International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 2992-2997

Received: 16-01-2018
Accepted: 17-02-2018

Luxmi Kant Tripathi
Assistant Professor, School of Agriculture, ITM University Gwalior, Madhya Pradesh, India

SK Ghosh
Professor, Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidhyalaya, Mohanpur, Nadia, West Bengal, India

PK Patra
Professor, Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidhyalaya, Mohanpur, Nadia, West Bengal, India

Arbind Kumar Gupta
Assistant Professor BUAT Banda, Uttar Pradesh, India

Correspondence
Luxmi Kant Tripathi
Assistant Professor, School of Agriculture, ITM University Gwalior, Madhya Pradesh, India

Efficacy of organic and inorganic amendments on Sulphur availability in relation to growth and yield of rice in an *Alfisol* soil

Luxmi Kant Tripathi, SK Ghosh, PK Patra and Arbind Kumar Gupta

Abstract
A greenhouse experiment was conducted in the department of Agricultural Chemistry and Soil Science, BCKV Nadia, West-Bengal during *rabi* season to study the efficacy of organic and inorganic amendments on S availability of rice crop in *Alfisol* soil collected from rice growing lowland cultivated field located in Jhargram Wet Bengal. Six kilograms of air dry processed soils were taken in each of the 10 kg capacity plastic pots. Farm yard manure (@ 7.5 t ha^{-1}) was incorporated 15 days before transplanting of rice seedlings (*CV. Shatabdi*) as per treatment. Fertilizers- Silicon (50 kg ha^{-1}) and phosphorus (50 kg ha^{-1}) were applied during transplanting of rice seedlings as basal. The experiment was laid out in completely Randomized Design (CRD) with three replications and eight treatments involving 24 pots in total viz., $Si_0P_0OM_0$ (Without any amendment), Si_1 (Silicon @ 50 kg ha^{-1}), P_1 (Phosphorus @ 50 kg ha^{-1}), OM_1 (Organic manure @ 7.5 t ha^{-1}), Si_1P_1 (Silicon @ 50 kg ha^{-1} + Phosphorus @ 50 kg ha^{-1}), Si_1OM_1 (Silicon @ 50 kg ha^{-1} + Organic manure @ 7.5 t ha^{-1}), P_1OM_1 (Phosphorus @ 50 kg ha^{-1}+ Organic manure @ 7.5 t ha^{-1}) and $Si_1P_1OM_1$ (Silicon @ 50 kg ha^{-1} + Phosphorus @ 50 kg ha^{-1} + Organic manure @ 7.5 t ha^{-1}). Pots were irrigated with water as and when required. The result showed that interaction effect of P, Si and FYM on the plant height (cm) and number of tillers $hill^{-1}$ was highest under the treatment $OM_0P_1Si_1$ i.e. 123.2 and 7 compared to control treatment. But the number of panicles $hill^{-1}$ recorded was the highest under treatment $OM_0P_1Si_0$ (5.68) in comparison to control. The recorded Grain and straw yield ($gpot^{-1}$) and total sulphur uptake ($mgpot^{-1}$) were the highest in the treatment $OM_1P_0Si_0$ (15.87, 16.46 and 9.46, respectively). The concentration of sulphur in rice grain and straw ($mgkg^{-1}$) was highest in the treatment $OM_1P_1Si_1$ (323.3 and 325.1, respectively) comparison to control treatment. Combined application of FYM, silicon and phosphatic fertilizer results in increased S availability, increased grain and straw yields and S uptake by rice in *Alfisol* soil.

Keywords: Silica, Sulphur availability

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 households. At global level, rice is grown in an area of 158.10 million hectare with a production of 447.42 Mt and productivity of 4.22 tha^{-1} (USDA, 2010) [23]. India has the largest acreage under rice (44 million hectare) and production of about 141 million tones. The national productivity of rice in around 3.21 tha^{-1}. The burgeoning population of our country may stabilize at 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) [5].

Rice is known as Si accumulator and a high Si demanding crop (Ma and Takahashi, 2002) [14]. Decreasing rice yield per unit area associated with Si depletion is a matter of concern (Savant *et al.* 1997) [19]. Plant available Si in the soils of tropical and subtropical areas including India are generally low (Meena *et al*. 2014) [15]. Silicon fertilizer has been used in many countries for improving rice yield (Guntzer *et al*. 2012) [6]. About 20 kg. Ha-1 SiO_2 is being removed from the soil to produce every 100 kg brown rice (Ma and Takahashi, 2002) [14].

Silicon (Si) ranks the second-most abundant element (after oxygen) in the earth’s crust with nearly 29% mean content (Sommer *et al.* 2006) [20]. Silicon content in soil ranges between 1%-45% depending on soil types (Sommer *et al*. 2006) [20]. Liang *et al.* (2015) [12] reported that Si content in latosols or latosolic red soils (highly weathered soil) in the tropical zone can be less 1% due to the presence of extremely active desilication.

In soil, Si mainly can be present in various categories of aluminosilicates and quartz (SiO_2), which consist of up to 75-95% of soil inorganic constituents (Liang *et al.* 2015; Meharg and Meharg, 2015) [12, 16].

Application of organic manure (farmyard manure FYM) improved soil physical properties through increased soil aggregation, improved aggregate stability, and decrease in the volume of micro-pores while increasing macro-pores, increased saturated hydraulic conductivity and water infiltration rate, and improved soil water-holding capacity at both field capacity and wilting point. Several studies have reported that FYM plus inorganic fertilizer applications in irrigated systems resulted in reduced bulk density, higher soil organic carbon (SOC) and hydraulic conductivity and improved soil structure and microbial communities. Inorganic fertilizers are usually applied to soil for increasing or maintaining crop yields to meet the increasing demand of food (Haynes *et al*. 1998) [7]. Application of inorganic fertilizers results in higher soil organic matter (SOM) accumulation and biological activity due to increased plant biomass production and organic matter returns to the soil in the form of decaying roots, litter and crop residues (Brar *et al*. 2015) [1].

Sulfur is an essential element in the life processes of all living things, including microorganisms, higher plants, animals and human. It plays essential role in the formation of amino acids such as methionine (21%), cystine (27%) and cysteine (26%), synthesis of proteins, chlorophyll, oil content of oil seeds and nutritive quality of forage crops. It is constituent of ferrodoxin-containing nitrogenase, which takes part in the biological nitrogen fixation (BNF) and other electron transfer reactions (Patra *et al*. 2012) [18]. Sulphur in soils is present in different forms like (1) *Solution $SO4^{-2}$ S*: Solution $SO4^{-2}$ sulphur is transported to roots by mass flow and diffusion; (2) *Adsorbed SO_4^{-2} S*: adsorbed $SO4^{-2}$ is important fraction in highly weathered, humid region soils containing large amounts of Al/Fe oxides. Many Ultisols (red yellow podzol) and oxisol (latosols) soils contain up to 100 ppm adsorbed S in subsoil and can significantly contribute to S nutrition of plants as root growth progress; (3) *Reduced inorganic S*: sulphides do not exist in well aerated soils. Under waterlogged, anaerobic conditions, H_2S accumulates as OM decay or S from added SO_4^{-2}; and (4) *organic S*: There is a close relationship between organic C, total N and total S in soils. The C: N: S ratio in most well-drained, non-calcareous soils is about 120:10:1.4. Organic sulphur fraction governs the production of plant available SO_4^{-2}. Three groups of organic S compounds in soil include: (i) *HI reducible S* (represents 40-60% of total organic S), (ii) *C-bonded* S (represent 10-12 % of total organic S) and (iii) *residual* S (represent 30-40 % of total organic S) (John *et al.* 2014) [10]. The present research project was formulated to evaluate the effect of organic matter (FYM) and silicon application on Sulphur availability in relation to Growth and Yield of Rice in an *Alfisol* soil of West Bengal in Eastern India.

Material and Methods

The study was conducted in greenhouse in the department of Agricultural Chemistry and Soil Science, Faculty of Agriculture, BCKV, Nadia, West-Bengal during *rabi (dry)* season. Bulk surface soil sample was collected from rice growing lowland cultivated field located at Jhargram. The relevant initial physico-chemical properties of the soil are presented in the Table-1. Six kilograms of air dry processed soils were taken in each of the 10 kg capacity plastic pots. Farm yard manure (@ 7.5 t ha^{-1}) was incorporated 15 days before transplanting of rice seedling (*CV. Shatabdi*) as per treatment. Half of N (100 kg ha^{-1}) and entire dose K (50 kg ha^{-1}) and S (30 kg ha^{-1}) were applied at the time of transplanting in all the pots through urea, muriate of potash (MOP) and Single super phosphate (SSP). The remaining one-half dose of N was applied at 21 days after transplanting of seedlings. Fertilizers Silicon (50 kg ha^{-1}) and phosphorus (50 kg ha^{-1}) were applied through Calcium Silicate and di-hydrogen orthophosphate (KH_2PO_4), respectively, during transplanting of rice seedlings as basal. Four seedlings were transplanted in each pot and thinned to two plants per pot after panicle initiation stage. The experiment was laid out in completely Randomized Design (CRD) with three replications and eight treatments involving 24 pots in total viz., $Si_0P_0OM_0$ (Without any amendment), Si_1 (Silicon @ 50 kg ha^{-1}), P_1 (Phosphorus @ 50 kg ha^{-1}), OM_1 (Organic manure @ 7.5 t ha^{-1}), Si_1P_1 (Silicon @ 50 kg ha^{-1} + Phosphorus @ 50 kg ha^{-1}), Si_1OM_1 (Silicon @ 50 kg ha^{-1} + Organic manure @ 7.5 t ha^{-1}), P_1OM_1 (Phosphorus @ 50 kg ha^{-1}+ Organic manure @ 7.5 t ha^{-1}) and $Si_1P_1OM_1$ (Silicon @ 50 kg ha^{-1} + Phosphorus @ 50 kg ha^{-1} + Organic manure @ 7.5 t ha^{-1}). Pots were irrigated with water as and when required. Biological parameters i.e., plant height (cm), number of tillers and number of panicles $hill^{-1}$ were taken at 45 days after transplanting. Yield of grain and straw were recorded at harvest after proper drying. Soil samples were collected at three critical rice growth stages viz. tillering, flowering and maturity and analyzed for available sulphur. Extraction of available sulphur from soil was done by using 0.15% $CaCl_2$ and KH_2PO_4 (500 ppm) following the method of Williams and Steinbergs (1959) [24] and Ensminger (1954) [3]. Plant samples collected during harvest were analyzed for total S contents in diacid (HNO_3:$HClO_4$) digest by adopting standard procedure (Jackson, 1973) [8].

Table 1: Initial Physico-chemical and chemical properties of soil used in the pot culture experiment

S. No.	Soil Characteristics	Value
1	pH	5.23
2	*EC (dSm^{-1})	0.14
3	*OC (%)	0.42
4	Sand (%)	68.16
5	Silt (%)	12
6	Clay (%)	19.84
7	Texture	Sandy Loam
8	Available N kg ha^{-1}	289.57
9	Available P kg ha^{-1}	37.424
10	Available K kg ha^{-1}	100
11	0.15% extractable S $mg.kg^{-1}$	10.79
12	KH_2PO_4 extractable S $mg.kg^{-1}$	40.97

*OC = organic carbon, *EC = electrical conductivity

Result and discussion

1. Changes in available S content ($mgkg^{-1}$) of soil under sole application of Si, P and FYM

The data presented in Table-2 revealed significant difference in available sulphur content of the soil ($mg.kg^{-1}$) extracted with 0.15% $CaCl_2$ and KH_2PO_4 at different growth stages of rice. The mean available S content of the experimental soil extracted with 0.15% $CaCl_2$ during tillering stage increased to 25.00 from its initial value of 10.79, registering 131.7% increase compared to the initial value while during flowering stage 16.7% decrease was observed. This could be because of accelerated S uptake due to higher S requirement during reproductive stage of rice growth. The available S content of soil during harvest stage however registered a slight (3.8%) increase compared to its initial value.

Application of P significantly influenced the mean available S content of the soil by both the extra ctants during flowering as well as during harvest stage of rice. An increase in available S content of the experimental soil was observed. While the increase in available S content of soil in P treated pots compared to P untreated pots during flowering and harvesting stages worked out to be 8.0 and 126.2%, respectively with $CaCl_2$, similar increase with KH_2PO_4 worked out to be 28.4 and 37.1%, respectively during the comparable growth stages. During the tillering stage of rice however, the influence of P was not significant.

Application of Si significantly increased the mean available S content of the soil extracted with either of the two extractants during tillering, flowering as well as during harvest stage of rice. Using $CaCl_2$, the increase in available S content during tillering, flowering and harvest stages in Si treated compared to Si untreated soil were 4.2, 39.4 and 36.7%, respectively and the corresponding values with KH_2PO_4 were 12.4, 22.4 and 17.3%. Silicon also favorably influenced sulphur uptake showing its synergistic effect with silicon application. Higher silicon content was associated with the higher rate of its application. 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) [11].

Application of FYM significantly influenced the mean available S content of the soil during tillering, flowering as well as during harvest stage of rice using either of the extractants. Using $CaCl_2$ as extractant, 51.9% and 52.8% increase in available S during tillering and flowering stage of rice, respectively, in FYM treated soil compared to FYM untreated soil was observed but during harvest stage 16.0% decrease in comparable treatments was recorded. Using KH_2PO_4 as extractant, 62.1% and 69.6% increase in available S during tillering and harvesting stage of rice, respectively, in FYM treated soil compared to FYM untreated soil was observed but during flowering stage 18.4% decrease in comparable treatments was recorded.

2. Interactive effect of P, Si and FYM on the available S content in soil:

Data presented in Table-3 revealed that during tillering stage, the highest available S extracted with $CaCl_2$ (39.60) in treatment with combined application of FYM and Si without P ($OM_1P_0Si_1$) and the lowest (14.56) in $OM_0P_0Si_0$, where neither organic manure nor P nor Si was applied. The increase in the available S content of the soil due to application of organic manure was 172.0%. During flowering stage, the highest available S (14.68) was recorded in treatment comprising application of P without organic manure or Si ($OM_0P_1Si_0$) and the lowest (3.89) without application of P, organic manure or Si ($OM_0P_0Si_0$). The percent increase in available S due to application of P and organic manure was 227.4% with respect to $OM_0P_0Si_0$ treatment. During harvest stage the highest available S (19.90) was recorded in treatment comprising combined application of organic manure, P and Si ($OM_1P_1Si_1$) and the lowest (4.07) without application of either organic manure, P or Si ($OM_0P_0Si_0$). The percent increase in available S due to application of P was 388.9% with respect to $OM_0P_0Si_0$ treatment. In our earlier report we also observed significant increase in the available Sulphur content of soils collected from different land use systems due to interactive effect of silicon and FYM application (Tripathi *et al.* 2018) [22].

Table 2: Effect of P, Si and OM on available sulphur content of soil at different growth stages of rice

Treatment	$CaCl_2$ extractable S ($mg.kg^{-1}$)			KH_2PO_4 extractable S ($mg.kg^{-1}$)		
	Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting
A. Levels of Phosphorus						
P_0	25.56	8.65	6.87	26.67	32.43	22.47
P_1	24.43	9.34	15.54	27.42	41.66	30.79
S. Em(±)	0.42	0.21	0.33	0.42	0.45	0.45
CD (p=0.05)	1.25	0.64	0.98	1.26	1.35	1.36
B. Levels of Silicon						
Si_0	24.47	7.51	9.46	25.47	33.32	24.51
Si_1	25.52	10.47	12.94	28.63	40.77	28.75
S. Em(±)	0.42	0.21	0.33	0.42	0.45	0.45
CD (p=0.05)	1.25	0.64	0.98	1.26	1.35	1.36
C. Levels of Organic Manure						
OM_0	19.85	7.13	12.18	20.64	40.80	19.75
OM_1	30.15	10.86	10.23	33.45	33.29	33.51
S. Em(±)	0.42	0.21	0.33	0.42	0.45	0.45
CD (p=0.05)	1.25	0.64	0.98	1.26	1.35	1.36

Table 3: Three factor effect among of P, Si and OM on available sulphur content of soil at different growth stages of rice

Treatments	$CaCl_2$ extractable S ($mg.kg^{-1}$)			KH_2PO_4 extractable S ($mg. kg^{-1}$)		
	Tillering	Flowering	Harvesting	Tillering	Flowering	Harvesting
G. Interaction Among Organic Manure, Phosphorus and Silicon						
$OM_0P_0Si_0$	14.56	3.89	4.07	13.37	21.67	14.28
$OM_0P_0Si_1$	24.47	11.66	7.33	23.40	38.04	20.34
$OM_1P_1Si_1$	21.38	4.15	19.90	19.88	54.50	24.01
$OM_1P_0Si_1$	39.60	7.33	4.21	38.49	33.19	30.43
$OM_1P_1Si_0$	18.97	8.81	17.41	25.91	49.01	20.40
$OM_0P_1Si_1$	23.61	11.71	11.86	31.43	36.83	24.82
$OM_0P_1Si_0$	22.33	14.68	9.68	30.13	23.91	29.34
$OM_1P_0Si_0$	35.04	9.70	15.15	33.76	39.22	49.43
Mean	25.00	8.99	11.20	27.05	37.05	26.63
S. Em(±)	0.83	0.43	0.65	0.84	0.89	0.90
CD (0.05)	2.50	1.29	1.97	2.52	2.69	2.72

3. Sole and interaction effect of silicon, phosphorus and FYM on different growth parameters of rice plants

Perusal of data presented in the Table-4 and Table-5 revealed significant influence of sole and interactive effect of Silicon, phosphorus and FYM on different plant growth parameters viz. plant height at harvest stage (cm), number of tillers hill^{-1}, number of panicles hill^{-1} and grain and straw yield (g.pot^{-1}).

Plant Height

Height (cm) of rice plants at harvest was significantly influenced by application FYM, silicon and phosphorus and their possible combinations. While due to application of phosphorus the increase in plant height was by 11.6%, that with application of FYM was 5.86% and with silicon by 3.54% as compared to respective control treatments. Pati *et al.* (2016) [17] also reported an increase in plant height with addition of Si fertilizer over control. Similarly, the interaction among FYM, P and Si also exerted significant influence on plant height and the tallest plants were recorded in $OM_0P_1Si_1$ (123.23 cm) in comparison to $OM_0P_0Si_0$ (92.0 cm) which produced the shortest plants. This increase in height was by 33.9% over the control treatment.

Number of tillers hill^{-1}

Number of tillers per hill at harvest was significantly influenced by application FYM, silicon and phosphorus and their possible combinations. While due to application of phosphorus the increase in tiller number was by 13.64%, that with application of FYM was only 1.37% and with silicon by 10.38% as compared to respective control treatments. In the present study, number of tillers per hill significantly increased with the application of Si fertilizer. Our findings are similar to Liang *et al.* (1994) [13], Gerami *et al.* (2012) [4] and Pati *et al.* (2016) [17], who also reported beneficial role of Si fertilizer in increasing number of tillers per hill. Similarly, the interaction among FYM, P and Si also exerted significant influence on tillering and the highest number of tillers were recorded in $OM_0P_1Si_1$ (7.0) in comparison to $OM_0P_0Si_0$ (4.67) which produced the lowest number of tillers. This increase in tiller number was by 49.9% over the control treatment.

Number of Panicles hill^{-1}

Number of panicles per hill at harvest was significantly influenced by application FYM, silicon and phosphorus and their possible combinations. While due to application of phosphorus the increase in panicle number was by 12.11% that with application of FYM was by 8.55% and with silicon by 5.00% as compared to respective control treatments. Jawahar *et al.* (2015) [9] reported the effectiveness of Si fertilizer in promoting assimilation of carbohydrates in panicles. Interactive effects among FYM, P and Si also exerted significant influence on panicle development and the highest number of panicles were recorded in $OM_0P_1Si_0$ (5.68) in comparison to $OM_0P_0Si_0$ (4.33) which produced the lowest number of panicles. This increase in panicle number was by 30.9% over the control treatment.

Grain Yield (g. pot^{-1})

Grain yield (g. pot^{-1}) at harvest was significantly influenced by application FYM, silicon and phosphorus and their possible combinations. While due to application of phosphorus the increase in grain yield (g.pot^{-1}) was by 27.36% that with application of FYM was by 21.34% and with silicon by 21.95%, as compared to respective control treatments. This might be due to application of Si, which ultimately led to increased 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) [21]. The interactive effcet among FYM, P and Si also exerted significant influence on grain yield and the highest grain yield (g.pot^{-1}) was recorded in $OM_1P_0Si_0$ (15.87) in comparison to $OM_0P_0Si_0$ (5.23) which produced the lowest grain yield (g.pot^{-1}). This increase in grain yield (g.pot^{-1}) was by 203.4% over the control treatment.

Straw Yield (g.pot^{-1})

Straw yield (g.pot^{-1}) at harvest was significantly influenced by application FYM, silicon and phosphorus and their possible combinations. While due to application of phosphorus the increase in straw yield (g.pot^{-1}) was by 10.63 % that with application of FYM was by 30.34% and with silicon by 11.02% as compared to respective control treatments. Deren *et al.* (1994) [2] and Pati *et al.* (2016) [17] also reported a significant increase in grain and straw yields of rice with increasing Si level. The interactive effects among FYM, P and Si also exerted significant influence on straw yield and the highest straw yield (g.pot^{-1}) was recorded in $OM_1P_0Si_0$ (16.46) in comparison to $OM_0P_0Si_0$ (6.58) which produced the lowest straw yield (g.pot^{-1}). This increase in straw yield (g.pot^{-1}) was by 150.2% over the control treatment.

Concentration of Sulphur in rice Straw (mg.kg^{-1})

Concentration of Sin rice straw (mg.kg^{-1}) at harvest was significantly influenced by application phosphorus, FYM and silicon and their possible combinations. While due to application of phosphorus the increase in concentration of Sin rice straw (mg.kg^{-1}) was by 37.0 % that with application of FYM was by 22.0% and with silicon by 9.2% as compared to respective control treatments. Similarly, the interactive effects among FYM, P and Si also exerted significant influence on S concentration in rice straw. The percent increase in S concentration of rice straw with combined application of FYM, P and Si was 260.9% as compared to the control where neither organic matter nor silicon nor phosphorus was applied ($OM_0P_0Si_0$).

Concentration of Sulphur in rice grain (mg.kg^{-1})

Concentration of Sin rice grain (mg.kg^{-1}) at harvest was significantly influenced by application FYM, silicon and phosphorus and their possible combinations. While due to application of phosphorus the increase in concentration of Sin rice grain (mg.kg^{-1}) was by 37.3 % that with application of FYM was by 21.8% and with silicon by 9.2% as compared to respective control treatments. Similarly, the interactive effects among FYM, P and Si also exerted significant influence on S concentration in rice grain. The percent increase in S concentration of rice grain with combined application of FYM, P and Si was 259.9% as compared to the control where neither organic matter nor silicon nor phosphorus was applied ($OM_0P_0Si_0$).

Total Uptake of Sulphur in rice grain and Straw (mg.pot^{-1})

Total uptake of Sin rice grain and straw (mg. pot^{-1}) at harvest was significantly influenced by application FYM, silicon and phosphorus. While due to application of phosphorus the increase in total uptake of Sin rice (mg.pot^{-1}) was by 53.2 % that with application of FYM was by 87.6% and with silicon by 27.4% as compared to respective control treatments. Similarly, the interaction among FYM, P and Si also exerted significant influence on S total uptake in rice grain. The percent increase in S total uptake of rice grain with combined application of FYM, P and Si was 887.2% as compared to the control where neither organic matter nor silicon nor phosphorus was applied ($OM_0P_0Si_0$).

Table 4: Growth parameters of rice under sole application of P, Si and OM in different treatments

Treatments	Plant Height (cm)	No. of Tiller hill^{-1}	No. of Panicle hill^{-1}	Grain Yield (g.pot^{-1})	Straw Yield (g.pot^{-1})	Total S (mgkg^{-1}, Straw)	Total S (mgkg^{-1}, Grain)	Total S Uptake (mgPot^{-1})
A. Levels of Phosphorus								
P_0	102.65	5.59	4.83	10.02	10.87	215.85	217.18	5.18
P_1	116.36	6.17	5.42	10.45	12.70	274.85	276.68	6.28
B. Levels of Organic Manure								
OM_0	107.25	5.75	4.92	8.23	10.55	195.93	197.35	4.06
OM_1	111.77	6.00	5.34	12.24	13.02	294.78	296.50	7.40
C. Levels of Silicon								
Si_0	108.46	5.50	5.00	10.48	12.79	222.83	224.75	5.80
Si_1	110.56	6.25	5.25	9.99	10.78	267.88	269.10	5.66

Table 5: Three factor effect among of P, Si and OM on growth parameters of rice under different treatments

Treatments	Plant Height (cm)	No. of Tiller hill^{-1}	No. of Panicle hill^{-1}	Grain Yield (g.pot^{-1})	Straw Yield (g.pot^{-1})	Total S (mg/kg, Straw)	Total S (mg/kg, Grain)	Total S Uptake (mg/Pot)
Interaction Among Organic Manure, Phosphorus and Silicon								
$OM_0P_0Si_0$	92.00	4.67	4.33	5.23	6.58	80.2	81.0	0.95
$OM_0P_0Si_1$	96.33	5.00	4.34	5.97	6.59	204.1	205.7	2.58
$OM_1P_1Si_1$	108.67	6.33	5.67	8.20	8.76	323.3	325.1	5.50
$OM_1P_0Si_1$	114.00	6.67	5.67	13.00	13.85	289.8	290.5	7.78
$OM_1P_1Si_0$	116.13	5.00	5.00	11.87	13.00	276.7	278.9	6.90
$OM_0P_1Si_1$	123.23	7.00	5.33	12.78	13.91	254.3	255.1	6.79
$OM_0P_1Si_0$	117.42	6.33	5.68	8.93	15.13	245.1	247.6	5.92
$OM_1P_0Si_0$	108.27	6.00	5.00	15.87	16.46	289.3	291.5	9.41
Mean	109.51	5.88	5.13	10.23	11.78	245.4	246.9	5.73
SEm(±)	3.17	0.72	0.50	0.50	0.57	10.50	10.57	0.31
CD(P=0.05)	9.509	2.15	1.50	1.50	1.70	31.49	31.68	0.94

References

1. Brar SB1, Singh J, Singh G, Kaur G. Effects of Long Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize-Wheat Rotation. Agronomy. 2015; 5:220-238.
2. Deren CW, Datnoff LE, Snyder GH, Martin FG. Silicon concentration, disease response and yield components of rice genotypes grown on flooded organic histosols. Crop Sci. 1994; 34(3):733-737.
3. Ensminger LE. Some fractions affecting the adsorption of sulphate by Alabama soils. Soil Science Society of America Proceedings. 1954; 18:259-264.
4. Gerami M, Fallah A, Moghadam MRK. Study of potassium and sodium silicate on the morphological and chlorophyll content on the rice plant in pot experiment (*Oryza sativa* L.). Int J Agric Crop Sci. 2012; 4(10):658-661.
5. Gulab Singh Yadav, Dinesh Kumar YS. Shivay Harmandeep Singh. Zinc-Enriched Urea Improves Grain Yield and Quality of Aromatic Rice. Better Crops. 2009; 3(1):4-5.
6. Guntzer F, Keller C, Meunier JD. Benefits of plant silicon for crops: A review. Agric Sust Dev. 2012; 32(1):201-213.
7. Haynes R, Naidu R. Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: A review. Nutr. Cycl. Agroecosys. 1998; 51:123-137.
8. Jackson ML. Soil Chemical analysis. Prentice hall of India Pvt. Ltd, New Delhi, 1973.
9. Jawahar S, Vijayakumar D, Bommera R, Jain N. Effect of silixol granules on growth and yield of rice. Int. J Curr. Res. Aca Rev. 2015; 3:168-174.
10. John LH, Samuel L, Tisdale Werner L, Nelson James, DB. Soil Fertility and Fertilizers-An Introduction to Nutrient Management. 8th ed. Published by Pearson Education, Inc., publishing as Pearson Prentice Hall, 2014, 239-252.
11. Kalyan Singh, Ragavendra Singh JP, Singh Yogeshwar Singh, KK Singh. Effect of level and time of Silicon application on growth, yield and its uptake by rice (*Oryza sativa*). Indian J Agric. Sci. 2006; 76(7):410-413.
12. Liang YC, Nikolic M, Bélanger R, Gong HJ, Song A. Silicon biogeochemistry and bioavailability in soil. *In*: Liang YC, Nikolic M, Bélanger R, Gong HJ, Song A. Silicon in Agriculture: From Theory to Practice. Netherlands: Springer, 2015, 45-68.
13. Liang YC, Ma TS, Li FJ, Feng YJ. Silicon availability and response of rice and wheat to silicon in calcareous soils. Commun Soil Sci Plant Anal. 1994; 25:2285-2297.
14. Ma JF, Takahashi E, Soil Fertilizer, Plant Silicon Research in Japan. Amsterdam-Boston-London-New York-Oxford-Paris-San Diego-San Francisco-Singapore-Sydney-Tokyo: Elsevier, 2002.
15. Meena VD, Dotaniya ML, Coumar V, Rajendiran S, Kundu S, Rao AS. A case for silicon fertilization to improve crop yields in tropical soils. Proc Natl Acad Sci Ind, Sect B: Biol Sci. 2014; 84:505-518.
16. Meharg C, Meharg AA. Silicon, the silver bullet for mitigating biotic and abiotic stress, and improving grain quality, in rice? Environ Exp Bot. 2015; 120:8-17.

17. Pati S, Pal B, Badole S, Hazra GC, Mandal B. Effect of silicon fertilization on growth, yield, and nutrient uptake of rice. Commun Soil Sci Plant Anal. 2016; 47:284-290.
18. Patra P, Mondal S, Ghosh GK Status of available sulphur in surface and sub-surface soils of red and lateritic soils of west-Bengal. International Journal of Plant, Animal and Environmental Sciences. 2012; 2:276-280.
19. Savant NK, Datnoff LE, Snyder GH. Depletion of plant-available silicon in soils: A possible cause of declining rice yields. Commun Soil Sci Plant Anal. 1997; 28:1245-1252.
20. Sommer M, Kaczorek D, Kuzyakov Y, Breuer J. Silicon pools and fluxes in soils and landscapes: A review. J Plant Nutr Soil Sci. 2006; 169(3):310-329.
21. Sudhakar PC, Singh JP, Singh K. Effect of silicon sources and fertility levels on transplanted rise. IRRN. 2004; 29(2):61-63.
22. Tripathi LK, Patra PK, Ghosh SK, Gupta AK. Availability of Sulphur in Alfisol soil from the different land use systems on application of silicon and organic manure. Journal of Pharmacognosy and Phytochemistry. 2018; 7(2):2483-2487.
23. USDA. Rice: Area, yield and production. United States Department of Agriculture, World Agricultural Production (03-10), 2010, 1-25.
24. Williams CH, Steinbergs A. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. Australian Journal of Agricultural Research. 1959; 10:340-352.