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EFFECT OF PHOSPHORUS AND SULPHUR APPLICATION ON SOIL NUTRIENT BALANCE UNDER CHICKPEA (*CICER ARIETINUM*) MONOCROPPING

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ABSTRACT

Soil nutrient mining is major threat to modern agriculture as soil fertility is continuously depleting as a result of cultivation of high yielding varieties. Field experiments were conducted at two locations for two years to study the effect of different levels of phosphorus and sulphur application on dry matter yield, soil nutrient balance and soil fertility status under chickpea (*Cicer arietinum*) monocropping. The treatments included three levels of phosphorus (0, 17 and 34 kg P ha^{-1}) and three levels of sulphur (0, 15 and 30 kg ha^{-1}) from two sulphur sources (gypsum and ammonium sulphate). Phosphorus and sulphur application resulted in increase in dry matter yield up to 27 and 10%, respectively. Inorganic nutrient application resulted in increase of nitrogen deficit in soil at the end of two year experiment. Soil phosphorus and sulphur balance at the end of experiment was positive in all the treatments, except control. Higher level of nutrient (34 kg P and 30 kg S ha^{-1}) should be applied to chickpea in order to maintain soil fertility status and to get crop yield on sustainable basis.

Key words: Nitrogen derived from atmosphere, gypsum, ammonium sulphate, soil fertility.

INTRODUCTION

Chickpea is the most important pulse crop of rainfed region of Pakistan. It is grown on an area of about 1 million hectare. Crop is grown on residual moisture of monsoon rainfall, as soil is kept fallow during summer season and ploughed at regular intervals in order to conserve moisture. Fertilizer use rate in rainfed area is below 30 kg ha^{-1} per annum. This fertilizer is mostly used for wheat and use of fertilizer for chickpea production is almost negligible (NFDC, 2011). Owing to this and many other agronomic and climatic factors, chickpea seed yield in Pakistan is almost 30% of that achieved in developed countries of the world (FAO, 2009).

Nutrients are mainly added in soil through mineral fertilizers, organic manures, biological nitrogen fixation and atmospheric deposition and by sedimentation in case of irrigated agriculture. Nutrient balance studies conducted at national level in Pakistan have shown that soil nutrient balance is becoming more negative with the passage of time (FAO, 1998). Situation seems to be more alarming for chickpea based mono cropping system as nutrient addition through organic and inorganic sources is negligible and crop residues are not returned to soil. Moreover, phosphorus (P) and sulphur (S) requirement of chickpea is much higher than that of cereal crops. Several studies conducted in India estimated that for chickpea seed yield of 1.5 Mg ha^{-1}, average amount of N, P and S absorbed by plant from soil is 91, 6 and 13 kg (Tandon, 2011).

In Pakistan, very little research work has been done regarding soil nutrient balance assessment (FAO, 1998). Information regarding a specific cropping sequence at micro level (plot or farm level) is lacking and information regarding effect of P and S application on nutrient budget and fertility status of soils under chickpea monocropping is very scarce. Therefore, the present study

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was conducted to assess the effect of P and S application on chickpea dry matter yield, soil nutrient balance and fertility status of soil.

MATERIAL AND METHODS

The details of the two year field experiments conducted using chickpea cultivar Balkassar 2000 at Barani Agricultural Research Institute (BARI), Chakwal and on farmer field Talagang during crop growing season 2006-2007 and 2007-2008 are described elsewhere (Islam et al., 2012). Physical and chemical properties of the experimental site are shown in table 1. The trial was laid out in randomised complete block design with split plot arrangement (plot size of 1.5 × 3.5 m) keeping P in main plots S sources in sub plots and S levels in sub subplots. There were eighteen treatments having different combinations of P (0, 40, 80 kg ha^{-1}) and S rates (0, 15, 30 kg ha^{-1}) from two S sources (gypsum and ammonium sulphate). Starter dose (26 kg ha^{-1}) of N was applied in the form of urea. However in S treatments, urea dose was adjusted accordingly, after taking into consideration the addition of N from ammonium sulphate (AS). Phosphorus was applied in the form of triple super phosphate. All the treatments were replicated three times. Chickpea crop was sown maintaining row to row distance of 30 cm. There were approximately 25 to 30 plants in an area of one square meter. All the fertilizers were applied as basal dose. Crop was grown under rainfed conditions and no supplemental irrigation was applied. There was no incidence of pest or disease attack so no chemical was sprayed. However, there was occurrence of frost especially at Chakwal during January 2008, which adversely affected crop growth. There were 12 to 20 nodules per plant as indicated by plant sampling prior to flowering. Rainfall data for both locations were recorded. Harvesting was done during last week of April. Samples of plant dry matter tissue of legume and non legume reference plant were taken for $\delta^{15}N$ determination at start of flowering (Unkovich et al., 2008).

Table 1. Location, rainfall and physical and chemical properties of the soils at experimental sites

Parameter	Unit	Chakwal	Talagang
Elevation	m	511	624
Latitude	N	32.5°	32.5°
Longitude	E	72.4°	72.2°
Mean annual rainfall (1979-2009)	mm	630	450
Cropping season (October to March) rainfall during (i) 2006-2007 (ii) 2007-2008	mm	 85 90	 362 30
Sand	%	69	80.8
Silt	%	21	6.7
Clay	%	10	12.5
Texture	-	Sandy loam	Loamy sand
pH	-	7.6	7.7
ECe	dSm^{-1}	0.32	0.26
Total organic carbon	mg g^{-1}	3.7	1.8
$CaCO_3$	%	5.2	2.9
Total N	%	0.02	0.01
NO_3-N (AB-DTPA extractable)	µg g^{-1}	11.2	5.6
Phosphorus (AB-DTPA extractable)	µg g^{-1}	3	1.4
Sulphate- Sulphur ($CaCl_2$ extractable)	µg g^{-1}	6.4	7.5
Zinc (AB-DTPA extractable)	µg g^{-1}	0.75	1.3
Copper (AB-DTPA extractable)	µg g^{-1}	1.21	0.92
Iron (AB-DTPA extractable)	µg g^{-1}	7.82	5.63
Manganese (AB-DTPA extractable)	µg g^{-1}	2.98	2.1

Percent nitrogen derived from air was estimated by: (% N_{dfa}) = 100 × (δ^{15}N (soil N) - δ^{15}N legume N)/(δ^{15}N (soil N)-B), where δ^{15}N (soil N) is commonly obtained from a non N fixing reference plant grown in the same soil as the legume; B is the δ^{15}N of the same N fixing plant when fully dependent on N fixation and its value is -2.0 (Kyei-Boahen et al., 2002).

Legume N uptake and Amount of N fixed were estimated by:

Legume N uptake (kg ha^{-1}) = legume dry matter yield (kg ha^{-1}) × N in plant tissue (%);

Amount of N fixed (kg ha^{-1}) = legume N uptake (kg ha^{-1}) × % N_{dfa}.

At physiological maturity, crop from an area of one meter square in the middle of each plot was harvested separately. The plant samples were dried and data were recorded for seed, straw and dry matter yield. Representative samples of 100 g from both seed and straw were collected from bulk sample, oven dried, ground and analysed for N and P (Ryan et al., 2001) and S (Verma, 1977). Nutrient uptake was determined by multiplying the respective nutrient concentration with dry matter yield. Soil N balance after chickpea production was obtained by subtracting N output from N input as follows (Amanuel et al., 2000):

$B = (N_f + N_{dfa}) - N_g$

where: B is soil N balance, N_f is the applied N, N_{dfa} is the total fixed N and N_g is the N removed by chickpea.

Phosphorus and sulphur balance in soil was determined by taking into account the input and out put of these nutrients (Liu et al., 2003). Soil samples were taken after crop harvest from upper soil layer (0-15 cm) and were analysed for extractable P (Ryan et al., 2001) and S (Verma, 1977). Data on all observations were subjected to analysis of variance (ANOVA) by using software MSTATC. Treatment means were compared by least significant difference (LSD) test.

RESULTS AND DISCUSSION

Dry matter yield

The precipitation during crop growing season (October to March) at experimental sites (Chakwal and Talagang) was 385 and 362 mm during first crop growing season (2006-2007) and 90 and 30 mm during second crop growing season (2007-2008), respectively. The long term average (1977-2009) annual precipitation is 630 mm for Chakwal and 450 mm for Talagang. Two third of total rainfall occurs in moon soon season (July to September).

There was significant difference between years and locations in respect of dry matter yield (Table 2). The highest dry matter yield was recorded at Talagang during first year which was followed by Chakwal during same year. Dry matter yield was higher at Talagang as compared to Chakwal. This was due to difference in climatic conditions as well as fertility status of soils of the two locations. Higher moisture availability at the time of sowing resulted in better germination and ultimately good crop stand and higher dry matter yield at Talagang. Intensity of frost was less at Talagang as compared to Chakwal, especially during second crop growing season. Another reason might be that well drained soils are suitable for the production of chickpea (Khalil and Jan, 2002). Soil at Talagang was well drained being loamy sand compared to sandy loam soil of Chakwal (Table 1).

Table 2. Effect of year and location on dry matter yield of chickpea (Mg ha^{-1})

Year	Chakwal	Talagang	Mean
2006-2007(Y_1)	3.82 b	4.20 a	4.01b
2007-2008 (Y_2)	2.30 d	2.60 c	2.40 a
Mean	3.06 b	3.35 a	3.20

Different letters in the same column denote significant differences among treatments ($P \leq 0.05$)

Dry matter yield was higher during first year as compared to second year. This was due to favourable climatic conditions during first year, especially timely rainfall throughout growing season. Although, there was abundant moisture supply at the time of sowing during second year, germination and crop growth was better at the start, but there was incidence of frost at flowering stage accompanied by prolonged drought, which adversely affected crop growth and yield. Total rainfall during second year from October 2007 to March 2008 was 90 mm and 30 mm at Chakwal and Talagang, respectively which was 77 and 92 percent less than first year (385 and 362 mm). Low temperatures slow down the rate of leaf extension and increase the time to reach full crop canopy cover (Hussain, 1998). Similar results were also reported by Khalid et al. (2012) and Hayat and Ali (2010). They observed that growth and yield of crop was better during cropping season of higher rainfall, due to abundant supply of moisture when crop was grown under rainfed conditions.

Table 3. Dry matter yield (Mg ha^{-1}) as function of P and S levels and S sources

Effect	Chakwal		Mean	Talagang		Mean	Overall mean
	2006-2007	2007-2008		2006-2007	2007-2008		
P levels (kg P_2O_5 ha^{-1})							
0	3.3 b	2.1 b	2.7 b	3.6 b	2.2 c	2.9 b	2.8 c
40	4.0 a	2.3 a	3.2 a	4.2 ab	2.5 b	3.4 a	3.3 b
80	4.3 a	2.4 a	3.4 a	4.8 a	2.7 a	3.8 a	3.6 a
LSD value	0.4	0.2	0.3	0.6	0.04	0.5	0.1
S sources							
Gypsum	3.8	2.3	3.0	4.1	2.5	3.3	3.2
Ammonium sulphate	3.9	2.3	3.1	4.3	2.5	3.4	3.3
LSD value	NS	NS	NS	NS	NS	NS	NS
S levels (kg S ha^{-1})							
0	3.6 b	2.2 b	2.9 b	4.0 b	2.4 c	3.2 b	3.0 b
15	3.9 a	2.3 a	3.1 a	4.3 a	2.5 b	3.4 a	3.3 a
30	4.0 a	2.4 a	3.2 a	4.3 a	2.6 a	3.5 a	3.3 a
LSD value	0.2	0.09	0.2	0.1	0.02	0.1	0.05
LSD vales for Interaction effects							
P × S sources	NS	NS	NS	NS	NS	NS	NS
P × S levels	0.3	0.1	0.1	0.2	0.03	NS	0.04
S sources × S levels	NS	NS	0.1	NS	0.03	NS	0.03
P × S sources × S levels	NS	NS	NS	NS	0.05	NS	NS

Different letters in the same column denote significant differences among treatments ($P \leq 0.05$).
The values correspond to averages of three replicates.

There was an increase up to 17 and 27% in dry matter yield with the application of 40 and 80 kg P_2O_5 ha^{-1}, respectively. Phosphorus application resulted in significant increase in dry matter yield at both locations (Table 4). Higher and lower level of P differed significantly in this respect, with dry matter yield increased from 2.8 to 3.6 Mg ha^{-1} as P application rate increased from 0 to 80 kg P_2O_5 ha^{-1} (Table 3). These results are in line with the findings of Aslam et al. (2000) who recorded 57 percent (770 kg ha^{-1}) increase in seed yield with application of 80 kg P_2O_5 ha^{-1} under rainfed conditions. However, Khan (2002) reported 75 percent increase in chickpea seed yield over control with application of 90 kg P_2O_5 ha^{-1}, which was much higher than observed in our study. Higher response might be due to irrigated condition, where response to nutrient application is generally higher than in rainfed conditions (Ahmad and Rashid, 2003).

Main effect of S was also significant on dry matter yield, with the highest yield recorded with the application of 30 kg S ha^{-1} (Table 3 and Table 4). There was an increase up to 10 % in dry matter yield with 30 kg S ha^{-1}. Dry matter yield increased from 3.0 to 3.3, as S application rate was enhanced from 0 to 30 kg S ha^{-1}. Increase in dry matter yield due to application of S confirms the finding of Sharma and Arora (2008), Gunes et al. (2009) and Islam (2012). The two S sources were similar in respect of dry matter yield at both the locations (Table 4). Similar to these findings, Khalid et al. (2012) did not record any difference between gypsum and AS in respect to dry matter yield of *Brassica napus.* However both the sources differed regarding S availability and AS was found to be superior where immediate relief from S deficiency is required (Gosh et al., 2000).

Table 4. Probability values of main and interaction effect of P and S using analysis of variance in respect of dry matter yield

Effect	Chakwal		Mean	Talagang		Mean	Overall Mean
	2006-2007	2007-2008		2006-2007	2007-2008		
P levels	≤ 0.01	≤ 0.01	≤ 0.01	0.02	≤ 0.01	≤ 0.01	≤ 0.01
S sources	NS	NS	NS	NS	NS	NS	NS
S levels	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
Interaction effects							
P × S sources	NS	NS	NS	NS	NS	NS	NS
P × S levels	0.01	NS	0.01	0.01	≤ 0.01	NS	≤ 0.01
S sources × S levels	0.08^{NS}	≤ 0.01	0.04	NS	≤ 0.01	NS	≤ 0.01
P × S sources × S levels	NS	NS	NS	NS	≤ 0.01	NS	NS

NS stands for non significant difference.

Soil nitrogen balance

Phosphorus application resulted in decline in soil N balance from 4 to -10 kg ha^{-1} at Chakwal and from -6 to -26 kg ha^{-1} at Talagang (Table 5 and Table 6). This was mainly due to increase in N removal by plants as a result of increase in dry matter yield. Although there was increase in amount of N fixed, yet it could not match plant N uptake, resulting in increase in N deficit in soil with P application. These results are in line with the findings of Ma et al. (2010) who observed that application of P along with N resulted in higher dry matter yield of maize, especially in years of normal rainfall. Thus, application of P resulted in negative soil N balance, though 150 kg N ha^{-1} was applied. Another reason for the negative soil N balance in our study was that the addition of N from rhizodeposition and roots, which are major source of N addition from leguminous crops in agro ecosystems (Wichern et al., 2008), was not taken in to account. Soil N balance was more negative (-26 kg ha^{-1}) at Talagang as compared to Chakwal (-10 kg ha^{-1}). This was mainly due to increased dry matter yield and higher N removal from soil at Talagang as compared to Chakwal. It was also observed that combined application of P and S resulted in more negative soil N balance as compared to their sole application (Table 5 and Table 6). This might also be due to increase in dry matter yield and nutrient uptake, as a result of balanced amount of inorganic nutrients.

Soil phosphorus balance

Soil P balance was positive in all the treatments, except control or plots receiving sole S, at both locations (Table 7). This indicates that the amount of P added through inorganic fertilizers was much higher than crop demand. Without P application, there was P deficit up to -9.3 kg ha^{-1} at Chakwal, and up to -7.3 kg ha^{-1} at Talagang. These results are in agreement with the findings of Sharma and Prasad (2009). They observed negative soil P balance of 21.8 in control treatment in a three year study using mungbean as test crop under irrigated conditions. Similar to our findings, Rafique et al. (2012) conducted a five year experiment on a similar type of soil, in cotton-wheat crop rotation and they observed that soil P balance was positive even when 26 kg P ha^{-1} was applied to wheat only, and cotton was grown on residual P. Smaller soil P depletion in our study was mainly due to rainfed conditions, where crop is under drought stress and less dry matter is produced (Khan and Joergensen, 2006). Soil was kept fallow during summer, which resulted in restoration of soil fertility to some extent, as compared to continuous cultivation (Ijaz and Ali, 2011).

Table 5. Balance sheet of N (kg/ha) for 2 years of chickpea cultivation as influenced by rates of phosphorus and sulphur application at Chakwal

Treatments	Nitrogen applied (kg N ha^{-1})	Amount of N fixed (kg P ha^{-1})	Nitrogen removed (kg P ha^{-1})	Nitrogen balance (kg P ha^{-1})
	(A)	(B)	(C)	(D= (A+B) – C)
P levels (kg P_2O_5 ha^{-1})				
0	52	54	102	4
40	52	65	124	-7
80	52	69	131	-10
S levels (kg S ha^{-1})				
0	52	56	110	-2
15	52	64	121	-5
30	52	68	126	-6
P × S levels				
P_0S_0	52	49	95	6
P_0S_{15}	52	54	102	4
P_0S_{30}	52	59	108	2
$P_{40}S_0$	52	57	112	-3
$P_{40}S_{15}$	52	67	126	-7
$P_{40}S_{30}$	52	72	134	-10
$P_{80}S_0$	52	62	122	-8
$P_{80}S_{15}$	52	72	135	-11
$P_{80}S_{30}$	52	74	136	-10

Table 6. Balance sheet of N (kg ha^{-1}) for 2 years of chickpea cultivation, as influenced by rates of phosphorus and sulphur application at Talagang

Treatments	Nitrogen applied (kg N ha^{-1})	Amount of N fixed (kg P ha^{-1})	Nitrogen removed (kg P ha^{-1})	Nitrogen balance (kg P ha^{-1})
	(A)	(B)	(C)	(D= (A+B) - C
P levels (kg P_2O_5 ha^{-1})				
0	52	59	117	-6
40	52	70	138.2	-16
80	52	81	159	-26
S levels (kg S ha^{-1})				
0	52	62	127	-13
15	52	71	139	-16
30	52	78	149	-19
P × S levels				
P_0S_0	52	53	109	-3
P_0S_{15}	52	59	116	-5
P_0S_{30}	52	66	126	-8
$P_{40}S_0$	52	62	127	-13
$P_{40}S_{15}$	52	71	138	-16
$P_{40}S_{30}$	52	78	150	-20
$P_{80}S_0$	52	72	146	-22
$P_{80}S_{15}$	52	84	162	-26
$P_{80}S_{30}$	52	88	169	-29

Table 7. Balance sheet of P (kg ha^{-1}) for 2 years of chickpea cultivation, as influenced by rates of phosphorus and sulphur application

Treatments	Phosphorus applied (kg P ha^{-1})	Phosphorus removed (kg P ha^{-1})		Phosphorus balance (kg P ha^{-1})	
	(A)	(B)		(C=A-B)	
		Chakwal	Talagang	Chakwal	Talagang
P levels (kg P_2O_5 ha^{-1})					
0	0	8.60	6.83	-8.60	-6.83
40	34.4	10.46	9.63	23.94	24.77
80	68.8	11.30	11.44	57.50	57.36
P × S levels					
P_0S_0	0	7.88	6.22	-7.88	-6.22
P_0S_{15}	0	8.56	6.97	-8.56	-6.97
P_0S_{30}	0	9.34	7.32	-9.34	-7.32
$P_{40}S_0$	34.4	9.48	8.84	24.92	25.56
$P_{40}S_{15}$	34.4	10.60	9.63	23.80	24.77
$P_{40}S_{30}$	34.4	11.30	10.40	23.10	24.00
$P_{80}S_0$	68.8	10.36	10.40	58.44	58.40
$P_{80}S_{15}$	68.8	11.94	11.71	56.86	57.09
$P_{80}S_{30}$	68.8	11.62	12.19	57.18	56.61

Soil sulphur balance

Soil S balance was negative in treatments without S application, at both the locations (Table 8). However, it was more negative at Talagang as compared to Chakwal due to higher dry matter yield. Results regarding the effect of S application on soil S balance have not been reported previously.

Table 8. Balance sheet of S (kg ha$^{-1)}$ for 2 years of chickpea cultivation as influenced by rates of phosphorus and sulphur application

Treatments	Sulphur applied (kg S ha^{-1})	Sulphur removed (kg S ha^{-1})		Sulphur balance (kg S ha^{-1})	
	(A)	(B)		(C=A-B)	
		Chakwal	Talagang	Chakwal	Talagang
S levels (kg S ha^{-1})					
0	0	10.49	12.44	-10.49	-12.44
15	30.0	11.98	14.82	18.02	15.18
30	60.0	12.73	15.61	47.27	44.39
P × S levels					
P_0S_0	0	8.87	10.46	-8.9	-10.5
P_0S_{15}	30	9.48	11.68	20.5	18.3
P_0S_{30}	60	10.15	12.81	49.9	47.2
$P_{40}S_0$	0	10.72	12.53	-10.7	-12.5
$P_{40}S_{15}$	30	12.45	14.90	17.6	15.1
$P_{40}S_{30}$	60	13.81	16.47	46.2	43.5
$P_{80}S_0$	0	11.88	14.34	-11.9	-14.3
$P_{80}S_{15}$	30	13.95	17.87	16.1	12.1
$P_{80}S_{30}$	60	14.21	17.55	45.8	42.5

Soil fertility status after crop harvest

Application of P resulted in significant increase in soil available P, as compared to control, at both locations (Table 9 and Table 10). Available soil P increased from 4.46 to 6.24 kg ha^{-1} at Chakwal and from 2.24 to 3.36 kg ha^{-1} at Talagang with application of 34 kg P ha^{-1}, as compared with control. These results are in agreement with the findings of

Sharma and Prasad (2009), who observed increase in available P from 14.2 to 18.5 with application of 35 kg P ha^{-1} in a three year experiment, using mungbean *(Vigna radiata)* as test crop.

Increase in soil P was much less in our study which might be due to difference between the extracting agent used for soil P estimation. Analysis of soil samples taken after crop harvest at the end of two year experiments indicated that soil available P declined in treatments without P, with 17 kg P ha^{-1} at Chakwal when compared with soil P status at start of experiment (Table 10).

Effect of S application on available P in soil was not significant at both locations (Table 9 and Table 10). Similar results were reported by Rao (2003) who observed no significant effect of gypsum application (250 kg ha^{-1}) on soil P content after harvest of mustard (*Brassica juncea*) crop. However in some studies, S application has been found to improve soil P availability status by reducing the pH of alkaline soils, thus increasing availability of P (Taalab et al., 2008; Hussain and Thomas, 2010). In a two year research study using red loam soil in Mewar, India, application of 2 tonnes of gypsum per hectare improved the availability of all macro and micronutrients after mustard harvest (Akbari et al., 2003).

Table 9. Effect of rates of phosphorus and sulphur on available P and S content and net change over initial value after 2 years of study at Chakwal

Treatments	Available P (kg/ha)	Net change over initial value of 6 kg ha^{-1}	Available S (kg/ha)	Net change over initial value of 12.8 kg ha^{-1}
P levels (kg P_2O_5 ha^{-1})				
0	4.46	-1.54	12.06	-0.74
40	5.32	-0.68	11.88	-0.92
80	6.24	0.24	11.62	-1.18
LSD value	0.5*		NS	
S levels (kg S ha^{-1})				
0	5.54	-0.46	9.72	-3.08
15	5.34	-0.66	12.58	-0.22
30	5.14	-0.86	13.30	0.50
LSD value	NS		0.6*	

Table 10. Effect of rates of phosphorus and sulphur on available P and S content and net change over initial value after 2 years of study at Talagang

Treatments	Available P (kg/ha)	Net change over initial value of 2.8 kg ha^{-1}	Available S (kg/ha)	Net change over initial value of 15 kg ha^{-1}
P levels (kg P_2O_5 ha^{-1})				
0	2.24	-0.56	14.1	-0.9
40	2.82	0.02	13.1	-1.9
80	3.36	0.56	13.0	-2.0
LSD value	0.2*		0.8*	
S levels (kg S ha^{-1})				
0	2.90	0.1	12.2	-2.8
15	2.78	-0.02	13.5	-1.5
30	2.72	-0.08	14.4	-0.6
LSD value	NS		0.7	

Available soil S was decreased in all P treatments, as compared to soil S status at start of experiment (Table 9 and Table 10), which was due to higher S uptake by plant as a result of accelerated plant growth due to P application. Sulphur application (30 kg S ha^{-1}) resulted in significantly higher soil S status, by 37 and 18 percent over control at Chakwal and Talagang respectively, after crop harvest. Contrary to these findings, Khalid et al.

(2012) reported non significant effect of S application from different S sources (gypsum, AS and single super phosphate) after harvest of *Brassica napus* in a two year study conducted in climatic and soil conditions similar to this study. The difference regarding soil S reserves might be due to the fact that oilseed crops have higher S requirement than that of pulses, and consequently higher S uptake by *Brassica napus* resulted in depletion of soil S reserves. There was considerable improvement in soil S reserves after crop harvest at Chakwal as compared with soil S status at the start of experiment. Hussain and Thomas (2010) also observed that available S in soil increased from initial level of 18.7 kg ha^{-1} to 20.5 with application of 60 kg S ha^{-1} after harvest of sunflower. These results are also in line with the findings of Deshbhratar et al. (2010).

CONCLUSIONS

Application of P and S resulted in increased dry matter yield of crop, but at the same time, it resulted in considerable improvement in soil fertility status of soil. Therefore higher level of P (34 kg ha^{-1}) and S (30 kg ha^{-1}) should be applied to chickpea grown under rainfed conditions in order to maintain soil health and sustainable crop yield.

REFERENCES

Ahmad, N. and Rashid, M., 2003. *Fertilizers and their use in Pakistan.* 3rd ed. National Fertilizer Development Centre Islamabad, Pakistan: 190-210.

Akbari, K.N., Karan, F., Qureshi, E.M., and Patel, V.N., 2003. *Effect of micronutrients, sulphur and gypsum on soil fertility and yield of mustard in red loam soils of Mewar (Rajasthan).* Indian J. Agri. Res., 37: 94-99.

Amanuel, G., Kühne, R.F., Tanner, D.G., and Vlek, P.L.G., 2000. *Biological nitrogen fixation in faba bean (Vicia faba L.) in the Ethiopian highlands as affected by P fertilization and inoculation.* Biol. Fert. Soils, 32: 353-359.

Aslam, M., Mahmood, I.A., Sultan, T., Ahmad, S., and Zahid, M.A., 2000. *Growth and yield response of chickpea (Cicer arietinum L.) to various Rhizobium strains fertilized with different phosphorus levels.* Int. J. Agri. Biol., 2: 89-91.

Deshbhratar, P.B., Singh, P.K., Jambhulkar, A.P., Ramtek,e D.S., 2010. *Effect of sulphur and phosphorus on yield, quality and nutrient status of pigeon pea (Cajanus cajan).* J. Environ. Biol., 31: 933-937.

FAO, 2009. FAOSTAT. Available on line at http://faostat.fao.org/site/567/Desktop Default. aspx?PageID=567#ancor (verified on October 21, 2011).

FAO, 1998. *Plant nutrition for sustainable agriculture development in Pakistan.* Agronomy Report, Food and Agriculture Organization of the United Nations, Rome.

Ghosh, P.K., Hati, K.M., Mandal, K.G., Misra, A.K., Chaudhry, R.S., and Bandyopadhyay, K.K., 2000. *Sulphur nutrition in oil seeds and oilseed based cropping systems.* Fertilizer News, 45: 27-40.

Gunes, A., Inal, A., Pilbeam, D.J., and Kadioglu, Y.K., 2009. *Effect of sulfur on yield and essential and non-essential element composition of alfalfa determined by Polarized energy dispersive X-ray fluorescence.* Commun. Soil Sci. Plant Analy., 40: 2264-2284.

Hayat, R., and Ali, S., 2010. *Contribution of water use efficiency of summer legumes for the production of rainfed wheat.* Int. J. Agri. Biol., 12: 655-660.

Hussain, A. 1998. *Crops and Their Relation to Environment.* In: Nazir, S., Bashir E., Bantel R., (eds), Crop Production. National Book Foundation, Islamabad, Pakistan: 34.

Hussain, S.S., and Thomas, T., 2010. *Effect of nitrogen and sulphur on yield, mineral accumulation and protein content of sunflower (Helianthus annuus* L.*) in Inceptisol*. Res. J, Agric. Sci., 1: 89-92.

Ijaz, S.S., and Ali, S., 2011. *Replacing clean fallow with minimum tilled pulse legume in a subtropical dryland at Pothwar, Pakistan.* Agrociencia, 45: 43-53.

Islam, M., 2012. *The effect of different rates and forms of sulfur on seed yield and micronutrient uptake by chickpea*. Plant Soil Environ., 58: 399-405.

Islam, M., Mohsan, S., and Ali, S., 2012. *Effect of different phosphorus and sulfur levels on nitrogen fixation and uptake by chickpea* (*Cicer arietinum* L.). Agrociencia, 46: 1-13.

Khalid, R., Khan, K.S., Islam, M., Yousaf, M., and Shabbir, G., 2012. *Effect of different sulfur levels and sources on rapeseed growth and soil sulfur fractions.* J. Chemical Society Pak., 34: 1023-1031

Khalil, I.A., and Jan A., 2002. *Cropping Technology.* National Book Foundation, Islamabad, Pakistan: 207.

Khan, M.A., 2002. *Production efficiency of chickpea as affected by inoculation, phosphorus levels and intercropping.* Ph. D. Thesis, University of Agriculture, Faisalabad, Pakistan.

Khan, K.S., and Joergensen, R.G., 2006. *Microbial C, N, and P relationships in moisture stressed soils of Pothwar, Pakistan.* J. Plant Nutr. Soil Sci., 169: 494-500.

Kyei-Boahen, S., Slankard, A., and Walley, F., 2002. I*sotopic fractionation during N_2 fixation by chickpea*. Soil Biol. Biochem., 34: 417-420.

Liu, X.J., Wang, J.C., Lu, S.H., Zhang, F.S., Zeng, X.Z., Ai, Y.W., Peng, S.B., and Christie, P., 2003. *Effects of non-flooded mulching cultivation on crop yield, nutrient uptake and nutrient balance in rice–wheat cropping systems.* Field Crops Res., 83: 297-311.

Ma, Q., Yu, W.T., Shen, S.M., Zhou, H., Jiang, Z.S., and Xu, Y.G., 2010. *Effects of fertilization on nutrient budget and nitrogen use efficiency of farmland soil under different precipitations in Northeastern China.* Nutrient Cycling in Agro-ecosystems, 88: 315-327.

NFDC, 2011. *Fertilizer Review 2009-10.* National Fertilizer Development Centre, Islamabad, Pakistan: 120 p.

Rafique, E., Mahmood-ul-Hassan, M., Rashid, A., and Chaudhary, M.F., 2012. *Nutrient balances as affected by integrated nutrient and crop residue management in cotton-wheat system in Aridisols. II. Phosphorus.* J. Plant Nutr., 35: 617-632.

Rao, S.S., 2003. N*utrient balance and economics of integrated nutrient management in groundnut* (*Arachis hypogaea* L.) - *mustard* (*Brassica juncea* L.). Madras Agric. J., 90: 465-471.

Ryan, J., Estefan, G., and Rashid, A., 2001. *Soil and Plant Analysis Laboratory Manual.* 2nd Edition. International Center for Agricultural Research in Dry Areas, Aleppo, Syria: 118-127.

Sharma, K.R., and Arora, S., 2008. *Effectiveness of gypsum and pyrite for sulfur fertilization on yield and quality of Indian mustard under rainfed conditions of north India.* Commun. Soil Sci. Plant Analy., 39: 2431-2439.

Sharama, N.S., and Prasad, R., 2009. *Effect of different sources of phosphorus on summer mungbean (Vigna radiata) in alkaline soil of Delhi.* Indian J. Agri. Sci., 79: 782-789.

Taalab, A.S., Hellal, F.A., and Abou-Seeda, M.A., 2008. *Influence of phosphatic fertilizers enriched with sulfur on phosphorus availability and corn yield in calcareous soil in arid region.* Ozean J. Applied Sci., 1: 105-115.

Tandon, H.L.S., 2011. *Sulphur in Soils, Crops and Fertilizers from Research to Practical Application.* Fertilizer Development and Consultation Organization, New Delhi, India: 204 p.

Unkovich, M., Herridge, D., Peoples, M., Cadisch, G., Boddey, B., Giller, K., Alves, B., and Chalk, P., 2008. *Measuring Plant-associated Nitrogen Fixation in Agricultural Systems.* Australian Centre for International Agricultural Research Monograph No. 136, Australia: 132-188.

Verma, B.C., 1977. An improved turbidimetric procedure for determination of sulphate in plants and soils. Talanta, 24: 49-50.

Wichern, F., Eberhardt, E., Maye,r J., Jorgensen, R.G., and Muller, T., 2008. *Nitrogen rhizodeposition in agricultural crops: methods, estimates and future prospects.* Soil Biol. Biochem., 40: 30-48.