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Effect of Potassium Fertilizer on Lupine (*Lupinus Termis* L.) Cultivars Grown Under Water Stress Conditions

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Abstract

This work reports the effect of potassium (K) fertilizer rates and water stress levels on the growth and seed yield of lupine (*Lupinus termis*, L.), cv. Giza1 and cv. Giza2 grown in pots under greenhouse conditions. Growth characters (plant height, fresh and dry weights and pods yield/plant) were significantly decreased with the rise in water stress levels in the two cultivars; while Lupinus termis cv.Giza2 was the higher tolerant to water stress treatments than *Lupinus termis* cv.Giza1. Application of K fertilizer rates counteracted the above adverse effects of water stress. The maximum growth characters and pods yield were obtained from plants irrigated with 80% available soil moisture (ASM) with K fertilizers rates (0.8 and 0.6 g K pot-1), respectively. Increasing the dosage of K fertilization significantly increased the tolerant of two cultivars to water stress. Maximum yield of seed was achieved with Giza2 cultivar while the minimum one was obtained with Giza1cultivar.

Keywords

Lupinus Termis L., Potassium, Water Stress, Growth Characters, Seed Yield, Cultivar

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1. Introduction

Lupinus termis is cultivated in a wide range of environments across Egypt and the seed have a nutritional quality similar to soybean seed and superior to other legumes seed (Raza and Jrnsgard, 2005), and could been important source of protein and oil. Lupine plant (*Lupinus termis* L.) was used for green manuring on the light lands. Seeds after boiling and prolonged steeping in water to get rid of their bitter and poisonous alkaloids are used as stock feed and for human consumption as important source of protein (El-Moursi et al., 2012). The medicinal value and uses of lupine its seeds are a valuable ancient legume which contains high amount of protein, dietary fiber, oil, minerals and different functional components as well as its adaptation to poor soils and dry climates (Hassan et al., 2012). In fact, Lupine seeds have been used for human consumption and as a medicinal plant in Egypt (Shahhat et al., 2014).

Environmental problems (e.g. water deficiency and inadequate mineral nutrients supply etc.) are increasing due to increasing world population and intensive use of natural resources. These environmental stresses contribute significantly to reduce crop yields below the potential maximums. Mineral-nutrient status of plants plays a critical role in increasing plant resistance to environmental stress factors (Marschner, 1995), such as potassium which plays a particular role in contributing to the survival of crop plants under water stress. Potassium is essential for many physiological processes, such as photosynthesis, translocation of photosynthetics into sink organs, maintenance of turgescence, activation of enzymes, proteinsynthesis (Marschner, 1995), and it mediates osmo-regulation during cell expansion, stomatal movements and tropisms. Furthermore, potassium is necessary for phloem

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solute transport and maintenance of the cation: anion balance in the cytosol as well as in the vacuole. Researchers have been focusing on potassium as an important osmotic regulator, because of its influence on the decrease of the plant's osmotic potential and thus, on water-loss prevention (Premachandra et al., 1991; Andersen et al., 1992).This study reports on the effects of water-stress levels and K rates on lupine growth and seed yield.

2. Materials and Methods

A pot experiment was carried out under the natural conditions of the greenhouse of the National Research Centre, Dokki, Giza, Egypt, during the season of 2006 and 2007. Seeds of lupine (*Lupinus termis*, L.), cv. Giza1 and cv. Giza2 were secured from Agriculture Research centre, Ministry of Agriculture, Giza, Egypt. Seeds were sown at October into pots of 30 cm diameter containing 10 kg of air-dried soil. The physical and chemical analyses of the soil were conducted according to Jackson (1973). The soil texture consisted of: 44.50% sand, 28.80% silt, 26.70% clay and 0.85% organic matter. Chemical analyses of the soil showed: pH = 8.25; E.C. (mmohs/cm) = 0.87; total nitrogen =0.11%; available phosphorus = 2.33mg/100gram; potassium = 19.03mg/100gram. Field capacity (FC) and wilting point (WP) were determined after the methods of Black. Means of field capacity, permanent wilting point, available soil moisture (ASM), and bulk density (BD), were 34.50%, 16.01%, 18.49% and 1.36 g/cm^3, respectively. Potassium sulphate (48% K2O) was applied at 3 wk post weeks transplantation at the rate of 0.0 (K0), 0.4 (K1), 0.6(K2) and 0.8 (K3) g/pot. At one month post sowing, irrigation treatments were at 80% (I1), 60% (I2) and 40% (I3)ASM which were equal to 30.8., 27.10 and22.61 ASM, respectively. Pots were weighed daily. When percent of soil moisture reached the above levels, pots were irrigated to reach field capacity (34.50%soil moisture). The differences between the needed soil moisture for the previous treatments and field capacity were calculated and added to the pots in the different treatments. The experimental layout was factorial in a complete randomized design, with three replications. Each replicate contained 7 pots of 3 plants each. All procedures other than experimental treatments were done according to the recommendations of the Ministry of Agriculture, Egypt recommendations. During growing season, the plants were harvested 2 times at vegetative and full mature seeds. Three replicates were drawn from different pots of each treatment; each replicate consisted of four plants. Vegetative characteristics were plant height, root length; fresh and dry weights of different plant organs (g/plant) and pods fresh and dry weights (g).

3. Statistical Analysis

Data were analyzed using the Analysis of Variance (ANOVA) with three replications. Duncan's multiple range test was used to compare the means of treatments at a probability of 5% (Walter and Duncan, 1969).

4. Results and Discussion

Tables 1, 2 and 3 indicate that decreasing irrigation water significantly decreased plant height, root length, fresh and dry weights of different plant organs (leaves, stem and root g/plant) and pods weight (g). Irrigation at 80% ASM resulted in the highest values of these parameters, while 40% treatment resulted in the lowest values. Increasing of water stress reduced growth characters which may be due to reduction in photosynthesis and plant biomass. Under increasing water stress levels, photosynthesis was limited by low CO_2 availability due to reduced stomatal and mesophyll conductance. The pronounced effect of increased irrigation on growth may be attributed to the availability of sufficient moisture throughout the roots system (Singh et al., 1997). Similar findings have been reported by others (Simon et al., 1992; Misra and Strivastava, 2000; Singh and Ramesh, 2000; Baher et al., 2002; Ezz El-Din, 2003; Mohamed and Saad , 2004; Nurhan and Ramon, 2005; Leithy et al., 2006; Moeini Alishah et al., 2006; Manivannan et al., 2007).

As shown in Tables 2 and 3, K fertilization significantly increased all growth parameters when compared with unfertilized treatments. Increasing K dose up to 0.8 g pot^{-1} significantly increased the mean values of these parameters. The maximum mean values of these parameters were observed from plants fertilized with 0.8 g pot^{-1}. The mean values of all parameters resulted from plants fertilized with 0.8 g pot^{-1} were twice those from unfertilized plants. There is increasing evidence that plants suffering from water stress have a larger internal requirement for potassium (Cakmak and Engels, 1999; Cakmak, 2005).Khalil and Ismael (2010) reported that decreasing soil moisture levels caused significant increase in plant height, No of leaves/plant, root length, fresh weight/plant (g), dry weight/plant (g), No of pods/plant, No of seeds/plant and 100seedsweight (g). Similar results were obtained by Mirsa and Srivastava (2000); villager and Cavagnaro (2006). Such decrease in shoot length in response to drought may either due to decrease in cell elongation resulting from water shortage which led to decrease in each of cell turgor cell volume and eventually cell growth (Boyer, 1990)and / or due to blocking up of xylem and phloem vessels thus hindering any translocation through (Abdalla and El-Khoshiban, 2007).

Table 1. Effect of irrigation levels, potassium fertilizer and their interactions on some growth characters of *Lupinus termis* L.

Treatments	Plant height (cm)				Stem fresh weight (g)				Leaves fresh weight (g)			
G1	46.08	b	±	8.36	5.59	b	±	2.54	3.37	b	±	1.41
G2	56.77	a	±	10.70	10.31	a	±	4.54	6.88	a	±	4.15
LSD at α 0.05	0.954				0.199				0.105			
K0	47.85	c	±	10.73	7.58	b	±	4.03	5.06	b	±	2.81
K100	55.91	a	±	11.29	9.46	a	±	4.85	6.38	a	±	4.73
K200	50.52	b	±	9.72	6.81	c	±	3.91	3.93	c	±	2.39
LSD at α 0.05	1.168				0.244				0.128			
G1xK0	44.09	e	±	10.32	5.70	e	±	2.70	3.39	e	±	1.95
G1xK100	49.01	d	±	6.62	6.31	d	±	2.70	3.95	d	±	1.07
G1xK200	45.14	e	±	7.86	4.76	f	±	2.25	2.76	f	±	0.83
G2xK0	51.61	c	±	10.31	9.46	b	±	4.38	6.73	b	±	2.58
G2xK100	62.80	a	±	10.95	12.61	a	±	4.52	8.81	a	±	5.75
G2xK200	55.91	b	±	8.60	8.85	c	±	4.25	5.09	c	±	2.90
LSD at α 0.05	1.652				0.345				0.181			
I-80	56.65	a	±	5.23	10.00	b	±	2.46	7.93	a	±	4.21
I-60	57.51	a	±	9.81	10.25	a	±	4.41	4.44	b	±	2.71
I-40	40.13	b	±	6.78	3.60	c	±	1.85	2.99	c	±	0.64
LSD at α 0.05	1.168				0.244				0.128			
G1xI-80	52.31	c	±	1.33	7.70	c	±	0.50	4.83	c	±	1.10
G1xI-60	50.66	d	±	2.54	6.70	d	±	1.54	2.75	e	±	1.16
G1xI-40	35.28	f	±	4.53	2.36	f	±	0.41	2.52	f	±	0.49
G2xI-80	60.99	b	±	3.75	12.29	b	±	0.88	11.02	a	±	3.86
G2xI-60	64.36	a	±	9.61	13.79	a	±	3.28	6.13	b	±	2.79
G2xI-40	44.98	e	±	4.92	4.83	e	±	1.91	3.47	d	±	0.33
LSD at α 0.05	1.652				0.345				0.181			
K0xI-80	57.61	b	±	5.63	9.74	c	±	1.61	7.01	b	±	1.14
K0xI-60	51.06	d	±	2.54	9.97	bc	±	3.78	5.53	d	±	3.60
K0xI-40	34.90	g	±	5.04	3.02	f	±	0.90	2.62	g	±	0.77
K100xI-80	58.47	b	±	6.14	10.22	b	±	2.83	10.58	a	±	6.11
K100xI-60	64.19	a	±	11.61	13.12	a	±	5.06	5.64	d	±	1.51
K100xI-40	45.06	e	±	5.41	5.05	e	±	2.52	2.92	f	±	0.40
K200xI-80	53.87	c	±	3.05	10.05	bc	±	3.14	6.20	c	±	2.95
K200xI-60	57.28	b	±	9.07	7.64	d	±	2.85	2.16	h	±	0.52
K200xI-40	40.43	f	±	6.28	2.73	f	±	0.79	3.43	e	±	0.47
LSD at α 0.05	2.024				0.422				0.222			
G1xK0xI-80	52.55	de	±	0.86	8.27	f	±	0.16	5.97	e	±	0.14
G1xK0xI-60	49.11	f	±	1.32	6.55	h	±	0.51	2.25	l	±	0.06
G1xK0xI-40	30.63	j	±	2.58	2.27	kl	±	0.39	1.93	m	±	0.08
G1xK100xI-80	53.05	d	±	1.07	7.65	g	±	0.31	5.01	f	±	0.11
G1xK100xI-60	53.71	cd	±	1.44	8.51	f	±	0.46	4.26	g	±	0.05
G1xK100xI-40	40.28	h	±	0.57	2.77	k	±	0.31	2.60	k	±	0.20
G1xK200xI-80	51.33	def	±	1.67	7.20	g	±	0.01	3.52	i	±	0.45
G1xK200xI-60	49.16	f	±	1.02	5.05	i	±	0.06	1.75	m	±	0.23
G1xK200xI-40	34.93	i	±	2.25	2.04	l	±	0.06	3.02	j	±	0.08
G2xK0xI-80	62.67	b	±	1.25	11.20	d	±	0.01	8.05	c	±	0.05
G2xK0xI-60	53.01	d	±	1.71	13.40	b	±	0.53	8.82	b	±	0.08
G2xK0xI-40	39.16	h	±	1.51	3.77	j	±	0.42	3.31	ij	±	0.21
G2xK100xI-80	63.88	b	±	2.26	12.78	c	±	0.38	16.15	a	±	0.05
G2xK100xI-60	74.68	a	±	2.28	17.73	a	±	0.26	7.02	d	±	0.08
G2xK100xI-40	49.85	ef	±	2.06	7.32	g	±	0.51	3.25	ij	±	0.18
G2xK200xI-80	56.40	c	±	1.05	12.90	bc	±	0.52	8.87	b	±	0.23
G2xK200xI-60	65.39	b	±	2.64	10.24	e	±	0.41	2.56	kl	±	0.36
G2xK200xI-40	45.93	g	±	1.68	3.42	j	±	0.36	3.85	h	±	0.18
LSD at α 0.05	2.862				0.597				0.314			

Table 2. Effect of irrigation levels, potassium fertilizer and their interactions on some growth characters of *Lupinus termis* L.

Treatments	Root fresh weight (g)				Root length (Cm)				Pods fresh weight (g)			
G1	0.62	b	±	0.22	11.06	b	±	2.97	5.86	b	±	3.34
G2	1.22	a	±	0.50	13.21	a	±	1.82	6.50	a	±	1.82
LSD at α 0.05	0.058				0.182				0.121			
K0	0.96	a	±	0.55	11.38	c	±	3.33	5.50	c	±	2.25
K100	1.01	a	±	0.53	12.35	b	±	2.61	6.78	a	±	2.86
K200	0.79	b	±	0.40	12.67	a	±	1.82	6.25	b	±	2.89
LSD at α 0.05	0.071				0.223				0.148			
G1xK0	0.63		±	0.30	9.64	d	±	3.11	5.04	d	±	2.79
G1xK100	0.71		±	0.19	11.76	c	±	3.64	6.25	b	±	3.62
G1xK200	0.51		±	0.12	11.78	c	±	1.54	6.29	b	±	3.77
G2xK0	1.28		±	0.56	13.12	b	±	2.66	5.95	c	±	1.58
G2xK100	1.32		±	0.58	12.94	b	±	0.70	7.32	a	±	1.91
G2xK200	1.07		±	0.38	13.57	a	±	1.71	6.22	b	±	1.86
LSD at α 0.05	N.S				0.316				0.210			
I-80	1.25	a	±	0.55	13.94	a	±	1.45	8.84	a	±	1.09
I-60	1.00	b	±	0.37	12.89	b	±	1.47	6.56	b	±	1.46
I-40	0.51	c	±	0.14	9.57	c	±	2.63	3.13	c	±	1.30
LSD at α 0.05	0.071				0.223				0.148			
G1xI-80	0.78	c	±	0.19	13.41	c	±	1.47	9.33	a	±	1.20
G1xI-60	0.68	cd	±	0.18	11.97	d	±	1.26	6.28	d	±	1.95
G1xI-40	0.39	e	±	0.08	7.80	f	±	2.41	1.96	f	±	0.47
G2xI-80	1.72	a	±	0.31	14.46	a	±	1.29	8.35	b	±	0.77
G2xI-60	1.33	b	±	0.17	13.82	b	±	1.06	6.83	c	±	0.72
G2xI-40	0.62	d	±	0.08	11.34	e	±	1.35	4.31	e	±	0.55
LSD at α 0.05	0.100				0.316				0.210			
K0xI-80	1.37	a	±	0.44	13.16	d	±	1.75	8.11	c	±	0.46
K0xI-60	1.05	b	±	0.52	13.43	cd	±	1.78	5.25	e	±	0.93
K0xI-40	0.44	e	±	0.15	7.55	g	±	2.23	3.13	f	±	1.07
K100xI-80	1.38	a	±	0.70	13.87	b	±	1.08	8.94	b	±	0.48
K100xI-60	1.07	b	±	0.20	13.58	bc	±	0.41	8.21	c	±	0.66
K100xI-40	0.59	d	±	0.13	9.59	f	±	2.86	3.21	f	±	1.96
K200xI-80	1.00	bc	±	0.46	14.78	a	±	1.14	9.47	a	±	1.58
K200xI-60	0.88	c	±	0.37	11.67	e	±	1.16	6.21	d	±	0.67
K200xI-40	0.50	de	±	0.13	11.57	e	±	0.81	3.07	f	±	0.89
LSD at α 0.05	0.123				0.387				0.257			
G1xK0xI-80	0.99	f	±	0.10	11.60	g	±	0.44	8.52	c	±	0.13
G1xK0xI-60	0.58	hij	±	0.08	11.81	fg	±	0.28	4.42	j	±	0.30
G1xK0xI-40	0.32	l	±	0.03	5.52	k	±	0.08	2.18	l	±	0.30
G1xK100xI-80	0.74	gh	±	0.08	14.83	b	±	0.25	8.55	c	±	0.05
G1xK100xI-60	0.90	fg	±	0.05	13.45	c	±	0.51	8.77	c	±	0.06
G1xK100xI-40	0.48	jkl	±	0.07	6.98	j	±	0.10	1.42	m	±	0.13
G1xK200xI-80	0.60	hij	±	0.09	13.79	c	±	0.47	10.92	a	±	0.08
G1xK200xI-60	0.55	ijk	±	0.09	10.65	h	±	0.30	5.66	h	±	0.31
G1xK200xI-40	0.38	kl	±	0.03	10.90	h	±	0.10	2.29	l	±	0.31
G2xK0xI-80	1.75	b	±	0.20	14.72	b	±	0.41	7.70	de	±	0.09
G2xK0xI-60	1.52	c	±	0.12	15.05	b	±	0.20	6.07	g	±	0.13
G2xK0xI-40	0.57	ij	±	0.08	9.59	i	±	0.16	4.08	jk	±	0.26
G2xK100xI-80	2.02	a	±	0.11	12.90	d	±	0.27	9.33	b	±	0.31
G2xK100xI-60	1.24	de	±	0.13	13.70	c	±	0.35	7.64	e	±	0.34
G2xK100xI-40	0.70	hi	±	0.05	12.20	ef	±	0.26	4.99	i	±	0.11
G2xK200xI-80	1.40	cd	±	0.23	15.77	a	±	0.31	8.03	d	±	0.08
G2xK200xI-60	1.21	e	±	0.03	12.70	de	±	0.36	6.77	f	±	0.32
G2xK200xI-40	0.61	hij	±	0.05	12.23	ef	±	0.56	3.85	k	±	0.17
LSD at α 0.05	0.174				0.547				0.363			

Table 3. Effect of irrigation levels, potassium fertilizer and their interactions on some growth characters of *Lupinus termis* L.

Treatments	Leaves dry weight (g)				Stem dry weight (g)				Root dry weight (g)				Pods dry weight (g)			
G1	1.07	b	±	0.30	1.60	b	±	0.62	0.18	b	±	0.06	1.67	b	±	0.60
G2	2.10	a	±	1.00	2.73	a	±	0.85	0.29	a	±	0.10	1.87	a	±	0.26
LSD at α 0.05	0.074				0.065				0.017				0.063			
K0	1.56	b	±	0.68	2.21	b	±	0.96	0.24	a	±	0.11	1.69	c	±	0.43
K100	1.93	a	±	1.22	2.48	a	±	1.00	0.26	a	±	0.11	1.85	a	±	0.54
K200	1.25	c	±	0.57	1.81	c	±	0.74	0.20	b	±	0.06	1.77	b	±	0.45
LSD at α 0.05	0.091				0.080				0.021				0.077			
G1xK0	1.04	e	±	0.36	1.67	e	±	0.62	0.18		±	0.08	1.58		±	0.54
G1xK100	1.23	d	±	0.21	1.78	d	±	0.77	0.19		±	0.04	1.72		±	0.73
G1xK200	0.93	e	±	0.27	1.34	f	±	0.38	0.16		±	0.03	1.73		±	0.58
G2xK0	2.08	b	±	0.50	2.75	b	±	0.96	0.29		±	0.10	1.80		±	0.27
G2xK100	2.63	a	±	1.41	3.17	a	±	0.67	0.32		±	0.13	1.99		±	0.20
G2xK200	1.58	c	±	0.62	2.28	c	±	0.72	0.25		±	0.06	1.82		±	0.30
LSD at α 0.05	0.128				0.113				N.S				N.S			
I-80	2.09	a	±	1.18	2.35	b	±	0.56	0.30	a	±	0.13	2.22	a	±	0.13
I-60	1.41	b	±	0.78	2.76	a	±	0.97	0.22	b	±	0.06	1.78	b	±	0.26
I-40	1.24	c	±	0.30	1.39	c	±	0.65	0.19	c	±	0.05	1.32	c	±	0.41
LSD at α 0.05	0.091				0.080				0.021				0.077			
G1xI-80	1.29	d	±	0.30	1.85	d	±	0.28	0.19	c	±	0.08	2.28	a	±	0.16
G1xI-60	0.90	e	±	0.26	2.05	c	±	0.55	0.19	cd	±	0.04	1.79	b	±	0.34
G1xI-40	1.01	e	±	0.22	0.90	e	±	0.07	0.16	d	±	0.04	0.96	d	±	0.19
G2xI-80	2.89	a	±	1.20	2.86	b	±	0.13	0.40	a	±	0.08	2.17	a	±	0.06
G2xI-60	1.93	b	±	0.80	3.46	a	±	0.77	0.24	b	±	0.06	1.77	bc	±	0.17
G2xI-40	1.47	c	±	0.17	1.89	d	±	0.57	0.21	c	±	0.04	1.67	c	±	0.20
LSD at α 0.05	0.128				0.113				0.030				0.109			
K0xI-80	1.71	bc	±	0.23	2.46	c	±	0.33	0.34	a	±	0.06	2.18	ab	±	0.09
K0xI-60	1.78	b	±	1.03	2.91	b	±	1.06	0.23	b	±	0.09	1.59	c	±	0.10
K0xI-40	1.19	e	±	0.46	1.26	g	±	0.44	0.14	d	±	0.04	1.31	d	±	0.37
K100xI-80	2.96	a	±	1.64	2.26	d	±	0.65	0.32	a	±	0.18	2.18	ab	±	0.08
K100xI-60	1.68	bc	±	0.52	3.39	a	±	0.74	0.22	bc	±	0.03	2.07	b	±	0.20
K100xI-40	1.16	e	±	0.19	1.79	f	±	0.91	0.22	bc	±	0.05	1.30	d	±	0.61
K200xI-80	1.60	c	±	0.79	2.33	cd	±	0.72	0.23	bc	±	0.11	2.31	a	±	0.16
K200xI-60	0.78	f	±	0.17	1.98	e	±	0.57	0.19	c	±	0.03	1.67	c	±	0.13
K200xI-40	1.38	d	±	0.19	1.12	h	±	0.30	0.19	c	±	0.02	1.34	d	±	0.25
LSD at α 0.05	0.157				0.139				0.037				0.134			
G1xK0xI-80	1.51	ef	±	0.04	2.19	f	±	0.19	0.29	cd	±	0.03	2.22	b	±	0.10
G1xK0xI-60	0.84	ijk	±	0.10	1.95	g	±	0.09	0.15	ghi	±	0.02	1.54	f	±	0.10
G1xK0xI-40	0.78	jk	±	0.11	0.87	k	±	0.08	0.11	i	±	0.01	0.99	g	±	0.02
G1xK100xI-80	1.47	ef	±	0.03	1.67	hi	±	0.07	0.16	ghi	±	0.04	2.17	b	±	0.11
G1xK100xI-60	1.21	gh	±	0.08	2.72	cd	±	0.10	0.23	ef	±	0.04	2.22	b	±	0.10
G1xK100xI-40	1.01	hi	±	0.10	0.96	k	±	0.06	0.19	fg	±	0.02	0.75	h	±	0.08
G1xK200xI-80	0.89	ij	±	0.10	1.68	h	±	0.10	0.13	hi	±	0.02	2.44	a	±	0.12
G1xK200xI-60	0.64	k	±	0.07	1.48	ij	±	0.10	0.18	fgh	±	0.04	1.60	ef	±	0.13
G1xK200xI-40	1.25	g	±	0.05	0.86	k	±	0.05	0.18	fgh	±	0.02	1.14	g	±	0.15
G2xK0xI-80	1.91	d	±	0.11	2.74	cd	±	0.06	0.39	b	±	0.03	2.14	b	±	0.06
G2xK0xI-60	2.71	b	±	0.07	3.87	a	±	0.15	0.31	c	±	0.06	1.64	ef	±	0.09
G2xK0xI-40	1.60	e	±	0.09	1.65	hi	±	0.13	0.18	fgh	±	0.02	1.63	ef	±	0.18
G2xK100xI-80	4.44	a	±	0.38	2.85	bc	±	0.06	0.49	a	±	0.03	2.19	b	±	0.07
G2xK100xI-60	2.15	c	±	0.05	4.05	a	±	0.06	0.22	ef	±	0.03	1.93	c	±	0.16
G2xK100xI-40	1.31	fg	±	0.08	2.62	de	±	0.12	0.25	de	±	0.05	1.85	cd	±	0.19
G2xK200xI-80	2.31	c	±	0.20	2.98	b	±	0.11	0.32	c	±	0.04	2.18	b	±	0.06
G2xK200xI-60	0.92	ij	±	0.08	2.47	e	±	0.26	0.20	efg	±	0.02	1.74	de	±	0.10
G2xK200xI-40	1.50	ef	±	0.21	1.38	j	±	0.13	0.21	ef	±	0.01	1.53	f	±	0.10
LSD at α 0.05	0.222				0.196				0.052				0.189			

Potassium plays a critical role in the operation and control of the stomata, and thus, the reason for enhanced need for K by plants suffering from drought appears to be that K is required for maintenance of photosynthetic CO_2 fixation, thus reduced photosynthesis in plants suffering from potassium deficiency, which was due to impairment of photosynthetic capacity as well as the growth was significantly reduced in plants suffering from K deficiency. Such leaves therefore have more sensitive and better stomatal control, and thus function better under water stress. Potassium also has a protective effect in plant cells (Robin et al., 1989; Behboudian and Anderson, 1990). Thus, when the soil water supply is limited, loss of turgor and wilting are typical systems of K deficiency. The lower sensitivity of K sufficient plants to drought stress is related to several factors (Lindhauer, 1985): (a) the role of K in stomatal regulation, which is the major mechanism controlling the water regime of higher plants, and (b) the importance of K for the osmotic potential in the vacuoles, maintaining high tissue water content even under drought conditions. Lower sensitivity to drought stress in terms of biomass production and yield might also be the result of higher K concentrations in the stoma and correspondingly higher rates of photosynthesis or of lower levels of ABA in the plants. These findings are in agreement with those of (Marschner H, Cakmak, 1989; Bar-Tal et al., 1991).

The interaction between irrigation treatments and K application resulted in a significant increment of growth characters and seed yield (Tables 1, 2 and 3). The maximum mean values were recorded from the combination of irrigation at 80% ASM and fertilization with 0.8 g K pot^{-1} dose while, the minimum values were resulted from the treatment of irrigation at 40% ASM and unfertilized treatment.

5. Conclusion

It could be concluded that potassium fertilizer increased growth characters and seed yield production under water stress conditions. Increasing irrigation levels increased the production of lupine and the optimum irrigation levels for the highest yields of growth characters and seed yield was 80% ASM. The highest growth characters and seed yield was recorded from the combination of irrigation at 80% ASM and fertilization with 0.8 g K pot^{-1} treatment.

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