CBCS
HTTP://AGROBIOL.SGGW.WAW.PL/CBCS

COMMUNICATIONS IN BIOMETRY AND CROP SCIENCE
VOL. 7, NO. 1, 2012, PP. 35–40

INTERNATIONAL JOURNAL OF THE FACULTY OF AGRICULTURE AND BIOLOGY,
WARSAW UNIVERSITY OF LIFE SCIENCES, POLAND

REGULAR ARTICLE

# Sulfur use efficiency of radish as affected by sulfur source and rate in typic ustifluvent soil

**M.V. Sriramachandrasekharan**

Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Annmalainagar-608002, Tamilnadu.
E-mail: ram_uthrat@yahoo.com

CITATION: Sriramachandrasekharan, M.V. (2012). Sulfur use efficiency of radish as affected by sulfur source and rate in typic ustifluvent soil. *Communications in Biometry and Crop Science* 7 (1), 35–40.

Received: 10 August 2009, Accepted: 28 October 2012, Published online: 4 January 2013


## ABSTRACT

Radish is one of the most popular root crops in the tropical and temperate regions. Sulfur deficiency is common in coarse textured soil due to leaching loss. Root yield of radish is reported to increase with sulfur application. Field experiments was conducted in two seasons to study the effect of sulfur (S) rate and source on radish (*Raphanus sativus* L.) nutrition, an experiment was conducted in a Padugai sandy clay loam (Typic Ustifluvents) deficient in available sulfur. The treatments consisted of four levels of S viz., 0, 25, 50 and 100 kg ha$^{-1}$ applied through four sources viz., ammonium sulfate, super phosphate, gypsum and potassium sulfate Data were recorded on radish root yield, S uptake, available S, S uptake efficiency (SUPE), S utilization efficiency (SUTE), S use efficiency (SUE), fertilizer S uptake efficiency (FSUPE), fertilizer S utilization efficiency (FSUTE) and fertilizer S use efficiency (FSUE). The results revealed that addition of graded rate of S significantly increased root yield, S uptake and available S over the control. Application of S at 100 kg ha$^{-1}$ gave highest root yield of 33.5 t ha$^{-1}$ (season- I) and 36.8 t ha$^{-1}$ (season-II) and also sulfur uptake and available sulfur. Among the S sources, gypsum was better than the other sources. Increased S-application increased SUPE and SUE. The SUTE was highest in control plants and decreased with S level. On the other hand FSUPE and FSUE were highest at a rate of 50 kg S ha$^{-1}$ and FSUTE was highest at 25 kg S ha$^{-1}$. Among S sources, gypsum had higher S use efficiency and its components compared to the other S sources.

**Key Words**: *Radish yield; sulfur uptake; available S; SUE; Entisol.*

## INTRODUCTION

Sulfur is ranked as the fourth element after N, P and K in balanced fertilization. Sulfur is directly or indirectly involved in various plant metabolic processes. Application of S as sulfate increases crop yield and quality (Oh, 1988). Sulfur deficiency is reported in many crops including vegetables grown in coarse textured soil due to leaching losses. Radish

(*Raphanus sativus* L.) is an important root vegetable cultivated in India mainly for its tender roots, which are used as salad or cooking vegetables. Radish is grown on an area of 67,345 ha with production of 803,000 t in India (Sundaram et al., 2005). Radish also has therapeutic value (Sundaram et al., 2005). Radish root yield is reported to increase with S application (Kute, 1997). Sulfur application affects crop yield through the effect on S use efficiency and its components (uptake efficiency and utilization efficiency). This experiment was designed to gain a deeper insight into radish S nutrition and its relationship to economic yield.

## MATERIAL AND METHODS

Field experiments were conducted in Padugai sandy clay loam– (Typic Ustifluvents) in 2002 and 2003 (August – September 2002 and February – March 2003) to study S use efficiency of radish as affected by S source and rate. The soil at the site of the experiment had a pH of 7.1, and EC of 0.65 d $Sm^{-1}$, OC of 5.1 g $kg^{-1}$ and available $KMnO_4$-N - 238 kg $ha^{-1}$ (Subbiah and Asija, 1956), Olsen-P- 16 kg $ha^{-1}$( Olsen et al.,1954) , $NH_4OAc$-K – 347 kg $ha^{-1}$( Stanford and English,1949) and 0.15% $CaCl_2$-S – 14.4 kg $ha^{-1}$ ( Chesnin and Yein, 1951). Treatments were four levels of S (0, 25, 50 and 100 Kg $ha^{-1}$) applied as four S sources viz. gypsum(15% S), ammonium sulfate (24% S), single superphosphate (12% S) and potassium sulfate (18%). The test crop was radish cv. Pusa chetki. All plots received a uniform rate of 50 Kg N/ha through urea, 100 kg $P_2O_5$/ha through DAP and 50 kg $K_2O$/ha through muriate of potash. The design of the experiment was randomized complete block design (r = 3) with a complete factorial arrangement sulfur source and sulfur rate. At the highest S-rate from different sources, the amount of other nutrient incidentally added were N (85.9 kg $ha^{-1}$), P2O5 (133.3 kg $ha^{-1}$), $K_2O$ (278 kg $ha^{-1}$) and Ca (183.3 kg $ha^{-1}$). The above level of nutrients was maintained in all the plots by adding the differences that arose through urea, DAP, KCl, and $Ca(OH)_2$. At harvest, root yield was recorded and expressed as t $ha^{-1}$. Radish roots were analyzed for S content (Bhargava and Raghupathi, 1995) and S uptake computed. Available soil S was analyzed using the method of Chesnin and Yein (1951). The following parameters were calculated:

1. Sulfur uptake efficiency (SUPE) = S in plant/S in soil
2. Sulfur utilization efficiency (SUTE) = Yield/S in plant
3. Sulfur use efficiency (SUE) = Yield/S in soil
4. Fertilizer S uptake efficiency (FSUPE)

$$\frac{\text{S in fertilized plant – S in control plant}}{\text{S applied}}$$

5. Fertilizer S utilization efficiency (FSUTE)

$$\frac{\text{Yield in fertilized plots – yield in control plot}}{\text{S in fertilized plant – S in control plants}}$$

6. Fertilizer S use efficiency (FSUE)

$$\frac{\text{Fertilized plot yield – control plot yield}}{\text{S applied}}$$

## RESULTS AND DISCUSSION

Addition of sulfur at different rates through various sources caused significant increase in root yield, S uptake and available S over control in both the seasons (Table1). Fresh radish root yield ranged from 9.81 to 33.45 t $ha^{-1}$ and 13.25 to 36.75 t $ha^{-1}$ in seasons I and II, respectively. The highest root yield obtained with 100 kg S $ha^{-1}$. The highest S level increased root yield by 241% and 177% over control in seasons I and II, respectively. Root yield response (t $ha^{-1}$) due to S level ranged from 5.79 to 23.34 (Season I) and 4.56 to 23.5 (Season II). Among sources, addition of S in gypsum gave the highest root yield. The high magnitude of root yield response indicates a greater contribution of S in root yield production. The higher response of radish to S application irrespective of S source was expected on this low S status soil (critical limit = 20 kg S ha$^{-1}$, Srinivasarao et al., 2004). Further, the important role of S is energy transformation and enzyme activation in carbohydrate metabolism and subsequent greater photosynthates partitioning in yield formation (Chatterjee et al., 1999). The interaction between sulfur sources and levels were significant (Table 2). The highest root yield (38.25 t ha$^{-1}$ in season I) and (41.95 t ha$^{-1}$ in season II) was obtained with 100 kg S ha$^{-1}$ applied through gypsum which was significantly superior to any other combinations of sources and S rates. At 100 kg ha$^{-1}$ S, addition of gypsum resulted in a 291% yield increase over the control, whereas potassium sulfate (266%), ammonium sulfate (241%) and superphosphate (166%) resulted smaller yield increases relative to the control. This was confirmed by a significant linear relationship between root yield and S uptake ($Y = 5.04 + 1.55x$; $r^2 = 0.99^{**}$) and root yield with available S ($Y = –10. 93 + 1.71x$; $r^2 = 0.92^{**}$) (Figure 1a, b). In this study SUPE and SUE were highest with 100 kg S ha-1 and FSUPE and FSUE were higher at 50 kg S ha$^{-1}$, which was reflected in higher root yield. Secondly, SUE and its components were highest with gypsum, which gave the highest root yields with S addition from gypsum. Higher yield due to S fertilizer had already been reported by Omprakash et al. (1997); Malhi et al. (2007); and Bharathi and Poongothai (2008). Hazra (1997) reported that gypsum as S source gave highest vegetable yields.

Table 1. Effect of sulfur source and rate on radish root yield, S uptake and available S.

| | Season-I | | | Season-II | | |
|---|---|---|---|---|---|---|
| Treatment | Root yield | S uptake | S available | Root yield | S uptake | S available |
| **S source** | - t ha$^{-1}$- | ------ kg ha$^{-1}$------ | | - t ha$^{-1}$- | ------ kg ha$^{-1}$------ | |
| Ammonium sulfate | 20.5 | 10.3 | 18.8 | 23.8 | 10.1 | 19.2 |
| Super phosphate | 17.2 | 7.9 | 17.9 | 20.3 | 8.5 | 18.6 |
| Gypsum | 25.2 | 12.9 | 20.0 | 27.2 | 12.6 | 22.1 |
| Potassium sulfate | 22.1 | 10.7 | 19.1 | 25.5 | 11.2 | 21.4 |
| $LSD_{0.05}$ | 1.1 | 1.1 | 0.9 | 1.5 | 1.2 | 1.1 |
| **S level, kg ha$^{-1}$** | | | | | | |
| 0 | 9.8 | 3.5 | 11.5 | 13.3 | 4.5 | 12.1 |
| 25 | 15.6 | 6.6 | 17.9 | 17.8 | 6.9 | 19.2 |
| 50 | 26.0 | 12.9 | 21.9 | 29.0 | 12.8 | 23.3 |
| 100 | 33.5 | 18.8 | 24.7 | 36.8 | 18.2 | 26.4 |
| $LSD_{0.05}$ | 1.1 | 1.1 | 0.9 | 1.5 | 1.2 | 1.1 |

Table.2 Interaction effect between sulfur source and rate on root yield of radish (t ha$^{-1}$)

| | Season-I | | | | Season-II | | | |
|---|---|---|---|---|---|---|---|---|
| | S level, kg ha$^{-1}$ | | | | | | | |
| S source | 0 | 25 | 50 | 100 | 0 | 25 | 50 | 100 |
| | ---------------------------------------- t ha$^{-1}$---------------------------------------- | | | | | | | |
| Ammonium sulfate | 10.2 | 14.6 | 23.7 | 33.5 | 15.5 | 16.8 | 26.4 | 36.8 |
| Super phosphate | 8.7 | 12.8 | 21.2 | 26.1 | 13.5 | 14.2 | 23.8 | 29.0 |
| Gypsum | 12.5 | 18.8 | 31.0 | 38.4 | 11.5 | 21.2 | 34.2 | 42.0 |
| Potassium sulfate | 7.9 | 16.3 | 28.3 | 35.9 | 12.5 | 18.6 | 31.6 | 39.3 |
| $LSD_{0.05}$ | -------------- 2.1---------------- | | | | -------------- 3.0---------------- | | | |

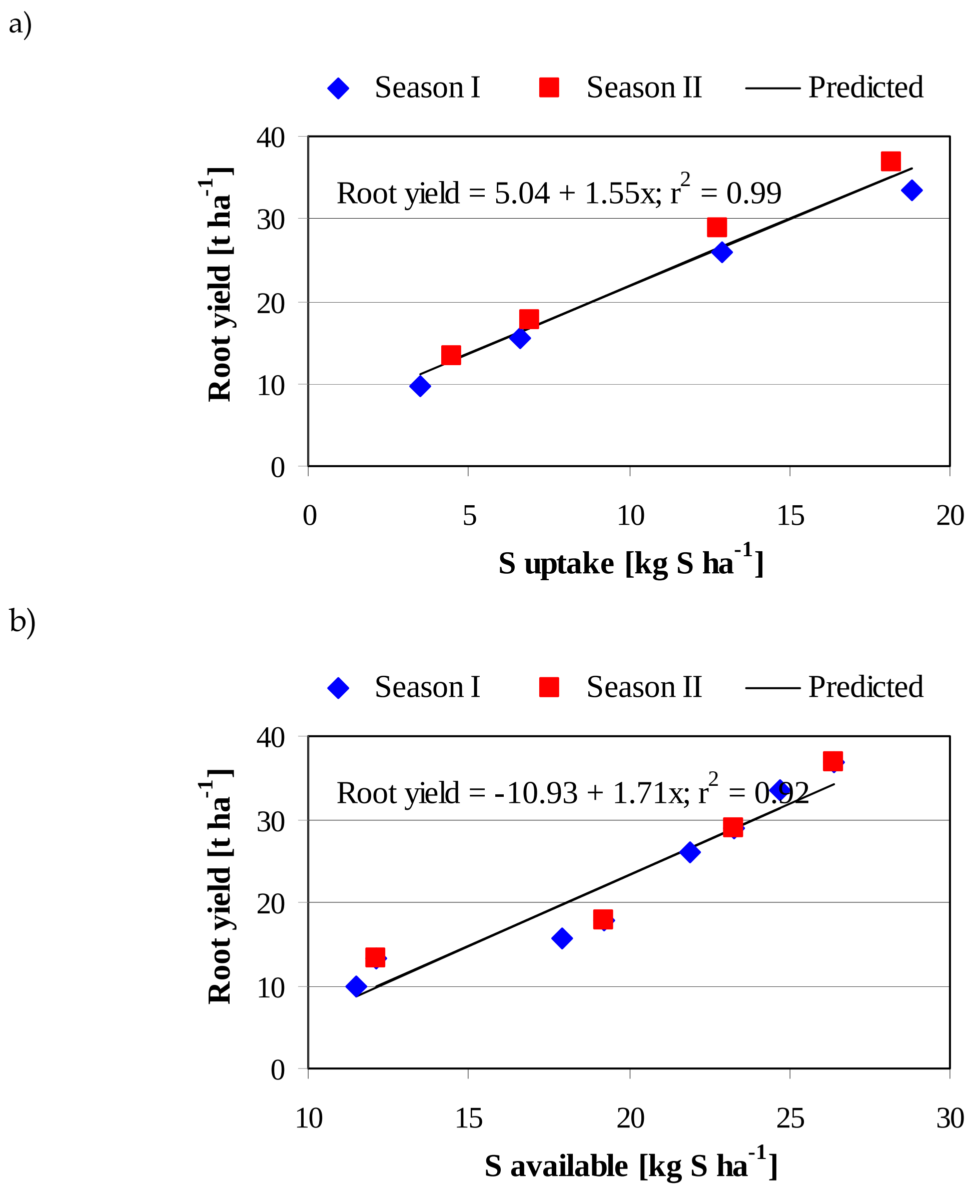


Figure 1. Linear relationship between root yield and a) sulfur uptake b) available sulfur

Application of sulfur irrespective of sources increased sulfur uptake over control (Table 2). Sulfur uptake increased from 3.50 to 18.8 kg $ha^{-1}$ and 4.5 to 18.2 kg $ha^{-1}$ in season I and II, respectively, with graded rate of S applied. The highest S uptake (18.8, 18.2 kg $ha^{-1}$) in seasons I and II was noticed at 100 kg S $ha^{-1}$. Addition of S through gypsum gave higher S uptake among all S sources tested. Increased S uptake could be due to higher soil S availability followed by rapid plant absorption and translocation S (Vinay Singh et al., 1995). A linear relationship existed between S uptake and root yield (Fig 1A).

Post harvest soil analysis showed a gradual increase of available S from 11.9 to 24.7 kg $ha^{-1}$ (season I) and 12.1 to 26.4 kg $ha^{-1}$ with graded rate of S applied from 0 to 100 kg $ha^{-1}$. It is clearly observed that addition of 25 kg S $ha^{-1}$ failed to raise the S status beyond the critical limit of 20 kg $ha^{-1}$, while addition of 50 and 100 kg S $ha^{-1}$ improved the S status beyond the critical limit. This indicated a positive residual effect on a subsequent crop. Linear relationship existed between available S and root yield (Fig. 1B). Increased available S following S addition was reported by Bharathi and Poongothi (2008).

Sulfur uptake efficiency – kg S in plants kg $S^{-1}$ in soil steadily increased with S level. The highest SUPE was with 100 kg S $ha^{-1}$. The maximum SUPE was with gypsum. Ammonium sulfate and potassium sulfate were comparable. Sulfur utilization efficiency (SUTE) - kg of root yield divided by kg of S in plant measures the efficiency with which S in plants is utilized to produce economic yield. In both seasons S application decreased radish SUTE. The SUTE was higher with superphosphate compared to other S sources.

Sulfur use efficiency is a measure of economic yield produced unit $S^{-1}$ in soil. The SUE increased with S levels and the maximum value was with 100 kg S $ha^{-1}$ with gypsum as the S source. Fertilizer S uptake efficiency (FSUPE) was highest with 50 kg S $ha^{-1}$ applied in gypsum. Fertilizer S utilization (FSUTE) was highest at 25 kg S $ha^{-1}$ and decreased with S level. Fertilizer S use efficiency (FSUE) was highest at 50 kg S $ha^{-1}$ applied in gypsum. The presence of calcium in addition to S in the gypsum was probably conducive to favorable physico-chemical environment for better S utilization and translocation of S and ultimately higher yield, which resulted in higher SUE and its components.

Table 3. Effect of sulfur source and rate on S use efficiency and its components in radish (mean of three replicates).

| | Sulfur uptake efficiency (SUPE) | | Sulfur utilization efficiency ( SUTE) | | Sulfur use efficiency (SUE) | | Fertilizer S uptake efficiency (FSUPE) | | Fertilizer S utiliz. efficiency (FSUTE) | | Fertilizer S use efficiency (FSUE) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Season-1 | Season-II | Season-1 | Season-II | Season-1 | Season-II | Season-1 | Season-II | Season-1 | Season-II | Season-1 | Season-II |
| **S source** | | | | | | | | | | | | |
| Ammonium sulfate | 0.55 | 0.52 | 198.5 | 236 | 108.8 | 124.2 | 0.16 | 0.13 | 139.3 | 116.9 | 22.6 | 15.9 |
| Super phosphate | 0.44 | 0.46 | 217.7 | 238.2 | 96.1 | 108.9 | 0.12 | 0.11 | 167.3 | 107.3 | 19.6 | 12.9 |
| Gypsum | 0.65 | 0.57 | 194.9 | 215.7 | 125.8 | 122.9 | 0.2 | 0.16 | 148.8 | 240.6 | 29.3 | 38.1 |
| Potassium sulfate | 0.56 | 0.52 | 206.6 | 227.5 | 115.8 | 119.1 | 0.15 | 0.14 | 244.5 | 210.9 | 34.2 | 29.7 |
| **S level, kg ha$^{-1}$** | | | | | | | | | | | | |
| 0 | 0.3 | 0.37 | 280.3 | 294.4 | 85.3 | 109.5 | - | - | - | - | - | - |
| 25 | 0.37 | 0.36 | 236.4 | 254.1 | 88.1 | 92.8 | 0.13 | 0.1 | 194.6 | 163 | 23.2 | 17.6 |
| 50 | 0.59 | 0.55 | 201.9 | 226.2 | 118.9 | 124.2 | 0.19 | 0.17 | 175.8 | 180.9 | 32.5 | 31.4 |
| 100 | 0.76 | 0.69 | 177.9 | 201.9 | 135.4 | 139.2 | 0.16 | 0.14 | 154.6 | 162.9 | 23.7 | 23.5 |

## REFERENCES


Bharathi, P., Poongothi, S. (2008). Direct and residual effect of sulfur on growth, nutrient uptake, yield and its use efficiency in maize and subsequent green gram. *Research Journal Agricultural Biological Sciences* 4, 368–372.

Bhargava, B.S., Raghupathi, H.B. (1995). Analysis of plant materials for macro and micronutrients, pp. 61–62. In: Tandon, H.L.S. (Ed.) *Methods of analysis of soils, plants, water and fertilizers*, Fertilizer Development and Consultation Organization, New Delhi.

Chatterjee, C., Gupta, J., Khurana, N. (1999). Effect of sulfur deficiency on onion metabolism. *Indian Journal Horticulture* 56, 155–158.

Chesnin, L., Yien, C.H. (1951). Turbid metric determination of available sulfur in soil. *Soil Science Society of American Proceedings* 15, 149–151.

Hazra, C.R. (1997). Soil sulfur status and crop responses to sulfur in Bundelkhand region. *Fertilizer News* 42, 35–45.

Kute, S.B. (1997). Sulfur in Indian agriculture. *National Symposium on Sulfur in Balanced Fertilization* New Delhi, pp-S 111-2/1 February 13–14.

Malhi, S.S., Gan, Y., Reney, J.P. (2007). Yield, seed quality and sulfur uptake of Brassica oilseed crops in response to S fertilization. *Agronomy Journal* 99, 570–577.

Oh, W.K. (1998). Plant response to sulfur application. *Proceedings International symposium on sulfur for Korean Agriculture*. Sulfur Institute, Washington D.C USA, 118–130.

Olsen, S.K., Cole, C.V., Watanabe, F.S., Dean, A.L. (1954). *Estimation of available P in soil by extraction with sodium carbonate*. USDA Circ.939.

Prakash, O., Singh, S., Singh, V. (1997). Status and response of sulfur in alluvial soils for higher yields of vegetable crops. *Fertilizer News* 42, 23–29.

Srinivasarao, C., Ganeshmurthy, A.N., Ali, H., Singh, K.K. (2004). Sulfur availability and response of mungbean and urdbean to sulfur on different soil types of pulse growing regions of India. *Communication in Soil Science and Plant Analysis* 35, 1783–1723.

Stannford, S., English, L. (1949). Use of flame photometer in rapid soil test of K and Ca. Agronomy Journal 41: 446–447.

Subbiah, S.S., Asija, C.L. (1956). A rapid procedure for the estimation of available nitrogen in soil. *Current Science* 25, 259–260

Sundaram, V., Udaykumar, A., Vadivel, E. (2005). Effective microorganisms on growth and yield of radish (*Raphanus sativus*. L.) cv. Pusa Chetki (short). http://www.eminfo.nl/radish.doc.

Singh, V., Singh, A., Metha, V.S. (1995). Effect of sulfur sources and levels on yield and uptake of nutrients by garlic. *Fertilizer News* 40, 47–49