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Response of sulfur and lime levels on productivity, nutrient content and uptake of sesame under guava (*Psidium guajava* L.) based agri-horti system in an acidic soil of Eastern Uttar Pradesh, India

R. S. MEENA, [1]S. KUMAR AND [2]A. PANDEY

School of Environment and Natural Resources, The Ohio State University, Columbus, OH, USA- 43 210
[1]Department of Agronomy, CCS Haryana Agricultural University, Hisar, Haryana, India – 125 004
[2]Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (UP)-221 005, India-2210 05

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ABSTRACT

Soil acidity is one of the major factors which have an apparent role in the production of crops predominantly in oilseeds. The present field investigation was carried out during summer (Kharif) season of 2014 with the aim to evaluate the response of sulfur (S) and lime ($CaCO_3$) application on the productivity and nutrient uptake of sesame in acidic soil. The field experiment was laid out according to a factorial randomized block design with three replications and 16 combinations. Elemental sulfur (S^0-S) was applied as basal dose @ 0, 15, 30 and 45 kg ha^{-1} along with three lime doses @ 0, 100, 250 and 350 kg ha^{-1}. Sulfur and lime application at all the levels considerably enhanced the values of all parameters. Sulfur application of 30 kg ha^{-1} performed well as compared to other levels in respect to seed yield (282.75 kg ha^{-1}), stalk yield (359.84 kg ha^{-1}), biological yield (632.44 kg ha^{-1}) and harvest index (44.15%) of sesame along with uptake and content of N, P, K and S in seed and stalk; although S application @ 30 kg ha^{-1} was observed statistically comparable at P=0.05 with 45 kg S ha^{-1}. Likewise, lime application @ 250 kg ha^{-1} found statistically at par with the lime rate of 350 kg ha^{-1} in respect to all these parameters.

***Keywords*:** Lime, Nutrient content, Nutrient uptake, Sesame, Sulfur, Yield

Sesame (*Sesamum indicum*) also known as 'til'; is the oldest oilseed known and used by human-being (Isha and Milind, 2013). It is a crop of the tropics and subtropics and extensively cultivated in India, China, Myanmar, Sudan, Nigeria and Mexico. Sesame is considered to be a drought-resistant crop. It is mainly distributed between 25°S and 25°N, but it can also be found growing up to 40°N in China, Russia and the USA, and up to 30°S in Australia and 35°S in South America. India is the major producer accounting for about 24 per cent of the world's sesame area and 17 per cent of production. Sesame grows well on a wide range of soils (Alfisols, Entisols, Vertisols, Ultisols), but it does not thrive on acidic soils. In such soils, the physical, chemical and biological properties of soils and, therefore the crop yields get affected strongly. Soil acidity affects soil characteristics and crop growth in ways that are very visible and easily determined, but at less limiting levels growth and yield may still be reduced without these obviously recognizable effects. Research has shown that sesame yields on acid soils with pH below 5.5 can be substantially increased by application of lime (Haynes and Naidu, 1998). This is because the liming materials encourage soil aggregation, availability, and uptake of essential plant nutrients and the activities of the soil microorganisms.

Sulfur plays a central role in the nutrition of oilseed crops as it is a key element of S-containing amino acids such as cystine, cysteine, and methionine. It is a building block of protein and a key ingredient in the formation of chlorophyll. Now a day sulfur is becoming increasingly deficient for various reasons of intensive cultivation with high yielding crops and use of high analysis sulfur free straight fertilizers (Sardana *et al*., 2007). Inadequate S supply can affect the yield and quality of the crop owing to impaired protein and enzyme synthesis (Scherer, 2001). Sulfur deficiency directly or indirectly affects the numerous plant biosynthetic and physiological processes (Nikiforova *et al*., 2005) which subsequently decreased the yield and quality parameters (McGrath *et al*., 1996). The yield and quality of sesame crop can be improved by the application of sulfur. The recent research findings indicate the use of sulfur for increasing the productivity of sesame (Vaijapuri *et al*., 2003; Maragatham et al., 2006; Singh *et al*., 2006). As the soil acidity (low pH) and progressively more S deficiency are the major constraints responsible for low yield of sesame in eastern Uttar Pradesh, India. Keeping in view the information available on these aspects, conjunctive efforts were made to ensure sustained sesame production with an application of variable levels of sulfur and lime in acidic soils.

Site Description: A field experiment was laid out for the period of summer season of 2014 at the Agronomy Farm of Rajiv Gandhi South Campus Banaras Hindu University, Barkachha, Mirzapur, India, positioned at 25^0 05' latitude, 82^0 59' longitude and altitude of 89 meters above mean sea level in eastern Uttar Pradesh.

Email: sandeepsihag1992@gmail.com
Short Communication

This region falls in agro-climatic zone III A (Semi-Arid Eastern Plain Zone), sub-zone of the Middle Gangetic Plain zone, and most crops are generally grown under rainfed conditions

Experimental details : The field study was conducted on sesame crop sown between the alleys of 8 years old guava trees planted in August 2006 at a spacing of 7 x 7 m^2 as agro-horti based system. The experiment was laid out with factorial randomized block design replicating thrice, assigning 16 treatment combinations, consisting of four sulfur levels (0, 15, 30 and 45 kg ha^{-1}) and four levels of lime (0, 100, 250 and 350 kg ha^{-1}).

Physico-chemical properties of experimental soil : The soil samples were randomly collected from plough layer (0-15 cm) depths at the three physiographic positions of the experimental field before the sowing of the crop. The collected soil sample was air dried and properly analyzed in the laboratory for determination of soil physical and chemical properties. The soils of plough layer of the experimental field were sandy loam in texture (Black et al.,1965) and contained soil organic carbon (SOC) concentration of 0.29%; determined by chromic acid rapid titration method (Walkey and Black, 1934), 202.36 kg ha^{-1} alkaline permanganate oxidizable N (Subbiah and Asija, 1956), 19.55 kg ha^{-1} available P; extracted by 0.5 M $NaHCO_3$ at pH 8.5 (Olsen and Sommers, 1982), 236 kg ha^{-1} available K; determined by the flame photometer method with 1N KCl and titrating sued 0.05N NaOH (McLean, 1982) and 13 kg ha^{-1} available S; determined by Turbidity method (Chesnin and Yein, 1950). The soil was acidic in reaction having a pH value of 4.02; determined by using glass electrode pH meter (Jackson, 1973) and electrical conductivity 0.01 dS m^{-1} at room temperature (25^{o}C) in 1: 2 (soil: water) suspension 0.01M potassium chloride solution (Reeuwijk, 2002). The bulk density, particle density, field capacity and maximum water holding capacity of soil was 1.45 Mg m^{-3}, 2.65 Mg m^{-3}, 30 and 19.13 per cent (Piper, 1966), respectively.

Fig. 1 Experimental site Mirzapur, India

Cultural practices: The field was ploughed with

Table 1 : Effect of sulfur and lime levels on biological yields and harvest index of sesame

Treatment	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Sulfur levels (kg ha^{-1})				
Control	198.25	278.75	497.84	24.93
15	240.08	308.85	566.87	33.73
30	282.75	359.84	632.44	44.15
45	288.83	365.31	647.58	45.56
SEm(±)	**2.38**	**9.26**	**19.56**	**2.96**
LSD (0.05)	**6.88**	**26.75**	**56.50**	**8.56**
Lime levels (kg ha^{-1})				
Control	183.83	282.66	491.17	25.37
100	248.50	309.67	572.02	34.11
250	286.08	358.28	633.42	43.23
350	291.50	361.29	648.11	45.65
SEm(±)	**2.38**	**9.26**	**19.56**	**2.96**
LSD (0.05)	**6.88**	**26.75**	**56.50**	**8.56**

Cultural practices: The field was ploughed with the help of disc plough followed by harrowing and planking, respectively. After that, sulfur and lime were applied just before the sowing of a crop as per the treatment for each plot separately and thoroughly incorporated into the soil with the help of spade. The sesame variety Shekhar was selected for the experimental work. It was released from CSAU&T, Kanpur (U.P.) in 2001 and characterized by white color seed, tolerant to phyllody, leaf curl, powdery mildew, moderately resistant to Phytophthora blight, capsule borer, and bud fly. The seed was sown in-furrow on 06, August, 2013 at 30 cm apart at a depth of 2.5 cm having the seed rate of 4 kg ha^{-1} followed by covering the seed from another side of the furrow. The recommended dose of fertilizer was applied as basal application at the time of sowing @ 30 kg of nitrogen, 60 kg of phosphorus and 30 kg potassium ha^{-1} though urea (an organic fertilizer containing 46% N) DAP (a complex fertilizer containing 46% P_2O_5 and 18% N) and muriate of potash (contains 60% K_2O), respectively. To maintain uniform plant population, thinning was done

Table 2: Effect of sulfur and lime levels on nutrient content in seed and straw of sesame

Treatments	Seed (%)				Straw (%)			
	N	**P**	**K**	**S**	**N**	**P**	**K**	**S**
Sulfur levels (kg ha^{-1})								
Control	2.81	0.521	0.612	1.02	1.39	0.190	1.02	0.105
15	3.06	0.569	0.643	1.08	1.53	0.212	1.09	0.112
30	3.51	0.621	0.712	1.12	1.71	0.249	1.12	0.127
45	3.62	0.632	0.723	1.18	1.72	0.259	1.18	0.132
SEm(±)	**0.08**	**0.033**	**0.038**	**0.01**	**0.04**	**0.013**	**0.01**	**0.005**
LSD (0.05)	**0.24**	**0.096**	**0.109**	**0.04**	**0.12**	**0.037**	**0.03**	**0.014**
Lime levels (kg ha^{-1})								
Control	2.71	0.537	0.642	0.99	1.36	0.196	1.01	0.106
100	3.13	0.583	0.675	1.10	1.56	0.208	1.08	0.112
250	3.49	0.618	0.718	1.15	1.67	0.258	1.15	0.121
350	3.66	0.643	0.745	1.17	1.73	0.265	1.17	0.133
SEm(±)	**0.08**	**0.033**	**0.038**	**0.01**	**0.04**	**0.013**	**0.01**	**0.005**
LSD (0.05)	**0.24**	**0.096**	**0.109**	**0.04**	**0.12**	**0.037**	**0.03**	**0.014**

Table 3: Effect of sulfur and lime levels on nutrient uptake in seed and straw of sesame

Treatments	Seed (kg ha^{-1})				Straw (kg ha^{-1})			
	N	**P**	**K**	**S**	**N**	**P**	**K**	**S**
Sulfur levels (kg ha^{-1})								
Control	14.17	0.543	0.484	0.693	23.42	2.96	12.69	1.47
15	16.54	0.747	0.595	0.805	25.44	3.18	13.09	1.62
30	19.19	1.52	0.703	0.923	27.58	3.35	13.82	1.72
45	20.11	1.64	0.767	0.939	28.01	3.59	14.08	1.74
SEm(±)	**0.36**	**0.040**	**0.016**	**0.017**	**0.59**	**0.05**	**0.25**	**0.03**
LSD (0.05)	**1.03**	**0.116**	**0.048**	**0.049**	**1.69**	**0.15**	**0.72**	**0.08**
Lime levels (kg ha^{-1})								
Control	14.09	0.605	0.470	0.622	22.34	2.93	12.71	1.44
100	15.81	0.912	0.584	0.821	25.61	3.19	13.01	1.55
250	19.45	1.28	0.727	0.952	27.12	3.42	13.79	1.69
350	20.66	1.51	0.767	0.966	28.38	3.62	14.09	1.74
SEm(±)	**0.36**	**0.040**	**0.016**	**0.017**	**0.59**	**0.05**	**0.25**	**0.03**
LSD (0.05)	**1.03**	**0.116**	**0.048**	**0.049**	**1.69**	**0.15**	**0.72**	**0.08**

after two weeks of sowing. For management of weeds, a manual weeding was done at 20-25 days after sowing when the soil moisture was sufficient for easy weed removal from the soil.

Observations: The crop was harvested at complete maturity as judged by visual observations on 02, October, 2013. The border rows were harvested first and kept aside. After that, the net plots were harvested, bundled and sun dried. After properly sun drying of a tagged bundle, each bundle was weighed, threshed and cleaned and winnowed separately of each plot and seed yield per plot was recorded. For recording stalk yield, seed yield was deducted from the total bundle weight. Harvest index was calculated by dividing economic yield (i.e. seed yield) with biological yield (seed + stover yield) and expressed as percentage –

$$\text{Harvest index (\%)} = \frac{\text{Economic yield kg ha}^{-1}}{\text{Bio log ical yield kg ha}^{-1}} \times 100$$

The plant and seed material was chopped, dried in an oven and grinded in Willey mill to pass through a 30 mesh sieve for chemical analysis of nutrient content for N (Colorimetric method; Lindner, 1944), P (Vanado molybdate yellow color method; Jackson, 1958), K (Flame-photometric method; Jackson, 1958) and S (Turbidity method; Chesnin and Yein, 1950). The nutrient uptake in seed and straw of sesame was calculated in kg ha^{-1} about dry matter production per ha by using the formula –

Nutrient uptake (kg ha^{-1}) =

$$\frac{\text{Nutrient content (\%)} \times \text{Yield (seed / straw in kg ha}^{-1})}{100}$$

Weather during the experiment: Sesame is basically a crop of warm regions of the tropics and subtropics. The normal period of the onset of monsoon in Mirzapur belt is the third week of June, and it lasts up to end of September or sometimes extends to the first week of October. On an average, out of the total annual rainfall major fraction (about 75%) is received from June to September. The winter months are cool whereas summers are hot and dry. The temperature begins to rise from the month of February and reaches its maximum in May. For the duration of the crop season, total rainfall was received 513.70 mm. Out of total rainfall, more than 88% received between 32 to 35 standard meteorological weeks (SMW). The mean maximum temperature during the crop growth season was 34.95^{0}C whereas; mean minimum temperature was 25.30^{0}C. The relative humidity varied between 92.10 and 96.57 per cent.

Statistical Analysis: All the data recorded were statistically analyzed using the standard procedures of randomized block design (Gomez and Gomez, 1984). Analysis of variance (ANOVA) was used to determine the influence of all treatment. Once F ratio was significant, a multiple mean comparisons was performed using Fisher's Least Significance Difference Test. Critical difference (CD) values at $p = 0.05$ were used to determine the significance of differences between mean values of treatments. The standard level of significance used to justify a claim of a statistically significant effect (Fisher, 1954).

Effect of sulfur

The sulfur level increased up to 30 kg ha^{-1} significantly improve the seed yield, stalk yield, biological yield and harvest index of sesame (Table 1). The maximum seed yield, stalk yield, biological yield and harvest index recorded with an application of 30 kg sulfur ha^{-1} were 282.75 kg ha^{-1}, 359.84 kg ha^{-1}, 632.44 kg ha^{-1} and 44.15 per cent respectively. The minimum values of these parameters recorded were 198.25 kg ha^{-1}, 278.75 kg ha^{-1}, 497.84 kg ha^{-1} and 24.93per cent, respectively in control plot. Further, increased sulfur levels up to 45 kg ha^{-1} were statistically *at par* with 30 kg sulfur ha^{-1}. The increased seed yield, stalk yield, biological yield and harvest index yield up to 30 kg sulfur ha^{-1} were 42.62, 29.09, 27.03 and 77.09 per cent respectively over control. This result seems to be due to enhancing sulfur availability faster to plants. Thereby, improvement in growth characters at initial growth stages and after that yield attributing parameters coupled with a nutritional concentration in plant leads to higher yield and harvest index. Scientific research also suggested the increased seed, straw, biological yield and harvest index with the application of sulfur in different oilseeds (Bhagat and Soni, 2000; Chanda *et al*., 2002; Meena and Meena, 2013; Meena *et al*., 2013). Similarly, with increased level of sulfur up to 30 kg ha^{-1} significantly increased the nitrogen, phosphorus, potassium and sulfur content in seed and stalk of sesame (Table 2). The maximum values of these parameters in seed (3.51, 0.621, 0.712 and 1.12 %, respectively) and stalk (1.71, 0.249, 1.12 and 0.127%, respectively) were observed with application of 30 kg sulfur ha^{-1}. However, further increased a level of sulfur up to 45 kg ha^{-1} was statistically at par with 30 kg sulfur ha^{-1}. The same trend with respect to uptake of nitrogen, phosphorus, potassium, sulfur and total nutrients in seed and stalk of sesame was found with the application of 30 kg sulfur ha^{-1} (Table 3 and Fig 2). This increase in nutrient concentration might be attributed due to increasing in the supply of sulfur to plant, which in turn has resulted in a profused shoot and root growth, thereby activating greater absorption of N, P, K and S from the soil. The increased photosynthetic efficiency, which favored dry matter production and nutrient concentration in a plant, seems to be the major factor responsible for higher nutrient uptake under the influence of sulfur application. The benefits of sulfur application suggest the potential role of sulfur fertilization to bring out the greater availability of not only sulfur but also another nutrient which are considered important for growth and development of the plants. This result indicated that application of 30 kg S ha^{-1} was optimum dose for sesame cultivation. Sulfur and nitrogen are linked to each other in metabolic activity. Control treatment showed the lowest N-metabolism in the seed because no S was supplied there. Judicious application of S significantly increased the uptake of N in straw and grain as reported by many workers (Badruddin, 1999; Malhi *et al.*, 2006; Fazli *et al*., 2008; Mondal *et al*., 2012).

Effect of lime

The effect of different levels of lime on seed yield, stalk yield, biological yield and harvest index of sesame were observed significant (Table 1). The results revealed that application of 250 kg lime ha^{-1} had significantly higher seed yield (286.08 kg ha^{-1}), straw yield (358.28

kg ha^{-1}) and biological yield (633.42 kg ha^{-1}) and harvested index (43.23%) of sesame compared to remaining levels. Further, application of 350 kg lime ha^{-1} recorded increased seed yield, stalk yield, biological yield and harvest index over 250 kg lime ha^{-1} but it was not significant. This result is supported by Munns *et al*. (1981); Quaggio *et al.* (2004); Basu *et al*. (2008); Guo *et al*. (2009); Chalk *et al*. (2010); Bekere *et al*. (2013) who reported beneficial effect of lime for oilseed grown in acidic soil. Similarly, with increased level of lime up to 250 kg ha^{-1} significantly increased the nitrogen, phosphorus, potassium and sulfur content in seed and stalk of sesame. The maximum values of these parameters in seed (3.49, 0.618, 0.718 and 1.15%, respectively) and stalk (1.67%, 0.258, 1.15 and 0.121%, respectively) were observed with application of 250 kg sulfur ha^{-1}. However, further increased a level of sulfur up to 350 kg ha^{-1} was statistically at par with 250 kg sulfur ha^{-1} (Table 2). The same trend was also noticed regarding uptake of N, P, K and S in seed and stalk of sesame at the level of 250 kg lime ha^{-1} (Table 3 and Fig 2). The increase in nutrient concentration might be attributed due to increase in supply of calcium to plant, which in turn has resulted in profused shoot and root growth, thereby activating greater absorption of N, P, K and S from soil or also to increased soil pH after addition of lime which increases availability of these nutrients to plants. The addition of $CaCO_3$ increased soil pH and might have accelerated the process of mineralization of nitrogen which intern promoted the uptake of nitrogen by sesame. Similar results were also reported by Basu *et al*. (2008); Ranjit *et al*. (2007); Meena and Varma (2016); Varma *et al*. (2016).

The significance of lime and sulfur application appears to be obvious, and there are no doubts about their role in soil fertility improvement, nutrient uptake, and crop yield. The sesame yield, nutrient content, and uptake were increased with increase in a rate of lime and sulfur but this increment was significant up to 250 kg ha^{-1} lime and 30 kg ha^{-1} sulfur.

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