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Effect of Phosphorus and Sulfur on the Yield and Nutrients Uptake of Wheat

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Abstract

A field experiment was conducted to study the effect of phosphorus and sulfur on the yield and nutrients uptake of wheat at New Developmental Research Farm (NDF) Malakandher, University of Agriculture, Peshawar in Rabi season during 2011-2012. The experiment was laid out in randomized complete block design (RCBD) with three replications. Phosphorus was applied at the rate of 60, 90 and 120 kg ha^{-1} as DAP whereas sulfur was applied at the rate of 45, 60 and 75 kg ha^{-1} as ammonium sulphat along with control (no fertilizer) and a treatment of just N and K as basal dose (120 + 60 kg ha^{-1}). The results showed that biological yield increased significantly ($p \leq 0.05$) over control when P and S were applied at the rate of 90-45 kg ha^{-1} whereas significantly higher grain yield was recorded in treatment receiving 120 kg P and 45 kg S along with a basal dose of N and K, Significantly highest straw yield of 4245 kg ha^{-1} was noted in treatment receiving 90 kg P along with 45 kg S ha^{-1}. The soil samples collected at anthesis stage and post-harvest stage showed that the P and S contents were significantly affected and the higher values were noted in plot receiving the maximum level of the respective fertilizer i.e P and S but the trend of increase was not consistent with respect to the amount of P and S applied. The P and S content in leaves indicated that higher level of S (75 kg ha^{-1}) resulted in significantly 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 applied.

Keywords: Phosphorus; Sulfur; yield; Nutrients Uptake; Antagonistic effect.

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1. Introduction

Wheat (*Triticum aestivum* L) belongs to family Poaceae, is an annual Rabi, self-pollinated and long day plant grown in all over Pakistan as a major winter crop. Wheat is the chief food grain of Pakistan and being the affix diet of the public. It occupies a central position in agricultural policies. The authors in [27] noted that In Pakistan, the total area grown by wheat was 8666 thousand ha that produced 23.5 million tones food grain, while in Khyber Pakhtunkhwa the total area grown with wheat was 769.5 thousand ha with a production of 1.2 million tons during 2011-12 .

The authors in [43] noted that the soils of Pakistan are mainly calcareous with alkaline in reaction and approximately 90% soils lack in phosphorus. Main crops including wheat grown on such type of soils endure from phosphorus deficit with stern yield losses. The limiting nutrient of crops phosphorus predominantly in calcareous soils is sturdily circumscribed and mostly unavailable for crop uptake. The making up of P is about 0.2% of a plant's dry weight.

The authors in [5] noted that Phosphorus is a basic structural element of the membrane system of the cell, the mitochondria and chloroplast. The structural nature of P play a significant role in macromolecules such as energy in the form of Adenosine Tri Phosphate (ATP) and nucleic acids in metabolic pathways of filth and biosynthesis.

The authors in [11] noted that Phosphorus, subsequent to nitrogen is the second most commonly off-putting macronutrient for plant augmentation. Phosphorus is taken up by plants as both H_2PO_4 or HPO_4 ions. The phosphorus inorganic forms is not taken up by plant. Most of the inorganic P is tied in phosphate rocks and minerals whereas organic P can be received from the vestiges of animals and plants. The phosphorous in inorganic form is present in soil in combination with Fe, Al, Ca, Mg and other elements.

The authors in [5] noted that Phosphorus is widely distributed in nature and occurs, together with N and K, as a primary constituent of plant and animal life. It plays a series of functions in the plant metabolism and one of the essential macronutrients required for plant growth and development. It has function of a structural nature in macromolecules such as nucleic acid and of energy transfer in metabolic pathways of biosynthesis and degradation. As low as 0.2 mg P L^{-1} in the soil solution is usually adequate for normal plant growth, however, this level must be maintained throughout the growth cycle of crop to get potential yield. The authors in [47] noted that the wheat reproductive growth appears to be more susceptible to S deficiency than vegetative growth, with decreased grain size under S-limiting environment. In addition to the possessions on yields, the S status of wheat grain is an imperative parameter for the eminence of wheat foodstuffs. The off-putting accessibility has been revealed to favour the synthesis and accrual of S poor or low S storage proteins such as ω-gliadin and High Molecular Weight (HMW) subunits of glutenin at the disbursement of S-rich proteins, deficiency also decreases the amount of polymeric proteins in entire proteins, but the distribution of polymeric proteins toward lower molecular weight. The changes in protein composition are allied with alterations of dough rheology. The responses of bread making are due to quality to the addition of S fertilizers having been recognized under field circumstances. The latest studies cover to facilitate bread making value is closely allied with grain S concentration than with N concentration. The authors in [41] noted that the deficiency of the plant nutrient in the past other than P, N and K was not pragmatic because of the low nutrient necessities of poor yielding crops varieties and fewer intensive cropping systems. The increasing population and the ensuing demand for raise food production has necessitated crop amplification, plant nutrients deficiency such as S have begun to emerge. Sulfur as attaining value in all regions of the world as of recurrent sulfur deficiencies in time and space. Foremost reasons in the wake of S-deficit are accredited mainly due to high yielding verities, crop residues removal for feed and fuel, through leaching and soil erosion, drastic decline in S free fertilizer such as N and P as increased utilization of S-free fertilizer progresses.Due to limited research work in the past on various aspects of sulfur and its interaction with P as needed to be explored. The significance of P and S on crop yield the present study is intended to investigate the effect of P and S on the yield and nutrient uptake of wheat.

1.1 Objectives

1. To investigate the influence of P and SO_4-S applied in combination on wheat yield.
2. To determine soil available P and SO_4-S in soil when P and S applied in combination.
3. To find out the concentration of P and SO_4-S in wheat leaves and their effect on yield and nutrient uptake of wheat.

2. Materials and methods

This trail was conducted at Malakandher Research Farm, University of Agriculture, Peshawar during Rabi season 2011-2012, to investigate the effect of phosphorus and sulfur on the yield and nutrient uptake of wheat. The study trial was carried out in Randomized Complete Block Design (RCBD). The experiment was replicated three times. There were eleven treatments having a plot size of 3 m × 5 m with row to row distance of 30 cm.

Table 1: Treatment Combinations

Treatments	N (urea) kg ha^{-1}	P_2O_5 (DAP) kg ha^{-1}	(K_2SO_4) kg ha^{-1}	$(NH_4)_2SO_4$ kg ha^{-1}
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

The experimental field was ploughed before sowing and divided in 3 blocks with 11 plots in each block. Before sowing the wheat crop, phosphorous, potassium and sulfur with half dose of nitrogen was applied to the experimental field. While half dose of nitrogen was applied when crop was at knee height. The P_2O_5 to required level was calculated in DAP that also carry N. The remaining N was taken from urea. Similarly, S calculation was made using $(NH_4)_2SO_4$ fertilizer and the additional N dose was compensated through urea. Central four rows from each treatment plot were harvested and the following data were recorded.

2.1 Bio mass yield

The harvested wheat bundles were left the in field for three days. After that the biomass yield was recorded.

$$\text{Biomass (kg ha}^{-1}\text{)} = \frac{\text{Biomass / plot} \times 10^4 \text{ m}^2}{\text{Size of plot m}^2}$$

2.2 Grain yield

The dry biomass was threshed with thresher and the grains were collected in bags and the yield was recorded per plot and then converted into ha basis.

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Wt of grain / plot} \times 10^4 \text{ m}^2}{\text{Size of the plot m}^2}$$

2.3 Straw yield

The straw yield was calculated by subtracting grain yield from biomass and the data were converted into ha basis.

$$\text{Straw yield (kg ha}^{-1}\text{)} = \frac{\text{(Biomass – grain yield) / plot} \times 10^4}{\text{Plot size m}^2}$$

2.4 1000 grains weight

A random sample from grain yield was collected and thousand grains were counted and weighted in electronic balance in laboratory.

2.5 sampling

2.5.1 Soil sampling

Composite soil sample from a depth of 0-15 cm was taken before sowing from the experimental location for determination of different physico -chemical properties. Soil samples from 0-15 cm depth from each plot were also collected at anthesis stage and after harvesting the crop for determination of phosphorus and sulfur.

2.5.2 Leaf sampling

Third fully matured leaves of wheat were taken from each plot for P and S determination at anthesis stage. The leaves were washed thoroughly with tape water followed by two washing with distilled water. The leaves were blotted with tissue paper, air dried ad kept in oven at 70^0C for 48 hours to a constant weight. The leaves were chopped with a stainless steel razor, and were ground with grinder.

2.6 Soil Analysis

The composite soil sample before sowing of experimental site was analyzed for soil texture, Electrical conductivity, pH, lime content, organic matter, K and total N. Available phosphorus and SO_4-S were also determine in the composite soil sample as given below in table 1. The samples collected at anthesis and post harvesting stage were analyzed for available SO_4-S and P concentration.

2.6.1 Texture

Soil texture of the soil samples were determined according to the procedure described by The authors in [21] Briefly, about 50 g soil was added with 10 ml of Na_2CO_3 and water and shaken for 5 minutes through dispersing machine. Hydrometer reading was noted after 40 sec and 2 hours along with temperature. 40 seconds readings were assumed to represent silt and clay and 2 hours to represent only clay in the suspension.

2.6.2 Soil pH

Five g of soil was added with 50 ml of distilled water and shaken for 20-30 minutes to make 1:5 suspensions. pH was determined in suspension using pH meter according to procedure of authors in [24

2.6.3 Electrical Conductivity

The Electrical conductivity of the soil samples was determined in 1:5 soil suspensions by using EC meter after calibrating with standard KCL solution using procedure of authors in [25].

2.6.4 Lime Content

Lime content in samples was determined by acid neutralization method describe by the authors in [34]. Five gram soil was transferred into 150 ml flask and was mixed with 50 ml 0.5 N HCl. The suspension was boiled for 5 minutes and then filtered through whatman filter paper 40. After cooling, the filtrate was titrated against 0.25 N NaOH by adding phenolphthalein as an indicator till pink color appears.

$CaCO_3$ was determined as:

$$CaCO_3 \text{ (equivalent in percent)} = \frac{\text{(meq. HCl added – meqs. NaOH used)} \times 5}{\text{Wt. of sample in g}}$$

2.6.5 Organic Matter

Organic matter was determined by treating 1 g of soil with 10 ml of 1 N $K_2Cr_2O_7$ + 20 ml concentrated H_2SO_4 and titrated against 0.5 N, $FeSO_4$ solution stated by the authors in [8].

2.6.6 Total Nitrogen

Total N in soil samples were analyzed according to the procedure reported by the authors in [9].

2.6.7 AB-DTPA Extractable K

The K in soil was analyzed by methods according to the authors in [39].

2.6.8 AB-DTPA extractable P

Phosphorous content was determined by the procedure reported by the authors in [39].10 g soil was taken in conical flask and 20 ml AB-DTPA solution was added. The content of the flask was shaken for 15 minutes and was filtered in bottles.

➢ Measurement of P

One ml sample was taken in 25-ml volumetric flask and 4 ml ascorbic acid mix reagent was added and the sample was diluted up to the mark .When a bluish color developed then reading was taken on Spectrophotometer.

2.6.9 Available Sulphate in Soil

Five gram air dried soil was taken in a 150 ml Erlenmeyer flask, after adding 25 ml 0.15% $CaCl_2$ dehydrate solution the flask was shaken for 30 minutes on a reciprocal shaker. Then the suspension was filter through Whatman # 42 filter paper. stated by the authors in [41].

➢ Preparation of Standard

A serious of standard 5, 10, 20, 30, 40 and 50 ppm were made. Also a blank with 10 ml 0.15% $CaCl_2$ dehydrate solution was made.

➢ Measurement of SO_4-S

One ml aliquot of the extract was added into a 50 ml test tube. One ml 6 M HCl solution, 5 ml 70% sorbital solution and finely about 1g barium chloride crystal was added. After it the suspension was shaken on a test tube shaker until the barium chloride dissolved and a homogenous suspension was obtained. Reading of the absorbance of the blanks, standards and samples was taken at 470 nm wavelength. The formula used for turbidimetric of sulphate in soil.

$$SO_4\text{-S (ppm)} = \frac{\text{ppm } SO_4\text{-S} \times A}{\text{Weight of sample}}$$

2.7 Leaf analysis

2.7.1 P Concentration in Leaf Samples

Leaf sample 0.5g of oven dry fully ground was taken into 150-ml conical flask. 15-ml conc.HNO_3 was added and kept for overnight. Five ml of per chloric acid and 2 ml conc. H_2SO_4 was added and heated gently until digested as evidenced by copious fumes and fumes layering within the beaker. After this, continued heating until fumes disappeared and liquid was clear. Cooled and about 50-ml distal water was added and heated. Filtered using whatman filter paper No. 40 and the filtrate was collected in a 100-ml volumetric flask and the volume was made trough distilled water. According to the method of authors in [34].

- Measurement of P

One ml sample was taken in 25-ml volumetric flask and 4 ml ascorbic acid mix reagent was added and the sample was diluted up to the mark. When a bluish color developed then reading was taken on Spectrophotometer.

2.7.2 SO_4-S Concentration in Leaf Samples

Leaf sample of 0.5g oven dry fully ground was taken into 150-ml conical flask. 15-ml conc.HNO_3 was added and kept for overnight. Five ml of per chloric acid and 2 ml conc. H_2SO_4 was added and heated gently until digested as evidenced by copious fumes and fumes layering within the beaker. After this, continued heating until fumes disappeared and liquid was clear. Cooled and about 50-ml distal water was added and heated. Filtered using whatmans filter paper No. 40 and the filtrate was collected in a 100-ml volumetric flask and the volume was made trough distilled water. According to the procedure of authors in [34] .

- Preparation of Standard

A series of standard 5, 10, 20, 30, 40 and 50 ppm were made. Also a blank with 10 ml 0.15% $CaCl_2$ dehydrate solution was made.

- Measurement of SO_4-S

Five ml aliquot of the extract was added into a 50 ml test tube and diluted with 5 ml distilled water. One ml 6 M

HCl solution, 5 ml 70% sorbital solution and finely about 1g barium chloride crystal was added. After it the suspension was shaken on a test tube shaker until the barium chloride dissolved and a homogenous suspension was obtained. . Reading of the absorbance of the blanks, standards and samples was taken at 470 nm wavelength. The formula used for turbidimetric of sulphate in plant. According to the method used by authors in [41].

$$SO_4\text{-}S\ (mg\ kg^{-1}) = \frac{(ppm\ SO_4\text{-}S) \times A}{\text{Weight of sample}}$$

Prior to research trail, a composite soil sample at 0-15 cm depth was collected for determination of soil physico-chemical properties.

Table 2: Physico-chemical properties of pre sowing soil

Soil Properties	**Unit**	**Values**
Sand	%	14.00
Clay	%	32.8
Silt	%	53.20
Soil Texture	-	Silty loam
pH (e)	-	7.20
EC(e)	dSm^{-1}	0.18
Organic matter	%	0.88
Lime	%	16.02
Total nitrogen	%	0.08
AB-DTPA extractable P	$mg\ kg^{-1}$	5.78
AB-DTPA extractable K	$mg\ kg^{-1}$	93
Available SO_4-S	$mg\ kg^{-1}$	13.5

The data (Table 3.2) shows that the soil of the experimental field was loamy in texture, with a pH of 7.20 with no salinity problem. The lime was 16.02 %, and deficient in total nitrogen and AB-DTPA extractable K. Both phosphorus and sulfur were deficient and the trial place was low in organic matter the authors in [44] stated that soil having 0-10 mg kg^{-1} SO_4–S is very low, 21-30 intermediate and > 30 mg kg^{-1} is high. On the basis of this study, the soil was considered marginal in SO_4-S.

2.8 Statistical Analysis

MSTATC software was run on field collected data for analysis. According to The authors in [36] .LSD test was also done for comparison of the means.

3. Results and discussion

This trial was conducted in New Developmental Research Farm of University of Agriculture, Peshawar in Rabi season 2011-12 to study the effect of phosphorus and sulfur on the yield and nutrients uptake of wheat.

3.1 Biological Yield

The results of total biological yields as influenced by various level of P and S are shown in Table 4.1 and the analysis of variance in appendix-1. The results revealed that application of phosphorus and sulfur significantly ($P<0.05$) improved the biological yield of wheat. The maximum biological yield (7277.8 kg ha^{-1}) was noted in treatment (T 6) where P and S were applied at the rate of 90 kg ha^{-1} P + 45 kg ha^{-1} S respectively. The minimum biological yield (2333 kg ha^{-1}) was recorded in control plot (untreated). Khan and his colleagues (2006) reported 41 % yield increase in dry matter yield of maize with the addition of 60 kg S ha^{-1}, whereby S application further than 60 kg ha^{-1} have no effect on maize yield. The results of the present study indicate that P fertilization at the rate of 90 kg ha^{-1} along with 45 kg ha^{-1} S was beneficial whereby levels increasing beyond that were not beneficial may be due to their antagonistic effect. The interaction of S with P is very rarely documented in the literature. In the present research, the biological yield beyond 90 kg P ha^{-1} along with 45 kg ha^{-1}may not be beneficial for achieving maximum bio mass as shown in the Fig.4.1.

Table 3: Effect of different levels of P and S on Biological yield, grain yield, straw yield and thousand grain weight of Wheat.

No	**Treatments (kg ha^{-1})**	**Biological yield**	**Grain yield**	**Straw yield**	**Thousand grain yield**
		(kg ha^{-1})			**(g)**
1	Control	2333.4 e	839.1 f	1494 c	50.700 e
2	120N + 60K	4855.6 d	1755.9 e	4005 ab	53.33 cd
3	60P + 45S	5733.3 bcd	1934 de	3983 ab	51.800 de
4	60P + 60S	5933.4 bcd	1950 de	3799 ab	55.667 abc
5	60P + 75S	5500.0 cd	1912 de	3744 ab	55.167 abc
6	90P + 45S	7277.8 a	2045 cde	4245 a	53.80 bcd
7	90P + 60S	6244.4 abc	2556 abc	3688 ab	55.933 ab
8	90P + 75S	6477.8 abc	2706 ab	3494 ab	55.700 abc
9	120P + 45S	5833.3 bcd	3034 a	3455 ab	56.567 a
10	120P +6 0S	6800.0 ab	2795 ab	3099b	55.233 abc
11	120P + 75S	5655.6 cd	2339 bcd	3772 ab	54.400 abc
LSD($P\leq0.05$)		1119.8	538.28	1093.4	2.475

Means with different letter (s) in columns are significantly different at P ≤0.05

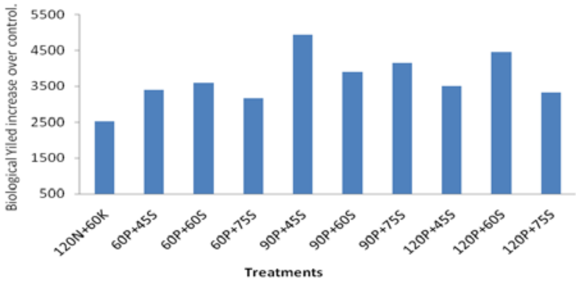

Figure1: Biological yield increase over control by different levels of P and S

3.2 Grain yield

The grain yield as influenced by different levels of P and S are presented in Table 4.1 and the analysis of variance in appendix-2. The total grain yield was influenced significantly (P≤0.05) by different fertilizers level of P and S application. The addition of 120kg P ha^{-1}+ 45 kg S ha^{-1} (T9) produced maximum grains yield (3034 kg ha^{-1}) which was significantly different from all other treatments. The minimum grains yield (839.1 kg ha^{-1}) was recorded in control plot shown in Fig.4.2. Although the overall grain yield of the wheat was lower compared to potential yield of wheat but the treatment combinations showed that P and S at the rate of 120 + 45 kg ha^{-1} respectively were beneficial. The authors in [14] reported maximum yield with 60 kg ha^{-1} S use where 72 kg ha^{-1} was reported best by The authors in [15] . Similar results were found by The authors in [16] who stated that grain yield improved with phosphorus use and those plots receiving 90 kg P ha^{-1} gave maximum grain yield as compared to lower dose. Furthermore, The authors in [19] reported that 43% raise in grain yield with the addition of 90 kg P and 60 kg ha^{-1} S. The gap in yield responses in different field trail may be due to the variation of both P and S in the diverse locations of soil.

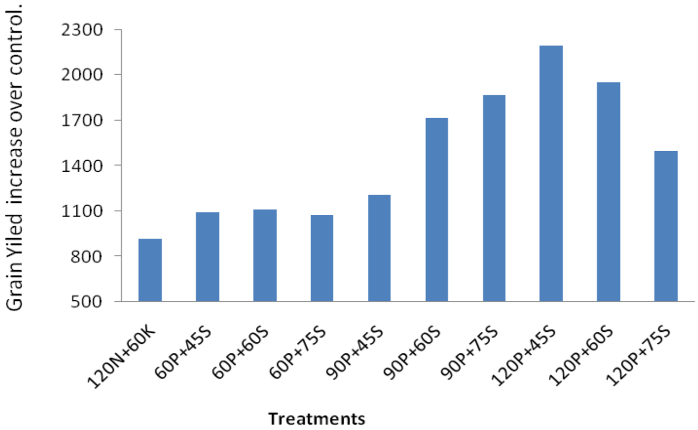

Figure 2: Grain yield increase over control by different levels of P and S

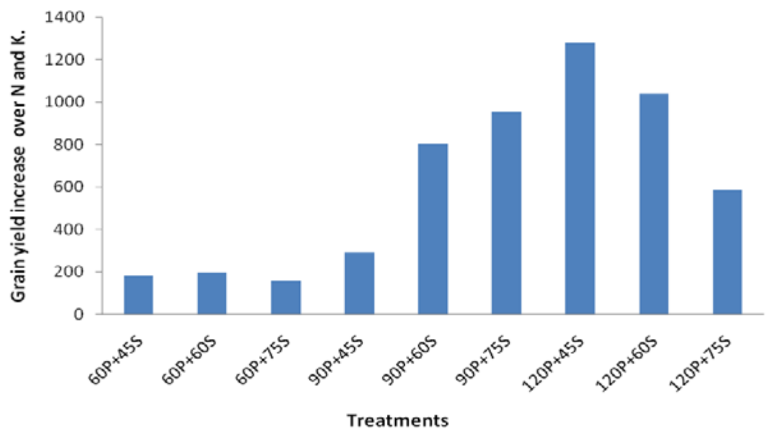

Figure 3: Grain yield increase over N and K by different levels of P and S.

3.3 Straw yield

The straw yield of wheat was influenced significantly (P≤0.05) by different fertilizers level of P and S application. The higher straw yield (4245kg ha^{-1}) was produced in T6 when 90kg P ha^{-1}+ 45kg S ha^{-1} were applied (Fig. 4.3). The minimum straw yield (1494 kg ha^{-1}) was recorded in control plot. The authors in [46] studid that the effect of P and S on cluster bean and concluded that with increasing level of both phosphorus and sulfur straw yield of clusterbean were increased significantly in level of P and S individually as well as in various combination

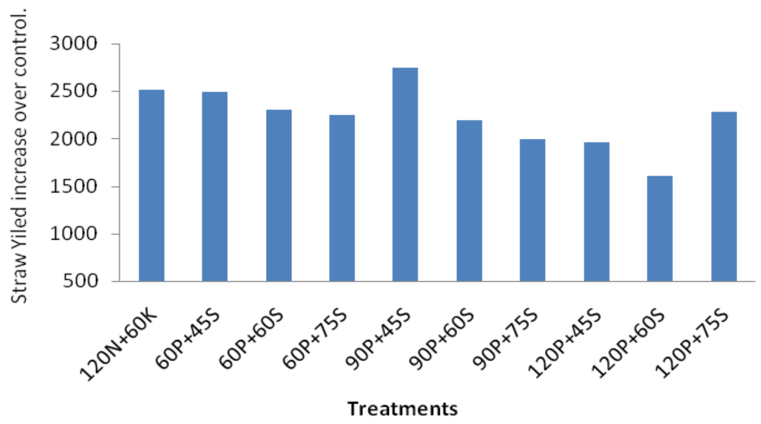

Figure 4: Straw yield increase over control by different levels of P and S

3.4 1000-grain weight

Data on 1000-grain weight are showed in Table 4.1 and the analysis of variance in appendix-4. The results showed that effect of P and S on 1000-grains weight was significant. Mean values of the data showed that heavier 1000 grains weight (56.6 g) was recorded in treatment (T9) where P and S were applied at the rate of 120 kg ha^{-1} P and 45 kg ha^{-1} S while minimum 1000 grains weight (50.7 g) was recorded in control. The results of T7 (90 kg P and 60 kg S ha^{-1}) were analogous with T8. The higher levels of P showed increased in grain weight along with 90 kg S ha^{-1} but the S levels beyond 45 kg ha^{-1} were not appropriate for raising the grain mass which might be due to dietary imbalance (Fig. 4.4). The results of The authors in [38] supported findings and assumed that fertilization of S at the rate of 30 kg ha^{-1} greatly boosted the 1000-grain weight where as levels above from 30 kg ha^{-1} were not favorable. It was further noted that although biological yield was higher with 90 kg P + 45 kg S but the higher grain yield was noted when 120 kg P + 45 kg S was applied, that was most probably due to heavier grains produced by this treatment.

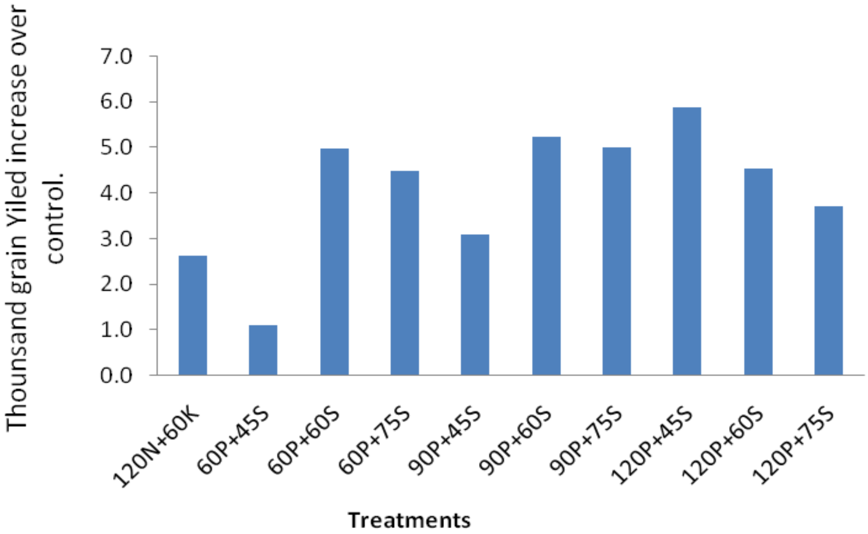

Figure 5: Thousand grain yield increase over control by different levels of P and S

3.5 Soil AB-DTPA Extractable P

The results (Table 4.2) showed that AB-DTPA extractable phosphorus concentrations in soil at anthesis stage were significant 5% level of probability.

The elevated absorption of P (40.13 mg kg^{-1}) was recorded in treatment (T9) where 120 kg ha^{-1} P + 45 kg ha^{-1} S were applied and low concentration (3.8 mg kg^{-1}) was noted in control. With the increase in S addition the extractability decreased that might due to formation of insoluble P complexes.

The phosphorus conc. after harvesting was also significantly affected by the fertilization of different levels of P and S (Table 4.2). The high P conc. (2.96 mg kg^{-1}) was recorded in treatment (T9) whereas 120 kg ha^{-1} P + 45 kg ha^{-1} S were applied and least conc. (0.67 mg kg^{-1}) was recorded in control.

The highest P conc. in T10 was statistically similar to T9 where P and S were applied at the rate of 120 kg ha^{-1} P + 60 kg ha^{-1} S. Compared to the P conc. at anthesis stage, it was noted that there was several fold decrease in P conc. during harvesting which may be due to crop removal.

Table 4: Soil AB-DTPA Extractable P at anthesis and after harvesting

S.No	**Treatments (kg ha^{-1})**	**Soil P concentration at anthesis**	**Soil P concentration after harvesting**
		mg kg^{-1}	
1	Control	3.80 c	0.67 f
2	120N + 60K	4.24 c	0.76 ef
3	60P + 45S	12.13 bc	1.09 def
4	60P + 60S	5.56 c	1.35 def
5	60P + 75S	6.72 c	1.53 cde
6	90P + 45S	20.16 bc	1.15 def
7	90P + 60S	13.04 bc	1.87 bcd
8	90P + 75S	18.22 bc	2.66 ab
9	120P + 45S	40.13 a	2.96 a
10	120P +6 0S	24.71 ab	2.23 abc
11	120P + 75S	19.44 bc	1.49 cdef
LSD ($P \leq 0.05$)		16.81	0.84

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

3.6 Soil SO_4-S concentration at anthesis stage

The SO4-S concentration of soil at anthesis was statistically significant for different levels of P and S application (Table 4.3) and the analysis of variance in appendix-7 showed higher S concentration (71.02 mg kg^{-1}) was observed in treatment (T6) where 90 kg ha^{-1} P + 45 kg ha^{-1} S were applied and low concentration (36.99 mg kg^{-1}) was observed in control plot.

The authors in [18] reported higher values of sulfur where high level of sulfur was applied compared to control or where low levels were applied to maize crop.

3.7 Soil SO_4-S concentration after harvesting

The higher concentration of SO_4-S in soil after harvesting was 64.03 mg kg^{-1} in T7 (90 kg ha^{-1} P + 60 kg ha^{-1}) and low concentration (20.89 mg kg^{-1}) was observed in control plot.

The authors in [18] studied that increasing S doses improved the existing SO_4-S in soil.The authors in [7] stated that SO_4-S in soil was amplified with afterward augmentation of S addition.

Table 5: Soil available SO_4-S concentration at anthesis and after harvesting

S.No	Treatments (kg ha^{-1})	Soil S concentration at anthesis	Soil S concentration after harvesting
		mg kg^{-1}	
1	Control	36.99 f	20.89 f
2	120N + 60K	38.64 ef	34.47 e
3	60P + 45S	68.44 ab	58.65 b
4	60P + 60S	37.95 ef	35.70 e
5	60P + 75S	61.42 abcd	48.49 cd
6	90P + 45S	71.02 a	33.58 e
7	90P + 60S	51.27 cdef	64.03 a
8	90P + 75S	67.05 abc	44.50 d
9	120P + 45S	54.14 cde	38.42 e
10	120P +6 0S	67.85 ab	52.05 c
11	120P + 75S	47.67 def	62.12 ab
LSD ($P\leq0.05$)		16.48	5.10

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

3.8 P concentration of leaves at anthesis stages

The data on concentration of P in wheat leaves at anthesis stage resulted significant variations when different levels of P and S were applied (Table 4.4) and the analysis of variance in appendix-9. Mean values of the result indicated that maximum P concentration (0.21 %) was recorded in treatment (T6) where P and S were used it the rate of 90 kg ha^{-1} P + 45 kg ha^{-1} S. The lowest P concentration (0.16 %) was recorded in control plot. These results showed that (Fig. 9) S addition beyond 45 kg ha^{-1} resulted in reduction in P content of leaves indication its antagonistic effect. The total grain yield was recorded i.e. rising S levels beyond 60 kg ha^{-1} results decline in weight of grain and grain yield. The authors in [4] stated that P with S be detrimental when limited dose of S was useful that might have prohibited P buildup in the plant and its absorption improved in soil.

3.9 Sulfur Concentration (SO_4-S) of wheat Leaves at anthesis stage

The sulfur concentrations in wheat leaves at anthesis stage are shown in Table 4.4 and the analysis of variance in appendix-10. The SO_4-S absorption in wheat leaves at anthesis stage was statistically significant for different levels of P and S application.

The highest value (0.27%) of S concentration was recorded in treatment (T6) where P and S were applied at the rate of 90 kg ha^{-1} P + 45 kg ha^{-1} S. The lowest S (0.11%) concentration was recorded in control plot (Fig.10).The authors in [18.22] also observed that the S concentration in plant tissue improved with higher rates of S application.

Table 6: Effect of different levels of P and S on plant P and S concentration of wheat

S.No	Treatments (kg ha^{-1})	Phosphorus concentration in plants		Sulfur concentration in plants	
		(%)			
1	Control	0.16	d	0.11	e
2	120N + 60K	0.18	b	0.21	b
3	60P + 45S	0.17	d	0.21	b
4	60P + 60S	0.17	bcd	0.16	d
5	60P + 75S	0.17	d	0.17	cd
6	90P + 45S	0.21	a	0.27	a
7	90P + 60S	0.17	cd	0.19	bcd
8	90P + 75S	0.17	bcd	0.20	bc
9	120P + 45S	0.17	d	0.26	a
10	120P +6 0S	0.20	a	0.19	bcd
11	120P + 75S	0.18	bc	0.22	b
LSD ($P \leq 0.05$)		0.016		0.033	

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

3.10 Phosphorus uptake in wheat leaves at anthesis stage

The uptake of phosphorus in wheat leaves at anthesis was statistically significant for different levels of P and S application (Table 4.5).

It mean values indicated that maximum P uptake (15.8%) was noted in treatment (T6) where P and S were applied at the rate of 90 kg ha^{-1} P + 45 kg ha^{-1} S. The lowest uptake of P (4.1 %) was noted in control plot.

3.11 Sulfur uptake in wheat leaves at anthesis stage

The results in the Table 6 showed that S uptake in wheat leaves at anthesis stage were significantly effected with the application of various level of P and S.

The higher uptake of P (19.5 %) was recorded in treatment (T6) where 90 kg ha^{-1} P + 45 kg ha^{-1} S were applied and low uptake (2.6 %) was noted in control.

The authors in [19] studded that S above 60 kg ha^{-1} when applied it reduced yield and yield components. The authors in [4] suggests an adverse effect of S on yield associated with elevated tissue S levels per se and / or with antagonistic effect of S on other nutrient such as phosphorus.

Table 7: Effect of different levels of P and S on nutrient (P and S) uptake of wheat

S.No	Treatments (kg ha^{-1})	Plant P Uptake	Plant S Uptake
		mgkg^{-1}	
1	Control	4.1 d	2.6 e
2	120N + 60K	9.2 b	10.6 b
3	60P + 45S	9.9 d	12.5 b
4	60P + 60S	10.4 bcd	9.9 d
5	60P + 75S	9.5 d	9.6 cd
6	90P + 45S	15.8 a	19.5 a
7	90P + 60S	10.8 cd	12.2 bcd
8	90P + 75S	11.1bcd	13.4 bc
9	120P + 45S	9.9 d	15.2 a
10	120P +6 0S	12.8 a	13.0 bcd
11	120P + 75S	11.4 bc	12.5 b
LSD ($P \leq 0.05$)		0.0160	0.0325

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

4. Conclusions

1: The maximum biological yield and straw yield was recorded in T6 where P and S were used at the rate of 90 P + 75 S kg ha^{-1} and the minimum yield was noted in control plot. The highest grain and 1000 grain weight was noted at T9 receiving P and S at the rate of 120 + 45 kg ha^{-1} respectively.

2: The highest AB-DTPA extractable phosphorus amounts in soil at various developmental stages were significantly different and the higher fraction of P was noted when 120 kg ha^{-1} P +45 kg ha^{-1} S was used (T9).

3: Likewise, the higher SO_4-S concentration of soil at anthesis and after harvesting stage was observed in T6 and T7 respectively where 45 and 60 kg ha^{-1} S + 90 kg ha^{-1} P was used.

4: The higher P and S concentration were recorded in treatment (T6) where P and S were supplied at the rate of 90 kg ha^{-1} P + 45 kg ha^{-1} S. The least amounts were noted in control plots.

5. Recommendations

1. Further experiments on different combination of S with P and other major elements like N and K are required for confirmation of results.

2. The residual effect of P and S on the following crop is needed to study the long term effect of S and P.

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