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Effect of sources and levels of sulphur on yield, quality and uptake of nutrients in pearl millet (*Pennisetum glaucum*) and wheat (*Triticum aestivum*) grown in sequence on an alluvial soil

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ABSTRACT

A field experiment was conducted for two consecutive years (2016-17 and 2017-18) to study the effect of source and levels of sulphur on yield, quality and uptake of nutrients by pearl millet [Pennisetum glaucum (L) RBr emend Stuntz) and wheat (Triticum aestivum (L) ement Fiori & Pool) grown in sequence on an alluvial soil of Agra (U.P.). Four sources of S (gypsum elemental S, SSP and pyrite) and levels of S (0, 10, 20 and 40 kg S ha^{-1}) were evaluated in factorial randomized block design with three replications. The results revealed that grain and stover yields of pearl millet were improved significantly with increasing level of sulphur up to 20 kg S ha^{-1} over control. An increase of 25.0 and 25.7% in grain and stover of pearl millet was recorded with 20 kg S ha^{-1}. Further increase in the level of S (40 kg ha^{-1}) had an adverse effect on yields of pearl millet. However, protein content and yield of pearl millet increased with the increase in levels of S. Among source of S, gypsum and SSP, being at par were significantly superior to elemental S and pyrites in respect of yields and quality of pearl millet. The residual S at 40 kg ha^{-1} significantly increased the yield of wheat grain and straw from 5.18 to 5.90t ha^{-1} and 7.38 to 8.2t ha^{-1}, respectively. Among the source of S, pyrites showed higher residual effect in increasing wheat yield as compared to rest. The content (13.8) and yield (814.2 kg ha^{-1}) of protein in wheat were recorded highest with 40 kg S ha^{-1}. Protein content in wheat was not affected by sources of S but protein yield was highest with pyrites. The uptake of N, P and S by both the crops increased significantly with sulphur application. The highest uptake of these nutrients was recorded with gypsum in pearl millet and with pyrites in wheat.

Keywords: Sulphur sources, residual effect, pearl millet, wheat, quality, yield.

INTRODUCTION

Pearl millet (*Pennisetum glaucum*) and wheat (*Triticum aestivum*) is an important crop sequence grown in Agra region of Western Uttar Pradesh. Being the exhaustive crops, both pearl millet and wheat require large amounts of nutrients for producing higher yields. Sulphur is considered as fourth major plant nutrient and plays an important role in improving yield and quality of the crops. It plays an important role in the formation of S-containing amino acids like cystine, Cystein and methionine which act as building blocks in the synthesis of protein. It has a role to play in increasing chlorophyll formation and aiding photosynthesis. Sulphur also plays a role in the activation of enzymes, nucleic acids and forms a part of biotin and thiamine. Sulphur fertilizers are most commonly available as either soluble sulphate or elemental forms. Use of rich reserves of indigenous sulphur sources, namely gypsum and pyrites could be a suitable alternative. Significant responses to sulphur application in crops viz., rice and pea (Kumar *et al.* 2014), green gram (Singh *et al.* 2017), pearl millet and lentil (Singh *et al.* 2016), soybean (Dixit *et al.* 2016), mustard (Singh *et al.*, 2020), wheat (Singh *et al.* 2014) have been reported. There is a need to evaluate suitable source of sulphur which should be agronomically effective, easily available as well as economically efficient. The aim of the present study was to evaluate the direct and residual effect of sources and levels of sulphur on yield, quality and uptake of nutrients in pearl millet and wheat grown in a sequence on alluvial soil of Agra district of western Uttar Pradesh.

MATERIALS AND METHODS

An experiment was conducted during kharif and rabi seasons of two consecutive years (2016-17 and 2017-18) at farmers field at Panwari village of Agra district (Uttar Pradesh). The experimental site is characterized by semi-arid climate with extreme temperature during summer (45^0 to 48^0 C) and very low temperature during winter (as low as 2^0 C). The average rainfall is about 650 mm, most of which is received from June to September. The

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experimental soil was sandy loam in texture having pH 7.9, organic carbon 3.1 g kg^{-1}, available N 145 kg ha^{-1}, available P 9.5 kg ha^{-1}, available K 106 kg ha^{-1} and available S 15.5 kg ha^{-1}. The experiment was laid out in factorial randomized block design with three replications. The treatments consisted of four sources of S viz. gypsum, pyrites, elemental sulphur and single superphosphate and four levels of S viz. 0, 10, 20 and 40 kg S ha^{-1}.The direct effect of sources and levels of S was studied with pearl millet and their residual effect was studied in the succeeding wheat crop. Gypsum and single superphosphate were applied at the time of sowing and pyriles and elemental sulphur were applied two weeks before sowing. A basal dose of 100 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} to pearl millet and 150 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} to wheat was applied through urea, diammonium phosphate and muriate of potash, respectively. Full dose of P and K and half dose of N were applied at the time of sowing. Remaining nitrogen was top-dressed in two splits. After the harvest of kharif pearl millet, wheat was grown as residual crop during the winter (rabi) season in the same layout without application of sulphur. Crops were harvested at maturity. At harvest, grain and stover/straw yields of both the crops were recorded. The grain and straw samples were digested in diacid mixture (3:1 of HNO_3: $HClO_4$) and analysed for P by molybdovanadate yellow colour method and S by turbidimetric method (Chesnin and Yien 1951). Nitrogen content in grain and straw was determined by modified Kjeldahl method (Jacson, 1973). Post harvest soil samples collected after two years of experiment were air dried ground to pass 2mm sieve and analysed for available S after extraction with 0.15% $CaCl_2$ solution. The data obtained from consecutive two years were statistically analysed as per procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield

The results indicated that the increase in the grain yield of pearl millet (3.85t ha^{-1}) over control (3.08t ha^{-1}) was to the extent of 25.0% due to the application of 20 kg S $ha^{-1,}$ while that of stover (9.09t ha^{-1}) was 25.7% over control (7.23t ha^{-1}). Further, increase in S levels above 20 kg S ha^{-1} had an adverse effect in increasing yield of pearl millet. Among the sources of S, gypsum and SSP produced higher grain yield of 3.68 and 3.66t ha^{-1}, respectively as compared to elemental sulphur (3.36t ha^{1}) and pyrites (3.38t ha^{-1}). Yield of pearl millet straw followed a similar trend as it was in case of grain with sources and levels of sulphur. Superiority of gypsum may be attributed to improved soil physical condition of soil which ultimately results in better growth of the crop. The poor response of elemental sulphur and pyrites might be due to low oxidation rate to form sulphate. Such response of sulphur was reported by Kumar *et al.* (2014) in rice, Singh *et al.* (2014) in pearl millet. Residual effect of applied levels and sources of sulphur to pearl millet was evident on succeeding wheat crop (Table 1).

Table 1: Effect of sources and levels of sulphur on yield and quality of pearl millet and wheat (mean of 2 years)

Treatment	Pearl millet				Wheat			
	Yield (t ha^{-1})		Protein Content (%)	Protein yield (kg ha^{-1})	Yield (t ha^{-1})		Protein Content (%)	Protein Yield (kg ha^{-1})
	Grain	Stover			Grain	Straw		
Sources of Sulphur								
Gypsum	3.68	8.52	10.4	382.7	5.47	7.77	13.4	733.0
PyriteS	3.38	7.85	10.1	341.8	5.73	7.98	13.6	779.2
Elemental S	3.36	7.89	10.1	339.3	5.64	7.87	13.5	761.4
SSP	3.66	8.49	10.3	377.0	5.43	7.72	13.4	727.6
CD (P=0.05)	0.10	0.23	0.24	8.16	0.14	0.17	NS	15.6
Sulphur (kg ha^{-1})								
0	3.08	7.23	9.8	301.8	5.18	7.38	13.0	673.4
10	3.56	8.07	10.2	363.1	5.47	7.76	13.3	727.5
20	3.85	9.09	10.5	404.2	5.72	8.03	13.6	778.0
40	3.60	8.37	10.6	381.6	5.90	8.26	13.8	814.2
CD (P=0.05)	0.10	0.23	0.24	8.16	0.14	0.17	0.23	15.6

The effect of residual S was more pronounced at higher level of S than at lower levels. The highest grain and straw yields were 5.90 and 8.26 t ha^{-1}, respectively with 40 kg S ha^{-1} and resulted in 16.9 and 15.7 % increase over control. Pyrites proved its superiority over gypsum and SSP in increasing the yield of wheat. Higher grain (5.73 t ha^{-1}) and straw (7.98 t ha^{-1}) yields were recorded with pyrites as compared to gypsum and SSP but remained at par with the yields obtained with elemental S. Higher efficiency of pyrites for supply of S might be due to the fact that after complete oxidation, it was relatively more efficient than gypsum and SSP as obtained by the residual response to wheat. Similar results were reported by Kumar *et al.* (2014).

Quality

Protein content of pearl millet grain was markedly increased due to sulphur application (Table 1). The magnitude of increase in protein content due to sulphur application varied from 98 to 10.6 per cent. Among the levels of S, maximum protein content was recorded with 40 kg S ha^{-1}. This increase in protein content with S application could be due to the fact that S is an integral part of S containing amino acids namely methionine, cystine and cystein (Singh *et al.* 2014). Application of 20 kg S ha^{-1} recorded the highest yield of protein (404.2 kg ha^{-1}) which may be attributed to higher grain yield as well as increased protein content. Application of gypsum remained at par with SSP which recorded higher protein content and yield of pearl millet as compared to pyrites and elemental sulphur Dwivedi *et al.* 2008.

Protein content in grain of wheat was significantly increased with increasing levels of applied sulphur to pearl millet crop (Table 1). The maximum value of protein content (13.8%) was recorded with 40 kg S ha^{-1}.Among the sources of sulphur, the protein content in wheat grain was marginally higher with residual SSP and gypsum but protein yield was significantly higher with pyrites compared to the other treatments. Residual levels and sources of sulphur increased the protein yield of wheat which varied from 673.4 to 814.2 kg ha^{-1} and from 727.6 to 779.2 kg ha^{-1}, respectively. Similar results were observed by Singh *et al.* (2017) in green gram.

Table 2: Effect of sources and levels of sulphur on uptake of nutrients (kg ha^{-1}) by pearl millet (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw
Sources of Sulphur						
Gypsum	61.4	45.6	9.2	9.2	8.4	12.3
Pyrites	55.4	36.0	8.0	8.6	8.0	12.0
Elemental S	54.7	38.0	8.4	9.2	7.1	9.5
SSP	59.3	41.9	8.7	9.1	8.0	11.4
CD(P=0.05)	1.90	1.08	0.46	0.38	1.10	1.30
Sulphur (kg ha^{-1})						
0	48.7	31.3	7.3	17.6	5.2	9.1
10	54.7	40.5	8.9	9.6	7.5	11.9
20	63.4	50.9	10.0	11.4	9.2	12.2
40	60.4	46.1	9.0	9.8	9.3	12.5
CD(P=0.05)	1.90	1.08	0.46	0.38	1.1	1.30

Uptake of nutrients

Nitrogen uptake by pearl millet grain and stover increased significantly with increasing levels of S and the highest N uptake was observed with 20 kg S ha^{-1} i.e. 63.4 and 50.9 kg ha^{-1} and lowest in the control i.e. 48.7 and 31.3 kg ha^{-1}. Higher values of N uptake with increasing levels of S are apparently the result of favourable effect of the sulphur on N content coupled with grain and stover yield. Similar results were also reported by Singh *et al.* (2016). Gypsum and SSP being at par, proved significantly superior to elemental S and pyrites in enhancing the uptake of nitrogen by pearl millet.The lower valuesofNuptakewithelemental S may be due to lower grain and stover yield of pearl millet. Singh *et al.* (2017)

alsoreported similar results in green gram. The uptake of P by pearl millet grain and stover increased significantly with increasing levels of S up to 20 kg ha^{-1}. The magnitude of increase in P uptake with 20 kg S ha^{-1} was 36.9 and 50.0 per cent in grain and stover, respectively over the control. The higher P removal due to S application could be attributed to the priming effect caused by higher crop growth and consequently higher removal due to balanced fertilization. The results corroborate with the finding of Singh *et al.* (2016). SSP proved significantly superior to elemental S and pyrite. The sulphur uptake by pearl millet grain and straw increased with added sulphur levels which varied from 5.2 to 9.3 kg ha^{-1} and 9.1 to 12.5 kg ha^{-1}, respectively. The corresponding ranges of S uptake by grain and straw with source of S were 7.1 to 8.4 kg ha^{-1} and 9.5 to 12.3 kg ha^{-1}. Gypsum remained at par with SSP and recorded higher uptake of S by grain and straw than that of pyrites. Among the levels of S, application of 20 kg S ha^{-1} recorded significantly higher S uptake as compared to the rest except 40 kg S ha^{-1}.

Table 3: Effect of sources and levels of sulphur on uptake of nutrients (kg ha^{-1}) by wheat (mean of 2 years)

Treatment	Ncitrogen		Phosphorus		Sulphur	
	Grain	Stover	Grain	Stover	Grain	Stover
Sources of sulphur						
Gypsum	118.6	42.7	12.2	11.1	14.3	14.5
Pyrites	123.1	42.2	12.6	11.6	15.3	15.3
Elemental S	121.8	42.4	12.4	11.0	15.7	16.5
SSP	116.7	40.9	11.9	11.5	14.1	13.8
CD (P=0.05)	4.32	1.13	NS	NS	1.09	1.23
Sulphur (kg ha^{-1})						
0	108.2	36.9	10.3	8.8	10.8	11.8
10	117.0	41.1	12.5	10.8	13.6	13.9
20	124.6	44.5	13.7	12.8	16.5	16.8
40	131.0	47.9	13.6	12.4	18.8	18.9
CD(P=0.05)	4.3	1.13	0.88	1.13	1.09	1.23

The uptake of N by wheat grain and straw was significantly affected by the residual effect of sulphur application in pearl millet. On an average the uptake of N by grain and straw increased with 40 kg S ha^{-1} applied in proceeding by 15.1 and 20.5 %, respectively over the control. Similar results were reported by Singh *et al.* (2014). Among the sources of sulphur, pyrites proved significantly superior to other sources of sulphur in enhancing the absorption of N from the soil by wheat SSP treated plants utilized lowest amounts of nitrogen due to lower grain and straw yield of wheat. The residual effect of S levels was noticed on P uptake by wheat grain and straw. The data (Table 3) revealed that there was a significant effect of the levels of S to produce higher P uptake by wheat than the control. This may be attributed to increase in P content and yield of crop with S application. Our results confirm the finding of Singh *et al.* (2020). Pyrites brought about a higher uptake of P by wheat over other sources of sulphur which may be attributed to higher grain and straw yield. The sulphur uptake by grain and straw of wheat ranged remarkably with the residual levels and sources of sulphur. Pyrites was found significantly superior to gypsum and SSP in respect of S uptake by wheat crop. Residual sulphur applied as elemental sulphur resulted in higher S uptake (15.7 kg ha^{-1} by grain and 16.5 kg ha^{-1} by straw) as compared to the rest. Among the levels of S, the uptake of sulphur increased progressively with the increase in residual sulphur levels from 10 to 40 kg S ha^{-1} (Table 3) similar results were reported by Singh *et al.* (2014).

It may be concluded from the results that a significantly beneficial effect in pearl millet and wheat grown in sequence could be achieved by the application of sulphur in alluvial soil. Application of gypsum or SSP recorded substantial increase in yield, quality and uptake of nutrients in pearl millet. Residual effect of 40 kg S ha^{-1} through pyrites applied in pearl millet proved beneficial for wheat crop grown in sequence in an alluvial soil.

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