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Effect of sulphur and zinc nutrition on nutrient uptake and fertility balance of chickpea (*Cicer arietinum* L.)

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Abstract
A field experiment on chickpea was conducted at Agriculture Farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.) during *rabi* season 2007-08 and 2008-09. Results revealed that basal application of sulphur 40 kg/ha and zinc 5 kg/ha recorded significantly superior grain and straw yield during both the years. Grain yield was also significantly improved with foliar spray of Zn 0.5 % and S 2%. Sulpur and zinc uptake by grain and straw of chickpea was recorded significantly superior under 40 kg S/ha however, it observed conspicuously higher total S and Zn uptake by chickpea (7.8 and 9.22 kg S/ha; 0.101 and 0.114 kg Zn) during two years. Basal application of zinc 5 kg/ha significantly improved S and Zn uptake by grain and straw and recorded markedly higher total S (7.3 and 8.11 kg/ha) and Zn uptake (0.108 and 0.111 kg/ha) by chickpea during both the years. Foliar spray of sulphur 2% significantly increased S uptake by grain and straw and observed numerically higher total uptake of chickpea while, zinc spray 0.5% recorded significantly greater Zn uptake by grain and straw and markedly higher total Zn uptake of chickpea. Positive fertility balance of sulphur in soil was noted in treatments with 40 kg S/ha and 20 kg S/ha however, maximum positive fertility balance was recorded in S_{20} x Zn_0 x FS_2 followed by in S_{40} x Zn_5 x FS_2. Maximum negative balance of S was noted in treatment with no sulphur application. Positive fertility balance in term of zinc availability in soil was recorded in Zn 5 kg/ha however, it was observed maximum in S_0 x Zn_5 x FS_3 (2.34 kg/ha) followed by in S_0 x Zn_5 x FS_2 (1.71 kg/ha). The negative fertility balance of zinc in soil was noted in treatment with no basal application of zinc in soil.

Keywords: Chickpea, yield, S and Zn uptake, fertility balance, sulphur, zinc, basal, foliar application

Introduction

Chickpea (*Cicer arietimum* L.) is the third most important food legume grown in over 45 countries in all Continents of the World. In India, chickpea ranks first among the legumes in area occupying of 105.73 lakh hectare, production of 111 lakh tonnes and productivity of 1056 kg/ha (Anonymous, 2018-19) [2]. Madhya Pradesh has contributed a significant 34% of the total chickpea area and 41% of total chickpea production in the country, thereby ranking first both in area and production. Chickpea is generally grown in rainfed areas which yield is low due to inadequate supply of nutrient, limited irrigation, unavailability of high yielding varieties and improper plant protection measures. If leguminous plant is adequately supplied with all mineral elements essential, *Rhizobium* can fix N_2 nitrogen actively. In this respect elements like P, Ca, S, Mo, Zn, Fe, Co and B play an important role (Shubba Rao, 1997) [12]. The supplementation of secondary nutrient like sulphur and micronutrient like zinc along with Rhizobium in chickpea may increase biological nitrogen fixation and there by its productivity.

Sulphur is most prominent essential nutrient plays an important role in sulphur containing amino acids and vitamins. It also helps in synthesis of chlorophyll and nodules formation and growth of *Rhizobium* bacteria. For several years, it was referred as neglected nutrient elements but now it is gaining increasing importance especially for pulse crops. Now a day, the adoption of intensive cropping and fertilization of adequate and imbalance amount has created the low soil-S-reserve in the various part of the region. Data indicated that S deficiency in Indian soil is extensive (up to 64% of the samples tested). Most of the pulse crops were responsive to S application, although the extent of response varied among crops depending upon soil test S. Since, the area specific adequate information on S nutrition of chickpea is not available therefore S nutrition for chickpea is the necessities of the today.

Zinc is an essential micronutrient and becoming deficient in large area under cultivation in India. Despite of this fact not much work has been done regarding response of legumes to zinc in India. Zinc is constituent of several enzymes, which regulates various metabolic activities in the plants. It is also associated with water uptake and water relation to plants. It influences the hormone formation and helps in reproduction of the plants. It has in a vital role for the synthesis of protein and nucleic acid and helps in the utilization of N and P in plants. It also promotes nodulation and N-fixation in leguminous crops. The major causes associated with zinc deficiency in soils are intensive cultivation, high soil pH, high carbonate content and no use of micronutrient fertilizers. In pulse growing areas, the needs of zinc is increasing due to there continues depletion in the soil. Several workers reported the response of Zn from 2 to 20 kg/ha in the different parts of India to pulse crops like gram, green gram, soybean and Pigeon pea (Ali and Kumar, 2005) [1]. Zinc concentration in roots and shoots of maize plants were increased by zinc application both in soil and foliar. Soil application of fertilizer leads to losses of nutrients in the form of leaching, volatilization and fixation affecting the nutrient use efficiency. There is increasing evidence showing that foliar or combined soil + foliar application of zinc fertilizers under field conditions are highly effective and very practical way to maximize uptake and accumulation of zinc in plants. Thus to maintain the soil health, basal and foliar spray of sulphur and zinc application are used to be standardised. Therefore, keeping this view, the studies were carried out to study the basal and foliar fertilization of sulphur and zinc on quality and nutrient uptake of chickpea.

Methods and Materials

The study was conducted at the Agriculture Farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidyalaya, Chitrakoot, Satna (M.P.) during the *rabi* season of 2007-08 and 2008-09. The soil of experimental field was sandy loam with neutral in soil pH (7.4 and 7.5) and low in organic carbon (0.23 and 0.47%) and available N (103 and 198 kg N/ha), medium to high phosphorus (24.35 and 28.1 kg P/ha), medium in potassium (124 and 228 kg K/ha), sulphur with 47.16 and 52.68 kg S/ha and zinc 2.14 and 2.28 kg Zn/ha during two respective years. The experiment consisted three levels of sulphur (0, 20, 40 kg S/ha), two levels of zinc (0, 5 kg Z/ha) and three levels of foliar spray (water spray, sulphur 2.0 %, zinc 0.5 %). In all 18 treatments will be tested in RBD (factorial) with three replications. An uniform doses of NPK @ 20: 40: 20 kg N_2: P_2O_5: K_2O/ha were applied as basal. Sulphur and zinc were applied as per treatment. However, foliar spray was done at initiation of flower and ten days after first spray. The chickpea variety Uday was sown on 11th Oct 2007 and 27th Sep 2008 in two respective years at a row spacing of 30 cm apart using seed rate 100 kg/ha. The plant to plant spacing was maintained 05 cm by thinning at 20 DAS. Crop was protected from weeds by using one hand weeding at 30 DAS. However, insect pest was controlled by spraying of Dimethoate @ 2 ml/litre water at pod formation stage. The crop was harvested on 25th March 2008 and 10th March 2009 in two respective years. The important growth parameters, yield attributes and yield were recorded at appropriate time as per standard procedure. Zinc was estimated by DTPA extractable zinc (Lindsay and Norvell, 1978) [8] with the help of Atomic Absorption Spectrophotometer. The fertility balance in term of nutrient was calculated by substracting the initial soil test value from soil test value at harvest. The experimental data was statistically analysed by Panse and Sukhatme (1985) [9]. The treatment differences were tested by using "F" test and critical differences at 5% probability.

Results and Discussion

Yield

The grain yield of chickpea was significantly increased (1923 and 2051 kg/ha) with the application of sulphur up to 40 kg/ha and showed 30.19 and 40.86 percent higher over control during 2007-08 and 2008-09, respectively. However, basal application of sulphur 40 kg/ha produced significantly superior straw yield and gave 28.02 and 32.97% more than that of control, in two respective years (Table 1). This could be ascribed due to superior value of growth parameters and yield attributes of chickpea. Sulphur application improved yield of chickpea with sulphur (Thomas *et al.*, 2010) [13].

Zinc application @ 5 kg Zn/ha produced significantly higher grain (1839 and 1968 kg/ha) and straw yield (1730 and 1821) of chickpea and gave 12.96 and 49.84% more grain yield and 9.6 and 8.24 % higher straw yield over control during two consecutive the years (Table 1). Such increase could be associated with greater value of growth and yield parameters which resulted superior grain yield. Similar results were also reported by Ram and Katiyar (2018) [11].

The grain yield of chickpea was significantly increased with the foliar application of zinc 0.5% (1806 and 1930 kg/ha) and sulphur 2% (1760 and 1803 kg/ha) over control during 2007-08 and 2008-09, respectively (Table 1). The straw yield of chickpea (1717 and 1829 kg/ha) was significantly enhanced with the application of zinc 0.5% over control and sulphur 2% two years. Foliar application zinc 0.5% produced 10.45 percent and 14.45 percent more seed yield and 6.33 and 7.78% straw yield than that of control in two respective years. The improvement in seed yield by zinc application might be due to increase in synthesis of carbohydrate and protein and their translocation to the sink through efficient physiological activity in plants as evident from superior physiological parameters like growth and yield contributing characters. The results are in accordance with those reported by Puste and Jana (1995) [10].

Sulphur and Zinc uptake by Plant

Sulphur uptake

Sulpur uptake by grain and straw of chickpea was recorded significantly higher under 40 kg S/ha over control and 20 kg S/ha during both the year except 2008-09 where S uptake in straw at 20 kg S/ha recorded statistically at par with 40 kg S/ha (Table 2). Total S uptake by chickpea was found conspicuously higher under 40 kg S/ha (7.8 and 9.22 kg S/ha) over control (5.02 and 4.9 kg S/ha) and 20 kg S/ha (7.13 and 7.91 kg S/ha) during two years. This might be due to higher value grain and straw yield and sulphur content in grain and straw under this treatment. This trend was perhaps to establish favourable N:S ratio in the vegetative tissue of the plant The uptake of phosphorous increased significantly with increasing levels of sulphur (Kachhave *et al.* 1997) [6]. Gupta and Singh (1983) [4] showed that uptake of sulphur increased significantly with nitrogen, phosphorous and sulphur application.

Basal application of zinc 5 kg/ha significantly improved S uptake by grain and straw over control. However, total S uptake (7.3 and 8.11 kg/ha) by chickpea was observed markedly higher under 5 kg Zn/ha than control during both

the years. It could be associated with marginal higher sulphur content in grain. Such higher S uptake might be due to synergistic effect of zinc on the sulphur uptake by plant.
Foliar spray of sulphur 2% significantly increased S uptake by grain and straw of chickpea over control during both the years however, total S uptake of chickpea was found conspicuously higher than control (Table 2). This could be ascribed due higher foliar supplement of sulphur to plant. Zinc foliar spray 0.5% recorded marginally higher S uptake by grain and straw of chickpea than that of control during two years however, total S uptake was noted numerically greater over control. This exhibited that balance supply of zinc might have promoted the uptake of sulphur by plant.

Zinc uptake

Zinc uptake by grain of chickpea was recorded significantly higher under 40 kg S/ha during both the years. However, zinc uptake by straw was significantly increased up to 40 kg S/ha during 2007-08 while in 2008-09, Zn uptake in straw was observed significantly up to 20 kg S/ha and statistically at par with 40 kg S/ha (Table 2). Total Zn uptake was found numerically higher under 40 kg S/ha (0.101 and 0.114 kg Zn) over control (0.068 kg Zn/ha) and 20 kg S/ha (0.091 and 0.094 kg Zn/ha) during two consecutive years. Such increase could be associated with superior grain and straw yield and zinc content in grain and straw. The solubility of Zn increases as soil pH decreases (Yoo and James, 2003) [15]. Therefore the increase in tissue Zn uptake might be due to acidifying effect of S which resulted in increased availability of Zn in soil (Cui and Wang, 2005) [3]. Similar results have been reported by Islam (2012) [5] in chickpea crop.
Application of zinc 5 kg/ha significantly improved Zn uptake by grain and straw of chickpea however, total Zn uptake (0.108 and 0.111 kg/ha) was observed markedly higher under 5 kg Zn/ha than control during two years (Table 2). This could be ascribed due to higher zinc content and greater yield of chickpea crop. Such increase in Zn uptake might be due to balance supply of zinc through basal addition of zinc in soil. Nutrients viz. N, P, K, S and Zn uptake in seed and stover were highest in 10 kg/ha zinc treatment (Ram and Katiyar, 2018) [11].
Foliar spray of sulphur 2% significantly enhanced Zn uptake by grain of chickpea over control during both the years. This might due to positive effect of sulphur on zinc uptake. Zinc foliar spray 0.5% recorded significantly higher Zn uptake by grain and straw of chickpea than that of control during two years however; total Zn uptake was noted numerically greater over control**.** This might be due to more availability of sulphur and zinc to plant through foliar spray which resulted greater uptake of these nutrient.

Fertility balance of sulphur and zinc in soil at harvest
Sulphur Status in soil

Fertility balance in term of available sulphur status in soil after harvest of the crop was expressed during two years. Positive balance of sulphur in soil was observed in all treatments which have received 40 kg S/ha, 20 kg S/ha with no zinc and foliar spray of water, 20 kg S/ha x Zn 5 kg/ha x foliar spray of water and S 2% and Zn 0.5% (Table 3a & 3b). However, maximum positive fertility balance was noted in S_{20} x Zn_0 x FS_2 (T_{14}) followed by in S_{40} x Zn_5 x FS_2 (T_{17}). Positive balance of S in soil could be ascribed due to basal application of sulphur with synergistic absorption of S by addition of foliar spray of S 2% or Zn 0.5% during two years. The results are in agreement with findings of Kader and Mona (2013) [7].
The treatment having no sulphur application (T1 to T6) and S 20 kg/ha with foliar spray of water, sulphur 2% and zinc 0.5% (T7 to T9) were exhibited negative fertility balance of sulphur during two years except sulphur 20 kg/ha + Zn 0 kg/ha + foliar spray of water which had showed marginal positive balance in soil. Negative S balance might be due to more uptake of S without addition of basal sulphur.

Zinc Status in soil

Fertility balance was expressed in term of zinc status in soil after harvest of the crop. All the treatment with Zn 5 kg/ha recorded positive fertility balance in soil. Maximum positive fertility balance in term of zinc availability in soil was noted in S_0 x Zn_5 x FS_3 (2.34 kg/ha) followed by in S_0 x Zn_5 x FS_2 (1.71 kg/ha), S_{20} x Zn_5 x FS_3 (1.25 kg/ha) and S_{20} x Zn_5 x FS_1 (1.25 kg/ha). While, the negative fertility balance or least positive balance of zinc in soil was noted in treatment with no basal application of zinc in soil during both the years (Table 4a & 4b). The positive balance of zinc in soil might be due to basal addition of zinc in soil with higher uptake of zinc by plant. The results are in agreement with findings of Kader and Mona (2013) [7] and Tripathi *et al.* (1997) [14].
Thus it can be concluded that basal application of sulphur 20 to 40 kg/ha and zinc 5 kg/ha and as well as foliar spray of S 2% and Zn 0.5% significantly increased the S and Zn uptake of chickpea. Positive fertility balance of sulphur and zinc in soil was found in basal addition of 20-40 kg S/ha with Zn 5 kg/ha.

Table 1: Effect of sulphur and zinc as basal and foliar application on yield of chickpea.

Treatment	Yield (kg/ha)			
	Grain		Straw	
	2007-08	2008-09	2007-08	2008-09
S Level (kg S /ha)				
0	1477	1456	1431	1504
20	1801	1913	1699	1751
40	1923	2051	1832	2000
SEm±	26.44	23.30	19.12	21.03
CD (P=0.5)	75.99	66.98	54.95	60.46
Zn level (kg Zn /ha)				
0	1628	1646	1578	1682
5	1839	1968	1730	1821
SEm±	21.59	19.03	15.61	17.17
CD (P=0.5)	62.04	54.69	44.87	49.37
Foliar Spray				
Water spray	1635	1687	1593	1720
S - spray 2%	1760	1803	1652	1707
Zn spray 0.5%	1806	1930	1717	1829
SEm±	26.44	23.30	19.120	21.038
CD (P=0.5)	75.99	66.98	54.95	60.46

Table 2: Effect of sulphur and zinc as basal and foliar application on S and Zn uptake of chickpea.

Treatment	S Uptake (kg/ha)						Zn uptake (kg/ha)					
	Grain		Straw		Total		Grain		Straw		Total	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
S level (kg S /ha)												
0	2.69	2.65	2.33	2.25	5.02	4.9	0.048	0.048	0.02	0.02	0.068	0.068
20	3.75	4.41	3.38	3.50	7.13	7.91	0.061	0.064	0.03	0.03	0.091	0.094
40	4.20	5.02	3.60	4.20	7.8	9.22	0.071	0.074	0.03	0.04	0.101	0.114
SE m±	0.115	0.09	0.097	0.083	-	-	0.002	0.001	0.001	0.001	-	-
CD (P=0.5)	0.33	0.28	0.28	0.24	-	-	0.005	0.00	0.002	0.003	-	-
Zn level (kg Zn /ha)												
0	3.27	3.50	2.73	3.08	6.0	6.58	0.052	0.053	0.02	0.02	0.072	0.073
5	3.83	4.55	3.47	3.56	7.3	8.11	0.068	0.071	0.04	0.04	0.108	0.111
SE m±	0.094	0.080	0.080	0.068	-	-	0.001	0.0011	0.0004	0.001		
CD (P=0.5)	0.27	0.23	0.23	0.20	-	-	0.004	0.003	0.001	0.002		
Foliar Spray												
Water spray	3.23	3.64	2.78	3.16	6.01	6.8	0.055	0.055	0.03	0.03	0.085	0.085
S spray 2%	4.02	4.23	3.39	3.44	7.41	7.67	0.060	0.061	0.02	0.02	0.08	0.081
Zn spray 0.5%	3.40	4.22	3.14	3.35	6.54	7.57	0.065	0.070	0.03	0.04	0.095	0.11
SE m±	0.1151	0.09	0.097	0.083	-	-	0.002	0.001	0.001	0.001		
CD (P=0.5)	0.33	0.28	0.28	0.24	-	-	0.005	0.004	0.002	0.003		

Table 3a: Effect of sulphur and zinc as basal and foliar application on fertility balance of sulphur after crop harvest during 2007-08.

Treatments		Initial S In Soil (kg/ha) (a)	S Added to soil (kg/ha) (b)	Total Available S (kg/ha) c = (a+b)	S uptake by grain (kg/ha) (d)	S uptake by straw (kg/ha) (e)	Total S uptake (kg/ha) f =(d+e)	Apparent S balance (kg/ha) g= (c-f)	Available S after crop harvest (kg/ha) (h)	Depletion(-) buildup(+) of soil S (kg/ha) over basic initial i= (h-a)
T_1	$S_0Zn_0Fs_1$	47.16	0	47.16	1.81	1.66	3.47	43.69	32.37	-14.79
T_2	$S_0Zn_0Fs_2$	47.16	0	47.16	2.77	2.43	5.20	41.96	35.51	-11.65
T_3	$S_0Zn_0Fs_3$	47.16	0	47.16	2.44	2.03	4.47	42.69	29.79	-17.37
T_4	$S_0Zn_5Fs_1$	47.16	0	47.16	2.85	2.35	5.20	41.96	27.46	-19.70
T_5	$S_0Zn_5Fs_2$	47.16	0	47.16	3.34	2.84	6.18	40.98	25.36	-21.80
T_6	$S_0Zn_5Fs_3$	47.16	0	47.16	2.95	2.69	5.64	41.52	24.70	-22.46
T_7	$S_{20}Zn_0Fs_1$	47.16	20	67.16	3.84	2.83	6.67	60.49	47.69	0.53
T_8	$S_{20}Zn_0Fs_2$	47.16	20	67.16	4.86	3.00	7.87	59.29	43.75	-3.41
T_9	$S_{20}Zn_0Fs_3$	47.16	20	67.16	3.79	3.71	7.50	59.66	43.23	-3.93
T_{10}	$S_{20}Zn_5Fs_1$	47.16	20	67.16	3.77	3.71	7.48	59.68	55.88	8.72
T_{11}	$S_{20}Zn_5Fs_2$	47.16	20	67.16	4.66	3.63	8.29	58.87	58.68	11.52
T^{12}	$S_{20}Zn_5Fs_3$	47.16	20	67.16	3.15	3.39	6.54	60.62	51.56	4.40
T_{13}	$S_{40}Zn_0Fs_1$	47.16	40	87.16	3.65	2.46	6.10	81.06	91.59	44.43
T_{14}	$S_{40}Zn_0Fs_2$	47.16	40	87.16	4.29	3.32	7.62	79.54	105.98	58.82
T_{15}	$S_{40}Zn_0Fs_3$	47.16	40	87.16	3.54	3.15	6.68	80.48	77.29	30.13
T_{16}	$S_{40}Zn_5Fs_1$	47.16	40	87.16	4.11	3.66	7.76	79.40	85.13	37.97
T_{17}	$S_{40}Zn_5Fs_2$	47.16	40	87.16	5.12	5.11	10.23	76.93	98.26	51.10
T_{18}	$S_{40}Zn_5Fs_3$	47.16	40	87.16	4.52	3.90	8.42	78.74	93.85	46.69

Fs_1= Foliar spray of water; Fs_2= Foliar spray of S 2%; Fs_3= Foliar spray of Zn 0.5%

Table 3b: Effect of sulphur and zinc as basal and foliar application on fertility balance of sulphur after crop harvest during 2008-09.

Treatments		Initial S In Soil (kg/ha) (a)	S Added to soil (kg/ha) (b)	Total Available S (kg/ha) c = (a+b)	S uptake by grain (kg/ha) (d)	S uptake by straw (kg/ha) (e)	Total S uptake (kg/ha) f =(d+e)	Apparent S balance (kg/ha) g= (c-f)	Available S after crop harvest (kg/ha) (h)	Depletion(-) buildup(+) of soil S(kg/ha) over basic initial i= (h-a)
T_1	$S_0Zn_0Fs_1$	52.68	0	52.68	1.58	1.84	3.43	49.25	29.09	-23.59
T_2	$S_0Zn_0Fs_2$	52.68	0	52.68	2.28	1.99	4.26	48.42	34.15	-18.53
T_3	$S_0Zn_0Fs_3$	52.68	0	52.68	2.38	1.90	4.28	48.40	28.81	-23.87
T_4	$S_0Zn_5Fs_1$	52.68	0	52.68	2.91	2.38	5.29	47.39	27.72	-24.96
T_5	$S_0Zn_5Fs_2$	52.68	0	52.68	3.47	2.75	6.22	46.46	30.30	-22.38
T_6	$S_0Zn_5Fs_3$	52.68	0	52.68	3.30	2.66	5.96	46.72	26.61	-26.07
T_7	$S_{20}Zn_0Fs_1$	52.68	20	72.68	3.68	3.12	6.80	65.88	46.24	-6.44
T_8	$S_{20}Zn_0Fs_2$	52.68	20	72.68	4.14	3.38	7.52	65.16	50.51	-2.17
T_9	$S_{20}Zn_0Fs_3$	52.68	20	72.68	4.17	3.55	7.72	64.96	46.99	-5.69
T_{10}	$S_{20}Zn_5Fs_1$	52.68	20	72.68	4.39	3.45	7.84	64.84	55.45	2.77
T_{11}	$S_{20}Zn_5Fs_2$	52.68	20	72.68	5.03	3.82	8.85	63.83	61.67	8.99
T^{12}	$S_{20}Zn_5Fs_3$	52.68	20	72.68	5.02	3.65	8.68	64.00	53.50	0.82
T_{13}	$S_{40}Zn_0Fs_1$	52.68	40	92.68	4.17	3.92	8.09	84.59	100.74	48.06
T_{14}	$S_{40}Zn_0Fs_2$	52.68	40	92.68	4.42	4.16	8.58	84.10	101.76	49.08
T_{15}	$S_{40}Zn_0Fs_3$	52.68	40	92.68	4.69	3.82	8.51	84.17	83.39	30.71
T_{16}	$S_{40}Zn_5Fs_1$	52.68	40	92.68	5.09	4.22	9.31	83.37	97.96	45.28

T_{17} $S_{40}Zn_5Fs_2$	52.68	40	92.68	6.00	4.54	10.54	82.14	103.15	50.47
T_{18} $S_{40}Zn_5Fs_3$	52.68	40	92.68	5.73	4.54	10.28	82.40	99.24	46.56

Fs_1= Foliar spray of water; Fs_2= Foliar spray of S 2%; Fs_3= Foliar spray of Zn 0.5%

Table 4a: Effect of sulphur and zinc as basal and foliar application on fertility balance of Zn after crop harvest during 2007-08.

Treatment		Initial Zn in Soil (kg/ha) (a)	Zn Added to soil (kg/ha) (b)	Total Available S (kg/ha) c = (a+b)	Zn uptake by grain (kg/ha) (d)	Zn uptake by straw (kg/ha) (e)	Total Zn uptake (kg/ha) f =(d+e)	Apparent Zn balance (kg/ha) g= (c-f)	Avail-able Zn after crop harvest (kg/ha) (h)	Depletion (-) buildup(+) of soil Zn (kg/ha) over basic initial i= (h-a)
T_1	$S_0Zn_0Fs_1$	2.14	0	2.14	0.03	0.01	0.04	2.10	1.00	-1.14
T_2	$S_0Zn_0Fs_2$	2.14	0	2.14	0.04	0.01	0.06	2.08	1.24	-0.90
T_3	$S_0Zn_0Fs_3$	2.14	0	2.14	0.05	0.02	0.06	2.08	2.29	0.15
T_4	$S_0Zn_5Fs_1$	2.14	5	7.14	0.05	0.03	0.08	7.06	3.26	1.12
T_5	$S_0Zn_5Fs_2$	2.14	5	7.14	0.05	0.02	0.08	7.06	3.85	1.71
T_6	$S_0Zn_5Fs_3$	2.14	5	7.14	0.06	0.05	0.11	7.03	4.48	2.34
T_7	$S_{20}Zn_0Fs_1$	2.14	0	2.14	0.05	0.02	0.06	2.08	1.95	-0.19
T_8	$S_{20}Zn_0Fs_2$	2.14	0	2.14	0.05	0.02	0.08	2.06	1.98	-0.16
T_9	$S_{20}Zn_0Fs_3$	2.14	0	2.14	0.06	0.03	0.09	2.05	2.22	0.08
T_{10}	$S_{20}Zn_5Fs_1$	2.14	5	7.14	0.06	0.05	0.12	7.02	2.87	0.73
T_{11}	$S_{20}Zn_5Fs_2$	2.14	5	7.14	0.07	0.01	0.08	7.06	2.83	0.69
T^{12}	$S_{20}Zn_5Fs_3$	2.14	5	7.14	0.07	0.04	0.11	7.03	3.39	1.25
T_{13}	$S_{40}Zn_0Fs_1$	2.14	0	2.14	0.05	0.01	0.07	2.07	2.51	0.37
T_{14}	$S_{40}Zn_0Fs_2$	2.14	0	2.14	0.06	0.01	0.07	2.07	2.31	0.17
T_{15}	$S_{40}Zn_0Fs_3$	2.14	0	2.14	0.06	0.03	0.09	2.05	1.95	-0.19
T_{16}	$S_{40}Zn_5Fs_1$	2.14	5	7.14	0.08	0.03	0.11	7.03	3.39	1.25
T_{17}	$S_{40}Zn_5Fs_2$	2.14	5	7.14	0.08	0.05	0.13	7.00	3.14	1.00
T_{18}	$S_{40}Zn_5Fs_3$	2.14	5	7.14	0.09	0.04	0.13	7.01	3.99	1.85

Fs_1= Foliar spray of water; Fs_2= Foliar spray of S 2%; Fs_3= Foliar spray of Zn 0.5%

Table 4b: Effect of sulphur and zinc as basal and foliar application on fertility balance of Zn aft crop harvest during 2008-09.

Treatment		Initial Zn in Soil (kg/ha) (a)	Zn Added to soil (kg/ha) (b)	Total Available S (kg/ha) c = (a+b)	Zn uptake by grain (kg/ha) (d)	Zn uptake by straw (kg/ha) (e)	Total Zn uptake (kg/ha) f =(d+e)	Apparent Zn balance (kg/ha) g= (c-f)	Avail-able Zn after crop harvest (kg/ha) (h)	Depletion(-) buildup (+) of soil Zn (kg/ha) over basic initial i= (h-a)
T_1	$S_0Zn_0Fs_1$	2.28	0	2.28	0.03	0.01	0.04	2.24	1.03	-1.25
T_2	$S_0Zn_0Fs_2$	2.28	0	2.28	0.04	0.01	0.05	2.23	1.64	-0.64
T_3	$S_0Zn_0Fs_3$	2.28	0	2.28	0.05	0.02	0.07	2.21	2.65	0.37
T_4	$S_0Zn_5Fs_1$	2.28	5	7.28	0.05	0.03	0.08	7.20	3.45	1.17
T_5	$S_0Zn_5Fs_2$	2.28	5	7.28	0.05	0.03	0.08	7.20	3.85	1.57
T_6	$S_0Zn_5Fs_3$	2.28	5	7.28	0.06	0.05	0.11	7.17	4.51	2.23
T_7	$S_{20}Zn_0Fs_1$	2.28	0	2.28	0.05	0.02	0.06	2.22	2.07	-0.21
T_8	$S_{20}Zn_0Fs_2$	2.28	0	2.28	0.05	0.02	0.08	2.20	2.08	-0.20
T_9	$S_{20}Zn_0Fs_3$	2.28	0	2.28	0.06	0.03	0.09	2.19	2.44	0.16
T_{10}	$S_{20}Zn_5Fs_1$	2.28	5	7.28	0.07	0.05	0.12	7.16	3.08	0.80
T_{11}	$S_{20}Zn_5Fs_2$	2.28	5	7.28	0.07	0.02	0.09	7.19	3.08	0.80
T^{12}	$S_{20}Zn_5Fs_3$	2.28	5	7.28	0.08	0.04	0.12	7.16	3.54	1.26
T_{13}	$S_{40}Zn_0Fs_1$	2.28	0	2.28	0.06	0.02	0.07	2.21	2.51	0.23
T_{14}	$S_{40}Zn_0Fs_2$	2.28	0	2.28	0.06	0.02	0.07	2.21	2.53	0.25
T_{15}	$S_{40}Zn_0Fs_3$	2.28	0	2.28	0.07	0.03	0.11	2.17	2.32	0.04
T_{16}	$S_{40}Zn_5Fs_1$	2.28	5	7.28	0.08	0.04	0.11	7.17	3.35	1.07
T_{17}	$S_{40}Zn_5Fs_2$	2.28	5	7.28	0.09	0.05	0.14	7.14	3.38	1.10
T_{18}	$S_{40}Zn_5Fs_3$	2.28	5	7.28	0.09	0.06	0.16	7.12	3.88	1.60

Fs_1= Foliar spray of water; Fs_2= Foliar spray of S 2%; Fs_3= Foliar spray of Zn 0.5%

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