Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.5412

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **6 (1):** 1634-1640 (2018)

International Journal of Pure & Applied Bioscience

Research Article

OPEN ACCESS

Potassium and Sulphur Fertilization of Wheat (*Triticum aestivum* L.) in Medium Black Calcareous Soils of Saurashtra Region of Gujarat

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Received: 9.08.2017 | Revised: 16.09.2017 | Accepted: 20.09.2017

ABSTRACT

A field experiment was conducted on wheat (Triticum aestrivum L.) during Rabi 2013-14, 2014-15 and 2015-16 at Wheat Research Station, Junagadh Agricultural University, Junagadh-Gujarat. The treatments comprised six levels of potassium (0, 30, 60, 80, 60 & 80 two split (1/2 as basal& 1/2 at 30 day after sowing -DAS kg K_2O ha^{-1}) and three levels of sulphur (0,20 and 40 kg Sha^{-1}) were evaluated in Randomized Complete -Block design with four replications. Results revealed that the growth and yields attributes viz., plant height, effectively tiller/m^2, No. of spikelet/spike, grain /spike and 1000 grain weight, grain and straw yields and nutrients (N,P,K and S) uptake increased significantly with increasing levels of K and S individually years as well as in pooled. Synergistic interaction effect of potassium and sulphur on grain and straw yield was highest at 60 kg K_2O ha^{-1} and 40 kg S ha^{-1}. The magnitude of increase in grain and straw yield was 38.8 and 23.6 % due to combined application of potassium and sulphur (K_{60} S_{40}) over control, respectively. Highest net return (Rs. 56,621) and benefit : cost ratio (2.30) was recorded with the treatment combinations of K_{60} S_{40}(60 kg K_2O ha^{-1} and 40 kg S ha^{-1}).

Key words: *Potassium, Sulphur, Wheat yields, Nutrients uptake, Economic*

INTRODUCTION

Wheat is second important food crop of India after rice. Western states of India, wheat is being grown in intensive cropping systems with the crops like groundnut which also require higher amount of fertilizer nutrients. Such systems has depleted soil fertility and affected soil health adversely. Special efforts are needed to improve the soil condition by proper nutrient management. Regular use of only nitrogenous and phosphatic fertilizers caused deficiency of potassium, sulphur and some of the micro-nutrients in the soil. Potassium is the third most limiting element and is the only monovalent action essential for plant growth. Though it is not a constituent of any plant structures or components, it plays a part in many important regulatory roles in the plant.

Cite this article: Ponkia, H.P., Vekaria, L.C., Ramani, V.B., Sakrvadia, H.L., Polara, K.B. and Babaria, N. B., Potassium and Sulphur Fertilization of Wheat (*Triticum aestivum* L.) in Medium Black Calcareous Soils of Saurashtra Region of Gujarat, *Int. J. Pure App. Biosci.* **6(1):** 1634-1640 (2018). doi: http://dx.doi.org/10.18782/2320-7051.5412

It is essential nearly in all processes needed to sustain plant growth and reproduction. It is known to activate at least sixty enzymes involved in plant growth. Sulphur is now recognized as the fourth major nutrient after N,P and K. As a nutrient sulphur is a basic requirement for protein synthesis especially S-containing amino acids i.e. methionine, cystine. It is a constituent of several other biologically active compounds like vitamins lipic acid, acetyl co-enzymes A and faredoxin glutathione. Thus proper availability of potassium and sulphur in addition to N and P in soil is essential for proper growth and crop yield. The soils of Gujarat as well as in Saurashtra are deficient in Sulphur and medium to high in Potassium. Therefore, the application of chemical fertilizers becomes essential to raise the crop yield. No work has been done on the effect of potassium and sulphur on yield and quality of wheat crop in this region. Keeping this in view, the investigation was carried out to study the effect of Potassium and Sulphur on growth, yield and quality of wheat crop.

MATERIAL AND METHODS

A field experiment was conducted during three consecutive *Rabi* seasons 2013-14, 2014-15and 2015-16 at Wheat Research Station, Junagadh Agricultural University, Junagadh, Gujarat (Latitide 21^{O} 30' N, longitude 70^{0}26' E and altitude 61m). The experimental site is characterized by semi-arid climate with extreme temperature during summer (41.7^{o}C) and very low temperature during *rabi* (9.5^{o}C).The total rainfall received was 1520.3, 1271.5 and 764.4 mm in 62, 40 and 28 rainy days, respectively. The soil was clayey in texture having $pH_{2.5}$-7.8, $EC_{2.5}$ -0.42dSm^{-1}, organic carbon (4.2 g kg^{-1}), low available N (198 kgha^{-1}) ,medium available P_2O_5 (37kg ha^{-1}),available K_2O(265 kgha^{-1}) and heat soluble sulphur (15.5 mgkg^{-1}). The field trial consisting six levels of K_2O (0,40,60,80,60& 80 two split kg K_2O ha^{-1} (1/2 as basal and 1/2 at 30 days after sowing DAS) and three levels of sulphur (0,20 and 40 kg S ha^{-1})was a factorial experiment laid out in Randomized Complete-Block design with four replication. The recommendation dose of 120 kg N and 60 kg P_2O_5ha^{-1}was applied through urea and diammonium phosphate, respectively, to all treatments plots at time of sowing. Half of the N and full of P_2O_5 were applied as basal dressing at sowing and while remaining half N was top dressed at the time of first irrigation at the crown-root initiation stage of crop. Potassium and sulphure were applied through muriate of potassium and gypsum, respectively, as per treatments. Wheat 'GW-366' was sown in rows, 20 cm apart using 100 kg seeds ha^{-1} in third week of November during all three years. Other agronomical management practices were followed as per the standard recommendation. The crop was harvested at maturity and grain and straw yields were recorded. Grain and straw samples were digested with di-acid mixture of HNO_3 and $HClO_4$ in 3:1 ratio. Nitrogen in grain and straw was determined by modified micro Kjeldahl method[3]. Phosphorus in digest was determined by vanadomplybdo phosphoric acid yellow colour method[3], K by flame photometer, Sulphur by turbidimertic method[2]. The treatment wise soil samples was also collected and analyzed for available N,P_2O_5,K_2O and Sulphur using standard method outline given by Jeckson[3]. The nutrients removal by crop was calculated by multiplying the concentration values. The economics of wheat production was worked out on the basis of prevailing market prices of different input and final produce. Data were statistically analyzed following standard method.

RESULTS AND DISCUSSION

Effect of Potassium on Growth, Yields and yields attributes

The application of potassium significantly increased grain and straw yield of wheat in individual years as well as in pooled results (Table1). Application of 80 kg K_2O ha^{-1} (in two split) produced significantly higher grain yield (5680, 4814,3969 and 4821 kg ha^{-1}) and straw yield (6902, 6279,4884 and 6022 kg ha^{-1}) in year 2013-14, 2014-15,2015-16 and in

pooled results, respectively and this treatment was statistically at par with 60 kg K_2O ha^{-1} either as base or two split(1/2 as basal and 1/2 at 30DAS).The mean grain yield of wheat increase by 11.0 ,16.2,and 18.9% owing to 30,60and 80 kgK_2Oha^{-1},respectively, over control. The corresponding increases in straw yield were 11.2,16.5 and 16.9 %, respectively, over control. As potassium is essential for grain development, the favorable effect of high dose of K on growth and yield attributes of wheat was mainly responsible for higher grain and straw yields. The results confirm the finding of Singh *et al*.[7] and Kumar *et al*[4]. All the growth and yield attributing characters were affected significantly by different levels of potassium (Table 2). Significantly higher plant height, effectively tiller/m^2, No. of spikelet/spike, grain /spike and 1000grain wt. were recorded at 80kg K_2O ha^{-1}(Two split), followed by 60 kgK_2O ha^{-1}.However, the higher levels of potassium (60and 80 kg $K_2Oha^{-1)}$were statistically at par in respect of growth and yield attributes. Potassium play a crucial role in meristematic growth through its effect on the synthesis of photo-hormones. Among various plant hormones, cytokinin plays important role in growth of tillers and bud[7]. Beneficial effect of K on growth and yields attributes have been reported by Jat *et al*[5].

Effect of Potassium on Nutrients uptake

The mean data of three years (Table 3) indicated that N,P,K and S uptake by grain and straw of wheat differed significantly due to varying levels of potassium. The maximum uptake of N, P, K and S by grain and straw were recorded with 80 kgK_2Oha^{-1}(Two splite) and was statistically at par with 60 kg K_2O ha^{-1} either basal or split (1/2 at basal and 1/2 at 30DAS).The application of $80kgK_2oha^{-1}$ recorded highest uptake of nutrients and registered 24.4,27.4,40.5,and 22.8 %higher N,P,K and S by grain and 24.4,27.4,40.4 and 22.8 % higher N,P,K and S uptake by straw of wheat, respectively, over control. The uptake of nutrients increase with higher levels of potassium might be due to increase in nutrient contents in grain and straw owing to increased availability of nutrients to the crop as a result of improved soil fertility with higher rates of K application may also be responsible for higher uptake of nutrients at increased rates of K application. The results are in conformity with the finding of *Singh et al*.[7] and Abedin *et al*[1].

Effect of sulphur on Growth, Yields and yields attributes

The application of sulphur significantly increased grain and straw yield of wheat in individual years as well as in pooled results (Table 1).With successive increasing sulphur levels, grain and straw yield of wheat increase significantly up to 20kg S ha^{-1} and further increase in sulphur level did not significantly enhanced the yield over $20kgSha^{-1}$in all three year and in pooled. However, the highest grain and straw yield of wheat were recorded with 40kg S ha^{-1}, which was registered12.4 and 11.3 % higher grain and straw yield over control. However, increase in yield was statistically non-significant at higher level (40kg S ha^{-1}) of Sulphur over 20 kg S ha^{-1}.The increase in yield owing to application of sulphur may be ascribed to improved growth and yield attributes and yield is directly related to these attributes. Increase in yield with application of sulphur is quite obvious, as the soil under study was marginal in available sulphure (15.5 mg ka^{-1}). This might be ascribed adequate supply of sulphur that resulted in higher production of photosynthetic and their translocation to sink, which ultimately increased the wheat yield .These results corroborate with the findings of Singh *et al*.[7] and Verma *et al*.[8]. The growth and yield attributes *viz.*, plant height, effectively tiller/m^2, No. of pikelet/spike, grain /spike and 1000 grain wt. were significantly affected by sulphur application (Table2). The significantly maximum plant height (80.4 cm), length of spike (7.2 cm), effectively tiller/m^2 (299), No. of pikelet/spike (14.9) , grain /spike(34.0) and 1000 grain wt. (51.0 g.) were recorded with 40 $kgSha^{-1}$ and this treatment was at par with 20 kg S ha^{-1} in all the cases. Increase in growth and yield attributes due to sulphur application might be due to the reason that the functions of sulphur with in plants are closely related to

those of nitrogen and the two nutrients are synergistic. It support the findings of Singh *et al*[7].

Effect of sulphur on Nutrients uptake:

The mean data of three years (Table 3) indicated that N, P, K and S uptake by grain and straw of wheat were differed significantly due to varying levels of Sulphur in all the three years, as well as in pooled. The maximum uptake of N,P,K and S by grain and straw were recorded with 40 kg S $ha^{-1}$and was statistically at par with 20 kg S ha^{-1}.The application of 40 kg S ha^{-1} recorded highest uptake of nutrients and registered14.1,14. 0,15.0 and 28.7 % higher N,P,K and S by grain and 16.5,14.3,15.7 and 41.1 % higher N,P,K and S by straw of wheat, respectively, over control. Such values of nutrients uptake by wheat crop might be attributed to grain and straw yield of wheat which were also recorded highest under application of 40 kg S ha^{-1}. Besides, increase in nutrient contents in grain and straw owing to increased availability of nutrients to the crop as a result of improved soil fertility with higher rates of S application may also be responsible for higher uptake of nutrients at increased rates of S application. The results are in close conformity with the findings of Singh *et al.*[7] and Muthu *et al*[6].

Interaction effect of K x S on yields on wheat yield

With increasing level of both potassium and sulphur, grain and straw yield of wheat were increased significantly (Table 4). The percent increase in grain yield due to potassium and sulphur varied from 11.0 to 18.6 % and 10.0 to 12.3%, respectively, whereas the straw yield was increased from 11.2 to 16.9% and 9.2 to 11.3%, respectively. The magnitude of response was more in case of potassium as compared to sulphur. Synergistic effect of potassium and sulphur interaction on grain and straw yield was highest at 60 kg K_2O ha^{-1} and 40 kg S ha^{-1}. The magnitude of increase in grain and straw yield was 38.0 and 36.6% due to combined application of potassium and sulphur (60 kg K_2O ha^{-1} and40 kg S ha^{-1}) over control, respectively. However, it was remain at par with all the treatment combinations, except K_0S_0, K_0S_{20}, K_0S_{40}, $K_{40}S_0$ and $K_{60}S_0$.The synergistic effect of K and S may be due to utilization of large quantities of nutrients by crop which might have resulted in better plant development and ultimately yield in medium K and S status in the experimental soil. These results confirm the earlier findings of Muthu *et al.*[6] Similar results were also reported by Singh *et al*[7].

Effect of Potassium and sulphur on soil available nutrients:

The soil available N and $P_2O_5$was not significantly affected by potassium and sulphur application, respectively (Table 6). While, application of potassium and sulphur significantly increased its availability in soil after harvest of wheat crop. Significantly higher available potassium (309 kg ha^{-1}) and sulphur (23.0 mg kg^{-1}) were observed with 80 kg K_2O ha^{-1} (in two split) and 40 kg S ha^{-1}, respectively and this treatment was at par with 60 kg K_2O ha^{-1} either as basal or two split (1/2 as basal and 1/2 at 30 DAS) and S_{20}, respectively.

Economies:

The cost of cultivation varied according to different levels of potassium and sulphur (Table5). Highest the cost of cultivation (Rs.43, 933) was with treatments $K_{80}S_{40}$ (80 kg K_2O ha^{-1} and 40 kg S ha^{-1}), because of higher cost of input like murate of potash and gypsum. Highest net return (Rs. 47,148) and benefit :cost ratio(2.10) was recorded with the treatment K_{60} S_{40}(60 kg K_2O ha^{-1} and 40 kg S ha^{-1}) ,follow by net return(Rs. 42,590) and benefit :cost ratio(2.01) with treatment $K_{40}S_{40}$(40 kg K_2O ha^{-1} and 40 kg S ha^{-1}).The application of 60 kg K_2O ha^{-1} and 40 kg S ha^{-1} to the wheat crop gave higher return per rupee invested than other treatment. This means for obtaining higher quantity of inorganic fertilizers required in higher investment but ultimately gave the higher return

Table 1: Effect of potassium and sulphur levels on grain and straw yield of wheat

Treatments	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	2013-14	2014-15	2015-16	Mean	2013-14	2014-15	2015-16	Mean
Potassium levels								
K_0	4751	4026	3359	4045	5848	5186	4168	5067
K_{30}	5286	4481	3705	4491	6406	5872	4633	5637
K_{60}	5539	4695	3869	4701	6764	6170	4768	5901
K_{80}	5650	4789	3981	4811	6848	6071	4848	5922
K_{60} Split	5654	4792	3995	4809	6891	6093	5066	6016
K_{80} Split	5680	4814	3969	4821	6902	6279	4884	6022
S.Em.±	136	106	105	67	168	184	124	93
C.D. at 5 %	391	305	302	189	484	528	528	260
Sulphur levels								
S_0	5041	4272	3564	4292	6125	5581	4464	5390
S_{20}	5557	4710	3906	4724	6784	6037	4859	5893
S_{40}	5683	4816	3969	4823	6921	6218	4861	6000
S.Em.±	96	75	74	48	119	130	88	66
C.D. at 5 %	276	215	214	134	342	373	252	184

Table 2: Effect of potassium and sulphur levels on growth and yield attributing characters of wheat (Mean data of three year)

Treatments	Plant height (cm)	Length of spike (cm)	Effective tiller/m^2	No. of spikelet/spike	Grain/ spike	1000 Grain weight (g)
Potassium Levels						
K_0	73.5	6.7	263	12.8	31.9	47.0
K_{40}	77.1	6.9	287	13.4	32.5	49.6
K_{60}	79.8	7.0	293	14.7	33.8	50.3
K_{80}	81.1	7.1	294	14.3	34.5	50.8
K_{60} - Split	80.4	7.1	291	14.4	34.8	51.0
K_{80} -Split	81.9	7.3	310	14.7	35.0	50.3
S.Em.±	0.9	0.1	4	0.2	0.2	0.4
C.D. at 5 %	2.4	0.3	11	0.5	0.5	1.0
Sulphure Levels						
S_0	77.1	6.9	281	13.0	33.3	48.7
S_{20}	79.4	7.0	289	14.2	33.9	49.8
S_{40}	80.4	7.2	299	14.9	34.0	51.0
S.Em.±	0.6	0.1	3	0.1	0.1	0.3
C.D. at 5 %	2.4	0.3	8	0.3	0.5	1.1

Table 3: Effect of potassium and sulphur levels on nutrients uptake by grain and straw of wheat (Mean data of three year)

Treatments	Grain (kg ha^{-1})				Straw (kg ha^{-1})			
	N	P	K	S	N	P	K	S
Potassium Levels								
K_0	97	15.2	26.6	9.2	29.8	5.1	11.1	13.6
K_{40}	105	17.1	31.2	10.4	33.7	5.8	13.1	15.5
K_{60}	108	18.1	34.7	11.2	35.3	6.3	14.4	16.5
K_{80}	112	18.6	37.5	11.7	35.5	6.2	15.4	16.5
K_{60} Split	111	18.6	35.3	11.4	36.1	6.1	14.7	16.3
K_{80} Split	112	18.9	37.5	11.8	37.1	6.5	15.6	16.7
S.Em.±	3	0.4	0.9	0.3	1.0	0.2	0.4	0.5
C.D. at 5 %	**8**	**1.2**	**2.7**	**0.8**	**2.8**	**0.5**	**1.1**	**1.3**
Sulphure Levels								
S_0	99	16.4	30.6	9.4	31.5	5.6	12.8	12.9
S_{20}	110	18.2	35.1	11.4	35.5	6.1	14.6	16.4
S_{40}	113	18.7	35.2	12.1	36.7	6.4	14.7	18.2
S.Em.±	2	0.3	0.7	0.2	0.7	0.1	0.3	0.3
C.D. at 5 %	**6**	**1.2**	**1.9**	**0.8**	**2.0**	**0.5**	**0.8**	**1.3**

Table 4: Interaction effect of potassium and zinc on grain and straw yield of wheat (Mean data of three year)

Treatments	Grain Yield (kg ha^{-1})			Straw Yield (kg ha^{-1})		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
K_0	3845	3918	4373	4823	4947	5432
K_{40}	3922	4553	4997	5100	5567	6243
K_{60}	4005	4794	5305	5108	6007	6588
K_{80}	4689	5005	4726	5816	6148	5802
K_{60} Split	4632	5015	4726	5708	6301	6041
K_{80} Split	4662	5061	4794	5784	6389	5892
		K x S			**K x S**	
S.Em.±		330			390	
C.D. at 5 %		**932**			**1102**	

Table 5: Interaction effect of potassium and zincon economic of wheat crop (Mean data of three years)

Treatment combinations	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross realization (Rs/ha)	Cost of cultivation (Rs/ha)	Net realization (Rs/ha)	B:C ratio
K_0S_0	3845	4823	65399	41000	24399	1.60
K_0S_{20}	3918	4947	66702	41090	25612	1.62
K_0S_{40}	4373	5432	74276	41181	33095	1.80
$K_{40}S_0$	3922	5100	67066	42176	24890	1.59
$K_{40}S_{20}$	4553	5567	77149	42266	34883	1.83
$K_{40}S_{40}$	4997	6243	84946	42357	42590	2.01
$K_{60}S_0$	4005	5108	68286	42764	25522	1.60
$K_{60}S_{20}$	4794	6007	81528	42854	38674	1.90
$K_{60}S_{40}$	5305	6588	90093	42945	47148	2.10
$K_{80}S_0$	4689	5816	79621	43352	36269	1.84
$K_{80}S_{20}$	5005	6148	84865	43442	41423	1.95
$K_{80}S_{40}$	4726	5802	80130	43533	36597	1.84
$K_{60}S_0$ Split	4632	5708	78576	43164	35412	1.82
$K_{60}S_{20}$ Split	5015	6301	85313	43254	42059	1.97
$K_{60}S_{40}$ Split	4794	6041	81598	43345	38253	1.88
$K_{80}S_0$ Split	4662	5784	79173	43752	35421	1.81
$K_{80}S_{20}$ Split	5061	6389	86164	43842	42322	1.97
$K_{80}S_{40}$ Split	4740	5892	80522	43933	36589	1.83

Price consider: Wheat grain :Rs.1450/q.,Straw : Rs 200/q, MOP :Rs.1764/q, Gypsum: Rs 84/q.

Table 6: Effect of potassium and sulphur on available nutrients in soil after harvest of wheat

Treatments	Soil available nutrients(kg ha^{-1})			S (ppm)
	N	P	K	
Potassium levels				
K_0	186	33	265	17.6
K_{40}	192	33	277	18.1
K_{60}	189	32	296	19.2
K_{80}	183	33	304	18.3
K_{60} Split	189	30	297	18.9
K_{80} Split	188	32	309	18.7
S.Em.±	3	1	6	0.5
C.D. at 5 %	**NS**	**NS**	**16**	**NS**
Sulphur Levels				
S_0	188	32	292	14.2
S_{20}	187	31	291	18.2
S_{40}	188	32	291	**23.0**
S.Em.±	2	1	4	0.3
C.D. at 5 %	**NS**	**NS**	**NS**	**1.3**

CONCLUSION

It may be concluded that, in medium black calcareous soils medium in available potassium and sulphur, potassium and sulphur fertilization are required to harvest optimum crop yield, nutrient uptake and economic output. Application of 60 kg K_2O ha^{-1}along with 40 kg S ha^{-1} was found best treatment combinations for maintaining higher wheat yield, net returns in clayey soil of Saurashtra Region of Gujarat.

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