ISPEC Tarım Bilimleri Dergisi
6(3): 597-609, 2022
© Telif hakkı ISPEC'e aittir
Araştırma Makalesi

E-ISSN:2717-7238

www.ispecjournal.com

ISPEC Journal of Agr. Sciences
6(3): 597-609, 2022
Copyright © ISPEC
Research Article

Poultry Manure with Sulphur Increased Growth and Productivity of Rice (*Oryza sativa* L.), and Improved Soil Health for Sustainable Crop Production in Sub-Tropical Climate

Nur Nahar Khatun[1a]

AKM. Mosharof Hossain[1b]

Md. Mahedy Alam[1c]

Md. Mizanur Rahman[2a]

Mohamad Sohidul Islam[3a*]

[1]Hajee Mohammad Danesh Science and Technology University, Department of Soil Science, Dinajpur, Bangladesh

[2]Independent Consultant

[3]Hajee Mohammad Danesh Science and Technology University, Department of Agronomy, Dinajpur, Bangladesh

[1a]**ORCID**: 0000-0002-9616-0599

[1b]**ORCID**: 0000-0002-6743-5098

[1c]**ORCID**: 0000-0003-1807-2283

[2a]**ORCID**: 0000-0003-2994-9343

[3a]**ORCID**: 0000-0002-9690-8720

[*]Corresponding author (Sorumlu yazar):

shahid_sohana@yahoo.com

DOI

https://doi.org/10.5281/zenodo.7040531

Alınış (Received): 05/05/2022

Kabul Tarihi (Accepted): 20/06/2022

Abstract

An experiment was conducted at the Soil Science Research Field of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during the period of December 2016 to April 2017 in order to investigate the effects of sulphur (S) and poultry manure (PM) on the growth and yield of boro rice (BRRI dhan29), as succeeding soil properties. Six different levels of sulphur and poultry manure were used as treatments *viz*., T_0 = 0 kg S + 0 t PM ha^{-1}, T_1 =9 kg ha^{-1} S + 0 t PM ha^{-1}, T_2 = 6.75 kg ha^{-1} S + 1.5 t PM ha^{-1}, T_3 = 4.5 kg ha^{-1} S + 3 t PM ha^{-1}, T_4= 2.25 kg ha^{-1} S + 4.5 t PM ha^{-1}, T_5= 0 kg ha^{-1} S + 6 t PM ha^{-1}. The experiment was laid out in a randomized complete block design with four replications. The experimental results revealed that plant height, 1000-seeds weight, unfilled grain, grain yield, straw yield were significantly influenced by S and PM. The treatment T_3 produced the longest plant (91.67cm) and panicle (24.69 cm), the maximum number of tillers (15.45) and filled grain (156.9), while the lowest values (83.57cm, 22.49 cm, 12.20 and 134.00, respectively) were found in control condition. The minimum number of unfilled grains (18.88) was recorded in T_3 treatment which was statistically different from other treatments, and the maximum unfilled grains (30.48) was obtained in T_0 treatment. The 1000-grain weight (23.40) was highest in T_3 treatment and lowest (21.65) in control treatment. The grain yield and straw yield of rice were significantly influenced with the application of S along with PM. It was found that the application of 4.5 kgha^{-1} S ha^{-1} and 4 t PM ha^{-1}showed the highest grain (6.90 t ha^{-1}) and straw yield (8.23 t ha^{-1}) and harvest index (45.60%), whereas the lowest grain and straw yield was obtained without S and PM. Combined application of S and PM showed than sole S but sole application of PM also showed better results. Sole PM (T_5) showed best results of soil properties like OM, total N, available P, and exchangeable K contents in the post-harvest soil which were statistically identical T_3 and T_4 treatments. The highest level of available S (20.69 ppm) was recorded at T_2 which was at par with T_3 treatment. Considering plant growth, yield and post-harvest soil health 4.5 kg ha^{-1}, S ha^{-1} and 4 t PM ha^{-1} may be suggested for the sustainable crop production.

Keywords
Sulphur, poultry manure, plant characteristics, yield, soil health, rice

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food grain crops all over the world (Islam et al., 2021), especially for the people of South Asia and it is widely grown in tropical and subtropical regions (Singh et al., 2012). Rice occupies about 11% of world's agricultural land and ranks second in terms of cultivated area (Tumrani et al., 2015). Although the geographical, climatic and edaphic conditions of Bangladesh are favorable for year-round rice cultivation, but the national average of rice yield is rather low (3.12 t ha^{-1}) (BBS, 2020). Intensive rice cultivation with higher doses of chemical fertilizers alone lead to a gradual decline of rice productivity (Islam et al., 2021). Random use of chemical fertilizers leads to create several problems like decline in soil organic matter, soil pollution, increasesoil salinity, severe attack of pest and diseases (Chakraborthi and Singh, 2014). Fertilizer management through organic and inorganic ways is one of the most strategic weapons of modern agriculture to increase rice productivity (Rimi, 2017; Khatun et al., 2018). Organic manures application in soil provide various kinds of plant nutrients including micronutrients, improve soil physical and chemical properties such as structure, porosity, permeability, cation exchange capacity, and hence nutrient holding and buffering capacity, consequently enhance microbial activities (Suzuki, 1997). Poultry manure (PM) is the most popular and promising bulky organic manure produced from the raw excreta of poultry in poultry industry. PM contains a considerable amount of essential plant nutrients and used as store house of nutrients that maintains soil fertility and productivity. A study reported that PM also contains appreciable amounts of calcium, sulfur, magnesium, calcium, chlorine, sodium, manganese iron, copper, zinc, molybdenum, and arsenic (Kelleher et al., 2002). It is widely used as an organic fertilizer that is effective in improving soil properties and crop production (Dikinya and Mufwanzala, 2010). Conversely, if organic manure is only added to the soil, desired rice yield is not achieved (Islam et al., 2021). Neither organic manure nor chemical fertilizer alone is enough to meet the demand of soil-plant systems (Rahman, 2013). Sulphur (S) is an essential macronutrient and plays a fundamental role in plant growth and development. S is required early in the growth of rice plants, anddeficiency of S at early growth stage significantly reduced the number of effective tiller and finally reduced the yield (Blair and Lefroy, 1987). S deficiency reduced rice yield by 10-20% (Bhuiyan and Islam, 1990). It has been reported earlier that addition of optimum amount of S in rice filed increased the grain by 9% (Sarkunan et al., 1998), 28.8% (Li and Li, 1999), 21% (Babu and Hedge, 2002), 14.8% (Sriramchandrasekharan et al., 2004a), 16-20.7% (Sriramchandrasekharan et al., 2004b), 19.76% (Haque and Chawdhury, 2004), and 18.12% (Jawahar and Vaiyapuri, 2016). S deficiency not only affects the yield of plants but also deteriorates the quality by reducing the synthesis of certain amino acids like cystine, cesteine and methionine, plant hormones and vitamins. S deficiency has been found to be widespread in Bangladesh soil. Farmers of Bangladesh normally use only the NPK fertilizers in the field but don’t use the S containing fertilizer which plays a vital role to increase the yield by improving yield components (Dubey and Khan, 1991). Moreover, application of PM in combination with recommended doses of fertilizers (RDF) including S can play an important role to increase rice productivity. However, the information on the performance of PM alone or in combination with RDF in rice production is limited. Having considered the above situation, the present research work was undertaken to find out the effect of S and PM with RDF on the growth, and yield of boro rice (BRRI dhan29) as well as post-harvest soil status in rice filed.

MATERIALS and METHODS

Location and duration

A field was conducted at the Research Field, Department of Soil Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh. The study was carried out during the period of December 2016 to April 2017 (Boro season).

Soil properties

The initial soil (0-15 cm depth) was collected for the valuation of physical and chemical properties. The soil of the experimental field was sandy loam with pH value 5.97.) and the soil contained 0.06% total nitrogen, 11.21 ppm phosphorus, 0.10 me 100 g^{-1} available potassium, 12.01 ppm soil Sulphur (Table 1).

Table 1. Physical and chemical characteristics of initial soil (0-15 cm) of experimental field

Characteristics	Analytical data	Critical level
pH	5.97	-
Textural class	Sandy loam	-
Organic matter (%)	1.20	-
Total nitrogen (%)	0.06	0.10
Available phosphorus (ppm)	11.21	8.0
Exchangeable potassium(me/100g soil)	0.10	0.08
Available sulphur (ppm)	12.01	10.0

Weather conditions

The experimental area conducted under subtropical climatic conditions. The means of methodological information, like temperature (maximum, minimum and average temperature, °C), rainfall (mm), and relative humidity (%) of the experimental site during the crop growing period are exposed in Table 2.

Table 2. Monthly average temperature (minimum, maximum, and mean), relative humidity (%), and rainfall (mm) during the experiment

Month	Temperature (^{0} C)			Relative Humidity (%)	Total Rainfall (mm)
	Minimum	Maximum	Average		
December	12.1	26.4	19.3	69	7.0
January	10.3	19.5	14.9	62	0
February	13.5	25.1	19.3	79	28.0
March	16.6	30.7	23.7	69	1.0
April	20.4	33.2	26.3	69	7.0
May	23.5	34.3	28.9	77	209.0

Experimental treatments and design

Randomized complete block design was used with four replications. A total number of six (6) treatments viz. T_0 = 0 kg S + 0 t PM ha^{-1}, T_1 =9 kg ha^{-1} S + 0 t PM ha^{-1}, T_2 = 6.75 kg ha^{-1} S + 1.5 t PM ha^{-1}, T_3 = 4.5 kg ha^{-1} S + 3 t PM ha^{-1}, T_4= 2.25 kg ha^{-1} S + 4.5 t PM ha^{-1}, and T_5= 0 kg ha^{-1} S + 6 t PM ha^{-1} were used in this experiment. Therefore, the total number of plots was 24 having each plot size of 4 m ×2.5 m. Recommended doses of sulphur and farmer's practice doses of PM were 9 kg$ha^{-1}$and 6 t ha^{-1}, respectively.

Plant materials

BRRI dhan29 was used as research crop for this experiment which is collected from Bangladesh Agricultural Development Corporation (BADC), Research Division Nashipur, Dinajpur.

Chemical composition of PM

The well decomposed PM contains 1.18% N, 1.13% P, 0.81% K and 0.35% S.

Experimentation

The seeds of the concerned variety were treated with a popular fungicide, Provax-200 WP @ 3g/kg of seed, which contains Carbox in and Thiram (marketed by Hossain Enterprise Bangladesh Ltd., Associated with Chemtura Corp., USA). Treated seeds were soaked in water and staged for 48 h by putting gunny bag on the seeds for quick sprouting. The sprouted seeds were sown in the wet nursery bed and the required care was taken up to 40 days. The PM was applied according to treatments before eight days before transplanting. The chemical fertilizers like Urea, TSP, MoP and Gypsum as nitrogen, phosphorous, potassium and sulphur were applied @ 75 kg, 12 kg, 45 kg, and 9 kg ha^{-1}, respectively (BARC, 2012). At the beginning of land preparation one half of urea, full doses of TSP, MoP and Gypsum were applied to the experimental plot. Seedlings were uprooted carefully and transplanted by 40 days old seedlings in a spacing of 20 cm × 15 cm. The remaining half of urea was applied in two splits, one at tillering and other at booting stages. Intercultural operations like gap filling, weeding, plant protection measures, etc. were done timely when those were required.

Data collection

Ten hills were randomly selected in each plot excluding border rows and the plants were selected randomly from which the data were collected. The data of two parameters (Plant height, tiller number) was recorded at harvest time. At final harvest, the data of yield and yield components were collected. The selected plant of each plot was separately bundled, properly tagged, collected from the field and take to laboratory for taking other data (panicle length, filled grain, unfilled grain, and 1000-grain weight). The crop was threshed to record the weight of total yield, total straw and biological yield. After sun dried, grain and straw yieldsplot^{-1} were recorded and converted to t ha^{-1}. Final grain and straw weight was adjusted to 13% moisture content by using the following formula:

$$\text{Moisture (\%)} = \frac{\text{Fresh weight - Oven dry weight}}{\text{Fresh weight}} \times 100$$

Biological yield was calculated by using the following formula:

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1}).

Harvest index (%) was calculated with the following formula as shown below (Gardner et al., 1985):

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Post-harvest soil analysis

Ten soil samples were collected from each plot randomly at 15 cm depth after harvesting the crop to determine soil pH, available sulphur (S), total nitrogen (N), available phosphorus (P), exchangeable potassium (K) and organic matter content (OM) as per standard protocol.

Statistical analysis

The data collected on different parameters under the experiment were statistically analyzed by MSTATC-computer software (Russell, 1986) and the significances were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS and DISCUSSION

Growth and yield contributing traits

The application of PM and S showed a significant and positive effect on the plant height (Table 3). The application of S and PM increased the plant height of rice having the highest of 91.67 cm in T_3treatment which was statistically identical with T_1, T_2, T_4 and T_5. This result indicates that S had a significant effect on the plant height i.e., in T_1 (9 kg ha^{-1} S + 0 t PM ha^{-1}) provided sufficient S, and T_5 treatment (0 kg ha^{-1} S + 6 t PM ha^{-1}) also added S from 6 t PM ha^{-1} that ensured satisfactory plant growth which ensured higher plant height. These findings are conformity with that of some previous studies, those reported that S significantly increased the plant height of rice (Yadav, 2000; Chandel et al., 2003; Gupta et al., 2004; Laroo et al., 2007; Rumi, 2017). The number of tillers hill^{-1} was significantlyinfluenced by the application of different levels of S and PM (Table 3). However, the highest number of tillers (15.45) was obtained from T_3 treatment which was statistically at par with all treatments except control. The result indicated that without addition of S either from inorganic or organic sources (T_0) significantly reduced the effective tillers. It was reported that the combined application of organic manures and chemical fertilizers increased the tillering of rice (Khatun et al., 2018). The results obtained in this study are consistent with research which reported that organic manures (cow dung and poultry manure) with inorganic fertilizers significantly increased the number of effective tillers per hill in BRRI dhan41, and performance of poultry manure was higher than cow dung (Kayem, 2007). The panicle length also significantly responded with the S and PM application and followed the similar trends as we observed for the number of effective tillers hills in this study (Table 3). Nonetheless, the longest panicle (24.69 cm) was recorded at T_3 treatment, and the lowest (22.49 cm) was found at T_0 treatment. S fertilization with organic manure along with NPK fertilizers significantly increased the panicle length (Rumi, 2017). The present study is in partial agreement with the results of previously done study (Balakrishnar and Natarajaratnam, 1986). Organic manure with RDF remarkably increased the panicle length, and PM produced longer panicle than CD (Kayem, 2007). Table 3 showed that the highest number of grains (156.9) was recorded in the treatment where 4.5 kg ha^{-1} S + 3 t ha^{-1} PM was applied, whereas the lowest numbers were found in the control treatment. Poultry manure increased the grains per panicle (Umanah et al., 2003; Usman, 2003). A similar finding was also claimed by an earlier research (Satyanarayana, 2002). Unfilled grains panicle^{-1} was observed statistically significant due to application of different level of S and PM (Table 3). The highest number of unfilled grains (30.48) was recorded in T_0 treatment, while the lowest number of unfilled grain (18.88) was recorded in T_3 treatment. The results of our investigation in line with numerous reports, those concluded that S with organic manure declined the number of unfilled grains panicle^{-1} of rice (Reddy et al., 2004; Sarkar et al., 2014; Rumi, 2017). S and PM influenced on the 1000-grains weight of rice (BRRI dhan29). The weight of 1000-grains increased with different levels of S up to 4.5 kg ha^{-1} and PM up to 3 t ha ^{1} with the highest 1000-grains weight (23.40g) was recorded in T_3 treatment (Table 3). These results suggest that combined use of appropriate doses of S and PM produced the maximum 1000-grains weight than the use of same dose of S or PM along. 1000-grain weight was increased by the application of chemical fertilizer along with organic manure (Reddy et al., 2004; Yang et al., 2004).

Table 3. Effect of S and PM on the plant height, number of tillers, panicle length, filled and unfilled grains per panicle, and 1000-grain weight of rice (BRRI dhan29)

Treatments	Plant height (cm)	Number of tillers hill^{-1}	Panicle length plant^{-1} (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight (g)
T_0	81.57 b	12.20 b	22.49 b	134.0 b	30.33 a	21.65 b
T_1	84.90 ab	13.40 a	23.96 a	140.6 a	21.20 bc	22.08 b
T_2	86.16 a	13.85 a	24.19 a	146.7 a	23.80 b	22.13 ab
T_3	91.67 a	15.45 a	24.69 a	156.9 a	18.88 c	23.40 a
T_4	90.94 a	14.25 a	23.76 a	148.6 a	21.43 bc	22.42ab
T_5	88.39 a	14.48 a	24.35 a	152.5 a	25.48 ab	22.48ab
LSD	6.08	3.400	1.706	31.42	10.09	1.193
CV%	11.72	15.67	4.50	13.61	27.23	3.39

T_0 = 0 kg S + 0 t PM ha^{-1}, T_1 =9 kgha^{-1} S + 0 t PM ha^{-1}, T_2 = 6.75 kgha^{-1} S + 1.5 t PM ha^{-1}, T_3 = 4.5 kgha^{-1} S + 3 t PM ha^{-1}, T_4= 2.25 kgha^{-1} S + 4.5 t PM ha^{-1}, T_5= 0 kgha^{-1} S + 6 t PM ha^{-1};In the column, figures having similar letter(s) do not differ significantly at 5% level of probability;CV% = Coefficient of variation;LSD = Level of Significance.

Yield (grain, straw and biological yield) and harvest index

The grain yield was significantly influenced by the application of S and PM as compare to their sole application with NPK fertilizers. Application of PM along with different levels of S showed the variation for grain yield (Table 4). The highest grain yield (6.90 t ha^{-1}) was obtained in the treatment T_3 which was closely identical to the treatment T_5. The results obtained in this study are similar in line with various investigations, those showed that combined application of organic and inorganic fertilizers (sulphur) increased the rice yield (Channabasavanna et al., 2001; Reddy et al., 2004; Brahmacharii et al., 2005; Bhuvaneswari and Sriramachandrasekharan, 2006). Application of cow dung, poultry manure and water hyacinth in combination with chemical fertilizers increased grain yield of BRRI dhan29 (Haque et al., 2001; Rajni et al., 2001). Combined application of S with cow dung significantly increased the grain yield of aromaric rice (Rumi, 2017). Combined application of organic manure and chemical fertilizers increased the grain and straw yields of rice as reported in many studies (Rana, 2003; Singh et al., 2006; Rahman et al., 2009; Islam et al., 2021). The S content was not satisfactory level (12.01 ppm) in the initial soil (Table 1), and addition of S might have responded remarkably and increased the grain yield. PM application with or without S also outstandingly increased the OM, N, P, K and S content in the soil (Table 5), and increased the plant characteristics (Table 3) which may be reflected to produce higher grain yield. The highest straw yield (8.23 t ha^{-1}) was recorded in T_3 treatment (4.5 $kgha^{-1}$ S and 3 t ha^{-1} PM) which was statistically similar (8.09 t ha^{-1}) to T_5 treatment (Table 4). Application of organic manure and chemical fertilizers increased the straw yields of rice (Rana, 2003; Rahman et al., 2009). These results also agreed to that of the earlier researchers (Haque, 1998; Ishaque, 1998; Saleque et al., 2004), who concluded that organic and inorganic fertilizers increased straw yield. It was found that there was a significant influence on the biological yield due to the application of different doses of S and PM. The maximum biological yield (15.13 t ha^{-1}) was showed on the treatment T_3 which was significantly superior compared to other treatments except T_5 treatment (Table 4). Similar results were also revealed by investigators, who reported that combined application of organic manure and inorganic fertilizers increased the straw yield as well as biological yield of rice (Rajput and Warsi, 1992; Rahman et al., 2006). The highest percentage of harvest index (HI, 45.60%) was observed on T_3 treatment which was statistically similar with the T_5 treatment, and the lowest harvest index (40.48%) was recorded at T_0 treatment. This result is in agreement with the findings, which reported that addition of S significantly increased the HI of rice with combined application organic manure (cow dung) (Rumi, 2017). Rest of the treatments showed moderate and statistically identical HI without PM and S. Those variations were observed in terms of percentage of HI of BRRI dhan29 as a result of the application of different levels of S and PM combinations.

Table 4. Effect of S and PM on the grain yield, straw yield, biological yield and harvest index of rice (BRRI dhan29)

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_0	4.50 c	6.53 c	11.03 c	40.80 c
T_1	5.00 b	6.80 b	11.80bc	42.37 b
T_2	5.25 b	6.90 b	12.15 b	43.21 b
T_3	6.90 a	8.23 a	15.13 a	45.60 a
T_4	5.38 b	6.95 b	12.33 b	43.63 b
T_5	6.65 a	8.09ab	14.74 a	45.12 a
LSD	1.22	3.159	3.251	2.952
CV %	6.62	16.66	6.96	12.15

T_0 = 0 kg S + 0 t PM ha^{-1}, T_1 =9 $kgha^{-1}$ S + 0 t PM ha^{-1}, T_2 = 6.75 $kgha^{-1}$ S + 1.5 t PM ha^{-1}, T_3 = 4.5 $kgha^{-1}$ S + 3 t PM ha^{-1}, T_4= 2.25 $kgha^{-1}$ S + 4.5 t PM ha^{-1}, T_5= 0 $kgha^{-1}$ S + 6 t PM ha^{-1};In the column, figures having similar letter(s) do not differ significantly at 5% level of probability; CV% = Coefficient of variation;LSD = Level of Significance.

Chemical Properties of the post-harvest soil

There were no significant differences in soil pH among the treatments of the post-harvest soil which ranged from 5.97 to 6.01 (Table 5). The study proved that soil reaction remained more or less same in the post-harvest soils compared to initial soil. These results differ from a study, in which it was found that application of organic manure (vermicompost) decreased the acidity both in acidic soil (pH from 4.9 to 5.7) and also in non-calcareous soil (from 6.5 to 7.2) (Zaman et al., 2015). The effect of S and PM was significant on organic matter (OM) content in the soil. The organic matter content in the soils increased with increasing the application of PM in the soils having the highest OM (1.72%) was recorded in T_5 treatment where applied the highest amount of PM (Table 5). Similar results were confirmed in a study, wherein it was concluded that application of 50% RDCF and PM (4 t ha^{-1}) significantly increased the OM content in soil (Islam et al., 2013). Incorporation of chemical fertilizer with organic manure increase soil OM (Zaman et al., 2002; Xu et al., 2008). There was a significant effect on total nitrogen (N) in post-harvest soil. As the S and PM increased the total soil N in different treatments, the maximum amount of soil N was found in T_5 treatment which followed to T_4 and T_3 treatments (Table 5). Residual N remaining in the soil was greater with PM than with chemical fertilizer (Zaman et al., 2002). The maximum phosphorus (P) content was found in the treatment T_5 which was closely followed by T_4 and T_3 treatments as compared statistically significant to other treatments (Table 5). In this context, it was cited that application of PM (3 t ha^{-1}) with chemical fertilizers significantly increased the available P in soil (Rahman et al., 2018). Nitrogen based manure or compost application increased the available soil P levels over the P-based manure or compost application (Hossain et al., 2010). The exchangeable potassium (K) content of the post-harvest soil was influenced by the different treatments which ranged from 0.10 to 0.19 meq 100 g^{-1} soil (Table 5), and the highest value (0.19 meq. 100 g^{-1} soil) was found in T_5 treatment. Previous works on available K in post-harvest soil have shown that PM with reduced chemical fertilizers increased the K content in soil, as we observed in the present study (Islam et al., 2013; Rahman et al., 2018). Application of chemical fertilizer with organic manure increased the N, P, K content in post-harvest soil (Ayoola and Makinde, 2009). The post-harvest soil which content available sulphur (S) was different in various treatments. The available S content in the studied soil ranged from 12.01 to 20.69 ppm (Table 5). The highest S content (20.69 ppm) was found in the treatment T_2 which was statistically superior to other treatments. This finding can be thrust to the findings of some studies, those revealed that application of organic manure with chemical fertilizers in rice significantly increased the S uptake in rice plant and availability in post-harvest soil (Uddin et al., 2002; Islam et al., 2013). The application of PM might may be improved the properties of the soil OM (Table 5), and thereby increased the availability of nutrients.

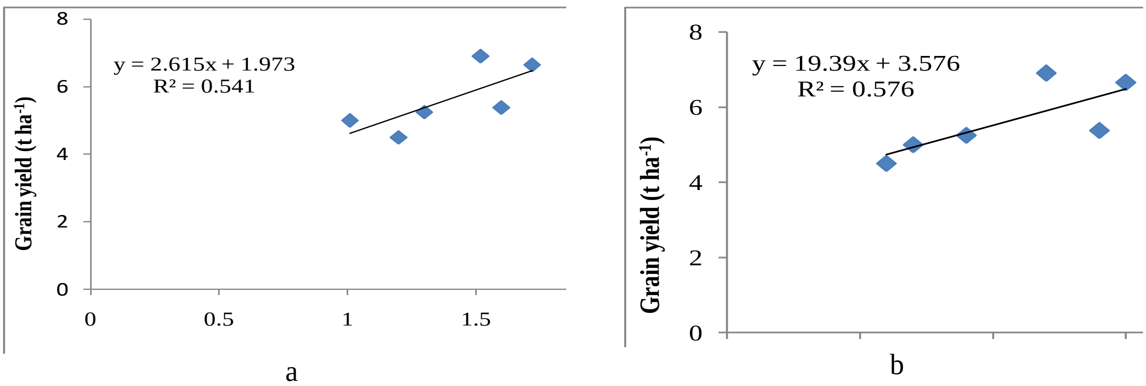
Table 5. Effect of S and PM on the soil pH, organic matter content, total N, available P, exchangeable K and available S of the studied post-harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (m.e./100g soil)	Available S (ppm)
T_0	5.97 a	1.20 bc	0.06 d	11.21 c	0.10 c	12.01d
T_1	5.98 a	1.01 c	0.07 cd	12.40 c	0.11 c	13.02 d
T_2	5.99 a	1.30 b	0.09 bcd	20.11 b	0.13 bc	20.69 a
T_3	6.00 a	1.52 a	0.12 abc	23.02 ab	0.15 abc	19.08 ab
T_4	6.00 a	1.60 a	0.14 ab	25.41 a	0.16 ab	17.06 bc
T_5	6.01 a	1.72 a	0.15 a	26.21 a	0.19 a	15.41 cd
LSD	1.205	0.2131	0.0498	4.668	0.0498	3.387
CV%	12.77	10.13	11.27	15.02	15.72	13.26

T_0 = 0 kg S + 0 t PM ha^{-1}, T_1 =9 kgha^{-1} S + 0 t PM ha^{-1}, T_2 = 6.75 kgha^{-1} S + 1.5 t PM ha^{-1}, T_3 = 4.5 kgha^{-1} S + 3 t PM ha^{-1}, T_4= 2.25 kgha^{-1} S + 4.5 t PM ha^{-1}, T_5= 0 kgha^{-1} S + 6 t PM ha^{-1};In the column, figures having similar letter(s) do not differ significantly at 5% level of probability; CV% = Coefficient of variation;LSD = Level of Significance.

Relationship between grain yield and soil properties (OM, N, P, K and S)

Grain yield is a complex characteristic, which results from interactive influences of different nutritional status of soil. The below graphs (a, b, c, d, e) showed that the grain yield was positively correlated in all cases with different nutrient status of the post-harvest soil like organic matter (%), total nitrogen (%), available phosphorus (ppm), exchangeable K (me/100g soil) and available S (ppm). Correlation and regression lines between grain yield and those post-harvest soil characteristics are shown in Figure 1. The influence of rice yield with the soil properties can be expressed by the regression equation. From the equations it can be stated that the rice yield can be increased at the rate of 2.62, 19.39, 0.11, 22.60 and 0.15 t ha^{-1} with an increase of 1% organic matter, 1% total nitrogen, 1 ppm P, 1 meq K/100g soil and 1 ppm S, respectively. The R2 values of 54, 58, 57, 63, and 29 from the equations indicate that rice yield can be explained as 54%, 58%, 57%, 63%, and 29% by the respective function.



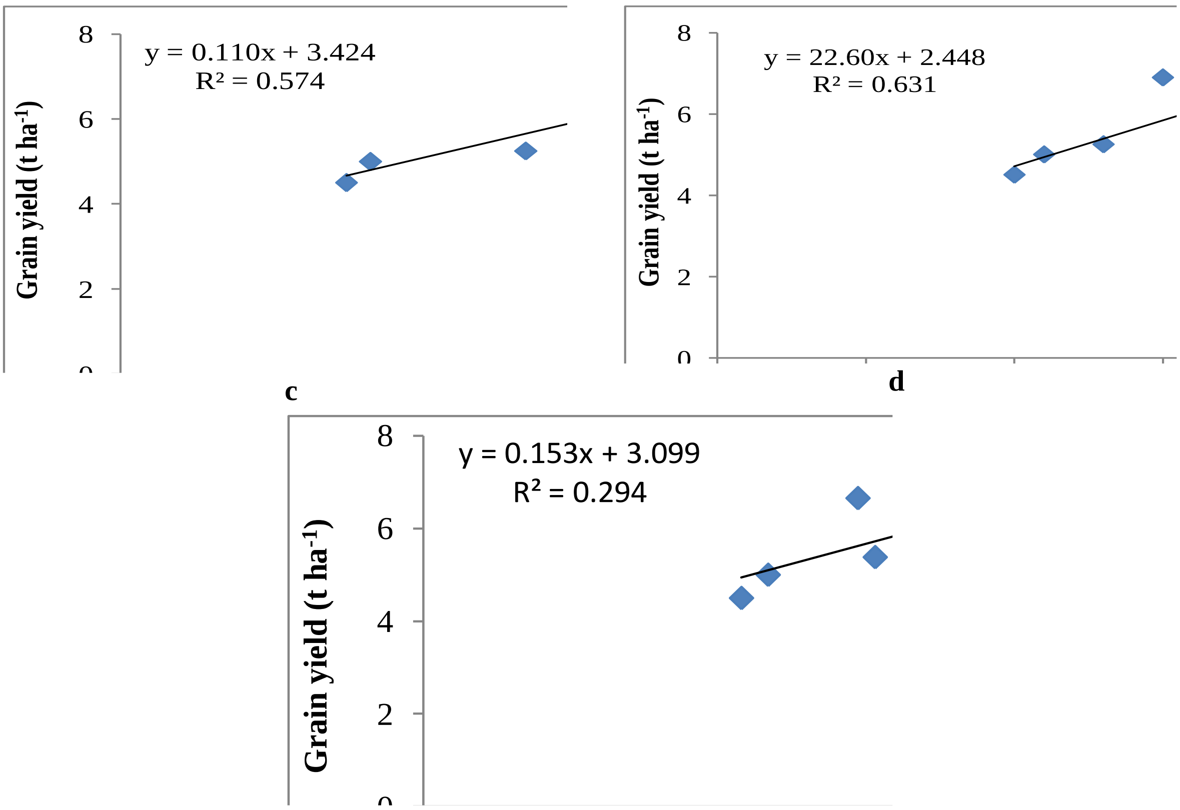


Figure 1. Contribution of soil organic matter (a), total N (b), available P (c), exchangeable K (d) and available S (e) on the grain yield of rice

CONCLUSION

From the observed results and discussion, it has been found that the rate of S and PM positively influenced the plant growth, yield contributing characteristics and yield of rice. Addition of S and PM with recommended NPK fertilizers also improved soil health by increasing the levels of OM, total N, available P and S, and exchangeable K in the post-harvest soil which are positively correlated with the grain yield of rice (BRRI dhan29). Application of 4.5 kgha^{-1} of S along with 3 t ha^{-1} of PM (T_3 treatment) contributed best results in terms of plant growth characteristics yield, and properties of post-harvest soil. Therefore, organic and inorganic fertilizers as a source of sulphur should be applied along with other recommended chemical fertilizers for increasing rice productivity and soil health which lead for sustainable agriculture.

ACKNOWLEDGMENT

We are obliged to several colleagues for communicating valuable information, and they acknowledge the generous financial support by the University Grants Commission (UGC), Dhaka and also Institute of Research and Training (IRT), HSTU, Grant No. 4829.

REFERENCES

Ayoola, O.T., Makinde, E.A. 2009. Maize growth, yield and soil nutrient changes with N enriched organic fertilizers. African J. Food Agric. Nutri. Develop., 9(1): 580-592.

Babu, S.N.S., Hegde, D.M. 2002. Delineation of sulphur deficient soil and evaluation of oil seed crops responses to sulphur. Fert. Market. News, 33(3): 9-17.

Balakrishnar, K., Natarajarotnam, N. 1986. Effect of Zn supplements on yields and yield components in certain rice verities. Madras Agric. J., 73(10): 598-600.

BARC (Bangladesh Agricultural Research Council), 2012. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Dhaka, Bangladesh. pp. 80: 248-256.

BBS (Bangladesh Bureau of Statistics), 2020. The Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bur. Stat., Stat. Div., Minis. Plan., Govt. Peoples Repub., Bangladesh, Dhaka. pp. 136-140.

Bhuiyan, N.I., Islam, MM. 1990. Sulphur deficiency problem is wet land rice soils of Bangladesh Agriculture. J Soils Fert., 53(1):203.

Bhuvaneswari, S., Sriramachandrasekharan, M.V. 2006. Influence of organic nutrients in conjunction with sulphur on yield and nutrient uptake by rice. Adv. Plant Sci. 19(2): 543-545.

Blair, G.J., Lefroy R.D.B. 1987. Sulphur cycling in tropical soils and the agronomic impact of increasing use of S free fertilizers, increased crop production and burning of crop residue. In: Proceedings of the Symposium on Fertilizer Sulphur Requirements and Sources in Developing Countries of Asia and the Pacific (pp. 12-17). FADI- NAP, FAO, TSI and ACIAR Bangkok, Thailand.

Brahmacharii, K., Mondal, S.S. 2000. Potassium and sulphur nutrition of crops with or without organic manure under jute-rice-rape seed sequence, Indian. J. Agron. 45(3): 501-507.

Chakraborthi, M., Singh, N.P. 2004. Bio-compost: A novel input to organic farming. Agrobios Newsletter, 2(8): 14-15.

Chandel, R.S., Sudhakar, P.C., Sing, K. 2003. Response of sulphur in rice-A Review Agric. Rev., 24(3): 167-174.

Channabasavanna, A.S., Yelamali, S.G., Biradar, D.P. 2001. Response of rice (*Oryza sativa*) to sources of organic manures and levels of zinc sulphate in deep black soils. Indian J. Agron., 46(3): 458-461.

Dikinya, O., Mufwanzala, N. 2010. Chicken manure enhanced soil fertility and productivity: Effects of application rates. J. Soil Sci. Environ. Manag., 1: 46–54.

Dubey, O.P., Khan, R.A. 1991. Effect of sulphur and nitrogen on dry matter, grain yield and nitrogen content at different growth stages of mustard (*Brassica juncea*) under irrigated vertisols. Indian J. Agron., 38(2): 270-276.

Gardner, F.P. Pearce, R.B., Mistechell, R.L. 1985. Physiology of Crop Plants. Iowa State University, Press, Powa. p. 66.

Gomez, K.A., Gomez A.A. 1984. Duncan's Multiple Range Test in statistical procedures for agricultural research. Awiley Inter science publication. John Wiley and Sons. New York, Brisbane. Singapore. pp. 139-240.

Gupta, V.K., Kumar, S., Singh, A.K. 2004. Yield and quality of wheat (*Triticum aestivum*) as influenced by sulphur nutrition and weed management. Indian J. Agril. Sci., 74(5): 254-256.

Haque, M.Q., Rahman, M.H., Islam, M.S., Rijpma, F.J., Kadir, M.M. 2001. Integrated nutrient management in relation to soil fertility and yield sustainability under Wheat-Mung-T. Aman cropping pattern. Online J. Biol. Sci., 1(8): 73 1-734.

Haque, M.S. 1998. Proceedings of the national workshop on integrated nutrient management for crop production and soil production and soil fertility. On Farm Research Division, Bangladesh Agric. Res. Inst., Joydebpur, Gazipur-1701, Bangladesh.

Haque, S.A., Chowdhury, L. 2004. Effects of rice straw and sulphur on the growth and yield of rice. J. Bangladesh Agril. Univ., 2(1): 5-18.

Hossain, A.T.M.S., Rahman, F., Saha, P.K., Solaiman, A.R.M. 2010. Effect of different aged poultry litter on the yield and nutrient balance in Boro rice cultivation. Bangladesh J. Agril. Res., 35(3): 497-505.

Ishaque, M. 1998. Integrated nutrient management with inorganic fertilizers organic manures for Boro-T aman rice cropping pattern. Soil Science Division, Bangladesh Agril. Res., Gazipur. p 113.

Islam, M.M.A.F., Khan, M.A., Fazle Bari, A.S.M., Hosain, M.T., Sabikunnaher. 2013. Effect of Fertilizer and Manure on the Growth, Yield and Grain Nutrient Concentration of Boro Rice (*Oryza sativa* L.) under Different Water Management Practices. The Agriculturists, 11(2): 44-51.

Islam, M.S., Khatun, M.K., Hafeez, A.S.M.G., Chowdhury, M.K., Konuşkan, Ö., Barutcular, C., Erman, M., Çiğ, F., Sabagh, A.E. 2021. The effect of zinc fertilization and cow dung on sterility and quantitative traits of rice. J. Aridland Agric., 7: 60-67.

Jawahar, S., Vaiyapuri, V. 2016. Effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. Intl. Res J. Chem., 4(1): 34-43.

Kayem, M.G. 2007. Effect of fertilizers, cow dung and poultry manure on the yield of rice. An MS Thesis, Dept. of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Kelleher, B., Leahy, J. Henihan, A. O'Dwyer, T., Sutton, D., Leahy, M. 2002. Advances in poultry litter disposal technology – a review. Bioresource Technol., 83: 27-36.

Khatun, M.K., Hasan, M.K., Rumi, M.S., Sabagh, A.E., Islam, M.S. 2018. Response of growth and yield attributes of aromatic rice to cow dung and zinc Fertilization. Azarian J. Agric., 5(5): 151-159.

Laroo, N.M., Shivay, Y.S., Kumar, D. 2007. Effect of nitrogen and sulphur fertilization on yield attributes, productivity and nutrient uptake of aromatic rice (*Oryza sativa*). Indian J. Agril. Sci., 77(11): 772-775.

Li, Y., Li, Y. 1999. The characteristics of sulphur requirement and the effect of Sulphur on yield and qualities of rice. Institute of soils and Fertilizers, Heilongijiang Academy of Agril. Sci. Heilongijiang, 1: 24-26.

Rahman, F., Hossain, A.T.M.S., Islam, M.R. 2018. Integrated Effects of Poultry Manure and Chemical Fertilizer on Yield, Nutrient Balance and Economics of Wetland Rice Culture. Bangladesh Rice J., 22(2): 71-77.

Rahman, M.S., Islam M.R., Rahman M.M., Hossain M.I. 2009. Effect of cowdung, poultry manure and urea-N on the yield and nutrient uptake of BRRI dhan29. Bangladesh Res. Pub. J., 2: 552-558.

Rahman, M.A. 2013. Integrated use of fertilizer with manure on mustard, potato and wheat and their residual effects on succeeding crops. Ph. D. Thesis. Dept. Soil Sci., Bangladesh Agril. Univ., Mymensingh.

Rahman, M.M., Bhuiya, M.S.U., Islam, M.A., Sikder, M.S.I., Islam, M.S. 2006. Response of BRRI dhan31 to nitrogen level and split application of *Sesbania aculeata* as green manure. Bangladesh J. Crop Sc., 17(1): 35-40.

Rajni, R., Srivastava, O.P., Rani, R. 2001. Effect of integration of organics with fertilizer N on rice and N uptake. Fert. News. 46(9): 63-65.

Rajput, A.L., Warsi, A.S. 1992. Effect of nitrogen and organic manure on rice (*Oryza sativa*) yield and residual effect on wheat (*Triticumaestivum*) crop. Indian J. Agron., 37: 716-720.

Rana, M.M. 2003. Effect of cow dung with and without chemical fertilizers on yield, protein and mineral composition in grain and straw of BRRI dhan29. An MS Thesis, Dept. of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Reddy, V.C., Ananda, M.G., Murthy, K.N.K. 2004. Effect of different sources of nutrients on growth and yield of paddy (*Oryza sativa* L.). Env. Ecol., 22(4): 622-626.

Rumi, M.S. 2017. Effect of cow dung and suplhur on the growth and yield of aromatic rice cv Tulshimala. An MS Thesis, Dept. of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

Russell, D.F. 1986. MSTAT-C (A computer based data analysis software), Crop and Soil Science Department, Michigan State University, USA.

Saleque, M.A., Abedin, M.S., Bhuiyan, N.I., Zaman, S.K., Panaullah, G.M. 2004. Longterm effect of inorganic and organic fertilizer sources on yield and nutrient accumulation of lowland rice. Field Crops Res., 86: 53-65.

Sarkar, S.K., Sarkar, M.A.R., Islam, N., Paul, S.K. 2014. Yield and quality of aromatic rice as affected by variety and nutrient management. J. Bangladesh Agril. Univ. 12(2): 279-284.

Sarkunan, V., Misra, A.K., Mohapatra, A.R. 1998. Effect of P and S on yield and uptake of P and S by rice. J. Indian Soc. Soil Sci., 46(3): 476-477.

Satyanarayana, V., Prasad, P.V., Murthy, V.R.K., Boote, K.J. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. J. Plant Nutr., 25: 2081-90.

Singh, A.K., Manibhushan, Meena, M.K., Upadhyaya, A. 2012. Effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of indo gangetic plains. J. Agril. Sci., 4(11): 162-170.

Singh, R. P., Yadav, P.K., Singh, R.K., Singh, M.K., Singh, J. 2006. Effect of chemical fertilizer, FYM and biofertilizer on performance of rice and soil properties. Crop Res., 32: 283-285.

Sriramachandrasekharan, M.V., Bhuvaneswari, R., Ravichandran, M. 2004a. Integrated use of organics and sulphur on the rice yield and sustainable soil health in sulphur deficient soil. Plant Arch., 4(2): 281-286.

Sriramachandrasekharan, M.V., Manivannan, R., Ravichandran, M. 2004b. Relative tolerance of rice genotypes to sulphur fertilization in sulphur Deficient soil. Plant Arch., 4(2): 427-431.

Suzuki, A. 1997. Fertilization of rice in Japan. Japan FAO Association, Tokyo, Japan.

Tumrani S.A., Pathan, P.A., Suleman, B.M. 2015. Economic contribution of rice production and food security in Indonesia. Asia Pacific Res. J., 33: 63-74.

Uddin, M.K., Islam, M.R. Rahman, M.M., Alam, M.K. 2002. Effects of sulphur, zinc and boron supplied from chemical fertilizers and poultry manure to wetland rice (cv. BRRI dhan30). Online J. Biol. Sci., 2(3): 166-167.

Umanah, E.E., Ekpe, E.O., Ndon, B.A., Etim, M.E., Agbogu, M.S. 2003. Effects of poultry manure on growth characteristics, yield and yield components of upland rice in South Eastern Nigeria. J. Sustainable Agric. Environ., 5(1): 105-110.

Usman, M., Ullah, E., Warrich, E.A., Earooq, M.A., Liaqat, A. 2003. Effect of organic manures on growth and yield of rice variety "Basmati 2000". Int. J. Agric. Biol., 5: 481-483.

Xu, M.G., Li, D.C., Li, J.M., Qin, D.Z., Yagikazuyuki, Hosen, Y. 2008. Effects of organic manure application with chemical fertilizers or Nutrient Absorption and yield of Rice in Hunan of Southern China. Agricultural Sciences in China, 7 (10): 1245-1252.

Yadav, D.S. 2000. Workshop on sulphur in balanced fertilization proc. TSI/FAI/IFA Workshop held on Feb. 7-8, New Delhi. pp. 55-63.

Yang, C.M., Yang, L., Yang, Y., Ouyang, Z. 2004. Rice root growth and nutrient uptake as influenced by organic manure in continuously and alternately flooded paddy soils. Agril. Water Manag., 70(1): 67-81.

Zaman, M.M., Chowdhury, M.A.H., Islam, M.R., Uddin, M.R. 2015. Effects of vermicompost on growth and leaf biomass yield of stevia and post-harvest fertility status of soil. J. Bangladesh Agril. Univ., 13(2): 169-174.

Zaman, S.K., Panaullah, G.M. Jahiruddin, M., Mian, M.H., Islam, M.R. 2002. Integrated nutrient management for sustainable yield in Rice-Rice cropping systems. Paper was presented in 17th WCSS symposium at Thailand on 14-21 August 2002.