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Effect of Phosphorus and Sulfur on the Yield and Nutrient Uptake of Maize

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ABSTRACT: A field experiment was conducted at Malakandher Research Farm, The University Agriculture, Peshawar-Pakistan during kharif season 2011, to study the effect of varying levels of phosphorus and sulfur on the yield and nutrient uptake of maize. The experiment was laid out in RCB design with three replications. Phosphorus was applied at the rate 60, 90 and 120 kg ha^{-1} in combination with varying sulfur level viz. 45, 60 and 75 kg ha^{-1} as ammonium sulfate along with control. The results revealed that all treatments significantly increased yield and yield parameters over control and the maximum biomass (both fresh and dry matter yield) was achieved when P and S were applied at the rate of 90 and 60 kg ha^{-1} respectively whereas higher values of 1000 grain weight (248 g) and grain yield (2414 kg ha^{-1}) was obtained in plots treated with 120 kg + 45 kg ha^{-1} P and S, respectively. The minimum yield and 1000 grain weight was recorded in control or plots receiving only basal dose of N and K fertilizers. The P and S content in soil samples collected at silking stage and post harvest stage were significantly affected and the higher values were recorded in plot receiving the maximum level of the respective fertilizer but the trend of increase was not consistent with respect to soil depth. The P and S content in leaves indicated that higher level of S (75 kg ha^{-1}) resulted low uptake of P and vice versa, indicating their antagonistic effect with each other. This antagonistic effect was displayed in the yield whereby maximum grain yield was obtained where higher dose of P along with lower level of S was beneficial.

***Keywords*:** Grain; Maize; Phosphorus; Sulfur; Yield

INTRODUCTION

Maize (*Zea mays L.*) is an important cereal crop ranks third after wheat and rice in the world food grain production. It is recognized as a leading commercial crop of great agro-economic value being used for variety of food products, oil production and animal feed. Area under maize crop in Pakistan is 950 thousands hectares with an annual production of 3487 thousands tones, (MINFAL, 2009-10). In Khyber Pakhtunkhwa it covers an area of 509 thousand hectares producing 958 thousand ton of maize and yield is 1880 kg ha^{-1}. There are many reasons of low productivity for maize crop in the area. Among them mismanagement of plant nutrition is considered to be the major one. Hence there is a need to improve this major component of the production technology for getting higher maize production of better quality.

Phosphorus (P) is the second major nutrient essential for plant growth. Phosphorus plays vital role in physiological processes, viz. photosynthesis, respiration, energy storage and transfer, cell division and enlargement, etc. Phosphate compounds are involved in metabolic reaction in plants (Barber, 1995). Phosphorus deficiency is wide spread in almost 90% soils of Pakistan and the application of P fertilizer is essential for crop production.

Continuous cropping without proper application of P fertilizer, contribute to low P content in soils. Current phosphorus fertilizer rates average approximately 40 kg P_2O_5 ha^{-1}, one third of what is actually recommended for optimal crop production (Rashid, 2001). Application of phosphorus significantly effect on grain yield, dry matter yield, number of leaves and leaf area (Ali, 2002 and Ayub, 2002).

Sulfur (S) is a building block of protein and a key ingredient in the formation of chlorophyll. Crops cannot reach their full potential in terms of yield or protein contents without adequate sulfur (Zhao, 1999). Growth of maize is sensitive to sulfur deficiency because it decreases grain size under sulfur-limiting condition. Sulfur has beneficial effects by lowering soil pH and improving physical condition of the soil (Choudry and Das, 1996). Grain yield enhance with rising quantities of both sulfur and nitrogen and when soil is deficient in sulfur, full yield potential of the crop cannot be realized regardless of other nutrients (Tandon, 1984). The nutrition value of cereals is also determined by the proportion of S containing amino acids (Katyal, 1987).

The use of balanced fertilizer is a vital factor of nutrient management. It plays a key role in increasing crop production. The presence of nutrients like N, P, K, S and Mg etc, in balanced form is essential for plant growth and yield formation (Mahmood 1994, Randhawa and Arora, 2000).

It has been reported that maize crop responds very well to variable rates of phosphorus, sulfur and thus increase grain yield and protein contents (Singh and Dukey, 1991). Phosphorus interacts with sulfur as phosphate ion is more strongly bond than sulphate (Hedge and Murthy, 2005). The application of phosphorous fertilizer results in increased anion adsorption sites, which releases sulphate ions into the solution (Tiwari and Gupta, 2006).

Several studies reported both synergistic and antagonistic relationship between sulfur and phosphorous, depends on their rate of application and crop species. Synergistic effect of applied P and S was observed by (Kumawat , 2004). Antagonistic relationship between P and S was observed in mung and wheat by (Islam , 2006). The interaction of these nutrients element may effect the critical level of available P and Sulfur (Choudry and Das, 1996).

The present study was aimed at evaluating the effect of different levels of phosphorus and sulfur on the yield and nutrient uptake of maize crop.

MATERIALS AND METHODS

The experiment was conducted at Malakandher Research Farm, The University Agriculture, Peshawar-Pakistan during kharif season 2011, to investigate the effect of phosphorus and sulfur on the yield and nutrient uptake of maize (Table 1). The experiment was carried out in RCB Design with three replications and eleven treatments, having plot size of 3×5m^2 and row to row distance of 0.75 m. Phosphorus was applied at the rate 60, 90 and 120 kg ha^{-1} in combination with varying sulfur level viz. 45, 60 and 75 kg ha^{-1} as ammonium sulfate along with control (no fertilizer) and a treatment of only N & K treatment as basal dose (120 + 60 kg ha^{-1}). Phosphorous, potassium and sulfur with half dose of nitrogen was applied at the time of sowing. While remaining half dose of nitrogen was applied at knee height stage of the crop. The source of basal dose was urea, sulfate of potash where P and S were supplied as DAP and ammonium sulfate. The agronomic parameters viz, fresh matter yield, total dry matter yield, grain yield, 1000-grain yield were recorded from the experimental field.

Table 1. Treatment Combination applied in the experiment

Treatments	N (urea) kg/ha	P_2O_5 (DAP) kg/ha	K_2O (K_2SO_4) kg/ha	SO_4 $(NH_4)_2SO_4$ kg/ha
T1	0	0	0	0
T2	120	0	60	0
T3	120	60	60	45
T4	120	60	60	60
T5	120	60	60	75
T6	120	90	60	45
T7	120	90	60	60
T8	120	90	60	75
T9	120	120	60	45
T10	120	120	60	60
T11	120	120	60	75

2.1.Soil analysis

Before sowing, composite soil sample from a depth of 0-15 cm was taken from the experimental site and analyzed for different physico-chemical properties. Soil samples from each plot, surface (0-15 cm) and subsurface (15-30 cm) depth were also collected at silking stage and post harvest stage of crop for determination of AB-DTPA extractable P and available SO_4-S. The soil texture (Kochler , 1984), pH (McClean, 1982), EC (Richard, 1954), lime (Rhoades and Loveday, 1990), organic matter (Nelson and Sommers, 1996), total nitrogen (Bremner, 1996), AB-DTPA extractable P, K (Soltanpour and Schwab, 1977) and available SO4-S (Bardsely and Lancaster, 1960) were determined by standard methods.

2.2.Leaf analysis

At silking stage, 20 entirely fully developed ear leaves from each treatment were collected from randomly selected plants for P and sulfate uptake. After wet digestion of leaf samples, phosphorous (Sultanpour and Schwab 1977) and SO_4-S (Bardsely and Lancaster, 1960) were determined.

2.3.Statistical Analysis

Data were analyzed by using MSTATC package (Russell 1989). Means were compared by using least significant difference (LSD) test.

RESULTS AND DISCUSSION

3.1.Physico-chemical properties of pre sowing soil

Before conducting experiment, a composite soil sample at 0-15 cm depth was taken for determination of soil physico-chemical properties presented in Table 2. The table shows that the soil of the experimental field was silt loam in texture, having pH 7.3 with no salinity problem (0.89 dS m^{-1}). The experimental site was low in organic matter, lime contents was 16.56 %, and adequate in total nitrogen (0.16 %) and AB-DTPA extractable K (95 mg kg^{-1}). Both available phosphorus and sulfur were marginal.

Table 2. Physic-chemical properties of experimental site

Soil Properties	Unit	Values
Sand	%	13.54
Clay	%	8.46
Silt	%	78
Soil Texture	-	Silt loam
pH (e)	-	7.30
EC(e)	d Sm^{-1}	0.89
Organic matter	%	0.75
Lime	%	16.56
Total nitrogen	%	0.16
AB-DTPA extractable P	mg kg^{-1}	2.25
AB-DTPA extractable K	mg kg^{-1}	95
Available SO_4-S	mg kg^{-1}	12.1

3.2.Fresh matter yield

The data indicated that results were significant for all treatment (Fig.1). The highest fresh biomass yield (9.86 t ha^{-1}) was recorded in treatment (T7) where P and S were applied @ 90 kg ha^{-1} P + 60 kg ha^{-1} S that was comparable (being at par) with T9 where 120 kg P + 45 kg S was applied. The lowest fresh matter yield (7.56 t ha^{-1}) was recorded in control plot that was at par with the yield obtained when higher level of both P and S i.e. 120 kg P + 75 kg S were applied that shows toxicity (antagonism) of sulfur beyond 60 kg application. These results are in conformity to the previous finding of Gurmani , (2006); Hussain and Khan (2003); Imran , (2007). In another study highest maize yield was obtained, when 72 kg ha^{-1} S was applied (Haq , 1989).

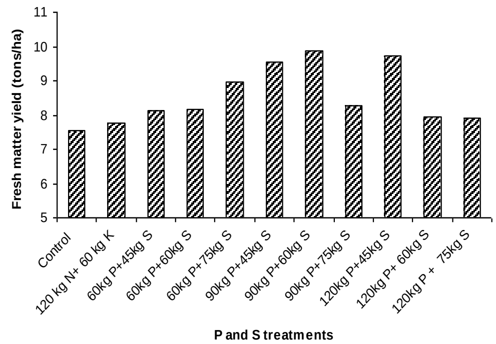

Figure 1. Effect of different levels of P and S on fresh matter yield of maize

3.3.Total Dry Matter Yield

The results of the dry matter yield followed almost similar trend as noted for fresh matter yield of maize given in Fig. 2. The results indicated that application of both phosphorus and sulfur significantly ($P<0.05$) increased the dry matter yield of maize. Maximum dry matter yield (7.81 t ha^{-1}) was recorded in treatment (T7) where P and S were applied @ 90 kg ha^{-1} P + 60 kg ha^{-1} S. The minimum dry matter yield (5.55 t ha^{-1}) was recorded in control plot (untreated). Mandal and Sikder (1999) and Singh , (1997) reported an increase in dry matter yield with 30 kg ha^{-1} S. Khan , (2006) reported 41 % increase in dry matter yield of maize with the application of 60 kg S ha^{-1}, whereby S application beyond 60 kg ha^{-1} had no effect on maize yield. The results of the present study (Fig. 2) indicates that P application at the rate of 90 kg ha^{-1} along with 60 kg ha^{-1} S was beneficial whereby levels increasing beyond that may be not effective due to their antagonistic effect. The interaction of S with P is very rarely documented in the literature. In the present investigation, the yield reduction beyond 90 kg ha^{-1} P application is associated to antagonism due to S addition.

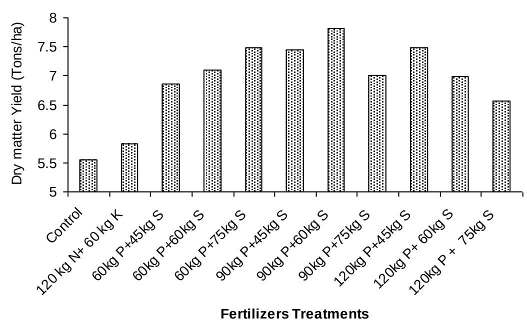

Figure 2. Effect of different levels of P and S on dry matter yield of maize

3.4.Grain yield

Results of grain yield as influenced by different levels of P and S are shown in Fig. 3. The total grain yield was influenced by different fertilizers level of P and S. Application of 120kg ha^{-1} P+ 45kg ha^{-1} S (T9) produced maximum grains yield (2414 kg ha^{-1}) which was at par with T7 but significantly different from all other treatments. The minimum grains yield (1344.3 kg ha^{-1}) was recorded in control plot. Although the over all grain yield of the maize was lower compared to potential yield of maize but the treatment combinations showed that P and S at the rate of 120 + 45 kg ha^{-1} respectively were beneficial and sulfur application beyond 45 kg ha^{-1} may not be useful for increasing maize yield. Increases of 0.99 t ha^{-1} in grain yield with application of 40 kg ha^{-1} was reported by Sakal (2000). Gupta (1997) reported maximum yield with 60 kg ha^{-1} S application where 72 kg ha^{-1} was reported optimum by Haq (1989). Khan (2006) reported 43% increase in grain yield when supplied with 90 kg P and 60 kg ha^{-1} sulfur. Aulakh (1990) noted negative impact of S on P. Similar data was also found by Hussain (2007) who found that grain yield increased with phosphorus application and plots receiving 90 kg ha^{-1} P gave maximum grain yield as compared to lower dose grain yield. The differential yield responses in different experiments may be due to the variation of both P and S in the different locations of soil where experiments were conducted.

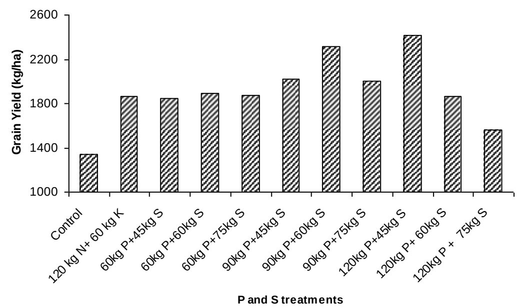

Figure 3. Effect of different levels of P and S on grain yield of maize

3.5.1000-grain weight

Data on 1000-grain weight is shown in Fig. 4. Effect of phosphorus and sulfur on 1000-grain weight was significant. Mean values of the data showed that heavier grain weight (248 g) was recorded in treatment (T9) where P and S were applied @120 kg ha^{-1} P + 45 kg ha^{-1} S while minimum 1000 grains weight (172.67 g) was recorded in control (T1). The results of T7 (90 kg P and 60 kg S ha^{-1}) were comparable with T9 (Fig. 4). These results showed that higher levels of P increased the grain weight along with 45 kg ha^{-1} S but the S levels beyond 45 kg ha^{-1} were not suitable for increasing the grain density which might be due to nutritional imbalance. Hussain (2007) observed an increase in 1000-grain weight with increase in NP application. These data are comparable to the result of Leghra (1999). Singh and Aggarwal (1998) also reported similar findings and establish that S applied at the rate of 30 kg ha^{-1} significantly increased the 1000-grain weight whereas levels beyond 30 kg ha^{-1} were not beneficial for increasing grain weight of maize.

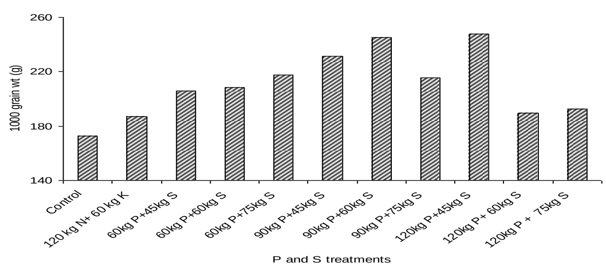

Figure 4. Effect of different levels of P and S on 1000 grain weight of maize

3.6. Soil AB-DTPA Extractable P at different growth stages

Results of AB-DTPA extractable phosphorus concentration in soil at different growth stages are showed in Table 3. The results of the data showed that AB-DTPA extractable phosphorus concentrations in soil at silking stage (0-15 cm) were significantly different from one another at 5% level of probability. The higher concentration of P (13.78 mg kg^{-1}) was observed in treatment (T9) where 120 kg ha^{-1} P + 45 kg ha^{-1} S were applied and lower P concentration (1.25 mg kg^{-1}) was recorded in control plot in 0-15 cm soil depth. In 15-30 cm soil depth, the higher concentration of P (9.43 mg kg^{-1}) was observed in T10, where 120 kg ha^{-1} P+ 60 kg ha^{-1} S were applied and low concentration (0.70 mg kg^{-1}) was observed in control plot. The concentration of AB-DTPA extractable P in soil varied with soil depth. The results showed that there was no consistent trend in P content with respect to application rate. These results are similar to the findings observed by Kumawat 2004. Yadav (2011) observed that available P and S in soil were increased with increasing levels of P and S, but in the present study this trend was not observed. It was further noted that increasing S application beyond 45 kg ha^{-1} reduced the available P content in soil at silking stage. The concentration of P content with depth was also not consistent and the overall results showed that surface soil has more P content compared to subsurface soil.

The P concentration of soil at both depths at post harvest stage was statistically significant at different level of P and S application. The high P concentration (9.57 mg kg^{-1}) was recorded in treatment (T11) where120 kg ha^{-1} P+ 75 kg ha^{-1} S were applied and low concentration (0.93 mg kg^{-1}) was recorded in control plot in 0-15 cm soil depth. In the sub soil, the high P concentration (9.54 mg kg^{-1}) was recorded in T11 where120 kg ha^{-1} P + 75 kg ha^{-1} S were applied and low concentration (1.09 mg kg^{-1}) was recorded in control plot in 15-30 cm soil depth. The highest P concentration in T11 was statistically similar to T9 where P and S were applied @ 120 kg ha^{-1} P + 45 kg ha^{-1} S. No significant variation was found in AB-DTPA extractable P concentration in two soil depths at harvesting stage. These results are in agreement with the findings of Shankalingappa (2000) who reported higher P values in the surface soils compared to subsurface soil when applied at variable rates.

Table 3. Effect of P and S on Phosphurus concentration (mg kg^{-1}) at different stages

Treatment (kg ha^{-1})	P at silking stage (mg kg^{-1})		P at harvesting stage(mg kg^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Control	1.25 e	0.70 d	0.93 e	1.09 e
120 kg N + 60 kg K	1.53 e	0.98 d	1.63 de	1.89 de
60kg P + 45kg S	1.90 e	1.11 d	3.29 d	3.81 de
60kg P + 60kg S	3.53 de	4.13 c	8.09 abc	4.18 cd
60kg P + 75kg S	3.99 de	7.19 ab	6.25 bc	3.54 de
90kg P + 45kg S	5.73 d	8.10 ab	8.36 ab	8.93 a
90kg P + 60kg S	11.13 ab	6.53 b	6.58 bc	4.81b cd
90kg P + 75kg S	9.53 b	6.82 b	5.82 c	7.12 abc
120kg P + 45kg S	13.78 a	7.63 ab	6.75 bc	9.05 a
120kg P + 60kg S	6.02 cd	9.43 a	7.93 abc	7.64 ab
120kg P + 75kg S	8.59 bc	7.19 ab	9.57 a	9.54 a
LSD ($P \leq 0.05$)	2.792	2.286	2.313	3.000

Means with different letter (s) in columns are significantly different at $P \leq 0.05$

3.7.Soil available SO_4-S concentration at different growth stages

The SO_4-S concentration of soil at silking stage was statistically significant for different levels of P and S application shown in Table 4. The higher S concentration (39.89 mg kg^{-1}) was observed in treatment (T11) where 120 kg ha^{-1} P + 75 kg ha^{-1} S were applied and low concentration (8.90 mg kg^{-1}) was observed in control plot in 0-15 cm soil depth. It was further noted that there were non significant variation in sulfur content of soil where higher level of sulfur (75 kg ha^{-1}) was applied. In case of subsurface soil, the higher S concentration (40.65 mg kg^{-1}) was observed in T_{10} where 120 kg ha^{-1} P + 60 kg ha^{-1} S were applied and low concentration (11.89 mg kg-1) was observed in control plot in lower soil depth (15-30) at silking stage. Over all results reveals that higher values were recorded (with few exception) in surface soil and lower values were noted in subsurface soil as was expected. The SO_4-S build up in soil profile with increasing sulfur additions has been reported by Barbora (1995) and Sreemanarayana and Raju (1994). Khan (2006) reported higher values of sulfur, where high level of sulfur was applied compared to control or where low levels were applied to maize crop.

The data on sulfur concentration in soil at both depths at post harvest stage was statistically significant at various levels of P and S. The higher SO_4-S concentration of 33.14 mg kg^{-1} in soil at 0-15 cm depth was observed in T8 (90 kg ha^{-1} P + 75 kg ha^{-1} S) and low concentration (6.39 mg kg^{-1}) was observed in control plot. The high sulfur concentration (32.23 mg kg^{-1}) was recorded in T10 (120 kg ha^{-1} P + 60 kg ha^{-1} S) and low concentration (7.29 mg kg^{-1}) was recorded in control in 15-30 cm soil depth at post harvest stage. Khan , (2006) reported that higher S doses enhance available SO_4-S in soil. Bharathi and poongothai (2008) found SO_4-S level in soil was increased respectively with subsequent enhancement on S addition.

Table 4. Effect of P and S on SO_4-S concentration (mg kg^{-1}) at at different stages

Treatment (kg ha^{-1})	SO_4-S at silking stage (mgkg^{-1}) 0-15 cm	15-30 cm	SO_4-S at harvesting stage (mg kg^{-1}) 0-15 cm	15-30 cm
Control	8.90 f	11.89 de	6.39 c	7.29 e
120 kg N + 60 kg K	16.12 def	15.13 e	7.63 c	7.44 e
60kg P + 45kg S	16.85 def	21.09 cde	20.49 b	15.86 d
60kg P + 60kg S	13.05 ef	17.53 de	19.73 b	17.46 cd
60kg P + 75kg S	33.76 ab	20.65 cde	20.15 b	22.92 b
90kg P + 45kg S	19.41 de	31.83 abc	29.53 a	16.74 cd
90kg P + 60kg S	22.49 cd	22.76 cde	31.06 a	21.24 bc
90kg P + 75kg S	32.12 ab	21.10 cde	33.14 a	29.17 a
120kg P + 45kg S	19.02 de	27.65 bcd	19.65 b	16.96 cd
120kg P + 60kg S	27.88 bc	40.65 a	32.95 a	32.23 a
120kg P + 75kg S	39.89 a	39.45 ab	31.65 a	30.18 a
LSD ($P \leq 0.05$)	8.154	12.73	6.191	7.786

Means with different letter(s) in columns are significantly different at $P \leq 0.05$

3.8.P concentration of maize leaves at silking stages

The data on P concentration in maize leaves at silking stage showed significant variations when different levels of P and S were applied (Fig. 5). Mean values of the data indicated highest P concentration (0.37 %) in treatment (T9) where P and S were applied at the rate of 120 kg ha^{-1} P + 45 kg ha^{-1} S. The lowest P concentration (0.11 %) was recorded in control plot that was at par with T2, where only N and K were applied as well as with the treatments where higher levels of S (75 kg ha^{-1}) were applied. These results showed that S addition beyond 45 kg ha^{-1} resulted in reduction in P content of leaves that indicates its antagonistic effect. The same trend in 1000 grain and total grain yield was noted i.e. increasing S levels beyond 45 kg ha^{-1} results reduction in weight of grain and grain yield. Aulakh (1990) reported that relation of P with S was more harmful when maximum dose of S was applied that might have prevented P accumulation in the plant and its concentration enhanced in soil. Phosphorus concentration increased in plant tissue when S was applied at the rate of 60 kg ha^{-1} but S application higher than 60 kg ha^{-1} reduced P uptake which was found in lined with the work of Deo and Khaldelwal (2009).

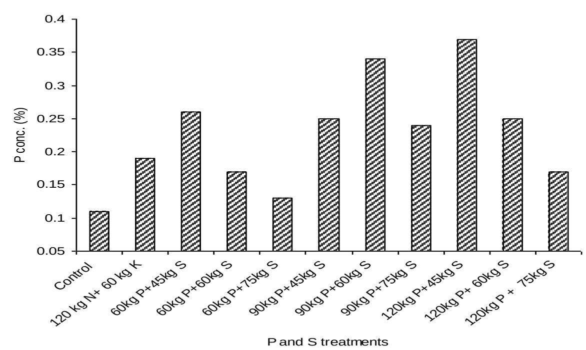

Fig. 5: P conc. of leaves as affeted by different levels of P and S.

3.9.Sulfur Concentration SO4-S of maize leaves at Silking Stage

Results on the sulfur concentration in maize leaves at silking stage are shown in Fig. 6. The SO_4-S concentration in maize leaves at silking stage was statistically significant for different levels of P and S application. The highest value of S concentration (0.44%) was recorded in treatment (T8) where P and S were applied at the rate of 90 kg ha^{-1} P + 75 kg ha^{-1} S. The lowest S (0.09%) concentration was recorded in control plot. The sufficiency level of S in plant leaves varies from 0.15 to 0.5% (Tandon, 1984) showing that the result of lower yield of maize in the plots supplied with no sulfur were suffering from S deficiency. Sulfur adequacy range was achieved with the application 60 kg ha^{-1} S that resulted tissue sulfur concentration of 0.44%. Khan (1992) and Mandata (1994) also reported that the S concentration in plant tissue increased with higher rates of S application. It was further noted that higher level of P application reduced the S uptake by plant that might be due to its antagonistic effect.

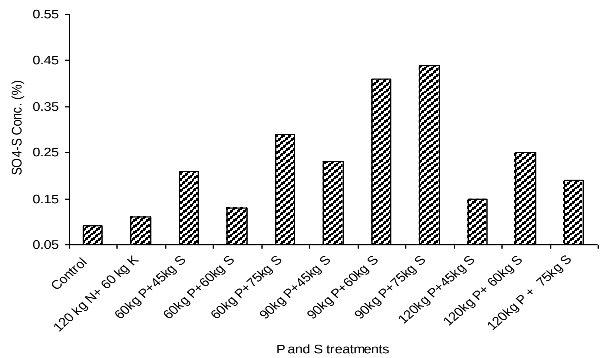

Fig. 6: SO4-S Conc. of leaves asaffected by different levels of P and S

3.Conclusions

It is concluded that fertilization of phosphorus and sulfur at the rate of 120 P + 45 kg ha^{-1} is appropriate and economical rate of P and S for obtaining maximum grain yield of maize under agro-ecological condition of Peshawar. AB-DTPA extractable phosphorus and SO_4-S content of soil were increased with increasing level of both P and S. Further experiments are needed for the confirmation of the results on different ecological condition of Pakistan.

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