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Effect of sulphur on yield, uptake of nutrients and economics of garlic (*Allium sativum*), onion (*Allium cepa*) and potato (*Solanum tuberosum*) in alluvial soil

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ABSTRACT

An experiment was conducted during winter (*Rabi*) season 2009-2011 to study the effect of sulphur fertilization on garlic (*Allium sativum* L.), potato (*Solanum tuberosum* L.) and onion (A*llium cepa* L.) on alluvial soil at Bichpuri, Agra (Uttar Pardesh) . The treatments comprised five levels of S (0, 15, 30, 45 and 60 kg/ha) were evaluated in randomized block design with four replications. The results revealed that the application of sulphur up to 45 kg/ha significantly increased the yields and dry matter production of vegetable crops, whereas, at higher sulphur level (60 kg/ha) the yield tended to decrease in potato. The magnitude of mean response to sulphur application differed from crop to crop and were recorded as onion (30.2 %) > garlic (22.5 %) > potato (17.0 %) over control. Sulphur application progressively increased the uptake of S in vegetable crops. A phenomenal increase in N, P and K uptake, except of Zn, was recorded in vegetable crops due to increasing levels of S up to 60 kg/ha. The maximum removal of N, P and K was recorded with potato tubers while those of S and Zn with onion bulbs. The higher amounts of protein and protein yield were recorded in potato followed by onion and garlic. Sulphur application significantly improved the content and yield of protein in these vegetable crops over control and maximum values were recorded at 60 kg S/ha. Garlic and onion gave maximum net returns and B:C ratio with 60 kg S/ha and potato at 45 kg/ha. The apparent recovery of sulphur was influenced by S levels with maximum at 45 kg S/ha, except potato where maximum (36.3 %) apparent recovery was recorded with 15 kg S/ha. Better sulphur use efficiency in garlic, onion and potato was obtained with 30 kg S/ha. The sulphur use efficiency decreased with its increasing levels and minimum use efficiency was recorded with 60 kg S/ha application.

Key words: Apparent recovery, Protein yield, Response, Sulphur, Vegetable crops

Vegetables play a very important role in the human diet. They are valuable roughages, which promote digestion and help to prevent constipation. They supply carbohydrate, fats, protein, vitamins and mineral elements. The vegetables have given a push to Indian economy and boosted up her trade. Average productivity of vegetable crops is however, very low and not sufficient to meet the need of local consumption. Among the several constraints, improper nutritional management is an important impediment for increasing the productivity of these crops. Vegetables crops like onion (*Allium cepa* L.), garlic (*Allium sativum* L.) and potato (*Solanum tuberosum* L.) have a high S requirement due to its many functions in plant growth. Sulphur, as a plant nutrient has the strongest impact on yield and quality of vegetables crops (Singh *et al.* 2015). Sulphur plays an important role in growth and development of crops. It plays an important role in the formation of S- containing amino acids like cystine (27% S), cysteine (26% S), methionine (21% S), which act as building blocks in the synthesis of proteins. It has a role to play in increasing chlorophyll formation and aiding photosynthesis (Marschner 1986). Sulphur also plays a role in the activation of enzymes, nucleic acids and forms a part of biotin and thiamine. In recent years, an increased frequency of S deficiency has been observed in crops and S may become a factor limiting yield and quality of crops. Sulphur deficiency is observed mainly due to high crop yield therefore, higher rate of S removed by crops and lesser use of containing fertilizers (Singh *et al.* 2014).The farmers of the area , by and large, use N , P and K in vegetable crops and as a consequence, deficiency of sulphur is increasing. About 41% soils of India suffer from various degrees of sulphur deficiency (Shukla *et al.* 2012). The responses of sulphur differed widely among the vegetable crops because of wide variations in sensitivity to sulphur stress and soil types. The information regarding the differential behavior of these crops to sulphur application under identical soil and weather conditions was considered to be of interest. It was felt imperative to find out

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the relative response of some vegetable crops to sulphur application for higher production and profitability. However, the information pertaining to relative response of vegetable crops to sulphur application in light textured soil is limited. Therefore, the present study was planned to compare the response of vegetable crops to sulphur application in alluvial soil.

MATERIALS AND METHODS

The field experiment was conducted during winter season of 2009-10 and 2010-11 at Research farm, Raja Balwant Singh College, Bichpuri, Agra (Uttar Pardesh). The farm is situated at 27°2" N latitude, 77°9" E longitude and at an altitude of 163.4 m above mean sea level. The experimental site is characterized by semi-arid climate with extreme temperature during summer (45° to 48°C) and very low temperature during winter (as low as 2°C). The average rainfall is about 650 mm, most of which is received from June to September. The experimental soil was sandy loam in texture having pH (7.8), EC (0.29 dS/m), organic carbon (3.2 g/kg), available N (140 kg/ha), P (9.7 kg/ha), K (110 kg/ha), S (8.0 mg/kg) and DTPA - Zn (0.48 mg/kg). The treatments consisting 5 levels of S (0, 15, 30, 45 and 60 kg/ha) were tested in randomized block design with four replications. Three vegetable crops namely white skinned garlic (*Allium sativum* L.), Kufri Bahar potato (*Solenum tuberosum*) and Nasik red onion (*Allium cepa* L.) were sown/transplanted on 20 October and 6 December in both years, respectively. A basal dose of 100 kg N, 60 kg P_2O_5 and 60 kg K_2O /ha to garlic, 150 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha to potato and 200 kg N 100 kg P_2O_5 and 60 kg K_2O/ha to onion was applied through urea, di-ammonium phosphate and muriate of potash, respectively. Full dose of phosphorus and potassium along with half nitrogen were applied at sowing/transplanting and remaining half dose of nitrogen was applied after 45 days of sowing/transplanting. The crops were raised with recommended agronomic practices. The vegetable crops were harvested at their maturity and yields were recorded. The potato tubers, garlic cloves and onion bulbs were cut in to small pieces, dried, ground and digested with di-acid mixture of HNO_3 and $HClO_4$ in 9:1 ratio. Phosphorus, K, S and Zn were determined by vanado molybdo phosphoric yellow colour method, flame photometer, turbidimetric method (Chesnin and Yien 1951) and atomic absorption spectrophotometer, respectively. Nitrogen content in these crops was determined following micro Kjeldahl method (Jackson 1973). The protein content was computed from the nitrogen content multiplied by a factor 6.25. The uptake of nutrient was calculated by multiplying the concentration values with respective economic yield data. The following formulae were used to calculate yield response and nutrient use efficiency.

Yield response (%) = [Yield (F) – Yield (C)/Yield (C)] × 100

Sulphur use efficiency (kg produce/kg S applied) = Yield (F) – Yield (C)/ Fertilizer S applied

Apparent S Recovery (%) = [Uptake of S in treated plot – Uptake of S in control plot/applied S dose] ×100

where, F and C are fertilizer treated and control plot, respectively.

The economics was computed on the basis of prevailing market prices of inputs and output. Data obtained from consecutive two years were statistically analyzed as per procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Economic yield

The results on economic yield distinctly indicated that all the test crops responded markedly to sulphur application. In general, each additional dose of sulphur application up to 45 kg S/ha increased significantly the yields and thereafter a decreasing trend was observed in potato only (Table 1). Application of 45 kg S/ha appeared to be the optimum dose for onion and garlic and 30 kg S/ha for potato under the experimental conditions. this increase in yields with S levels seems to be associated with the increased S availability from applied sulphur as the experimental soil was low in available S. The response to S may be attributed to improved nutritional management as a result of increased S supply which might have favourable influence on the growth and yield of vegetable crops. Singh *et al*. (1995), Jaggi *et al.* (2006), Singh *et al.* (2014) and Pandey *et al*. (2015) also reported significant response of garlic, onion and potato to sulphur application, respectively. It was also apparent that vegetable crops differed significantly amongst themselves in their magnitude of response to sulphur application. The per cent mean yield response of garlic, onion and potato was 22.5, 30.2 and 17.0, over control, respectively. In terms of yields the vegetable crops responded in the order: onion > garlic > potato. Omprakash *et al.* (1997) reported similar results in vegetable crops to sulphur application. Increasing levels of sulphur significantly increased dry matter production in garlic cloves from 0.91 to 1.07 tonnes /ha, onion bulbs from 4.04 to 5.70 tonnes /ha up to 60 kg S / ha and potato tubers from 6.76 to 8.20 tonnes/ha up to 45 kg S/ha (Table 1). The average dry matter yields of vegetable crops exhibited practically no difference at higher levels of S. Hence, 45 kg S/ha can be regarded as suitable dose for onion and garlic and 30 kg S/ha for potato. Increase in drymatter production due to sulphur addition was largely a function of improved growth, translocation of more photosynthete towards sink and consequent accumulation of dry matter in garlic cloves, onion bulbs and potato tubers (Singh *et al.* 2015). Dry matter yield of potato crop tended to reduce at 60 kg S/ha. Sharma *et al.* (2015) also reported significant response of the crops to sulphur application.

Quality

Increasing levels of sulphur significantly increased the protein content in garlic cloves, onion bulbs and potato tubers from 6.90 to 7.68 , 3.84 to 4.65 and 6.09 to 7.00%, respectively, with 60 kg S/ha (Table 1). This may be attributed

Table 1 Effect of sulphur levels on yield, quality and economics of vegetable crops (mean of two years)

Sulphur (kg/ha)	Economic yield (t/ha)	Response (%)	Dry matter (t/ha)	Protein content (%)	Protein yield (kg/ha)	Net return (₹/ha)	B:C ratio
			Garlic				
0	5.97	—	0.91	6.90	63.1	259480	2.62
15	6.54	9.5	1.09	7.03	70.3	274465	2.77
30	7.29	22.1	1.10	7.15	78.6	299050	3.02
45	7.67	28.5	1.16	7.53	87.3	320035	3.24
60	7.73	29.5	1.17	7.68	89.8	323020	3.27
SEm±	0.13		0.03	0.15	1.30		
CD (P=0.05)	0.28		0.06	0.32	2.70		
			Onion				
0	25.31	—	4.04	3.84	155.1	95480	1.69
15	28.67	13.3	4.58	4.21	193.2	115625	2.05
30	31.95	26.2	5.10	4.34	221.5	135290	2.39
45	35.52	40.3	5.67	4.46	253.4	156695	2.77
60	35.67	40.9	5.70	4.65	265.0	157580	2.79
SEm±	0.51		0.09	0.14	4.90		
CD (P=0.05)	1.10		0.20	0.31	10.19		
			Potato				
0	31.50		6.76	6.09	412.0	86908	1.23
15	34.26	8.8	7.34	6.35	466.0	100643	1.42
30	37.28	18.3	7.98	6.65	530.6	115728	1.63
45	38.54	22.3	8.20	6.88	547.8	120763	1.70
60	37.34	18.5	8.00	7.00	560.0	115998	1.64
SEm±	0.65		0.11	0.12	8.50		
CD(P=0.05)	1.40		0.23	0.25	18.27		

to significant role of sulphur in protein in protein synthesis and nitrogen metabolism in the plants (Singh *et al.* 2015). Among these vegetable crops, the minimum value of protein content was recorded in onion, potato and garlic contained relatively higher amounts of protein in their reproductive parts as compared to onion bulb. The protein yield increased up to the level of 60 kg S/ha over control. The maximum value of protein yield was recorded in potato (560 kg/ha) followed by onion (265.0 kg/ha) and garlic (89.8 kg/ha) at 60 kg S/ha. This increase in protein yield may be attributed to higher production of vegetable crops and improvement in protein content. This increase in protein yield due to sulphur levels may be attributed to increased yield and protein content in these crops. The increase in protein yield with sulphur application has been also reported by Dash *et al.* (2013).

Uptake of nutrient

Nitrogen uptake by garlic, onion and potato increased significantly with increasing levels of sulphur and the highest N uptake was observed with 60 kg S/ha, i.e. 14.1, 42.4 and 92.6 kg/ha and the lowest in the control, i.e. 10.0, 24.8 and 65.9 kg/ha (Table 2). Thus, the beneficial effect of S on N uptake by these crops seems to be associated with promoted nitrogen availability with a concomitant increase in crop yields. The garlic crop accumulated the lowest amount of P in its cloves whereas, potato crop utilized the highest amount of P in its tubers. On the basis of P uptake, the crops may be arranged in order as garlic < onion < potato. The differences in P uptake of these crops may be attributed to the genetic makeup of the vegetable crops that controls the capability to utilize soil P. The significant increase in P uptake of these vegetable crops was noticed with the application of S and maximum P uptake values were recorded at 60 kg S/ha. Thus, sulphur application increased the efficiency of vegetable crops to utilize the phosphorus. The results are in agreement with those of Singh and Singh (2005) and Singh *et al.* (2014). The potato tubers utilized the higher amounts of K at all the levels of S as compared to onion and garlic. A progressive increase in S up to 45 kg/ha gradually increased K uptake by the vegetable crops. Higher uptake of K might be due to higher yield and K content in these vegetable crops (Singh and Singh 2005). Application of 60 kg S/ha increased its uptake in garlic, onion and potato from 6.5 to 12.0, 23.6 to 51.5 and 21.3 to 36.6 kg/ha, respectively. It was observed that potato removed lesser amount of sulphur than onion. Omprakash *et al.* (1997) reported that the quantity of S removal from soil was highest by onion than potato. It seems that application of sulphur enriched the readily available S status in soil which was easily utilized by these crops. This could be ascribed to increase in the available S content in plant tissues and also greater biomass production at higher rates of sulphur application. Since, the uptake of nutrient is a function of dry matter and nutrient content, the increased dry matter yields of vegetable crops with higher S content resulted in greater uptake of this element. The results

Table 2 Effect of sulphur levels on uptake of nutrients and efficiency indices in vegetable crop (mean of two years)

Sulphur (kg/ha)	Nutrient Uptake					Apparent S	SUE (kg produce/
	N(kg/ha)	P(kg/ha)	K(kg/ha)	S(kg/ha)	Zn(g/ha)	recovery (%)	kg sulphur)
				Garlic			
0	10.0	3.4	9.5	6.5	17.9		
15	11.6	3.9	10.0	7.8	18.8	8.7	38.0
30	12.5	4.5	11.8	9.3	19.4	9.3	44.0
45	13.7	5.0	12.5	11.4	17.4	10.9	37.8
60	14.1	5.1	12.8	12.0	17.0	9.1	29.3
SEm+	0.57	0.22	0.37	0.60	0.54		
CD (P=0.05)	1.19	0.47	0.78	1.27	1.15		
				Onion			
0	24.8	8.2	30.9	23.6	159.2		
15	30.9	10.0	35.9	29.5	176.0	39.6	223.9
30	35.4	11.7	41.6	37.7	191.8	47.0	226.8
45	40.5	13.3	47.0	48.4	205.2	55.2	221.3
60	42.4	13.9	48.7	51.5	202.1	46.5	172.5
SEm+	1.43	0.47	0.84	2.92	1.87		
CD (P=0.05)	3.01	1.00	1.78	6.13	3.94		
				Potato			
0	65.9	20.6	137.6	21.3	133.6		
15	76.3	23.4	150.8	26.7	143.6	36.3	183.3
30	87.8	26.7	164.8	31.9	149.6	35.3	192.3
45	94.7	28.3	171.0	36.5	145.6	33.7	150.5
60	92.6	27.6	170.0	36.6	138.3	28.8	120.5
SEm+	3.91	0.79	2.45	1.71	3.04		
CD (P=0.05)	8.30	1.68	5.16	3.62	6.38		

confirm the findings of Jaggi *et al.* (2006) and Singh *et al.* (2014). The relatively higher amounts of zinc were utilized by onion bulbs than those of potato tubers and garlic cloves. The zinc uptake increased from 17.9 to 19.4, 159.2 to 205.2 and 133.6 to 149.6 g/ha with 30 kg S/ha. Thereafter, zinc uptake decreased at higher levels of S. The results indicate an adverse effect on zinc utilization by these crops under higher levels of sulphur (Singh *et al.* 2015).

Economics

All the three vegetable crops gave higher net returns with sulphur application (Table 1). Among vegetable crops, higher net returns and B:C ratio were obtained in garlic followed by onion and potato. The highest net income of ₹ 323 020/ha was obtained with garlic under 60 kg S/ha. It was followed by onion (₹ 157 580/ha) under 60 kg S/ha, and potato (₹ 120 763/ha) under 45 kg S/ha. Similarly, the maximum values of B:C ratio in garlic (3.27), onion (2.79) with 60 kg S/ha and potato (1.70) were obtained with 45 kg S/ha. This might be owing to higher productivity of garlic and relatively low production cost per unit of yield. Owing to better response of vegetable crops to sulphur, the net returns were greater at higher rates of its application, i.e. 45 and 60 kg S/ha. Minimum net returns were received with all the three vegetable crops without sulphur application. The reason of high profitability with garlic crop is due to higher cost of produce as compared to onion and potato. Highest mean benefit: cost ratio was noted with garlic and lowest with potato. Application of 60 kg S/ha fetched about 1.5 times benefit over control. The increase in yield with sulphur application under different vegetable crops might be the reason for these results. Sharma *et al.* (2014) and Pandey *et al.* (2015) also reported higher net profit and B:C ratio with sulphur levels in potato.

Efficiency indices

The maximum values of apparent recovery of sulphur by garlic and onion were 10.9 and 55.2 %, respectively, at 45kg S/ha except potato where maximum (35.3 %) apparent recovery of sulphur was noted at 15kg S/ha (Table 2). The minimum values of apparent recovery of sulphur in all the vegetable crops were noted at 60 kg S/ha level. The yield improvement over unit quantity of S addition was calculated as S use efficiency. Critical examination of the data (Table 2) showed that the different levels of S tried had a marked influence on S use efficiency in the vegetable crops. The response varied from 29.3 to 44.0 kg cloves / kg S in garlic, 172.5 to 226.8 kg bulbs/kg S in onion and 120.5 to 192.3 kg tubers/kg S in potato. Sulphur use efficiency (kg produce increase /kg sulphur) increased with an increase in the rates of sulphur up to the level of 30 kg S/ha in all the vegetable crops. Better sulphur use efficiency was obtained with 30 kg S/ha and recorded 44.0 kg in garlic cloves, 226.8 kg in onion bulbs and 192.3 kg produce in potato tuber per kg sulphur applied. The SUE in all the three vegetable crops decreased at 60 kg S/ha. This may be due to the fact that input-output relationship follows the law of diminishing return as far as the relationship between sulphur and yield is concerned. Similar findings was reported by Dash *et al.* (2013) and Sharma *et al.* (2015).

Based on two years of field study, it may be concluded that application of sulphur @ 45 kg/ha to garlic and onion and 30 kg/ha to potato is sufficient dose for increased productivity and quality of produce under sulphur deficient soils. Garlic and onion crops are more responsive to sulphur application as compared to potato. The mean relative response of vegetable crops to sulphur application was in the following sequence: onion > garlic > potato. This indicated the differential behavior of three vegetable crops with respect to their sulphur requirement.

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