the highest value (89.4 gr/m^2) obtained from application of 2 ton/ha mulch (Table 2). The highest harvest index of lentil was obtained in I_1 treatment.

Table 1. Analysis of variance of water use efficiency and yield of lentil affected by irrigation and straw mulch.

S.O.V	df	Biological WUE	Grain WUE	Biological yield	Grain yield	Harvest Index
Block	2	0.02	0.006	282.094	47.813	0.511
Irrigation	3	2.347**	0.296**	35600.683**	5268.632**	31.481**
Error	6	0.13	0.01	385.989	33.06	0.269
Straw mulch	1	14.013**	1.482**	4186.250**	532.984**	0.882
Irrigation× mulch	3	0.102*	0.009**	42.887	6.482	0.076
Error	8	0.015	0.001	53.024	3.737	0.171

* and ** , Significant at 5% and 1% probability level, respectively.

Table 2. The mean compassion of the main effect of irrigation and straw mulch on lentil harvest index, biological and grain yield.

Treatment	Biological yield (g/m^2)	Grain yield (g/m^2)	Harvest Index (%)
Irrigation			
I_1	324.1^a	110.1^a	33.9^a
I_2	320.3^a	105.7^a	33.1^a
I_3	249.7^b	77^b	30.8^b
I_4	160^c	46.1^c	28.8^c
Mulch			
Control	250.3^b	80.1^b	31.4^a
2 Ton/ha	276.7^a	89.4^a	31.8^a

The means with same letters in each column are not significantly different at $p \leq 0.05$.

The interaction effect of irrigation and straw mulch treatments on grain and biological water use efficiency of lentil was significant (Table 1). The highest WUE did not correspond to the highest grain yield, but reached its maximum value from I_2treatment (Figure 1 and 2). Biological and grain water use efficiency increased with increasing irrigation. This shows that irrigation is an efficient measure, capable of decreasing water stress and significantly increasing WUE_G and WUE_B of crops, which is consistent with the findings of Rudich *et al.*, (1977) and Hedge (1987). Results indicated that straw mulch significantly influences WUE_G and WUE_B, which is in agreement with the results of Albright *et al.*, (1989), Zhao *et al.*, (1996), Raeini-Sarjaz and Barthakur (1997).

Straw mulch can both decrease evapotranspiration and soil water depletion, and increase water-use efficiency. Thus, it significantly increased the lentil yield. When available water becomes limited, water deficits are unavoidable in some periods of the crop growing season. Irrigation scheduling then becomes more important and complex because irrigation decisions need to be made based on water use–grain yield relationships and water use efficiency. Mulching with crop residues is an obvious way to reduce evaporation and it may have other desirable effects such as reducing run off, increasing infiltration, and decreasing surface temperature, contributing the improve WUE (Hartkamp *et al.*, 2004).

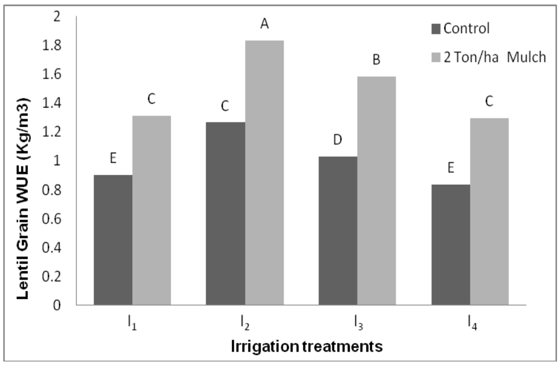

Fig. 1. Effect of different irrigation (I1, I2, I3 and I4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) and mulch treatments on grain WUE of lentil (Different letters indicate significant difference at p≤ 0.05).

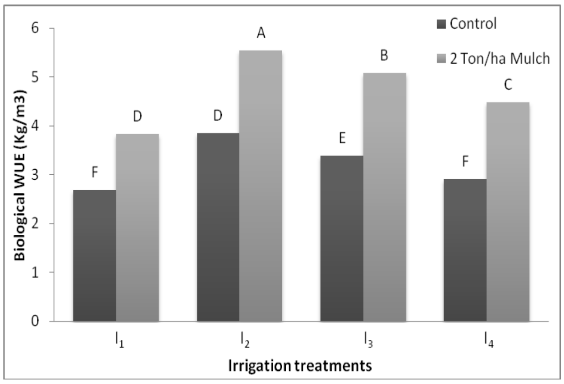

Fig. 2. Effect of different irrigation (I1, I2, I3 and I4: irrigation after 40, 70, 100 and 130 mm evaporation from class A pan, respectively) and mulch treatments

on biological WUE of lentil (Different letters indicate significant difference at p≤ 0.05).

Generally, surface mulching reduces evaporation by protecting the moist layer of air close to the surface from wind and moderates soil temperature. Maximum soil temperature is often reduced because mulching materials generally reflect more solar radiation and have lower thermal conductivity than soil (Jalota and Prihar, 1998). When evapo-transpiration was relatively low, an increase in crop water use could result in large increases in both grain yield and WUE. However, once WUE reached the maximum values, an increase in crop water use could still lead to an increase in grain yield, but it could only cause WUE to decrease. If we only aim for maximum grain yield under limited irrigation, it will require too much water and result in low WUE. However, if achieving maximum WUE is the purpose of limited irrigation, a lower grain yield will be obtained. These results indicate that aiming for maximum grain yield without considering WUE could lead to uneconomical irrigation management. It is clear that we need to strike a balance between grain yield and WUE in order to develop sustainable irrigation management schemes.

We can conclude that wheat straw mulch could be widely employed in the region which is not irrigated due to its significant effect and its easy implementation. However, straw mulch can only decrease water stress and increase wheat yields to a certain degree. Optimal irrigation can significantly increase wheat yields compared to those under straw mulch. Irrigation or a combination of irrigation and straw mulch may be the best option in achieving high crop yields and advancing the sustainable development of the agriculture in the region.

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