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Integrated Use of Potassium Fertilizer and Water Schedules on Growth and Yield of Two Wheat Genotypes under Arid Environment in Saudi Arabia 1- Effect on Growth Characters

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Abstract: Drought is a global problem reducing plant growth and productivity worldwide. Under arid and semiarid regions of the world, where limited rainfall, high evapo-transpiration and high temperature, agronomic practices play serious role in leaf water content and plant water required. Field experiments were conducted in Agriculture Research Station, College of Food and Agriculture Sciences, King Saud University during two successive seasons to study the effect of three irrigation schedules (50,100 and 150 mm of cumulative pan evaporation (CPE) and three rates of potassium fertilizers (100,200 and 300 kg K_2O / ha) on growth parameters of two wheat genotypes (Yecora Rojo and Line L95-2). Data obtained, clearly indicated that gradual decrease in most of growth studied parameters are in line with decreasing irrigation schedules. Results also showed that, no significant difference was evident between irrigation at 100 and 150 mm of CPE with regard to studied growth characters. The results indicated also that K rates influenced growth vigor mostly through leaf area and dry matter which in turn influence successively (RGR) and (NAR). However, significant differences among wheat genotypes were observed in all traits. Selected local genotype L95-2 surpassed the introduced one Yecora Rojo.

Key words: Potassium fertilizer · Irrigation schedules · Wheat genotypes · CPE · Arid environment

INTRODUCTION

Wheat is one of the most important crops, successfully grown under different environment due to its flexibility to unfavorable conditions. The world total production of wheat is about 582.7 million tons facing by human demands estimated by 600.0 million tons [1]. Potassium (K) is the third macronutrient required for plant growth, after nitrogen (N) and phosphorus (P). Potassium fertilizers are not subject to leaching or volatilization therefore can be applied to a wide range of environment conditions by different methods of application. K has an important osmotic role in plants [2, 3]. Potassium plays major roles in enzyme activation, energy relations, assimilate translocation, protein and starch synthesis [4-6]. Under Saudi Arabia condition farmers and farming industries are generally fertilized wheat, either with nitrogen only or with nitrogen (N) and phosphorus (P) fertilizers. They believed that there is no need for application of potassium fertilizers since soil and water can supply K in quantities sufficient for plant optimum growth and yield. Intensive agriculture, high-out put practices and high yielding verities led to potassium depletion and needed therefore; take time and investment to rebuild soil potassium to a sufficient range [7, 8].

Recently, there is immense scope of increasing productivity through adequate application of K [9]. Wheat has proved to have a higher agronomic K efficiency as indicated by a greater relative yield under K deficient conditions [10]. Several investigators have proposed the efficiency of potassium application, adequate potassium results in superior of water use efficiency and maintain a normal balance between carbohydrate and proteins [11]. Shen *et al.* [12] and Khalid Nawab *et al.* [13] indicated that the greatest plant vigor was produced by application potassium fertilizers compared with no-application and sufficient potassium resulted in stronger wheat straw and assists in grain filling. Sweeney *et al.* [14] reported that potassium fertilizers regulated wheat growth and reflected in increasing grain yield and reduced leaf rust.

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Concerning the effect of water stress, under arid and semi-arid condition, water availability is one of the major limiting wheat productivity [15]. Wheat is classified as relatively tolerant to a high ground water table and as being fairly tolerance to drought. It can be grown under wide range of climates, as rain fed crop and under different water regime [16]. In absence of nutrient limitations, the most critical factor dominated yield and growth of wheat is water use efficiency (WUE), usually known as ratio of dry weight to transpiration. In low water condition of arid and semi-arid environment, yield dramatically reduced, therefore, the effective use of irrigation water to sustainable management natural resources is rapidly becoming a greatest challenges facing agriculture [17-21], they found that, the most effective damage can be detected in the period of flowering, it is can not be recovered by providing adequate water later growth period [1]. Whereas, slight water deficits in the vegetative period may have little effect or may even some what hasten maturation. Under specific location the soils are used to be irrigated with margin water containing certain percent of salts. The presence of such salts in the root medium is known to have detrimental effect on plant growth and yield [22]. Considerable variability in water-use efficiency is strongly influenced by weather conditions affecting transpiration and assimilation by leaves, plants and crop differently [23]. Also, James [11] concluded that varieties are nearly equal in their water requirement, although different varieties will yield slightly different with equal amount of water. In contrast Alderfasi and Morgan [24] found that varieties are differing in their yield reduction under water stress condition.

Keeping in view of the above facts, the present study was proposed with the objectives of appraises the role of potassium fertilizer rates under different water stress on growth characters of two wheat genotypes.

MATERIALS AND METHODS

Field experiments were carried out in Agricultural and Research Station , College of Food and Agricultural Sciences, Derab, near Riyadh, King Saud University, Saudi Arabia (24°42N latitude and 46° 44 E Longitudes, Altitude 600 m), during 2004/2005 and 2005/2006 growing seasons. The main objective of this study was to monitor the effect of application of different rates of potassium fertilizers, irrigation schedules, on growth and yield of two wheat genotypes [Yecora Raja (semi dwarf and early mature variety, introduced from USA and L95-2 (Promising line selected from the wheat program of the Plant Production Department, College of Food and Agriculture Sciences, King Saud University)]. Total rainfall, during the growing season was 203.0 and 330.0 mm for 1 st and 2 nd season, respectively. Prior to the field experiment, the field soil was sampled 0-30 cm depth from eight sites for physical and chemical analyses by the methods described by Cottenie, *et al.* [25] and But [26]. Soil texture was sandy clay loam (50 % sand, 26 % silt and 24 % clay), soil pH in 1:25 soil water (8.15) , EC (2.1 dS/m) in extracted soil paste (2:1) and $CaCO_3$ (29.9 %). Soil macronutrients N, P and K were 120.6, 270.0 and 124.0 mg/Kg soil, respectively. While soil micronutrients were 2.4, 15.1, 13.1 and 0.3 mg/Kg soil for Fe, Zn, Mn and Cu, respectively. Values of cations in irrigation water content in meq/Liter were 6.0, 3.2, 13.0 and 0.7 for Ca, Mg, Na, K and for anions CO_3^-, HCO_3^-, CL, $SO4^-$ were 0.0, 5.8, 8.61 and 8.5, respectively. Irrigation water EC (2.3 dS/m), pH (7.2) and sodium adsorption ratio (6.06). Seed bed was prepared before sowing as recommended according to the conventional production practices followed at the central region of Saudi Arabia. Phosphorus fertilizer was applied at the rate of 70 (kg P_2O_5/ ha) as the form of super phosphate (15.5 % P_2O_5) broadcasting during soil preparation, where as recommended dose of N (100 kg N/ha) was applied in three split equal doses in the form of ammonium nitrate (33.3 % N), at sowing, during tillering and at anthesis. Experimental soil sites were divided into plots, each plot consisted 8 lines 20 cm apart, 3m in length. Plot area was 4.80 m^2 Split- split plot design with four replications was laid out. Irrigation schedules were randomly assigned in main plots, whereas, genotypes were occupied the sub plots and sub- sub plots involving three rates of potassium fertilizers (100,200 and 300 kg K_2O / ha). Grains of two genotypes were sown by hand drill at the rate of (140 Kg/ha) on November, 28 in both seasons. Irrigation took place during the growing season, when cumulative pan evaporation (CPE) reach to 50,100 and 150 mm. using flooding irrigation system through line pipe provide with meter gages for measuring total water applied (50 mm in each irrigation). The CPE was calculated as a sum of daily - recorded evaporation from USWB class A open pan. Amount of water application over the growing season was calculated, results are presented in Table 1.

Table 1: Number of irrigation and amount of water applied for each treatment over the growing season (Means of two growing seasons)

Water irrigation at different cumulative pan evaporation, (CPE)	Mean of water apply. over growing season (m3/ha)	Mean of number of irrigations over two growing season
Irrigation at 50 CPE	8000	16
Irrigation at 100 CPE	6000	12
Irrigation at 150 CPE	4000	8

During growth period, four representative samples were taken from square meter for sub-plot after 56, 70, 77 and 107 days after sowing (DAS) for measuring main stem length (cm), number of tillers, dry matter /m^2. Sub-samples of ten leaves was taken for determining leaf area (cm^2), leaf relative water content (RWC) and relative water loss (RWL).Leaf relative water content (RWC) was measured by sampling two similar fully - expanded leaves per plot. Leaf samples for RWC were sealed in plastic, placed above ice in cooler and transported to the lab for determination fresh weight. Leaves were then floated on water for 24 hours to saturate and weighted, dried at 60°C until constant weight was reached. RWC were calculated according to formula described by Barrs [27]. Leaf relative water loss (RWL) was measured by using fresh weight and allowed to leaf samples to desiccate at 22°C in a dark room for 24 hours .Then re-weighted and oven dried at 70 ^{0}C until constant weight was achieved. Samples weighted again and RWL was calculated according to Winter *et al.* [28]. Relative growth rate (RGR), was determined, using the equation described by Lacher [29]:

$$RGR= (\ln W_2 - \ln W_1) / (t_2-t_1)\ mg.g^{-1}.week^{-1}.$$

Where, $W2_{and} W_1$ are the plant dry weight at the time of t_2 and t_1 .corresponding to the second and the first sample, respectively.

Net assimilation rate (NAR), was determined, according to McCollum [30], using the following equation.

$$NAR = [(W_2 - W_1)\ (L_2 - L_1)] \times [(\ln L_2 - \ln L_1) / (t_2 - t_1)]\ mg.g^{-1}.week^{-1}.\ m^2.$$

Where, W_2 and W_1 and t_2 and t_1 as described before and L_2 and L_1 are the leaf area at t_2 and t_1, corresponding to the second and the first sample, respectively.

Data were subjected to statistical analysis of variance according to the methods described by Gomez and Gomez [31]. Since the data in both seasons took similar trends and variance were homogeneous according to Bartletts test, the combined analysis of the data of the two seasons was done. Means of the treatments were compared by the Least Significant Differences Test (LSD) at (0.05) level of significance.

RESULTS

Effect of Irrigation Schedules: It could be clearly obvious that, progressive increase in most of studied characters accompanying with increasing plant age up till the fourth stage. In the respect of water schedules, low water supplies treatments reduced all growth characters under investigation. Data given elucidated that main stem length in cm and tillers number /m^2 were significantly reduced as irrigation supplies decreased. The highest main stem length (59.97, 76.14, 86.17 and 97.88) and number of tillers/m^2 (361.32, 539.65, 607.21 and 623.26) were recorded at 50 CPE, at the first, second, third and fourth stage, respectively (Fig. 1 and 2). Contrary, the shortest stem length and the lowest tiller numbers (53.61, 57.10, 61.56 and 64.35) and (264.55, 318.90, 384.78 and 402.61) at the four growth stages, respectively were obtained when water irrigation applied at 150 CPE. The same picture was also observed in leaf area, (cm^2) and total dry weight (g/m^2); gradual decrease was observed in line with decreasing cumulative pan evaporation. RGR and NAR were significantly depressed under low irrigation treatments; in contrast an increase was detected at high irrigation treatments. As regards to (RWC %) and (RWL %), data obtained indicated that, both characters were significantly affected by water irrigation treatments, gradually decreased in RWC by increasing water deficit, whereas relative water loss was increased as a result of decreasing water irrigation level (Fig 3 and 4) .

Effect of Potassium Fertilizer: Accordance to the data obtained in the present investigation, clearly obvious that, statistical differences were found among the application of K rates. In both growing seasons, at different growth stages, application K fertilizer at the rate of 200 kg K_2O/ha recorded the highest value of most growth characters. Furthermore, increasing potassium rates had no significant effect.

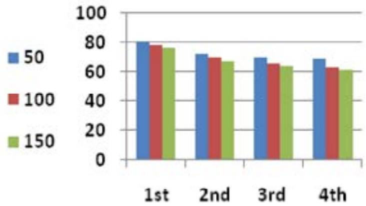

Fig. 1: Effect of water scheduling ,CPE on main stem length

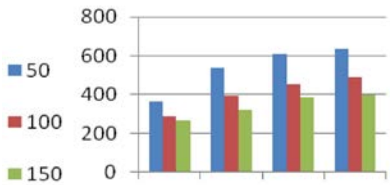

Fig. 2: Effect of water scheduling ,CPE on number of tillers /m^2

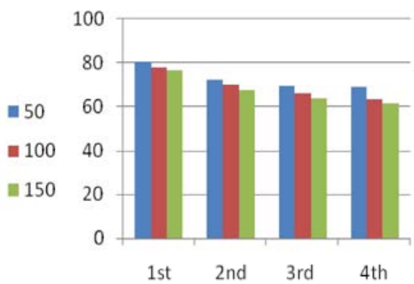

Fig 3: Effect of water scheduling ,CPE on Leaf relative content,(RWC)%

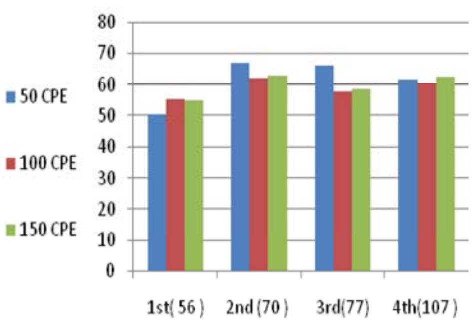

Fig. 4: Effect of water scheduling ,CPE on leaf relative water loss (RWL)

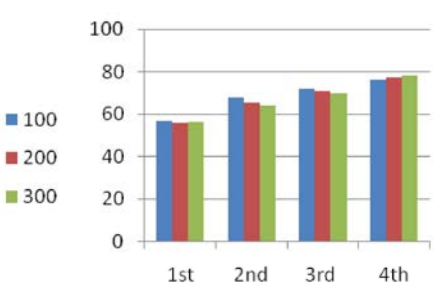

Fig. 5: Effect of potassium rates on on main stem length

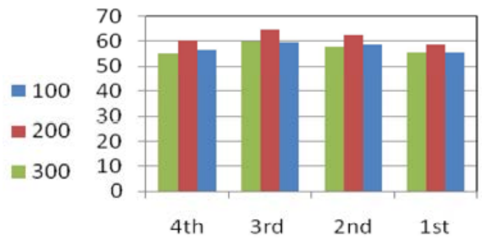

Fig. 6: Effect of potassium rates on number of tillers/m^2

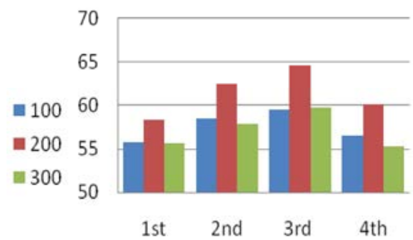

Fig.7: Effect of potassium rates on leaf relative water loss (RWL)

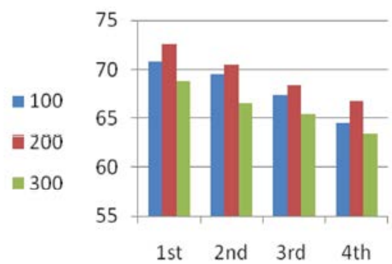

Fig. 8: Effect of potassium rates on leaf relative water content (RWC)

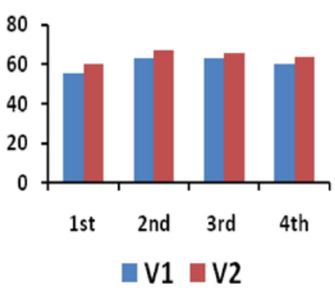

Fig. 9: Variation between two genotypes on main stem length

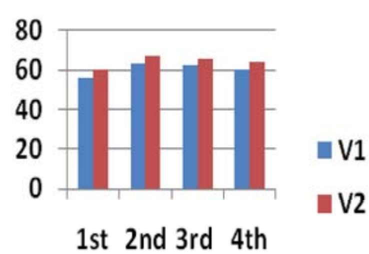

Fig 10: Variation between two genotypes on number of tillers/m^2

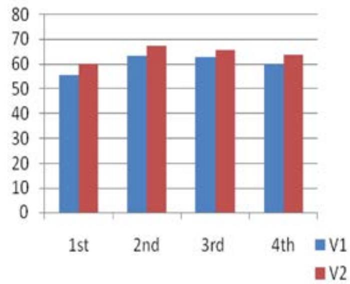

Fig. 11: Variation between two genotypes on Leaf relative water content, (RWC)

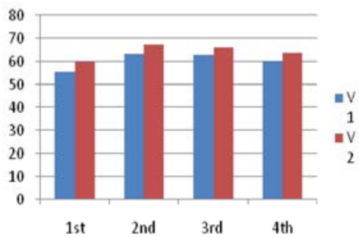

Fig. 12: Variation between two genotypes on leaf relative water loss, (RWL)

Effect of Genotypic Variation: Data obtained in the present study for the four growth stages, worthy demonstrated that the differences between the two genotypes were significant in most of the studied characters. Selected line L95-2(V_2), surpassed the introduced one Yecora Raja (V_1) in most of studied characters and recorded the highest value of main stem length 78.60 cm, number of tillers/m^2 508.75 ; Leaf area, 30.87 cm^2 and dry weight 472.14 g/m^2 RGR 0.168 ;NAR 18.48 ; RWC 67.55% and RWL 63.69 % .

Effect of Interactions: Concerning the effect of interactions between two genotypes and water irrigation schedules supplies, genotypes X potassium fertilizer as well as the third order interaction (genotypes X irrigation schedules X potassium fertilizer). Data obtained clearly indicated that, more or less values were recorded in most of studied characters as the changes in the interactions (Tables 2, 3 and 4).

Table 2: Influence of water schedule, potassium rates on main stem length and number of tillers of two wheat genotypes at different growth stages (Mean of two growing seasons)

			Main stem length, (cm)				No. of tillers /m2			
			No. Plant samples (days from sowing)				No. Plant samples (days from sowing)Water			
Schedule, CPE (mm)	K rates (Kg/ha)	Genotype	1^{st}(56)	2^{nd} (70)	3^{rd}(77)	4^{th}(107)	1^{st}(56)	2^{nd} (70)	3^{rd}(77)	4^{th}(107)
50	100	V1	62.88	88.86	92.21	98.82	363.33	523.44	568.45	588.46
		V2	54.25	66.25	77.89	79.4	368.26	587.64	596.77	682.44
	200	V1	62.09	89.47	98.59	101.71	291	436.67	580.9	601.78
		V2	60.15	65.43	77.88	100.17	375.86	533.45	640.23	642.34
	300	V1	62.01	79.5	90.15	98	376.62	546.67	603.66	621.8
		V2	58.46	67.34	80.29	109.16	392.87	610	653.24	656.71
General mean of CPE 50 mm.			59.97	76.14	86.17	97.88	361.32	539.65	607.21	632.26
100	100	V1	51.67	66.34	68.11	75.65	310	436.67	443.33	470
		V2	58.99	67.92	69.5	75.25	285.67	393.33	510	560
	200	V1	57.28	64.18	65.85	67.88	280.43	380.22	433.43	480
		V2	50.58	59.5	62.55	66.18	253.33	396.67	406.67	470
	300	V1	52.92	58.75	60	63.76	303.33	390.66	466.67	473.34
		V2	57.33	65.67	66.42	71.92	296.67	383.33	469.27	483.33
General mean of CPE 100 mm.			54.8	63.73	65.41	70.11	288.24	396.81	454.9	489.45
150	100	V1	55.6	57.52	60.22	62.25	298.72	341.52	458.22	470.85
		V2	56.47	60.92	65.46	67.22	257.42	298.85	315.79	340.77
	200	V1	50.72	54.82	58.27	60.25	254.76	335.72	430.75	425.9
		V2	52.92	58.24	63.41	69.72	259.9	298.77	335.22	399.7
	300	V1	50.17	54.25	56.77	58.22	257.62	338.71	428.45	435.96
		V2	55.76	56.84	65.22	68.41	258.89	299.82	340.26	342.5
General mean of CPE 150 mm.			53.61	57.1	61.56	64.35	264.55	318.9	384.78	402.61
LSD at 0.05 % level for: Water schedules (A)			3.16	5.36	2.95	21.4	20.65	98.27	88.7	99.45
schedules x potassium rates (AB			1.19	2.18	1.83	5.27	12.41	70.44	54.23	74.22
potassium rates x genotypes (BC			2.12	1.54	2.85	3.41	8.59	65.15	50.12	43.61
genotypes x schedules (AC			1.77	1.53	1.43	2.15	9.22	50.44	24.11	31.22
Ax B x C			2.41	1.4	1.55	2.65	6.74	67.56	25.71	25.45

Table 3: Influence of water schedule, potassium rates on leaf area and total dry weight of two wheat genotypes (Mean of two growing seasons)

			Main stem length, (cm^2)				No. of tillers /m^2			
			No. Plant samples (days from sowing)				No. Plant samples (days from sowing)Water			
Schedule, CPE (mm)	K rates (Kg/ha)	Genotype	1st(56)	2nd (70)	3rd(77)	4th(107)	1st(56)	2nd (70)	3rd(77)	4th(107)
50	100	V1	25.53	26.43	27.35	28.72	248.91	261.34	258.98	618.74
		V2	23.38	24.53	25.41	26.56	209.55	235.16	267.66	654.33
	200	V1	27.08	28.61	29.89	30.57	290.33	307.74	398.65	645.13
		V2	26.35	27.67	30.89	32.31	282.9	322.56	387.45	598.43
	300	V1	30.19	31.44	33.53	34.44	405.45	420.45	461.73	659.55
		V2	29.88	30.98	33.55	35.66	398.78	407.56	435.75	622.56
General mean of CPE 50 mm.			27.07	28.28	30.1	31.38	305.99	325.8	368.37	633.12
100	100	V1	20.98	21.73	23.33	25.56	212.37	218.02	201.98	499.18
		V2	25.42	25.89	26.27	28.97	206.25	207.41	228.74	336.92
	200	V1	24.98	26.22	29.88	30.41	217.96	227.59	259.71	445.77
		V2	22.16	23.19	28.47	31.23	198.67	239.85	246.11	347.04
	300	V1	25.76	27.33	28.89	29.88	221.77	230.46	226.92	352.76
		V2	29.3	30.22	31.73	33.29	218.92	239.72	312.57	371.82
General mean of CPE 100 mm.			24.77	25.76	28.1	29.89	212.66	227.18	246.01	392.25
150	100	V1	20.22	23.38	24.62	27.03	204.64	217.51	228.76	312.67
		V2	23.24	24.78	25.74	26.87	208.55	225.88	214.63	244.86
	200	V1	21.22	23.22	26.44	27.99	205.98	209.53	258.16	395.53
		V2	23.26	23.61	28.86	31.29	213.82	218.65	217.79	295.13
	300	V1	24.91	23.34	27.33	29.78	208.35	219.81	228.34	324.91
		V2	21.22	26.16	31.16	31.67	219.04	227.89	229.7	296.34
General mean of CPE 150 mm.			22.35	24.08	27.36	29.11	210.06	219.88	229.56	311.57
LSD at 0.05 % level for: Water schedules (A)			1.54	1.76	1.42	1.28	14.89	28.54	46.45	98.66
schedules x potassium rates (AB			2.41	1.54	0.75	0.47	7.45	6.47	18.72	42.51
potassium rates x genotypes (BC			1.62	2.17	1.21	0.64	5.44	4.56	7.22	33.14
genotypes x schedules (AC			2.41	1.78	0.87	1.24	9.14	3.45	4.15	16.54
Ax B x C			2.37	2.13	1.47	0.84	4.22	2.45	8.43	12.44

Table 4: Influence of water schedule, potassium rates on relative growth rate and net assimilation rate of two wheat genotypes (Mean of two growing seasons)

			Relative growth rate (mg.g /week)			Net assimilation rate (mg/m^2/week)		
Water schedule,CPE(mm)	K rates(Kg/ha)	Genotype	(56 -70)	(70 - 77)	(77-107)	(56 -70)	(70 - 77)	(77-107)
50	100	V1	0.160	0.184	0.129	13.92	22.17	22.40
		V2	0.186	0.196	0.134	12.75	23.40	20.14
	200	V1	0.237	0.375	0.214	14.29	28.90	22.77
		V2	0.244	0.388	0.198	13.44	28.98	24.67
	300	V1	0.175	0.191	0.154	12.45	23.19	21.22
		V2	0.214	0.266	0.182	13.40	22.54	21.87
General mean of CPE 50 mm.			0.203	0.267	0.169	13.38	24.86	22.18
100	100	V1	0.131	0.157	0.115	11.88	18.50	16.07
		V2	0.202	0.212	0.146	12.55	20.64	17.35
	200	V1	0.219	0.375	0.213	10.57	21.37	19.33
		V2	0.205	0.358	0.191	10.93	21.55	20.46
	300	V1	0.149	0.165	0.134	11.89	22.17	22.49
		V2	0.210	0.252	0.170	12.73	23.66	21.98
General mean of CPE 100 mm.			0.186	0.253	0.162	11.76	21.32	19.61
150	100	V1	0.126	0.163	0.121	11.44	19.58	13.39
		V2	0.185	0.198	0.136	12.69	18.76	15.76
	200	V1	0.185	0.304	0.196	11.14	18.72	13.96
		V2	0.215	0.331	0.192	11.14	17.25	12.66
	300	V1	0.144	0.142	0.133	10.64	18.46	11.45
		V2	0.152	0.225	0.161	11.36	17.88	11.41
General mean of CPE 150 mm.			0.168	0.227	0.157	11.40	18.44	13.11
LSD at 0.05 % level for: Water schedules (A)			0.012	0.014	0.011	1.35	2.17	2.43
schedules x potassium rates (AB			0.034	0.023	0.037	1.22	1.21	1.62
potassium rates x genotypes (BC			0.017	0.012	0.032	1.10	0.66	0.91
genotypes x schedules (AC			0.021	0.016	0.014	0.98	3.21	0.78
Ax B x C			0.033	0.042	0.036	1.13	2.41	2.63

DISCUSSION

Under arid and semiarid regions of the world, where limited rainfall, high evapo-transpiration and high temperature, agronomic practices play serious role in leaf water content and plant water required. Among these practices, regulation water schedule, adopting more tolerant genotype and application of optimum K rate as well as their interactions are the most effective factors affecting in growing wheat under arid and semi arid environment. In the respect of water supplies indicated that significant reduction in most of growth characters was noticed with low water supplies. Such effect may be attributed to the availability of water in root zone promoted growth and proliferation of root, thereby increased the absorption of water with soluble nutrients and resulted in higher number of tillers per square meter and large leaves, which manifested in increasing LA, RGR and NAR. All these parameters put together to increase the rate of photosynthesis; better translocation of photosynthates from leaves and stems to the sink, this is turn favorably influenced the highest growth vigor. Similar results were also reported by Salter and Goode [32], Misra *et al.* [33], Chauhan *et al.* [34], Imtiyaz *et al.* [35], Hussain and Al-Jaloud [36], Ghandorah *et al.* [37] and Abdel Ghany [38]. In addition, the same trend was found by Kramer and Boyer [19], Alderfasi *et al.*[20,21], Pawar *et al.*[39], Reginato [40], Regiato and Carrot [41],Singh *et al.* [42] and Alderfasi *et al.*[43], they reported that low soil moisture content caused an irreversible loss in yield potential.

In the respect of genotypic variation, the results obtained herein subjecting that, lines L95-2(V_2) exhibited the highest growth capacity as compared to Yecora Raja (V_1). The superiority of the selected line was expected, since the selection of this line was done under the local condition of Saudi Arabia by plant production department program, Faculty of Food and Agricultural sciences, King Sound University.

Regarding to potassium efficiency, the present results concur the findings of Hanadi *et al.* [10] reported, that plant species differ in their potassium efficiency, but the mechanisms are nearly the same. Wheat requires potassium for optimal growth and development. Adequate potassium results in superior quality of the whole plant due to improved efficiency of photosynthesis, increased resistance to some diseases and greater water use efficiency. It helps maintain a normal balance between carbohydrates and proteins. Sufficient potassium results in stronger wheat straw and assists in grain filling. The present results are in agreement with those obtained by Singh *et al.*[44], they found better growth and yield of wheat crop has been observed with the addition of' K. Also, Sanchez *et al.* [8] concluded that high-out put practices led to K depletion from the soil. It would take time and investment to rebuild soil K to a sufficient range. Moreover, potassium ion may act together with sugars and other inorganic and organic ions as osmotic-adjustment substances. In addition, K^+ may counteract the competitive effect of high concentration of other cations specially Na^+ in saline soils [7].

CONCLUSION

Water supply or water schedule is often the most critical factor limiting crop growth in arid and semiarid areas and the most expensive input of irrigated crops. Therefore, crop production usually requires maximizing growth on limited available water resources along with K fertilizer. Therefore, for sustaining soil fertility and optimum crop productivity on long term basis, K removal through the crops should be replenished with balanced and adequate K fertilization. Considerable variability also attributed to genotypic variation x environment interactions. One of the key components of crop production is to achieve the greatest management practices that allow WUE to be maximized.

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