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DIRECT AND RESIDUAL EFFECTS OF SULPHUR IN PEARL MILLET-WHEAT CROP SEQUENCE

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ABSTRACT

A field experiment was conducted for two consecutive years (2008-09 and 2009-10) at Lakhaoti (Bulandshahr) to assess the direct and residual effects of different rates of applied sulphur on yield of pearl millet and wheat and uptake of nutrients by the crops and soil fertility under pearl millet-wheat crop sequence. The experiment was laid out in randomized block design with five levels of S (0, 15, 30, 45 and 60 kg ha^{-1}) with four replications. Results indicated that increasing levels of S upto 30 kg ha^{-1}, significantly increased the grain and stover yield of pearl millet by 28.8 and 26.4%, respectively, over control. The grain and straw yields of succeeding wheat increased significantly by 13.9 and 14.8%, respectively at 45 kg S ha^{-1} applied to preceding pearl millet crop over control. The protein content and protein yield of pearl millet and wheat increased significantly with S level over control. The uptake of N, P, K, S and Zn by pearl millet significantly increased with S levels upto 45 kg ha^{-1}. On the other hand, uptake of N, P, K, and S significantly increased with 60 kg S ha^{-1}, but Zn uptake increased upto 45 kg S ha^{-1}. Agronomic efficiency and apparent S recovery were also higher at 15 kg S ha^{-1} in peral millet and at 30 kg S ha^{-1} in wheat. Application of 60 kg S ha^{-1} significantly improved the available S status in soil after harvest of pearl millet and wheat. Net return and B:C ratio in crop sequence were highest at 45 kg S ha^{-1}.

Key words: Direct, residual effect, sulphur, yield, nutrients uptake, pearl millet, wheat.

INTRODUCTION

Intensification of cropping without balanced fertilization had led to depletion of soil fertility to a great extent. Pearl millet wheat cropping system, a most important cereal-based cropping system followed in western Uttar Pradesh, is of no exception. This will result in decline in yield of both the crops. In recent years sulphur emerged as a vital nutrient and is non widely accepted as the fourth major plant nutrient alongwith N, P and K. Sulphur influences yield and quality of cereal crops as it is involved in the synthesis of essential ammo acids like cysteine, cystine and methionine. Being the exhaustive crops, pearl millet and wheat require huge amount of nutrients for producing more yield. The experimental results at various places indicated that both pearl millet and wheat responded well to sulphur application (Sharma and Manohar 2002). Jena et al (2006) reported that the 60 kg S ha^{-1} as gypsum to groundnut- rice cropping system recorded highest cumulative grain yields (groundnut -1.75 t ha^{-1} and rice -3.00 t ha^{-1}). The nutrients applied in one crop are not fully utilized, which leads to their residual effect on succeeding crop. Thus, sulphur application benefits more than one crop and shows a significant residual effect on the following crop. Since, information on direct and residual effects of sulphur in pearl millet-wheat crop sequence in Agra region is meager. Therefore a field experiment was conducted with the aim to study the direct and residual effect of sulphur application on productivity, protein content, nutrient uptake in pearl millet-wheat crop sequence.

MATERIALS AND METHODS

A field experiment was conducted from rainy season 2008 to 2009 to rabi season 2008-10 at A.S. College Research farm Lakhaoti, (Bulandshahr). The soil was sandy loam in texture, alkaline (pH 8.2) in reaction, low in initial available N (140 kg ha^{-1}) and S (8.5 mg kg^{-1}) and medium in available P_2O_5 (22.0 kg ha^{-1}) and K_2O (179.0 kg ha^{-1}). The experiment comprising of 4 levels sulphur (0, 15, 30, 45 and 60 kg ha^{-1}) was laid out in randomized block design with four replications. Pearl millet was sown in the last week of June during both the years at a row spacing of 45 cm using seed rate of 5 kg ha^{-1}. A uniform dose of 120 kg N, 60 kg P_2O_5 and 40 Kg K_2O ha^{-1} was applied through urea, triple superphosphate and muirate of potash, respectively. Elemental sulphur was applied as a source of S to pearl millet only as per treatments- One third of nitrogen and full dose of phosphorus and potassium were drilled basally at the time of sowing. Remaining N was applied 30 days after sowing of the crop. The crop was raised with recommended package of practices. After harvesting of pearl millet, wheat PBW 343 was sown in the same plots. In the first week of November using seed rate of 125 kg ha^{-1}

at a row spacing of 20 cm. Recommended dose of N (150 kg), P (60 kg P_2O_5 ha^{-1}) and potassium (60 kg K_2O ha^{-1}) were applied through urea, diammonium phosphate and muriate of potash, respectively. Half dose of N and full doses of P and K were applied at the time of sowing and the remaining N was applied in two equal splits at the time of first and second irrigation. The crop was raised with recommended package of practices. Grain and straw yields were recorded at harvest. Nitrogen in grain and straw samples of both the crops was analysed by micro Kjeldahl method. Grain and straw samples were digested in diacid ($HClO_4$ and HNO_3) mixture. Phosphorus, K, S and Zn in the acid digest were determined by vanado molybdo yellow colour method, flamephotometer, (Jackson, 1973) turbidimetric method (Chesnin and yean 1951) and atomic absorption spectrophoto meter, respectively. The protein content in grain was calculated by multiplying nitrogen percentage in grain with a factor of 6.25.

RESULTS AND DISCUSSION

Direct effect on peral millet

Increasing levels of S significantly increased the grain and straw yields of pearl millet up to 30 kg S ha^{-1}. The mean increases were 28.8 and 26.9% in grain yield and stover yield due to application of 30 kg S ha^{-1}. The increase in the yield of pearl millet was because of higher rate of protein synthesis and enhanced photosynthetic actively of the plants with increased chlorophyll synthesis due to fertilizer with sulphur. Similar results were reported by Sharma and Manohar (2002) and Kumar *et al.* (2011) who reported that grain and stove yields of pearl millet and rice were higher in the S-treatment plots than those in control.

Residual effect on wheat

Sulphur fertilization recorded significant residual effect on succeeding wheat crop (Table 1). Application of 45 kg S ha^{-1} to pearl millet increased the grain and straw yields of succeeding wheat by 13.9 and 14.8% over control. It was interesting to note that the improvement due to residual effect of S was continuous with an increasing level of S application to the preceding pearl millet crop. Residual effect of S was observed on wheat crop due to improved nutritional environment in rhizosphere and consequently in plant system (Dwivedi *et al.* 2008). Thus, it indicated that the higher level of S application was necessary to obtain higher crop yields of succeeding wheat in pearl millet wheat cropping system. Similar were the findings of Kumar *et al.* (2011) in rice-wheat cropping system.

Table 1: Effect of sulphur levels on yield, protein content of pearl millet and wheat (mean of 2 years)

Sulphur (kg ha^{-1})	Crop yield (q ha^{-1})				Protein (%)		Protein yield (kg ha^{-1})	
	Pearl millet (direct)		Wheat (residual)					
	Grain	Straw	Grain	Straw	Pearl millet	Wheat	Pearl millet	Wheat
0	18.23	45.56	41.21	53.56	9.87	13.24	179.8	545.7
15	20.50	50.63	42.82	56.10	10.00	13.40	205.0	573.8
30	23.48	57.61	45.20	59.88	10.31	13.53	242.0	611.6
45	23.36	57.23	46.96	61.50	10.46	13.71	244.3	639.6
60	21.05	51.76	46.38	60.84	10.62	13.90	223.5	644.4
CD (P=0.05)	1.17	2.60	2.86	4.61	0.19	0.21	24.9	36.67

Quality

Application of 60 kg S ha^{-1} to pearl millet crop significantly increased the protein content in grain from 9.87 to 10.62 percent. Residual effect of S upto 60 kg S/ha significantly improved the protein content in wheat grain from 13.24 to 13.90 percent (Table 1). This may be attributed to significant role of S in protein, synthesis and nitrogen metabolism in the plant. Trivedi *et al.* (2008) also reported similar results. There was a consistent and significant increase in protein yield of pearl millet and wheat with increasing levels of sulphur and maximum values in pearl millet (244.3 kg ha^{-1}) and wheat (644.4 kg ha^{-1}) were recorded at 45 and 60 kg S ha^{-1} respectively. This increase in protein yield due to S levels may be attributed to increased yield and protein content in both the crops, Ram *et al.* (2014) reported similar results in rice-wheat cropping system.

Nutrient uptake

Average over two years, application of 15, 30, 45 and 60 kg S ha^{-1} increased the total N uptake in pearl millet by 14.2, 25.8, 40.5 and 28.8% over control, respectively. Corresponding increases in total N uptake in wheat crop were 6.4, 14.5, 19.7 and 23.4%. Since, N uptake is the product of N concentration and yield, so highest total N uptake was observed in pearl millet and wheat with 45 and 60 kg S ha^{-1}, respectively. Application of 60 kg S ha^{-1} to preceding pearl millet crop showed maximum residual effect on N uptake in succeeding wheat crop. Sulphur is an essential constituent of enzymes involved N metabolism, i.e. nitrate reductase; its application could lead to increase in N assimilation. Ram *et al.* (2014) reported that sulphur has positive interaction with nitrogen; application of sulphur increases the N uptake by the crop. Addition of sulphur also resulted in increased P and K uptake by pearl millet and wheat (Table 2). Sulphur improves the growth of roots and shoots of the plants in S deficient soil, so plant roots enhance the uptake rate of both the nutrients. The P and K uptake by pearl millet and wheat were increased significantly upto 45 and 60 kg S ha^{-1} over control, respectively. Sulphur applied to preceding pearl millet crop showed significant residual effect on P and K uptake by wheat. Kumar *et al.* (2011) and Ram *et al.* (2014) reported that P and K uptake were stimulated in the presence of sulphur.

Table 2: Direct and residual effect of S levels on total uptake of NPK S (kg ha^{-1}) and Zn (g ha^{-1}) by pearl millet and wheat

Sulphur (kgha^{-1})	Pearl millet					Wheat				
	N	P	K	S	Zn	N	P	K	S	Zn
0	50.6	9.5	101.4	9.7	181.7	116.0	14.6	135.8	15.6	247.5
15	57.8	11.1	112.1	11.8	199.8	123.5	17.2	143.3	18.4	254.3
30	63.7	11.9	120.3	13.8	207.8	132.8	19.2	155.4	21.5	211.4
45	71.1	13.7	131.9	16.9	220.7	138.8	20.4	159.3	24.7	252.4
60	65.2	13.0	119.5	16.0	194.4	143.1	21.5	160.0	27.5	239.2
CD (P=0.05)	5.2	2.42	8.94	1.32	11.75	7.46	4.70	16.86	2.68	9.87

Sulphur application upto 45 kg ha^{-1} in pearl millet significantly increased its total uptake by the crop. The residual effect of S was also beneficial in enhancing the total uptake of S by wheat crop upto 60 kg S ha^{-1}. Since, grain and straw yields of both the crops were recorded higher with application of sulphur, so total S uptake by both the crops was also recorded greater with S application. The total S uptake in pearl millet increased by 21.6, 42.2, 74.2 and 65.0% with 15, 30, 45 and 60 kg S ha^{-1}, respectively. The corresponding increases in total S uptake in wheat were 17.4, 37.8, 58.3 and 76.3%. This could be due to the balanced nutritional environment inside the plant and higher photosynthetic efficiency which may favour better growth and crop yield and ultimately higher uptake of S. The total uptake of Zn by pearl millet increased significantly upto 45 kg S ha^{-1} followed by a reduction at 60 kg S ha^{-1}. The significant residual effect of sulphur on total Zn uptake by succeeding wheat was observed upto 45 kg S ha^{-1}. The higher level of S tended to decrease the uptake of Zn by the crop which might be due to antagonistic effect of S on Zn utilization.

Economics

Maximum net returns of ` .56509.90 ha$^{-1}$ was recorded with 45 kg S ha$^{-1}$ which was higher by `. 9698.90 ha^{-1} compared with control. The benefit cost ratio was highest (3.33) at 45 kg S ha^{-1} application. Increasing levels of S beyond 45 kg ha^{-1} reduced the net returns and benefit cost ratio in pearl millet-wheat crop sequence due to increased cost of these inputs. Likewise the benefit cost ratio was increased from 2.94 in control to 3.33 in 45 kg S ha^{-1}. The increase in net returns with S application might be due to positive effect on yield.

Table 3: Effect of direct and residual effect of S levels on net return of crop sequence, apparent recovey and status of available S in soil after harvest of wheat

Sulphur (kg ha^{-1})	Crop sequence		Pearl millet		Available S (mg kg^{-1})	Wheat	
	Net return (Rs ha^{-1})	B:C Ratio	% apparent recovery	S use efficiency (kg grain increased/kg S)		%, apparent recovery	S use efficiency (kg grain increased/kg S)
0	46811	2.94	-	-	7.6	-	-
15	50071	3.08	5.46	12.33	8.5	10.93	10.73
30	54032	3.32	5.31	10.86	9.8	11.81	13.30
45	56509.9	3.33	5.68	11.40	11.5	10.57	11.49
60	54026.9	3.01	3.51	4.66	13.0	9.84	9.58
CD (P=0.05)					0.81		

Efficiency indices

Data on sulphur use efficiency (SUE) and apparent sulphur recovery (ASR) are present in Table 3. The sulphur use efficiency ranged from 4.66 to 12.33 kg gram increased/ kg S in pearl millet. The corresponding range of SUE in wheat was from 9.58 to 13.30 kg grain increased/kg S. The maximum value of SUE was 12.33 kg grain increased/ kg S in pearl millet at 15 kg S ha^{-1} and 13.30 kg grain increased/kg S in wheat at 30 kg S ha^{-1}. Percent apparent sulphur recovery tended to decrease in both the crops with increasing levels of S and minimum values were recorded at 60 kg S ha^{-1}. Similar results were reported by Jena *et al.* (2006).

The available S content in post harvest soils ranged from 7.6 to 13.0 mg kg^{-1} with S application (Table 3). The available S in control was 7.6 mg kg^{-1} as against the initial value of 8.5 mg kg^{-1} indicating the depletion of native sulphur by 10.6%. The available S increased significantly with increasing S level from 7.6 to 13.0 mg kg^{-1}. This increase in available S content in soil was due to its addition.

From the present investigation, it may be inferred that application of 30 kg S ha^{-1} in pearl millet resulted in higher yields and uptake of nutrients by pearl millet with a residual effect that could produce wheat gram and straw yield which was at par with the effect of highest S application (45 kg ha^{-1}) Therefore, it is concluded that application of 45 kg S ha^{-1} appears to be the best dose for obtaining higher productivity and utilization of nutrients in pearl millet-wheat crop sequence under agro-climatic condition of Agra region.

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