Effect of Potassium Nutrition on Elemental Composition in Irrigated Cotton Grown in Aridisols

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Summary: A nutrient applied to a soil favourably or adversely affects the plant availability of other nutrients present in the soil. Such interaction may occur within the soil, within the plant or at the root surface. Nutrients acting synergistically or antagonistically may imbalance the nutrition of crop plants. Therefore, the effect of potassium (K) nutrition [0, 62.5, 125.0, 250.0 kg K ha^{-1} of K_2SO_4 or KCl] on interaction of different ions in four cultivars i.e., CIM-448, CIM-1100, Karishma, S-12 of irrigated cotton (*Gossypium hirsutum* L.) was quantified in silt loam soil. Various plant parts i.e., leaves, stems, burs, seed, lint were analyzed for their ionic composition, i.e., nitrogen (N), phosphorus (P), K, calcium (Ca), magnesium (Mg), sodium (Na), chloride (Cl), and sulphur (S) at maturity. The K concentration in different plant parts increased with an increase in soil K-level. Averaged across cultivars and K-doses, K concentration in different plant parts was in the order of leaves > burs > stems > seed > lint. As N concentration increased with increasing levels of K-fertilizer, the relationship between K and N concentration in cotton plant parts was positive (r 0.87** to 0.98**). However, the relationships between K and P, Ca, or Na concentration in leaf tissues were negative i.e. (r -0.64** to – 0.75**; -0.78** to -0.96**; - 0.65** to -0.91**) respectively. Application of $K_{25.0}$ in the form of KCl raised Cl content by 175.0, 138.1, 136.4, 111.0 and 33.3 percent in burs, stems, seed, leaves and lint, respectively. There was highly significant r = (0.77** to 0.99**) relationship between K and Cl under KCl treated plots. However, addition of K_2SO_4 produced non-significant effect (r 0.03 to 0.50) by addition of K_2SO_4 between K and Cl content. Thus, findings suggest that soil K supply influences ionic relations in cotton plant. Hence, sufficiency levels of N, P, K., Ca, Mg, Na, Cl and S in cotton plant may be considered with respect to K-dose and form of K-fertilizer applied.

Introduction

Potassium (K) is unique among the essential nutrients in the diversity of roles it plays in plant metabolic processes [1]. Once passive and active pro-cesses take up K^+, it is finally accumulated through-out the plant, although in different concentrations depending on the organs and physiological stage of the plant development [2]. Various researchers reported that difficulties arise in maintaining an adequate supply of K during critical periods for optimum yield. [3]. The presence of favourable ionic composition and absence of undesir-able constituents in soil-plant systems are very important for normal growth of cotton plant [4]. Other researchers [5] also reported that a nutrient applied to a plant favourably or adversely affects the availability of other nutrients present in the soil. Such interactions may occur within soil, plant or at the root surface. Nutrients acting synergistically or antagonistically may imbalance the nutrition of crop plants and hence depress yield. Adequate amounts of available soil K is needed to maintain soil above the critical level for sustained supply to the plant. In an other study, it was reported that addition of K-fertilizer increased K^+ concentration in plant tissues and decreased with advancement of growth stage [6].

Adequate K is needed in the plant, when large amounts of nitrogen (N) are supplied, so as to maintain N metabolism [7]. The large absorption of ammonium (NH_4^+) with the application of large amounts of K indicated a complementary effect on uptake between ammonium (NH_4^+) and potassium [5]. The other researchers working with rice (*Oryza sativa* L.) also concluded that it was unlikely that K^+ competes with NH_4^+ for selective binding sites in the absorption process [8]. Another researcher also suggested that increased K allowed for rapid assimilation of N in the plant [9]. Furthermore, K deficiency adversely affects the translocation of photosynthetic assimilates out of the leaves into the

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developing bolls. The reason being that absorption of nitrate, the predominant form of soil N, requires chemical energy that is derived from photosynthetic assimilates. Thus, K deficiency affects the ability of cotton to utilize soil N [10].

Phosphorus requires adequate levels of K for maximum crop response to added-P. Various researchers while working on solution culture work with Cowpeas (*Vigna unguiculata* L.) reported that K^+ deficiency markedly decreased P-uptake, even though P was adequate in the solution [11]. It is postulated that a specific P ion absorption site exists that is activated by K^+. Other researchers reported in contrary to it, antagonistic ionic interaction between K^+ and P while working with sorghum [12]. In an earlier study, other researcher supported the concept of a P-K^+ interaction in the plant as a part of the cation-anion balance system in which organic acids play a significant role [13].

Potassium application increases have a fairly consistent effect on lowering tissue concentrations of calcium ($Ca_{0.5}^+$) and magnesium ($Mg_{0.5}^+$) in most plant species [13]. Various researchers reported that excess of K applications, antagonism between $Mg_{0.5}^+$ and K^+ may induce $Mg_{0.5}^+$ deficiency symptoms in cereals, maize, and potatoes. Evidence for the antago-nistic effect of these elements was related to charge balance among them [14-15]. A strong antagonism between K^+ and $Ca_{0.5}^+$ was well characterized by [16]. In culture solution, $Ca_{0.5}^+$ enrichment resulted in a 30 % decrease of the K concentration in all the organs of grape compared to that in control plants.

The adverse effects of Sodium (Na^+) on plant growth are attributed to its antagonistic relationship with $Ca_{0.5}^+$, K^+ and zinc (Zn) in plants and increased salinity and alkalinity hazards in soils [17]. The synergistic or antagonistic effect between K^+ and Na^+ depends on the amount of each element present in the soil and on the plant type [13]. Different researchers have demonstrated the antagonistic effects of K^+ and Na^+ in faba in tomato plants [18-19].

Chloride (Cl^-) generally accumulates in the vegetative parts, mainly in the leaves of cotton and lettuce [20]. Cotton seeds maintained a Cl^- concentration in the range of 0.48-0.59 mg g^{-1} d.w. When Cl application was increased upto 3200 mg kg^{-1} soil [21] Chloride concentrations varied markedly among plant parts, due to differences between cultivars and interaction between Cl^- and K^+. Potassium is the main cation associated with either inorganic anions or organic acid anions in the vacuoles. Therefore, K^+ is taken up by plants together with an anion particularly Cl^-. Various researchers found that applying K increased the Cl^- content in tomato, pepper and egg plant [13-22].

Under conditions of K^+ deficiency, inhibition of protein synthesis is inhibited [13]. The sulphate content is extremely low in deficient plants and increases markedly when the sulphate supply is sufficient for optimal growth. Other researchers suggested that cation and anion interaction occur at both the membrane and in cellular processes after absorption [23] Potassium interactions with sulphur are less evident in the literature that those with some other nutrients. Therefore, field experiment was undertaken to study the effects of potassium nutrition on elemental composition in irrigated cotton grown in Aridisols conditions.

Results and Discussion

Potassium concentration in different plant parts differed significantly ($p \leq 0.01$) due to K-fertili-zation and cultivars. However, interaction between cultivars and K-rates was non-significant (Table-1). The absorption of K^+ by various plant parts increased with an increase in varying level of K-fertilizer. The K^+ concentration was much higher in leaves, stems and burs compared with seed and lint. Application of 250 kg K ha^{-1} increased K concentration of 73.7, 43.8, 43.2, 39.1, and 24.2 percent in burs, seed, stems, lint and leaves, respectively compared to K-unfertilized treatments. Cultivars CIM-448 and CIM-1100 contained the highest K^+ concentration in their whole pant parts compared to cvs. Karishma and S-12. Averaged across cultivars and doses, relative K concentration in plant parts was in decreasing in order of leaves > burs > stems > seed > lint.

Data for N concentration in various plant parts of the plant differed significantly ($p \leq 0.01$) due to K-fertilization and cultivars. However, interaction between cultivars and K-rates was non-significant (Table-2). The concentration of N increased with increasing levels of K-fertilizer. The K and N concentration in leaf tissues was positively

Table-1:Effect of K-fertilizer on K^+ concentration (%) in plant parts of cotton at maturity

Cultivar	Kg K ha^{-1}			
	0	62.50	125.0	250.0
		Leaves		
CIM-448	2.11	2.31	2.44	2.57
CIM-1100	2.02	2.29	2.35	2.51
Karishma	1.83	2.11	2.26	2.30
S-12	1.78	2.03	2.20	2.26
LSD ($p < 0.05$)	Cultivar 0.02**	Dose 0.02**	Interaction	0.05^{ns}
		Stems		
CIM-448	1.16	1.29	1.43	1.56
CIM-1100	0.98	1.16	1.30	1.36
Karishma	0.88	1.07	1.17	1.26
S-12	0.77	0.94	1.10	1.23
LSD ($p < 0.05$)	Cultivar 0.02**	Dose 0.01**	Interaction	0.03^{ns}
		Burs		
CIM-448	2.13	2.29	3.31	3.70
CIM-1100	2.20	2.97	3.38	3.76
Karishma	2.24	2.94	3.55	3.87
S-12	2.08	2.95	3.18	3.72
LSD ($p < 0.05$)	Cultivar 0.09**	Dose 0.10**	Interaction	0.19^{ns}
		Seed		
CIM-448	0.92	1.10	1.16	1.27
CIM-1100	0.97	1.15	1.24	1.32
Karishma	0.70	0.89	0.96	1.02
S-12	0.61	0.78	0.87	0.96
LSD ($p < 0.05$)	Cultivar 0.02**	Dose 0.01**	Interaction	0.04^{ns}
		Lint		
CIM-448	0.77	0.88	0.92	1.01
CIM-1100	0.74	0.84	0.95	1.00
Karishma	0.61	0.82	0.90	0.96
S-12	0.62	0.63	0.73	0.84
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.02^{ns}

N.B. since the two sources of K did not differ significantly, data for both were pooled

ns = non-significant at the 0.05 level.

** significant at the 0.01 level.

correlated ($Y = 0.2439X+2.2391$, $r = 0.91^{**}$). Moreover, relationships between these two nutrients in other plant organs were also positively correlated (Table-3). These data clearly demonstrate the synergistic effects of K-fertilizer on absorption of N by various plant organs. Application of 250 kg ha^{-1} increased N concentration of 33.3, 33.3, 30.1, 6.6 and 4.4 percent in burs, lint, seed, stems and leaves, respectively compared to K-unfertilized treatment. Cultivars differed significantly in maintaining N content in various organs of the plant. Cultivars CIM-448 and CIM-1100 maintained higher N contents than those of other cultivars.

Table-2: Effect of K- fertilizer on N concentration (%) in cotton plant parts at maturity.

Cultivar	Kg K ha^{-} ^{1}0	62.50	125.0	250.0
		Leaves		
CIM-448	2.08	2.12	2.12	2.15
CIM-1100	2.08	2.09	2.12	2.14
Karishma	2.00	2.08	2.14	2.16
S-12	2.10	2.13	2.14	2.19
LSD ($p < 0.05$)	Cultivar 0.03**	Dose 0.03**	Interaction	0.05^{ns}
		Stems		
CIM-448	0.60	0.62	0.63	0.63
CIM-1100	0.64	0.66	0.68	0.70
Karishma	0.57	0.60	0.61	0.64
S-12	0.53	0.56	0.59	0.60
LSD ($p < 0.05$)	Cultivar 0.02**	Dose 0.02**	Interaction	0.04^{ns}
		Burs		
CIM-448	0.37	0.40	0.42	0.46
CIM-1100	0.41	0.44	0.48	0.54
Karishma	0.32	0.36	0.41	0.46
S-12	0.34	0.40	0.43	0.46
LSD ($p < 0.05$)	Cultivar 0.02**	Dose 0.01**	Interaction	0.02^{ns}
		Seed		
CIM-448	2.18	2.27	2.47	2.98
CIM-1100	2.20	2.39	2.64	2.92
Karishma	2.36	2.50	2.58	2.93
S-12	2.28	2.57	2.72	2.92
LSD ($p < 0.05$)	Cultivar 0.07**	Dose 0.07**	Interaction	0.06^{ns}
		Lint		
CIM-448	0.08	0.08	0.10	0.12
CIM-1100	0.08	0.08	0.11	0.12
Karishma	0.09	0.12	0.12	0.12
S-12	0.09	0.11	0.12	0.12
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.01^{ns}

N.B. since the two sources of K did not differ significantly, data for both were pooled

ns = non-significant at the 0.05 level.

** significant at the 0.01 level.

Phosphorus concentration in various parts of the plant differed significantly ($p < 0.01$) due to K-fertilization and cultivars. However, interaction between cultivars and K-rates was non-significant (Table-4). The concentration of P decreased with an increase in K-rates. The relationship between K^+ and P concentrations in leaf tissue was negatively corre-lated ($Y = 0.0967X^2 - 0.5916X + 1.096$, $r = -0.64^{**}$). Moreover, relationships between these two ions in stems, burs, seed, lint were negatively correlated (Table-5). Data show that application of K-fertilizer had depressing effect on absorption P by the crop. Averaged across doses, cv. CIM-448 maintained the highest P content than other cultivars. Cultivars were arranged in descending order of CIM-448 > CIM-1100 > Karishma > S-12 with respect to maintaining P content.

Calcium ($Ca_{0.5}^{+}$) concentration in different organs of plant differed significantly ($p < 0.01$)

Table-3: Relationship between K^+ concentration (%) [X] and N concentration (%) [Y] in various plant parts of cotton at maturity.

Variables	Regression equation	Correlation coefficient (r)
K^+ conc. In leaves vs. N conc. in leaves	$Y= 0.243935x + 2.2391126$	0.91**
K^+ conc. In stems vs. N conc. in stems	$Y= 0.052586x+1.0687355$	0.87**
K^+ conc. In burs vs. N conc. in burs	$Y= 0.116x+0.99$	0.98**
K^+ conc. In seed vs. N conc. in seed	$Y= 2.654x^2-7.544x+7.677$	0.95**
K^+ conc. In lint vs. N conc. in lint	$Y= 0.321x+0.073$	0.94**

** significant at the 0.01 level

Table-4: Effect of K fertilizer on P concentration (%) in cotton plant parts at maturity.

Cultivar	Kg K ha^{-1} 0	62.50	125.0	250.0
		Leaves		
CIM-448	0.13	0.11	0.11	0.11
CIM-1100	0.12	0.11	0.11	0.11
Karishma	0.10	0.10	0.10	0.09
S-12	0.10	0.09	0.09	0.09
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01	Interaction	0.01
		Stem		
CIM-448	0.07	0.06	0.06	0.06
CIM-1100	0.06	0.05	0.05	0.05
Karishma	0.06	0.05	0.05	0.05
S-12	0.06	0.05	0.05	0.05
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.01
		Burs		
CIM-448	0.13	0.12	0.12	0.12
CIM-1100	0.11	0.10	0.10	0.10
Karishma	0.10	0.07	0.07	0.07
S-12	0.10	0.09	0.09	0.09
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.02
		Seed		
CIM-448	0.47	0.44	0.44	0.44
CIM-1100	0.45	0.42	0.42	0.41
Karishma	0.43	0.39	0.39	0.39
S-12	0.44	0.41	0.41	0.41
LSD ($p < 0.05$)	Cultivar 0.02**	Dose 0.01**	Interaction	0.03^{ns}
		Lint		
CIM-448	0.05	0.05	0.05	0.05
CIM-1100	0.04	0.04	0.04	0.04
Karishma	0.04	0.04	0.04	0.04
S-12	0.04	0.04	0.04	0.04
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.007**	Interaction	0.01^{ns}

N.B. since the two sources of K did not differ significantly, data for both were pooled

ns = non-significant at the 0.05 level.

** significant at the 0.01 level.

because of K-fertilization and cultivars. In interaction terms (cultivar x K-rates) were non-significant (Table 6). Concentration of $Ca_{0.5}^+$ decreased significantly with concurrent increase in varying levels of K-fertilizer. The relationship between K^+ and $Ca_{0.5}^+$ concentration in leaf tissues was negatively correlated ($Y = - 0.4119X^2 = 2.1772X - 1.5528$, $r = - 0.83$**). Similarly, relationships between these two ions in plant parts (stems, burs, seed and lint) were negatively correlated (Table-7). Application of 250 kg K ha^{-1} decreased $Ca_{0.5}^+$ concentration by 43.5, 42.9, 38.9, 33.3 and 8.7 percent in burs, seed, stems, lint and leaves, respectively compared to K-unferti-lized treatment. Data show that antagonistic effect occurred between increased assimilation of K^+ with corresponding decrease in $Ca_{0.5}^+$ content. Cultivars varied greatly amongst themselves in maintaining $Ca_{0.5}^+$ content in the whole plant. Cultivar CIM-448 absorbed maximum concentration of $Ca_{0.5}^+$ compared to other cultivars.

Magnesium ($Mg_{0.5}^+$) concentration in different organs of plant differed significantly ($p < 0.01$) due to K-fertilization and cultivars. In interaction terms (cultivar x K-rates) were non-significant (Table-8). Magnesium concentration decreased linearly with increasing K-levels. The relationship between K^+ and $Mg_{0.5}^+$ concentration in leaf tissues was negatively correlated ($Y = - 0.2517x^2 + 1.2414x - 1.178$; $r = -0.95$**). Furthermore, relationship between these two ions in other plant parts were negatively correlated (Table-9). The reduction in $Mg_{0.5}^+$ concentration by addition of 250 kg K ha^{-1} was 52.2, 38.5, 37.0, 30.0 and 28.6 percent in burs, seed, leaves, stems and

Table-5: Relationship between K^+ concentration (%) [X] and P concentration (%) [Y] in various organs of cotton plant

Variables	Regression equation	Correlation coefficient (*r*)
K^+ conc. in leaves vs. P conc. in leaves	$Y= 0.097x^2-0.592x+1.096$	-0.64**
K^+ conc. in stems vs. P conc. in stems	$Y= 0.004x+0.093$	0.16^{ns}
K^+ conc. in burs vs. P conc. in burs	$Y= -0.020x+0.304$	-0.75**
K^+ conc. in seed vs. P conc. in seed	$Y= 0.605x^2-2.149x+2.257$	-0.66**
K^+ conc. in lint vs. P conc. in lint	$Y= -0.016x+0.115$	-0.30^{ns}

ns = non significant at the 0.05 level

** significant at the 0.01 level

Table-6: Effect of K-fertilizer on $Ca_{0.5}$ concentration (%) in different cultivars at maturity.

Cultivar	Kg K ha^{-1} 0	62.50	125.0	250.0
		Leaves		
CIM-448	1.19	1.13	1.10	1.07
CIM-1100	1.14	1.12	1.10	1.07
Karishma	1.12	1.06	1.04	1.01
S-12	1.12	1.08	1.05	1.04
LSD ($p < 0.05$)	Cultivar 0.013**	Dose 0.011**	Interaction 0.023 ^{ns}	
		Stems		
CIM-448	0.62	0.55	0.46	0.37
CIM-1100	0.54	0.46	0.41	0.35
Karishma	0.53	0.45	0.37	0.30
S-12	0.45	0.35	0.32	0.30
LSD ($p < 0.05$)	Cultivar 0.019**	Dose 0.014**	Interaction 0.028 ^{ns}	
		Burs		
CIM-448	0.27	0.23	0.18	0.15
CIM-1100	0.21	0.19	0.15	0.12
Karishma	0.23	0.18	0.12	0.11
S-12	0.20	0.16	0.13	0.12
LSD ($p < 0.05$)	Cultivar 0.011**	Dose 0.012**	Interaction 0.028 ^{ns}	
		Seed		
CIM-448	0.25	0.19	0.16	0.13
CIM-1100	0.20	0.17	0.15	0.13
Karishma	0.18	0.15	0.13	0.12
S-12	0.21	0.16	0.12	0.11
LSD ($p < 0.05$)	Cultivar 0.008**	Dose 0.009**	Interaction 0.019 ^{ns}	
		Lint		
CIM-448	0.03	0.02	0.02	0.02
CIM-1100	0.03	0.02	0.02	0.02
Karishma	0.02	0.02	0.01	0.01
S-12	0.02	0.02	0.02	0.01
LSD ($p < 0.05$)	Cultivar 0.002**	Dose 0.002**	Interaction 0.004 ^{ns}	

N.B. Since the two sources of K did not differ significantly, data for both were pooled
ns = non-significant at the 0.05 level.
** significant at the 0.01 level.

lint, respectively compared to K-unfertilized treatment. This study shows that antagonistic phenomenon occurred, *i.e.*, K^+ content increased with correspon-ding decrease in $Mg_{0.5}^+$ content. Cultivars showed differential response to absorption of $Mg_{0.5}^+$ ion by their various organs Cultivar CIM-448 absorbed higher concentration of $Mg_{0.5}^+$ than that of other cultivars.

Sodium (Na^+) concentration in different parts differed significantly ($p < 0.01$) because of K-rates and cultivars. However, interaction between K-rates and cultivars were non-significant (Table-10). Sodi-um concentration decreased linearly with concurrent increase in K-rates. The relationship between K^+ and Na^+ concentration in leaf tissues was negatively correlated ($Y = -0.3102x+1.3367$, $r = -0.89^{**}$). The relationships between K^+ and Na^+ in other plant organs were also negatively correlated (Table-11). The reduction in Na^+ concentration by application of 250 kg K ha^{-1} was 33.3, 31.8, 28.6, 28.6 and 25.7 percent in burs, leaves, seed, lint and stems, respecti-vely compared to K-unfertilized plots. Data further show that there was antagonistic effect between K^+ and Na^+ ions in cotton plant. Cultivars showed differential response to absorption of Na^+ ion by the plant. Cultivar CIM-448 maintained higher concen-tration of Na^+ in its whole plant tissues compared to other cultivars.

Chloride (Cl^-) concentration in different parts differed significantly ($p < 0.01$) due to K-rates and K-sources (Table-12). The interaction terms (K-rate x K-sources) were also significant. This depicted that Cl^- concentration is dependent upon K-dose and K-source. Chloride content was significantly affected by increasing doses of K-fertilizer in the form of KCl, however, its values were influenced non-significantly under K_2SO_4 treatment (Table-13). Application of 250 kg K ha^{-1} in the form of KCl raised Cl^- content by 175.0, 138.1, 136.4, 111.0 and 33.3 percent in burs, stems, seed, leaves, and lint, respectively compared to K-unfertilized plots. The positive linear relationship ($Y = 1.6715x - 3.2832$, $r = -0.99^{**}$) and non-significant relationship ($Y = 0.064x + 0.9162$, $r = 0.47^{ns}$) in leaf tissues under KCl and K_2SO_4 treated

Table-7: Relationship between K^+ concentration (%) [X] and $Ca_{0.5}^+$ concentration (%) [Y] in different parts of the cotton

Variables	Regression equation	Correlation coefficient (r)
K^+ conc. in leaves vs. $Ca_{0.5}^+$ conc. in leaves	Y= -2.177x+1.552	-0.83**
K^+ conc. in stems vs. $Ca_{0.5}^+$ conc. in stems	Y= -0.185x+0.539	-0.95**
K^+ conc. in burs vs. $Ca_{0.5}^+$ conc. in burs	Y= -0.07x+0.453	-0.96**
K^+ conc. in seed vs. $Ca_{0.5}^+$ conc. in seed	Y= -0.142x+0.496	-0.86**
K^+ conc. in lint vs. $Ca_{0.5}^+$ conc. in lint	Y= -0.043x+0.089	-0.78**

ns = non significant at the 0.05 level
** significant at the 0.01 level

Table-8: Effect of K-fertilizer on $Mg_{0.5}^{+}$ concentration (%) in cotton plant parts of different cultivars at maturity.

Cultivar	Kg K ha^{-} ^{1}0	62.50	125.0	250.0
		Leaves		
CIM-448	0.33	0.29	0.26	0.23
CIM-1100	0.30	0.27	0.22	0.18
Karishma	0.24	0.19	0.16	0.11
S-12	0.21	0.19	0.15	0.13
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.02 ^{ns}
		Stems		
CIM-448	0.10	0.08	0.07	0.07
CIM-1100	0.09	0.08	0.07	0.07
Karishma	0.10	0.09	0.08	0.07
S-12	0.10	0.09	0.08	0.07
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.01 ^{ns}
		Burs		
CIM-448	0.26	0.22	0.19	0.15
CIM-1100	0.24	0.21	0.16	0.11
Karishma	0.20	0.16	0.13	0.09
S-12	0.19	0.13	0.10	0.09
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.03 ^{ns}
		Seed		
CIM-448	0.13	0.11	0.09	0.08
CIM-1100	0.14	0.12	0.10	0.09
Karishma	0.13	0.11	0.09	0.08
S-12	0.12	0.10	0.08	0.08
LSD ($p < 0.05$)	Cultivar 0.01**	Dose 0.01**	Interaction	0.08 ^{ns}
		Lint		
CIM-448	0.007	0.005	0.005	0.005
CIM-1100	0.006	0.005	0.005	0.005
Karishma	0.006	0.005	0.005	0.004
S-12	0.007	0.005	0.004	0.004
LSD ($p < 0.05$)	Cultivar 0.0003**	Dose 0.0003**	Interaction	0.0006 ^{ns}

N.B. since the two sources of K did not differ significantly, data for both were pooled

ns = non-significant at the 0.05 level.

** significant at the 0.01 level.

plots, respectively clearly demonstrate that Cl^{-} content were dependent upon the K-source. Averaged across plant parts, Cl^{-} content increased from 0.22 to 0.63 percent by addition of zero K to 250 kg K ha^{-1} in the form of KCl. However, Cl^{-} values remained constant under K_2SO_4 treated plots.

Cultivars showed differential response to added K-fertilizer in the form of KCl and/ or K_2SO_4 (Table-14). Averaged across sources, cvs. CIM-448 and S-12 maintained 0.32 percent Cl^{-} compared to cvs. CIM-1100 and Karishma having 0.29 percent in their whole plant. Crop contained 0.96, 0.30, 0.25, 0.016 and 0.007 percent Cl^{-} in tissues of leaves, stems, burs, seed and lint, respectively.

Sulphate-sulphur (SO^{2-}_4) content in different parts differed significant ($p \leq 0.01$) due to K-rates, cultivars, K-sources. Moreover, the interaction terms (cultivar x K-sources and K-doses x K-sources were significant, depicting that SO^{2-}_4 contents were affected by K-sources and cultivars. (Table-15). SO^{2-}_4 content was significantly affected by increasing doses of K-fertilizer added in the form of K_2SO_4, however, its values were non-significantly affected under KCl treatment. There were positive relationship ($Y = 1.1149x^2 - 5.95x + 8.7144$, $r = 0.81^{**}$) and non-significant relationship ($Y = -0.004x + 0.802$ $r = 0.089^{NS}$) in leaf tissues under KCl and /or K_2SO_4 treated plots (Table-16). Data clearly show that SO^{2-}_4 content was dependent upon the K-source. Averaged across plant parts and cultivars, Cl^{-} content increased from 0.17 to 0.27 percent by addition of zero K to 250 kg K ha^{-1} in the form of K_2SO_4, However, it values, remained relatively constant under KCl treated plots. Cultivars showed differential response to added K-fertilizer in the form of KCl and/or K_2SO_4. Averaged across sources and plant parts, cultivars were arranged in decreasing order of CIM-448 > Karishma > CIM-1100 > S-12 in maintaining SO_4-S in their whole plant. Crop fertilized with K_2SO_4 and/ or KCl contained 0.23 and 0.18 percent SO^{2-}_4, respectively. Crop maintained 0.61, 0.19, 0.08, 0.07 and 0.04 percent SO_4-S in leaves, seed, lint, burs and stems, respectively.

Table-9: Relationship between K^{+} concentration (%) [X] and $Mg_{0.5}^{+}$ concentration (%) [Y] in different plant parts of the cotton at maturity

Variables	Regression equation	Correlation coefficient (*r*)
K^{+} conc. in leaves vs. $Mg_{0.5}^{+}$ conc. in leaves	$Y = -1.241x + 1.75$	-0.95*
K^{+} conc. in stems vs. $Mg_{0.5}^{+}$ conc. in stems	$Y = -0.035x + 0.232$	-0.87**
K^{+} conc. in burs vs. $Mg_{0.5}^{+}$ conc. in burs	$Y = -0.283x + 0.042$	-0.91**
K^{+} conc. in seed vs. $Mg_{0.5}^{+}$ conc. in seed	$Y = -0.132x + 0.371$	-0.88**
K^{+} conc. in lint vs. $Mg_{0.5}^{+}$ conc. in lint	$Y = -0.006x + 0.015$	-0.86**

** significant at the 0.01 level

Potassium concentration increased linearly with an increase in level of K-fertilizer. The relative K^{+} concentration in plant parts were in decreasing

Table-10: Effect of K-fertilizer on Na^+ concentration (%) in cotton plant parts of different cultivars at maturity.

Cultivar	Kg K ha^{-1} 0	62.50	125.0	250.0
		Leaves		
CIM-448	0.47	0.40	0.32	0.29
CIM-1100	0.41	0.36	0.30	0.30
Karishma	0.44	0.34	0.29	0.29
S-12	0.41	0.38	0.34	0.29
LSD ($p < 0.05$)	Cultivar 0.019**	Dose 0.013**	Interaction	0.026 ^{ns}
		Stems		
CIM-448	0.45	0.41	0.37	0.30
CIM-1100	0.39	0.35	0.32	0.29
Karishma	0.36	0.32	0.30	0.28
S-12	0.36	0.32	0.29	0.27
LSD ($p< 0.05$)	Cultivar 0.014**	Dose 0.013**	Interaction	0.026 ^{ns}
		Burs		
CIM-448	0.14	0.11	0.10	0.08
CIM-1100	0.12	0.10	0.10	0.08
Karishma	0.12	0.10	0.10	0.08
S-12	0.10	0.08	0.08	0.08
LSD ($p < 0.05$)	Cultivar 0.005**	Dose 0.004**	Interaction	0.014 ^{ns}
		Seed		
CIM-448	0.07	0.06	0.06	0.05
CIM-1100	0.08	0.06	0.05	0.05
Karishma	0.06	0.05	0.05	0.05
S-12	0.05	0.04	0.04	0.04
LSD ($p < 0.05$)	Cultivar 0.008**	Dose 0.005**	Interaction	0.010 ^{ns}
		Lint		
CIM-448	0.007	0.005	0.005	0.005
CIM-1100	0.007	0.005	0.005	0.005
Karishma	0.007	0.006	0.006	0.005
S-12	0.006	0.005	0.005	0.005
LSD($p< 0.05$)	Cultivar 0.0003**	Dose 0.0003**	Interaction	0.0009 ^{ns}

N.B. Since the two sources of K did not differ significantly, data for both were pooled
ns = non-significant at the 0.05 level.
** significant at the 0.01 level.

Table-11: Relationship between K concentration (%) [X] and Na concentration (%) [Y] in various plant parts of cotton plant at maturity.

Variables	Regression equation	Correlation co-efficient (r)
K^+ conc. in leaves vs. Na^+ conc. in leaves	$Y = -0.13x+1.337$	-0.89**
K^+ conc. in stems vs. Na^+ conc. in stems	$Y = -0.087x+0.68$	-0.91**
K^+ conc. in burs vs. Na^+ conc. in burs	$Y =-0.015x+0.112$	-0.68**
K^+ conc. in seed vs. Na^+ conc. in seed	$Y = -0.049x+0.151$	-0.78**
K^+ conc. in lint vs. Na^+ conc. in lint	$Y = -0.004x+0.013$	-0.65**

** significant at the 0.01 level

order of leaves > burs > stems > seed > lint. These results are in conformity with those of [1-6].

The positive correlation between K^+ and N concentration in various parts indicated a synergistic interaction between these ions in the plant. Various researchers [5, 6] also reported that a large absorption of NH_4^+ with the application of heavy amounts of K indicate a complementary effect on uptake between NH_4^+ and K^+. These results agree with those of (Streeter and Barta, 1984; Krauss, 1993) that absorp-tion of NO_3-N requires chemical energy, that is derived from photosynthetic assimilates. Thus, K^+ deficiency affects the ability of cotton to utilize soil N.

Phosphorus content decreased with concurrent increase in K-rates in the whole plant. The negative correlation co-efficient ($p \leq 0.01$) between K^+ and P concentration maintained by various parts of plant demonstrated the antagonistic interaction. Various researchers reported that a specific P ion absorption site exists that is activated by K^+. Various researchers advocated the concept of a P-K^+ interaction in the plant as a part of the cation-anion balance system in which organic acids play a significant role [11-13]. Several authors [12-24] also reported similar results that antagonistic ionic interaction occurred between K^+ and P. It was also found great variability in different cotton cultivars in absorption of P concen-tration due to their genetic make-up and nutrient status.

The application of K fertilizer caused reduc-tion in absorption of $Ca_{0.5}^+$ in various plants parts. This relationship of K^+ and $Ca_{0.5}^+$ is the phenomenon known as viets effects. Similar results have been reported by [5, 13, 16, 25]

Application of varying levels of K-fertilizer had a fairly consistent effect on lowering concen-tration of $Mg_{0.5}^+$. The excess use of K-applications, antagonism between $Mg_{0.5}^+$ and K^+ may induce $Mg_{0.5}^+$ efficiency in cereals, maize, and potatoes [14]. Different researchers [13, 15-16] reported that antagonistic effects of these elements were related to change balance among them.

Table-12: Chloride concentration (%) in cotton plant parts as influenced by K-doses and sources at maturity.

K-dose	Leaves		Stems		Burs		Seed		Lint	
kg K ha^{-1}	KCl	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4
0	0.73	0.73	0.21	0.21	0.16	0.16	0.011	0.011	0.006	0.006
62.5	1.18	0.73	0.40	0.21	0.29	0.16	0.017	0.011	0.007	0.006
125.0	1.32	0.73	0.44	0.21	0.39	0.16	0.023	0.011	0.007	0.006
250.0	1.54	0.73	0.50	0.21	0.44	0.16	0.026	0.011	0.008	0.006
LSD ($p<0.05$)										
Dose	0.023**		0.013**		0.011**		0.0005**		0.0003**	
Source	0.018**		0.09**		0.008**		0.0004**		0.0003**	
Interaction	0.032**		0.015**		0.014**		0.0008**		0.0007 ^{ns}	

ns = nonsignificant at the 0.0.5 level. ** significant at the 0.01 level.

Table-13: Relationship between K concentration (%) [X] and Cl concentration (%) [Y] in various plant parts of cotton plant at maturity.

Variables	Regression equation	Correlation coefficient (r)
	KCl	
K^+ conc. in leaves vs. Cl^- conc. in leaves	$1.672x-3.283$	0.99**
K^+ conc. in stems vs. Cl^- conc. in stems	$-1.564x^2+4.187x-3.364$	0.99**
K^+ conc. in burs vs. Cl^- conc. in burs	$-1.406x^2+4.209x-3.818$	0.98**
K^+ conc. in seed vs. Cl^- conc. in seed	$-0.039x^2+0.17x-0.151$	0.99**
K^+ conc. in lint vs. Cl^- conc. in lint	$0.005x+0.002$	0.77**
	K_2SO_4	
K^+ conc. in leaves vs. Cl^- conc. in leaves	$0.064x+0.916$	0.47 ^{ns}
K^+ conc. in stems vs. Cl^- conc. in stems	$0.014x+0.282$	0.50 ^{ns}
K^+ conc. in burs vs. Cl^- conc. in burs	$0.002x+0.0273$	0.11 ^{ns}
K^+ conc. in seed vs. Cl^- conc. in seed	$0.066x-0.089$	0.31 ^{ns}
K^+ conc. in lint vs. Cl^- conc. in lint	$0.0001379x+0.007$	0.03 ^{ns}

ns = non significant at the 0.0.5 level. ** significant at the 0.01 level.

Table-14: Chloride concentration (%) in mature plant parts as influenced by cotton cultivars and K-sources.

Cultivar	Leaves		Stems		Burs		Seed		Lint	
	KCl	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4	KCl	K_2SO_4
CIM-448	1.19	0.80	0.41	0.25	0.34	0.16	0.024	0.012	0.007	0.006
CIM-1100	1.13	0.63	0.38	0.20	0.40	0.15	0.016	0.011	0.007	0.006
Karishma	1.18	0.68	0.35	0.18	0.33	0.18	0.017	0.010	0.007	0.006
S-12	1.27	0.82	0.41	0.19	0.31	0.17	0.020	0.011	0.007	0.005
LSD ($p< 0.05$)										
Cultivar	0.024**		0.013**		0.006**		0.006**		0.0005**	
Source	0.018**		0.090**		0.008**		0.004**		0.0003**	
Interaction	0.038**		0.018**		0.016**		0.009**		0.007**	

** significant at the 0.01 level.

Sodium content decreased with concurrent increase in K-rates. It was reported that synergistic or antagonistic effect between K^+ and Na^+ depends on the amount of each element present in the soil and on the plant type [13]. These results corroborate with those of who also demonstrated the antagonistic effects of K^+ and Na^+ in faba bean and tomato plants [18-19].

Chloride content increased with increasing doses of K-fertilizer applied in the form of KCl and was little affected by addition of K_2SO_4. It was reported that K^+ is the main cation associated with other organic anions or organic acid anions in the vacuoles. Therefore, K^+ is taken up by plants together with an anion particularly Cl^- [13]. These results agree with those of [18-19, 22] that application of K-fertilizer increased Cl^- content in tomato, pepper and egg plant.

Sulphate-sulphur content increased with increasing levels of K-fertilizer added in the form of K_2SO_4. [23] advocated that cation and anion inter-action occur at both the membrane and in cellular processes after absorption. These results are in agree-ment with those of [13] that sulphate

Table-15: Effect of K-fertilizer on SO_4^{2-}-S concentration (%) in plant parts of various cotton cultivars at maturity.

Cultivar	KCl				K_2SO_4			
	0	62.50	125.0	250.0	62.50	125.0	250.0	
				Leaves				
CIM-448	0.59	0.60	0.62	0.60	0.71	0.76	0.81	
CIM-1100	0.50	0.50	0.50	0.52	0.67	0.71	0.78	
Karishma	0.62	0.52	0.63	0.63	0.73	0.75	0.77	
S-12	0.41	0.42	0.42	0.42	0.60	0.67	0.75	
LSD ($p < 0.05$)	Cultivar 0.031**			Dose 0.025**	Source 0.016**	CxS 0.033**	DxS 0.029**	
				Stems				
CIM-448	0.04	0.04	0.04	0.04	0.05	0.05	0.05	
CIM-1100	0.04	0.04	0.04	0.04	0.05	0.06	0.06	
Karishma	0.03	0.03	0.03	0.03	0.04	0.06	0.06	
S-12	0.03	0.03	0.03	0.03	0.05	0.06	0.06	
LSD ($p < 0.05$)	Cultivar 0.004**			Dose 0.004**	Source 0.003**		CxS 0.006**	
				Burs				
CIM-448	0.08	0.08	0.08	0.08	0.11	0.13	0.14	
CIM-1100	0.06	0.06	0.06	0.06	0.10	0.13	0.14	
Karishma	0.04	0.04	0.04	0.04	0.10	0.12	0.12	
S-12	0.03	0.03	0.03	0.03	0.07	0.07	0.08	
LSD ($p < 0.05$)	Cultivar 0.006**			Dose 0.006**	Source 0.004**		CxS 0.008**	DxS .009**
				Seed				
CIM-448	0.17	0.17	0.17	0.18	0.25	0.26	0.28	
CIM-1100	0.16	0.16	0.16	0.16	0.24	0.27	0.28	
Karishma	0.16	0.16	0.16	0.16	0.22	0.23	0.25	
S-12	0.19	0.19	0.19	0.19	0.25	0.28	0.29	
LSD ($p < 0.05$)	Cultivar 0.008**			Dose 0.010**	Source 0.008**		DxS 0.014**	
				Lint				
CIM-448	0.08	0.08	0.08	0.08	0.11	0.11	0.11	
CIM-1100	0.06	0.06	0.06	0.06	0.11	0.11	0.11	
Karishma	0.08	0.08	0.08	0.08	0.11	0.11	0.11	
S-12	0.08	0.08	0.08	0.08	0.11	0.11	0.11	
LSD ($p < 0.05$)	Cultivar 0.008**			Dose 0.007**			Source 0.006**	

**= significant at the 0.01 level

Table-16: Relationship between K^+ concentration (%) [X] and SO^{2-}_4-S concentration (%) [Y] as influenced addition of K-fertilizer in the form of KCl and K_2SO_4 in various parts of cotton plant.

Variables	Regression equation	Correlation coefficient (*r*)
KCl		
K^+ conc. in leaves vs. SO^{2-}_4-S conc. in leaves	$-0.004x + 0.802$	-0.084^{ns}
K^+ conc. in stems vs. SO^{2-}_4-S conc. in stems	$0.006x+0.044$	0.47^{ns}
K^+ conc. in burs vs. SO^{2-}_4-S conc. in burs	$0.005x+0.14$	0.39^{ns}
K^+ conc. in seed vs. SO^{2-}_4-S conc. in seed	$0.018x+1.494$	0.44^{ns}
K^+ conc. in lint vs. SO^{2-}_4-S conc. in lint	$0.051x+0.482$	0.46^{ns}
K_2SO_4		
K^+ conc. in leaves vs. SO^{2-}_4-S conc. in leaves	$1.115x^2-5.95x+8.714$	0.81**
K^+ conc. in stems vs. SO^{2-}_4-S conc. in stems	$0.027x^2-0.066x+0.079$	0.92**
K^+ conc. in burs vs. SO^{2-}_4-S conc. in burs	$0.039x^2-0.085x+0.175$	0.97**
K^+ conc. in seed vs. SO^{2-}_4-S conc. in seed	$0.442x^2-1.243x+1.022$	0.92**
K^+ conc. in lint vs. SO^{2-}_4-S conc. in lint	$-0.376x^2+1.125x-0.729$	0.84**

ns = non-significant at the 0.05 level. ** = significant at the 0.01 level.

content is extremely low in deficient plants and increases markedly when the sulphate supply is sufficient for optimal growth.

Experimental

A field experiment was conducted at Central Cotton Research Institute, Multan, Pakistan. Soil samples were collected prior to imposition of fertili-zer treatments and planting. Analyses of soil samples were carried out as per [26]. Soil characteristics were as follows: pH, 8.3; $CaCO_3$ equiv., 4.8 %; organic mater, 0.67 %, $NaHCO_3$ P = 7.2 mg kg^{-1}; NH_4 OAcK, 90 mg kg^{-1} soil. The soil is moderately calcareous, weakly structured and developed in an arid sub-tropical continental climate in a sub-recent flood plain. The soil is alluvial having mixed mineralogy, smectite and mica being dominant clay minerals followed by kaolinite and chlorite at various stages of weathering. The soil belongs to Miani soil series and is classified as Calearic Cambisols [27] and fine silty, mixed hyperthermic Fluventic Haplocambids [28].

Four cotton cultivars i.e. CIM-448, CIM-1100, Karishma and S-12 were fertilized with four K doses, 0, 62.5, 125.0, 250.0 kg K ha^{-1} as two K fertilizer sources i.e., sulphate of potash (K_2SO_4) and muriate of potash (KCl). The design of the experiment was split plot (main plots: cultivars, sub-plots: K-rates, sub-plots: K sources) having four replications. Uniform doses of 50 kg 22 P ha^{-1} at planting and 150 kg N ha^{-1} in three splits, i.e., planting, flower, initiation and peak flowering were applied in all experimental units. *Stomp 330 E*, 2.5 L ha^{-1}, a pre-emergence herbicide, was applied at planting to control weeds. The crop was kept free from insect-pest attack through regular sprays of common pesticides. The crop received normal irrigation and standard production practices throughout the season.

At maturity *i.e.,* at 153 days after planting, the plants were harvested from within one square meter area, brought to the laboratory, and partitioned into leaves, stems, burs, seeds and lint fractions according to [25. The plant parts were analyzed for N, P, K, Ca, Mg and Na [24] and Cl and SO_4-S [29-30]. Data were analyzed statistically as suggested by [31].

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