EFFECT OF DIFFERENT LEVELS OF SULPHUR ON GROWTH AND YIELD OF THREE RICE VARIETIES IN *BORO* SEASON

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF DIFFERENT LEVELS OF SULPHUR ON GROWTH AND YIELD OF THREE RICE VARIETIES IN *BORO* SEASON"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **SABA TAHSIN**, Registration No. 19-10373under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

June, 2021

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Dedicated to
My
Beloved Parents

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The Author

EFFECT OF DIFFERENT LEVELS OF SULPHUR ON GROWTH AND YIELD OF THREE RICE VARIETIES IN *BORO* SEASON

ABSTRACT

The experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka during November 2019 to May 2020 to study the effect of sulphur on popular three BRRI released rice varieties. The experiment consisted of three rice varieties *viz*., V_1 (BRRI dhan88), V_2 (BRRI dhan89) and V_3 (BRRI dhan100) in combination with four sulphur treatments *viz*., S_0 (control; 0 kg S ha^{-1}), S_1 (30 kg S ha^{-1}), S_2 (40 kg S ha^{-1}) and S_3 (50 kg S ha^{-1}). The experiment was laid out in Randomized complete Block Design (RCBD) with three replications. Among different rice varieties, V_3 (BRRI dhan100) showed better performance on different growth parameters, but considering yield and yield contributing characters V_2 (BRRI dhan89) exhibited better performance,whereas V_1 (BRRI dhan88) gave the least performance. Among sulphur treatments, S_2 (40 kg S ha^{-1}) gave the best results considering other treatments followed by S_3 (50 kg S ha^{-1}) whereas control treatment S_0 (0 kg S ha^{-1}) showed the lowest performance. In terms of combined effect of variety and sulphur treatment, V_2S_2 showed better results regarding yield contributing and yield characters and gave the highest number of effective tillers $hill^{-1}$ (21.67), panicle length (29.87 cm), number of filled grains $panicle^{-1}$ (114.80), 1000 grain weight (24.30 g), grain yield (8.57 t ha^{-1}), straw yield (9.59 t ha^{-1}) and harvest index (47.16%), whereas the lowest results were recorded from V_1S_0. Therefore, among the treatment combinations, V_2S_2 (BRRI dhan89 with 40 kg S ha^{-1}) can be considered as the best treatment combinations followed by V_2S_3 (BRRI dhan89 with 50 kg S ha^{-1}) compared to other treatment combinations.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization of the United Nations
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is the staple food for at least 62.8% of total planet inhabitants and it contributes on an average 20% of apparent caloric intake of the world population and 30% of population in Asian countries. This caloric contribution varies from 29.5% for China to 72.0% for Bangladesh (Calpe and Prakash, 2007).

Rice is the staple food of Bangladesh and over 95% people depend on rice for their daily diets and it engages over 85% of the total agricultural labour force in Bangladesh. Bangladesh is predominantly an agrarian country. Due to its very fertile land and favorable weather, varieties of crops grow abundantly in this country. Agriculture sector contributes about 13.31 percent to the country's Gross Domestic Product (GDP) and employs more than 49 percent of total labour force (BBS, 2019). Rice is cultivated in Bangladesh throughout the year as Aus, Aman or Boro. Aman (broadcast and transplanted) is generally cultivated from June-July to October-November, Boro from December-January to April-May, and Aus from March-April to June-July.

In Bangladesh about 11422 hectare land is under rice cultivation with a production of 36,603 thousand metric tons (BBS, 2020). In 2019-2020, total land under rice cultivation in *Aus* season was 1095 thousand hectare which produced 2756 metric tons rice, accordingly 5562 and 4763 thousand hectares of land was in *Aman* and *Boro* season respectively which produced 14204 and 19646 metric tons rice respectively (BBS, 2020). Besides, based on the rice cultivation, Bangladesh is the 5th largest country of the world (BBS, 2016). Alam (2012) also reported that rice covers about 82% of the total cropped land of Bangladesh. It accounts for 92% of the total food grain production in the country and provides more than 50% of the agricultural value addition employing about 44% of total labour forces. According to the latest estimation made by BBS, per capita rice consumption is about 166 kg year^{-1}. Rice alone provides 76% of the calorie intake and 66% of total protein requirement and shares about 95% of the total cereal food supply (Alam, 2012).

Variety plays an important role for successful crop production. Significant variation was found due to varietal difference on yield of rice. HYV and hybrid rice varieties have 15-30% yield advantage over local inbred (Julfiquar *et al*., 2009; Abou Khalifa, 2009). Slow senescence and more strong photosynthetic capability of flag leaf, higher LAI at grain filling period and higher post heading-CGR plays major role for higher yield formation in modern rice. Greater biomass accumulation before heading and higher shoot reserve translocation are the decisive factors of higher yield in HYV rice (Haque *et al*., 2015).

Sulphur is an essential macronutrient nutrient for plants ranked 4th after nitrogen, phosphorus and potassium because of its indispensable role in proteins synthesis, vitamins, enzyme and flavoured compounds in plant (Bera and Ghosh, 2015 and Islam *et al*., 2017). About 90% of plant sulphur present in amino acid (methionine and cysteine) and a variety of metabolites (thiamine, thiamine, pyrophosphate, glucosinolates, glutathione and phytochelatins), which play a pivotal role in building blocks of protein, formation of chlorophyll, activation of enzymes etc. (Tewari *et al*., 2010; Hoefgen *et al*., 2008). In recent years, S deficiency has been receiving much attention as a major limiting factor for wetland rice. For rice cultivation, next to nitrogen, S application is very important. So, in fertilizer schedule, it is commonly included (Islam *et al*., 2009). Sulphur is absorbed by plants in the form of sulphate ($SO4^{2-}$) ion. Sulphur is considered to be one of the most important major nutrients along with nitrogen phosphorus and potassium for balanced fertilization. The low productivity of rice in India is attributed by several factors including balance nutrition. Balanced nutrition especially application of sulphur and zinc to the rice crop is one of the important inputs that can enhance productivity to a great extent (Singh *et al*., 2012).

With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

1. To study the effect of different doses of sulphur on growth and yield of three BRRI released inbred rice varieties.
2. To find out the suitable dose(s) of sulphur for achieving maximum grain yield from above mention rice varieties.

CHAPTER II

REVIEW OF LITERATURE

Varietal performance is one of the major reasons of yield reduction of rice. So, varieties are the most important factor needed to be considered in rice production. Sulphur nutrition is another important factor for maximizing the rice yield. Some of the important and informative works and research findings related to the variety and sulphur nutrition done at home and abroad have been reviewed under the following headings:

2.1 Effect of variety

A field experiment with six rice varieties was conducted by Khatun (2020) and reported maximum number of filled spikelet in Binadhan-17 (164.89panicle^{-1}), maximum 1000-seed weight (27.25 g) and highest grain yield (6.13 t ha^{-1}) compared to BRRI dhan39, BRRI dhan33 and Binadhan-16 while BRRI dhan39 showed lowest grain yield (4.49 t ha^{-1}).

Salam *et al*. (2019) carried out an experiment in Boro season to study the yield performance of BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan86 and reported higher germination rate, plant height and effective tiller number in BRRI dhan67 than the other varieties but lower than BRRI dhan28. BRRI dhan67 also gave significantly higher number of spikelets per panicle, filled grain and 1000-grain weight compared to the other varieties which was significantly same to BRRI dhan28.

Murshida *et al*. (2017) conducted an experiment with three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems to examine the effect of variety and water management system on the growth and yield performance of boro rice. At 100 DAT, the highest plant height, maximum number of tillers hill^{-1}, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were obtained from BRRI dhan29 and the lowest values were found in Binadhan-14. Variety had significant effect on all the crop characters under study except 1000-grain weight. The highest grain yield was obtained from BRRI dhan29 and the lowest value was recorded from Binadhan-14.

Rashid *et al*. (2017) conducted an experiment to evaluate the yield performance of seven aromatic rice varieties of Bangladesh *viz*. Jirakatari, Chiniatab, Chinigura, Kataribhog, Kalizara, Badshabhog and BRRI dhan34. The highest plant height (167.0 cm) was found in the variety Chinigura and the lowest (120.1 cm) in the variety Chiniatab. In the variety Kataribhog number of filled grains panicle^{-1} was found highest (255.6) and the lowest (130.7) was recorded in the variety Badshabhog. Badshabhog produced the highest 1000-grain weight (18.3 g) and the lowest (11.4 g) was recorded from the variety Kataribhog. The highest grain yield (2.54 t ha^{-1}) was obtained from Kataribhog and the lowest grain yield (1.83 t ha^{-1}) was obtained from Kalizara. Among the seven aromatic rice varieties under North-west condition Kataribhog and BRRI dhan34 are suitable in respect of yield.

Wagan *et al.* (2015) conducted a study to compare the economic performance of hybrid and conventional rice production and reported that total costs per hectare of hybrid rice was 148992.23 Rs per hectare which was more then conventional rice was 140661.68 Rs per hectare. On an average higher yield (196.14 monds per hectare) was obtained from hybrid rice while conventional rice yield (140.14 monds per hectare) was less then hybrid rice. There was 16.64 percent increase in hybrid rice yield comparing with conventional rice which gives additional income to poor farmers.

Jisan *et al*. (2014) carried out an experiment to examine the yield performance of some transplant aman rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties *viz*. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57. Among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), highest number of effective tillers hill^{-1} (11.28), grains panicle^{-1} (121.5) and 1000-grain weight (23.65 g) whereas the lowest values of these parameters were produced by BRRI dhan57. Highest grain yield (5.69 t ha^{-1}) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest one (4.25 t ha^{-1}) was obtained from BRRI dhan57.

Akter (2014) investigated the growth, yield and nutrient content of 15 *Boro* rice cultivars. BR 15, BRRI dhan29 and BRRI dhan28 were the three rice cultivars having high potentials for grain and straw production during *Boro* season. The highest yield was recorded 5.26 t ha^{-1} which is still very low compared to other rice growing countries of the world. Chola *Boro* and Sada boro are two local land races having potentials for producing higher number of effective tillers and higher 1000 grain weight. Sada *Boro* and Chola *Boro*, two local cultivars were found very high in grain nitrogen content compared to other test cultivars.

Sarkar *et al*. (2014) conducted an experiment to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties *viz*. BRRI dhan34, BRRI dhan37 and BRRI dhan38. The tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

Islam *et al*. (2013) conducted an experiment to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38. The tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34. The highest grain protein content (8.17%) was found in BRRI dhan34 whereas the highest aroma was found in BRRI dhan37 and BRRI dhan38.

Sritharan and Vijayalakshmi (2012) evaluated the physiological traits and yield potential of six rice cultivars *viz.*, PMK 3, ASD 16, MDU 3, MDU 5, CO 47 and RM 96019. The plant height, total dry matter production and the growth attributes like leaf area index, crop growth rate and R:S ratio were found to be higher in the rice cultivar PMK 3 that showed significant correlation with yield. Yield and yield components like number of productive tillers, fertility co-efficient, panicle harvest index, grain weight and harvest index were found to be higher in PMK 3.

Khushik *et al*. (2011) studied to assess the performance of rice hybrid and other varieties planted in rice growing areas of Sindh and Balochistan. The results revealed that average yield of hybrid rice was 195 mds ha^{-1}, followed by IRRI-6 (151 mds ha^{-1}), B-2000 (91 mds ha^{-1}) and Rosi (94 mds ha^{-1}). This indicates that the yield of hybrid rice was higher by 29% than the major variety IRRI-6.

Samonte *et al.* (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income.

Islam (2011) conducted a field experiment at BINA, Mymensingh on five aromatic rice genotypes viz., BRRIdhan34, Ukunimadhu, RM-100/16, KD5 18-150 and Kalozira by at BINA, Mymensingh. Among the varieties, KD5 18-150 showed higher grain yield, total dry matter $plant^{-1}$ and harvest index under temperature stress.

Islam *et al.* (2010) found that the rice cultivar 1R76712H produced the highest grain yield (7.7 t ha^{-1}) followed by 1R75217H and Magat (7.6 t ha^{-1}) in WS; in DS, 1R79118H produced the highest grain yield (9.17 t ha^{-1}) followed by 1R73855H (8.9 t ha^{-1}) and SL-8H (8.8 t ha^{-1}) due to high harvest index. Hybrid produced higher spikelets $panicle^{-1}$ and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice.

Razzaque *et al.* (2009) studied on salt tolerant genotypes PVSB9, PVSB19, PNR381, PNR519, Iratom24 and salt sensitive genotype NS15 along with one standard check salt tolerant rice cultivar Pokkali. The different morphological characters studied include plant height, total number of tillers, Root Dry Weight (RDW), Shoot Dry Weight (SDW) and Total Dry Matter (TDM) content of the selected rice genotypes in view to evaluate their response at different salinity levels. The genotypes Pokkali, PVSB9, PVSB19 showed significantly higher values and the lowest value of all these characters were recorded in NS15.

Hossain *et al*. (2008) conducted the study to observe the yield and quality of ten popular aromatic rice varieties of Bangladesh. The varieties were Kataribhog (Philippines), Kataribhog (Deshi), Badshabhog, Chinigura, Radhunipagal, Kalizera, Zirabhog, Madhumala, Chiniatab and Shakhorkora. All the yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest grain yield was obtained from Kataribhog (Philippines) which identically followed by Badshabhog. In respect of quality, Zirabhog gave the highest head rice outturn that was statistically similar to Badshabhog and Chiniatab. All the tested varieties had bold type shape. Grain protein content ranged from 6.6-7.0 % in brown rice.

Ashrafuzzaman *et al.* (2008) conducted a field experiment to study the growth and yield of inbred and hybrid rice with tiller separation at different growth periods. The experiment was conducted with two levels of treatments *viz.* (a) Variety: BRRI dhan32 and Sonarbangla-1; and (b) tiller separation days: 20, 25, 30, 35 and 40 days after mother plant transplantation. Maximum filled grains panicle^{-1} (144.28) was observed from the tiller separation at 20 DAT. Total and effective tillers hill^{-1}was affected by tiller separation beyond 30 DAT. Delayed tiller separation extended the flowering and maturity duration. Therefore, it was concluded that earlier tiller separation (20-30 DAT) resulted higher grain yield in hybrid variety but no such variations was observed in inbred variety.

Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check varieties and these can be released as new varieties after series of yield trials. With improved yield, the new varieties are expected to increase rice production. The elite lines generated are also potential germplasm for rice improvement projects. The initial effort to identify high biomass rice will enhance the development of dedicated feedstock for bioenergy production.

Khan *et al*. (2006) reported that the variety Rachna showed the highest yield of 4009.590 kg ha^{-1} followed by Basmati-385, Shaheen and Super with the production of 3678.983, 2939.257 and 2175.303 kg ha^{-1}, respectively. However, the plant height (cm) of Rachna was at 2nd position (125.400 cm) after Basmati-385 at 129.767 cm. The maximum tiller $plant^{-1}$ (18) was obtained by variety Rachna, which significantly differ from variety Super that produced 10 tillers $plant^{-1}$. The maximum spike $plant^{-1}$18 were shown by variety Rachna and the number of tiller $plant^{-1}$ produced by Rice variety Basmati-385 i.e., 17. The highest yield of Rachna variety was due to the best performance in terms of tillers $plant^{-1}$, spike $plant^{-1}$ and weight of 1000 grains.

Wang *et al.* (2006) studied the effects of plant density on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Chowdhury *et al*. (2005) conducted an experiment to study their effect on the yield and yield components of rice varieties BR23 and Pajam with 2, 4 and 6 seedlings $hill^{-1}$ during the *Aman* season. They reported that the cv. BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers $hill^{-1}$, length of panicle, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam produced significantly the tallest plant, total number of grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin1 and Saegyehwa varieties.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti and observed that Mukti (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) compared to the others.

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar dhan1) and two high yielding cultivars (HYV) as controls (Pant dhan 4 and Pant dhan 12) and reported that KHR 2 gave the best yield (7.0 t/ha) among them.

Anwar and Begum (2004) reported that time of tiller separation of rice significantly influenced plant height, total number of tiller hill^{-1}, number of bearing tillers and panicle length but grain and straw yields were unaffected. Therefore, Sonarbangla-1 appeared to be tolerant to tiller separation and separation should be done between 20 to 40 DAT without hampering grain yield.

Siddiquee *et al.* (2002) conducted a study to evaluate the difference between hybrid and inbred rice in respect of their growth duration, yield and quality. Among the varieties, Aalok 6201 had the highest grain yield followed by BRRI dhan29 and IR68877H but statistically they were similar. BRRI dhan28 had the lowest grain yield, which was statistically similar to Loknath503. BRRI dhan28 and the tested hybrid rice had lower growth duration than BRRI dhan29.

Rahman *et al.* (2002) carried out an experiment with 4 varieties of transplant *Aman* rice *viz.,* BR1l, BR22, BR23 and Tuishimala and 6 structural arrangement of rows *viz.*, 25 cm + 25 cm, 30 cm + 20 cm, 35 cm + 1 5 cm, 40 cm + 10 cm) 45 cm + 05 cm and haphazard planting at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. Thousand grains weight and grain yield were highest in BR23 and these were lowest in Tulshirnaia.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) and filled grains $panicle^{-1}$ (111.0) than other varieties, whereas IR36 gave the highest 1000- grain weight (21.07 g) and number of panicles m^{-} than other tested varieties.

Patel (2000) studied that the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

Julfiquar *et al.* (1998) evaluated 23 hybrids along with three standard checks during *Boro* season 1994-95 as preliminary yield trial at Gazipur and reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. They also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during *Boro* season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}.

BRRI (1995) conducted three experiments to find out the performance of different rice varieties. Results of the first experiment indicated that BR4, BR10, BR11, Challish and Nizersail produced grain yield of 4.38, 3.12, 3.12, 3.12 and 2.70 t ha^{-1}, respectively. Challish cultivar flowered earlier than all other varieties. BR22 and BR23 showed poor performance. Second experiment with rice cv. BR10, BR22, BR23 and Rajasail at three locations in aman season. It was found that BR23 yielded the highest (5.17 t ha^{-1}), and Rajasail yielded the lowest (3.63 t ha^{-1}).

Growth duration of BR22, BR23 and Rajasail were more or less similar (152-155 days). Third experiment with BR22, BR23, BR25 and Nizersail during *Aman* season at three locations-Godagari, Noahata, and Putia where BR25 yielded the highest and farmer preferred it due to its fine grain and desirable straw qualities.

2.2 Effect of sulphur on growth and yield of rice

Singh *et al*. (2019) carried out a study on the effect of nitrogen and sulphur fertilization on growth and yield of rice (*Oryza sativa* L.). Nine treatments combinations are comprised. The experimental results indicated that, T_9-$_{150}$ kg N + 60 S ha^{-1}, resulted in highest values of all the growth parameters such as plant height (cm), no. of tillers per m^2 area, fresh weight (g plant^{-1}), dry weight (g plant^{-1}), and yield attributes as like number of effective tillers/m^2 area, panicle length (cm), number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, fertility (%), 1000- seed weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index (%) respectively, over rest of the treatments.

Kumar *et al*. (2018) conducted an experiment comprises ten treatments *viz*. 100% NPK (150:60: 40: kg ha^{-1}), 100% NPK+ 75% S through SSP, 100% NPK+ 100% S through SSP, 100% NPK + 125% S through SSP, 100% NPK + 75% S through Phospho Gypsum, 100% NPK + 100% S through Phospho Gypsum, 100% NPK + 125% S through Phospho Gypsum, 100% NPK + 75% S through Sulphur Bentonite, 100% NPK + 100% S through Sulphur Bentonite and 100% NPK + 125% S through Sulphur Bentonite replicated thrice in Randomized Block Design. Rice variety Sarjoo-52 was taken for experimentation. The data revealed that growth parameters *viz*. plant height, no. of tillers per running meter and leaf area index were found significantly superior over other treatments with the application of 100% NPK + 125% S through SSP.

Singh *et al*. (2018) conducted a field experiment to assess the effect of different levels of sulphur and zinc on yield of kharif rice (*Oryza sativa* L). The treatments consisted of four levels of suphur (0, 15, 20 and 25 kg ha^{-1}) and four levels of zinc (0, 5, 10 and 15 kg Zn ha^{-1}). Application of 20 kg S ha^{-1} recorded highest number of effective tillers m^{-2} (233.99), filled grains $panicle^{-1}$ (100.95), grain yield (56.3 q ha^{-1}), straw yield (64.8 q ha^{-1}) and harvest index (46.27%) over the remaining treatment. Regarding test weight also 20 kg S ha^{-1} recorded the highest value and least with control (0 kg S ha^{-1}).

Tarafdar *et al*. (2018) initiated an experiment and repeated it for three years to evaluate the immediate effect of sulphur in rice and thereafter the residual effect of sulphur on succeeding mustard and green gram crops. Sulphur was applied once in a year through SSP and elemental S during rice transplantation and the NPK were applied at recommended dose of the respective crops. The application of sulphur have the direct effect on plant characters and as well as on yield parameters of rice. In all cases the control treatment received no sulphur produced the lowest yield.

Uddin *et al*. (2014) conducted an experiment with four levels of Phosphorus (P) *viz*. P_0: without Phosphorus (control), P_1: 20 kg ha^{-1}, P_2: 40 kg ha^{-1} and P_3: 60 kg ha^{-1} and four levels of Sulphur *viz*. S_0: without Sulphur (control), S_1: 10 kg ha^{-1}, S_2: 20 kg ha^{-1} and S_3: 30 kg ha^{-1}. All the traits were significant by S application except plant height at 55, 85 DAT and at harvest, filled grains $panicle^{-1}$ and 1000-grain weight whereas 20 kg S ha^{-1} obtained the tallest plant (109.40 cm) at harvest and maximum tillers $hill^{-1}$ (16.28) at 85 DAT. The maximum effective tillers $hill^{-1}$ (12.12), longest panicle (21.35), higher weight of grain, straw and biological yield 4.75, 8.08 and 12.82 t ha^{-1}, respectively and harvest index (36.90%) were taken in 20 kg S ha^{-1} at harvest. It was also observed the minimum non effective tillers $hill^{-1}$ (2.83) and unfilled grains $panicle^{-1}$ (12.04) whereas all the Sulphur levels were produced statistically similar filled grains $panicle^{-1}$ and 1000-grain weight at harvest due to non significant variation.

Ram *et al*. (2014) conducted a field experiment on rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping system was conducted with 5 treatments in rice (*viz*. control and 30 and 60 kg S ha^{-1} each through gypsum and phosphogypsum) and 3 treatments in wheat (*viz*. 0, 15 and 30 kg S ha^{-1} through elemental sulphur). Irrespective of the sources, sulphur application had a positive and significant influence on growth parameters, sulphur uptake, sulphur-use efficiency, yield attributes and grain yield of aerobic rice. The sulphur uptake by grain and straw of rice increased with sulphur applied through gypsum or phosphogypsum. The highest agronomic efficiency, crop-recovery efficiency and physiological efficiency was ob 1 served with S applied @ 30 kg S ha^{-1} through gypsum. Averaged across 2 years, application of sulphur through gypsum @ 30 kg S ha^{-1}, gypsum @ 60 kg S ha^{-1}, phosphogypsum @ 30 kg S ha^{-1} and phosphogypsum @ 60 kg S ha^{-1} increased the grain yield of rice by 9.5, 11.2, 8.7 and 10.7% respectively, over the control (no sulphur). However, significant response to sulphur was observed only up to 30 kg S/ha applied through either of the sources.

Singh *et al*. (2012) carried out a study on the effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil. Based on three years of experimentation, results revealed that rice plant height is significantly affected by sulphur. Dry matter share of root was in general less than 15% across the levels of sulphur and zinc during all the phenological stages. Maximum rice yield (7.63 t ha^{-1}) was recorded with combined application of 30kg sulphur and 6kg zinc, whereas corresponding minimum rice yield (7.09 t ha^{-1}) was recorded with absolute control plots where no application of zinc and sulphur was done during entire experimentation period. Maximum (281.2 kg ha^{-1}) nitrogen uptake was recorded with 6kg zinc treatment. However highest uptake of P (91.1 kg ha^{-1}) and K (150.4 kg ha^{-1}) was recorded in the plot supplemented with no Zn and sulphur at 40 kg ha^{-1}, respectively. Soil parameters *viz*., pH, EC and organic carbon content did not influenced with the S and Zn. N, P, K, S and Zn were affected significantly due to sulphur and zinc nutrition.

Rahman *et al*. (2008) conducted an experiment to evaluate the effect of S and Zn on rice (cv. BRRI dhan29). There were seven treatments *viz*. S_0Zn_0, $S_{10}Zn_0$, $S_{20}Zn_0$, $S_0Zn_{1.5}$, S_0Zn_3, $S_{10}Zn_{1.5}$ and $S_{20}Zn_3$. The subscripts of S and Zn represent the dose in kg ha^{-1}. The highest grain (5.76 t ha^{-1}) and straw (7.32 t ha^{-1}) yields were recorded in the $S_{20}Zn_3$ treatment (100% recommended dose). The S_0Zn_0 (control) had the lowest grain yield with 4.35 t ha^{-1} as well as the lowest straw yield with 5.47 t ha^{-1}. The application of both S and Zn fertilizers significantly increased S and Zn contents as well as their uptake over control.

Haque and Chowdhury(2004) carried out **a** field experiment to investigate the effects of addition of rice straw and S on growth and yield of high yielding variety of rice (BRRI Dhan 30) under flooded condition and on post harvest soil. The treatments used in the experiment were (1) Control (-S), (2) Rice straw @ 6 t ha^{-1}, (3) S @ 20 kg S ha^{-1} and (4) Rice straw @ 6 t ha^{-1} and S @ 20 kg S ha^{-1}. Gypsum was used as the source of S. Basal fertilizers, such as urea @ 70 kg N, TSP @ 17.5 kg P, MOP @ 33.2 kg K and ZnO @ 3 kg Zn per hectare were applied along with gypsum at the time of transplanting of rice seedlings. Dry matter yield of rice plants significantly increased at both maximum tillering and panicle initiation stage in treatment with rice straw and S applied together. Grain and straw yields of rice significantly increased due to application of rice straw and S together over the control treatment. Grain yield increases were 11.90, 19.76 and 25.95% in rice straw, S and rice straw and S (together) treatments respectively over the control treatment.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of sulphur fertilizer on growth and yield of modern high yielding variety of rice *viz*. BRRI dhan88, BRRI dhan89 and BRRI dhan100 (Bangabandhu dhan100). This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses. The details of experimental materials and methods are described below:

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.3 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period.

Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.4 Planting material

BRRI dhan88, BRRI dhan89 and BRRI dhan100 (Bangabandhu dhan100) were used in this study as test crops.

3.5 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Variety – 3 varieties of rice

1. V_1 = BRRI dhan88
2. V_2 = BRRI dhan89
3. V_3 = BRRI dhan100 (Bangabandhu dhan100)

Factor B: Sulphur– 4 doses

1. S_0 = 0 kg ha^{-1}
2. S_1 = 30 kg ha^{-1}
3. S_2 = 40 kg ha^{-1}
4. S_3 = 50 kg ha^{-1}

There were total 12 (3×4) combination as a whole *viz.*, V_1S_0, V_1S_1, V_1S_2, V_1S_3, V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_3S_0, V_3S_1, V_3S_2 and V_3S_3.

3.6 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three modern HYV rice varieties and four levels of sulphur including control. Three replications were maintained in this experiment. The total number of unit plots was 36 (12×3). The size of each unit plot was 2.00 m × 1.50 m. The whole experimental area was divided into three equal blocks, each representing a replication.

3.7 Growing of crops

3.7.1 Seed collection and sprouting

This variety's seeds were obtained from the Bangladesh Rice Research Institute (BRRI) in Gazipur, Bangladesh. Clean seeds were soaked in water in a pail for 24 hours to produce seedlings. The imbibed seeds were then removed from the water and placed in gunny bags. After 48 hours, the seeds sprouted and were ready for planting in the seed bed in 72 hours.

3.7.2 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Sprouted seeds were sown in the seed bed on November, 2019 in order to transplant the seedlings in the main field.

3.7.3 Raising of seedlings

The sprouted seeds were sown on beds as uniformly as possible at 20th November, 2019. Irrigation was gently provided to the bed when needed. No fertilizer was used in the nursery bed.

3.7.4 Land preparation

The plot selected for conducting the experiment was opened on the 17th December, 2019 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. The experimental plot was partitioned into unit plots in accordance with the experimental design at 24th December, 2019.

3.7.5 Fertilizers and manure application

The fertilizers N, P, K, S and B in the form of Urea, TSP, MP, gypsum and borax, respectively. The doses of sulphur were applied as per treatment through gypsum.

The following doses of fertilizer were applied for cultivation of crop as recommended by BRRI, 2016.

Fertilizer	**Recommended doses (kg ha^{-1})**
Urea	150
TSP	100
MP	100
Gypsum	As per treatment
Borax	10

The fertilizers N, P, K, S and B in the form of urea, TSP, MP, gypsum and borax, respectively were applied. The entire amount of TSP, MP, gypsum and borax were applied during the final preparation of plot land. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation. Boron application as borax was applied according to the treatment considering recommended dose.

3.7.6 Transplanting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted on 25th December, 2019 in well puddled plot with spacing of 20 cm × 15 cm. One seedling was transplanted in each hill. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.8 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.8.1 Irrigation and drainage

Irrigation was given to maintain a consistent level of standing water up to 6 cm during the early phases of seedling establishment, and thereafter the quantity of drying and wetting was maintained throughout the whole vegetative period. There was no water stress during the reproductive and ripening phases.

3.8.2 Weeding

Weeding was done to keep the plots weed-free, which resulted in enhanced seedling growth and development. The weeds were mechanically pulled at 20 DAT (days after transplanting) and 40 DAT.

3.8.3 Insect and pest control

Furadan5G was used in the plot at 25 and 45 DAT. Leaf roller (*Cnaphalocrosis medinalis*) was discovered and treated with Malathion 10 EC @ 1.12 L ha^{-1} through sprayer at 40 and 60 DAT, but no disease infection was recorded in the field.

3.9 Harvesting, threshing and cleaning

Depending on the variety, the crop was harvested after 80-90% of the grains had become straw in colour. The harvested crop was wrapped individually, correctly labelled, and sent to the threshing floor. For each plot, the grains were dried, washed, and weighed. The weight was changed to contain 14% moisture.

3.10 Recording of data

The following data were collected during the study period:

3.10.1. Growth characters

1. Plant height
2. Number of leaves $hill^{-1}$
3. Number of total tillers $hill^{-1}$

4. Dry weight hill^{-1}
5. Growth rate

3.10.2 Morphological parameters

1. Days to first flowering
2. Flag leaf area
3. Flag leaf chlorophyll content

3.10.3 Yield contributing parameters

1. Number of effective tillers hill^{-1}
2. Panicle length
3. Number of filled grains panicle^{-1}
4. Number of unfilled grains panicle^{-1}
5. 1000 grain weight

3.10.4 Yield parameters

1. Grain yield
2. Straw yield
3. Harvest index

3.11 Procedures of recording data

A brief outline of the data recording procedure is given below:

3.11.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of same 5 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.11.2 Number of leaves hill^{-1}

Number of leaves hill^{-1} was counted from the average of same 5 plants pre-selected at random from the inner rows of each plot.

3.11.3 Number of total tillers hill^{-1}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. It was counted from the average of same 5 plants pre-selected at random from the inner rows of each plot.

3.11.4 Dry weight hill^{-1}

Dry matter hill^{-1} was recorded at 30, 50, 70 DAT and at harvest from 5 randomly collected hill of each plot from inner rows leaving the boarder row. Collected hill were oven dried at 70°C for 72 hours then transferred into dessiccator and allowed to cool down at room temperature, final weight was taken and converted into dry matter content hill^{-1}.

3.11.5 Crop growth rate

CGR is the rate of dry matter production per unit of ground area per unit of and was worked out by the following formula (Evans, 1972),

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A} \text{ g cm}^{-2} \text{ day}^{-1}$$

Where,

W_1 = dry weight of the plant at time t_1
W_2 = dry weight of the plant at time t_2
A = land area covered by the plant in cm^2
t_2 and t_1 = time interval in days

3.11.6 Days to first flowering

From randomly select 10 plants, days to first anthesis was recorded by keen observation and mean value was counted.

3.11.7 Flag leaf area

Flag leaf area was measured by counting number, length and breadth of flag leaf from 10 selected plants and mean values were recorded and expressed in cm^2.Leaf area can be simply calculated by flag leaf number multiplying with leaf length and width by a constant (0.75) (Yoshida, 1976).

3.11.9 SPAD value

SPAD value of flag leaf was determined by SPAD meter (Model: FT Green LLC, Wilmington, DE, USA) at flowering stage and grain filling stage

3.11.10 Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted from 5 selected hills at harvest and average value was recorded.

3.11.11 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicles and the average value was recorded in cm.

3.11.12 Number of filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 5 plants of a plot and then average number of filled grains panicle^{-1} was recorded.

3.11.13 Number of unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from selected 5 plants of a plot and then average number of unfilled grains panicle^{-1} was recorded.

3.11.14 Weight of 1000 grain

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram(g).

3.11.15 Grain yield

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.11.16 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.11.17 Biological yield

Biological yield was determined using the following formula

Biological yield = Grain yield + Straw yield

3.11.18 Harvest index

It denotes the ratio of grain yield to biological yield and was calculated with the following formula.

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

3.12 Statistical analysis

The data collected on different parameters were statistically analyzed with split plot design using the MSTAT computer package program developed. Least Significant Difference (LSD) technique at 5% level of significance was used by DMRT to compare the mean differences among the treatments (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to study the tillering dynamics and yield contributing characters and yield of hybrid rice in *Boro* season. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Growth parameters

4.1.1 Plant height

Effect of variety

Different rice varieties showed significant variation on plant height at harvest (Figure 1 and Appendix IV). Results indicated that the highest plant height (112.40 cm) was achieved from the variety V_2 (BRRI dhan89) which was followed by the variety V_3 (BRRI dhan100) whereas the lowest plant height (106.10 cm) was found from the variety V_1 (BRRI dhan88). The result obtained from the present study was similar to the findings of Sritharan and Vijayalakshmi (2012), Murshida *et al*. (2017) and Salam *et al*. (2019); they found significant variation on plant height among different varieties.

Effect of sulphur

Different doses of sulphur to rice showed significant influence on plant height (Figure 2 and Appendix IV). It was observed that the treatment S_3 (50 kg S ha^{-1}) gave the highest plant height (118.20 cm) that was significantly different to other treatments followed by S_2 (40 kg S ha^{-1})whereas the lowest plant height (97.09 cm) was found from the control treatment S_0 (0 kg S ha^{-1}). Singh *et al*. (2019), Kumar *et al*. (2018) and Uddin *et al*. (2014) also found supported result with the present study.

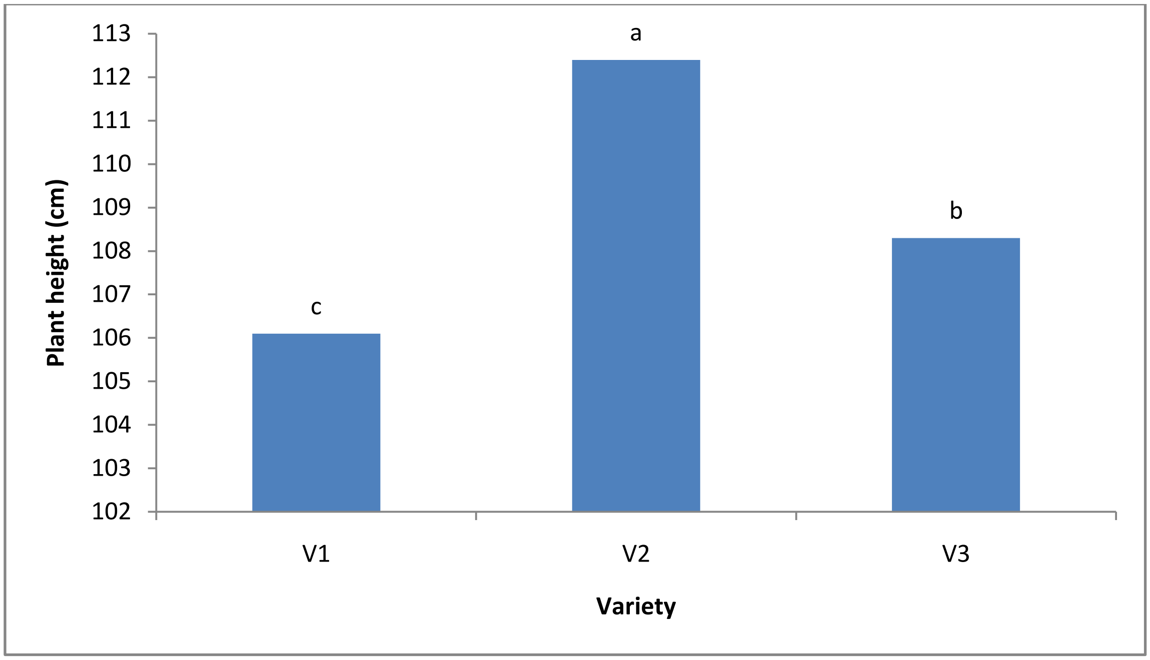

Figure 1. Effect of variety on plant height of three rice varieties

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

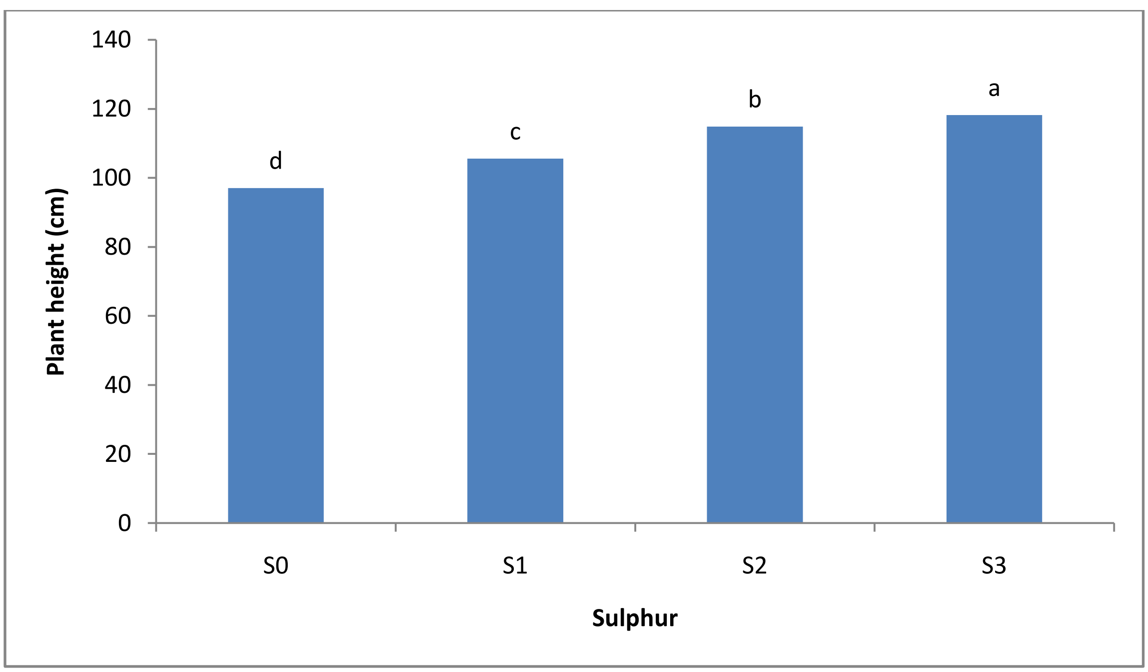

Figure 2. Effect of different levels of sulphur on plant height of three rice varieties

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

Combined effect of variety and sulphur

Plant height of riceat harvest varied significantly due to combined effect of variety and sulphur doses (Table 1 and Appendix IV). The treatment combination of V_2S_3 showed the highest plant height (122.20 cm) which was statistically same to the treatment combination ofV_2S_2 whereas V_1S_0 gave the lowest plant height (95.06 cm) that was significantly different to other treatment combinations.

4.1.2 Number of leaveshill^{-1}

Effect of variety

Different rice varieties showed significant variation for number of leaves hill^{-1}at harvest (Figure 3 and Appendix IV). Results indicated that the highest number of leaves hill^{-1} (646.11) was achieved from the variety V_3 (BRRI dhan100) that was significantly different to other varieties followed by the variety V_2 (BRRI dhan89) whereas the lowest number of leaves hill^{-1} (40.97) was found from the variety V_1 (BRRI dhan88). Similar result was also observed by the findings of Sritharan and Vijayalakshmi (2012).

Effect of sulphur

Application of different doses of sulphur to rice showed significant influence on number of leaves hill^{-1} at harvest (Figure 4 and Appendix IV). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest number of leaves hill^{-1} (51.10) followed by S_3 (50 kg S ha^{-1}) whereas the lowest number of leaves hill^{-1} (32.97) was found from the control treatment S_0 (0 kg S ha^{-1}). Supported result was also observed by Kumar *et al*. (2018).

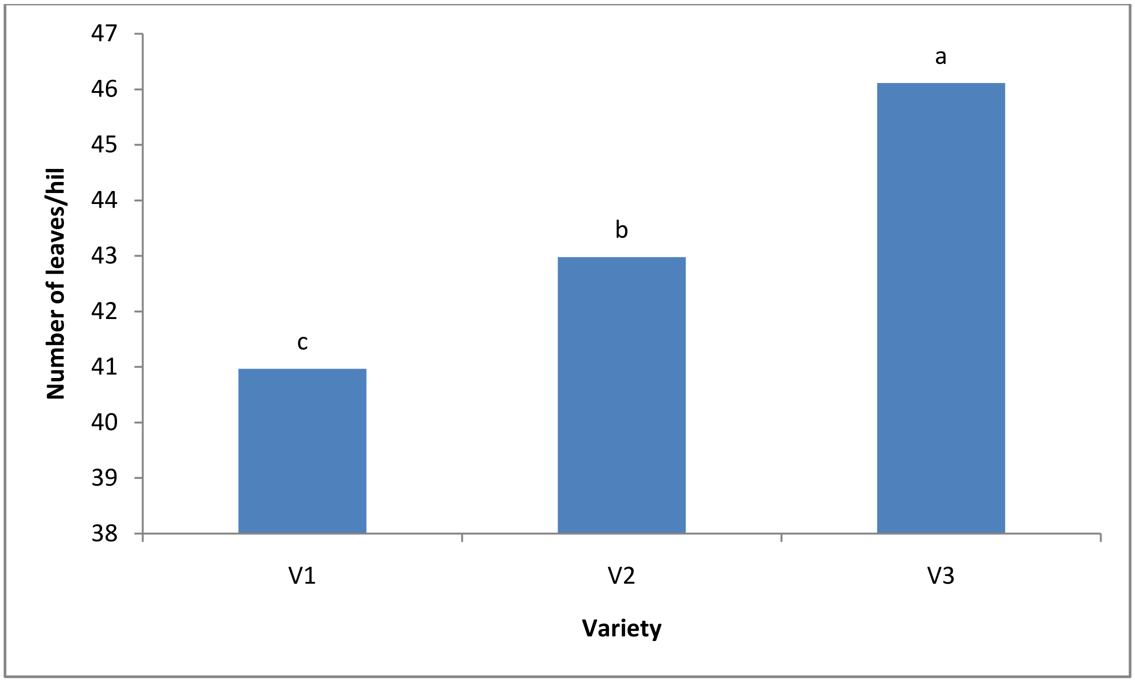

Figure 3. Effect of variety on number of leaves hill^{-1} of three rice varieties

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

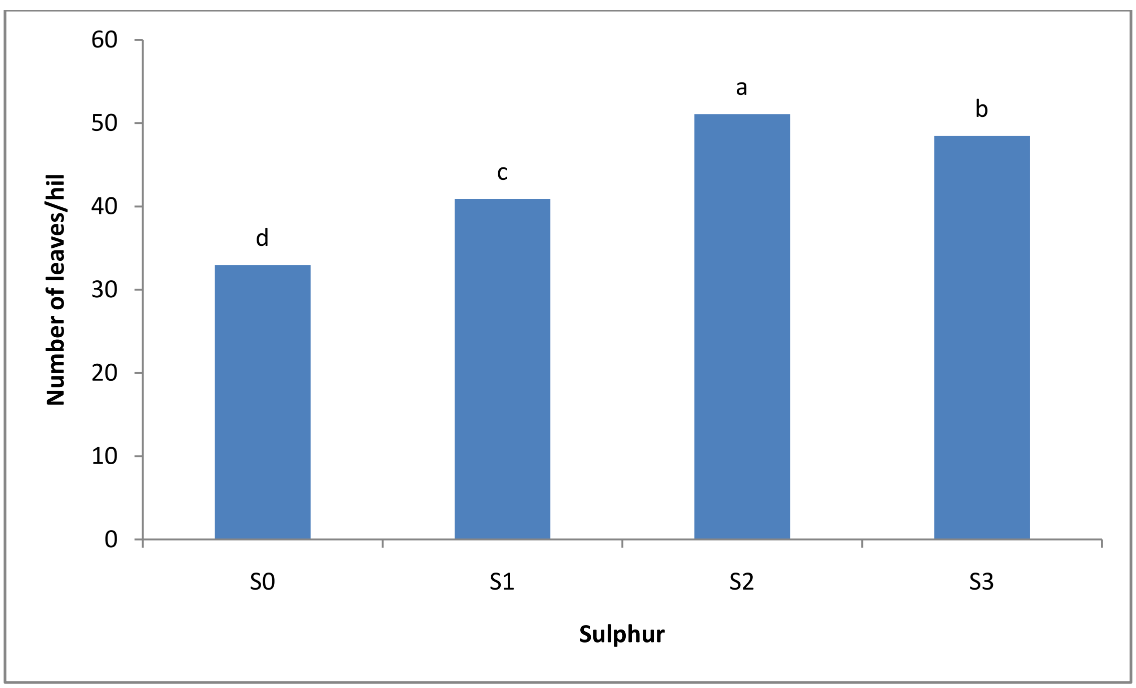

Figure. 4. Effect of sulphur on number of leaves hill^{-1} of three rice varieties

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

Combined effect of variety and sulphur

Treatment combination of variety and sulphur doses showed significant variation on number of leaves hill^{-1} of rice at harvest (Table 1 and Appendix IV). The treatment combination of V_3S_2 showed the highest number of leaves hill^{-1} (54.80) and it was significant same to the treatment combination of V_3S_3.Reversely, the treatment combination of V_1S_0 gave the lowest number of leaves hill^{-1} (31.13) that was statistically identical to V_2S_0.

4.1.3 Number of total tillers hill^{-1}

Effect of variety

Number of total tillers hill^{-1} varied significantly due to varietal difference of rice (Figure 5 and Appendix IV). Results indicated that the highest number of total tillers hill^{-1} (16.67) was recorded from the variety V_3 (BRRI dhan100) that was significantly different to other varieties followed by V_2 (BRRI dhan89) whereas the lowest number of total tillers hill^{-1} (13.48) was found from the variety V_1 (BRRI dhan88). This finding was also similar with the findings of Murshida *et al*. (2017)and they worked with three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14).

Effect of sulphur

Sulphur application to rice at different doses gave significant variation on number of total tillers hill^{-1} at harvest (Figure 6 and Appendix IV). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest number of total tillers hill^{-1} (20.34) followed by S_3 (50 kg S ha^{-1}) whereas the lowest number of total tillers hill^{-1} (10.33) was found from the control treatment S_0 (0 kg S ha^{-1}). The result obtained from the present study was similar with the findings of Singh *et al*. (2019) and Kumar *et al*. (2018), they reported that sulphur had significant effect on tiller production in rice.

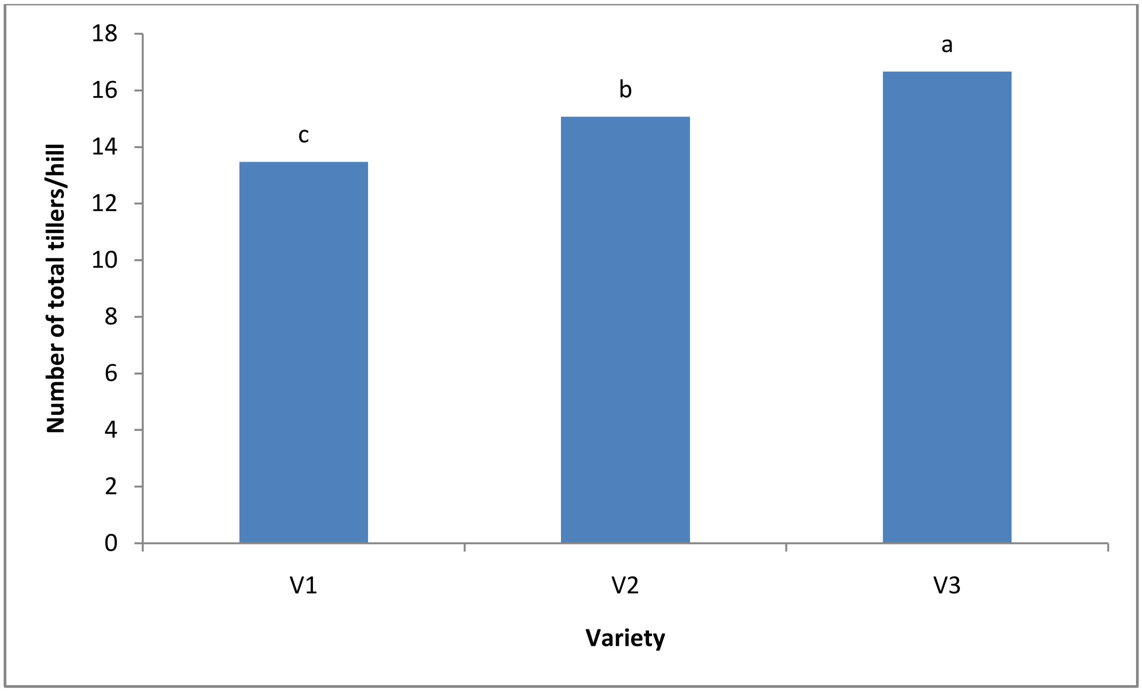

Figure 5. Effect of variety on number of total tillers hill^{-1} of three rice varieties

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

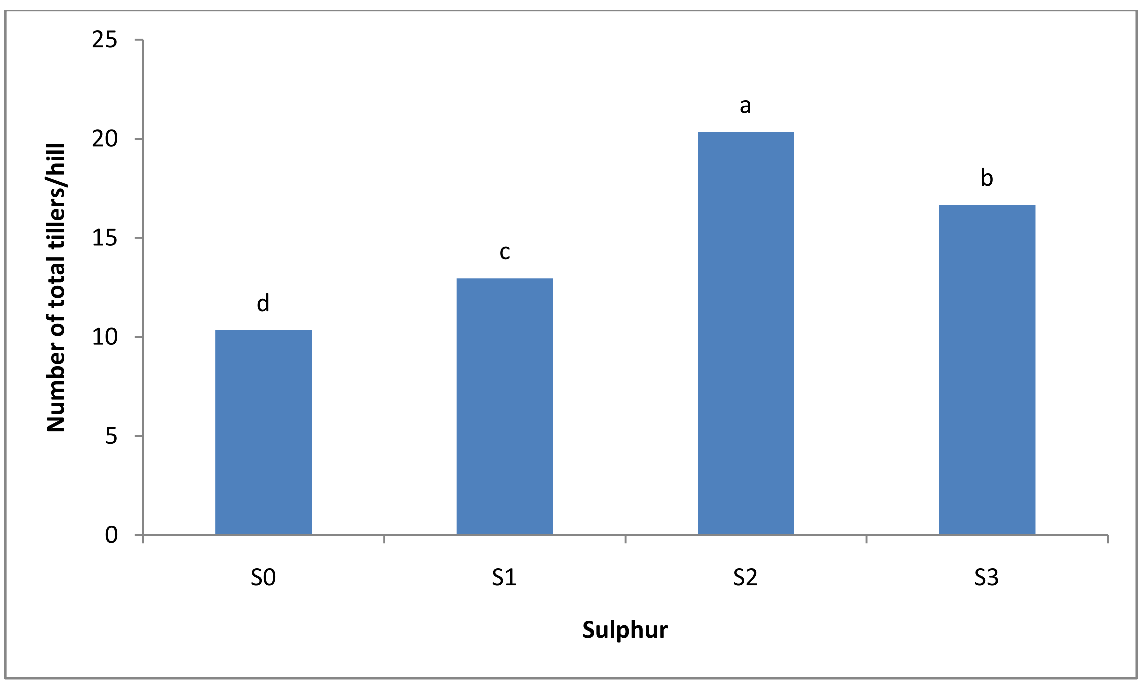

Figure 6. Effect of sulphur on number of total tillers hill^{-1} of three rice varieties

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

Combined effect of variety and sulphur

Different rice varieties in combination with different sulphur doses showed significant variation on number of total tillers hill^{-1} at harvest (Table 1 and Appendix IV). Results revealed that the treatment combination of V_3S_2 showed the highest number of total tillers hill^{-1} (23.00) that was significantly different to other treatment combinations followed by V_2S_2 and V_3S_3.Reversely, the treatment combination of V_1S_0 gave the lowest number of total tillers hill^{-1} (10.07) that was statistically identical to $V_2S_0$and V_3S_0.

Table 1. Effect of sulphur on growth parameters of three rice varieties

Treatments	Growth parameters		
	Plant height (cm)	Number of leaves hill^{-1}	Number of total tillers hill^{-1}
V_1S_0	95.06 h	31.13 g	10.07 g
V_1S_1	103.30 f	39.57 e	11.57 f
V_1S_2	110.60 d	48.30 bc	17.50 c
V_1S_3	115.50 bc	44.90 d	14.77 d
V_2S_0	99.33 g	32.57 g	10.43 g
V_2S_1	107.80 e	41.50 e	13.73 e
V_2S_2	120.30 a	50.20 b	20.53 b
V_2S_3	122.20 a	47.67 c	15.60 d
V_3S_0	96.87 h	35.20 f	10.50 g
V_3S_1	105.70 e	41.63 e	13.57 e
V_3S_2	113.80 c	54.80 a	23.00 a
V_3S_3	116.80 b	52.80 a	19.60 b
$LSD_{(0.05)}$	2.157	2.395	0.949
CV (%)	7.17	9.26	6.72

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

4.1.4 Dry weight hill^{-1} at 80 DAT

Effect of variety

Different rice varieties had significant influence on dry weight hill^{-1} at 80 DAT (Table 2 and Appendix V). It was observed that the highest dry weight hill^{-1} at 80 DAT (37.20 g) was found from the variety V_3 (BRRI dhan100) that was significantly different to other varieties followed by V_2 (BRRI dhan89) whereas the lowest dry weight hill^{-1} at 80 DAT (31.99 g) was found from the variety V_1 (BRRI dhan88). Similar findings was also reported by Murshida *et al*. (2017) and Sritharan and Vijayalakshmi (2012) which supported the present study.

Effect of sulphur

Different doses of sulphur to rice showed significant influence on dry weight hill^{-1} at 80 DAT (Table 2 and Appendix V). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest dry weight hill^{-1} at 80 DAT (42.10 g) followed by S_3 (50 kg S ha^{-1}) whereas the lowest dry weight hill^{-1} at 80 DAT (25.08 g) was found from the control treatment S_0 (0 kg S ha^{-1}). This result was in agreed with the findings of Singh *et al*. (2019), Singh *et al*. (2012) and Haque and Chowdhury (2004).

Combined effect of variety and sulphur

Treatment combination of variety and sulphur doses showed significant variation on dry weight hill^{-1} at 80 DAT of rice (Table 2 and Appendix V). The treatment combination of V_3S_2 showed the highest dry weight hill^{-1} at 80 DAT (45.15 g) and it was significant same to the treatment combination of V_3S_3.On the other hand, the treatment combination of V_1S_0 gave the lowest dry weight hill^{-1} at 80 DAT (24.57 g) that was statistically identical to V_3S_0.

4.1.5 Dry weight hill^{-1} at 120 DAT

Effect of variety

Dry weight hill^{-1} at 120 DAT varied significantly among different rice varieties (Table 2 and Appendix V). It was observed that the the variety V_3 (BRRI dhan100) gave the highest dry weight hill^{-1} at 80 DAT (54.26 g) and it significantly different to other varieties followed by V_2 (BRRI dhan89) whereas the variety V_1 (BRRI dhan88) gave the lowest dry weight hill^{-1} at 120 DAT (48.14 g).

Effect of sulphur

Among different sulphur treatments, dry weight hill^{-1} at 120 DAT influenced significantly (Table 2 and Appendix V). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest dry weight hill^{-1} at 120 DAT (60.32 g) that was significantly different to other treatments followed by S_3 (50 kg S ha^{-1}) whereas the lowest dry weight hill^{-1} at 120 DAT (41.08 g) was found from the control treatment S_0 (0 kg S ha^{-1}).

Combined effect of variety and sulphur

Among different treatment combinations of variety and sulphur, significant variation on dry weight hill^{-1} of rice at 120 DAT was recorded (Table 2 and Appendix V). The treatment combination of V_3S_2 showed the highest dry weight hill^{-1} at 120 DAT (64.63 g) whichwas significantly different to other treatment combination followed by V_3S_3.Again, the treatment combination of V_1S_0 gave the lowest dry weight hill^{-1} at 120 DAT (40.10 g) which was not significantly differed to V_2S_0andV_3S_0.

4.1.6Crop growth rate (CGR)

Effect of variety

Different rice variety showed non-significant variation on crop growth rate (CGR) at 80 to 120 DAT (Table 3 and Appendix VI). However, the variety V_3 (BRRI dhan100) showed the maximum CGR (1.433 mg/cm^2/day) whereas the maximum CGR (1.347 mg/cm^2/day) was achieved from the variety V_1 (BRRI dhan88). Similar result was also observed by Sritharan and Vijayalakshmi (2012).

Effect of sulphur

Different levels of sulphur showed significant variation on crop growth rate (CGR) of rice at 80 to 120 DAT (Table 3 and Appendix VI). Results revealed that the treatment S_2 (40 kg S ha^{-1})gave the maximum CGR (1.52 mg/cm^2/day) which was statistically similar to S_3 (50 kg S ha^{-1}) whereas the minimum CGR (1.334 mg/cm^2/day) was recorded from the control treatment S_0 (0 kg S ha^{-1}).

Combined effect of variety and sulphur

Crop growth rate (CGR) of rice at 80 to 120 DAT varied significantly due to combined effect of variety and sulphur (Table 3 and Appendix VI). It was observed that the treatment combination of V_3S_2 showed the maximum CGR (1.623 mg/cm^2/day) which was statistically similar to the treatment combinations ofV_1S_2, V_2S_2, V_2S_3 and V_3S_3 whereas V_1S_0 gave the minimum CGR (1.293 mg/cm^2/day) which was statistically similar to the treatment combinations of V_1S_1, V_1S_3, V_2S_0, V_2S_1, V_3S_0 and V_3S_1.

Table 2. Dry weight and crop growth rate (CGR) of different rice varieties as influenced by different sulphur doses

Treatments	Dry weight and crop growth rate (CGR)		
	Dry weight $hill^{-1}$ at 80 DAT (g)	Dry weight $hill^{-1}$ at 120 DAT (g)	CGR (80-120 DAT) ($mg/cm^2/day$)
Effect of variety			
V_1	31.99 c	48.14 c	1.347
V_2	33.83 b	50.89 b	1.424
V_3	37.20 a	54.26 a	1.433
$LSD_{(0.05)}$	0.814	1.199	0.114^{NS}
CV (%)	6.80	8.77	9.53
Effect of sulphur			
S_0	25.08 d	41.08 d	1.334 b
S_1	30.83 c	46.80 c	1.332 b
S_2	42.10 a	60.32 a	1.520 a
S_3	39.34 b	56.19 b	1.404 ab
$LSD_{(0.05)}$	0.939	1.385	0.131
CV (%)	6.80	8.77	9.53
Combined effect of variety and sulphur			
V_1S_0	24.57 h	40.10 g	1.293 b
V_1S_1	28.73 g	44.43 f	1.310 b
V_1S_2	39.33 c	56.87 c	1.463 ab
V_1S_3	35.33 d	51.17 d	1.320 b
V_2S_0	25.00 h	41.10 g	1.343 b
V_2S_1	30.43 f	47.10 e	1.390 b
V_2S_2	41.83 b	59.47 b	1.473 ab
V_2S_3	38.03 c	55.90 c	1.490 ab
V_3S_0	25.67 h	42.03 g	1.367 b
V_3S_1	33.33 e	48.87 de	1.297 b
V_3S_2	45.15 a	64.63 a	1.623 a
V_3S_3	44.65 a	61.50 b	1.403 ab
$LSD_{(0.05)}$	1.628	2.398	0.227
CV (%)	6.80	8.77	9.53

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

4.1.7 Flag leaf area

Effect of variety

Different rice varieties showed significant variation on flag leaf area (Table 3 and Appendix VI). Results indicated that the highest flag leaf area (41.72 cm^2) was achieved from the variety V_2 (BRRI dhan89) which was statistically identical to the variety V_3 (BRRI dhan100) whereas the lowest flag leaf area (38.75 cm^2) was found from the variety V_1 (BRRI dhan88). Similar result was also observed by the findings of Sritharan and Vijayalakshmi (2012).

Effect of sulphur

Different doses of sulphur to rice showed significant influence on flag leaf area (Table 3 and Appendix VI). It was observed that the treatment S_2 (40 kg S ha^{-1}) gave the highest flag leaf area (47.02 cm^2) that was significantly different to other treatments followed by S_3 (50 kg S ha^{-1}) whereas the lowest flag leaf area (34.21 cm^2) was found from the control treatment S_0 (0 kg S ha^{-1}). Supported result was also observed by Kumar *et al*. (2018).

Combined effect of variety and sulphur

Flag leaf area of rice at harvest varied significantly due to combined effect of variety and sulphur doses (Table 3 and Appendix VI). The treatment combination of V_2S_2 showed the highest flag leaf area (48.86 cm^2) which was statistically same to the treatment combination of V_3S_2 whereas V_1S_0 gave the lowest flag leaf area (33.60 cm^2) that was significantly different to other treatment combinations.

4.1.8 SPAD value of flag leaf at flowering stage

Effect of variety

Different rice varieties showed significant variation for SPAD value of flag leaf at flowering stage (Table 3 and Appendix VI). Results indicated that the highest SPAD value of flag leaf at flowering stage (58.60) was achieved from the variety V_3 (BRRI dhan100) that was significantly different to other varieties followed by the variety V_2 (BRRI dhan89) whereas the lowest SPAD value of flag leaf at flowering stage (53.94) was found from the variety V_1 (BRRI dhan88).

Effect of sulphur

Application of different doses of sulphur to rice showed significant influence on SPAD value of flag leaf at flowering stage (Table 3 and Appendix VI). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest SPAD value of flag leaf at flowering stage (63.51) followed by S_3 (50 kg S ha^{-1}) whereas the lowest SPAD value of flag leaf at flowering stage (46.90) was found from the control treatment S_0 (0 kg S ha^{-1}).

Combined effect of variety and sulphur

Treatment combination of variety and sulphur doses showed significant variation on SPAD value of flag leaf at flowering stage of rice at harvest (Table 3 and Appendix VI). The treatment combination of V_3S_2 showed the highest SPAD value of flag leaf at flowering stage (66.77) which was statistically similar to the treatment combination of V_3S_3.Reversely, the treatment combination of V_1S_0 gave the lowest SPAD value of flag leaf at flowering stage (46.00) that was statistically identical to V_2S_0 and V_3S_0.

4.1.9 SPAD value of flag leaf at grain filling stage

Effect of variety

Significant variation was found for SPAD value of flag leaf at grain filling stage among different varieties of rice (Table 3 and Appendix VI). Results indicated that the highest SPAD value of flag leaf at grain filling stage (45.38) was achieved from the variety V_3 (BRRI dhan100) that was significantly different to other varieties followed by V_2 (BRRI dhan89) whereas the variety V_1 (BRRI dhan88) gave the lowest SPAD value of flag leaf grain filling stage (41.26).

Effect of sulphur

Different doses of sulphur application to rice showed significant influence on SPAD value of flag leaf grain filling stage (Table 3 and Appendix VI). Results showed that the highest SPAD value of flag leaf grain filling stage (49.98) was recorded from the treatment S_2 (40 kg S ha^{-1}) which was followed by S_3 (50 kg S ha^{-1}) whereas the lowest SPAD value of flag leaf grain filling stage (34.86) was found from the control treatment S_0 (0 kg S ha^{-1}).

Combined effect of variety and sulphur

Statistically significant influence was observed on SPAD value of flag leaf grain filling stage of rice affected by different treatment combination of variety and sulphur doses (Table 3 and Appendix VI). The treatment combination of V_3S_2 showed the highest SPAD value of flag leaf grain filling stage (52.27) which was statistically similar to the treatment combination of V_3S_3.On the other hand, the treatment combination of V_1S_0 gave the lowest SPAD value of flag leaf grain filling stage (34.47) which was significantly same to V_2S_0 and V_3S_0.

Table 3. Flag leaf area and chlorophyll content of different rice varieties as influenced by different sulphur doses

Treatments	Flag leaf area and chlorophyll content		
	Flag leaf area (cm^2)	SPAD value of flag leaf at flowering stage	SPAD value of flag leaf at grain filling stage
Effect of variety			
V_1	38.75 b	53.94 c	41.26 c
V_2	41.72 a	55.23 b	42.69 b
V_3	41.46 a	58.60 a	45.38 a
$LSD_{(0.05)}$	0.7149	1.100	0.850
CV (%)	12.08	11.48	12.33
Effect of sulphur			
S_0	34.21 d	46.90 d	34.86 d
S_1	37.97 c	52.92 c	40.22 c
S_2	47.02 a	63.51 a	49.98 a
S_3	43.38 b	60.37 b	47.37 b
$LSD_{(0.05)}$	0.825	1.270	0.982
CV (%)	12.08	11.48	12.33
Combined effect of variety and sulphur			
V_1S_0	33.60 h	46.00 h	34.47 h
V_1S_1	36.57 ef	51.67 g	37.90 g
V_1S_2	44.01 c	60.80 cd	48.30 cd
V_1S_3	40.83 d	57.30 e	44.37 e
V_2S_0	33.87 gh	46.57 h	34.60 h
V_2S_1	37.90 e	52.70 fg	39.70 f
V_2S_2	48.86 a	62.97 bc	49.38 bc
V_2S_3	46.27 b	58.70 de	47.07 d
V_3S_0	35.17 fg	48.13 h	35.50 h
V_3S_1	39.43 d	54.40 f	43.07 e
V_3S_2	48.20 a	66.77 a	52.27 a
V_3S_3	43.03 c	65.10 ab	50.67 ab
$LSD_{(0.05)}$	1.430	2.200	1.700
CV (%)	12.08	11.48	12.33

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

4.2 Yield contributing parameters

4.2.1 Days to first flowering

Effect of variety

Days to first flowering varied significantly due to varietal difference of rice (Table 4 and Appendix VII). Results indicated that the lowest days to first flowering (75.25 days) was recorded from the V_2 (BRRI dhan89)that was significantly different to other varieties whereas the highest days to first flowering (80.67 days) was recorded from the variety V_3 (BRRI dhan100) followed by V_1 (BRRI dhan88). Similar result was also observed by Ashrafuzzaman *et al.* (2008).

Effect of sulphur

Sulphur application to rice at different doses gave significant variation on days to first flowering (Table 4 and Appendix VII). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the lowest days to first flowering (75.33 days) that was significantly different to other treatments whereas the highest days to first flowering (79.22 days) was found from the control treatment S_0 (0 kg S ha^{-1})followed by S_1 (30 kg S ha^{-1}).

Combined effect of variety and sulphur

Different rice varieties in combination with different sulphur doses showed significant variation on days to first flowering (Table 4 and Appendix VII). Results revealed that the treatment combination of V_2S_2 showed the lowest days to first flowering (73.00 days) which was statistically similar to the treatment combination of V_1S_2.Again, the treatment combination of V_3S_0showed the highest days to first flowering (81.33 days) that was statistically identical to V_3S_1.

4.2.2 Number of effective tillers $hill^{-1}$

Effect of variety

Different rice varieties had significant influence on number of effective tillers $hill^{-1}$ (Table 4 and Appendix VII). It was observed that the highest number of effective tillers $hill^{-1}$ (15.68) was found from the variety V_2 (BRRI dhan89) that was significantly different to other varieties whereas the lowest number of effective tillers $hill^{-1}$ (12.73) was found from the variety V_1 (BRRI dhan88)which was statistically identical to V_3 (BRRI dhan100).This finding was also agreed with the findings of Jisan *et al*. (2014) and Salam *et al*. (2019) who reported the variation on effective tillers due to varietal difference.

Effect of sulphur

Different doses of sulphur to rice showed significant influence on number of effective tillers $hill^{-1}$ (Table 4 and Appendix VII). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest number of effective tillers $hill^{-1}$ (17.84) followed by S_3 (50 kg S ha^{-1}) whereas the lowest number of effective tillers $hill^{-1}$ (9.90) was found from the control treatment S_0 (0 kg S ha^{-1}). This result was similar with the findings of Singh *et al*. (2018).

Combined effect of variety and sulphur

Treatment combination of variety and sulphur doses showed significant variation on number of effective tillers $hill^{-1}$ of rice (Table 4 and Appendix VII). The treatment combination of V_2S_2 showed the highest number of effective tillers $hill^{-1}$ (21.67) and it was significant different to the other treatment combinations followed by V_2S_3.On the other hand, the treatment combination of V_1S_0 gave the lowest number of effective tillers $hill^{-1}$ (9.67) that was statistically identical to V_2S_0.

4.2.3 Panicle length

Effect of variety

Panicle length varied significantly among different rice varieties (Table 4 and Appendix VII). It was observed that the variety V_2 (BRRI dhan89) gave the highest panicle length (25.98 cm) and it significantly different to other varieties whereas the variety V_1 (BRRI dhan88) gave the lowest panicle length (23.92 cm) that was significantly same to V_3 (BRRI dhan100). Sarkar *et al*. (2014) and Islam *et al*. (2013) also found significant variation on panicle length among different varieties which supported the present finding.

Effect of sulphur

Among different sulphur treatments, panicle length influenced significantly (Table 4 and Appendix VII). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest panicle length (28.21 cm) that was significantly different to other treatments followed by S_3 (20.66 cm) whereas the lowest panicle length (20.66 cm) was found from the control treatment S_0 (0 kg S ha^{-1}). Uddin *et al*. (2014) and Singh *et al*. (2019) also recorded significant variation on panicle length due different sulphur doses which supported the present finding.

Combined effect of variety and sulphur

Among different treatment combinations of variety and sulphur, significant variation on panicle length was recorded (Table 4 and Appendix VII). The treatment combination of V_2S_2 showed the highest panicle length (29.87 cm) which was significantly different to other treatment combination followed by V_2S_3.Again, the treatment combination of V_1S_0 gave the lowest panicle length (20.33 cm) which was not significantly differed to $V_2S_0$and V_3S_0.

4.2.4 Number of filled grains panicle^{-1}

Effect of variety

Different rice varieties showed significant variation on number of filled grains panicle^{-1} (Table 4 and Appendix VII). Results indicated that the highest number of filled grains panicle^{-1} (102.80) was achieved from the variety V_2 (BRRI dhan89) that was significantly different to other varieties followed by V_3 (BRRI dhan100) whereas the lowest number of filled grains panicle^{-1} (95.01) was found from the variety V_1 (BRRI dhan88). Rashid *et al*. (2017), Ashrafuzzaman *et al.* (2008) and Chowdhury *et al*. (2005) also found similar result of the present study; and reported significant variation on number of filled grains panicle^{-1} due to varietal difference.

Effect of sulphur

Different doses of sulphur to rice showed significant influence on number of filled grains panicle^{-1} (Table 4 and Appendix VII). It was observed that the treatment S_2 (40 kg S ha^{-1}) gave the highest number of filled grains panicle^{-1} (108.90) that was significantly different to other treatments followed by S_3 (50 kg S ha^{-1}) whereas the lowest number of filled grains panicle^{-1} (83.28) was found from the control treatment S_0 (0 kg S ha^{-1}). This result was also conformity with the findings of Singh *et al*. (2019), Singh *et al*. (2018) and Uddin *et al*. (2014).

Combined effect of variety and sulphur

Number of filled grains panicle^{-1} of rice at harvest varied significantly due to combined effect of variety and sulphur doses (Table 4 and Appendix VII). The treatment combination of V_2S_2 showed the highest number of filled grains panicle^{-1} (114.80) which was statistically same to the treatment combination of V_2S_3 whereas V_1S_0 gave the lowest number of filled grains panicle^{-1} (80.93) that was statistically similar to V_3S_0.

4.2.5 Weight of 1000 seeds

Effect of variety

Different rice varieties had significant influence on 1000 seed weight (Table 4 and Appendix VII). It was observed that the highest 1000 seed weight (23.91 g) was found from the V_2 (BRRI dhan89) that was significantly different to other varieties followed by V_1 (BRRI dhan88) whereas the lowest 1000 seed weight (16.01 g) was found from the variety V_3 (BRRI dhan100). Khatun (2020), Salam *et al*. (2019), Murshida *et al*. (2017) and Jisan *et al*. (2014) also found similar result with the present study.

Effect of sulphur

Different doses of sulphur to rice showed non-significant influence on 1000 seed weight (Table 4 and Appendix VII). However, the treatment S_2 (40 kg S ha^{-1}) showed the highest 1000 seed weight (20.89 g) whereas the lowest 1000 seed weight (20.30 g) was found from the control treatment S_0 (0 kg S ha^{-1}). Similar result was also observed by Singh *et al*. (2019) and Uddin *et al*. (2014).

Combined effect of variety and sulphur

Treatment combination of variety and sulphur doses showed significant variation on 1000 seed weight of rice (Table 4 and Appendix VII). The treatment combination of V_2S_2 showed the highest 1000 seed weight (24.30 g) and it was significant differed to the other treatment combinations followed by V_2S_3.On the other hand, the treatment combination of V_3S_0 gave the lowest 1000 seed weight (15.72 g) that was statistically similar to V_3S_1.

Table 4. Effect of sulphur on yield contributing parameters of different rice varieties

Treatments	Yield contributing parameters				
	Days to first flowering	Number of effective tillers $hill^{-1}$	Panicle length (cm)	Number of filled grains $panicle^{-1}$	1000 grain weight (g)
Effect of variety					
V_1	75.75 b	12.73 b	23.92 b	95.01 c	21.81 b
V_2	75.25 b	15.68 a	25.98 a	102.80 a	23.91 a
V_3	80.67 a	13.44 b	24.39 b	97.67 b	16.01 c
$LSD_{(0.05)}$	0.608	1.030	0.944	1.418	0.131
CV (%)	5.73	4.96	8.99	9.70	4.75
Effect of sulphur					
S_0	79.22 a	9.90 d	20.66 d	83.28 d	20.30
S_1	77.89 b	12.62 c	23.87 c	96.49 c	20.47
S_2	75.33 d	17.84 a	28.21 a	108.90 a	20.89
S_3	76.44 c	15.43 b	26.31 b	105.40 b	20.66
$LSD_{(0.05)}$	0.549	0.677	0.481	1.637	0.707^{NS}
CV (%)	5.73	4.96	8.99	9.70	4.75
Combined effect of variety and sulphur					
V_1S_0	78.67 c	9.67 f	20.33 h	80.93 h	21.63 e
V_1S_1	76.33 e	11.33 e	23.37 g	94.63 f	21.75 e
V_1S_2	73.33 gh	15.70 c	27.07 c	104.40 c	22.03 d
V_1S_3	75.00 f	14.23 d	24.89 de	100.10 d	21.83 de
V_2S_0	77.67 d	10.10 f	20.90 h	85.67 g	23.55 c
V_2S_1	76.00 e	13.27 d	24.47 ef	98.50 de	23.77 c
V_2S_2	73.00 h	21.67 a	29.87 a	114.80 a	24.30 a
V_2S_3	74.00 g	17.67 b	28.67 b	112.40 a	24.03 b
V_3S_0	81.33 a	9.93 f	20.73 h	83.23 gh	15.72 h
V_3S_1	81.33 a	13.25 d	23.77 fg	96.33 ef	15.88 gh
V_3S_2	79.67 b	16.17 c	27.70 c	107.40 b	16.33 f
V_3S_3	80.33 b	14.40 d	25.37 d	103.70 c	16.11 fg
$LSD_{(0.05)}$	0.952	1.172	0.833	2.836	0.262
CV (%)	5.73	4.96	8.99	9.70	4.75

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

4.3 Yield parameters

4.3.1 Grain yield

Effect of variety

Grain yield of rice varied significantly among different varieties (Table 5 and Appendix VIII). It was observed that the variety V_2 (BRRI dhan89) gave the highest grain yield (6.94 t ha^{-1}) and it significantly different to other varieties followed by V_1 (BRRI dhan88)whereas the variety V_3 (BRRI dhan100) gave the lowest grain yield (5.85t ha^{-1}). The result obtained from the present study was similar with the findings of Khatun (2020), Salam *et al*. (2019), Murshida *et al*. (2017), Jisan *et al*. (2014) and Sarkar *et al*. (2014).

Effect of sulphur

Among different sulphur treatments, grain yield influenced significantly (Table 5 and Appendix VIII). Results showed that the treatment S_2 (40 kg S ha^{-1}) showed the highest grain yield (7.51t ha^{-1}) that was significantly different to other treatments followed by S_3 (50 kg S ha^{-1}) whereas the lowest grain yield (5.13t ha^{-1}) was found from the control treatment S_0 (0 kg S ha^{-1}). Supported result was also observed by the findings of Uddin *et al*. (2014), Singh *et al*. (2018) and Singh *et al*. (2019).

Combined effect of variety and sulphur

Among different treatment combinations of variety and sulphur, significant variation on grain yield was recorded (Table 5 and Appendix VIII). The treatment combination of V_2S_2 showed the highest grain yield (8.57t ha^{-1}) which was significantly different to other treatment combination followed by V_2S_3.On the other hand, the treatment combination of V_1S_0 gave the lowest grain yield (5.03t ha^{-1}) which was statistically similar to $V_2S_0$and V_3S_0.

4.2.2 Straw yield

Effect of variety

The recorded data on straw yield varied significantly due to varietal performance of rice (Table 5 and Appendix VIII). The maximum straw yield (8.51 t ha^{-1}) was registered from the variety V_2 (BRRI dhan89) that was significantly different to other varieties whereas the minimum straw yield (7.71 t ha^{-1}) was recorded from the variety V_1 (BRRI dhan88) which was statistically same to V_3 (BRRI dhan100). Akter (2014) and Chowdhury *et al*. (2005) also found similar result with the present study.

Effect of sulphur

Application of sulphur treatment applied to rice showed significant variation on straw yield (Table 5 and Appendix VIII). Treatment S_2 (40 kg S ha^{-1})gave the higheststraw yield (8.82 ktg ha^{-1}) followed by S_3 (50 kg S ha^{-1})whereas the minimum straw yield (7.37 t ha^{-1}) was registered by control treatment S_0 (0 kg S ha^{-1})that was significantly different to other treatments. Supported result was also observed by Singh *et al*. (2019), Singh *et al*. (2018) and Uddin *et al*. (2014) who recorded variation on straw yield due to variation in sulphur application.

Combined effect of variety and sulphur

Straw yield of rice varied significantly due to combined effect of variety and sulphur doses (Table 5 and Appendix VIII). Results indicated the treatment combination of V_2S_2 gave the maximum straw yield (9.59t ha^{-1}) which was statistically identical to V_2S_3 whereas V_1S_0 gave the minimum straw yield (7.20 t ha^{-1}) which was statistically similar to the treatment combinations of V_2S_0 and V_3S_1.

4.2.3 Harvest index

Effect of variety

Different rice varieties showed significant variation on harvest index (Table 5 and Appendix VIII). Results indicated that the highest harvest index (44.60%) was achieved from the variety V_2 (BRRI dhan89) which was statistically identical to the variety V_3 (BRRI dhan100) whereas the lowest harvest index (42.96%) was found from the variety V_1 (BRRI dhan88). Sritharan and Vijayalakshmi (2012) and Islam (2011) also observed similar result with the present study.

Effect of sulphur

Different doses of sulphur to rice showed significant influence on harvest index (Table 5 and Appendix VIII). It was observed that the treatment S_2 (40 kg S ha^{-1}) gave the highest harvest index (45.89%) that was significantly different to other treatments followed by S_3 (50 kg S ha^{-1}) whereas the lowest harvest index (41.06%) was found from the control treatment S_0 (0 kg S ha^{-1}).Similar result was also observed by Singh *et al*. (2019) and Uddin *et al*. (2014).

Combined effect of variety and sulphur

Harvest index of rice at harvest varied significantly due to combined effect of variety and sulphur doses (Table 5 and Appendix VIII). The treatment combination of V_2S_2 showed the highest harvest index (47.16%) that was significantly different to other treatment combinations followed by $V_2S_3$and V_3S_2 whereas V_1S_0 gave the lowest harvest index (40.38%) that was statistically identical to V_3S_0.

Table 5. Effect of sulphur on yield parameters of different rice varieties

Treatments	Yield parameters		
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Effect of variety			
V_1	5.85 c	7.71 b	42.96 b
V_2	6.94 a	8.51 a	44.60 a
V_3	6.17 b	7.84 b	43.93 a
$LSD_{(0.05)}$	0.204	0.261	0.721
CV (%)	8.82	10.84	6.72
Effect of sulphur			
S_0	5.13 d	7.37 c	41.06 d
S_1	5.78 c	7.51 c	43.50 c
S_2	7.51 a	8.82 a	45.89 a
S_3	6.86 b	8.41 b	44.87 b
$LSD_{(0.05)}$	0.235	0.301	0.637
CV (%)	8.82	10.84	6.72
Combined effect of variety and sulphur			
V_1S_0	5.03 h	7.20 f	40.38 g
V_1S_1	5.57 fg	7.47 def	42.77 ef
V_1S_2	6.73 d	8.28 bc	44.83 bc
V_1S_3	6.07 e	7.76 de	43.88 cd
V_2S_0	5.21 gh	7.43 ef	41.97 f
V_2S_1	5.94 ef	7.73 de	43.46 de
V_2S_2	8.57 a	9.59 a	47.16 a
V_2S_3	8.03 b	9.50 a	45.82 b
V_3S_0	5.15 h	7.47 def	40.85 g
V_3S_1	5.82 ef	7.33 ef	44.27 cd
V_3S_2	7.23 c	8.60 b	45.69 b
V_3S_3	6.49 d	7.97 cd	44.91 bc
$LSD_{(0.05)}$	0.408	0.522	1.104
CV (%)	8.82	10.84	6.72

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BRRI dhan88, V_2 = BRRI dhan89, V_3 = BRRI dhan100

S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1}, S_3 = 50 kg Sha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2019 to May 2020 to study the effect of different levels of sulphur on modern rice varieties. The experiment comprised of two factors: Factor A (3 rice varieties) *viz.*, V_1 = BRRI dhan88, V_2 = BRRI dhan89 and V_3 = BRRI dhan100 and Factor B (4 sulphur doses) *viz.*, S_0 = 0 kg S ha^{-1}, S_1 = 30 kg S ha^{-1}, S_2 = 40 kg S ha^{-1} and S_3 = 50 kg S ha^{-1}. The experiment was laid out in Randomized complete Block Design (RCBD) with three replications. Data on different growth parameters, physiological parameters and yield with yield contributing characters were recorded. The collected data were statistically analyzed for evaluation of the treatments effect.

5.1 Summary

Different rice varieties showed significant variation on maximum parameters of the study but CGR at 80-120 DAT was non-significant among the varieties. Regarding parameters, the variety V_2 (BRRI dhan89) showed the maximum plant height (112.40 cm), flag leaf area (41.72 cm^2) but the maximum number of leaves hill^{-1} (46.11), number of total tillers hill^{-1} (16.67), dry weight hill^{-1} at 80 DAT (37.20 g), dry weight hill^{-1}at 120 DAT (54.26 g), SPAD value of flag leaf at flowering stage (58.60) and SPAD value of flag leaf at grain filling stage (45.38) whereas the minimum plant height (106.10 cm), number of leaves hill^{-1} (40.97), number of total tillers hill^{-1} (13.48), dry weight hill^{-1} at 80 DAT (31.99 g), dry weight hill^{-1}at 120 DAT (48.14 g), flag leaf area (38.75 cm^2), SPAD value of flag leaf at flowering stage (53.94) and SPAD value of flag leaf at grain filling stage (41.26) were obtained from the variety V_3 (BRRI dhan100). Regarding yield contributing and yield parameter, the minimum days to first flowering was recorded by V_2 (BRRI dhan89) whereas the maximum days to first flowering was recorded by V_3 (BRRI dhan100). Again, the highest number of effective tillers hill^{-1} (15.68), panicle length (25.98 cm),number of filled grains panicle^{-1} (102.80), 1000 grain weight (23.91 g),grain yield (6.94 t ha^{-1}), straw yield (8.51 t ha^{-1}) and harvest index (44.60%) were achieved by the variety V_2 (BRRI dhan89) whereas the lowest highest number of effective tillers hill^{-1} (12.73), panicle length (23.92 cm),number of filled grains panicle^{-1} (95.01), grain yield (5.85 t ha^{-1}), straw yield (7.71 t ha^{-1}) and harvest index (42.96%) were given by the variety V_1 (BRRI dhan88) but the variety V_3 (BRRI dhan100) gave the lowest 1000 grain weight (16.10 g).

In case of sulphur treatments, significant influence was recorded for all the studied parameters except 1000 seed weight. Considering growth parameters, the maximum plant height (118.20 cm) was recorded from S_3 (50 kg S ha^{-1}) treatment but the maximum number of leaves hill^{-1} (51.10), number of total tillers hill^{-1} (20.34), dry weight hill^{-1} at 80 DAT (42.10 g), dry weight hill^{-1}at 120 DAT (60.32 g), CGR at 80-120 DAT) (1.52 mg/cm^2/day), flag leaf area (47.02 cm^2), SPAD value of flag leaf at flowering stage (63.51), SPAD value of flag leaf at grain filling stage (49.98) were obtained from S_2 (40 kg S ha^{-1}) treatment whereas the lowest plant height (97.09 cm), number of leaves hill^{-1} (32.97), number of total tillers hill^{-1} (10.33), dry weight hill^{-1} at 80 DAT (25.08 g), dry weight hill^{-1}at 120 DAT (60.32 g), CGR at 80-120 DAT) (1.334 mg/cm^2/day), flag leaf area (34.21 cm^2), SPAD value of flag leaf at flowering stage (46.90), SPAD value of flag leaf at grain filling stage (34.86) were recorded from control treatment S_0 (0 kg S ha^{-1}). Yield contributing parameters and yield parameter influenced by S treatment, S_2 (40 kg S ha^{-1}) gave the maximum number of effective tillers hill^{-1} (17.84), panicle length (28.21 cm), number of filled grains panicle^{-1} (108.90), 1000 grain weight (20.89 g), grain yield (7.51 t ha^{-1}), straw yield (8.82 t ha^{-1}) and harvest index (44.60%) whereas the minimum number of effective tillers hill^{-1} (9.90), panicle length (20.66 cm), number of filled grains panicle^{-1} (83.28), 1000 grain weight

(20.30 g), grain yield (5.13 t ha^{-1}), straw yield (7.37 t ha^{-1}) and harvest index (45.89%) were given by control treatment S_0 (0 kg S ha^{-1}). The minimum days to first flowering (75.25 days) was recorded from the treatment S_2 (40 kg S ha^{-1}) whereas control treatment S_0 (0 kg S ha^{-1}) showed maximum days to first flowering (79.22 days).

Combined effect of variety and sulphur treatment showed significant variation for all the studied parameters. Regarding growth parameters, the highest plant height (122.20 cm) and flag leaf area (48.86 cm^2) were recorded from the treatment combinations of V_2S_3 and V_2S_2, respectively but the highest number of leaves $hill^{-1}$ (54.80), number of total tillers $hill^{-1}$ (23.00), dry weight $hill^{-1}$ at 80 DAT (45.15 g),dry weight $hill^{-1}$at 120 DAT (64.63 g), CGR at 80-120 DAT (1.623 $mg/cm^2/day$),SPAD value of flag leaf at flowering stage (66.77), SPAD value of flag leaf at grain filling stage (52.27) were recorded from the treatment combination of V_3S_2 whereas the minimum plant height (95.06 cm), number of leaves $hill^{-1}$ (31.13), number of total tillers $hill^{-1}$ (10.07), dry weight $hill^{-1}$ at 80 DAT (24.57 g),dry weight $hill^{-1}$ at 120 DAT (40.10 g), CGR at 80-120 DAT (1.293 $mg/cm^2/day$),flag leaf area (33.60 cm^2), SPAD value of flag leaf at flowering stage (46.00), SPAD value of flag leaf at grain filling stage (34.47) were recorded from the treatment combination of V_1S_0. Regarding yield contributing parameters and yield parameters, V_2S_2 showed minimum days to first flowering (73.00 days) whereas the maximum days to first flowering (81.33 days) was recording from V_3S_0. Similarly, the maximum number of effective tillers $hill^{-1}$ (21.67), panicle length (29.87 cm), number of filled grains $panicle^{-1}$ (114.80), 1000 grain weight (24.30 g), grain yield (8.57 t ha^{-1}), straw yield (9.59 t ha^{-1}) and harvest index (47.16%) were achieved by V_2S_2 whereas the minimum number of effective tillers $hill^{-1}$ (9.67), panicle length (20.33 cm), number of filled grains $panicle^{-1}$ (80.93), grain yield (8.03 t ha^{-1}), straw yield (7.20 t ha^{-1}) and harvest index (40.38%) were achieved by V_1S_0 but the minimum 1000 grain weight (15.72 g) was recorded from V_3S_0.

5.2 Conclusion

From the above findings it can be concluded that the variety V_2 (BRRI dhan89) gave best results in most of the parameters regarding yield and yield contributing parameters whereas V_1 (BRRI dhan88) showed least performance. Again, among sulphur treatments, S_2 (40 kg S ha^{-1}) showed best performance compared to other treatments regarding the results of growth, yield and yield contributing parameters whereas control treatment S_0 (0 kg S ha^{-1}) lowest performance. Similarly, among the treatment combinations of variety and sulphur treatments, V_2S_2 (BRRI dhan89 with 40 kg S ha^{-1}) gave the best performance considering yield and yield contributing characters. So, the treatment combination of V_2S_2 (BRRI dhan89 with 40 kg S ha^{-1}) can be considered as the best compared to all other treatment combinations followed by V_2S_3 (BRRI dhan89 with 50 kg S ha^{-1}).

5.3 Recommendation

Further experiment can be conducted in respect of many other varieties of rice including local, HYV and hybrids with other similar doses of sulphur and other nutrients like N, P, K etc. at different locations of Bangladesh for final recommendation for best variety with best nutrients recommendation.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

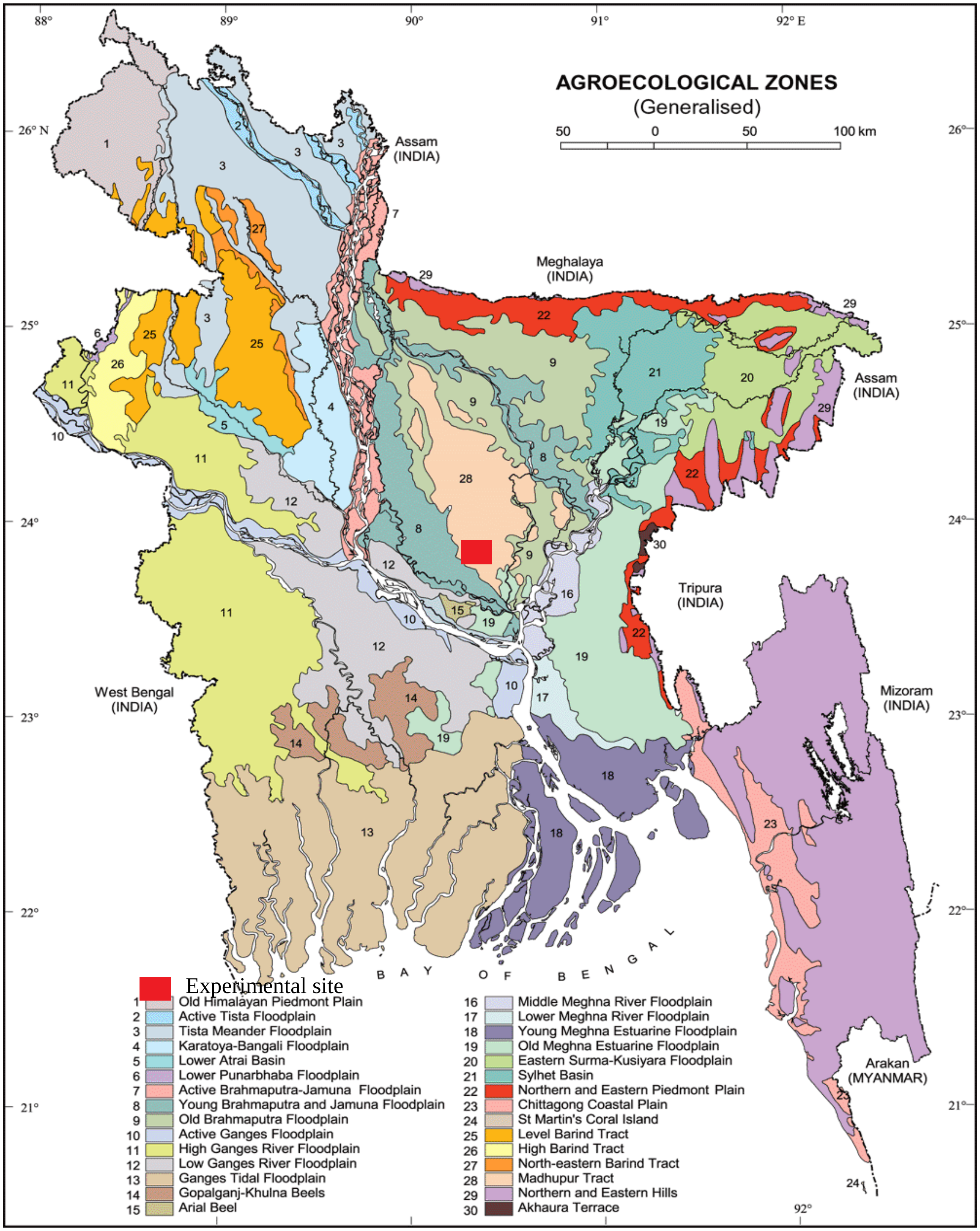


Figure 7. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2019 to May 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0
2020	March	35.20	21.00	28.10	52.44	20.4
2020	April	34.70	24.60	29.65	65.40	165.0
2020	May	32.64	23.85	28.25	68.30	182.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Effect of sulphur on growth parameters of different rice varieties

Sources of variation	Degrees of freedom	Mean square of growth parameters		
		Plant height (cm)	Number of leaves hill^{-1}	Number of total tillers hill^{-1}
Replication	2	3.631	4.354	0.495
Factor A	2	122.131*	80.300*	30.560*
Factor B	3	817.220*	599.83*	171.72*
AB	6	5.812**	6.065**	5.587**
Error	22	1.623	2.000	0.314

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Dry weight and crop growth rate (CGR) of different rice varieties as influenced by different sulphur doses

Sources of variation	Degrees of freedom	Mean square of dry weight and crop growth rate (CGR)		
		Dry weight hill^{-1} at 80 DAT (g)	Dry weight hill^{-1}at 120 DAT (g)	CGR (80-120 DAT) (mg/cm^2/day)
Replication	2	0.602	2.610	0.007
Factor A	2	83.700*	112.621*	0.024^{NS}
Factor B	3	550.05*	689.643*	0.070**
AB	6	9.282*	10.762*	0.011**
Error	22	0.924	2.006	0.018

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Flag leaf area and chlorophyll content of different rice varieties as influenced by different sulphur doses

Sources of variation	Degrees of freedom	Mean square of flag leaf area and chlorophyll content		
		Flag leaf area (cm^2)	SPAD value of flag leaf at flowering stage	SPAD value of flag leaf at grain filling stage
Replication	2	0.829	0.930	0.120
Factor A	2	32.465*	69.406*	52.428*
Factor B	3	290.15*	503.23*	425.46*
AB	6	6.343**	6.407**	3.914**
Error	22	0.713	1.688	1.008

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Effect of sulphur on yield contributing parameters of different rice varieties

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Days to first flowering	Number of effective tillers $hill^{-1}$	Panicle length (cm)	Number of filled grains $panicle^{-1}$	1000 grain weight (g)
Replication	2	0.194	0.273	1.780	0.941	0.014
Factor A	2	107.52*	28.311*	13.956*	189.984*	201.05*
Factor B	3	25.852*	106.64*	95.861*	1171.36*	0.578^{NS}
AB	6	2.380**	6.605*	2.124**	14.590*	0.020**
Error	22	0.316	0.479	0.242	2.805	0.024

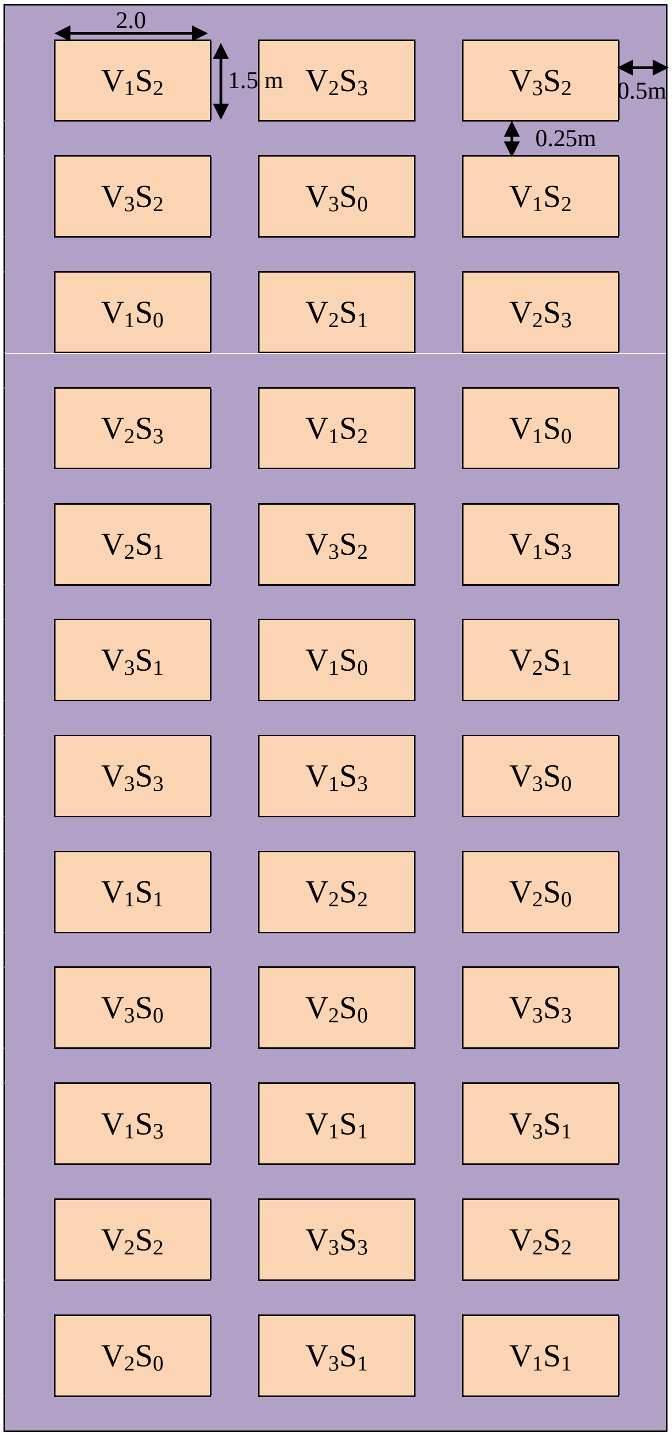
NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Effect of sulphur on yield parameters of different rice varieties

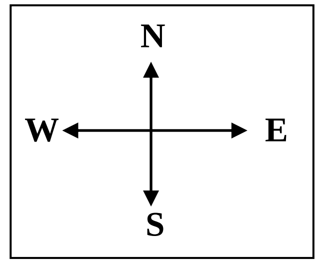
Sources of variation	Degrees of freedom	Mean square of yield parameters		
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Replication	2	0.019	0.296	1.666
Factor A	2	3.741**	2.102**	8.144*
Factor B	3	10.29*	4.454*	39.30*
AB	6	0.765**	0.737**	0.847**
Error	22	0.058	0.095	0.425

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Layout of the experiment field



Legend



Treatments

Factor A: Variety – 3 varieties of rice

1. V_1 = BRRI dhan88
2. V_2 = BRRI dhan89
3. V_3 = BRRI dhan100 (Bangabandhu dhan100)

Factor B: Sulphur– 4 doses

1. S_0 = 0 kg S ha^{-1}
2. S_1 = 30 kg S ha^{-1}
3. S_2 = 40 kg S ha^{-1}
4. S_3 = 50 kg S ha^{-1}

Fig. 8. Layout of the experimental plot