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Productivity, profitability and nutrient uptake in carrot (*Daucus carota*) and radish (*Raphanus sativus*) crops under sulphur nutrition

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ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2009-10 and 2010-11 to study the response of sulphur fertilization on carrot (*Daucus carota* L.) and radish (*Raphanus sativus* L.) on alluvial soil at Bichpuri, Agra (Uttar Pradesh). The treatments comprised five levels of sulphur (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 30 and 45 kg/ha significantly increased the edible root yields and dry matter production of carrot and radish, respectively. The magnitude of mean response to sulphur application differed from crop to crop and was recorded as carrot (17.5%) and radish (18.6%) over control. Successive sulphur levels had a significant effect on its uptake by both the vegetable crops up to 60 kg S/ha. A phenomenal increase in N, P and K uptake, except of Zn was recorded in these crops due to increasing levels of S up to 60 kg/ha. The maximum removal of N, P, K and S was recorded with radish roots while that of Zn with carrot. The higher amounts of protein and protein yield were recorded in carrot followed by radish. 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. Carrot gave maximum net returns ₹ 137 665/ha and B:C ratio (2.51) with 45 kg S/ha. However, the net returns (₹ 65 640/ha) and B:C ratio (1.57) were the highest in radish with 60 kg S/ha. The apparent recovery of sulphur was influenced by S levels with maximum at 30 kg S/ha in carrot and radish. Better sulphur use efficiency in carrot (179.5 kg produce kg/S applied) and radish (186.1 kg produce kg/S applied) 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, Carrot, Protein yield, Radish, Response, Sulphur

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. Radish (*Raphanus sativus* L.) is cultivated for its enlarged edible roots. Carrot (*Dacus carota* L.) is grown all over India both for forage and human consumption. 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. Vegetable crops have a high sulphur requirement due to its many functions in plant growth. Sulphur application is less expensive but can give higher profits than other nutrients (Tandon and Messick 2007). Sulphur, as a plant nutrient, has the strongest impact on yield and quality of vegetable 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 sulphur 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 sulphur removed by crops and lesser use of sulphur containing fertilizers (Singh *et al.* 2014). The farmers of the area, by and large, use N, P and K fertilizers in vegetable crops and as a consequence, deficiency of sulphur is increasing. About 61% vegetable growing soils of Agra district suffer from various degrees of sulphur deficiency (Singh and Singh 2014). The response 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 the relative response of carrot and radish crops to sulphur

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application for higher production and profitability. However, the information pertaining to relative response of carrot and radish crops to sulphur application in light textured soil is limited. Therefore, the present study was planned to compare the response of carrot and radish crops to sulphur application in alluvial soil of Agra district of Uttar Pradesh.

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 Pradesh). The farm is situated at 27º 2" N latitude, 77º 9" E longitude and at an altitude of 163.4 meter above mean sea level. The experimental site is characterized by semi-arid climate with extreme temperature during summer (45º to 48º C) and very low temperature during winter (as low as 2º C). The average rainfall is about 650 mm, most of which is received from June to September. The 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. Two vegetable crops namely Pusa Kesar carrot and Pusa Chetki radish were sown on 25 October in both years. A basal dose of 100 kg N, 60 kg P_2O_5 and 100 kg K_2O/ha to carrot and 100 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha to radish 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 and remaining half dose of nitrogen was applied after 45 days of sowing. The crops were raised with recommended agronomic practices. The vegetable crops were harvested at their physiological maturity and root yields were recorded. The carrot and radish roots were cut in to small pieces, dried, ground and digested with di-acid mixture of HNO_3 and $HCIO_4$ in 9:1 ratio. Phosphorus, K, S and Zn were determined by vanadomolybdophosphoric yellow colour method, flame photometer, turbidimetric method (Chesnin and Yien 1951) and atomic absorption spectrophotometer, respectively. Nitrogen content 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 dry matter yield data. The following formulae were used to calculate sulphur use efficiency and apparent S recovery:

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 study 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 both the test crops responded markedly to sulphur application. In general, each additional dose of sulphur application up to 30 and 45 kg S/ha increased significantly the yields (edible roots) in carrot and radish, respectively. Thereafter, a decreasing trend was observed in carrot only at 60 kg S/ha (Table 1). The per cent increases in root yields of carrot due to 30 kg S/ha and radish due to 45 kg S/ha over control were 18.8 and 22.5, respectively. 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 sulphur 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. Sriramachandrasekharan and Arumugham Shakila (2010), Singh *et al.* (2014) and Pandey *et al.* (2015) also reported significant response of vegetable crops to sulphur application. It was also apparent that these too vegetable crops differed significantly between them in their magnitude of response to sulphur application. The mean per cent yield response of carrot and radish was 17.5 and 18.6 over control, respectively, indicating higher response of S in radish than carrot. Omprakash *et al.* (1997) reported similar results in vegetable crops to sulphur application. Increasing levels of sulphur

Table 1 Effect of sulphur fertilization on yield and quality of carrot and radish (mean of 2 years)

Sulphur (kg/ha)	Carrot					Radish				
	Economic yield (t/ha)	% response	Dry matter yield (t/ha)	Protein content (%)	Protein yield (t/ha)	Economic yield (t/ha)	% response	Dry matter yield (t/ha)	Protein content (%)	Protein yield (t/ha)
0	28.70		3.81	3.93	1.13	29.26		4.67	3.46	1.01
15	31.15	8.5	4.14	4.21	1.31	31.83	8.7	5.08	3.77	1.20
30	34.10	18.8	4.53	4.56	1.55	34.58	19.1	5.57	4.15	1.45
45	35.00	21.9	4.65	4.84	1.69	35.86	22.5	5.64	4.43	1.59
60	34.70	20.9	4.61	4.96	1.72	36.37	24.2	5.79	4.55	1.65
SEm ±	0.44		0.05	0.12	4.04	0.36		0.06	0.14	0.05
CD (P=0.05)	0.95		0.12	0.28	0.09	0.84		0.15	0.31	0.11

Table 2 Uptake of N, P, K, S (kg/ha) and Zn (g/ha) in carrot and radish as influenced by sulphur fertilization (mean of two years)

Sulphur	Carrot					Radish				
(kg/ha)	N	P	K	S	Zn	N	P	K	S	Zn
0	23.9	10.8	23.2	14.6	130.8	25.9	11.2	26.8	17.0	102.0
15	27.9	12.1	26.1	18.1	138.6	30.7	12.9	29.7	21.5	105.1
30	33.0	13.9	29.2	22.1	138.0	37.0	15.0	33.6	26.6	104.0
45	35.9	14.7	31.4	25.1	137.6	40.7	16.2	35.2	30.0	103.8
60	36.5	15.1	32.0	26.0	130.7	42.4	17.1	36.3	31.6	100.5
SEm ±	1.03	0.50	0.64	0.95	3.10	1.20	0.41	0.86	1.44	1.04
CD (P=0.05)	2.14	1.04	1.35	2.01	6.53	2.53	0.86	1.81	3.02	2.19

significantly increased dry matter production in carrot roots from 3.81 to 4.65 tonnes/ha and radish roots from 4.67 to 5.80 tonnes/ha with 45 and 60 kg S/ha, respectively (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 these two vegetable crops. Increase in dry matter production due to sulphur addition was largely a function of improved growth, translocation of more photosynthate towards sink and consequent accumulation of more dry matter in edible roots of carrot and radish (Singh *et al.* 2015). The lowest dry matter production in both crops was noted in control. Sharma *et al.* (2015) also reported significant response of the vegetable crops to sulphur application.

Quality

Increasing levels of sulphur significantly increased the protein content in edible roots of carrot and radish from 3.93 to 4.96 and 3.46 to 4.55%, respectively, with 60 kg S/ha (Table 1). This may be attributed to significant role of sulphur in protein synthesis and nitrogen metabolism in the plants (Singh *et al.* 2015). The relatively lower vaues of protein content were recorded in radish roots as compared to roots of carrot. The increasing suphur levels up to 60 kg S/ha resulted in higher protein yield in both vegetable crops over lower levels of sulphur and control. Since, protein yield is mainly the function of dry matter yields and their respective protein content in the roots, protein yield increased with increase in sulphur levels. The maximum value of protein yield was recorded in edible roots of carrot (1.72 tonnes/ha) followed by radish (1.65 tonnes/ha) at 60 kg S/ha. The increase in protein yield with sulphur application was also reported by Dash *et al.* (2013). The lowest values of protein content and yield in both vegetable crops were recorded in control.

Uptake of nutrients

Nitrogen uptake by carrot and radish increased significantly with increasing levels of sulphur and the highest N uptake was observed with 60 kg S/ha, i.e. 36.5 and 42.4 kg/ha and the lowest in the control, i.e. 23.9 and 25.9 kg/ha (Table 2). Thus, the beneficial effect of sulphur on nitrogen uptake by these crops seems to be associated with promoted nitrogen availability with a concomitant increase in crop yields. The carrot crop accumulated relatively lower amount of P in its roots as compared to radish roots. The differences in P uptake by these crops may be attributed to their genetic makeup that controls the capability to utilize soil phosphorus. The significant increase in P uptake by these vegetable crops was noticed with the application of sulphur and maximum values were recorded at 60 kg S/ha. Thus, sulphur application increased the efficiency of vegetable crops to utilize the phosphorus (Singh *et al*. 2014). The radish roots utilized the higher amounts of K at all the levels of S as compared to carrot. A progressive increase in S levels up to 60 kg/ha gradually increased K uptake by these vegetable crops. Higher uptake of K might be due to higher yield and K content in the edible roots of these too crops (Singh and Singh 2005). It was observed that carrot removed lower amounts of sulphur than radish. Application of 60 kg S/ha increased its uptake in carrot and radish from 14.6 to 26.0 and 17.0 to 31.6 kg/ha, respectively. 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 yield and nutrient content, the increased dry matter yields of vegetable crops with higher S content resulted in greater uptake of this element (Singh *et al.* 2014). The relatively higher amounts of zinc were utilized by carrot roots than that of radish roots. The zinc uptake increased from 130.8 to 138.6 and 102.0 to 105.1 g/ha with 15 kg S/ha. Thereafter, zinc uptake decreased a 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

Both the vegetable crops gave higher net returns with sulphur application over no sulphur (Table 3). The higher net returns and B:C ratio were obtained in carrot than radish. The highest net income of ₹ 137 665/ha was obtained with carrot under 45 kg S/ha. But in radish, it was highest (₹ 43 470/ha) under 60 kg S/ha. Similarly, the maximum values of B:C ratio in carrot (2.51) and in radish (1.57) were obtained with 45 and 60 kg S/ha, respectively. This might be owing to higher productivity of carrot and relatively low production cost per unit of yield. Owing to better response of vegetable crops to sulphur, the net returns were greater at

Table 3 Effect of sulphur levels on economics and efficiency indices in carrot and radish (mean of two years)

Sulphur level (kg/ha	Carrot				Radish			
	Net return (₹/ha)	B:C ratio	Apparent S recovery (%)	SUE (kg produce/kg S supplied)	Net return (₹/ha)	B:C ratio	Apparent S recovery (%)	SUE (kg produce/kg S supplied)
0	103 170	1.88			44 370	1.02		
15	116 630	2.13	23.3	163.3	52 065	1.19	30.3	171.3
30	132 785	2.42	24.9	179.5	61 110	1.40	32.1	186.1
45	137 665	2.51	23.2	139.5	64 125	1.47	28.8	146.5
60	136 110	2.48	18.4	99.9	65 640	1.57	24.3	118.4

higher rates of its application, i.e. 45 and 60 kg S/ha. Minimum net returns were received with carrot (₹ 103 170/ ha) and radish (₹ 44 370/ha) crop without sulphur application. The higher mean benefit: cost ratio was noted with carrot and lesser with radish. The increase in yield with sulphur application under both 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 vegetable crops.

Efficiency indices

The maximum values of apparent recovery of sulphur by carrot and radish were 24.9 and 32.1%, respectively, at 30 kg S/ha (Table 3). The minimum values of apparent recovery of sulphur in both the 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 3) showed that the different levels of S had marked influence on the S use efficiency. The response varied from 163.3 to 179.5 kg edible roots/kg S in carrot and 171.3 to 186.1 kg edible roots/kg S in radish. 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 both the vegetable crops. Better sulphur use efficiency was obtained with 30 kg S/ha and recorded 179.7 kg in carrot roots and 186.1 kg produce in radish roots per kg sulphur applied. The SUE in both these vegetable crops decreased at higher levels of sulphur (45 and 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 have been 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 45 kg S/ha to carrot and radish is sufficient dose for increased productivity and quality of produce under sulphur deficient soils. Radish crop is more responsive to sulphur application as compared to carrot. Radish was also found to have superior utilization of sulphur in terms of SUE and apparent S recovery compared with carrot. This indicated the differential behavior of these crops with respect to their sulphur requirement.

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