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Effect of Irrigation Regimes and Phosphorus Fertilization on Water-use Efficiency, Phosphorus-agronomic Efficiency and Yield of Grass Pea (*Lathyrus sativus* L.) Ecotypes

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ABSTRACT

Background: Grass pea (*Lathyrus sativus* L.) is a crop of immense economic significance. It is one of the most resilient to climate changes and to be survival food during drought-triggered famines.

Methods: In a field study split factorial experiment based on a randomized complete block design with 3 replications were used, effects of irrigation regimes (50, 75 and 100% evaporation of Pan class A) and different rates of phosphorous fertilizer (triple superphosphate 0, 60 and 120 kg/ha) on growth and yield of two grass pea ecotypes (Lalehzar and Sharekord) in Lalezar area (Kerman province, Iran) was carried out during 2018 and 2019.

Result: The results showed that drought stress reduced grass pea seed yield (401 kg/ha^{-1}) and biological yield (863 kg/ha^{-1}) and this reduction was depended on the severity of stress. In the other side, application of phosphorous fertilizer (60 kg/ha^{-1}) increased grass pea yield (2401 kg/ha^{-1}). This means that phosphorus fertilizer could partiaiiy offset the effect of drought stress and had a significant effect on the water use efficiency and phosphorus agronomic efficiency. Finally, drought stress, either no-application phosphorus fertilizer, could decrease yield. Overally, Shahrekord ecotype showed the higher and most desirable grain yield (2401 kg/ha^{-1}), biological yield (5612 kg/ha^{-1}), grain water use efficiency and biological water use efficiency, respectively, with (0.74 and 1.72 m^3 water/ha^{-1}) and phosphorus agronomic efficiency (18.76 kg yield/kg P) to the applied treatments (75% irrigation+ triple superphosphate fertilizer 60 kg/ha).

Key words: Biomass yield, Grass pea, Lalehzar, Seed yield.

INTRODUCTION

Grass pea (*Lathyrus sativus* L.) is an annual plant of the leguminoseae, dicotyledonous, autumn and spring that grows well in adverse condition. This plant can be grown in most climatic conditions as rainfed and irrigated and can be grown anywhere in Iran.

Regards the following properties, *Lathyrus sativus* L. is considered as an important agricultural product a grain plant whose aerial parts are used as forage,high amount of protein, high amount of dry matter production in a short time, high rate of growth,high ability of competition and prepotency against the weeds,its effect on soil improvement and its high level of tolerance toward the harsh environmental conditions such as drought, flood stress, salinity, low soil fertility and resistance to pests and plant diseases are the significant properties of this plant that have caused its production and cultivation economically viable and cost effective (Boukecha *et al*. 2018; Campell, 1997). Other studies have shown that the type of drought tolerance of this plant can be useful for drought resistance studies in te other plants (Choudhary *et al*. 2016).

Water deficit is one of the most important factors that not only affect plants growth and deveopment but also limit productivity (Boyer, 1982; Choudhary and Suri, 2014). In agronomy, the economic effeciency of irrigation is important, To evaluated this effeciency, a concept called water use effeciency is used. According to the definition, the ratio of crop yield to the amount of water that enters the field is called water use effeciency (Esmaeilan, 2017). Rastegari *et al*. (2015), in their field research to determine the effect of different levels of irrigation on the legume or forage traits of this plant reported that irrigation levels had no significant effect on grain weight and relative stability in biomass production by doubling the irrigation level, from 40 to 80 mm of water evaporation, indicates the high tolerance of this plant to drought.

The legumes that have not received the required phosphorus do not have a very satisfactory growth and the importance of phosphorus in accelerating the time of seed ripening and increasing the plant tolerance to drought at the end of the season, which usually coincides with seed formation, has also been proven. Also phosphorus is necessary for root development and seed formation; and in

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addition, in severe dehydration or water shortage conditions, the release of phosphorus in the soil will be prolonged, which has a reduced effect on the uptake of phosphorus by the plant; however, phosphorus is effective in increasing and producing a number of vitamins and proteins and Nowadays, crop efficiency index or efficiency of phosphorus consumption/uptake has been proposed as a practical index to evaluate the efficiency of consumption of this element for the production of the crops per unit of phosphorus consumed and becomes as a key indicator in the management of phosphorus fertilizers in crop production (Heydari Sharif Abad, 2019). Alizadeh *et al*. (2014) reported critical role of phosphorus fertilizers on growth and yield of grass pea.The agronomic efficiency of applied phosphorus in different treatments was expressed in term of phosphorus response ratio (Yadav *et al*, 2017). In Fanaei *et al*. (2014) experiment, the effect of different amounts of phosphorus fertilizer on grain yield, oil and some agronomic traits of *Brassica junceae* L. under drought stress was investigated and was reported that the effect of drought stress and consumption of phosphorus was significant on grain yield; as well, increasing the phosphorus consumption increases the grain yield, but among fertilizer treatments, the highest grain yield belonged to 150 kg treatment of triple superphosphate per hectare, which was 35% higher than the other non-phosphorus treatments. The consumption or usage of phosphorus from 150 kg to 200 kg caused a decrease of yield. Therefore, the purpose of this study was to investigate the agronomic characteristics of *Lathyrus sativus* L. and compare the efficiency of water use and phosphorus in two native ecotypes of *Lathyrus sativus* L. of Shahrekordi and Lalehzar under different irrigation plans and in cold mountainous climates of Lalehzar region of Kerman province, which is one the most important centers of *Lathyrus sativus* L. production in Iran.

MATERIALS AND METHODS

Descripton of study area

Field studies were conducted on grass pea two ecotypes (Lalehzar and Sharekord) cropping system during 2018-2019 in Lalehzar town (Kreman provice, Iran). The Lalehzar is located along one of Iran's tallest mountains (Lalehzar Shah Mountains) at an altitude of over 4300 meters and has a hilltop position. The climate of the experimental area is characterized as cold and mountanous with cool summers (April to August) and very cold winters (October to March) and with (29° 29′ N latitude and 56° 42′ E longitude, 3000 m above mean sea level). Average annual rainfull 213.6mm and the highest maximum temperature +32°C and the lowest minimum temperature is -21°C. Physico-chemical properties of experimental soil and Chemical properties of the irrigation water before initiation of field experimentation (Table 1 and 2). Mean temperature, rainfall and evaporation at experimental site (Lalehzar, Kerman) during 2018 and 2019 (March to August) (Fig 1 and 2).

Experimental treatment and design

The experiment was designed as split factorial (split plot) comprised of 18 treatments replicated thrice in a randomized complete blocks design at Lalehzar during two consecutive years, 2018 and 2019. Irrigation treatments based on 3 levels

Table 1: Physico-chemical properties of experimental soil before initiation of field experimentation.

Soil parameters	Status/value 2018		Status/value 2019		Methods employed
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	International pipette method (Piper, 1950)
Mechanical separates (%)	Deep 0-30 cm	Deep 0-60 cm	Deep 0-30 cm	Deep 0-60 cm	
Sand	74	72	75	73	
Silt	12	12	13	13	
Clay	14	16	12	14	
Chemical properties					
Soil reaction (pH)	7.8	7.7	8	7.9	1:2.5 soil:water suspension (Jackson, 1967)
Organic carbon (%)	0.87	0.70	0.97	0.94	Rapid titration method (Walkley and Black, 1934)
EC(ds /m)	0.49	0.40	0.57	0.50	
Available nutrients (mg kg^{-1})					
•P	8	3.9	3.9	4	
•K	272	196	230	180	
DTPA extractable micronutrients (mg kg^{-1})					DTPA method
•Fe	4.32	3.39	4	3.1	(Lindsay and Norvell, 1978)
•Mn	5.6	4.5	5.1	4.2	
•Zn	3.1	2.1	3	2	
•Cu	1.1	0.9	1	0.8	

Table 2: Chemical properties of the irrigation water.

Water class	SAR	Na+	Ca+2 + Mg+2 (mEq / lit)	Cl-	pH	EC (µmoh / cm)	Year
C2S1	2.01	2.15	2.3	1.1	7.1	400	2018
C2S1	1.95	2	2.1	1	7.1	390	2019

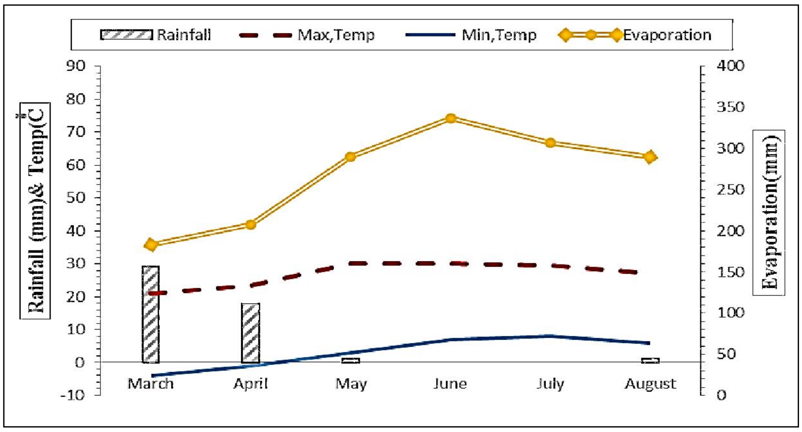

Fig 1: Mean temperature, rainfall and evaporation at experimental site (Lalehzar, Kerman) during 2018 (March to August).

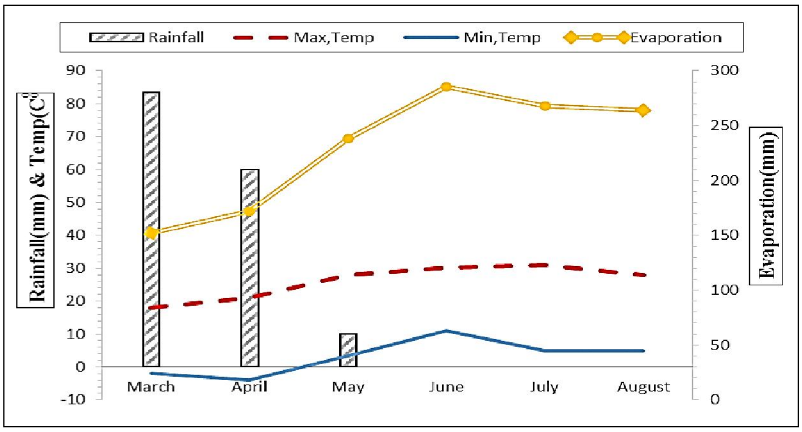

Fig 2: Mean temperature, rainfall and evaporation at experimental site (Lalehzar, Kerman) during 2019 (March to August).

of water (50, 75, 100% evaporation from Class A evaporation Pan) as main factor and 3 levels of single super phosphate fertilizer source (P_2O_5) (0, 60 and 120 kg ha^{-1}) and two ecotypes (Lalehzar and Sharekord) as sub factor (Table 3).

Irrigation scheduling

The values of water with constant irrigation interval of seven days were obtained using the following formula:

Amount of water (m^3 water ha^{-1}): mm evaporation during 7 days in class A pan × 75% (class A pan coefficient) × coefficient for each treatment × 10

The amount of water per plot using water cubic meters per hectare (m^3 water ha^{-1}) and the level of each plot is specified and each treatment was provided using a discharge tube. Irrigaion treatments were carried out after plant emergence (Table 4).

Water use efficiency

The water use efficiency (WUE) was computed by using following formula:

$$\text{WUE (Kg ha}^{-1}\text{ m}^3\text{ water)} = \frac{Y}{TWU^*} \qquad \text{Esmaeilan, (2017)}$$

Where,

Y was the yield (kg ha^{-1}) and TWU refers to total amount of water (m^3) used in a hectare.

*Total water used (TWU) was calculated by taking into consideration the total number of irrigations and water applied through irrigation (m^3 ha^{-1}) and effective rainfall during crop growth.

Agronomic efficiency of applied P

Following methodology suggested by Dordas *et al*. (2008) was used to calculate different efficiencies of applied phosphorus (P) in the current study:

$$PAE = \frac{YP\text{-}YO}{FP}$$

Where,

Yp was crop yields with applied P (kg ha^{-1}), Y0 was crop

Table 3: Details of experimental treatments evaluated in grass pea in current study.

Treatment no.	Treatment details	Treatment code
T_1	Grass pea ecotype Lalehzar + 0kg P_2O_5 ha^{-1} +Irrigation at $IW/CPE^*_{50\%}$	$E_1P_0\ Iw_{50\%}$
T_2	Grass pea ecotype Lalehzar + 60 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{50\%}$	$E_1P_{50\%}\ Iw_{50\%}$
T_3	Grass pea ecotype Lalehzar + 120 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{50\%}$	$E_1P_{100\%}\ Iw_{50\%}$
T_4	Grass pea ecotype Sharekord + 0 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{50\%}$	$E_2P_0\ Iw_{50\%}$
T_5	Grass pea ecotype Sharekord + 60 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{50\%}$	$E_2P_{50\%}\ Iw_{50\%}$
T_6	Grass pea ecotype Sharekord + 120 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{50\%}$	$E_2P_{100\%}\ Iw_{50\%}$
T_7	Grass pea ecotype Lalehzar + 0 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE^*_{75\%}$	$E_1P_0\ Iw_{75\%}$
T_8	Grass pea ecotype Lalehzar + 60 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{75\%}$	$E_1P_{50\%}\ Iw_{75\%}$
T_9	Grass pea ecotype Lalehzar + 120 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{75\%}$	$E_1P_{100\%}\ Iw_{75\%}$
T_{10}	Grass pea ecotype Sharekord + 0 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{75\%}$	$E_2P_0I_{W75\%}$
T_{11}	Grass pea ecotype Sharekord + 60 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{75\%}$	$E_2P_{50\%}I_{W75\%}$
T_{12}	Grass pea ecotype Sharekord + 120 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{75\%}$	$E_2P_{100\%}I_{W75\%}$
T_{13}	Grass pea ecotype Lalehzar + 0 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE^*_{100\%}$	$E_1P_0I_{W100\%}$
T_{14}	Grass pea ecotype Lalehzar + 60 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{100\%}$	$E_1P_{50\%}I_{W100\%}$
T_{15}	Grass pea ecotype Lalehzar + 120 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{100\%}$	$E_1P_{100\%}I_{W100\%}$
T_{16}	Grass pea ecotype Sharekord + 0 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{100\%}$	$E_2P_0I_{W100\%}$
T_{17}	Grass pea ecotype Sharekord + 60 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{100\%}$	$E_2P_{50\%}I_{W100\%}$
T_{18}	Grass pea ecotype Sharekord + 120 kg P_2O_5 ha^{-1} + Irrigation at $IW/CPE_{100\%}$	$E_2P_{100\%}I_{W100\%}$

Note 1. IW: Irrigation water (m^3water/ha^{-1}); *CPE: cumulative class (A) Pan evaporation (mm); $IW_{50\%}$ = Mean 2307.75 m^3 water ha^{-1}. $IW_{75\%}$ = Mean 3261 m^3 water ha^{-1}; $IW_{100\%}$ = Mean 4615.5 m^3 water ha^{-1}.

2. Recommend NPK dose for grass pea is 40:120:70 kg ha^{-1}.

3. *Rabi* season: The season started in Aprill and ended in August.

yield (kg ha^{-1}) in a control treatment with no P and Fp was Amount of fertilizer P applied (kg ha^{-1}),

Statistical analysis

All the data obtained from grasspea crops for the consecutive 2 years were statistically analyzed using the MSTAT- C (1982) and the comparison of mean values was done by the use of Duncan's new multiple range test at $P \leq 0.05$ level.

RESULTS AND DISCUSSION

Grain yield in grass pea

The effect of drought stress reduction (50% of irrigation water) was especially evident in the no-fertilizer treatments in both ecotypes $E_1P_0Iw_{50\%}$ and $E_2P_0Iw_{50\%}$ (Table 5).

Data in Table 6 show that was no significant difference between $E_1P_{100\%}Iw_{75\%}$ and $E_2P_{50\%}I_{W75\%}$, this means that phosphorus fertilizer could partiaiiy offset the effect of drough stress.

The most desirable and highest grain yield of $E_2P_{50\%}I_{W75\%}$ (2401 kg ha^{-1}) and the lowest grain yield (401 kg ha^{-1}) in both years 2018-2019 was from non fertilizer (control) treatment with severe stress (50% irrigation) of $E_2P_0\ Iw_{50\%}$ (Table 5).

In a field research on pea (*Pisum sativum* L.) results showed that by increasing phosphorus fertilizer from 50% to 100% pea yield increased from 1.2 to 2.2 t ha^{-1} (Yadav *et al*. 2017). P application can significantly increase grain yield and biomass in wheat (Zhang, 2006).

Table 4: Amount of irrigation water used in each treatment based on Class A pan evaporation (m^3 ha^{-1}).

Evaporation of Pan class A 100%	Evaporaton of Pan class A 75%	Evaporaton of Pan class A 50%	Year
(m^3 water / ha^{-1})			
4811	3210	2407.5	2018
4416	3312	2208	2019

Khan *et al*. (2010) reported that phosphorus from different sources such as superphosphate or superphosphate triple and di-ammonium-phosphate depending on planting conditions, experiment location and cultivar type could have different effects on plant yield.

Biological yield in grass pea

The effect of drought stress reduction 50% irrigation was especially evident in the no-fertilizer treatments in both ecotypes: $E_1P_0\ Iw_{50\%}$ and $E_2P_0\ Iw_{50\%}$ (Table 6).

The highest biological yield was obtained from 75 and 100% irrigation treatments with 60 kg ha^{-1} phosphorus fertilizer from Shahrekord ecotype with treatmeants code $E_2P_{50\%}I_{W100\%}$; $E_2P_{50\%}I_{W75\%}$ (Table 7).

The lowest biological yield was obtained from non-fertilizer treatment with severe drought stress 50% irrigation: $E_2P_0\ Iw_{50\%}$ (Table 6).

Data in Table 6 showed that $E_2P_{50\%}I_{W75\%}$ treatmeant as the most desirable biological yield (Shahrekord ecotype was obtained in 75% irrigation with 60 ha^{-1} kg phosphorus).

Table 5: Effect of irrigation regimes and fertilization phosphorus on grain yield and water use efficiency in grass pea ecotypes during 2018-19 (pooled data of 2 years).

Treatment		Mean 2018-19 Grain yield (kg ha^{-1}) (1)	Mean 2018-19 TWU*(m^3w ha^{-1}) (2)	Mean 2018-19 Grain WUE (m^3 w ha^{-1}) (1÷2)
T_1	E_1P_0 $Iw_{50\%}$	547e	2307.75	0.24g
T_2	$E_1P_{50\%}$ $Iw_{50\%}$	566e	2307.75	0.24g
T_3	$E_1P_{100\%}$ $Iw_{50\%}$	769.3d	2307.75	0.33de
T_4	E_2P_0 $Iw_{50\%}$	401e	2307.75	0.17h
T_5	$E_2P_{50\%}$ $Iw_{50\%}$	774d	2307.75	0.34de
T_6	$E_2P_{100\%}$ $Iw_{50\%}$	503e	2307.75	0.22gh
T_7	E_1P_0 $Iw_{75\%}$	1353c	3261	0.41c
T_8	$E_1P_{50\%}$ $Iw_{75\%}$	1741b	3261	0.53b
T_9	$E_1P_{100\%}$ $Iw_{75\%}$	2291a	3261	0.70a
T_{10}	$E_2P_0I_{W75\%}$	1275c	3261	0.39c
T_{11}	$E_2P_{50\%}I_{W75\%}$	2401a	3261	0.74a
T_{12}	$E_2P_{100\%}I_{W75\%}$	1679b	3261	0.51b
T_{13}	$E_1P_0I_{W100\%}$	1372c	4615.5	0.30ef
T_{14}	$E_1P_{50\%}I_{W100\%}$	1721b	4615.5	0.37cd
T_{15}	$E_1P_{100\%}I_{W100\%}$	2425a	4615.5	0.53b
T_{16}	$E_2P_0I_{W100\%}$	1238c	4615.5	0.27fg
T_{17}	$E_2P_{50\%}I_{W100\%}$	2389a	4615.5	0.52b
T_{18}	$E_2P_{100\%}I_{W100\%}$	1814b	4615.5	0.39c
	Mean square	153664.7**	-	0.006**
	LSR 1%	366.11	-	0.116
	CV	10.04	-	10.23

Total water use (TWU*)= Water applied through irrigation (m^3 ha^{-1}) + effective rainfall (mm). Mean within columns followed by different letter are significantly different (Duncan's multiple test, P≤0.05). n.s, * and **: non-significant and significant at 5 and 1% probability levels, respectively.

Table 6: Effect of irrigation regimes and fertilization phosphorus on biological yield and water use efficiency in grass pea ecotypes during 2018-19 (pooled data of 2 years).

Treatment		Mean 2018-19 Biological yield (kg ha^{-1}) (1)	Mean 2018-19 TWU*(m^3w ha^{-1}) (2)	Mean 2018-19 Biological WUE (m^3 w ha^{-1}) (1÷2)
T_1	E_1P_0 $Iw_{50\%}$	1068i	2307.75	0.46hi
T_2	$E_1P_{50\%}$ $Iw_{50\%}$	1181i	2307.75	0.51h
T_3	$E_1P_{100\%}$ $Iw_{50\%}$	1451h	2307.75	0.63j
T_4	E_2P_0 $Iw_{50\%}$	863i	2307.75	0.38i
T_5	$E_2P_{50\%}$ $Iw_{50\%}$	1537h	2307.75	0.67j
T_6	$E_2P_{100\%}$ $Iw_{50\%}$	1075i	2307.75	0.47hi
T_7	E_1P_0 $Iw_{75\%}$	2972g	3261	0.91e
T_8	$E_1P_{50\%}$ $Iw_{75\%}$	3730de	3261	1.14c
T_9	$E_1P_{100\%}$ $Iw_{75\%}$	4821c	3261	1.48b
T_{10}	$E_2P_0I_{W75\%}$	3327fg	3261	1.02d
T_{11}	$E_2P_{50\%}I_{W75\%}$	5612a	3261	1.72a
T_{12}	$E_2P_{100\%}I_{W75\%}$	3934d	3261	1.21c
T_{13}	$E_1P_0I_{W100\%}$	3397e	4615.5	0.74fg
T_{14}	$E_1P_{50\%}I_{W100\%}$	3707de	4615.5	0.80f
T_{15}	$E_1P_{100\%}I_{W100\%}$	5170b	4615.5	1.12c
T_{16}	$E_2P_0I_{W100\%}$	3315fg	4615.5	0.72fg
T_{17}	$E_2P_{50\%}I_{W100\%}$	5666a	4615.5	1.23c
T_{18}	$E_2P_{100\%}I_{W100\%}$	4681c	4615.5	1.01de
	Mean Square	1039161.61**	-	0.058**
	LSR 1%	777.83	-	0.232
	CV	9.37	-	9.77

Total water use (TWU*)= Water applied through irrigation (m^3 ha^{-1}) + effective rainfall (mm). Mean within columns followed by different letter are significantly different (Duncan's multiple test, P≤0.05). n.s, * and **: non-significant and significant at 5 and 1% probability levels, respectively.

Table 7: Effect of applied phosphorus and irrigation regimes on phosphorus agronomic efficiency in grass pea ecotypes during 2018 – 19 (pooled data of 2 years).

Treatment		Mean 2018-19 grain yield (kg ha^{-1})	Mean 2018-19 PAE (kg yield/kg P)
T_1	E_1P_0 $Iw_{50\%}$	547e	0.00h
T_2	$E_1P_{50\%}$ $Iw_{50\%}$	566e	2.11fg
T_3	$E_1P_{100\%}$ $Iw_{50\%}$	769.3d	2.18fg
T_4	E_2P_0 $Iw_{50\%}$	401e	0.00h
T_5	$E_2P_{50\%}$ $Iw_{50\%}$	774d	6.21cd
T_6	$E_2P_{100\%}$ $Iw_{50\%}$	503e	0.85gh
T_7	E_1P_0 $Iw_{75\%}$	1353c	0.00h
T_8	$E_1P_{50\%}$ $Iw_{75\%}$	1741b	6.46cd
T_9	$E_1P_{100\%}$ $Iw_{75\%}$	2291a	7.80bc
T_{10}	$E_2P_0I_{W75\%}$	1275c	0.00h
T_{11}	$E_2P_{50\%}I_{W75\%}$	2401a	18.76a
T_{12}	$E_2P_{100\%}I_{W75\%}$	1679b	3.35ef
T_{13}	$E_1P_0I_{W100\%}$	1372c	0.00h
T_{14}	$E_1P_{50\%}I_{W100\%}$	1721b	6.03cd
T_{15}	$E_1P_{100\%}I_{W100\%}$	2425a	8.88b
T_{16}	$E_2P_0I_{W100\%}$	1238c	0.00h
T_{17}	$E_2P_{50\%}I_{W100\%}$	2389a	19.18a
T_{18}	$E_2P_{100\%}I_{W100\%}$	1814b	4.80de
	Mean Square	153664.7**	36.156**
	LSR 1%	366.11	3.97
	CV	10.04	31.79

PAE: Phosphorus agronomic efficiency.

Mean within columns followed by different letter are significantly different (Duncan's multiple test, $P \leq 0.05$).

n.s, * and **: non-significant and significant at 5 and 1% probability levels, respectively.

The results of this study regarding low drought stress are in agreement with the results reported by Rastgari, (2015) and increasing phosphorus fertilizer according by Yadav *et al*. (2017) increases grain yield in pea (*Pisum sativum* L.). Therefore, it can be concluded that higher grain yield under optimum irrigation conditions can be attributed to better vegetative growth, canopy development and thus better utilization of solar and photosynthetic irradiation under optimum irrigation conditions, which is consistent with the report Mozaffari *et al*. (2000).

In this experiment, application of 75% water irrigation and 60 kg ha^{-1} phosphorus fertilizer ($E_2P_{50\%}I_{W75\%}$) was recommended for optimum yield and recommended under water restriction conditions.

Grain water use efficiency in grass pea

The highest grain water use efficiency of $E_2P_{50\%}I_{W75\%}$; $E_1P_{100\%}$ $Iw_{75\%}$ and the lowest grain water use efficiency was observed the E_2P_0 $Iw_{50\%}$ treatment, this means that phosphorus fertilizer can partially increase grain water use efficiency (Table 5).

Kumar *et al*. (2016) reported that increasing phosphorus fertilizer causes increased water use efficiency which, was in consistent with our results. Some genotypes increase dry weight due to higher water use efficiency (Ghaedi, 2014).

Forage water use efficiency in grass pea

The highest forage water use efficiency of $E_2P_{50\%}I_{W75\%}$ and the lowest forage water use efficiency was observed in 50% irrigation and non-fertilizer treatment in the ecotype of Shahrekord ($E_2P_0IW_{50\%}$). This means that phosphorus fertilizer can increase forage water use efficiency (Table 6). Hasan *et al*. (2016) reported that drоght stress cause increased water use effecincy in sorghum and that ratio is higher than maize.

Agronomic efficiency of applied -P

The data analyzed on two years mean basis data of phosphorus agronomic efficiency was tabulated in (Table 7). The effect of reducing drought stress (50% irrigation) was especially evident in the $E_1P_0Iw_{50\%}$ and $E_2P_0Iw_{50\%}$ (non-fertilizer treatments in both ecotypes). The highest phosphorus agronomic efficiency was obtained the $E_2P_{50\%}I_{W75\%}$; $E_2P_{50\%}I_{W100\%}$ there was no significant difference between these treatments. The $E_2P_{100\%}Iw_{50\%}$ exhibited the lowest phosphorus agronomic efficiency in the current study (Table 7). In a field study by Kumar *et al*. (2015) Influence of AM-fungi and applied phosphorus on growth indices,production efficiency, phosphorus-use efficiency and fruit-succulence in okra (*Abelmoschus esculentus*)-pea (*Pisum sativum*) cropping system in an acid Alfisol results showed that in irrigation treatment, under-irrigated conditions have increased phosphorus use efficiency and Similar magnitude of increases in PEP (partial factor productivity of applied phosphorus) both in okra and pea were also registered in treatments irrigated at 40% AWC (Available water holding capacity) in the presence or absence of AMF at varying applied phosphorus and also Overall, there was an impressive increase in phosphorus use efficiency in AMF imbedded treatments though, the response was comparatively lower at higher applied phosphorus probably due to lower efficiency of AMF at higher phosphorus (Harrier and Watson 2003). However, in pursuance of the law of diminishing returns, phosphorus use efficiency decreased as the phosphorus levels increased both in AMF inoculated and non-inoculated counterparts with every additional increment of phosphorus.

CONCLUSION

In the cultivation of grass pea as a forage crop, the optimal use of water and phosphorus fertilizers follow the eco-physiological relationships of the plant; so that the balanced consumption of phosphorus fertilizers is useful in saving water consumption at least up to 25% and avoid the over use of chemical fertilizers. In this study, the highest level of grain yield, biological properties, water use efficiency for grain and biomass yield were obtained in the conditions of 75% of the plant irrigation water, which can result in at least 25% of water savings to produce this product in Lalehzar and similar regions. Also, by comparing the two ecotypes of Shahrekord and Lalehzar, it was found that Shahrekord ecotype was superior in terms of less phosphorus fertilizer and less water usage.

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