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MANAGING DROUGHT RISK ON LENTIL USING DEFICIT IRRIGATION IN ARID ZONES

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ABSTRACT

Grain legumes (pulses) are important crops for global food security, especially in developing countries. They also play an important role in enhancing sustainability through intensification and diversification of agricultural production systems. Meanwhile, the deficit irrigation strategy is one of the most important options for reducing water losses and maximizing water use efficiency in arid zones. A 2-year field experiment was conducted in the Agricultural Research Station, Higher Education Complex of Saravan during the growing seasons of 2018 and 2019. The experiment was split plot based on a randomized complete block design (RCBD) with four replications. The main plots included four levels of irrigation (60, 80, 100, and 120%). Subplots were two different landraces from Iran for lentil crop (Baluchestan and Kurdestan). The results revealed that the effect of deficit irrigation was significant on grain yield, biological yield, harvest index, and water use efficiency. Apart from the landraces, with increasing water consumption, the grain yield of control treatment (100%) grew by 107% in comparison to 60% irrigation treatment, but this elevation was not significant at 120% level in comparison to the control treatment. Further, 120% irrigation treatment led to reduction in water use efficiency. The highest water use efficiency (2.9 kg ha^{-1} mm^{-1}) was obtained in 80% irrigation treatment with 10% reduction in grain yield compared with control treatment. The highest harvest index was observed in the interaction of Baluchestan zones × 80% water treatment (0.24). Although the interaction of Baluchestan landrace × 80% water treatment had 10% grain yield lower than control treatment, its biological yield decreased by 27% compared to control treatment, which eventually led to 20% rise of the harvest index. Thus, our study revealed that deficit irrigation was a useful method to protect the water resources and could be used in cultivation of other plants in arid zones.

Keywords: grain yield, biological yield, harvest index, water use efficiency, landrace.

INTRODUCTION

Lentil (*Lens culinaris* Medik.) is the oldest plant of the Fabaceae family. There has been evidence of its use by humans back to 13,000 BC (Sandhu and Singh, 2007). This legume plays a vital role in feeding people in developing countries especially Iran as a valuable source of protein (20 to 36%). The cultivated area and production of lentil is 170,000 hectares and 83,000 tons, respectively, in Iran, claiming a special status among legumes (Iranian Ministry of Agriculture; Jahad, 2015). Lentil is cultivated mainly rainfed and planted in spring in the western and northwestern regions of Iran, but in arid and semi-arid regions such as Sistan and Baluchestan, it is cultivated more irrigated and planted in winter, which requires proper management of limited water resources in this region.

Agriculture is the main consumer of available water resources. Agriculture consumes approximately 60 to 80% of water resources (Huffaker and Hamilton, 2007) which contrasts with the growing global demand for food and water resources. On the other hand, food security can be achieved via irrigation, since compared to rainfed cultivation, irrigation would enhance the grain yield. Thus, water resources should be used with the highest efficiency. Optimal water management is an important method to achieve this goal in agriculture (Fereres and Soriano, 2007). Full irrigation is done by farmers in both regions without and with

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water limitation. Recently, full irrigation of crops can be reduced by alternative methods with a slight reduction in yield or without a significant effect on yield. Deficit irrigation is one of the most important methods to save and enhance water use efficiency in irrigating cultivation. The main objective of deficit irrigation is to boost water use efficiency by lowering irrigation and removing that part of water that has no significant effect on increasing the yield (Geerts and Raes, 2009).

The results of Zang et al. (2000) confirmed that lentil production increased with elevation of irrigation rate, but in regions with irrigation limitation, a supplementary irrigation at the critical stages especially flowering stage significantly boosted the production. Hosseini et al. (2011) evaluated lentil cultivars under drought risk conditions and concluded that increasing the duration of grain filling period augmented the weight of 100 seeds at optimal irrigation treatments. Also, water stress decreased the grain filling period and finally 100 grain weight. Esmaeili et al. (2020) in evaluating the effect of deficit irrigation on soybean production in Kermanshah region stated that treatment of 40% deficit irrigation compared with full irrigation (100%) reduced the grain production by 36%, but water use efficiency increased in this condition. Furthermore, Saremi et al. (2015) evaluated the effect of deficit irrigation on production and water use efficiency of lentil in Khorramabad region. Their findings showed that water use efficiency increased in the treatment of 50% of water demand, and this treatment had a slight difference with 100% treatment, which was as a solution in managing water resources in arid zones. Furthermore, evaluation of different levels of irrigation on yield and water use efficiency of soybean in Khorramabad region approved that 20% less irrigation treatment compared with the control (full irrigation) lowered the grain yield up to 8%, but water use efficiency improved by up to 12% (Haghiabi, 2017).

Meanwhile, water resources are limited in arid and semi-arid zones due to global climate change. Thus, developing an appropriate irrigation program is inevitable for boosting water use efficiency. The objective of this study was to investigate different levels of deficit irrigation on the biological yield, grain yield, and water use efficiency of the landraces of Baluchestan and Kurdestan in the arid climatic conditions.

MATERIAL AND METHODS

The experiment was conducted at the research field of the Faculty of Agriculture Higher Education Complex of Saravan (27.20 N, 62.20 E), Iran with an average annual rainfall of 250 mm during growing seasons of 2018 and 2019. Note that lentil is one of the forgotten beans in this region, which according to the climate of the region can be grown in autumn and harvested in early spring before the onset of heat stress. Furthermore, soil texture was sandy loam with the relative humidity in field capacity and permanent wilting point being 15.5 and 9%, respectively. The experiment was a split plot based on a randomized complete block design with four replications. The main factor consisted of four levels of irrigation (including 120, 100, 80 and 60%) and the sub-factor of two lentil landraces (Baluchestan and Kurdestan). The length of each subplot was 3 m, the distance between planting rows was 50 cm, and the distance between each plant on the row was 4 cm. Furthermore, 4 rows of plants were planted in each plot. Plant density was the same on all plots, that is, 50 plants per square meter (planting intervals was 50 × 4). In order to prevent water leakage to adjacent plots, two rows (50 cm) were left unplanted between two adjacent plots. The planting date was 10 November. After planting, irrigation was done uniformly for all treatments. The weeds were controlled twice during the growing season on days 25 and 50 after planting.

On the other hand, in the control treatment (100%), irrigation was done when 35% of the available soil moisture was drained at the depth of 20 cm. Thus, the irrigation period varied from 6 to 22 days depending on the weather conditions. At each irrigation in the control treatment, soil moisture was returned to the field capacity to the depth of 50 cm.

The amount of soil moisture deficit was calculated from Equation (1):

$$SMD_{control} = (\Theta_{FC} - \Theta_s) \times D_r \tag{1}$$

where, SMD, Θ_{FC}, Θ_s, and D_r represent the amount of moisture deficit (mm), content of soil moisture in the field capacity, (15.5), the content of soil moisture at the depth of 20 cm before irrigation, and the effective depth of lentil root (50 cm), respectively.

Further, the amount of irrigation water for each plot in the control treatment was calculated from Equation (2):

$$I_{control} = SMD_{control} \times A \tag{2}$$

where, $I_{control}$, $SMD_{control}$, and A is the amount of irrigation water (mm), the amount of moisture deficit (mm) calculated in Equation (1), and the plot area (m^2), respectively. To compensate for each millimeter of moisture deficit per square meter, 1 L of water was used. The required amount of water was applied to the plots in a flooded irrigation method. Irrigation in any deficit irrigation treatment was performed simultaneously with the control, but in each treatment, a percentage (60, 80, and 120%) of full irrigation was applied.

The harvest was carried out at the end of the growing season on 18 April and 10 April 2018 and 2019, respectively. The evaluated traits were grain yield, biological yield, harvest index, and water use efficiency. Water use efficiency was calculated based on grain yield (kg ha^{-1}) per water applied (mm) during the growing season period. The data were statistically analyzed using SAS software version 9.1 (SAS Institute, 2001). Duncan test was employed at the 5% probability level to compare the means. Excel software was also used to draw charts.

RESULTS AND DISCUSSION

Grain yield

The results revealed that the effects of irrigation level, landrace, and the interaction of irrigation level × landrace were significant on grain yield in both years (Table 1). The highest grain yield was obtained in 120 and 100% treatments with 680 and 643 kg ha^{-1}, respectively for Baluchestan landrace, which were not statistically significant (Figure 1). The lowest grain yield was observed in the interaction 60% of water requirement × Kurdestan landrace with 244 kg ha^{-1} (Figure 1). Furthermore, by reducing the amount of irrigation water from 100 to 80 and 60%, the yield decreased between 5 and 50% in studied landraces (Figure 1). Further, increasing irrigation by 20% compared with the control treatment only led to 5% rise of lentil yield.

Table 1. Analysis of variance (MS) for grain yield, biological yield, harvest index and water use efficiency of two landraces at different levels of irrigation during the growing seasons of 2018 and 2019

S.O.V.	d.f.	Water use efficiency	Grain yield	Biological yield	Harvest index
2018					
Replication	3	0.007^{ns}	177^{ns}	28794^{ns}	0.01^{*}
Irrigation level (I)	3	0.640^{**}	111320^{**}	2487946^{**}	0.25^{**}
Error (I)	9	0.008	394	6693	0.00
Landrace (L)	1	2.720^{**}	138928^{**}	349933^{**}	1.0^{*}
L × I	3	0.032^{**}	4499^{**}	193394^{**}	0.11^{**}
Error (L)	12	0. 029	1184	19409	0.00
C.V		6.66	7.15	5.23	3.42
2019					
Replication	3	0.012^{ns}	201^{ns}	29373^{ns}	0.08^{*}
Irrigation level (I)	3	0.702^{**}	123411^{*}	2676852^{**}	0.19^{*}
Error (I)	9	0.012	403	7011	0.01
Landrace (L)	1	2.469^{**}	142314^{**}	362362^{**}	1.6^{*}
L × I	3	0.036^{**}	4522^{**}	201239^{**}	0.16^{**}
Error (L)	12	0. 031	1231	18978	0.02
C.V		7.23	7.61	6.12	4.53

ns: Non-significant, *and **: Significant at 0.05 and 0.01 probability levels, respectively.

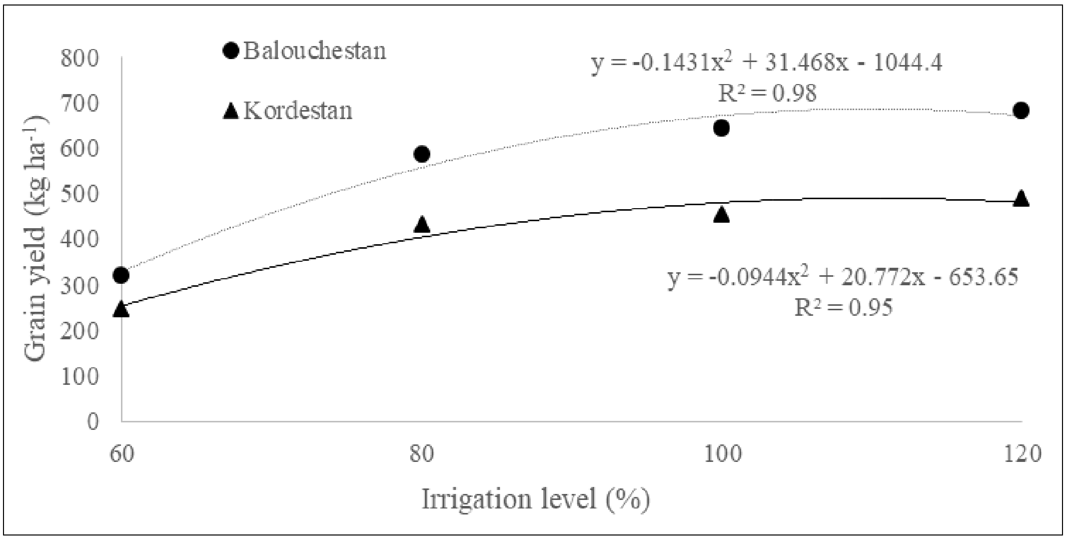

Figure 1. The effect of irrigation levels on lentil yield of Baluchestan and Kurdestan landraces

Overall, the results showed that the treatment of 60% of water requirement compared with 100% water requirement (control) led to decrease a 50% of grain yield, while treatment of 80% water requirement compared with control resulted in 16% reduction of grain yield. Karimzadeh et al. (2017) in the evaluation of the effect of deficit irrigation on the production of beans genotypes in Shahrekord stated that treatment of 60% water requirement compared with 100% water requirement led to 34 to 76% drop of grain yield.

Biological yield

The effects of irrigation level, landrace, and the interaction of irrigation level × landrace on biological yield were significant in both years (Table 1). The highest biological yield was obtained in the interaction treatment of 120% of water requirement × Baluchestan landrace with 3555 kg ha^{-1} (Figure 2). The lowest biological yield, on the other hand, was observed in the treatment of 60% of water requirement for the landraces of Baluchestan and Kurdestan with 1933 and 1719 kg ha^{-1}, respectively, which were not significantly different. Upon reduction of the amount of irrigation from 120% to 100, 80, and 60%, the biological yield dropped by 6, 33, and 45%, respectively, for the Baluchestan landrace. Further, the descending trend of irrigation for Kurdestan landrace led to 9, 13, and 43% fall of biological yield.

On the other hand, biological yield decreased by up to 6% in the interaction of 100% irrigation treatment × Baluchestan landrace compared with 120% irrigation treatment, but its grain yield was not significantly different with 120% water requirement treatment. However, this result showed that Baluchestan landrace with a lower biological yield led to higher grain yield. Generally, with reduction of water consumption, biological yield decreased, which was parallel with the results of research by Farooq et al. (2009) and Saremi et al. (2015). Furthermore, Ramirez Builes et al. (2011) in the study of six bean genotypes concluded that water stress lowered the biological yield in all six genotypes. Further, the rate of reduction of biomass due to water stress was different for all genotypes.

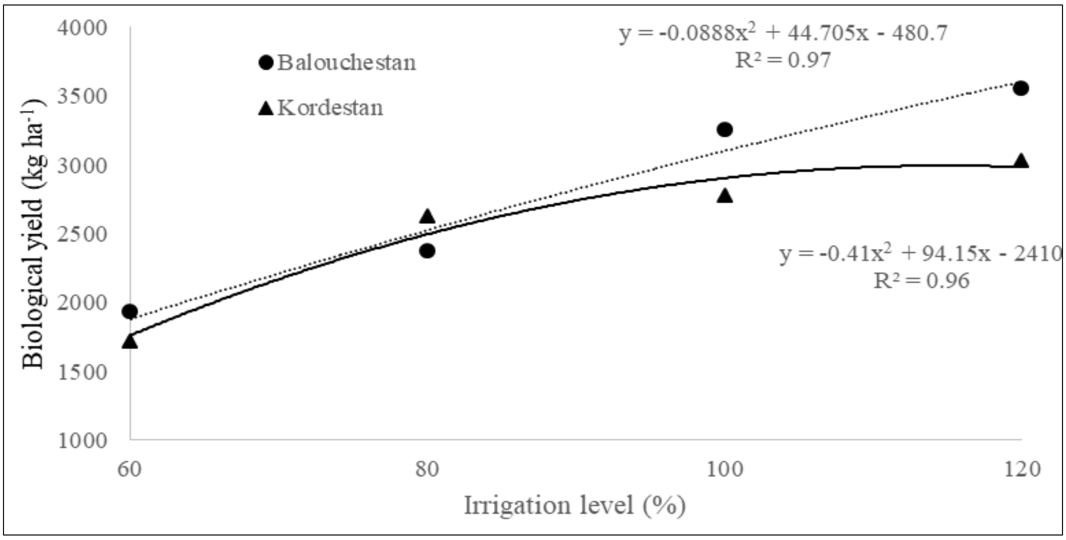

Figure 2. The effect of irrigation levels on biological yield of Baluchestan and Kurdestan landraces

Harvest index

The effects of irrigation level, landrace, and the interaction of irrigation level × landrace on harvest index were significant in both years (Table 1). The highest and lowest harvest indices were obtained for the interaction of Baluchestan landrace × 80% water requirement treatment (0.24) and Kurdestan landrace × 60% water requirement treatment (0.14), respectively (Figure 3). Although the grain yield of Baluchestan landrace in the treatment of 80% of water requirement in comparison to the treatment of 100% of water requirement was reduced by up to 10% (Figure 1), its biological yield dropped by up to 27%, which led to higher harvest index. On the other hand, the harvest index of Baluchestan landrace fell by up to 20% in 100 and 120% water requirement treatments as the highest biological yields were observed in these treatments, causing decreased harvest index (Figure 2).

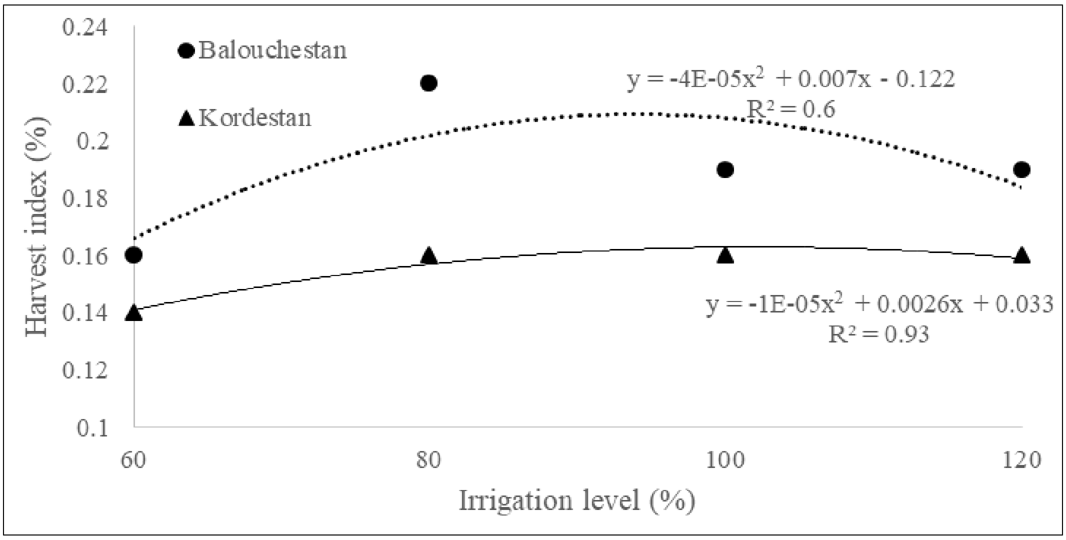

Figure 3. The effect of irrigation levels on harvest index of Baluchestan and Kurdestan landraces

Water use efficiency

The effect of irrigation level, landrace, as well as interaction of irrigation level × landrace on water use efficiency was significant in both years (Table 1). The amount of water used in irrigation treatments of 120, 100, 80, and 60% was 281, 240, 200, and 160 mm, respectively. The highest water use efficiency was obtained in the interaction of Baluchestan landrace × treatment of 80%

of water requirement with 2.9 kg ha^{-1} mm^{-1} (Figure 4). On the other hand, the lowest water use efficiency was obtained in the interaction of Kurdestan landrace × treatment of 60% of water requirement with 1.5 kg ha^{-1} mm^{-1}. Hence, by reducing the amount of irrigation water up to 80% of the water requirement, water use efficiency can be enhanced. Although the grain yield diminished by 58 kg ha^{-1} in the treatment of 80% of water requirement compared with 100% of water requirement, its water use efficiency was 0.3 kg ha^{-1} mm^{-1} higher than in the treatment of 100% of water requirement. Ghorbani-Nasrabadi and Hezarjaribi (2010) also reported that water use efficiency could grow due to reduced water consumption. Another study by Karrou and Oweis (2012) on chickpea and lentil approved that the highest grain yield and water use efficiency could be obtained in deficit irrigation (one third of full irrigation).

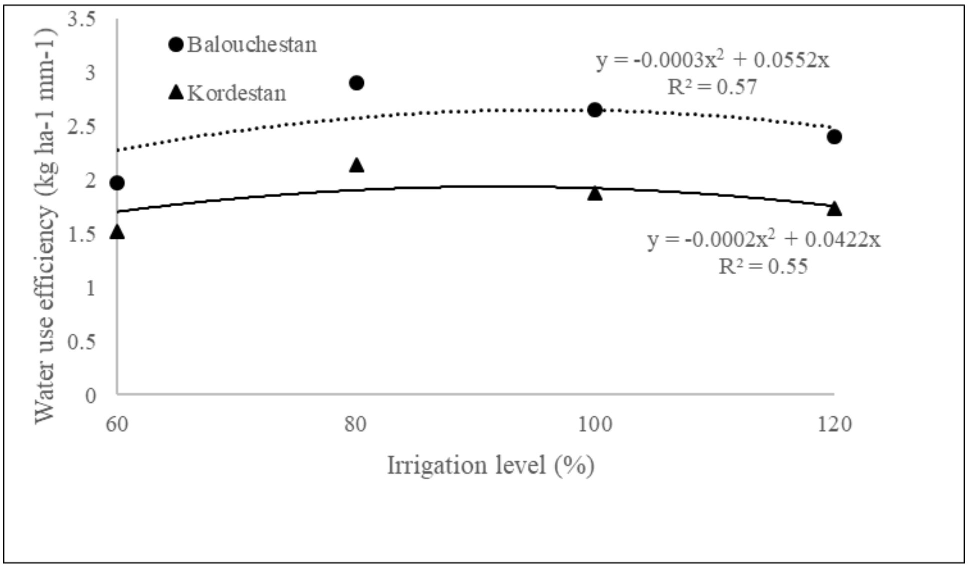

Figure 4. The effect of irrigation levels on water use efficiency of Baluchestan and Kurdestan landraces

CONCLUSIONS

Water resources are one of the most important limiting factors which affect the expansion of cultivation areas in Iran. Furthermore, by applying deficit irrigation method, the yield and water use efficiency of lentil can be improved. Our results revealed that the highest water use efficiency was obtained in the interaction of Baluchestan landrace × treatment of 80% of water requirement with 2.9 kg ha^{-1} mm^{-1}, while the yield of this treatment had only a slight difference with 100% of water requirement. Thus, it could be a good option to deal with the limitation of water resources in arid zones especially in Saravan region.

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