Annals of Plant and Soil Research 20(3): 233–238 (2018)

Direct effect of sulphur and zinc on productivity, quality and nutrient uptake by pearl millet (*Pennisetum glaucum)*and their residual effect on succeeding wheat (*Triticum aestivum*) in pearl millet – wheat crop sequence

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Received: January, 2018; Revised accepted: May, 2018

ABSTRACT

A field experiment was conducted at Research farm of Raja Balwant Singh College, Bichpuri, Agra to study the effect of sulphur and zinc on productivity, nutrient uptake and quality of pearlmillet (Pennisetum glaucum L.) in pearl millet-wheat crop sequece during 2015-16 and 2016-17. Sulphur and zinc levels alone and in different combinations were applied to pearl millet crop during 2015 and 2016 and their residual effect was studied in succeeding wheat (Triticum aestivum) crop. Higher levels of S and Zn along with RDFrecorded higher growth and yield attributes at harvest viz., plant height, length and width of ear and and test weight of pearl millet crop than recommended dose of fertilizers and other treatments. Significantly higher grain and stover yield of pearl millet crop was recorded with the combined application of 20 kg S + 4 kg Zn ha^{-1} along with recommended dose of NPK fertilizers (RDF) which was significantly superior to RDF. The highest levels of S and Zn (40 kg S + 8 kg Zn + RDF) could not improve the yield significantly over 20 kg S + 4 kg Zn + RDF. The uptake of S and Zn by both grain and straw of pearl millet crop also increased with increasing levels of both these elements and was superior to RDF as well as RDF along with sole application of S or Zn. Protein contents also followed the same increasing trend. The residual effect of combined application of 40 kg S + 8 kg Zn ha^{-1} on the grain and straw yields of succeeding wheat crop was also significant; the increases were 26.5 and 12.5 per cent for grain and straw yield, respectively over RDF. Protein content in grain and straw of wheat also increased significantly with residual effect of 40 kg S + 8 kg Zn ha^{-1}. Sulphur and zinc uptake by wheat crop also showed an increasing trend which was statistically significant over RDF alone and other treatments. The status of S and Zn in post harvest soil was also improved with their application.

Key words: Sulphur, pearl millet- wheat crop sequence, productivity, yield, zinc

INTRODUCTION

Pearl millet-wheat is a popular cropping sequence adopted in sandy loam areas, where deficiancy of Zn is a common occurrence. Even with the application of recommended dose of fertilizers, yield potential of pearlmillet-wheat has reached a platean (Chaube *et al.* 2007). Pearl millet is an energy rich crop which requires the major, secondary and micronutrients in adequate quantity for higher production. Pearl millet is quite responsive to secondary (S) and micronutrients (Zn) which plays an important role in growth and development of this crop. Zinc has vital role in carbohydrate and protein metabolism as well as it controls the plant growth hormone indole acetic acid (IAA). It is an essential component of dehydrogenase, proteinase and promotes starch formation, seed maturation and production. Sulphur is now recognized as fourth element whose deficiency is widespread in India. Sulphur deficiency is observed primarily due to high crop yield and, therefore, higher rate of removal by crop and lesser use of S containing fertilizers. The deficiencies of any one of the micronutrients adversely affect plant growth, development and ultimately yield thus minimizing the usefulness of other agricultural inputs including recommended dose of fertilizers comprising nitrogen, phosphorus and potassium. Moreover, it has been reported that S and Zn fertilizers have residual effects on crops (Rattan *et al. 2009*). Therefore, a suitable combination of S and Zn needs to be developed under pearl millet-wheat crop sequence. No information is available for the optimum dose and residual effect of sulphur and zinc fertilizers application for pearl millet-wheat system practiced in Agra region of Uttar Pradesh. Accordingly, the present investigation was undertaken to study the effect of S and Zn levels on yield, uptake and quality of pearl millet and their residual effect on wheat grown in alluvial soils of Agra region.

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MATERIALS AND METHODS

A field experiment was conducted at the research farm of Raja Balwant Singh College Bichpuri, Agra (U.P.) during kharif and rabi seasons of 2015-16 and 2016-17.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 soil of the experimental site is sandy loam in texture having p^H 8.0 with low organic carbon content (3.1 g kg^{-1}) and low in available N (175 kg ha^{-1})and medium in available P (11 kg ha^{-1}) and K (120 kg ha^{-1}). The soil had $CaCl_2$ extractable sulphur content of 16 kg ha^{-1} and DTPA extractable - Zn 0.54 mg kg ha^{-1}. The experiment was conducted in randomized block design with nine treatments replicated thrice. The treatments were T_{-1}: recommended dose of fertilizers (RDF) @ 100:60:40 kg ha^{-1} NPK, T_2: RDF + 20 kg S ha^{-1}, T_3: RDF + 40 kg S ha^{-1}, T_4 : RDF + 4 kg Zn ha^{-1}, T_5: RDF + 8 kg Zn ha^{-1}, T_6: RDF + 20 kg S + 4 kg Zn ha^{-1}, T_7: RDF + 20 kg S + 8 kg Zn ha^{-1}, T_8: RDF + 40 kg S + 4 kg Zn ha^{-1} and T_9: RDF + 40 kg S + 8 kg Zn ha^{-1}. Pearl millet (var. Pioneer 86 M 86) was grown as a test crop and sown in rows 30 cm apart in the first week of July and harvested in first week of October during both the years. Half dose of N and full amounts of P, K, S and Zn were applied at the time of sowing and the remaining N was top- dressed at first irrigation.. The nutrients were supplied using urea, diammonium phosphate, muriate of potash, elemental sulphur and zinc oxide, respectively. The residual effect of S and Zn levels was studied in succeeding wheat crop with PBW 502as test crop. The RDF *viz*., 150:60:40 kg ha^{-1} N, P_2O_5 and K_2O was applied to wheat during the following rabi season in both the years of experimentation. The plant height, test weight, grain and straw yields were recorded at maturity. The grain and straw yields were recorded plot-wise after threshing of the produce. The grain and straw samples of pearl millet and wheat were collected for the chemical analysis of S and Zn. The Zn content in grain and straw of pearl millet and wheat was determined using atomic absorption spectrophotometer from di-acid (nitric and perchloric acid) digest. Sulphur content in the grain and straw samples was analyzed by turbidimetric method (Chesnin and Yion, 1951). Sulphur content in soil was extracted with 0.15% $CaCl_2$ solution and determind by turbidimetric method. The DTPA extractable Zn in soil was estimated in post-harvest samples after wheat crop as per method of Lindsay and Norvell (1978). Total N content in pearl millet and wheat samples was determined by Kjeldahl method and protein content was obtained by multiplying with a factor of 6.25. The uptake of nutrients was computed from their concentrations in grain and straw and respective yields of both crops. Data obtained from consecutive two years were statistically analyzed as per procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield attributes and yield of pearl millet

Growth and yield parameters like plant height, length and width of ear, grain/ ear and 1000 seeds weight were influenced significantly with different treatments of S and Zn (Table-1). Higher values of these parameters were recorded with RDF + 20 kg S + 4 kg Zn ha^{-1}. Plant height was recorded significantly highest in RDF + 20 kg S + 4 kg Zn ha^{-1} which was at par with RDF +40 kg S + 4 kg Zn ha^{-1} and RDF +40 kg S + 8 kg Zn ha^{-1} but found significantly superior over other treatments. Length and width of ear and number of grains/ear were also recorded significantly higher in RDF + 20 kg S + 4 kg Zn ha^{-1} and remained at par with RDF +20 kg S + 8 kg Zn ha^{-1} but significantly superior to RDF and other treatments. Test weight, showed significant increase with RDF + 20 kg S + 4 kg Zn ha^{-1}, over 75% RDF only. Singh *et al.* (2015) also reported increased growth and yield attributes with S in pearl millet crop. Positive effect of Zn on growth and yield attributes of pearl millet was also reported by Jain and Dahama (2006) and Singh and Singh (2017). Significantly higher pearl millet grain yield of 33.75 q ha^{-1} was observed in treatment RDF + 20 kg S + 4 kg Zn ha^{-1}, which was at par with treatments RDF + 20 kg S + 8 kg Zn ha^{-1} and RDF +40 kg S + 8 kg Zn ha^{-1} but remained significantly superior over RDF and other treatments. The increase in grain yield was recorded to the tune of 22.7 per cent with RDF + 20 kg S + 4 kg Zn ha^{-1} over RDF. Stover yield was also recorded highest in T_7 but remained significantly superior to RDF and other treatments (Table 1). The higher doses of S and Zn (40 kg S + 8 kg Zn ha^{-1}) could not improve the yields significantly over 20 kg S + 4 kg Zn ha^{-1}. The higher values of yield may be attributed to application of S and Zn along with RDF as S and Zn are involved in cell division, enzyme activation and with their increased supply to mustard, their availability, acquisition, mobilization and influx into the plant tissuse increased and thus improved growth attributes and yield components and finally the yield. These results are in conformity with those of Singh *et al.* (2015) Chaube *et al.* (2007) and Chauhan *et al.* (2017) who also observed that the combined application of Zn and S resulted in higher yield than the application of S and Zn alone.

Table 1: Effect of sulphur and zinc levels on growth, yield attributes and yield of pearl millet in pearl millet-wheat crop sequence (pooled data of 2 years)

Treatments		Plant height (cm)	Length of ear (cm)	Width of ear (cm)	Grain weight /ear (g)	Test weight (g)	Yield (q /ha)	
							Grain	Stover
T_1	RDF	188	21.80	11.1	22.4	11.40	27.50	68.75
T_2	RDF + 20kg S ha^{-1}	191	21.90	11.3	22.7	11.55	30.10	76.75
T_3	RDF + 40 kg S ha^{-1}	195	22.05	11.5	23.0	11.66	32.00	79.50
T_4	RDF + 4kg Zn ha^{-1}	188	21.60	11.2	22.5	11.53	29.75	73.85
T_5	RDF + 8kg Zn ha^{-1}	193	21.80	11.4	22.8	11.55	30.80	77.05
T_6	RDF + 20kg S + 4 kg Zn ha^{-1}	198	22.48	11.8	23.3	12.10	33.75	84.00
T_7	RDF + 20kg S + 8 kg Zn ha^{-1}	200	22.50	11.9	23.5	12.20	35.27	86.75
T_8	RDF + 40kg S + 4 kg Zn ha^{-1}	201	22.49	11.9	23.4	12.30	36.10	87.00
T_9	RDF + 40kg S + 8kg Zn ha^{-1}	202	22.50	12.0	23.5	12.35	36.85	87.87
CD (P=0.05)		5.12	1.18	0.15	0.27	0.17	1.75	3.15

Sulphur and zinc uptake by pearl millet

Sulphur and Zn uptake by pearl millet crop differed in different treatment combinations and higher uptake of these nutrients was observed in treatment supplying nutrients in high quantity. Sulphur, uptake by both grain and stover of pearl millet was observed highest in treatment RDF + 40 kg S + 8 kg Zn ha^{-1} though it remained at par with treatment RDF + 20 kg S + 4 kg Zn ha^{-1}, but was found significantly superior to RDF and other treatments (Table-2). Zinc uptake was also reported highest in RDF + 20 kg S + 8 kg Zn ha^{-1} though it remained at par with treatments RDF + 40 kg S + 4 kg Zn ha^{-1} and RDF +20 kg S + 8 kg Zn ha^{-1} and significantly superior to RDF and other treatment combinations (Table 2). The higher nutrient uptake (Zn and S) in grain and stover of pearl millet was mainly attributed to higher levels of these nutrients as the nutrient uptake was increased with successive increase in chemical fertilization. The balanced nutrition also enhanced the synergistic effect on uptake of plant nutrients (Singh *et al.* 2012 and Singh and Singh, 2017).

Protein

Protein content in pearl millet grain increased significantly over RDF with application of S and Zn (Table 2). The maximum protein content of 9.56 % was recorded with RDF + 40 kg S + 8 kg Zn ha^{-1} which was significantly superior to RDF. This might be due to increased N content with concomitant application of S and Zn in grain leading to higher protein. Verma *et al.* (2012) and Singh *et al.* (2015) also reported that the application of S and Zn significantly increased grain yield and protein content and nutrient uptake in pearl millet.

Table 2: Effect of various treatments on sulphur and zinc uptake, quality indices of pearl millet in Pearl millet – wheat crop sequence (pooled data of 2 years)

Treatments	Sulphur uptake (kg ha^{-1})		Zinc uptake (g ha^{-1})		Protein content (%)
	Grain	Stover	Grain	Stover	
T_1 RDF	4.1	4.8	59.1	203.5	9.06
T_2 RDF + 20kg S ha^{-1}	5.1	6.9	64.4	224.1	9.19
T_3 RDF + 40 kg S ha^{-1}	5.7	7.9	68.8	235.3	9.31
T_4 RDF + 4kg Zn ha^{-1}	4.5	5.9	76.0	251.1	9.12
T_5 RDF + 8kg Zn ha^{-1}	4.3	6.2	90.8	263.5	9.25
T_6 RDF + 20kg S + 4 kg Zn ha^{-1}	5.7	9.2	78.8	255.3	9.37
T_7 RDF + 20kg S + 8 kg Zn ha^{-1}	5.8	11.2	73.7	255.9	9.50
T_8 RDF + 40kg S + 4 kg Zn ha^{-1}	5.4	8.7	95.5	348.0	9.40
T_9 RDF + 40kg S + 8kg Zn ha^{-1}	6.3	10.5	99.0	337.4	9.56
CD (P=0.05)	0.43	0.56	2.91	5.44	0.25

Residual effect of S and zinc on wheat

Yield attributes and yield

Residual effect of applied S and Zn levels to pearl millet crop was evident on succeeding wheat crop (Table 3). Impact of residual S and Zn was more pronounced at their higher levels (40 kg S+8 kg Zn ha^{-1}) along with RDF than at lower level (20 kg S+4 kg Zn ha^{-1}). Residual effect of S and Zn showed significant effect on yield attributes of wheat. The residual effect of higher levels of 40 kg S + 8 kg Zn ha^{-1} along with RDF was significant on length of ear, width of ear, grain weight / ear and test weight. The favourable effect of residual S and Zn on growth and yield attributes may be attributed to their role in many physiological processes and cellular functions in plant. It is quite obvious that the experimental soil was deficient in S and Zn, so residual effect was found favourable on the growth and yield attributes of wheat (Jain and Dhama, 2006, Singh *et al.* 2015). The grain and straw yield of wheat increased under the residual effect of increasing S and Zn levels. The residual effect of different combinations of S and Zn in preceding pearl millet crop resulted in increased yield of succeeding wheat crop. In wheat crop, increased level of S up to 40 kg ha^{-1} and Zn up to 8 kg ha^{-1} in combination with RDF recorded highest grain (53.37 q ha^{-1}) and straw (76.13 q ha^{-1}) yield in wheat crop. Increase in grain and straw yield was to the tune of 26.4 and 55.2 per cent more in treatment supplying 40 kg S+8 kg Zn ha^{-1} over RDF, respectively (Table 3). In general, the marked impovement in productivity of wheat with residual effect of S and Zn could be ascribed to the enhancement of S and Zn content in soil. These finding are in accordance with those reported by Chaube *et al.* (2007), Singh *et al.* (2015).

Table 3: Residual effect of sulphur and zinc on growth, yield attributes and yield of wheat in pearl millet-wheat sequence (pooled data of 2 years)

Treatments	Plant height (cm)	Length of ear (cm)	Grain weight/ ear (g)	Test weight (g)	Yield (q ha^{-1})	
					Grain	Straw
T_1 RDF	83.7	8.03	37.1	46.9	42.20	60.43
T_2 RDF + 20kg S ha^{-1}	85.0	8.10	38.1	47.5	43.45	61.10
T_3 RDF + 40 kg S ha^{-1}	86.0	8.15	38.9	48.0	45.50	66.06
T_4 RDF + 4kg Zn ha^{-1}	84.8	8.0	37.8	47.1	42.90	61.32
T_5 RDF + 8kg Zn ha^{-1}	85.2	8.10	38.5	47.6	4.89	63.00
T_6 RDF + 20kg S + 4 kg Zn ha^{-1}	87.8	8.20	39.6	48.0	47.02	67.48
T_7 RDF + 20kg S + 8 kg Zn ha^{-1}	88.8	8.26	40.2	8.6	49.50	69.43
T_8 RDF + 40kg S + 4 kg Zn ha^{-1}	89.2	8.60	41.5	48.9	51.49	73.67
T_9 RDF + 40kg S + 8kg Zn ha^{-1}	90.5	9.13	43.0	49.1	53.37	76.13
CD (P=0.05)	2.30	0.24	2.06	0.66	3.53	5.61

Protein

Residual effect of sulphur and zinc levels had significant beneficial effect on protein percentage in wheat grain over RDF alone. The maximum percentage of protein content in grain (12.31%) was recorded under RDF + 40 kg S+8 kg Zn ha^{-1} applied in preceding pearl millet crop. Similar increase in protein content in wheat was also reported by Singh *et al.* (2015).

Uptake of nutrients

The uptake of S and Zn by wheat grain and straw was significantly affected by their residual effect. The uptake of S and Zn by grain and straw increased with combined application of S and Zn in different proportions and maximum values of S and Zn uptake were recorded with residual effect of 40 kg S+8 kg Zn ha^{-1} treatment (Table 4). The response of wheat crop to applied S and Zn in preceding pearl millet crop may be attributed to an enhanced availability of S and Zn in soil at a level below which the optimum requirement of crop is fulfilled. This showed that enhancement in S and Zn levels not only increased the yield but also increased their content and ultimately their uptake (Chaube *et al.* 2007, Singh *et al.* 2015).

Table 4: Residual effect of sulphur and zinc on their uptake by wheat crop and status of S and Zn post harvest soil (pooled data of 2 years)

Treatments	Sulphur uptake (g/ ha^{-1})		Zinc uptake (g/ha^{-1})		Protein content (%)	Avail. B (mg /kg)	Avail. Zn (mg /kg)
	Grain	Stover	Grain	Stover			
T_1 RDF	7.6	6.0	78.0	142.6	12.00	13.2	0.50
T_2 RDF + 20kg S ha^{-1}	8.7	6.7	82.5	146.6	12.12	17.0	0.51
T_3 RDF + 40 kg S ha^{-1}	10.0	7.9	89.2	171.7	12.25	21.2	0.53
T_4 RDF + 4kg Zn ha^{-1}	8.1	6.7	98.7	169.8	12.06	13.3	0.71
T_5 RDF + 8kg Zn ha^{-1}	8.5	6.3	110.0	189.0	12.19	13.5	0.85
T_6 RDF + 20kg S + 4 kg Zn ha^{-1}	10.3	8.1	112.0	191.6	12.25	17.7	0.69
T_7 RDF + 20kg S + 8 kg Zn ha^{-1}	10.4	7.6	117.8	180.7	12.37	18.0	0.84
T_8 RDF + 40kg S + 4 kg Zn ha^{-1}	11.8	9.6	125.6	191.5	12.19	22.0	0.66
T_9 RDF + 40kg S + 8kg Zn ha^{-1}	11.7	9.1	123.5	213.1	12.31	22.5	0.80
CD (P=0.05)	1.11	0.72	3.51	6.82	0.35	0.17	0.10

Soil fertility status

Different levels of Zn (4 and 8 kg ha^{-1}) and S (20 and 40 kg ha^{-1}) significantly increased the available Zn and S content in post harvest soil over RDF (Table 4). However, Zn applied @ 4 and 8 kg ha^{-1} alone or in combination with S were found at par but proved significantly superior to RDF with respect to available Zn status in post harvest soil. Higher Zn content of 0.84 mg kg^{-1} was reported in treatment RDF + 20 kg S + 8 kg Zn ha^{-1} which was significantly superior to RDF and treatments where only S was applied (T_4 and T_5). The lowest content of Zn was observed in RDF (0.50 mg kg^{-1}). Sulphur content in post harvest soil was observed highest (22.5 mg kg^{-1}) in RDF + 40 kg S + 8 kg Zn ha^{-1} and lowest (13.2 mg kg^{-1}) in RDF These results are in conformity with those of Singh and Singh (2017) who also reported increased Zn status in soils after harvesting of wheat.

The study showed that the application of 20 kg S + 4 kg Zn ha^{-1} along with RDF in soil might be useful in enhancing productivity and quality of pearl millet. The residual effect on wheat was evident up to 40 kg S + 8 kg Zn ha^{-1}. The highest S and Zn uptake by both the crops was recorded with 40 kg S + 8 kg Zn ha^{-1}. These results can be applicable for obtaining higher productivity and quality of both crops in pearl millet – wheat crop sequence in alluvial soils of Agra having deficiency of S and zinc.

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