EFFECT OF SULPHUR AND SILICON FERTILIZATION ON YIELD, NUTRIENT UPTAKE AND ECONOMICS OF RICE

*S. JAWAHAR AND V. VAIYAPURI
DEPARTMENT OF AGRONOMY, FACULTY OF AGRICULTURE,
ANNAMALAI UNIVERSITY,ANNAMALAI NAGAR-608002.
TAMIL NADU, INDIA.
jawa_au@yahoo.com

ABSTRACT:

Field experiment was conducted at Experimental Farm, Annamalai University, Annamalai Nagar, Tamil Nadu, India during 2007-2008 to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. The treatments comprised four levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) and silicon (0, 40, 80 and 120 kg ha^{-1}) and were laid out in factorial randomized block design with three replications. Among the different levels of sulphur and silicon, sulphur at 45 kg ha^{-1} and 120 kg Si ha^{-1} recorded higher values for yield (grain and straw) and nutrient uptake (NPKS and Si) of rice, respectively. The combined effect of S at 45 kg ha^{-1} and Si at 120 kg ha^{-1} registered its superiority over its lower levels. The same treatment combination recorded maximum net return and return $rupee^{-1}$ invested in rice crop.

KEY WORD: *Rice, Sulphur, Silicon, Yield, Nutrient Uptake And Economics.*

INTRODUCTION:

Rice is the important staple food crop for more than two third of the population of India. The slogan ‘Rice is life’ is most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural household. At global level, rice is grown in an area of 158.10 million hectare with a production of 447.42 million tonnes and having the productivity of 4.22 t ha^{-1}(USDA, 2010). India has the largest acreage under rice of 44 million hectare and with a production of about 141 million tones and the national productivity of 3.21 t ha^{-1}. The burgeoning population of our country may stabilize around 1.4 and 1.6 billion by 2025 and 2050, requiring annually 380 and 450 mt of food grains respectively (Gulab Singh Yadav, 2009). Rice yields are either decelerating/stagnating/declining in post green revolution era mainly due to imbalance in fertilizer use, soil degradation, type of cropping system practiced, lack of suitable rice genotypes for low moisture adaptability and disease resistance (Prakash, 2010).

Sulphur(S) is one of the sixteen essential plant nutrients and ranks fourth major nutrient next to N, P and K. Crop requires sulphur generally as much phosphorus and one tenth of nitrogen. Among the essential elements, sulphur is very much beneficial for increasing the production of rice and is one of the major essential nutrient elements involved in the synthesis of chlorophyll, certain amino acids like methionine, cystine, cysteine and some plant hormones such as thiamine and biotin (Rahman *et al*., 2007). Accumulation of inorganic nitrogen or organic non-protein nitrogen in the tissue, leaf area, seed number plant^{-1}, floral initiation and anthesis in plants are affected by the presence or absence of sulphur (Tiwari, 1994). Growing of sulphur responsive crops, high intensive cropping and use of sulphur free fertilizers caused S deficiency in soils of India (Tandon and Tiwari, 2007).

Fly ash contains naturally occurring essential elements as similar to that of soil except humus and nitrogen and it has also been successfully used as a source of essential plant nutrients for boosting crop production and it's a cheap and rich source of silicon for crop production (Raghupathy, 1988 and Tripathi and Sahu, 1997). Silicon (Si) is the second most abundant element of the earth's surface and plays a significant role in imparting biotic, abiotic stress resistance and enhancing crop productivity. It is also crucial in preventing or minimizing lodging in cereal crops, a matter of great importance in agricultural productivity. Silicon is the only element known that does not damage plants with excess accumulation. Rice is a high Si accumulator plant and this element has been demonstrated to be necessary for healthy growth and stable production. For this reason, Si has been recognized as an "agronomically essential element" in Japan and silicate fertilizers have since then been applied to paddy soils (Ma *et al.,* 2001). Hence, it became imperative to study the combined effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice.

MATERIALS AND METHOD:

Experimental site, soil and treatments

The experiment was performed on a wetland field of Annamalai University Experimental Farm, (11º 21' N and 79º 44' E with an altitude of + 5.7 m a. m.s.l.), Annamalai Nagar, Tamil Nadu, India during 2007-2008. The soil of the experimental field is moderately fertile and clay loam in texture with the pH of 7.6. The treatment comprised of four levels of sulphur (0, 15, 30 and 45 kg S ha^{-1} through Gypsum) and silicon (0, 40, 80 and 120 kg Si ha^{-1} through Fly ash) and were applied as basal along with recommended dose of fertilizers (150:50:50 kg NPK ha^{-1}). The amount of applied K and S were adjusted according to the nutrients content of fly ash. The experiment was laid out in factorial randomized block design and replicated thrice.

Measurements:

Yield

Harvesting of rice was done by cutting the stem close to ground level and transported to threshing floor for threshing. The grain yield was recorded from the net plot area and expressed in kg ha^{-1} at 14 per cent moisture level. The straw yield of rice was recorded from the net plot area after enough sun drying and expressed in kg ha^{-1}.

Nutrient uptake

The plant samples used for dry matter estimation were ground into fine powder and used for chemical analysis to estimate the uptake of major nutrients at harvesting stage of rice crop with procedure outlined in the following table

Si. No.	Nutrient	Method	Reference
1.	Total nitrogen	Micro-Kjeldahl method	Humphries (1956)
2.	Total phosphorus	Tripleacid extraction	Jackson (1973)
3.	Total potassium	Spectrophotometry triple acid digestion	Jackson (1973)
4.	Total sulphur	Turbidimetric method	Bhargava and Raghupathi (1995)
5.	Total silica	'P' yellow color method	Jackson (1973)

Economic evaluation

The cost of inputs, labour charges and prevailing market rates of farm produce were taken into consideration for working out gross and net returns per hectare. The benefit cost ratio was worked out for various treatments by dividing the gross returns by cost of cultivation.

Statistical analysis

The experimental data's were analyzed as per the procedure outlined by Gomez and Gomez (1994). The critical difference was worked out as five percent probability level for significant results.

RESULTS AND DISCUSSIONS:

Yield

Sulphur and silicon application significantly influenced the grain and straw yield of rice (Table 1). Among the different levels of sulphur, application of 45 kg S ha^{-1} recorded maximum grain and straw yield of rice, which was closely followed by 30 kg S ha^{-1}. This treatment recorded 18.12, 7.47 and 2.43 per cent increase over 0,15 and 30 kg S ha^{-1} . Higher grain and straw yield due to S may be attributed to increase in growth and yield characters of rice and to be stimulating effect of applied S in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency, which in turn increased the yield (Biswas and Tewatia, 1992). Islam *et al.* (1996) reported 23 per cent increase in rice yield due to sulphur, confirmed this finding of the present study.

Table 1.Effect of sulphur and silicon fertilization on yield and nutrient uptake of rice (kg ha^{-1})

Treatments	Yield (kg ha^{-1})		Nutrient uptake (kg ha^{-1})				
	Grain	**Straw**	**N**	**P**	**K**	**S**	**Si**
Sulphur levels(S) (kg ha^{-1})							
0	**5012.12**	**8001.38**	**115.16**	**22.89**	**137.94**	**18.01**	**256.14**
15	**5652.66**	**9030.93**	**121.53**	**27.36**	**146.97**	**21.94**	**263.26**
30	**5960.65**	**9471.57**	**125.55**	**29.75**	**150.02**	**24.00**	**268.27**
45	**6109.15**	**9829.09**	**128.60**	**31.35**	**152.33**	**25.44**	**271.90**
CD	**159.42**	**223.27**	**1.97**	**1.17**	**1.27**	**1.15**	**2.07**
Silicon levels(Si)							

(kg ha^{-1})							
0	**5048.38**	**8244.01**	**117.55**	**24.28**	**141.31**	**18.90**	**251.41**
40	**5647.52**	**8980.66**	**121.19**	**27.16**	**146.06**	**21.61**	**264.58**
80	**5957.78**	**9439.18**	**124.50**	**29.22**	**148.96**	**23.63**	**269.82**
120	**6080.90**	**9669.11**	**127.59**	**30.69**	**150.93**	**25.25**	**273.76**
CD	**121.08**	**175.00**	**1.45**	**0.91**	**0.94**	**0.67**	**2.51**
Interaction (S X Si)							
CD	**185.39**	**274.18**	**3.01**	**1.45**	**1.9**	**1.32**	**3.25**

Increasing levels of silicon increased the grain and straw yield of rice up to 120 kg Si ha^{-1}. This was 17.14, 7.13 and 2.02 per cent increase over 0, 40 and 80 kg Si ha$^{-1.}$ This could be due to adequate silicon supply might have been improved the photosynthetic activity which enable rice plant to accumulate sufficient photosynthates which increased dry matter production and these together with efficient translocation resulted in more numbers of filled grains with increased test weight and ultimately led to higher grain and straw yield (Rani and Narayanan,1994). Among the different combinations, application of sulphur at 45 kg S ha^{-1} and silicon at 120 kg ha^{-1} significantly increase the yield attributes and yield of rice. This was 32.52 per cent increase over control. This might be due to combined and sustained nutrient supply by S and Si applied plots, which ultimately leads to photosynthetic activity by the crop and resulted in higher values for yield attributes and yield. These results are in conformity with the findings of Sudhakar *et al*. (2004).

Nutrient uptake

Addition of sulphur increased NPKS and Si uptake by crop and the maximum uptake was recorded at 45 kg S ha^{-1} (Table 1) .It was well understood that sulphur is essential for the activity of enzyme involved in the nitrate reduction in plants. Therefore, it is imperative that N uptake increased with S application. Sinha *et al*.

(1995) reported that increase in N due to S seems to be associated with increase in N content with concomitant increase in grain yield. Higher P uptake in the presence of S could be due to the capacity of S in mobilizing soil P into available form. Muneshwar Singh *et al.* (2001) reported that P and K uptake were stimulated in the presence of S. Significant increase in S uptake within S levels could be due to increased availability of S in the soil from applied with concomitant increase in grain yield. Vaiyapuri and Sriramachandrasekharan (2001) had reported increase in sulphur uptake by rice with increase in S levels earlier. Maximum Si uptake of rice with S could be due to increase in Si availability in soil and enhanced root system.

Application of Si at 120 kg ha^{-1} significantly increased NPKS and Si uptake of rice. The N uptake was higher with Si_{120} compared to its lower levels due to its potential to raise the soil available nitrogen (Ho *et al*., 1980). Silicon fertilized plant gained maximum benefits of ample nitrogen availability. Increasing silicon levels increased phosphorus content due to decreased retention capacity of soil and increased solubility of phosphorus leading to increased efficiency of phosphotic fertilizer (Subramanian and Gopalswamy, 1990). Positive response of higher silicon application towards potassium can be linked to silicification of cell wall. This is in line with Chanchareonsook *et al*. (2002) who reported that application NPK fertilizer in combination with Si significantly increased total N, P and K uptake of rice. Silicon also favorably influenced the sulphur uptake showing its synergistic effect with silicon application. The higher silicon content was associated with the higher rate of silicon application (120 kg ha^{-1}).This might be due to increase in root growth and enhanced soil silicon availability with silicon application. This finding is in agreement with the reports of Kalyan Singh *et al*. (2006).

Combined application of sulphur and silicon recorded maximum NPKS and Si uptake of rice over their individual application. The maximum NPKS and Si uptake was noticed with 45 kg S ha^{-1} and silicon at 120 kg ha^{-1} (S_4Si_4).This could be due to increased root activity and enhanced the soil nutrient availability. This is in accordance with the reports of Wani *et al*. (2000). Further, the increased uptake with crop growth might be attributed to the increased DMP produced with growth of crop due to the enhanced release and consequent availability of nutrients to the crops.

Economics

Among the different treatment imposed on rice, addition of S at 45 kg ha^{-1}in combination with Si at 120 kg ha^{-1}resulted in more net return and return $rupee^{-1}$invested in rice crop (Table 2). The next best treatments were 45 kg S with 80 kg Si ha^{-1} and 30 kg S with 120 kg Si ha^{-1} but were almost on par with each other. This could be due to increased grain yield achieved under these treatment combinations. In the light of above said facts, it can be concluded that the conjoint application of 45 kg S with 120 kg Si ha^{-1} holds immense potentiality to boost the productivity and profitability of rice.

Table 2.Effect of sulphur and silicon fertilization on economics of rice cultivation

Treatments	Cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	Return $rupee^{-1}$ invested
S_0Si_0	18433	34127	15694	1.85
S_0Si_{40}	18518	38353	19835	2.07
S_0Si_{80}	18603	41179	22576	2.21
S_0Si_{120}	18688	42403	23715	2.27
$S_{15}Si_0$	18536	38663	20127	2.09
$S_{15}Si_{40}$	18621	44280	25659	2.38
$S_{15}Si_{80}$	18706	46449	27743	2.48
$S_{15}Si_{120}$	18791	46944	28153	2.50
$S_{30}Si_0$	18640	41804	23164	2.24
$S_{30}Si_{40}$	18725	46345	27620	2.48
$S_{30}Si_{80}$	18810	48351	29541	2.57
$S_{30}Si_{120}$	18895	49341	30446	2.61

$S_{45}Si_{0}$	**18743**	**42968**	**24225**	**2.29**
$S_{45}Si_{40}$	**18828**	**47114**	**28286**	**2.50**
$S_{45}Si_{80}$	**18913**	**49716**	**30803**	**2.63**
$S_{45}Si_{120}$	**18998**	**50916**	**31918**	**2.68**

*** Data not statistically analyzed**

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