REVIEW ARTICLE

ROLE OF SULPHUR IN OILSEED CROPS: A REVIEW

Pooja K. Patel*, Varis Ali H. Kadivala and Vimal N. Patel

B. A. College of Agriculture, Anand Agricultural University, Anand -388 110
Email:patelpooja388@gmail.com

Received-04.03.2019, Revised-23.03.2019

Abstract: India is largest producer and consumer of vegetable oil in the world. Oilseeds have been the backbone of agricultural economy of India since long. Oilseed crops are primarily grown for edible oil. Sulphur is an important nutrient for the higher yield and quality of oilseed crops. Sulphur plays a remarkable role in protein metabolism. It is required for the synthesis of proteins, vitamins and chlorophyll and also sulphur containing amino acids such as cystine, cysteine and methionine which are essential components of protein. Among the sulphur supplying sources, gypsum and elemental sulphur are being abundantly used in sulphur deficient soils.Use of high analysis sulphur free fertilizers, heavy sulphur removal by the crops under intensive cultivation and neglect of sulphur replenishment contributed to widespread sulphur deficiencies in arable soils. Due to Sulphur Deficiency, plants leaves becomepale green, yellowish green or complete yellowcolouration.The leaves are smaller and narrower and stem growth is affected.

Keywords: Sulphur, Growth, Oilseed, Quality

INTRODUCTION

India is one of the major oilseed grower and importer of edible oils. India's vegetable oil economy is world's fourth largest economy after USA, China & Brazil. The oilseed accounts for 13% of Gross Cropped Area, 3% of the Gross National Product and 10% value of all agricultural commodities. In India, oilseeds are cultivated over an area of 24.65 million hectares with a production of 31.31 million tones (Anon, 2018). Gujarat ranks third in the production of oilseeds in India whereas Madhya Pradesh tops the list and Rajasthan is in second position.The diverse agro-ecological conditions in the country are favourable for growing annual oilseed crops, which include 7 edible oilseeds (groundnut, rapeseed & mustard, soybean, sunflower, sesame, safflower and niger) and two non-edible oilseeds (castor and linseed) (Table 1).

Oilseed crops generally are one of the most important crops in the world. Their role in human diet and industrial application cannot be underestimated. The major oilseed crops include soyabean,coconut, oil palm, sesame, rapeseed, sunflower, safflower, olive seed, *etc*. The byproducts (hull, meal and oil) of oilseed crops had been integrated into human and animal diets due to its nutrient compositions. Majority of the oilseed meal consists of proteins and high contents of essential amino acid which are beneficial to human health and wellbeing. Likewise, the fat yields of oilseed crops are generally high, though varied from crop to crop (specie) and methods of extraction; high polyunsaturated fatty acids contents also prevent against coronary heart disease. Apart from the food value of oilseeds, several industrial products such as biodiesel, fertilizer, medicine, cosmetics, animal feeds, fibers, paint, button *etc*. have also been reported. Oilseed crops are promising crop with high potentials to improve human diets, prevent malnutrition and food insecurity and to provide employment through income generation in the society. Several researches had been carried out on the extraction of oil from oilseeds using different methods, production of improved breed of oilseed and detoxification of oilseed meals.It is known that one of the essential nutrients in human consumption is oil or fat, derived from the plant or animal sources. However, there is a limited increase in animal fat production. Therefore, in order to meet the increasing need in oil production is bound to the improvement and growth in oil plants. Oil is important due to the fact that not only it isan energy source in human consumption but also it is essential in the use of A, D, E, K vitamins and it contains oleic, linoleic (78%) fatty acids. Protein, oil, fiber and carbohydrate composition and energy value of different oilseed crops are given in table 2(Singh, 1999).

Sulphur (S) ranks 13th in terms of abundance in the earth's crust and is the fourth major plant nutrient after Nitrogen (N), Phosphorus (P), and Potassium (K). Generally, the oilseed crops require as much S as they need P. Sulphur is used as soil amendment for amelioration, as plant nutrient for increasing yield and quality of crop produce, as chemical agent to acidulate other nutrient and as pesticides (Kanwar and Mudahar, 1986). Sulphur plays an important role in the nutrition of oil seed crop and it act as a constituent of sulphur containing amino acids cystine, cysteine and methionine. (Parmar *et al.,* 2018 and Gangadhara, 1990). They considered that the oil seeds require more sulphur than other crops; its concentration and uptake vary with the availability of sulphur in soil. The overall requirement of sulphur for oil seed crops is as high as phosphorus (Aulakh and Pasricha, 1988). In oil seed crops, it is also involved in the formation of glucocides or glucosinolates which on hydrolysis

*Corresponding Author

increase the oil content. One of the main functions of sulphur in proteins or polypeptides is the formation of disulphide bonds between polypeptide chains. Disulphide linkages are important in stabilizing and determining the configuration of proteins. The application of sulphur increased the uptake of various macro and micro nutrients in groundnut (Singh, 1999). Sulphur deficiencies in soil and plant are recognized as a wide spread problem. Crop grown in sulphur deficient soil have poor utilization of N, P, K and a significant reduction in sulphur content in plants. Sulphur is also essential for the formation of chlorophyll and improves root growth besides this is involved in the formation of vitamins and enzymes required for the plant to conduct its biochemical processes (Jat*et al.*,2017 and Scherer *et al.,* 2008). Ultimately it only reduces the grain yield and quality of produce but also make a sharp impact in agro-based economy (Patil *et al.,* 2014 and Fismesa*et al.,* 2000). Sulphur can be applied to the soil through any suitable sulphur carriers *viz.* gypsum, elemental sulphur, ammonium sulphate and potassium sulphate *etc.* The choice depending on crop, local availability, price and need for other nutrients. Among the sulphur supplying sources, gypsum and elemental sulphur are being abundantly used in sulphur deficient soil.

Physiology and biochemistry of sulphur nutrition

The importance of S as plant nutrient has been recognized since the middle of the last century. Plants satisfy their S requirements from soil, atmosphere, irrigation water, and application of S containing fertilizers. An adequate supply of S to plant can improve yield, quality, and efficiency of other nutrients utilization besides reducing the incidence of diseases and is as important as phosphorus for oilseed crop. The functions of S, their requirement, yield responses and quality improvement and deficiency symptoms are discussed here.

Sulphur requirement

The oilseeds require more amount of S for its growth and development than other crops. The crops require S to make specific amino acids and various metabolites containing S, protein synthesis and process required for efficiency from other inputs. Being comparatively a drought tolerant with low transpiration, the oilseeds are susceptible to nutritional disorders especially S due to insufficient supply. The S requirement of oilseed crops in the field has been worked out by several workers (Banu *et al.,* 2017; Tandon 1991a, 1991b; Aulakhand Pasricha, 1988; Pasricha *et al.,* 1988 and Kanwar *et al.,* 1983).Based on the number of published data,Aulakh and Pasricha (1988) and Dhage*et al.* (2014) reported that the S uptake ranged from 5 to 20 kg t^{-1} of oilseeds and ranked the S requirement of oilseeds crucifers>sesame= sunflower>legumes > linseed. Sulphur requirement of oilseeds can be met through a number of S-containing materials such as gypsum, elemental S, pyrite and phosphogypsum. Generally, application of 30-40 kg S ha^{-1} to groundnut was more beneficial (Patel *et al.,* 2018;Kale, 1993 and Patra *et al.,* 1995).Application of S increased 4.5 to 7.5 kg groundnut yield per kg ha^{-1} of nutrient applied (Singh and Chaudhari, 1997).

Functions of Sulphur

The sulphur accounts for 0.1-0.5% dry wt. of the oilseeds where it is present in both organic and inorganic form. The sulphate uptake is slightly lower than phosphate. The S is mainly taken up by plant through roots as sulphate (SO_4^{-2}), but S also can be absorbed by leaves as SO_2 gas from the atmosphere. However, this gaseous S has to be subsequently transformed into the sulphate. In the chloroplast, the sulphate is first reduced to sulphide and thenincorporated into cysteine. A major portion of cysteine S is transferred to methionine, and bulk of these two is incorporated into proteins, where cysteine is responsible for secondary structure. The sulphide which is not incorporated into protein convert back to sulphate and stored in the leaves and to a lesser degree, in the seeds and can be mobilized whenever necessary. The S is required for the synthesis of protein, oils and vitamins. About 90% of the reduced S is required for the protein as it is constituent of methionine (21% S), cysteine (26% S), cystine (27% S). Some 50% of the total sulphur content of proteins are in methionine. Cystine is formed by the oxidation of two molecules of cysteine. Sulphur is also important for chloroplast and chlorophyll synthesis owing to its role in protein synthesis and important enzymes and redox reactions. Sulphur is also associated with flowering, nodulation and the quality of oilseeds and especially of groundnut crop. The S deficiency disrupt nitrogen metabolism, reduce protein quality, and induces carbohydrates accumulation.

Effect of Sulphur on crop quality and yield

The economic value of oilseeds is determined by its yield and quality, which are the resultant in part of the grower's ability to exploit the plant genetic make-up and part of less tractable components of the environment in which it is growing.Sulphur is involved in oil synthesis, and oil storage organs which are rich in S.The composition of oil and meals of most of the oilseeds has received greater attention from quality point of view.The oil in low erucic acid is nutritionally more desirable for human consumption. Low glucosinolate meals are acceptable for feed for livestock.The S is a part of oil compounds and its application increases the oil content in most of the oilseeds. On an average 5% increase in oil content has been observed with S fertilization (Naiknawar*et al.,* 2015 and Pasricha *et al.,* 1987).Effect of sulphur application on cell division, enlargement and elongation resulting in overall improvement in plant organ associated with faster and uniform vegetative growth of the crop (Noman *et al.,* 2015). Patel *et al.* (2018) reported that

the application of sulphur increase the protein content, oil content, haulm yield and pod yield in groundnut at Anand, India (Table 3)(Patel *et al.*, 2018).

Deficiency symptoms of sulphur

The S deficiency causes production of pale green, yellowish green or complete yellowcolouration of the leaves (Fig. 1).The S deficiency resembles those of nitrogen, but appear first on younger leaves due to its lesser mobility in plant. The S stored in the older leaves as sulphate is easily mobilized and transferred to growing organ to a certain extent, but not the one that has already been incorporated into organic compound. However, the S mobilized from older leaves is not sufficient to maintain the normal growth, as a result the youngest leaves remain small and more or less yellow owing to lack of protein and chlorophyll. The S content of older leaves is thus somewhat higher than the young leaves. The S deficient plants are stunted and have a rigid erect appearance. The leaves are smaller and narrower, stem growth is affected. As the oilseeds has very high requirement for S, the S-deficiency in oilseeds can reduce the yields from 20 to 40% even without or mild visible symptoms. The visible symptoms are the indication of severe stress of S-deficiency and fertilization is must to sustain the production. The deficiency symptoms available for individual oilseeds are given in table 4.

Determination of Sulphur Deficiency

Soil Analysis: A number of chemical methods have been developed and tested for estimating the available sulphur status of soils. The important thing is the selected method should be accurate, precise, rapid and highly correlated with crop response to sulphur application. The most often used method in India and some other places involve extraction of soil sulphur with 0.15 percent solution of $CaCl_2$. Soils containing less than 10 ppm sulphur are considered to be low or deficient in plant available sulphur by this method (Williams and Stainbergs,1959). Globally, monocalcium phosphate is also a popular extractant.

Plant Analysis: Plant analysis is carried out by standard analytical methods. Normally, if leaves of cereal plants contain less than 0.2% sulphur are considered to be deficient in sulphur and require sulphur application for optimal growth and yield production. S is estimated in plant digest obtained by dry ashingby wet digestion with HNO_3 and $HClO_4$(Chaudhary and Cornfield, 1966).

Sources of sulphur useful for various oilseed crops

There are now many sources of S fertilizers, but the comparative response of various S sources on oilseeds has been studied by a few workers (Banu *et al.*, 2013; Bandopadhyay and Samui, 2000; Chaubey*et al.*, 2000 andDutta and Patra, 2005). The most commonly used S fertilizers are ammonium sulphate (24% S), single superphosphate (12% S), Gypsum (13% S), pyrite (22-30% S), elemental S (85-100% S). The other S sources are phosphogypsum (16% S), potassium sulphate (18% S), magnesium sulphate (13% S), pressmud (2-3% S), sulphur sludge (10-16% S). The S fertilizers containing SO_4^{-2}-S were effective for most of the oilseed crops, (Tandon, 1991a). The gypsum is reported to be efficient for groundnut and mustard.

As the elemental S require oxidation before its uptake by plants hence should be applied 20-25 days before planting. The efficacy of elemental S increases with increase in soil pH but not in soil with high sodium. Pyrite is also a slow-release fertilizer (Tiwari *et al.*, 1984) and suitable for calcareous and alkaline soils. It also requires application 20 to 25 days before planting in moist soil. The gypsum and phosphogypsum are suitable for both alkaline and acid soils but more suitable for crop requiring high Ca such as groundnut (Rao *et al.*, 2013). The ammonium sulphate is most suited for non-nitrogen fixing oilseed crops and corrects both the N and S deficiencies. The singlesuperphosphate is a good source of S and P and required for integrated P and S application in most of the oilseeds.

How to apply the S fertilizers?

Broadcast or dribble banded, broadcast and subsequent incorporation, band placement, seed placement and banded near the seed are the major methods of application of sulphur fertilizers in soils. Among these methods broadcasting and band placement methods are widely used.

Managing sulphur fertilization in soil using 4R nutrient stewardship principle (Right Source of nutrient applied at the Right Rate, Right Time, and Right Place) is a modern tool to enhance the use efficiency of S-fertilizers.

Scientific management practices can be adopted to avoid the losses of the nutrient element S. A combination of soluble SO_4^{-2} and elemental S may be useful to provide both an immediate and a prolonged source of plant nutrition.

Table 1. Common Oilseed crops grown in India**.**

Common name	Botanical name	Others name
Groundnut	*Arachis hypogaea*	Moongphali, Chinabadam, Bhoising, Kadalcayi, Bhu mung, Verusanaga.
Rapeseed-Mustard	*Brassica compestris (Sarson)* *B. juncea (Raya)*	Rai, Sorse, Sasuve, Aasur, Kadugu, Mohori, Sorisa,
Niger	*Guizotiaabyssinica*	Kala til, Ramtil, Gurellu, Karale, Kattelu, Valasulu

Sunflower	*Helianthus annuuas*	Surya mukhi, Suraj mukhi, Surya kantihi
Sesamum	*Sesamum indicum*	Til, Acchellu, Rasi, Nuvvulu
Safflower	*Carthamumtinctoris*	Kardi, Kushmaginzalu
Soyabean	*Glycin max*	Bhatmas, Garikalai, Muth
Caster	*Ricinus cummunis*	Aranda, Erandi, Rendi, Haralu
Linseed	*Linumusitatissimum*	Tichi, Tishi, Java, Alsi, Seeme, Pesi

Table 2. Composition and energy value of oilseeds.

Composition (%)						**Energy(Cal/100 g kernel)**
Oilseeds	**Moisture**	**Protein**	**Oil**	**Fiber**	**Carbohydrate**	
Groundnut	5.0	28.5	47.5	2.8	13.3	595
Mustard	8.5	20.0	39.7	1.8	23.8	541
Niger	4.2	23.9	39.0	10.9	17.1	515
Sunflower	5.5	19.8	52.1	1.0	17.9	620
Sesamum	5.3	18.3	43.3	2.9	25.0	563
Safflower	5.5	13.5	25.6	34.9	17.9	356
Soyabean	8.1	43.2	19.5	3.7	20.9	432

Table 3. Effect of sulphur levels on protein content, oil content, haulm yield and pod yield of groundnut**.**

Sulphur level	**Protein content (%)**	**Oil content (%)**	**Haulm yield (kg ha^{-1})**	**Pod yield (kg ha^{-1})**
0 kg S ha^{-1}	27.00	41.76	3704	1745
20 kg S ha^{-1}	27.29	43.08	4141	1956
40 kg S ha^{-1}	27.48	43.75	4349	2083

Table 4. Deficiency symptoms of major oilseed crops**.**

Crops	**Deficiency Symptoms**
Rapeseed-Mustard	Deficiency symptoms first occur on younger leaves. Chlorosis of leaf margins, development of purple pigmentation. Inward curling of young leaf lamina giving rise to a cupped appearance followed by scorching and withering.
Groundnut	Stunted growth, and general yellowing of plants. Delay in maturity. Acute sulphur deficiency causes the entire plant turn to yellow.
Sunflower	Yellowing spreads from the base to the apex. Growth of plants is reduced. The size of capitulum is severely restricted. Inflorescence may remain covered within the bracts. Maturity of flowers is often delayed.
Sesame	Growth is retarded, leaves are smaller and fully emerged leaves first turn pale and then golden yellow. Number of flowers and pods are reduced; hence yield is reduced.
Canola	Younger leaves are lime-green, often with interveinal chlorotic mottles and pale leaf margins. Leaves are cupped or roll inwards and become thickened and crisp and brittle.

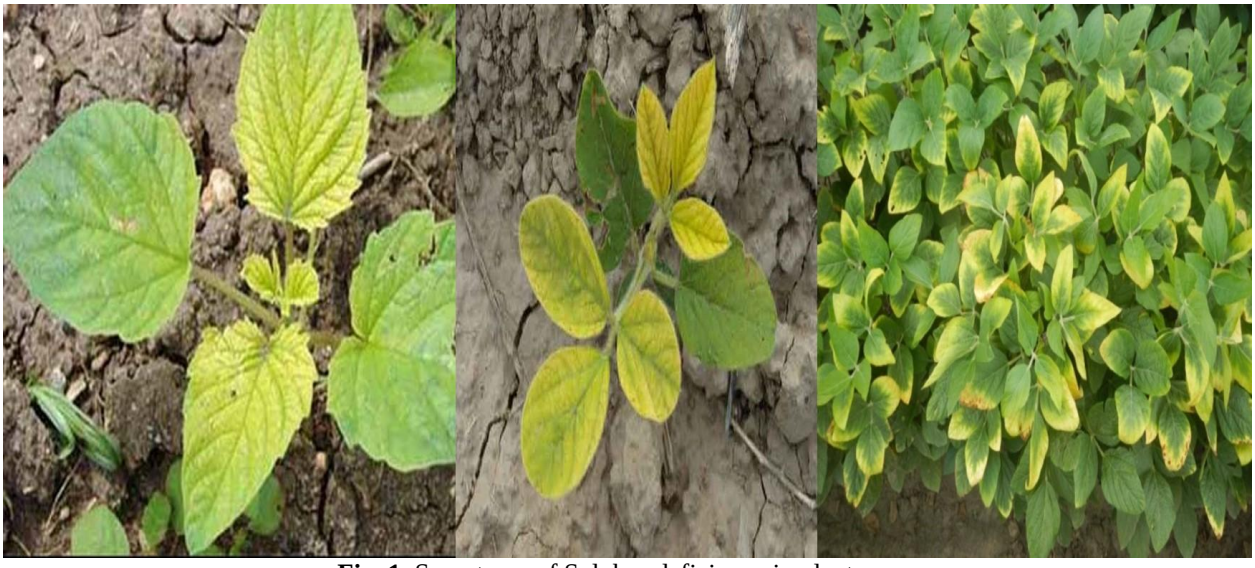

Fig. 1. Symptoms of Sulphur deficiency in plants

CONCLUSION

The application of sulphur @ 30 to 40 kg ha^{-1} significantly influence the growth, yield, nutrient uptake and economics of oilseed crops in different agro climatic zone of the country. Sulphur applications has pronounced effect on quality parameters of oilseeds.

REFERENCES

Anonymous (2018). Agricultural statistics at a glance, Government of India, Ministry of Agriculture & Farmer Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics & Statics.

Aulakh, M.S. and Pasricha, N.S. (1988). Sulphur fertilization of oilseeds for yield and quality. Proc. TSI-FAI Symposium on Sulphur in Indian Agriculture, New delhi, India. SII/3: 1-14.

Bandopadhyay, P. and Samui, R.C. (2000). Response of groundnut (*Arachis hypogaea* L.) cultivars to levels and sources of sulphur in west Bengal. *Ind. J. Agron.*45(4): 761- 764.

Banu, R., Shroff, J.C. and Shah, S.N. (2017). Effect of sources and levels ofsulphur and bio-fertilizer on growth, yield and quality of summer groundnut. *Int J Agr Sci.* 13(1): 67-70.

Chaubey, A.K., Singh, S.B. and Kaushik, M.K. (2000). Response of groundnut (*Arachis Hypogaea* L.) to source and level of sulphur fertilizer in mid-western plains of Uttar Pradesh. *Ind. J.Agron*. 45(1): 166-169.

Chaudhry, I.A. and Cornfield, A.H. (1966). The Determination of Total Sulphur in soils and plant material. *Analyst*. 91: 528-530.

Dutta, D. and Patra, B.C. (2005). Response of groundnut (*Arachis hypogaea* L.) to sources and levels of sulphur fertilization in alluvial soils of West Bengal. *J.interacademicia*. 9(1): 45-48.

Dhage, S.J., Patil, V.D. andPatange, M.J. (2014). Effect of various levels of phosphorus and sulphur on yield, plant nutrient content, uptake and availability of nutrients at harvest stages of soybean (Glycine max L.). *IJCMAS*. 3(12): 833-844.

Fismesa, J., Vong, P.C., Guckert, A. and Frossard, E. (2000). Influence of sulphur on appearant N use efficiency, yield and quality of oilseed rape (*Brassica napus* L.) grown on a calcareous soil. *Euro.J.Agron.* 12(2): 127-141.

Gangadharan, G.A. (1990). Effect of S on yield, oil content of sunflower and uptake ofmicronutrients by plants. *J. Ind. Soil. Sci. Soc.*38: 692-695.

Jat, R., Naga, S., Choudhary, R. and Mohammad, I. (2017). Effect of Potassium and Sulphur on Quality of Sesame (*Sesamum indicum* L.). *IJCMAS*.6(4): 1876-1878.

Kale, M.R. (1993). Effect of sulphur on growth and yield of groundnut. *Indian J. Agron*. 38(3): 504-505.

Kanwar, J.S. and Mudahar, M.S. (1986). Fertiliser Sulphur and Food Production. MartinusNijhoff/Dr. W. Junk Publisher, Dordrecht: 247p.

Kanwar, J.S., Nijhawan, H.L.and Raheja, S.K. (1983). Groundnut Nutrition and FertilizerResponses in India. ICAR New Delhi: 185p.

Naiknaware, M.D., Pawar, G.R. andMurumkar, S.B. (2015). Effect of varying levels of boron and sulphur on growth, yield and quality of summer groundnut (*Arachis hypogea* L.).*Int J Trop Agric*. 33(2): 471-474.

Noman, H., Rana, D.S. and Rana, K.S. (2015). Influence of Sulphur and zinc leveland zinc solubilizer on productivity, economics and nutrient uptake in groundnut (*Arachis hypogaea* L.). *Indian J. Agron.* 60(2): 301-306.

Parmar, N.N., Patel, A.P. and Choudhary, M. (2018). Effect of Sources and Levels of Sulphur on Growth, Yield and Quality of Summer Sesame under South Gujarat Condition (*Sesamum indicum* L.). *IJCMAS*,7(2): 2600-2605.

Pasricha, N.S., Aulakh, M.S., Bahl, G.S. and Baddesh, H.S. (1987). Nutritional requirementof oilseed and pulse crops in Punjab. Department of Soils., PAU, Ludhiana.

Pasricha, N.S., Aulakh, M.S., Sahota, N.S. and Baddesh, H.S. (1988). Fertilizer use research inoilseed crops. *Fert. News*. 33(9): 15-22.

Patel, P K., Viradiya, M.B., Kadivala, V.H. and Shinde, R.D. (2018). Effect of potassium and Sulphur on yield and quality of summer groundnut (*Arachis hypogaea* L.) under middle Gujaratcondition. *IJCMAS*.**7**(9): 2268-2273.

Patil, S.S., Choudhary, A.A., Goley, A.V. and Rasal, S.J. (2014). Effect of phosphorus and sulphur on growth yield and economics of linseed. *J. Soils Crops*, 24(1):159-164.

Patra, AK., Tripathy, S.K. and Samui, R.C. (1995). Response of groundnut (*Arachis hypogea*L.) to sulphur. *Indian J. Agric. Sci.* 65(80): 597-598.

Rao, K., Rao, T., Upendra, A. and Sekhar, D. (2013). Effect of Sources and Levels of Sulphur on Groundnut. *J. Acad. Ind. Res.* 2(5): 268-270.

Scherer, H.W., Pacyna, S., Spoth, K.R. and Schulz, M. (2008). Low levels of ferredoxin, ATP, and leghemoglobin contribute to limited N_2 fixation of peas (*Pisum sativum* L.) and alfalfa (*Medicago sativa* L.) under S deficiency conditions. *Bio-fert soils*. 44: 909-916.

Singh, A.L. (1999). Mineral nutrition of groundnut. *In: Advances in plant physiology scientific publisher, Indai.* 2: 161-200.

Singh, A.L. and Chaudhari, V. (1997). Sulphur and micronutrient nutrition of groundnut in acalcareous soil. *J. Agron. Crop Sci.* 179: 107-114.

Tandon, H.L.S. (1991a). Sulphur Research and Agriculture Production in India 3rd editionFDCO, New Delhi, India.

Tandon, H.L.S. (1991b). Secondary and micronutrients in Agriculture-GuideBook-cum-Directory. 2nd Ed. FDCO, New Delhi, India: 122 pp.

Tiwari, K.N., Dwivedi, B.S. and Pathak, A.N. (1984). Evaluation of iron pyrites as sulphur fertilizer. *Fer. Res.* 5: 235-243.

Williams, C.H. and Steinbergs (1959). Soil sulphur fraction as chemical indices of available sulphur in some Australian Soils. *Aus. J. Agric. Res.* 10: 340-352.