# IMPROVEMENT OF YIELD AND AROMATIC QUALITY OF FRAGRANT RICE THROUGH SUPPLEMENTATION OF POTASSIUM AND SULPHUR

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***Dedicated to***

***My***

***Beloved Parents***

**INSTITUTE OF SEED TECHNOLOGY**
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# *CERTIFICATE*

*This is to certify that the thesis entitled, "**IMPROVEMENT OF YIELD AND AROMATIC QUALITY OF FRAGRANT RICE THROUGH SUPPLEMENTATION OF POTASSIUM AND SULPHUR**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN INSTITUTE OF SEED TECHNOLOGY**, embodies the result of a piece of bona fide research work carried out by **MD. HAZROT ALI** Registration No. 14-05902 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

*I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.*

***Dated:***
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**DEDICATED TO**

**MY**

**BELOVED PARENTS**

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The author

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## ABSTRACT

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December, 2019 with a view to finding out improvement of yield and aromatic quality of fragrant rice through supplementation of potassium and sulphur in Aman season. The experimental treatments included two T. *aman* rice varieties *viz*., BRRI Dhan 80 and BRRI Dhan 34 , three levels of potassium *viz*., $K_1$= 60 kg MoP $ha^{-1}$, $K_2$= 65 kg MoP $ha^{-1}$, $K_3$= 70 kg MoP $ha^{-1}$ and three levels of sulphur *viz.,* $S_1$= 45 kg Gypsum $ha^{-1}$, $S_2$= 50 kg Gypsum $ha^{-1}$, $S_3$= 55 kg Gypsum $ha^{-1}$. The experiment was laid out in a split-split plot design with three replications. There were 18 treatments combinations. The total numbers of unit plots were 54. Results showed that rice varieties differed significantly in all growth characters and BRRI Dhan 80 produced higher grain yield (4.39 t $ha^{-1}$).Among the review, the 65 kg MoP $ha^{-1}$ gave the highest grain yield (4.30 t $ha^{-1}$). Increase of K level 50 kg Gypsum $ha^{-1}$ performed well in growth and gave higher grain yield (4.35t $ha^{-1}$). Interaction results showed that significantly higher grain yields were given by transplanting BRRI Dhan 80 with 65 kg MoP $ha^{-1}$ (4.71 t $ha^{-1}$),Combination with the application of 50 kg Gypsum $ha^{-1}$ in BRRI Dhan 80 (4.51t $ha^{-1}$). The maximum grain yield (5.04 t $ha^{-1}$) was obtained from the combination of BRRI Dhan 80 with 65 kg MoP $ha^{-1}$ and 50 kg Gypsum $ha^{-1}$.The higher grain yield was attributed mainly to the number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ and 1000-grain weight. Protein content(8.55%) and grain 2-AP content( 1.02 µg $g^{-1}$) was found from the combination of BRRI Dhan 80 with 65 kg MoP $ha^{-1}$ and 50 kg Gypsum $ha^{-1}$. It may be concluded that the application of 65 kg MoP $ha^{-1}$ and 50 kg Gypsum $ha^{-1}$ along with recommended dose of other fertilizers may be use for producing good quality aromatic rice.

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# LIST OF ACRONYMS

AEZ = Agro- Ecological Zone
BARC = Bangladesh Agricultural Research Council
BBS = Bangladesh Bureau of Statistics

| | | |
|---|---|---|
| BINA | = | Bangladesh Institute of Nuclear Agriculture |
| BRRI | = | Bangladesh Rice Research Institute |
| cm | = | Centi-meter |
| cv. | = | Cultivar |
| DAT | = | Days after transplanting |
| $^0$ C | = | Degree Centigrade |
| DF | = | Degree of freedom |
| EC | = | Emulsifiable Concentrate |
| *et al.* | = | and others |
| etc. | = | Etcetera |
| FAO | = | Food and Agricultural Organization |
| G | = | Gram |
| HI | = | Harvest Index |
| HYV | = | High yielding variety |
| hr | = | hour |
| IRRI | = | International Rice Research Institute |
| Kg | = | kilogram |
| LV | = | Local variety |
| LYV | = | Low yielding varieties |
| LSD | = | Least significant difference |
| m | = | Meter |
| $m^2$ | = | meter squares |
| MPCU | = | Mussorie phos-coated urea |
| MV | = | Modern variety |
| mm | = | Millimeter |
| *viz.* | = | namely |
| N | = | Nitrogen |
| Ns | = | Non significant |
| % | = | Percent |
| CV % | = | Percentage of Coefficient of Variance |
| P | = | Phosphorus |
| K | = | Potassium |
| ppm | = | Parts per million |
| PU | = | Prilled urea |
| SAU | = | Sher-e- Bangla Agricultural University |
| S | = | Sulphur |
| SCU | = | Sulphur coated urea |
| t $ha^{-1}$ | = | Tons per hectare |
| UNDP | = | United Nations Development Program |
| USG | = | Urea supergranules |
| Zn | = | Zinc |

# Chapter I

# INTRODUCTION

Rice cultivation is favoured by the hot, humid climate and the large number of deltas across Asia's vast tropical and subtropical areas. As a main source of nourishment for more than two billion people in Asia and many millions in Africa and Rice (*Oryza sativa* L.) is a semi aquatic cereal among the oldest and most important Latin America, it is by far one of the most important commercial food crops. Rice is a nutritious food, providing about 90 percent of calories from carbohydrates and as much as 13 percent of calories from protein (Anon., 2005).Rice is the staple food of about 140.6 million people of Bangladesh and contributes 14.6% to the national GDP and supplies 71% of the total calories and 51% of the protein in a typical Bangladeshi diet. Bangladesh with its flat topography, abundant water and humid tropical climate constitutes an excellent habitat for the rice plant. In Bangladesh, 5.55 million hectare of arable land of which 75% is devoted to rice cultivation (BBS, 2020). Rice is grown in the country under diverse ecosystem like irrigated, rainfed and deep water conditions in three distinct overlapping seasons namely *aus*, *aman* and *boro*. Among these three seasons, the monsoon rice, transplanted *aman* covers the largest area (50.58% of total rice area) and average yield of *aman* rice is 2.55 t $ha^{-1}$ (BBS, 2020). The population of Bangladesh is still growing by two million every year and may increase by another 30 millions over the next 20 years.

Now a days, Fine rice is more popular because of its palatability , aromatic quality and overall acceptability. Fine rice is mainly used by the people in the preparation of palatable dishes and sold at a higher price in the market due to its special appeal for aroma and acceptability. Bangladesh imports around 50 thousand tons of aromatic rice each year from neighboring countries (Bayes, 2003). Still Bangladesh has a bright prospect for export of this fine rice thereby earning foreign exchange. Islam *et al. (*1996) observed that the yield of aromatic rice is much lower than those of other rice growing countries because of lack of improved variety and judicious fertilizer management. Selection of appropriate variety and application of integrated nutrient management, the yield can be increased. Another drawback is that the aroma of rice is gradually decreased with advancing storage period. Researchers have identified approximately 200 different volatile compounds that contribute to rice aroma. Buttery *et al.* (1988) reported that 2-acetyl-1-pyrroline (2-AP), (E)-2-nonenal, octanal, decanal (E,E)-2-decenal, hexanal, 4-vinylphenol are the key contributors to rice aroma. The 2-AP production is genetically controlled but the concentration is also actually affected by other factors such as environment, climate, location and nutrient elements (Yoshihashi *et al.,* 2004). Evidence from previous studies showed that different nutrient elements *viz*. N, P, Ca, Zn, Mn and Mg affect aroma formation in aromatic rice and showed a significant relationship with 2-AP biosynthesis (Yoshihashi, 2004). After the introduction of high yielding varieties research interest shifted from local varieties to modern varieties of rice and thus the local varieties, the indigenous resources remained neglected. Bangladesh has a large reserve of local rice cultivar.

Potassium has significant contribution in photosynthesis, enzyme activation, cell turgor maintenance and ion homeostasis (Marschner, 1995). Inside plant, K is found in ionic form only; it is co-factor of many enzymes. Major role of K in plant is osmotic adjustment. Potassium is essential to all plants and in most terrestrial plants $K^+$ is the major cationic inorganic nutrient and it also enhances several enzyme functions. Potassium acts to balance the charge in the cytoplasm of the cell, where $K^+$ is the dominant counter ion for the large excess of negative charge on proteins and nucleic acids (Yang *et al.*, 2004).

Among the essential elements, sulphur is very much beneficial for increasing the production of rice and is one of the major essential nutrient elements involved in the synthesis of chlorophyll, certain amino acids likemethionine, cystine, cysteine and some plant hormones such as thiamine and biotin

(Rahman *et al*., 2007). Sulphur, however, is taken up by the roots of most plants in the oxidized sulphate form. Accumulation of sulphur in the plant tissue affected floral initiation and anthesis of rice (Tiwari, 1994). Growing of sulphur responsive crops, high intensive cropping and use of sulphur free fertilizers caused S deficiency in soils. Sulphur requirement of rice varies according to the nitrogen supply. Sulphur is required early in the growth of rice plants. If it is limited during early growth, then tiller number and therefore final yield might be reduced (Blair and Lefroy, 1987).

Bangladeshi farmers are widely used N, P and K fertilizers but not S and Zn fertilizer. A marked higher incidence of micronutrient deficiency is found in crop due to intensive crop cultivation, loss of fertile top soil and losses of nutrient (Rahman *et al*., 2008; Somani, 2008 and Singh *et al*., 2011). There is a need to ascertain and promote the use fertilizers required to correct the deficiency of all these nutrients especially potassium and sulphur.

Based on above proposition, this research work is designed to improvement of yield and aromatic quality of fragrant rice through supplementation of potassium and sulphur in Aman season with the following specific objectives:

1. To find out the optimum level of K and S for improving the grain quality, sensory, milling and physiochemical traits of fragrant rice.
2. To select suitable combination of K and S for maximizing yield and grain quality traits of fragrant rice.

# Chapter II

# REVIEW OF LITERATURE

Rice is the main food crop of the people of Bangladesh. Research on this crop is going on various aspects in increase its potential yield including management practices. Potassiun and sulphur fertilizer is the essential factor for sustainable soil fertility and crop productivity. Sole and combined use of rice varieties, potassiun and sulphur fertilizer stimulated plant growth, yield contributing characters and that leads to highest yield. Experimental information evidences that the use of variety, potassiun and sulphur have an intimate effect on the yield and yield attributes of rice. An attempt is made to review the available literature that is related to the improvement of yield and aromatic quality of fragrant rice through supplementation of potassium and sulphur in Aman season. The following section describes some of the findings observed and reported by other researchers.

## 2.1 Effect of variety on the growth and yield of rice

Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. Some available information and literature related to the effect of variety on the yield of rice are discussed below.

Wirnas *et al*. (2015) reported that the genotypes evaluated Mekongga, and IPB 3S have higher yield potential and significantly different from IR 64, Situ Patenggang, and Kalimutu. All of the varieties evaluated had lower total grain number due to high temperature stress, but only significantly different for Inpari 13, IPB 4S, IPB 5R, and IPB 7R. The Inpari 13, IPB 3S, IPB 4S, IPB 5R, and IPB 7R varieties had lower grain weight and 1000 grain weight due to high temperature stress. Varieties IR 64 and Situ Patenggang were able to sustain the grain weight under high temperature stress, but have a lower grain weight than other varieties.

Wiangsamut *et al*. (2015) found that the plant height of RD14 rice genotype was significantly taller than San–pah–tawng1 rice genotype. Grain yield of RD14 rice genotype was significantly higher than San–pah–tawng1 rice genotype; mainly due to RD14 rice genotype having had higher filled grain number panicle$^{-1}$and harvest index.

Roy *et al*. (2014) evaluated 12 indigenous Boro rice varieties where the plant height and tillers hill$^{-1}$at different DAT varied significantly among the varieties up to harvest. At harvest, the tallest plant (123.80 cm) was recorded in Bapoy and the shortest (81.13 cm) in GS. The maximum tillers hill$^{-1}$ (46.00) was observed in Sylhety Boro and the minimum (19.80) in Bere Ratna. All of the parameters of yield and yield contributing characters differed significantly at 1% level except grain yield, biological yield and harvest index. The maximum effective tillers hill$^{-1}$ (43.87) was recorded in the variety Sylhety Boro while Bere ratna produced the lowest effective tillers hill$^{-1}$(17.73). The highest (110.57) and the lowest (42.13) filled grains panicle$^{-1}$was observed in the variety Koijore and Sylhety Boro, respectively. Thousand grain weight was the highest (26.35 g) in Kali Boro and the lowest (17.83 g) in GS one. Grain did not differ significantly among the varieties but numerically the highest grain yield (5.01 t ha$^{-1}$) was found in the variety Koijore and the lowest in GS one (3.17 t ha$^{-1}$).

Haque *et al*. (2015) evaluated the two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrid varieties out yielded the inbred. However, the hybrids and inbred varieties exhibited statistically identical yield in late planting. Filled grain (%) declined significantly at delayed planting in the hybrids compared to elite inbred due to increased temperature impaired–inefficient transport of assimilates. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

Sokoto and Muhammad (2014) conducted a pot experiment to determine the effect of water stress and variety on productivity of rice. The results indicated significant ($P < 0.05$) differences among genotypes. Faro 44 differed significantly from others in plant height, number of leaves plant$^{-1}$, harvest index and grain yield. FARO 44 differed significantly from NERICA 2 and FARO 15 at all the parameters under study.

Shiyam *et al*. (2014) conducted an experiment to evaluate the performance of four Chinese hybrid rice varieties where it was showed comparative superiority of FARO 15 to the hybrids in all growth and yield components assessed. FARO 15 was taller (140 cm) with more productive tillers (11.0), higher spikelets plant$^{-1}$(166.0), higher filled grains panicle$^{-1}$ (156.17), higher filled grains (92.17%), highest 100–grain weight of 2.63 g and the higher paddy yield (5.021 t ha$^{-1}$) than others. Despite the comparative poor performance of the hybrids, Xudao151came close to FARO 15 with grain yield of 2.987 t ha$^{-1}$.

Sarker *et al*. (2013) found that the BRRIdhan 28 was shorter in plant height, having more tillering capacity, higher leaf number which in turn showed superior growth character and yielded more than those of the local cultivars. The HYV BRRIdhan 28 produced higher grains panicle$^{-1}$ and bolder grains resulted in higher grain yield over the local cultivars. The BRRIdhan 28 produced higher grain yield (7.41 t ha$^{-1}$) and Bashful, Poshurshail and Gosi yielded ha$^{-1}$, respectively. Among the local rice cultivars, Gosi showed the higher yielding ability than Bashful and Poshursail.

Islam *et al*. (2013) found that the highest plant height (116.00 cm) was found in the variety Morichsail and the lowest in the variety Khaskani. Filled grains panicle–1was found highest (100) with the variety Khaskani and the lowest was recorded in the variety Raniselute. Raniselute produced the highest 1000–grain weight (32.09 g) and the lowest (13.32 g) was recorded from the variety Kalijira. The variety Morichsail produced the highest grain yield (2.53 t ha$^{-1}$) followed by Kachra (2.41 t ha$^{-1}$), Raniselute (2.13 t ha$^{-1}$) and Badshabhog (2.09 t ha$^{-1}$) and the lowest grain yield (1.80 t ha$^{-1}$) was obtained from Kalijira.

Hossaina *et al*. (2013) reported that the evaluated five rice cultivars showed wide variations regarding most of the yield–contributing characters. Modern cultivar BR16 produced the highest panicle length, number of grain panicle$^{-1}$ and grain yield ha$^{-1}$. At the same time as local cultivar Pari generated the lowest number of tiller plant$^{-1}$, panicle length, grain number panicle$^{-1}$ and grain yield ha$^{-1}$

.Garba *et al*. (2013) studied on the effects of variety, seeding rate and row spacing on growth and yield of rice. Variety Ex–China produced significantly (P<0.05) higher numbers of tillers plant–1and spikes hill–1. However, NERICA–1 produced significantly (P<0.05) higher numbers of spikelets spike–1, seeds spike–1, weight of seed spike–1, weight of seed hill–1, 1000 grain weight and yield in kg ha–1than Ex–China.

Yao *et al*. (2012) found insignificant difference in grain yield between the cv. AWD and CF. On average, YLY6 produced 21.5% higher yield than HY3 under AWD conditions. Like grain yield, YLY6 showed consistently higher water productivity and physiological nitrogen use efficiency than HY3. Both total dry weight and harvest index contributed to higher grain yield of YLY6.

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.

Panwar *et al*. (2012) studied to evaluate the performance of rice varieties. Growth parameters viz plant height (cm), No. of tillers m–2, leaf area index and dry matter accumulation (g) was highest in JGL–3844 over rest of varieties. The effective tillers m–2 (331.6), panicle length (25.63), grains panicle–1 (68.23), sterility per cent (12.1), grain yield (60.9 q ha–1) and straw yield (92.58 q ha–1) yield were also highest in variety JGL–3844.

Oko *et al*. (2012) assessed the agronomic characteristics of 15 selected indigenous and newly introduced hybrid rice varieties in Ebonyi State, Nigeria. Significant variation ($P<0.05$) was detected among the 20 rice varieties for all the traits evaluated. The results showed that plant height ranged between 144.01 cm in "Mass (I)" and 76.00 cm in "Chinyeugo". Cv. "E4197" had the highest value of 38±0.02 cm for panicle length and "Chinyereugo" had the highest value of 6.3g ± 0.03 for panicle weight. Leaf area showed the highest value of 63.8cm2 ± 0.01 in "Mass (I)". Cv. "Co–operative" had high number of seeds panicle–1(139 ± 0.19). "Chinyereugo" had the highest value of 25.9g ±1.4 for 1000–grains weight. The grain of "E4314" was the longest (8.00 mm ± 0.89) of the varieties studied.

Mannan *et al*. (2012) reported that the Badshabhog and Kalijira showed taller plants and Chinigura was shorter while Chinigura produced the greatest tillers at early, mid and at later growth stages and the lower tillers was observed in Badshabhog. Chinigura produced the highest amount of DM and while least amount of DM was observed in Kataribhog. The Chinigura produced significantly the highest panicles but it was statistically identical with Kalijira, while, Kataribhog exhibited lower number of panicles but number of grains panicle–1 was found more in Badshabhog. The heaviest grain was found in Kataribhog while the light grain was observed in Badshabhog. The grain yield of Chinigura and Kalijira was almost identical. Lower grain yield was found in Kataribhog which may be attributed to the lower number of panicles and grain panicle$^{-1}$

Alam *et al.* (2012) found that the cultivar BRRI dhan33 gave significantly the tallest plant (113.17 cm), while the shortest plant was found in BRRI dhan32 cultivar (105.07 cm). Among the cultivars, BR11 produced the maximum total tillers hill$^{-1}$ (12.33), maximum fertile spikelets panicle$^{-1}$ (103.83) while lowest fertile spikelets panicle$^{-1}$ (102.10) and minimum total tillers hill$^{-1}$ (10.17) were found in BRRI dhan32. BR11 also produced the highest 1000–grain weight (23.79g) and highest grain yield (5.92 t ha$^{-1}$) while BRRI dhan33 produced the lowest 1000–grain weight (21.69 g) and grain yield. The cultivar BR11 produced the highest grain yield, it might be due to the highest number of total tillers hill$^{-1}$, number of effective tillers hill$^{-1}$and 1000–grain weight and lowest number of sterile spikelets panicle$^{-1}$.

Mahamud *et al*. (2013) showed that rice cultivars differed significantly in all growth characters, such as plant height, tillers number, chlorophyll content and dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, filled grain percentage, 1000–grain weight, grain yield and straw yield.

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 were 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.

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.

Baset Mia and Shamsuddin (2011) reported that the aromatic rice cultivars showed tallest plant stature, profuse tillers hill$^{-1}$, panicle hill$^{-1}$and larger panicle but smaller grain, higher grain yield, lowest straw yield and harvest index compare modern rice. Modern rice cultivars generally had higher TDM, LAI, LAR, CGR, RGR whereas aromatic cultivars resulted in higher NAR. The highest grain yield of modern rice cultivars was due to the higher harvest index. Poor yield in aromatic rice cultivars was due to lower translocation of assimilates.

Akinwale *et al*. (2011) evaluated 14 rice varieties (10 commercial hybrids, 2 inbred and 2 lowland NERICAs) at the Africa Rice Center to compare the grain yield performance. The number of panicles $m^{-2}$, number of grains $panicle^{-1}$ were significantly higher in the hybrids than in the inbred and inter–specific varieties. The hybrids had the highest grain yield compared to the inbred and the inter–specific lowland NERICA varieties. The results indicated that hybrids exhibited significant yield increase of 13.44% over the best lowland NERICAs and 15.17% over the best inbred variety WITA 4.

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 $10ha^{-1}$) 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.

Islam *et al*. (2009b) reported that the genotype BINAdhan 5 and BINAdhan 6 showed similar performance in respect of most of the parameters but BINA dhan 6 produced the highest grain yield (40.26 g $hill^{-1}$) compared to BINA dhan 5 (35.54 g hill–1) and Tainan 3 (33.90 g $hill^{-1}$).

Islam *et al*. (2009a) reported that BRRI dhan–3l had about 10–15% higher plant height, very similar tillers $plant^{-1}$, 15–25% higher LA at all DAT compared to Sonarbangla–1 in 2001. Sonarbangla–1 had about 40% higher DM production at 25 DAT but had very similar DM production at 50 and 75 DA. BRRI dhan–3l had higher panicles $plant^{-1}$than Sonarbangla–1, but Sonarbangla–1 had higher grains $panicle^{-1}$, 1000–grain weight and grain yield than BRRI dhan–31. In 2002, BRRI dhan–31 had the highest plant height at 25 DAT, but at 75 DAT, BRRI hybrid dhan–l had the highest plant height. Sonarbangla–1 had the largest LA at 25 and 50 DAT while BRRI dhan–31 had the largest LA.

Sohel *et al*. (2009) found that BRRI dhan41 produced higher grain yield (4.7 t $ha^{-1}$) which was the contribution of higher number of grains panicle and heavier grain weight. Lower yield (4.51 t $ha^{-1}$) was recorded in BRRI dhan 40.

Jeng *et al*. (2009) found that the cultivar Tainung 67 had greater yield (7.2 mg $ha^{-1}$) than SA419 (6.2 mg $ha^{-1}$). The greater yield of SA419 than Tainung 67 in autumn was due to its higher net assimilation rate and better dry matter partitioning during grain filling. Significant panicle branch effects on the distribution pattern of grain weight were also found between Tainung 67 and SA419 with greater variation for the former than the latter.

Ashrafuzzaman *et al*. (2009) reported that the Kalizira was the tallest (107.90 cm) while it was shortest (93.40 cm) in Chiniatop and was identical to Kataribhog (95.30 cm) due to genetic makeup of the cultivar, but the environmental factors also influence it. There was also significant difference on 1000–grains weight among the cultivars whereas the highest 1000–grains weight was recorded in BR38 (20.13 g) and the lowest was recorded in BR34 (12.17 g). BR34 produced the maximum grain yield and Basmati produced the lowest. The highest harvest index was recorded from BR34 (34.94%) and the lowest harvest index was obtained from Basmati (31.51%).

Alam *et al.* (2009) reported that the tallest plant was observed with BRRI dhan 29 due to its genetic characters while numerically the highest DM of plant was found in Hira 2 and lowest in BRRI dhan 29 at all the growth stages except 25 DAT. They also found that the CGR values increased progressively with time reaching the highest at 75–100 DAT regardless of variety while CGR was maximum in Hira–2 (33.24 g m–2d–1) at 75–100 DAT and it was identical with Aloron (31.79 g m–2d–1), while CGR was lowest in BRRI dhan 29 during the whole growth period.

Masum *et al*. (2008) reported that that Nizershail produced the taller plant height than BRRI dhan44 at different DAT. Total tillers $hill^{-1}$was significantly influenced by variety at all stages. At 30 and 60 DAT, Nizershail had significant by higher amount of DM (35.46% higher at 30 DAT and 18.01%

higher at 60 DAT) than BRRI dhan44 but at harvest BRRI dhan44 had significantly higher amount of DM (39.85 g $hill^{-1}$) that was 18.42% higher than Nizershail. BRRI dhan44 produced higher (4.85 t $ha^{-1}$) grain yield than Nizershail (2.46 t $ha^{-1}$). Nizershail produced higher (7. 22 t $ha^{-1}$) straw yield compared to BRRI dhan44 (6.34 t $ha^{-1}$).

Hossain *et al*. (2008) reported that all the yield contributing characters differed significantly due to cultivar. The tallest plant was observed in Chinigura (162.8 cm) which statistically similar to Kataribhog. Kalizira produced the maximum number of grains panicle–1(135.90). Among the cultivars, BRRI dhan 38 gave the maximum grain yield (4.00 t $ha^{-1}$). Five varieties were evaluated by Ndaeyo *et al*. (2008). Among the varieties, the variety WAB224–8–HB produced the highest grain yield (4.73 and 4.40 t $ha^{-1}$) followed by WAB189–B–B–B–8–HB (4.37 and 4.20 t $ha^{-1}$) for both years.

Akram *et al*. (2007) studied on fifteen rice hybrids where two hybrids viz., MK Hybrid 111 and 27P72 produced more productive tillers than KS 282. All most all the hybrids produced more number of grains panicle–1 and higher 1000–grain weight. Yield advantage of the hybrids over the commercially grown rice variety ranges between 4.59–21.33% except RH–257 and GNY–40. These two hybrids were low yielder by 4.20 % and 14.95%, respectively, than the check variety.

## 2.2 Effect of potassium on the growth, yield and quality of rice

Bohra and Doerffling (1993) grew a salt-tolerant (Pokkali) and a salt-sensitive (IR28) variety of rice (*Oryza sativa* L.) in a phytotron to investigate the effect of K (0, 25, 50 and 75 mg K $kg^{-1}$ soil) application on their salt tolerance. Potassium application significantly increased potential photosynthetic activity (Rfd value), percentage of filled spikelets, yield and K concentration in straw. At the same time, it also significantly reduced Na and Mg concentrations and consequently improved the K/Na, K/Mg and K/Ca ratios. IR28 responded better to K application than Pokkali. Split application of K failed to exert any beneficial effect over basal application.

Fageria (2003) evaluated the dry matter production and the concentration of nutrients in rice (*Oryza sativa* L.) cultivars from soil adjusted to different levels of salinity under a greenhouse conditions. Soil salinity levels were produced by applying 0.34 mol $L^{-1}$ solution of NaCl which resulted in the following levels, control (0.29), 5, 10 and 15 dS $m^{-1}$ conductivity of saturation extract. The effect of salinity on dry matter production varied from cultivar to cultivar. The concentrations of P and K in the tops of rice cultivars decreased with increasing soil salinity. But the concentrations of Na, Zn, Cu and Mn increased. Significant varietal differences were found in relation to salinity tolerance.

Kandil *et al.* (2010) conducted three field experiments at El-Sirw Agricultural Research Station, Damietta during 1999, 2000 and 2001 under saline soil. The field experiments were laid out in split-split plot design with four replications. The main plots were devoted to four irrigation treatments *i.e.* continuous flooding (I1), water withholding for 12 days at 15 days after transplanting (DAT) (I2), at 25 DAT (I3) and at 35 DAT (I4). The sub plots were allocated to the three rice cultivars viz. Sakha 101, Sakha 102 and Giza 178. Three K rates 0, 48 and 46 kg $K_2Oha^{-1}$ was randomized in the sub-sub-plots. The growth characteristic like leaf area index (LAI), dry matter productions (DM) $g/m^2$, chlorophyll content, heading date were studied along with the chemical traits i. e Na and K contents of shoot as well as Na/K ratio. It was observed that water stress at any growth stage significantly decreased LAI, DM and chlorophyll content and delayed the heading date. Similarly water stress increased Na and K contents (%) in shoots while it had no effect on Na/K ratio. Varietal differences were found significant in all studied characters. Giza 178 had the superiority in this concern as compared to other varieties while Sakha 102 was found inferior in all parameters under these conditions. K rates significantly increased LAI, DM, chlorophyll content and K% up to 48 kg $K_2O$/ha while lessen Na% and Na/K ratio and hastened the heading date. The interaction between irrigation treatments and varieties affected LAI, DM, chlorophyll content and heading date while the interactive effects of irrigation and K rates had significant effect on LAI, while cultivars and K rates significantly affected DM and chlorophyll content.

Mehdi *et al.* (2007) conducted a field experiment to evaluate the response of rice crop to potassium fertilization in saline-sodic soil during 2005. Soil samples were collected before transplanting of rice crop and analysed for physical and chemical properties of the soil. In this experiment five rates of $K_2O$ (0, 25, 50, 75 and 100 kg $ha^{-1}$) were applied in the presence of basal doses of N and $P_2O_5$ i.e., 110 and 90 kg $ha^{-1}$, respectively. Whole of P, K and ½ of N were applied at the time of rice transplanting. Twelve and half kg $ha^{-1}$ $ZnSO_4$ was also applied 15 days after rice transplanting. The remaining half of N was applied 30 days after rice transplanting. The system of layout was Randomized Complete Block Design with four replications. The net plot size was 6x4 m. Fertilizer sources of NPK were urea, TSP and SOP, respectively. Rice salt tolerant line PB-95 was used as test crops. The data of growth parameters and yield was recorded and samples of paddy and straw were collected treatment-wise and analysed for N, P and K contents. Soil samples after harvesting the crop were also collected, processed and analysed for the changes in the extractable soil K. The results showed that increasing rates of potassium fertilizer increased the number of tillers $m^{-2}$, plant height (cm), 1000-paddy weight and paddy as well as straw yield significantly. Maximum paddy (3.24 t $ha^{-1}$) and straw (3.92 t $ha^{-1}$) yields were obtained in $T_5$ (100 kg $K_2O$ $ha^{-1}$) which was at par with $T_4$ (75 kg $K_2O$ $ha^{-1}$). With increasing rates of potassium fertilizer, concentration of potassium in paddy and straw increased significantly. After harvesting the crop, the extractable potassium contents of soil increased from that of the original soil. It was concluded from the results that there was an increase of 30.65% in paddy over control by applying potassium (100 kg $K_2O$ $ha^{-1}$) in saline-sodic soil.

Zayed *et al*. (2007) conducted two field experiments at the experimental farm of El Sirw Agriculture Research Dammiatta prefecture, Egypt during 2005 and 2006 seasons. The study aimed to investigate the effect of various potassium rates; Zero, 24, 48 and 72 Kg $K_2O$ $ha^{-1}$, on growth, sodium, potassium leaf content and their ratio at heading, grain yield and yield components of three hybrids: SK2034H, SK2046H and SK2058H and three varieties; Giza 177, Giza 178 and Sakha 104. The economic values were also estimated. The experimental soil was clayey with salinity levels of 8.5 and 8.7 dS/m in the first and second seasons, respectively. The experiments were performed in a split plot design with four replications. The main plots were devoted to the tested rice varieties, while potassium rates were distributed in the sub plots. The studied varieties varied significantly in their growth parameters, $Na^+$ and $K^+$ leaf content at heading as well as ratio, yield components and their economic values. SK2034H surpassed the rest varieties without any significant differences with SK2046H. SK2058H didn't show advantage over Giza 178 or Sakha 104. Giza 177 was the worst under such conditions. Increasing potassium rate significantly improved all studied traits leading to high grain yield. Furthermore, potassium succeeded to reduce $Na^+$, lower $Na^+$ /$K^+$ ratio and raised $K^+$ resulted in considerable salinity withstanding. The hybrids of SK2034H and SK2046H as well as the salt sensitive rice variety Giza 177 were the most responsive cultivars for potassium fertilizer up to 72 kg $K_2O$ /ha. Consequently, the economic estimates SK2034H had the higher net return and the high potassium level of 72 kg $K_2O$ $ha^{-1}$ gave the highest values of economic parameters under the tested saline soil conditions.

YiMing *et al*. (2014) stated that two conventional aromatic rice cultivars 'Guixiangzhan' and 'Nongxiang 18', using four potassium levels followed by $K_2O$ 0 kg/$hm^2$ (K0), 37.5 kg/$hm^2$ (K1), 112.5 kg/$hm^2$ (K2) and 187.5 kg/$hm^2$ (K3), the effects of different potassium levels on the free proline content, proline dehydrogenase activity, 2-Acetyl-1-pyrroline (2-AP) contents, total K accumulation and quality of aromatic rice were evaluated. The results showed that compared with KO, potassium fertilizer could significantly increase 2-AP the contents of two aromatic rice cultivars, with an increase of 10.70%-67.65%, as potassium fertilizer could generally improve the free proline content and proline dehydrogenase activity of aromatic rice, the highest 2-AP content of Guixiangzhan was treated by K2, with an increase of 5.31%-67.65%, compared with others. The highest 2-AP content of Nongxiang 18 was treated by K3, with an increase of 25.72%-40.04%, compared with others. Simulated by a quadratic curve, the 2-AP contents of Guixiangzhan and Nongxiang 18 reached their maxima under potassium fertilizer application rate of $K_2O$ 123.46 and 187.50 kg/hm$^2$. In addition, potassium fertilizer could decrease chalky rice rate and chalkiness degree. On the contrary, potassium fertilizer could improve protein content and amylase content, but potassium fertilizer had little effect on the processing quality of rice. Potassium fertilizer could promote 2-AP contents in aromatic brown rice and had a certain improvement to the quality of aromatic rice. Under the experimental conditions, taking into account of the aroma reactions of two aromatic rice cultivars for potassium fertilizer, the suitable fertilizers application rate was 112.5-187.5 kg/hm$^2$.

Paul *et al.* (2021) was conducted to study dry matter partitioning,

Yield and grain protein content of fine aromatic *Boro* rice (cv. BRRI dhan50) in response to nitrogen and potassium fertilization.The experiment consisted of four levels of nitrogen *viz.*, 0, 50, 100 and 150 kg/ha and four levels of potassium *viz.*, 0, 30, 60 and 90 kg/ha. The results revealed that at growth stage, the highesttotal dry matter partitioning and accumulation were obtained from 150 kg N/ha along with 90 kg K/ha at physiological maturity stage. At harvest, the highest number of tillers/hill (8.58), number of grains/panicle (113.9), grain yield (5.15 t/ha) and grain protein content (8.30%) were obtained from 100 kg N/ha along with 90 kg K/ha. Total dry matter partitioning and accumulation were greatly influenced by the application of 150 kg N/ha along with 90 kg K/ha. Application of 100 kg N/ha along with 90 kg K/ha interaction appeared as the promising practice in fine aromatic rice (cv. BRRI dhan50) cultivation in terms of yield and grain protein content.

## 2.3 Effect of sulphur on growth , yield and quality of rice

The productivity of wheat–rice cropping system is declining over time despite adequate supply of major Nutrients Is reported by Singh and Singh (2014). It may be due to deficiency of nutrients like sulphur. A field experiment was conducted with treatments consisting of three sulphate-sulphur (0, 15, 30 and 45 kg $ha^{-1}$) levels to study the sulphur balance and productivity in wheat-rice cropping sequence in a sandy clay loam soil. The agronomic efficiency and apparent sulphur recovery decreased with increase in levels of sulphate but the percent response increased with increasing sulphate application. Application of sulphur showed the positive sulphur balance, while, it was negative under control.

A field experiment was conducted by Dixit *et al*. (2012) to study the effect of sulphur and zinc on yield, quality and nutrient uptake by hybrid rice grown in sodic soil and found that application of 40 kg S $ha^{-1}$ recorded significantly high grain and straw yield, protein content and sulphur uptake.

A field experiment was conducted by Jawahar and Vaiyapuri (2011) at Experimental Farm, Annamalai University, Annamalai Nagar, Tamil Nadu, India to study the effect of sulphur and silicon fertilization on yield, nutrient uptake and economics of rice. The treatments comprised four levels of sulphur (0, 15, 30 and 45 kg ha-1) and silicon and were laid out in factorial randomized block design with three replications. Among the different levels of sulphur, sulphur at 45 kg ha-1 recorded higher values for yield (grain and straw) and nutrient uptake (NPKS) of rice, respectively.

An experiment was conducted by Rahman *et al*. (2009) to know the effect of different levels of sulphur on growth and yield of BRRI dhan41 at soil science Laboratory of Bangladesh Agricultural University, Mymensingh biological yield and 1000-grain weight except plant height and panicle length of BRRI dhan41 significantly responded to different levels of S. Generally treatment T6 performed the best result and T0 did the worst.during T. Aman season. There were eight treatments and they were T0(without S), T1(50% RFD of S), T2(75% RFD of S), T3(100% RFD of S), T4 (125% RFD of S), T5 (150% RFD of S), T6 (175% RFD of S) and T7 (200% RFD of S). All yield contributing characters like effective tillers hill-1, filled grain panicle-1, grain yield, straw yield, biological yield and 1000-grain weight except plant height and panicle length of BRRI dhan41 significantly responded to different levels of S. Generally treatment T6performed the best result and T0 did the worst.

Mrinal and Sharma (2008) conducted a field trials during the rainy (kharif) season to study the relative efficiency of different sources (gypsum, elemental sulphur and cosavet) and varying levels of sulphur (0, 10, 20, 30 and 40 kg S ha-1) in rice. The growth and yield attributing characters of rice increased with the sulphur application. The grain and straw yields of rice increased significantly with increasing levels of sulphur up to 30 kg S ha-1. The difference between sulphur sources was generally not significant.

Alamdari *et al*. (2007) conducted a field experiments to study the effect of sulphur (S) and sulfate fertilizers on zinc (Zn) and copper (Cu) by rice. The maximum Cu content in the leaves was attained when N, P, K, S and Cu sulfate were applied compared to the control. But, both Zn and Cu contents in the grain increased when N, P, K, S and Zn, Cu and Mn sulfate were applied together.

Bhuvaneswari *et al*. (2007) conducted a field experiment during kharif season, to study the effect of sulphur (S) at varying rates, i.e. 0, 20, 40 and 60 kg $ha^{-1}$, with different organics, i.e. green manure, farmyard manure, sulfitation press mud and lignite fly ash, each applied at 12.5 t $ha^{-1}$, on yield, S use efficiency and S optimization of rice cv. ADT 43. The results revealed that rice responded significantly to the application of S and organics compared to the control. The highest grain (5065 kg $ha^{-1}$) and straw yields (7524 kg $ha^{-1}$) was obtained with 40 kg S $ha^{-1}$.

Oo *et al*. (2007) a field experiment was conducted during the rainy season at the research farm of the Indian Agricultural Research Institute, New Delhi to study the effect of N and S levels on the productivity and nutrient uptake of aromatic rice and concluded that aromatic rice requires 20 kg S ha-1 for increased productivity and uptake of N, P, K and S under transplanted puddled conditions.

Basumatary and Talukdar (2007) conducted a field experiment at the University, Jorhat, Assam, India to find out the direct effect of sulphur alone and in combination with graded doses of farmyard manure on rapeseed and its residual effects on rice with respect to yield, uptake and protein content. The N:S ratio in both crops progressively decreased with increasing sulphur levels up to 45 kg ha-1. The lowest N:S ratio was observed upon treatment with 45 kg S ha-1 alone with 3.0 tonnes farmyard manure per hectare.

Islam *et al*. (2006) an experiment was conducted in Bangladesh to evaluate the effect of gypsum (100 kg ha-1) applied before planting, and at 30 and 60 days after planting, on the nutrient content of transplanted Aus rice (BR-2) in the presence of basal doses of N, P, K fertilizers from May to September 1996. A control without gypsum application was included. Application of gypsum at different dates increased progressively all the nutrients such as N, P, K, S, Ca and Mg, whereas the Na content was found to decreased due to gypsum application. The highest increase of N, P, K, S, Ca and Mg was obtained when the gypsum was applied at 30 days after planting. Synthesis of protein was accelerated with all the treatments of gypsum, and the content was much higher due to application of gypsum at 30 days after planting.

Huda *et al.* (2004) conducted an experiment at the Soil Science Department of Bangladesh Agricultural University, Mymensingh, Bangladesh to evaluate the suitable extractants for available sulphur and critical limits of sulphur for wetland rice soils of Bangladesh. Twenty-two soils from 0-15 cm depth were collected from different locations of old Brahmaputra Flood plains of the country. Both geographical and statistical methods were used to determine the critical levels of S. The critical limit for S was found to be 0.12% at 56 days of crop growth.

Biswas *et al*. (2004) reported the effect of S in different region of India. The optimum S varied between 30-45 kg ha-1. Rice yields increased from 5 to 51%. Across the crops and regions the agronomic efficiency varied from 2 to 27%.

Xue *et al*. (2002) showed that rice yield increases due to S application ranged from 0.5 to 22.9% (average of 7.3%) or from 12 to 1135 kg hm-2(average of 386 kg ha-2). S at 15-30 kg hm-2 was optimum for rice production.

Singh and Singh (2002) carried out a field experiment to see the effect of different nitrogen levels and S levels (0, 20 and 40 kg $ha^{-1}$) on rice cv. Swarna and PR-108 in Varanasi, Uttar Pradesh. India. They reported that plant height, tillers m-2 row length, dry matter production, panicle length and grains $panicle^{-1}$ were significant with increasing levels of S up to 40 kg S $ha^{-1}$. They also found that total N uptake, grain, straw and grain protein yields significantly improved with the increasing level S application being the maximum at 40 kg S $ha^{-1}$, respectively.

Sen *et al.* (2002) carried out an extensive study on application of sulphur through single super phosphate in a sulphur deficient area of Murshidabad district, in India, in a rice-mustard cropping sequence. Significant yield increase in rice with application of sulphur at 30 kg $ha^{-1}$ and its residual effect on mustard was observed. Sulphur application not only helped to increase yield in both crops but also helped to control the movement and distribution of different cationic micronutrients in both the crops.

Peng *et al*. (2002) carried out a field experiment where the average content of available S in these soil samples was 21.7 mg $kg^{-1}$. The soil with available S content was lower than the critical value of 16 mg $kg^{-1}$ accounted for 57.8%. Field experiments showed that there was a different yield-increasing efficiency by applying S at the doses of 20-60 kg $ha^{-1}$to rice plant.

# CHAPTER III

# MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

## 3.1 Experimental period

The experiment was conducted during the period from July to December, 2019 in T. *aman* season.

## 3.2 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding about the experimental site is shown in the Map of AEZ of Bangladesh in Appendix I.

## 3.3 Climate

The experimental area 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 at the experimental site are shown in Appendix II.

## 3.4 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. 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 at Soil

Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

### 3.5 Crop / planting material

Rice variety BRRI dhan 34 and BRRI dhan 80 were used as the test crop.

### 3.6 Seed collection and sprouting

Seeds of BRRI dhan 34 and BRRI dhan 80 were collected from BRRI, Joydebpur, Gazipur. Healthy seeds were selected following standard method. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

### 3.7 Raising of seedlings

A common procedure was followed in raising of seedlings in the seedbed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown(1$^{st}$ July) as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

### 3.8 Preparation of experimental land

The experimental field was first opened on 16 July, 2019 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 25 July, 2019 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

### 3.10 Fertilizer management

At the time of first ploughing cowdung at the rate of 10 t ha$^{-1}$ was applied. The experimental plots were fertilized with @ 70, 10 kg ha$^{-1}$ in the form of triple superphosphate (TSP) and zinc sulphate, respectively (BRRI, 2011) one day before transplanting. Urea was top dressed @ 90 kg N $ha^{-1}$ in three equal splits at 10, 30 and 50 DAT. The Muriate of potash (MoP), gypsum was applied as per treatment The entire amounts of triple superphosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate were applied at final land preparation as basal dose.

**3.11 Experimental treatments**

Three sets of treatments included in the experiment were as follows:

**A. Potassium level (3)**

1. $K_1$= 60 kg MoP $ha^{-1}$ (recommended dose)
2. $K_2$= 65 kg MoP $ha^{-1}$(5 kg Supplemented)
3. $K_3$= 70 kg MoP $ha^{-1}$(10 kg Supplemented)

**B. Sulphur (3)**

1. $S_1$= 45 kg Gypsum $ha^{-1}$ (recommended dose)
2. $S_2$= 50 kg Gypsum $ha^{-1}$(5 kg Supplemented)
3. $S_3$= 55 Gypsum $ha^{-1}$(10 kg Supplemented)

**C. Variety (2)**

1. $V_1$= BRRI Dhan 80
2. $V_2$= BRRI Dhan 34

**3.12 Experimental design**

The experiment was laid out in a split-split plot design with three replications having Potassium in the main plots, Sulphur in the sub-plots and Variety in the sub-split plots. There were 18 treatments combinations. The total numbers of unit plots were 54. The size of unit plot was 1.25 m x 2 m = 2.50 $m^2$. The distances between sub-split plot to sub-split plot, sub-plot to sub-plot, main plot to main plot and replication to replication were, 0.5, 0.75, 1.0 and 1.5 m respectively.

### 3.13 Uprooting and Transplanting of seedlings

Thirty days old seedlings were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted as per experimental treatment on the well puddled plots on 29 July 2019.

### 3.14 Intercultural operations

#### 3.14.1 Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

#### 3.14.2 Weeding

During plant growth period two hand weeding were done, first weeding was done at 15 DAT (Days after transplanting) followed by second weeding at 25 DAT followed by third weeding at 38 DAT.

#### 3.14.3 Application of irrigation water

Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

#### 3.14.4 Method of water application

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed in each plot which were used to measure depth of irrigation water.

#### 3.14.5 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of

Marshal 25 EC @ 2.5 ml $L^{-1}$ on 20 August and 3 September, 2019. Crop was protected from birds during the grain filling period.

**3.15 Harvesting and post harvest operation**

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting was done on ten pre-selected hills from which data were collected and 6 mid lines from each plot was separately harvested, bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t $ha^{-1}$.

**3.16 Recording of data**

Plant height (cm)

Number of tillers $hill^{-1}$

Spade value

Dry matter weight of plant at 30 days interval

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

Number of filled grains $panicle^{-1}$

Number of unfilled grains $panicle^{-1}$

Weight of 1000- grains(g)

Weight of 1000-kernels(g)

Grain yield (t $ha^{-1}$)

Straw yield (t $ha^{-1}$)

Harvest index (%)

Protein content(%)

Grain-2AP content

### 3.17 Experimental measurements

Experimental data collection began at 20 days after transplanting, and continued till harvest. The necessary data on agronomic characters were collected from five selected hills from each plot in field and at harvest.

**Plant height**

Plant height was measured at 20 days interval and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of panicle after heading.

**Number of tillers hill$^{-1}$**

Number of tillers hill$^{-1}$ were counted from pre selected hills and finally averaged as their number hill$^{-1}$. Only those tillers having three or more leaves were considered for counting.

**SPAD value**

SPAD value was determined from plant samples by using an automatic SPAD meter immediately after removal of leaves from plants to avoid rolling and shrinkage.

**Dry matter weight of hill**

The sub-samples of 5 hills plot$^{-1}$ uprooting from 2$^{nd}$ line were oven dried until a constant level from which the weight of above ground dry matter were recorded.

**Panicle length**

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

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

The panicles which had at least one grain was considered as effective tiller.

**Number of filled grains panicle$^{-1}$**

Filled grains were considered to be fertile if any kernel was present there in. The number of total filled grains present on each panicle was recorded.

**Number of unfilled grains panicle$^{-1}$**

Unfilled grains means the absence of any kernel inside in and such grains present on each panicle were counted.

**Weight of 1000-grain**

One thousand cleaned dried seeds were counted randomly from each plot and weighted by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

**Weight of 1000-kernel**

One thousand cleaned dried kernels were counted randomly from each sample and weighted by using a digital electric balance and the mean weight were expressed in gram.

**Grain yield**

Grain yield was determined from the central 1 $m^2$ the plot and expressed as t $ha^{-1}$ on 12% moisture basis.

**Straw yield**

Straw yield was determined from t $ha^{-1}$. After threshing, the sample was oven dried to a constant weight and finally converted to t $ha^{-1}$.

**Protein content**

The protein content of rice grains was determined by the Micro-Kjeldahl method using an automated nitrogen determination system (AOAC, 1990).

**Grain-2AP content**

The 2-AP content in grain was estimated using the method described by Huang *et al.* (2012), prior to analysis, grains were ground by mortar and pestle. Approximately 10 g grains were mixed homogeneously with 150 ml purified water into a 500 ml round-bottom flask attached to a continuous steam distillation extraction head. The mixture was boiled at 150°C in an oil pot. A 30 ml aliquot of dichloromethane was used as the extraction solvent and was added to a 500 ml round-bottom flask attached the other head of the continuous steam distillation apparatus, and this flask was boiled in a water pot at 53°C. The continuous steam distillation extraction was linked with a cold water circulation machine in order to keep temperature at 10°C. After approximately 35 min, the extraction was complete. Anhydrous sodium sulfite was added to the extract to absorb the water. The dried extract was filtered by organic needle filter and analyzed for 2-AP content by GCMS-QP 2010 Plus. High purity helium gas was used as the carrier gas at flow rate of 2 ml/min. The temperature gradient of the GC oven was as follows: 40°C (1 min), increased at 2°C $min^{-1}$ to 65°C and held at 65°C for 1 min, and then increased to 220°C at 10°C $min^{-1}$, and held at 220°C for 10 min. The retention time of 2-AP was confirmed at 7.5 min. Each sample had three replicates, and 2-AP was expressed as µg $g^{-1}$.

Grain-2 AP content were measured at Bangladesh Rice Research Institute (BRRI)and Bangladesh Council of Scientific and Industrial Research (BCSIR),Dhaka.

**3.18 Analysis of data**

The data obtained for different characters were statistically analyzed using MSTAT- C software to observe the significant difference among the different rice variety. The mean values of all the characters were calculated and factorial analysis of variance was performed. The significance of difference among the treatment means was separated by Duncan 's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

## Chapter IV

# RESULTS AND DISCUSSION

The experiment was conducted to improvement of yield and aromatic quality of fragrant rice through supplementation of potassium and sulphur. BRRI Dhan 80 and BRRI Dhan 34 were considered as modern and traditional variety, respectively and 3 levels of potassium with 3 levels of sulphur were treated to find out the results.

## 4.1. Plant height

### 4.1.1 Effect of level of potassium

Level of potassium had no significant effect on plant height (Figure 2). The tallest plant (58.26, 94.64, 117.5 and 157.70 cm at 20, 40, 60 DAT and at maturity, respectively) was obtained from $K_2$ (65 kg MoP ha$^{-1}$) treatment and the shortest plant (55.78 , 93.68 , 115.8 and 154.6 cm) was obtained from $K_1$ (60 kg MoP ha$^{-1}$) treatment.

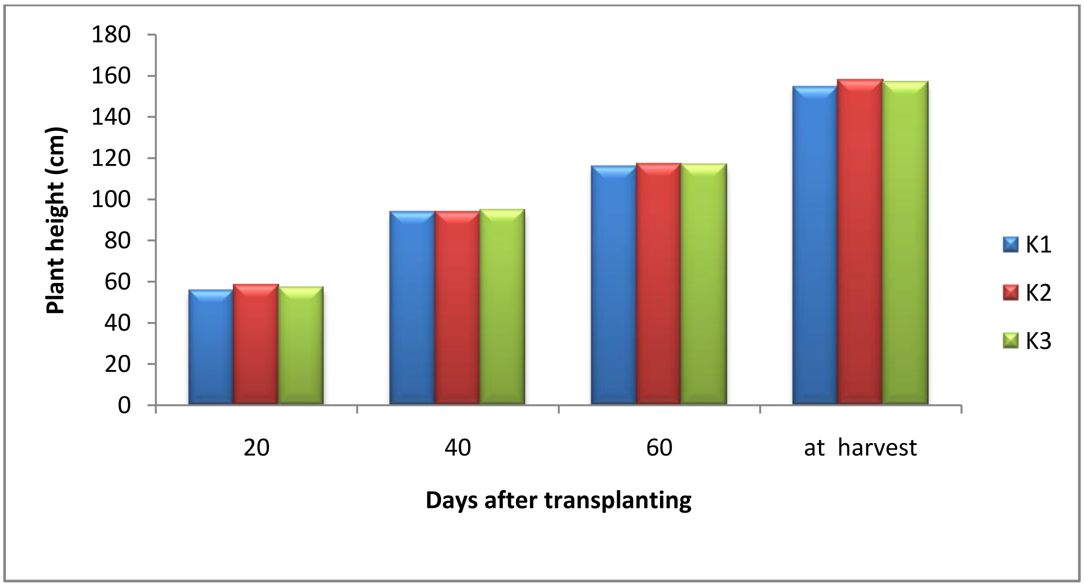



**Figure 2. Effect of level of potassium on plant height (cm) of *aman* rice at different days after transplanting**

$K_1$= 60 kg MoP ha$^{-1}$ , $K_2$= 65 kg MoP ha$^{-1}$, $K_3$= 70 kg MoP ha$^{-1}$

5% Level of Significance, ns = Non significance

### 4.1.2 Effect of level of sulphur

There was no significant effect at 20, 40, 60 DAT and at maturity on plant height due to the level of sulphur (Figure 3). Figure 3 shows that the tallest plant (57.18, 94.87, 117.5, 157.3 at 20, 40, 60 DAT and at maturity, respectively) was recorded from $S_2$ (50 kg Gypsum/ha) treatment and the shortest plant (56.79, 93.07, 115.2, 155.4 cm at 20, 40, 60 DAT and at maturity, respectively) was obtained from $S_3$ (55 kg Gypsum/ha) treatment. Data revealed that with the increase of application of sulphur nutrients plant height showed increasing trend and after a certain level it was also decreased. Tandon and Tiwari (2007) reported that growing of sulphur responsive crops, high intensive cropping and use of sulphur free fertilizers caused S deficiency. Rahman *et al*. (2007) stated that among the essential elements, sulphur is very much beneficial for the growth and development of rice plant and is one of the major essential nutrient elements involved in the synthesis of chlorophyll, certain amino acids like methionine, cystine, cysteine and some plant hormones such as thiamine and biotin which influences vegetative growth of rice.

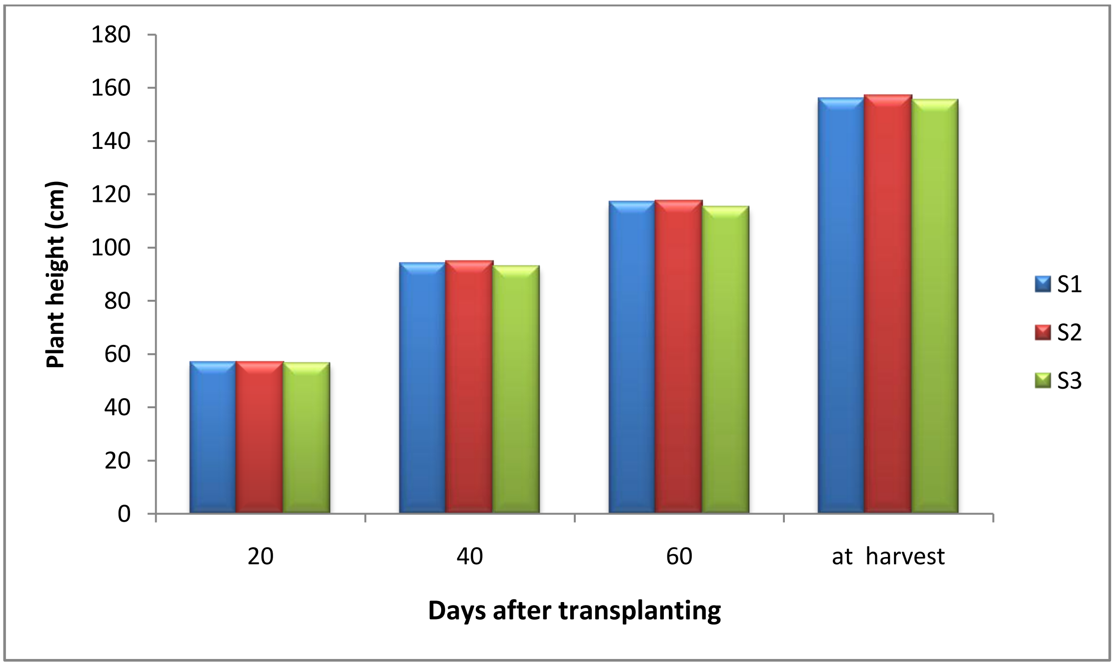



**Figure 3. Effect of level of sulphur on plant height (cm) of T. *aman* rice at different days after transplanting**

$S_1$=45 kg Gypsum ha$^{-1}$, $S_2$=50 kg Gypsum ha$^{-1}$, $S_3$= 55 kg Gypsum ha$^{-1}$

5% Level of Significance, ns = Non significance

### 4.1.3. Effect of variety

Plant height of the cultivars were measured at 20, 40, 60 DAT and at maturity. It was evident from Figure 1 that the height of the plant was not significantly influenced by variety at all the sampling dates. (Figure 1). shows that irrespective of varieties, the height of rice plants increased rapidly at the early stages of growth and rate of progression in height was slow at the later stages. BRRI Dhan 80 produced the taller plant (57.78, 94.43, 117.75 and 159.37 cm at 20, 40, 60 DAT and at maturity, respectively) and BRRI Dhan 34 produced shorter (56.23, 93.61, 115.41, 153.21 cm at 20, 40, 60 DAT and at maturity, respectively). Probably the genetic makeup of varieties was responsible for the variation in plant height. This confirms the reports of BRRI (1991) that plant height differed due to varietal variation.

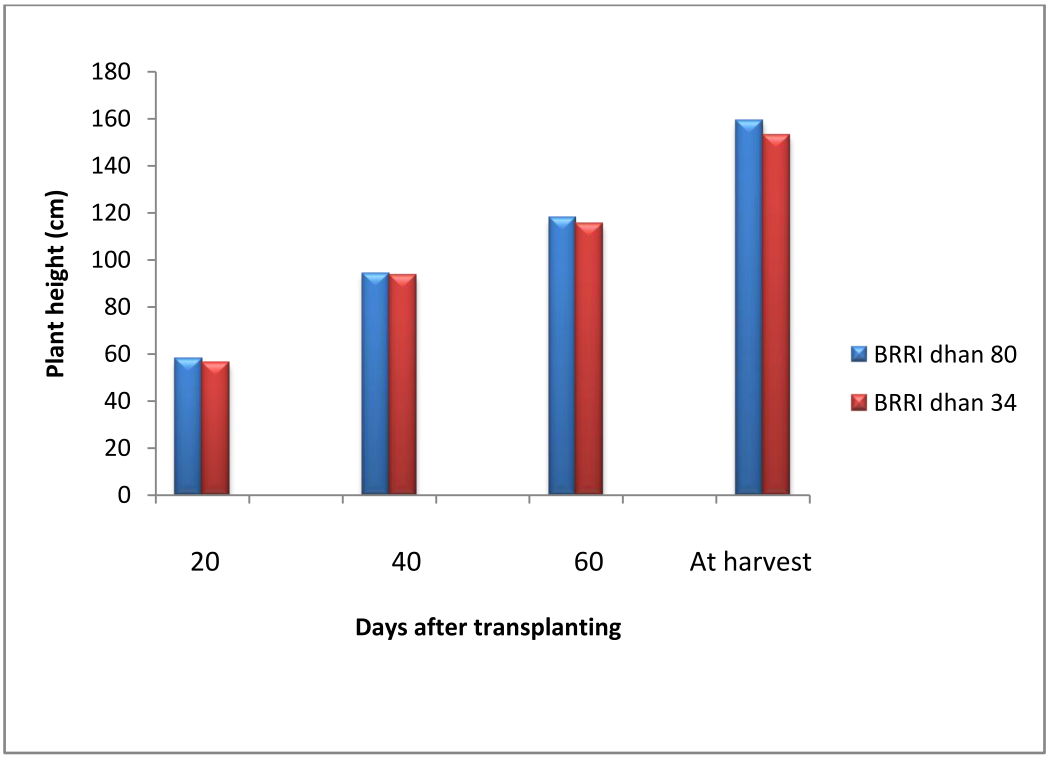



**Figure 1. Effect of variety on plant height (cm) of *aman* rice at different days after Transplanting ( 5% level of Significance , ns = Non significance)**

### 4.1.4 Interaction effect of variety and level of potassium

Interaction effect of variety and level of potassium on plant height was found significant at different date of sampling (Table 1). The tallest plant (58.67, 95.07, 120.9, 171.3 cm at 20, 40, 60 DAT and at maturity, respectively) found from $K_2V_1$ treatment and shortest plant (53.46, 92.47, 112.6, 143.4 cm at 20, 40, 60 DAT and at maturity, respectively) was found from $K_1V_2$ treatment.

### 4.1.5 Interaction effect of level of sulphur and variety

Plant height at different date of sampling was significantly influenced by the interaction between level of sulphur and variety (Table 1). The tallest plant (57.96, 95.56, 119.5, 159.9 cm at 20, 40, 60 DAT and at maturity, respectively) was found $S_2V_1$ and shortest plant (56.01, 92.96, 114.9 and 152.2 cm at 20, 40, 60 DAT and at maturity, respectively) from $S_3V_2$ treatment.

### 4.1.1.6 Interaction effect of level of potassium and level of sulphur

It was revealed that at different date of sampling interaction of level of potassium and level of sulphur on plant height showed significantly variation among treatment combination. The $K_2S_2$ treatment produced tallest plant (59.67, 95.6, 118.7, 160 cm at 20, 40, 60 DAT and at maturity, respectively) and the shortest plant (55.27, 91.6, 114.2, 154.6 cm at 20, 40, 60 DAT and at maturity, respectively) was produced from $K_1S_3$ treatment.

### 4.1.7 Interaction effect of variety, level of potassium and level of sulphur

From the interaction data of variety, level of potassium and levels of Sulphur fertilizer at different date of sampling (Table 2), it was found that plant height was significant at 20, 40, 60 DAT and at harvest. Such type of discontinuity in increasing plant height might have been caused by the variation between varieties in response to K and S or might be due to differences in crop growth pattern. The tallest plant height (61.00, 96.33, 122.5 and 174.7cm at 20, 40, 60 DAT and at harvest) obtained from $K_2S_2V_1$. Shortest (52.87, 90, 111.7, 141.5 cm at 20, 40, 60 DAT and at harvest, respectively) plant was observed from $K_1S_3V_2$ treatment combination.

**Table 1. Interaction effect of variety and level of potassium, level of sulphur on plant height (cm) of *aman* rice at different days after transplanting**

| Treatments | Plant height (cm) at | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20DAT | | 40DAT | | 60DAT | | Harvest | |
| Variety and levels of potassium | | | | | | | | |
| $K_1V_1$ | 58.11 | a | 94.89 | a | 116.00 | bc | 165.70 | c |
| $K_1V_2$ | 53.46 | b | 92.47 | d | 112.60 | d | 143.40 | d |
| $K_2V_1$ | 58.67 | a | 95.07 | a | 120.90 | a | 171.30 | a |
| $K_2V_2$ | 57.84 | a | 93.29 | c | 118.40 | ab | 144.10 | d |
| $K_3V_1$ | 56.57 | a | 94.22 | b | 116.30 | bc | 144.90 | d |
| SE value | 0.70 | | 1.88 | | 1.59 | | 1.37 | |
| Variety and levels of sulphur | | | | | | | | |
| $S_1V_2$ | 56.29 | ab | 93.69 | bc | 115.60 | b | 159.60 | a |
| $S_2V_1$ | 57.96 | a | 95.56 | a | 119.50 | a | 159.90 | a |
| $S_2V_2$ | 56.40 | ab | 94.18 | bc | 115.80 | b | 158.60 | a |
| $S_3V_1$ | 57.30 | ab | 93.18 | c | 115.60 | b | 154.80 | b |
| $S_3V_2$ | 56.01 | b | 92.96 | c | 114.90 | b | 152.20 | b |
| SE value | 1.21 | | 1.53 | | 1.30 | | 1.12 | |
| Levels of potassium and levels of sulphur | | | | | | | | |
| $K_1S_1$ | 55.78 | b | 93.37 | bc | 116.30 | d | 152.00 | f |
| $K_1S_2$ | 56.17 | ab | 94.50 | ab | 117.40 | bc | 155.00 | e |
| $K_1S_3$ | 55.27 | b | 91.60 | c | 114.20 | e | 154.60 | e |
| $K_2S_1$ | 58.93 | ab | 94.00 | ab | 118.00 | ab | 158.50 | b |
| $K_2S_2$ | 59.67 | a | 95.60 | a | 118.70 | a | 160.00 | a |
| $K_2S_3$ | 56.30 | ab | 93.17 | bc | 116.50 | cd | 156.70 | cd |
| $K_3S_1$ | 56.43 | ab | 95.00 | ab | 118.30 | ab | 157.80 | bc |
| $K_3S_2$ | 56.60 | ab | 94.50 | ab | 114.80 | e | 156.70 | cd |
| $K_3S_3$ | 57.92 | ab | 94.43 | ab | 115.00 | e | 155.30 | de |
| SE value | 0.99 | | 1.53 | | 1.30 | | 1.13 | |
| CV% | 5.21 | | 4.89 | | 5.34 | | 5.55 | |

5% Level of significance ns = Non significance

$K_1$ = 60 kg MoP $ha^{-1}$ $S_1$= 45 kg Gypsum $ha^{-1}$ $V_1$= BRRI Dhan 80

$K_2$= 65 kg MoP $ha^{-1}$ $S_2$ = 50 kg Gypsum $ha^{-1}$ $V_2$= BRRI Dhan 34

$K_3$= 70 kg MoP $ha^{-1}$ $S_3$= 55 kg Gypsum $ha^{-1}$

**Table 2. Combined interaction effect of variety and level of potassium, level of sulphur on plant height (cm) of *aman* rice at different days after transplanting**

| Treatments | Plant height (cm) at | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 20DAT | | 40DAT | | 60DAT | | Harvest | |
| $K_1S_1V_1$ | 58.59 | abc | 95.33 | ab | 120.90 | ab | 169.00 | abc |
| $K_1S_1V_2$ | 52.97 | c | 91.40 | fg | 113.70 | bcd | 162.50 | d |
| $K_1S_2V_1$ | 57.67 | abc | 96.00 | a | 117.70 | a-d | 144.30 | e |
| $K_1S_2V_2$ | 54.53 | bc | 92.67 | ef | 112.30 | cd | 165.70 | cd |
| $K_1S_3V_1$ | 58.07 | abc | 93.00 | def | 119.30 | a-d | 144.30 | e |
| $K_1S_3V_2$ | 52.87 | c | 90.00 | g | 111.70 | d | 141.50 | e |
| $K_2S_1V_1$ | 60.33 | ab | 93.33 | b-f | 117.70 | a-d | 172.00 | ab |
| $K_2S_1V_2$ | 57.53 | abc | 94.67 | a-e | 118.30 | a-d | 145.00 | e |
| $K_2S_2V_1$ | 61.00 | a | 96.33 | a | 122.50 | a | 174.70 | a |
| $K_2S_2V_2$ | 58.33 | abc | 95.20 | abc | 119.70 | abc | 141.80 | e |
| $K_2S_3V_1$ | 54.67 | bc | 93.20 | c-f | 112.70 | cd | 167.30 | bcd |
| $K_2S_3V_2$ | 57.67 | abc | 93.33 | b-f | 117.30 | a-d | 145.30 | e |
| $K_3S_1V_1$ | 55.33 | abc | 95.00 | a-d | 120.00 | abc | 144.30 | e |
| $K_3S_1V_2$ | 57.53 | abc | 95.00 | a-d | 116.70 | a-d | 171.30 | abc |
| $K_3S_2V_1$ | 55.20 | abc | 94.33 | a-e | 114.30 | bcd | 145.00 | e |
| $K_3S_2V_2$ | 58.00 | abc | 94.67 | a-e | 115.30 | a-d | 168.30 | bcd |
| $K_3S_3V_1$ | 59.17 | ab | 93.33 | b-f | 114.70 | bcd | 145.30 | e |
| $K_3S_3V_2$ | 56.67 | abc | 95.53 | a | 113.70 | bcd | 165.30 | cd |
| SE value | 0.99 | | 2.65 | | 2.24 | | 1.95 | |
| CV (%) | 5.21 | | 4.89 | | 5.34 | | 5.55 | |

5% Level of significance ns = Non significance

$K_1$ = 60 kg MoP $ha^{-1}$ $S_1$= 45 kg Gypsum $ha^{-1}$ $V_1$= BRRI Dhan 80

$K_2$= 65 kg MoP $ha^{-1}$ $S_2$ = 50 kg Gypsum $ha^{-1}$ $V_2$= BRRI Dhan 34

$K_3$= 70 kg MoP $ha^{-1}$ $S_3$= 55 kg Gypsum $ha^{-1}$

## 4.2 Total number of total tiller hill$^{-1}$

### 4.2.1 Effect of level of potassium

Total numbers tiller hill$^{-1}$ was not significantly influenced by the different level of potassium (table 3). The maximum number of tillers hill$^{-1}$ (17.01) was counted from $K_1$ treatment and minimum (16.19) number of tillers hill$^{-1}$ was counted from $K_3$ treatment.

### 4.2.2 Effect of level of sulphur

S fertilizer influenced tiller production significantly at all observations of crop growth (Table 3). The maximum number of tillers hill$^{-1}$ (17.33) was counted from $S_1$ treatment and minimum (15.71) number of tillers hill$^{-1}$ was counted from $S_2$ treatment. Sulphur is required early in the growth of rice plants. If it is limiting during early growth, then tiller number reduced (Blair and Lefroy, 1987). Singh and Singh (2002) reported that tillers m$^{-2}$ row length was significant with increasing levels of S up to 40 kg S ha$^{-1}$.

### 4.2.3 Effect of Variety

The total number of tillers hill$^{-1}$ was influenced by variety at all stages of crop growth (Table 3). Varietal effects on the total number of tillers are shown in Figure 4. BRRI Dhan 34 was achieved maximum (16.93) tiller. The minimum total number of tillers (16.30) was obtained from BRRI Dhan 80. The value decreased because some of the last emerged tillers died due to their failure in competing for light and nutrients as observed by Ishhizuka and Tanaka (1963). This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992). Variable effect of variety on number of total tillers hill$^{-1}$ was also reported by Hussain *et al*. (1989) who noticed that number of total tillers hill$^{-1}$ differed among the varieties.

**Table 3. Effect of variety, level of potassium and level of potassium on the Total number of tillers plant$^{-1}$, Dry weight hill $^{-1}$, SPAD value, effective tiller plant$^{-1}$ and Panicle length of aman rice**

| Treatments | Total number of tillers plant$^{-1}$ | Dry weight hill$^{-1}$ (g) | SPAD value | Effective tiller plant$^{-1}$ | Panicle length (cm) |
|---|---|---|---|---|---|
| Effect of potassium | | | | | |
| $K_1$ | 17.01a | 87.54 a | 40.65a | 15.19a | 26.18a |
| $K_2$ | 16.63b | 87.77 a | 40.59a | 15.27a | 26.22a |
| $K_3$ | 16.19b | 84.08 b | 40.51b | 15.15b | 25.69b |
| SE value | 0.33 | 4.11 | 0.22 | 0.40 | 0.80 |
| CV% | 8.32 | 10.17 | 5.28 | 11.09 | 5.46 |
| Effect of sulphur | | | | | |
| $S_1$ | 17.33 a | 80.85 c | 40.82a | 15.22a | 26.07a |
| $S_2$ | 15.71 c | 91.29 a | 40.42a | 15.33a | 26.13a |
| $S_3$ | 16.79 b | 87.25 b | 40.51a | 15.06b | 25.90b |
| SE value | 0.26 | 3.35 | 0.17 | 0.32 | 0.07 |
| CV% | 8.32 | 10.17 | 5.28 | 11.09 | 5.46 |
| Effect of variety | | | | | |
| $V_1$ | 16.30b | 91.39a | 40.48b | 16.18a | 26.29a |
| $V_2$ | 16.93a | 81.53b | 40.69a | 14.23b | 25.77b |
| SE value | 0.32 | 4.11 | 0.21 | 0.39 | 0.07 |
| CV% | 6.31 | 9.27 | 4.21 | 9.90 | 4.56 |

5% Level of significance    ns = Non significanc

$K_1$ = 60 kg, MoP ha$^{-1}$  $S_1$=45 kg Gypsum ha$^{-1}$    $V_1$=BRRI Dhan 80

$K_2$= 65 kg MoP ha$^{-1}$ ,,  $S_2$ = 50 kg Gypsum ha$^{-1}$    $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ ,  $S_3$= 55 kg Gypsum ha$^{-1}$

### 4.2.4 Interaction effect of variety and level of potassium

Interaction effect of variety and level of potassium was observed to be significant (Table 4). The maximum (19.00) tillers hill$^{-1}$ was found from the combination of $K_1V_2$ treatment and minimum (15.02) was found from $K_1V_1$ treatment.

### 4.2.5 Interaction effect of variety and level of sulphur

The effect of level of sulphur and variety were statistically significant on tillers hill$^{-1}$(Table 4). Apparently, the maximum total number of tillers hill$^{-1}$ (17.81) was obtained from $S_1V_2$ treatment, which was statistically similar with $S_3V_2$ . The minimum total number of tillers hill$^{-1}$ (15.67) was obtained from $S_2V_2$ treatment, which was statistically similar with $S_2V_1$.

### 4.2.6 Interaction effect of level of potassium and level of sulphur

Interaction effect of level of potassium and level of sulphur on tillers hill$^{-1}$ of the crop was found significant (Table 4). Maximum (17.87) tillers hill$^{-1}$ was observed from the combination of $K_1S_3$ treatment, which was statistically similar with $K_1S_1$ and $K_2S_1$. The minimum total number of tillers hill$^{-1}$ (15.37 ) was observed from the combination of $K_1S_2$ treatment, which was statistically similar with $K_2S_2$ and $K_3S_3$.

### 4.2.7 Interaction effect of variety, level of potassium and level of sulphur

Tiller production was influenced significantly due to the interaction of variety, level of potassium and level of sulphur (Table 5). At harvest, it was observed that total tillers hill$^{-1}$ numerically maximum (20.97) comes from the combination of $K_1S_3V_2$ treatment and minimum (14.40) was observed from the combination of $K_2S_2V_2$ treatment.

**Table 4. Interaction effect of variety and level of potassium, variety and level of sulphur, level of potassium and level of sulphur on total tiller production hill$^{-1}$, Dry weight hill$^{-1}$, SPAD value, Effective tiller plant$^{-1}$, panicle length of *aman* rice**

| Treatments | Total number of tiller plant$^{-1}$ | | Dry weight hill$^{-1}$ (g) | | SPAD value | | Effective tiller plant$^{-1}$ | | Panicle length (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety and levels of potassium | | | | | | | | | | |
| $K_1V_1$ | 15.02 | c | 84.29 | d | 41.11 | a | 17.51 | a | 25.80b | |
| $K_1V_2$ | 19.00 | a | 90.79 | b | 40.19 | ab | 13.02 | b | 26.30a | |
| $K_2V_1$ | 17.86 | ab | 95.56 | a | 40.41 | ab | 17.59 | a | 26.57a | |
| $K_2V_2$ | 15.41 | bc | 87.83 | c | 40.78 | ab | 13.44 | b | 26.14a | |
| $K_3V_1$ | 16.01 | bc | 79.98 | e | 39.91 | b | 16.86 | a | 25.22b | |
| $K_3V_2$ | 16.38 | abc | 80.33 | e | 41.10 | a | 12.80 | b | 26.17a | |
| SE value | 0.56 | | 7.12 | | 0.38 | | 0.68 | | 0.13 | |
| CV% | 8.32 | | 10.17 | | 5.28 | | 11.09 | | 5.46 | |
| Variety and levels of sulphur | | | | | | | | | | |
| $S_1V_1$ | 16.86 | b | 66.80 | f | 40.63b | | 14.93 | ab | 25.77 | b |
| $S_1V_2$ | 17.81 | a | 94.90 | b | 41.01a | | 15.51 | ab | 26.37 | ab |
| $S_2V_1$ | 15.76 | c | 97.47 | a | 40.44a | | 16.56 | a | 25.66 | b |
| $S_2V_2$ | 15.67 | c | 81.80 | e | 40.40b | | 16.48 | a | 26.61 | a |
| $S_3V_1$ | 16.28 | b | 85.11 | d | 40.36b | | 14.11 | ab | 25.90 | ab |
| $S_3V_2$ | 17.31 | a | 81.80 | e | 40.66a | | 13.63 | b | 25.90 | ab |
| SE value | 0.46 | | 5.81 | | 0.30 | | 0.56 | | 0.11 | |
| CV% | 8.32 | | 10.17 | | 5.28 | | 11.09 | | 5.46 | |
| Levels of potassium and levels of sulphur | | | | | | | | | | |
| $K_1S_1$ | 17.80 | a | 87.00 | c | 41.38a | | 15.50 | ab | 25.87b | |
| $K_1S_2$ | 15.37 | b | 78.59 | f | 40.18b | | 14.68 | ab | 26.18a | |
| $K_1S_3$ | 17.87 | a | 86.15 | d | 40.38a | | 15.40 | ab | 25.98b | |
| $K_2S_1$ | 17.63 | a | 80.51 | e | 39.87b | | 15.37 | ab | 26.38a | |
| $K_2S_2$ | 15.40 | b | 97.01 | a | 40.62a | | 16.25 | a | 26.70a | |
| $K_2S_3$ | 16.87 | ab | 85.58 | d | 41.30a | | 15.85 | ab | 26.10a | |
| $K_3S_1$ | 16.57 | ab | 75.04 | g | 41.22a | | 14.80 | ab | 25.95b | |
| $K_3S_2$ | 16.37 | ab | 97.00 | a | 40.47a | | 14.75 | ab | 25.52b | |
| $K_3S_3$ | 15.65 | b | 91.27 | b | 39.83b | | 14.23 | b | 25.62b | |
| SE value | 0.47 | | 5.81 | | 0.31 | | 0.56 | | 0.11 | |
| CV % | 8.32 | | 10.17 | | 5.28 | | 11.09 | | 5.46 | |

5% Level of significance ns = Non significance, $K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ $V_1$= BRRI Dhan 80 ,$K_2$= 65 kg MoP ha$^{-1}$ $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34

$K_3$= 70 kg MoP ha$^{-1}$ $S_3$= 55 kg Gypsum ha$^{-1}$

**Table 5. Interaction effect of variety and level of potassium, variety and level of sulphur, level of potassium and level of sulphur on total tiller production hill$^{-1}$, Dry weight hill$^{-1}$, SPAD value, Effective tiller plant$^{-1}$, panicle length of *aman* rice**

| Treatments | Total number of tiller plant$^{-1}$ | | Dry weight hill$^{-1}$ (g) | | SPAD value | | Effective tiller plant$^{-1}$ | | Panicle length (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_1S_1V_1$ | 14.97 | cd | 70.20 | i | 41.92 | a | 14.27 | c-h | 25.60 | f-i |
| $K_1S_1V_2$ | 20.63 | a | 103.80 | ab | 40.83 | a-e | 16.73 | a-d | 26.13 | b-f |
| $K_1S_2V_1$ | 15.33 | cd | 88.52 | f | 40.70 | a-e | 12.73 | fgh | 25.80 | d-h |
| $K_1S_2V_2$ | 15.40 | cd | 68.66 | i | 39.67 | cde | 16.63 | a-e | 27.60 | a |
| $K_1S_3V_1$ | 14.77 | cd | 94.14 | e | 40.70 | a-e | 11.40 | h | 25.99 | b-f |
| $K_1S_3V_2$ | 20.97 | a | 99.89 | cd | 40.07 | b-e | 14.97 | c-g | 25.97 | b-f |
| $K_2S_1V_1$ | 18.53 | ab | 76.87 | h | 39.30 | de | 16.87 | a-d | 26.37 | bcd |
| $K_2S_1V_2$ | 16.73 | bcd | 84.15 | g | 40.43 | a-e | 13.87 | d-h | 26.40 | bcd |
| $K_2S_2V_1$ | 16.40 | bcd | 105.90 | a | 40.70 | a-e | 19.40 | a | 26.03 | b-f |
| $K_2S_2V_2$ | 14.40 | d | 88.64 | f | 40.53 | a-e | 13.50 | e-h | 26.33 | b-e |
| $K_2S_3V_1$ | 18.63 | ab | 80.47 | g | 41.23 | abc | 18.73 | ab | 26.50 | bc |
| $K_2S_3V_2$ | 15.10 | cd | 90.69 | f | 41.37 | abc | 12.97 | fgh | 25.70 | e-i |
| $K_3S_1V_1$ | 17.07 | bcd | 53.34 | j | 40.67 | a-e | 13.67 | d-h | 25.33 | ghi |
| $K_3S_1V_2$ | 16.07 | bcd | 96.74 | de | 41.77 | ab | 15.93 | b-f | 26.57 | b |
| $K_3S_2V_1$ | 15.53 | cd | 83.66 | g | 39.93 | cde | 13.20 | fgh | 25.13 | i |
| $K_3S_2V_2$ | 17.20 | bc | 88.10 | f | 41.00 | a-d | 19.30 | a | 25.90 | c-g |
| $K_3S_3V_1$ | 15.43 | cd | 80.71 | g | 39.13 | e | 12.20 | gh | 25.20 | hi |
| $K_3S_3V_2$ | 15.87 | cd | 101.80 | bc | 40.53 | a-e | 17.30 | abc | 26.03 | b-f |
| SE value | 0.79 | | 10.06 | | 0.53 | | 0.97 | | 0.19 | |
| CV (%) | 8.32 | | 10.17 | | 5.28 | | 11.09 | | 5.46 | |

5% Level of significance , ns = Non significance ,

$K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ , $V_1$= BRRI Dhan 80 ,

$K_2$= 65 kg MoP ha$^{-1}$ , $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ , $S_3$= 55 kg Gypsum ha$^{-1}$

## 4.3 Total dry matter production

### 4. 3.1 Effect of level of potassium

Dry matter production was significantly influenced by different level of potassium at harvest (Table 3). The maximum TDM was 87.77 g $hill^{-1}$ recorded $K_2$ treatment, which was statistically similar with $K_1$ treatment. The minimum TDM was 84.08 g $hill^{-1}$ recorded $K_3$ treatment.

### 4.3.2 Effect of level of sulphur

The TDM production was influenced significantly at harvest by the levels of S fertilizer (Table 3). It could be observed from the Table 3 that at each sampling, the $S_2$ treatment gave higher TDM compared to $S_1$ treatment. Maximum (91.29 g $hill^{-1}$) TDM found from $S_2$ treatment. The minimum (91.29 g $hill^{-1}$) TDM found from $S_1$ treatment.

### 4.3.3 Effect of Variety

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. TDM of leaves, leaf sheath + stem and or panicles of used varieties data were measured at harvest (Table 3). The higher amount of dry matter of 91.39 g $hill^{-1}$ was obtained from variety of BRRI dhan 80. The Lower amount of dry matter production (81.534g $hill^{-1}$) at harvest was obtained in BRRI dhan 34. This confirms the reports of Amin *et al.* (2006) and Son *et al.* (1998) that total dry matter production differed due to varietal variation.

### 4.3.4 Interaction effect of variety and level of potassium

Total dry matter production was significantly affected due to the interaction of variety and level of potassium at harvest (Table 4). The maximum TDM (95.56 g $hill^{-1}$) was found from the combination of $K_2V_1$ treatment, whereas minimum (79.98 g $hill^{-1}$) was found from the combination of $K_3V_1$ treatment, which was statistically similar with $K_3V_2$ treatment.

### 4.3.5 Interaction effect of variety and level of sulphur

The (table 4). revealed that interaction of variety and level of sulphur on TDM production significantly varied at harvest. The maximum (97.47. g hill$^{-1}$) TDM was found from the combination of $S_2V_1$ and minimum (66.8 g hill$^{-1}$) from the combination of $S_1V_1$ treatment.

### 4.3.6 Interaction effect of level of potassium and level of sulphur

It was observed from the (table 4). that interaction effect of level of potassium and level of S showed significant in TDM production at all sampling dates. The maximum (97.01 g hill$^{-1}$) TDM was found from the combination of $K_2S_2$, which was statistically similar with $K_3S_2$ treatment and minimum (75.04 g hill$^{-1}$) from $K_3S_1$.

### 4.3.7 Interaction effect of variety, level of potassium and level of sulphur

From the table 5 it was observed that the interaction of variety, level of potassium and level of sulphur on TDM production had significant effect at harvest. The numerically maximum (105.9 g hill$^{-1}$) TDM found from the combination of $K_2S_2V_1$ and minimum (53.34 g hill$^{-1}$) from the combination of $K_3S_1V_1$ treatment.

## 4. 4 SPAD value

### 4.4.1 Effect of level of potassium

Numbers of level of potassium had remarkable influence on SPAD value (Table 3). There were not significant variations among different level of potassium treatments . The maximum SPAD value (40.65) was obtained from $K_1$. Minimum SPAD value (40.51) was counted $K_3$.

### 4.4.2 Effect of level of sulphur

There was no statistical difference in the values of SPAD value observed due to levels of S fertilizer (Table 3). Maximum (40.82) SPAD value was found $S_1$ treatment. The minimum SPAD value (40.42) was counted $S_2$.

### 4.4.3 Effect of variety

SPAD value was influenced by variety (Table 3). The highest SPAD reading of leaf (40.69) was obtained from $V_2$ and the lowest Spade reading of leaf (40.48) was attained from $V_1$ treatment

### 4.4.4 Interaction effect of variety and level of potassium

Interaction effect of variety and level of potassium significantly affected the SPAD value (Table 4).The highest (41.11) SPAD value was found in combination $K_1V_1$ treatment which was statistically similar with the combinations $K_3V_{2.}$ The lowest SPAD value (39.91) was observed in combination $K_3V_1$.

### 4.4.5 Interaction effect of variety and level of sulphur

The effect of interaction between variety and source of S was found to be insignificant in respect of SPAD value. Combination of $S_1V_2$ produced the highest (41.01) SPAD value which was statistically similar to $S_2V_2$ (Table 4) and the lowest (40.36) was observed in combination $S_3V_1$.

### . 4.4.6 Interaction effect of level of potassium and level of sulphur

There was not significant effect of interaction of level of potassium and levels of S fertilizer on SPAD value (Table 4). Numerically the highest SPAD value (41.38) was found from the treatment combination of $K_1S_1$. The lowest numbers of SPAD value (39.83) was observed in combination $K_3S_3$.

### 4.4.7 Interaction effect of variety, level of potassium and level of sulphur

From (Table 5). it was observed that there was remarkable effect on SPAD value with the combination of variety, level of potassium and levels of S. Numerically the highest (41.92) SPAD value was found from the combination of $K_1S_1V_1$ and the lowest (39.13) was observed from the combination of $K_3S_3V_1$ (Table 5).

## 4.5 Effective tiller hill$^{-1}$

### 4.5.1 Effect of level of potassium

Numbers of effective tiller hill$^{-1}$ was not significantly influenced by level of potassium (Table 3). The highest numbers of effective tiller hill$^{-1}$ (15.27) was counted $K_2$ treatment that was followed by other treatments. The lowest numbers of effective tiller hill$^{-1}$ (15.15) was counted $K_3$ treatment.

### 4.5.2 Effect of level of sulphur

Numbers of effective tiller hill$^{-1}$ was not significantly influenced by level of S (Table 3). The highest numbers of effective tiller hill$^{-1}$ (15.33) was counted $S_2$ treatment. The lowest numbers of effective tiller hill$^{-1}$ (15.06) was counted $S_3$ treatment.

### 4.5.3 Effect of variety

Total tillers determine the amount of dry matter production unit area$^{-1}$ while productive tillers unit area$^{-1}$ determined the final yield of rice. This is why it is said that the higher the effective tillers, the higher the yield. It was evident from (Table 3). that variety had significant effect on numbers of effective tiller. BRRI Dhan 80 produced higher number of effective tiller (16.81) and BRRI Dhan 34 produced lower number (14.23) of productive tiller. This confirms the report of Sawnat *et al.* (1986), who reported that variable effect variety on the number of effective tillers hill$^{-1}$. Although Nizersail produced higher number of tiller but a high tiller number also increased tiller abortion rate as was observed in this study. The same result was reported by Peng *et al.* (1996) and Schnier *et al.* (1990). They found a negative correlation between maximum tiller number and percentage of productive tillers.

### 4.5.4 Interaction effect of variety and level of potassium

Interaction effect of variety and level of potassium significantly affected the effective tiller hill$^{-1}$ (Table 4). The highest productive tiller (17.59) was found in combination $K_2V_1$ treatment which was statistically similar with the combinations $K_1V_1$ and $K_3V_1$ of and the lowest (12.8) was observed in combination $K_3V_2$.

**4.5.5 Interaction effect of variety and level of sulphur**

The effect of interaction between variety and source of S was found to be significant in respect of effective tiller hill$^{-1}$. Combination of $S_2V_1$ produced the highest effective tiller hill$^{-1}$(16.56), which was statistically similar to $S_2V_2$ (Table 4) and the lowest (13.63) was observed in combination $S_3V_2$.

. **4.5.6 Interaction effect of level of potassium and level of sulphur**

There was significant effect of interaction of level of potassium and levels of S fertilizer on numbers of effective tiller hill$^{-1}$ (Table 4). Numerically the highest numbers of effective tiller hill$^{-1}$ (16.25) was found from the treatment combination of $K_2S_2$. The lowest numbers of effective tiller hill$^{-1}$ (14.23) was observed in combination $K_3S_3$.

**4.5.7 Interaction effect of variety, level of potassium and level of sulphur**

From(Table 5) it was observed that there was remarkable effect on effective tiller hill$^{-1}$ with the combination of variety, level of potassium and levels of S. Numerically the highest effective tillers hill$^{-1}$(19.4) was found from the combination of $K_2S_2V_1$ and the lowest (11.4) was observed from the combination of $K_1S_3V_1$ (Table 5).

**4.6 Panicle length**

**4.6.1 Effect of level of potassium**

The panicle length did not vary significantly due to level of potassium shown in (Table 3). The longest panicle (26.22cm) and the shortest (25.69cm) panicle length was observed in $K_2$ and $K_3$ level of potassium, respectively though the value did not differ significantly (Table 4).

### 4.6.2 Effect of level of sulphur

Panicle length was not statistically unaffected by level of sulphur (Table 3). Longest panicle (26.13 cm) was produced from $S_2$ treatment. The shortest (25.90cm) panicle was produced from $S_3$ treatment. Singh and Singh (2002) reported that panicle length was significant with increasing levels of S up to 40 kg S $ha^{-1}$. Rahman *et al*. (2009) reported that panicle length of BRRI dhan41was not significantly responded to different levels of S.

### 4.6.3 Effect of variety

The panicle length did not vary significantly due to variety shown in (Table 3). It was observed that BRRI Dhan 80 produced longer panicle (26.29 cm) than BRRI Dhan 34 (25.77 cm). This confirms the report of Ahmed *et al.* (1997) and Idris and Matin (1990) that panicle length was differed due to variety.

### 4.6.4 Interaction effect of variety and level of potassium

Panicle length was not significantly affected by the interaction of variety and level of potassium (Table 4).The Longest panicle length (26.57 cm) was observed from the combination $K_2V_1$ and the lowest (25.22 cm) was found from $K_2V_1$ treatment.

### 4.6.5 Interaction effect of variety and level of sulphur

Panicle length was statistically influenced by the interaction of variety and level of sulphur (Table 4). It was ranged from 25.66 cm to 26.61 cm. the Longest (26.61 cm) panicle length was observed from the combination $S_2V_1$ and the lowest (25.66 cm) was found from $S_2V_1$ treatment.

### 4.6.6 Interaction effect of level of potassium and level of sulphur

Interaction of number of level of potassium and level of sulphur exerted statistically non significant influence on panicle length (Table 4). However, in the present experiment numerically the longest panicle (26.70 cm) was obtained in the treatment $K_2S_2$ and the shortest in (25.52 cm) was obtained in the treatment $K_3S_2$.

### 4.6.7 Interaction effect of variety, level of potassium and level of sulphur

From the (Table 5). it was observed that interaction effect of variety, level of potassium and level of sulphur had significant effect on panicle length.The highest (27.6 cm) panicle length was observed from the combination of $K_1S_2V_2$ and the lowest (25.13 cm) from $K_3S_2V_1$.

## 4.7 Number of filled grains panicle$^{-1}$

### 4.7.1 Effect of level of potassium

Number of filled grains panicle$^{-1}$ was not significantly influenced by the level of potassium (Table 6). The highest filled grains panicle$^{-1}$ (140.3) and the lowest (135.7) of filled grains panicle$^{-1}$ was obtained with $K_2$ and $K_1$ treatment, respectively.

### 4.7.2 Effect of level of sulphur

From the (table 6). it was observed that there was a statistical variation in number of filled grains panicle$^{-1}$ due to levels of S fertilizer. Results showed that the highest number of filled grains panicle$^{-1}$ (142.5) was obtained with $S_2$. The lowest number of filled grains panicle$^{-1}$ (132.4) was obtained with $S_1$. Rahman *et al*. (2009) reported that filled grain panicle$^{-1}$ significantly responded to different levels of S.

### 4.7.3 Effect of variety

(Table 6). shows that cultivars affected significantly in number of filled grains panicle$^{-1}$. From the (Table 6) it was revealed that BRRI Dhan 34 gave significantly higher number (153.64) grains panicle$^{-1}$ than BRRI Dhan 80 (121.39). BRRI (1994) found that number of filled grains panicle$^{-1}$ significantly differed due to variety.

### 4.7.4 Interaction effect of variety and level of potassium

Results presented in (Table 7). shows that interaction effect of variety and level of potassium was significant on filled grains panicle$^{-1}$. The highest (185.8) filled grains panicle$^{-1}$ was found from the combination of BRRI Dhan 80 with 65 kg MoP ha$^{-1}$ which was statistically similar with the other seedlings combinations of same variety and the lowest (87.22) was found from BRRI Dhan 80 with 70 kg MoP ha$^{-1}$.

### 4.7.5 Interaction effect of variety and level of sulphur

Interaction effect of variety and level of S fertilizer was found significant on filled grains panicle$^{-1}$ (Table 7). From the results of (Table 7). it was observed that highest (156.9) filled grains panicle$^{-1}$ was found from the combination of $S_2V_2$ which was statistically similar with the combination of $S_1V_2$ and $S_3V_2$. The lowest (109.2) filled grains panicle$^{-1}$ was found from the combination of $S_1V_1$. It indicated that BRRI Dhan 80 was the best performer with 50 kg gypsum ha$^{-1}$ in terms of filled grains panicle$^{-1}$.

**Table 6. Effect of variety, level of potassium and level of potassium on the Filled grain panicle$^{-1}$, Unfilled grain panicle$^{-1}$, 1000 grain weight and 1000 kernel weight of aman rice**

| Treatments | Filled grain panicle$^{-1}$ | Unfilled grain panicle$^{-1}$ | 1000 grain weight | 1000 kernel weight |
|---|---|---|---|---|
| Effect of potassium | | | | |
| $K_1$ | 135.7bc | 32.63a | 17.97c | 15.43ab |
| $K_2$ | 140.30a | 27.47bc | 18.93a | 15.52a |
| $K_3$ | 136.5b | 28.43b | 18.11ab | 14.99c |
| SE value | 3.13 | 1.40 | 0.04 | 0.02 |
| CV% | 9.68 | 9.14 | 6.13 | |
| Effect of sulphur | | | | |
| $S_1$ | 132.40 b | 30.27a | 18.69a | 15.20ab |
| $S_2$ | 142.50 a | 28.67b | 18.43ab | 15.70a |
| $S_3$ | 137.70 ab | 29.58bc | 17.89c | 15.04c |
| SE value | 2.56 | 1.14 | 0.08 | 0.01 |
| CV % | 9.08 | 9.14 | 6.13 | 6.35 |
| Effect of variety | | | | |
| $V_1$ | 121.39b | 32.85a | 20.93a | 17.55a |
| $V_2$ | 153.64a | 26.17b | 15.74b | 13.07b |
| SE value | 3.13 | 1.40 | 0.04 | 0.01 |
| CV% | 7.09 | 8.01 | 5.65 | 4.78 |

5% Level of significance , ns = Non significance ,

$K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ , $V_1$= BRRI Dhan 80 ,

$K_2$= 65 kg MoP ha$^{-1}$ , $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ , $S_3$= 55 kg Gypsum ha$^{-1}$

**Table 7. Interaction effect of variety and level of potassium, variety and level of sulphur, level of potassium and level of sulphur on filled grain panicle$^{-1}$, unfilled grain panicle$^{-1}$, 1000 grain weight and 1000 kernel weight of *aman* rice**

| Treatments | Filled grain panicle$^{-1}$ | | Unfilled grain panicle$^{-1}$ | | 1000 grain weight | | 1000 kernel weight | |
|---|---|---|---|---|---|---|---|---|
| **Variety and levels of potassium** | | | | | | | | |
| $K_1V_1$ | 95.17 | bc | 41.48 | a | 25.78 | a | 9.09 | b |
| $K_1V_2$ | 176.30 | a | 23.78 | b | 10.17 | b | 8.65 | b |
| $K_2V_1$ | 185.80 | a | 20.21 | b | 26.40 | a | 22.20 | a |
| $K_2V_2$ | 98.78 | b | 18.08 | b | 11.47 | b | 21.96 | a |
| $K_3V_1$ | 87.22 | c | 36.87 | a | 25.56 | a | 21.36 | a |
| $K_3V_2$ | 181.80 | a | 36.64 | a | 10.66 | b | 8.61 | b |
| SE value | 5.43 | | 2.42 | | 0.08 | | 0.03 | |
| **Variety and levels of sulphur** | | | | | | | | |
| $S_1V_1$ | 109.20 | c | 35.87 | a | 21.24 | a | 17.68 | a |
| $S_1V_2$ | 155.60 | a | 26.49 | ab | 16.11 | b | 13.26 | b |
| $S_2V_1$ | 128.10 | b | 30.86 | ab | 21.27 | a | 18.14 | a |
| $S_2V_2$ | 156.90 | a | 24.68 | b | 15.62 | b | 12.71 | b |
| $S_3V_1$ | 126.90 | b | 31.83 | ab | 20.29 | a | 16.84 | a |
| $S_3V_2$ | 148.50 | a | 27.33 | ab | 15.50 | b | 13.25 | b |
| SE value | 4.43 | | 1.98 | | 0.07 | | 0.03 | |
| **Levels of potassium and levels of sulphur** | | | | | | | | |
| $K_1S_1$ | 122.50 | e | 28.38 | bc | 17.93c | | 15.84a | |
| $K_1S_2$ | 134.00 | c | 34.85 | a | 18.00b | | 14.95b | |
| $K_1S_3$ | 128.10 | d | 34.65 | a | 17.98c | | 15.39a | |
| $K_2S_1$ | 145.10 | b | 30.08 | abc | 19.02a | | 15.95a | |
| $K_2S_2$ | 152.90 | a | 28.57 | bc | 19.18a | | 15.28ab | |
| $K_2S_3$ | 145.40 | b | 26.63 | cd | 18.60b | | 15.45a | |
| $K_3S_1$ | 129.60 | cd | 32.35 | ab | 19.12a | | 15.31ab | |
| $K_3S_2$ | 148.00 | ab | 22.60 | d | 18.11b | | 15.36ab | |
| $K_3S_3$ | 132.00 | cd | 27.47 | bcd | 17.10c | | 14.29bc | |
| SE value) | 4.44 | | 1.98 | | 0.06 | | 0.03 | |
| CV (%) | 9.68 | | 9.14 | | 6.13 | | 6.35 | |

5% Level of significance , ns = Non significance

, $K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ , $V_1$= BRRI Dhan 80

, $K_2$= 65 kg MoP ha$^{-1}$ , $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ , $S_3$= 55 kg Gypsum ha$^{-1}$

### 4.7.6 Interaction effect of level of potassium and level of sulphur

Interaction effect of level of potassium and level of sulphur showed a significant response on filled grains panicle$^{-1}$ (Table 7). The combination of $K_2S_2$ numerically produced the highest (152.9) filled grains panicle$^{-1}$. The lowest (122.5) filled grains panicle$^{-1}$ was found from the combination of $K_1S_1$.

### 4.7.7 Interaction effect of variety, level of potassium and level of sulphur

Many factors affect the grains panicle$^{-1}$ such as genotype, cultural practices used and growing conditions. Results presented in (Table 8). shows that interaction of variety, level of potassium and level of sulphur was significant on filled grains panicle$^{-1}$. The highest (197.00) filled grains panicle$^{-1}$ was found from the combination of $K_2S_2V_2$ which was statistically similar with $K_2S_3V_1$ and $K_3S_1V_2$. The lowest (66.73) filled grains panicle$^{-1}$ was found from the combination of $K_3S_1V_1$.

## 4.8 Number of unfilled grains panicle$^{-1}$

### 4.8.1 Effect of level of potassium

Number of unfilled grains panicle$^{-1}$ was not statistically influenced by the level of potassium (Table 6). The minimum number (27.47) of unfilled grains panicle$^{-1}$ was counted at $K_2$ treatment and the maximum number (32.63) was found at $K_1$ treatment.

### 4.8.2 Effect of level of sulphur

Number of unfilled grains panicle$^{-1}$ was not statistically influenced from the S source (Table 6). However, numerical variation was noticed. Numerically minimum (28.67) unfilled grains panicle$^{-1}$ was obtained from the application of 50 kg Gypsum ha$^{-1}$. The maximum (30.27) unfilled grains panicle$^{-1}$ was obtained from the application of 45 kg Gypsum ha$^{-1}$.

**Table 8. Interaction effect of variety, level of potassium and level of sulphur on filled grain panicle$^{-1}$, unfilled grain panicle$^{-1}$, 1000 grain weight and 1000 kernel weight of *aman* rice**

| Treatments | Filled grain panicle$^{-1}$ | | Unfilled grain panicle$^{-1}$ | | 1000 grain weight | | 1000 kernel weight | |
|---|---|---|---|---|---|---|---|---|
| $K_1S_1V_1$ | 93.27 | i | 45.57 | a | 26.30 | bc | 9.17 | h |
| $K_1S_1V_2$ | 106.40 | g | 29.73 | bcd | 9.57 | k | 8.57 | k |
| $K_1S_2V_1$ | 91.07 | i | 39.97 | ab | 25.07 | d | 21.50 | f |
| $K_1S_2V_2$ | 176.90 | c | 22.60 | de | 10.93 | h | 8.39 | l |
| $K_1S_3V_1$ | 101.20 | h | 38.90 | ab | 25.97 | c | 21.77 | e |
| $K_1S_3V_2$ | 155.10 | e | 30.40 | bcd | 10.00 | j | 9.00 | i |
| $K_2S_1V_1$ | 167.60 | d | 21.97 | def | 11.03 | h | 9.12 | hi |
| $K_2S_1V_2$ | 77.30 | k | 38.20 | ab | 27.00 | a | 22.57 | b |
| $K_2S_2V_1$ | 184.50 | b | 11.20 | f | 12.27 | f | 23.33 | a |
| $K_2S_2V_2$ | 197.00 | a | 34.53 | abc | 26.10 | bc | 21.40 | f |
| $K_2S_3V_1$ | 193.20 | a | 16.07 | ef | 11.10 | h | 9.00 | i |
| $K_2S_3V_2$ | 112.60 | f | 37.20 | ab | 26.10 | bc | 21.90 | d |
| $K_3S_1V_1$ | 66.73 | l | 40.07 | ab | 26.47 | b | 21.97 | d |
| $K_3S_1V_2$ | 192.40 | a | 24.63 | cde | 11.77 | g | 8.64 | k |
| $K_3S_2V_1$ | 108.60 | fg | 30.00 | bcd | 26.40 | b | 22.38 | c |
| $K_3S_2V_2$ | 187.40 | b | 15.20 | ef | 9.82 | jk | 8.35 | l |
| $K_3S_3V_1$ | 86.30 | J | 40.53 | ab | 23.80 | e | 19.74 | g |
| $K_3S_3V_2$ | 177.70 | c | 14.40 | ef | 10.40 | i | 8.84 | j |
| SE value | 7.68 | | 3.43 | | 0.11 | | 0.04 | |
| CV (%) | 9.68 | | 9.14 | | 6.13 | | 6.35 | |

5% Level of significance , ns = Non significance ,

$K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ , $V_1$= BRRI Dhan 80 ,

$K_2$= 65 kg MoP ha$^{-1}$ , $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ , $S_3$= 55 kg Gypsum ha$^{-1}$

### 4.8.3 Effect of variety

Among the traits made, number of unfilled grains panicle$^{-1}$ plays a vital role in yield reduction. Results showed that variety had significant effect in respect of the number of unfilled grains panicle$^{-1}$ (Table 6). BRRI Dhan 34 produced minimum number (26.17) of unfilled grains panicle$^{-1}$ and BRRI Dhan 80 produced maximum number (32.852) of unfilled grains panicle$^{-1}$ and this variation might be due to genetic characteristics. BINA (1993) and Chowdury *et al.* (1993) also reported differences in number of unfilled grains panicle$^{-1}$ due to varietal differences.

### 4.8.4 Interaction effect of variety and level of potassium

Interaction of variety and level of potassium had significant effect on unfilled grains panicle$^{-1}$ (Table 6). From the (table 6). it was observed that minimum (36.87) unfilled grains panicle$^{-1}$ was observed from $K_3V_1$ which was statistically similar to $K_1V_2$ and $K_2V_1$ maximum (41.48) unfilled grains panicle$^{-1}$ from $K_1V_1$ which was statistically similar to $K_3V_1$ and $K_3V_2$.

### 4.8.5 Interaction effect of variety and level of sulphur

Interaction of variety and level of sulphur showed significant response on unfilled grains panicle$^{-1}$ (Table 7). From the table it was observed that minimum (24.68) unfilled grains panicle$^{-1}$ was observed from $S_2V_2$ and maximum (35.87) unfilled grains panicle$^{-1}$ from $S_1V_1$.

### 4.8.6 Interaction effect of level of potassium and level of sulphur

Interaction of level of potassium and levels of S fertilizer showed a significant response on unfilled grains panicle$^{-1}$ (Table 7). Numerically minimum (22.6) unfilled grains panicle$^{-1}$ was found from the combination of $K_3S_2$ and maximum (34.85) unfilled grains panicle$^{-1}$ was found from the combination $K_1S_2$.

### 4.8.7 Interaction effect of variety, level of potassium and level of sulphur

Interaction effect of variety, level of potassium and level of sulphur on unfilled grains panicle$^{-1}$ showed significant response, in all respect of combination and it was ranged from 11.20 to 45.57 unfilled grains panicle$^{-1}$ (Table 8). Minimum (11.20) from $K_2S_2V_1$combination and maximum (45.57) unfilled grains panicle$^{-1}$ was found from $K_1S_1V_1$ combination.

## 4.9 1000-grain weight(g)

### 4.9.1 Effect of level of potassium

Weight of 1000 grain was not significantly influenced by the level of potassium (Table 6). The heaviest (18.93 g) 1000-grain weight was found under the transplanting $K_2$ treatment and the lowest (17.97 g) 1000-grain weight was found at $K_1$ treatment. The results showed that 1000 grain weight was declined with increasing level of potassium (Table 6).

### 4.9.2 Effect of level of sulphur

There was no significant variation in 1000-seed weight due to different level of S (Table 5). The weight of 1000-grain was 17.89 g and 18.69 g for $S_3$ and $S_1$, respectively. The 1000-grain weight of rice is more or less a stable genetic character (Yoshida, 1981).Rahman *et al*. (2009) reported that 1000-grain weight of BRRI dhan41 significantly increased for S application.

### 4.9.3 Effect of variety

Variety had significant effect on 1000-grain weight (Table 6). From the (Table 5), it was revealed that 1000-grain weight of BRRI Dhan 80 much heavier (20.93 g) than that of BRRI Dhan 34 (15.743 g), which is attributed to bold and larger grain size of this variety. This result is an agreement with the findings of Rafey *et al.* (1989) who stated that weight of 1000-grain differed due to the varietal differences.

#### 4.9.4 Interaction effect of variety and level of potassium

Interaction effect of variety and level of potassium on 1000-grain weight was observed significant (Table 7) and the heaviest (26.4g) 1000-grain weight was found in the combination of $K_2V_1$.

#### 4.9.5 Interaction effect of variety and level of sulphur

Interaction of variety and different levels of S was showed significant on 1000-grain (Table 7). It was ranged between 21.27 to 15.5g. The heaviest (21.27 g) 1000-grain weight was obtained from $S_2V_1$ and the lowest (15.5g) was obtained from $S_3V_2$. Rahman *et al*. (2009) reported that 1000-grain weight of BRRI dhan41 significantly increased for S application.

#### 4.9.6 Interaction effect of level of potassium and level of sulphur.

Level of potassium and source of S fertilizer had insignificant interaction effect on 1000-grain weight (Table 7). Numerically the highest (19.18 g) 1000 grain weight obtained from $K_2S_2$ and the lowest (17.1 g) was from $K_3S_3$.

#### 4.9.7 Interaction effect of variety, level of potassium and level of sulphur

Interaction of variety, level of potassium and levels of S fertilizer had significant effect on 1000 grain weight (Table 8). The highest (23.33 g) 1000-grain weight obtained from $K_2S_2V_1$ and the lowest (8.39 g) 1000-grain weight obtained from $K_1S_2V_2$.

### 4.10 1000-kernel weight(g)

#### 4.10.1 Effect of level of potassium

Weight of 1000 kernel was not significantly influenced by the level of potassium (Table 6). The heaviest (15.52 g) 1000-kernel weight was found under the transplanting $K_2$ treatment and the lowest (14.99 g) 1000-kernel weight was found at $K_3$ treatment. The results showed that 1000 kernel weight was declined with increasing level of potassium (Table 6).

### 4.10.2 Effect of level of sulphur

There was no significant variation in 1000-grain weight due to different levels of S (Table 6). The weight of 1000-grain was 15.04 g and 15.7 g for $S_3$ and $S_1$, respectively. The 1000-kernel weight of rice is more or less a stable genetic character (Yoshida, 1981) .

### 4.10.3 Effect of variety

Variety had significant effect on 1000-kernel weight (Table 6). From the (Table 5), it was revealed that 1000-kernel weight of BRRI Dhan 80 much heavier (17.55 g) than that of BRRI Dhan 34 (13.07 g), which is attributed to bold and larger kernel size of this variety.

### 4.10.4 Interaction effect of variety and level of potassium

Interaction effect of variety and level of potassium on 1000-kernel weight was observed significant (Table 7) and the heaviest (22.20g) 1000-kernel weight was found in the combination of $K_2V_1$. The lowest (8.611g) 1000-kernel weight was found in the combination of $K_3V_2$.

### 4.2.10.5 Interaction effect of variety and level of sulphur

Interaction of variety and different levels of S was showed significant on 1000-kernel (Table 7). It was ranged between 12.71 to 18.14 g. the heaviest (18.14g) 1000-kernel weight was obtained from $S_2V_1$ and the lowest (12.71 g) was obtained from $S_2V_2$.

### 4.10.6 Interaction effect of level of potassium and level of sulphur.

Level of potassium and source of S fertilizer had insignificant interaction effect on 1000-kernel weight (Table 7). Numerically the highest (15.95 g) 1000 kernel weight obtained from $K_2S_2$ and the lowest (14.29g) was from $K_3S_3$.

### 4.10.7 Interaction effect of variety, level of potassium and level of sulphur

Interaction of variety, level of potassium and levels of S fertilizer had significant effect on 1000 kernel weight (Table 8). The highest (23.33 g) 1000-kernel weight obtained from $K_2S_2V_1$ and the lowest (8.347 g) 1000-kernel weight obtained from $K_3S_2V_2$

## 4.11 Grain yield

### 4.11.1 Effect of level of potassium

Grain yield was not significantly influenced by the level of potassium (Table 9). The highest (4.30 t $ha^{-1}$) grain yield was found with $K_2$ treatment and the lowest (4.23 t $ha^{-1}$) grain yield was found with $K_1$.

### 4. 11.2 Effect of level of sulphur

Grain yield affected significantly due to the levels of S-fertilizer (Table 9). The higher (4.35t $ha^{-1}$) grain yield by $S_2$ treatment indicated its superiority over the treatment of $S_3$ (4.21 t $ha^{-1}$). Mrinal and Sharma (2008) reported that grain yield of rice increased significantly with increasing levels of sulphur up to 30 kg S $ha^{-1}$. Rahman *et al*. (2009) reported that grain yield of BRRI dhan41 significantly responded to different levels of S. Jawahar and Vaiyapuri (2011) reported that sulphur at 45 kg $ha^{-1}$ produced the higher grain yield of rice.

### 4.11.3 Effect of variety

Grain yield is a function of interplay of various yield components such as number of productive tillers, grains $panicle^{-1}$ and 1000-grain weight (Hassan *et al.*, 2003). In present experiment variety had significant effect on grain yield (Table 9). It was evident from (Table 9) that BRRI Dhan 80 produced higher (4.39 t $ha^{-1}$) grain yield which was contributed from higher number of effective tiller $hill^{-1}$, and more weight of 1000-grain than BRRI Dhan 34 (4.15 t $ha^{-1}$). Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1988) and IRRI (1978) who recorded variable grain yield among tested varieties. The probable reason for variation in yield due to the heredity of the variety.

**Table 9. Effect of variety, level of potassium and level of potassium on the grain yield, straw weight hill$^{-1}$, harvest index, protein content and grain 2-AP of aman rice**

| Treatments | Grain yield (t ha$^{-1}$ ) | Straw weight hill$^{-1}$ (g) | Harvest index (%) | Protein content (%) | Grain 2-AP (µg g-1) |
|---|---|---|---|---|---|
| Effect of potassium | | | | | |
| $K_1$ | 4.23b | 73.46ab | 28.41b | 8.05b | 0.91b |
| $K_2$ | 4.3a | 75.94a | 29.11ab | 8.32a | 0.97a |
| $K_3$ | 4.27ab | 71.12b | 30.21a | 8.04b | 0.92b |
| SE value | 0.11 | 1.77 | 1.80 | 0.01 | 0.06 |
| CV% | 11.38 | 10.22 | 5.08 | 10.12 | 6.07 |
| Effect of sulphur | | | | | |
| $S_1$ | 4.25b | 75.32 a | 28.16b | 8.12b | 0.92b |
| $S_2$ | 4.35a | 67.38 b | 31.18a | 8.10b | 0.94a |
| $S_3$ | 0.09 | 77.82 a | 28.39b | 8.19a | 0.93a |
| SE value | NS | 1.44 | 1.92 | 0.01 | 0.02 |
| CV% | 11.38 | 10.22 | 5.08 | 10.22 | 6.07 |
| Effect of variety | | | | | |
| $V_1$ | 4.39a | 70.66b | 28.92b | 8.15a | 0.94a |
| $V_2$ | 4.15b | 76.35a | 29.57a | 8.13a | 0.92b |
| SE value | 0.11 | 1.77 | 0.02 | 0.01 | 0.01 |
| CV% | 9.38 | 8.90 | 5.38 | 7.80 | 4.09 |

5% Level of significance , ns = Non significance ,

$K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ , $V_1$= BRRI Dhan 80 ,

$K_2$= 65 kg MoP ha$^{-1}$ , $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ , $S_3$= 55 kg Gypsum ha$^{-1}$

### 4. 11.4 Interaction effect of variety and level of potassium

Grain yield was significantly influenced by the interaction of variety and level of potassium (Table 10). From (Table 10).The highest (4.71 t $ha^{-1}$) grain yield was observed from the combination of $K_2V_1$ which was statistically similar with the combination $K_1V_1$ and $K_3V_1$. The lowest (3.84 t $ha^{-1}$) was found from the combination of $K_3V_2$ which was statistically similar with the combination of $K_1V_2$ and $K_1V_2$.

### 4. 11.5 Interaction effect of variety and level of sulphur

From the (Table 10). it was evident that interaction of variety and levels of S significantly influenced the grain yield. In case of both varieties superior grain yield was found by the application of 50 kg gypsum/ha. Significant the highest (4.51t $ha^{-1}$) grain yield was found from the combination of $S_2V_1$ and the lowest (3.98 t $ha^{-1}$) from $S_3V_2$.

### 4. 11.6 Interaction effect of level of potassium and level of sulphur

The interaction between number of level of potassium and levels of S-fertilizer produced significant variation on yield (Table 10). Apparently the highest (4.47 t $ha^{-1}$) grain yield was recorded by the treatment combination of $K_2S_2$ which was statistically similar with the combination of $K_1S_3$ and $K_3S_1$.

**Table 10. Interaction effect of variety and level of potassium, variety and level of sulphur, level of potassium and level of sulphur on grain yield, straw weight hill$^{-1}$, harvest index, protein content and grain 2-AP of aman rice**

| Treatments | Grain yield (t ha$^{-1}$ ) | | Straw weight hill$^{-1}$ (g) | | Harvest index (%) | | Protein content (%) | | Grain 2-AP (µg g-1) |
|---|---|---|---|---|---|---|---|---|---|
| Variety and levels of potassium | | | | | | | | | |
| $K_1V_1$ | 4.48 | a | 73.03 | ab | 26.07b | | 8.08 | b | 0.90c |
| $K_1V_2$ | 3.97 | b | 73.88 | ab | 30.75ab | | 8.02 | b | 0.91bc |
| $K_2V_1$ | 4.71 | a | 71.23 | ab | 31.77a | | 8.27 | a | 0.98a |
| $K_2V_2$ | 3.98 | b | 80.66 | a | 26.45bc | | 8.37 | a | 0.95ab |
| $K_3V_1$ | 4.62 | a | 67.71 | b | 28.91ab | | 8.08 | b | 0.93ab |
| $K_3V_2$ | 3.84 | b | 74.52 | ab | 31.50a | | 8.00 | b | 0.91b |
| SE value | 0.19 | | 3.06 | | 1.31 | | 0.02 | | 0.03 |
| CV% | 11.38 | | 10.22 | | 5.08 | | 10.12 | | 6.07 |
| Variety and levels of sulphur | | | | | | | | | |
| $S_1V_1$ | 4.46 | a | 74.83 | ab | 27.45 | b | 8.13b | | 0.91c |
| $S_1V_2$ | 3.99 | b | 75.81 | ab | 28.86 | ab | 8.10ab | | 0.93b |
| $S_2V_1$ | 4.51 | a | 63.8 | c | 31.25 | a | 8.11ab | | 0.95a |
| $S_2V_2$ | 4.23 | ab | 70.96 | bc | 31.11 | a | 8.10a | | 0.93b |
| $S_3V_1$ | 4.43 | a | 73.34 | ab | 28.04 | b | 8.20a | | 0.94b |
| $S_3V_2$ | 3.98 | b | 82.29 | a | 28.73 | ab | 8.19bc | | 0.93b |
| SE value | 0.16 | | 2.5 | | 0.47 | | 0.02 | | 0.02 |
| CV% | 11.38 | | 10.22 | | 5.08 | | 10.22 | | 6.07 |
| levels of potassium and levels of sulphur | | | | | | | | | |
| $K_1S_1$ | 4.06 | d | 79.7 | a | 26.12 | b | 8.08bc | | 0.89b |
| $K_1S_2$ | 4.22 | c | 60.88 | d | 30.97 | ab | 8.02bc | | 0.91bc |
| $K_1S_3$ | 4.41 | a | 79.78 | a | 28.13 | ab | 8.06bc | | 0.93ab |
| $K_2S_1$ | 4.26 | bc | 77.52 | a | 27.69 | ab | 8.23ab | | 0.94ab |
| $K_2S_2$ | 4.47 | a | 71.78 | bc | 30.12 | ab | 8.23ab | | 1.00a |
| $K_2S_3$ | 4.18 | c | 78.53 | a | 29.52 | ab | 8.50a | | 0.97ab |
| $K_3S_1$ | 4.43 | a | 68.75 | c | 30.66 | ab | 8.05bc | | 0.94ab |
| $K_3S_2$ | 4.36 | ab | 69.47 | c | 32.46 | a | 8.05bc | | 0.93bc |
| $K_3S_3$ | 4.03 | d | 75.13 | ab | 27.51 | ab | 8.02c | | 0.91bc |
| SE value | 0.17 | | 2.5 | | 1.40 | | 0.01 | | 0.07 |
| CV% | 11.38 | | 10.22 | | 5.08 | | 10.22 | | 6.07 |

5% Level of significance , ns = Non significance , $k_1$=60 kg MoP ha$^{-1}$, $k_2$= 65 kg MoP ha$^{-1}$,$k_3$= 70 kg MoP ha$^{-1}$,$s_1$=45 kg Gypsum ha$^{-1}$,$s_2$=50 kg Gypsum ha$^{-1}$, $s_3$=55 kg Gypsum ha$^{-1}$,$v_1$= BRRI Dhan 80, $v_2$= BRRI Dhan 34

### 4. 11.7 Interaction effect variety, level of potassium and level of sulphur

It was revealed that the interaction effect of variety, level of potassium and level of sulphur had significant effect on grain yield (Table 11). Maximum (5.04 t $ha^{-1}$) grain yield was obtained from the combination of $K_2S_2V_1$ and the lowest (3.65 t $ha^{-1}$) grain yield was obtained from the combination of $K_3S_3V_2$ which was statistically identical with many other combinations.

## 4.12 Straw yield

### 4.12.1 Effect of level of potassium

Straw yield was not significantly influenced by the different level of potassium (Table 9). Numerically the maximum (75.94 g $hill^{-1}$) straw yield was found with $K_2$ treatment and the minimum (71.12g $hill^{-1}$) straw yield was from $K_3$ treatment. The higher straw yield with four level of potassium was mainly due to higher number of total tillers $hill^{-1}$. The other possible reasons were that they could produce more biomass but mutual shading hampered translocation of enough food materials from body to growing panicles and thus favour the production of more straw instead of grain.

### 4.12.2 Effect of level of sulphur

From the (Table 9). it was found that straw yield was significantly varied due to the levels of S fertilizer. The mean straw yield due to levels of S fertilizer revealed that straw yield was the highest (77.82 g $hill^{-1}$) in $S_3$ treatment. The minimum (67.38 g $hill^{-1}$) straw yield was from $S_2$ treatment.

**Table 11. Interaction effect of variety, level of potassium and level of sulphur on grain yield, straw weight hill$^{-1}$, harvest index, protein content and grain 2-AP of aman rice**

| Treatments | Grain yield (t ha$^{-1}$ ) | | Straw weight hill$^{-1}$ (g) | | Harvest index (%) | | Protein content (%) | | Grain 2-AP (µg g-1) | |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_1S_1V_1$ | 4.31 | a-d | 81.87 | ab | 22.89 | g | 8.11 | ef | 0.89 | ef |
| $K_1S_1V_2$ | 3.8 | cd | 77.53 | ab | 29.36 | a-e | 8.04 | fgh | 0.88 | F |
| $K_1S_2V_1$ | 4.09 | bcd | 62.5 | cde | 28.30 | c-f | 8.04 | fgh | 0.90 | def |
| $K_1S_2V_2$ | 4.34 | a-d | 59.27 | e | 33.63 | a | 8.01 | fgh | 0.91 | c-f |
| $K_1S_3V_1$ | 3.91 | cd | 74.73 | a-d | 27.01 | d-g | 8.10 | ef | 0.92 | c-f |
| $K_1S_3V_2$ | 3.78 | cd | 84.83 | a | 29.25 | a-e | 8.02 | fgh | 0.93 | b-f |
| $K_2S_1V_1$ | 4.2 | a-d | 80.87 | ab | 29.09 | b-e | 8.17 | e | 0.94 | b-f |
| $K_2S_1V_2$ | 4.31 | a-d | 74.17 | a-d | 26.28 | efg | 8.28 | c | 0.93 | b-f |
| $K_2S_2V_1$ | 5.04 | a | 61.4 | de | 33.28 | ab | 8.55 | a | 1.02 | a |
| $K_2S_2V_2$ | 3.91 | cd | 82.17 | ab | 26.97 | d-g | 8.27 | cd | 0.97 | abc |
| $K_2S_3V_1$ | 3.83 | cd | 71.43 | a-e | 32.95 | ab | 8.44 | b | 0.99 | ab |
| $K_2S_3V_2$ | 4.53 | a-d | 85.63 | a | 26.10 | efg | 8.19 | de | 0.95 | b-e |
| $K_3S_1V_1$ | 5.01 | ab | 61.77 | de | 30.39 | a-e | 8.10 | ef | 0.96 | bcd |
| $K_3S_1V_2$ | 3.85 | cd | 75.73 | a-d | 30.92 | a-d | 7.99 | h | 0.91 | c-f |
| $K_3S_2V_1$ | 4.7 | abc | 67.5 | b-e | 32.19 | abc | 8.09 | efg | 0.94 | b-f |
| $K_3S_2V_2$ | 4.02 | cd | 71.43 | a-e | 32.73 | abc | 8.01 | fgh | 0.92 | c-f |
| $K_3S_3V_1$ | 4.41 | a-d | 73.87 | a-d | 24.17 | fg | 8.06 | fgh | 0.90 | def |
| $K_3S_3V_2$ | 3.65 | d | 76.4 | abc | 30.85 | a-d | 7.99 | gh | 0.91 | c-f |
| SE value) | 0.28 | | 4.33 | | 1.33 | | 0.03 | | 0.02 | |
| CV (%) | 11.38 | | 10.22 | | 5.08 | | 10.12 | | 6.07 | |

5% Level of significance , ns = Non significance ,

$K_1$ = 60 kg MoP ha$^{-1}$ $S_1$= 45 kg Gypsum ha$^{-1}$ , $V_1$= BRRI Dhan 80 ,

$K_2$= 65 kg MoP ha$^{-1}$ , $S_2$ = 50 kg Gypsum ha$^{-1}$ $V_2$= BRRI Dhan 34 ,

$K_3$= 70 kg MoP ha$^{-1}$ , $S_3$= 55 kg Gypsum ha$^{-1}$

### 4.12.3 Effect of variety

The straw yield was observed to differ significantly due to varieties (Table 9). It is evident from the experimental results BRRI Dhan 80 produced higher (76.35 g $hill^{-1}$) straw yield compared to BRRI Dhan 34 (70.66 g $hill^{-1}$). The variety BRRI Dhan 80 was tall variety produced higher straw yield compared to dwarf variety BRRI Dhan 34. The result is in agreement with the findings of Panda and Leeuwrik (1971) who reported that the straw yield could be assigned to plant height.

### 4.12.4 Interaction effect of variety and level of potassium

It was evident from the (Table 10). that interaction of variety and level of potassium had significant effect on straw yield. Numerically the highest (80.66 g $hill^{-1}$) straw yield was found from the combination of $K_2V_2$ and the lowest (67.71 g $hill^{-1}$) from the combination $K_3V_1$.

### 4.12.5 Interaction effect of variety and level of sulphur

Interaction effect of variety and levels of S fertilizer was observed significant on straw yield (Table 10). The highest (82.29 g $hill^{-1}$) straw yield was found from the combination of $S_3V_2$ and the lowest (6.07 g $hill^{-1}$) from the combination of $S_2V_1$.

### 4.12.6 Interaction effect of level of potassium and level of sulphur

Straw yield differed significantly due to interaction of numbers of level of potassium and levels of S fertilizer, apparently, the highest (79.7 g $hill^{-1}$) straw yield was obtained from the treatment combination of $K_1S_3$, which was statistically similar with $K_1S_{1,}$ $K_2S_1$ and $K_2S_3$. The lowest one (60.88 g $hill^{-1}$) was from the treatment combination of $K_1S_2$ (Table 10).

### 4.12.7 Interaction effect of variety, level of potassium and level of sulphur

It was observed from the (Table 11). that interaction of variety, level of potassium and levels of S fertilizer had no significant effect on straw yield. The highest (85.63 g $hill^{-1}$) straw yield was found from the combination of $K_2S_3V_2$ and the lowest (59.27 g $hill^{-1}$) from the combination of $K_1S_2V_2$.

### 4.13 Harvest index

#### 4.13.1 Effect of level of potassium

Harvest index was not significantly influenced by the different level of potassium (Table 9). Numerically the maximum (30.21%) harvest index was found with $K_3$ treatment and the minimum (28.41%) harvest index was from $K_1$ treatment.

#### 4.13.2 Effect of level of sulphur

From the (Table 9). it was found that harvest index was significantly varied due to the levels of S fertilizer. The mean harvest index due to levels of S fertilizer revealed that harvest index was the highest (31.18%) in $S_2$ treatment.

#### 4.13.3 Effect of variety

The harvest index was observed to differ significantly due to varieties (Table 9). It is evident from the experimental results BRRI Dhan 34 produced higher (29.57 %) harvest index compared to BRRI Dhan 80 (28.82 %). The minimum (28.16%) harvest index was from $S_1$ treatment.

#### 4.13.4 Interaction effect of variety and level of potassium

It was evident from the (Table 10). that interaction of variety and level of potassium had not significant effect on harvest index. Numerically the highest (31.77%) straw yield was found from the combination of $K_3V_1$ and the lowest (26.07%) from the combination $K_1V_1$.

#### 4.13.5 Interaction effect of variety and level of sulphur

Interaction effect of variety and levels of S fertilizer was observed significant on harvest index (Table 10). The highest (31.25) harvest index was found from the combination of $S_3V_1$ and the lowest (27.45) from the combination of $S_1V_1$.

### 4.13.6 Interaction effect of level of potassium and level of sulphur

Harvest index differed significantly due to interaction of numbers of level of potassium and levels of S fertilizer, apparently, the highest (32.46%) harvest index was obtained from the treatment combination of $K_2S_2$,. The lowest one (26.12%) was from the treatment combination of $K_1S_1$ (Table 10).

### 4.13.7 Interaction effect of variety, level of potassium and level of sulphur

It was observed from the (Table 11) that interaction of variety, level of potassium and levels of S fertilizer had significant effect on harvest index. The highest (33.63%) harvest index was found from the combination of $K_1S_2V_1$ and the lowest (22.89%) from the combination of $K_1S_2V_2$.

## 4.14 Protein content

### 4.14.1 Effect of level of potassium

Protein content was not significantly influenced by the different level of potassium (Table 9). Numerically the maximum (8.32%) Protein content was found with $K_2$ treatment and the minimum (8.04) protein content was from $K_3$ treatment.

### 4.14.2 Effect of level of sulphur

From the (Table 9). it was found that Protein content was significantly varied due to the levels of S fertilizer. The mean protein content due to levels of S fertilizer revealed that protein content was the highest (8.19%) in $S_3$ treatment. The minimum (8.10%) Protein content was from $S_2$ treatment.

### 4.14.3 Effect of variety

The Protein content was observed to differ significantly due to varieties (Table 9). It is evident from the experimental results BRRI Dhan 80 produced higher (8.15%) protein content compared to BRRI Dhan 34 (8.13%).

### 4.14.4 Interaction effect of variety and level of potassium

It was evident from the (Table 10). that interaction of variety and level of potassium had significant effect on protein content. Numerically the highest (8.37%) protein content was found from the combination of $K_2V_2$, which was statistically similar with $K_2V_1$ and the lowest (8.08 %) from the combination $K_3V_1$.

### 4.14.5 Interaction effect of variety and level of sulphur

Interaction effect of variety and levels of S fertilizer was observed significant on Protein content (Table 10). The highest (8.20 %) protein content was found from the combination of $S_3V_1$ and the lowest (8.10%) from the combination of $S_1V_2$.

### 4.14.6 Interaction effect of level of potassium and level of sulphur

Protein content differed significantly due to interaction of numbers of level of potassium and levels of S fertilizer, apparently, the highest (8.50%) Protein content was obtained from the treatment combination of $K_2S_3$. The lowest one (8.02%) was from the treatment combination of $K_1S_2$ (Table 10).

### 4.14.7 Interaction effect of variety, level of potassium and level of sulphur

It was observed from the (Table 11). that interaction of variety, level of potassium and levels of S fertilizer had no significant effect on protein content. The highest (8.55%) Protein content was found from the combination of $K_2S_2V_1$and the lowest (7.99%) from the combination of $K_3S_1V_2$.

## 4.15 Grain 2- AP

### 4.15.1 Effect of level of potassium

Grain 2- AP was not significantly influenced by the different level of potassium (Table 9). Numerically the maximum (0.97) grain 2-AP was found with $K_2$ treatment and the minimum (0.91) protein content was from $K_3$ treatment.

### 4.15.2 Effect of level of sulphur

From the (Table 9). it was found that grain 2-AP was significantly varied due to the levels of S fertilizer. The mean grain 2-AP due to levels of S fertilizer revealed that grain 2-AP was the highest (0.94) in $S_2$ treatment. The minimum (0.91) grain 2-AP was from $S_1$ treatment.

### 4.15.3 Effect of variety

The grain 2- AP was observed to differ significantly due to varieties (Table 9). It is evident from the experimental results BRRI Dhan 80 produced higher (0.94) grain 2- AP compared to BRRI Dhan 34 (0.92).

### 4.15.4 Interaction effect of variety and level of potassium

It was evident from the (Table 10). that interaction of variety and level of potassium had not significant effect on grain 2-AP. Numerically the highest (0.98) grain 2-AP was found from the combination of $K_2V_1$, and the lowest (0.90) from the combination $K_1V_1$.

### 4.15.5 Interaction effect of variety and level of sulphur

Interaction effect of variety and levels of S fertilizer was not observed significant on grain 2-AP (Table 10). The highest (0.95) grain 2-AP was found from the combination of $S_2V_1$ and the lowest (0.91) from the combination of $S_1V_1$.

### 4.15.6 Interaction effect of level of potassium and level of sulphur

Grain 2-AP differed no significantly due to interaction of numbers of level of potassium and levels of S fertilizer, apparently, the highest (0.99) grain 2-AP was obtained from the treatment combination of $K_2S_2$. The lowest one (0.89) was from the treatment combination of $K_1S_1$ (Table 10).

### 4.15.7 Interaction effect of variety, level of potassium and level of sulphur

It was observed from the (Table 11). that interaction of variety, level of potassium and levels of S fertilizer had n significant effect on grain 2-AP. The highest (1.02) grain 2-AP was found from the combination of $K_2S_2V_1$ and the lowest (0.88) from the combination of $K_1S_1V_2$.

## Chapter V

# SUMMERY AND CONCLUSIONS

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December, 2019 with a view to find out the improvement of yield and aromatic quality of fragrant rice through supplementation of potassium and sulphur in Aman season. The experimental treatments included two T. *aman* rice varieties *viz*., BRRI Dhan 80 and BRRI Dhan 34 variety, three levels of potassium *viz*., $K_1$= 60 kg MoP $ha^{-1}$, $K_2$= 65 kg MoP $ha^{-1}$, $K_3$= 70 kg MoP $ha^{-1}$, and three levels of sulphur *viz*., $S_1$= 45 kg Gypsum $ha^{-1}$, $S_2$= 50 kg Gypsum $ha^{-1}$, $S_3$= 55 Gypsum $ha^{-1}$. The experiment was laid out in a split-split plot design with three replications. There were 18 treatments combinations. The total numbers of unit plots were 54. The size of unit plot was 2 m x 1.25 m = 2.50 $m^2$.

The data on plant height was recorded at 20, 40, 60 and at harvest stage yield as well as yield contributing characters like number of effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, percent filled and unfilled grains, 1000-grain weight, 1000-kernel weight, grain and straw yield were recorded after harvest. Finally grain $m^2$ were recorded and converted to t $ha^{-1}$ and analyses using the MSTAT-C computer package program developed. The mean differences among the treatments were compared by Duncan`s new Multiple Range Test (DMRT) test at 5 % level of significance.

Results of the experiment showed that variety had difference for all the characters, like plant height, total tillers $hill^{-1}$, SPAD value, total dry matter production, effective tiller $hill^{-1}$, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, 1000-grain weight, and grain yield. BRRI Dhan 80 produced the taller plant (57.78, 94.43, 117.75 and 159.37 cm at 20, 40, 60 DAT and at maturity, respectively). BRRI Dhan 80 was achieved maximum (16.93) tiller, dry matter of 91.39 g hill$^{-1}$, number of effective tiller (16.81), panicle (26.29 cm, 1000-grain weight (20.93 g), 1000-kernel weight (17.55 g). The highest Spade reading of leaf (40.69), number (153.64) grains panicle$^{-1}$ was obtained from BRRI Dhan 80. BRRI Dhan 80 produced minimum number (26.17) of unfilled grains panicle$^{-1}$. BRRI Dhan 80 produced higher (4.39 t ha$^{-1}$) grain yield. BRRI Dhan 34 produced higher (76.35 g hill$^{-1}$) straw yield. BRRI Dhan 80 produced higher (8.15%) protein content and (0.94) grain 2-AP.

Level of potassium had no significant effect on plant height. The tallest plant (58.26, 94.64, 117.5 and 157.70 cm at 20, 40, 60 DAT and at maturity, respectively) was obtained from $K_2$ (65 kg MoP ha$^{-1}$) treatment. The maximum number of tillers hill$^{-1}$ (17.01), Spade value (40.65) was counted from $K_1$ treatment. The maximum TDM was 87.77 g hill$^{-1}$, numbers of effective tiller hill$^{-1}$ (15.27), panicle (26.22cm), filled grains panicle$^{-1}$ (140.3), 1000-grain weight (18.93 g), (15.52 g) 1000-kernel weight recorded $K_2$ treatment. The minimum number (27.47) of unfilled grains panicle$^{-1}$ was counted at $K_2$. The highest (4.30 t ha$^{-1}$) grain yield was found with $K_2$ treatment. The maximum (75.94 g hill$^{-1}$) straw yield was found with $K_2$ treatment. The maximum (8.32%) Protein content and (0.97) grain 2-AP was found with $K_2$ treatment.

There was no significant effect at 20, 40, 60 DAT and at maturity on plant height due to the level of sulphur. The tallest plant (57.18, 94.87, 117.5, 157.3 at 20, 40, 60 DAT and at maturity, respectively) was recorded from $S_2$ (50 kg Gypsum/ha) treatment. The maximum number of tillers hill$^{-1}$ (17.33), Spade value (40.82), 1000-grain (18.69 g), 1000-grain was 15.7 g was counted from $S_1$ treatment. The highest numbers of effective tiller hill$^{-1}$ (15.33), panicle (26.13 cm), number of filled grains panicle$^{-1}$ (142.5) was counted $S_2$ treatment. The minimum (28.67) unfilled grains panicle$^{-1}$ was obtained from the application of 50 kg Gypsum ha$^{-1}$. The highest (4.35t ha$^{-1}$) grain yield was obtained from $S_2$ treatment. The straw yield was the highest (77.82 g hill$^{-1}$) in $S_3$ treatment. The protein content was the highest (8.19%) in $S_3$ treatment. The mean grain 2-AP due to levels of S fertilizer revealed that grain 2-AP was the highest (0.94) in $S_2$ treatment

Interaction effect of variety and level of potassium on plant height was found significant at different date of sampling (Table 1). The tallest plant (58.67, 95.07, 120.9, 171.3 cm at 20, 40, 60 DAT and at maturity, respectively) found from $K_2V_1$ treatment. The maximum (19.00) tillers hill$^{-1}$ was found from the combination of $K_1V_2$ treatment. The maximum TDM (95.56 g hill$^{-1}$), productive tiller (17.59), panicle length (26.57 cm), filled grains panicle$^{-1}$ was (185.8), 1000-grain weight (26.4g), (22.20g) 1000-kernel weight found from the combination of $K_2V_1$ treatment. The highest (41.11) Spade value was found in combination $K_1V_1$ treatment. The minimum (36.87) unfilled grains panicle$^{-1}$ was observed from $K_3V_1$. The highest (4.71 t ha$^{-1}$) grain yield was observed from the combination of $K_2V_{1.}$ The highest (80.66 g hill$^{-1}$) straw yield was found from the combination of $K_2V_2$. The highest (8.37%) protein content was found from the combination of $K_2V_{2.}$ the highest (0.98) grain 2-AP was found from the combination of $K_2V_1$.

The tallest plant (57.96, 95.56, 119.5, 159.9 cm at 20, 40, 60 DAT and at maturity, respectively) was found $S_2V_1$. The maximum total number of tillers hill$^{-1}$ (17.81), SPAD value (41.01) was obtained from $S_1V_2$ treatment. The maximum TDM (97.47. g hill$^{-1}$), effective tiller hill$^{-1}$(16.56), panicle length (26.61 cm), 1000-grain weight (21.27 g), (18.14g) 1000-kernel weight was found from the combination of $S_2V_1$. The highest (156.9) filled grains panicle$^{-1}$ was found from the combination of $S_2V_2$. The minimum (24.68) unfilled grains panicle$^{-1}$ was observed from $S_2V_2$. The highest (4.51t ha$^{-1}$) grain yield was found from the combination of $S_2V_1$. The highest (82.29 g hill$^{-1}$) straw yield was found from the combination of $S_3V_2$. The highest (8.20 %) protein content was found from the combination of $S_3V_1$. The highest (0.95) grain 2-AP was found from the combination of $S_2V_{1.}$

It was revealed that at different date of sampling interaction of level of potassium and level of sulphur on plant height showed significantly variation among treatment combination. The $K_2S_2$ treatment produced tallest plant (59.67, 95.6, 118.7, 160 cm at 20, 40, 60 DAT and at maturity, respectively). Maximum (17.87) tillers hill$^{-1}$ was observed from the combination of $K_1S_3$ treatment. The maximum (97.01 g hill$^{-1}$) TDM, numbers of effective tiller hill$^{-1}$ (16.25), length of panicle (26.70 cm), filled grains panicle$^{-1}$(152.9), (19.18 g) 1000 grain weight, (15.95 g) 1000 kernel weight was found from the combination of $K_2S_2$. Numerically the highest Spade value (41.38) was found from the treatment combination of $K_1S_1$. The minimum (22.6) unfilled grains panicle$^{-1}$ was found from the combination of $K_3S_{2.}$ The highest (4.47 t ha$^{-1}$) grain yield was recorded by the treatment combination of $K_2S_2$. The highest (79.7 g hill$^{-1}$) straw yield was obtained from the treatment combination of $K_1S_3$. the highest (8.50%) Protein content was obtained from the treatment combination of $K_2S_3$. The highest (0.99) grain 2-AP was obtained from the treatment combination of $K_2S_2$

Combined interaction effect of variety, P and S was significant influence by all parameter. The tallest plant height (61.00, 96.33, 122.5 and 174.7cm at 20, 40, 60 DAT and at harvest) obtained from $K_2S_2V_1$. , it was observed that total tillers hill$^{-1}$ numerically maximum (20.97) comes from the combination of $K_1S_3V_2$ treatment. The numerically maximum (105.9 g hill$^{-1}$) TDM, effective tillers hill$^{-1}$(19.4), 1000-grain weight (23.33 g), (23.33 g) 1000-kernel weight were found from the combination of $K_2S_2V_1$. Numerically the highest (41.92) Spade value was found from the combination of $K_1S_1V_1$. The highest (27.6 cm) panicle length was observed from the combination of $K_1S_2V_{2.}$. The highest (197.00) filled grains panicle$^{-1}$ was found from the combination of $K_2S_2V_2$. Minimum unfilled grains (11.20) were found from $K_2S_2V_1$ combination. Maximum (5.04 t ha$^{-1}$) grain yield was obtained from the combination of $K_2S_2V_1$. The highest (85.63 g hill$^{-1}$) straw yield was found from the combination of $K_2S_3V_2$. The highest (8.55%) Protein content was found from the combination of $K_2S_2V_1$. The highest (1.02) grain 2-AP was found from the combination of $K_2S_2V_1$.

It may be concluded that BRRI Dhan 80 with 65 kg MoP $ha^{-1}$ and 50 kg Gypsum $ha^{-1}$ along with recommended dose of other fertilizers may be used for producing good quality aromatic rice. However, to reach a specific conclusion and recommendation, more research work on aromatic variety, K and S fertilizer should be done over different Agro-ecological zones.

# REFERENCES

Akinwale, M.G., Gregorio, G., Nwilene, F., Akinyele, B.O., Ogunbayo, S.A., Odiyi, A.C. and Shittu, A. (2011). Comparative performance of lowland hybrids and inbred rice varieties in Nigeria. *Int. J. Plant Breeding and Gen*. **5**(3): 224–234.

Akram, M., Rehman, A., Ahmad, M. and Cheema, A.A. (2007). Evaluation of rice hybrids for yield and yield components in three different environments. *J. Ani. Plant Sci*. **17**(3–4): 70–75.

Alam, M.M., Hasanuzzaman, M. and Nahar, K. (2009). Growth pattern of three high yielding rice varieties under different phosphorus levels. *Advances in Biol. Res*. **3**(3–4): 110–116.

Alam, M.S., Baki, M.A., Sultana, M.S., Ali, K.J. and Islam, M.S. (2012). Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant aman rice. *Int. J. Agri. Agril. Res*. **2**(12): 10–15.

Alamdari, M.G., Rajurkar, N.S., Patwardhan, A.M. and Mobasser, H.R. (2007). The effect of sulfur and sulfate-fertilizers on Zn and Cu uptake by the rice plant (*Oryza sativa*). *Asia J. Plant Sci*., **6**(2): 407-410.

Anonymous (2005). Encarta Reference Library ( 2005). 1993-2004 Microsoft Corporation.

Ashrafuzzaman, M., M.R. Islam, M.R. Ismail, S.M. Shahidullah and M.M. Hanafi. (2009). Evaluation of six aromatic rice varieties for yield and yield contributing characters. *Int. J. Agri. Biol*. 11: 616–620.

BRRI (Bangladesh Rice Research Institute ).(2011). Adhunik Dhaner Chash( In Bangla) 16$^{th}$ Edition.Joydebpur, Gazipur, Bangladesh.

BBS(Bangladesh Bureau of Statistics ).(2020).Statistical Year Book Bangladesh 2020. 40th Edition . Dhaka , Bangladesh.

Baset Mia, M.A. and Shamsuddin, Z.H. (2011). Physio–morphological appraisal of aromatic fine rice (*Oryza sativa* L.) in relation to yield potential. *Int. J. Botany*. **7**(3): 223–229.

Basumatary, A. and Talukdar, M.C. (2007). Integrated effect of sulfur and farmyard manure on yield and mineral nutrition of crops in rapeseed (*Brassica napus*)-rice (*Oryza sativa*) sequence. *Indian J. Agric. Sci.*, **77**(12): 797-800.

Bayes, A. (2013).Research for rich rice. The Daily Star July 30, 2013.

Buttery, R. G., Turnbaugh, J. G. and Ling, L. C. (1988).Contribution of volatiles to rice aroma.*J.Agric*. Food Chem. **36**(5): 1006-1009.

Bhuvaneswari, R., Sriramachandrasekharan, M.V. and Ravichandram, M. (2007). Effect of organics and graded levels of sulfur on rice yield and sulfur use. *Indian J. Interacademicia*. **11**(1): 51-54.

Biswas, B.C., Sarker, M.C., Tanwar, S.P.S., Das, S. and Kaiwe, S.P. (2004). Sulfur deficiency in soils and crop response to sulfur fertilizer in India. Fertilizer News. **49**(10): 13-18.

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

Bohra, J.S. and Doerffling , K. (1993). Potassium nutrition of rice (*Oryza sativa* L.) varieties under NaCl salinity. Plant soil. **152**(2): 299-303.

Cha-um, S., Vejchasarn, P. and Kirdmanee, C. (2005). An Effective Defensive Response in Thai Aromatic Rice Varieties (*Oryza sativa* L. spp. indiK) to Salinity. *J. Crop Sci. Biotech*.**10**(4): 257 – 264.

Din, C., Mehdi, S.M., Sarfraz, M., Hassan, G. and Sadiq, M. (2001). Comparative Efficiency of Foliar and Soil Application of K on Salt Tolerance in Rice. *Pakistan J. Biol.Sci*. **4**(7): 815 – 817.

Dixit, V., Parihar, A. K. S. and Shukla, G. (2012). Effect of Sulphur and Zinc on Yield Quality and Nutrient uptake of Hybrid Rice in Sodic Soil. *J. Agril. Sci. & Tech.*, **1**(2): 74-79.

Fageria, N.K. (2003). Salt tolerance of rice cultivars. Plant Soil. **88**(2): 237-243.

Garba, A.A., Mahmoud, B.A., Adamu, Y. and Ibrahim, U. (2013). Effect of variety, seed rate and row spacing on the growth and yield of rice in Bauchi, Nigeria. *African J.Food, Agri., Nutrition & Development.* **13**(4): 8155.

Haque, M.M., Pramanik, H.R., Biswas, J.K., Iftekharuddaula, K.M. and Hasanuzzaman, M. (2015). Comparative performance of hybrid and elite inbred rice varieties with respect to their source–sink relationship. *The Sci. World J*. 2015: 1–11.

Hossain, M.B., Islam, M.O. and Hasanuzzaman, M. (2008). Influence of different nitrogen levels on the performance of four aromatic rice cultivars. *Int. J. Agri. Biol*. 10: 693696.

Hossaina, M.M., Sultana, F. and Rahmana, A.H.M.A. (2013). A comparative screening of hybrid, modern varieties and local rice cultivar for brown leaf spot disease susceptibility and yield performance. Archives of Phytopathology and Plant Protection. **47**(7): 795–802.

Huda, M.N., Islam, M.R. and Jahiruddin, M. (2004). Evaluation of extractants and critical limits of sulfur in rice soils of Bangladesh. *Asian J. Plant Sci.,* **3**(4): 480-483.

Islam, M. ,Rafiqul, B. A. A., Mustafi, A. and Hossain, M. (1996). Socio-economic aspects of Fine quality rice cultivation in Bangladesh Rice Research Prioritization.

Islam, M.N., Ara, M.I., Hossain, M.M., Arefin, M.S., Hossain, G.M.A. (2006). Effect of different dates of gypsum application on the nutrient content of transplanted Aus rice (BR2). *Intl. J. Sustainable Agril. Technol*., **2**(6): 5-8.

Islam, M.R., Akther, M. Afroz, H. and Bilkis, S. (2013). Effect of nitrogen from organic and inorganic sources on the yield and nitrogen use efficiency of BRRI dhan28. *Bangladesh J.Prog. Sci. and Tech*. **11**(2): 179–184.

Islam, M.S., Hasanuzzaman, M., Rokonuzzaman, M. and Nahar, K. (2009b). Effect of split application of nitrogen fertilizer on morpho–physiological parameters of rice genotypes. *Int. J. Plant production*. **3**(1): 51–62.

Islam, M.S., Peng, S., Visperas, R.M., Bhuiya, M.S.U., Hossain, S.M.A. and Julfiqur, A.W. (2010). Comparative study on yield and yield attributes of hybrid, inbred, and npt rice genotypes in a tropical irrigated ecosystem. *Bangladesh J.Agri. Res*. **35**(2): 343–353.

Islam, M.S.H., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. (2009a). Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net–house during T. aman season. *Bangladesh J.Agri. Res*.**34**(1): 67–73.

Islam, M.T.(2011). Effect of temperature on photosynthesis, yield attributes and yield of aromatic rice genotypes. *Int. J. Sustain. Crop Production*. **6**(1): 14–16.

Jawahar S. and Vaiyapuri, V. (2011). Effect of Sulfur and Silicon fertilization on yield, nutrient uptake and economics of rice. *Int. Res. J. Chem. (IRJC):* **12**(1): 34-43.

Jeng, T.L., Tseng, T.H., Wang, C.S., Chen, C.L. and Sung, J.M. (2009). Yield and grain uniformity in contrasting rice genotypes suitable for different growth environments. Field Crops Research. **99**: 59–66.

Kandil, A.A., Sultan, M.S ., Badawi, M.A., El-Rahman, A.A.A. and Zayed, B.A. (2010). Performance of rice cultivars as affected by irrigation and potassium fertilizer under saline soil conditions. 1-Physiological and chemical characteristics. *Crop Environ*. **1**: 35-38.

Khushik, A.M., Lashari, M.I. and Memon, A. (2011). Performance of rice hybrid and other varieties in Sindh and Balochistan. *J. Agri. Res*.**49**(4): 561–570.

Mahamud, J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted aman rice varieties influenced by seedling densities per hill. *Int. J. Sustain. Agri*. **5**(1): 16–24.

Mannan, M.A., Bhuiya, M.S.U., Akhan, M.I.M. and Rana, M.M. (2012). Influence of date of planting on the growth and yield of locally popular traditional aromatic rice varieties in Boro season. *J. Sci. Foundation*. **10**(1): 20–28.

Marschner H.(1995). Mineral nutrition of higher plants. second edition.pp. 889. London: Academic Press.

Masum, S.M., Ali, M.H. and Ullah, M.J. (2008). Growth and yield of two aman rice varieties as affected by seedling number hill$^{-1}$ and urea super granules. *J. Agri. Education and Tech*. **11**(1&2): 51–58.

Mehdi, S.M., Sarfraz, M. and Hafeez, M. (2007). Response of rice advance line PB-95 to potassium application in saline-sodic soil. *Pak. J. Biol. Sci.* **10:** 2935-2939.

Mrinal, B. and Sharma, S.N. (2008). Effect of rates and sources of sulfur on growth and yield of rice (Oryza sativa) and soil sulfur. *Indian J. Agric. Kyushu Univ*., **24**: 110-118.

Mustafi, B. A. A., Siddique, M. R., Islam, M. R., Ahmed, A. U., Razzaque, M. A. and Billah, K. A. (1993). Economics of low land rice cultivation under different production systems in an area of Bangladesh. *Bangladesh Rice J.* **4**(1&2): 47-53.

Oko, A.O., Ubi, B.E. and Efisue, A.A. (2012). A Comparative Study on Local and Newly Introduced Rice Varieties in Ebonyi State of Nigeria based on Selected Agronomic Characteristics. *Int. J.Agric.and Forestry*.**2**(1): 11–17

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

Panwar, C.S., Vishwakarma, S.K. and Verma, N. (2012). Comparative performance of different rice varieties in relation to growth and yield. Bioinfolet. **9**(4A): 631–632.

Paul,N.C., Pauk,S.K., Salam,M.A. and Paul,S.C.(2021). Dry Matter Partitioning , Yield and Grain Protein Content of Fine Aromatic Boro Rice (cv.BRRI dhan 50) in Response to Nitrogen and Potassium Fertilizer.*Bangladesh J. Bot*. **50**(1):103-111.

Peng, J.G., Zhang, M.Q., Lin, Q., Yang, J. and Zhang, Q.F. (2002). Effect of sulfur on the main cereal and oilseed crops and cultivated soil available S status in Southest Fujian. *Fujian J. Agric. Sci*., **17**(1): 52.

Rahman M.T., Jahiruddin M., Humauan M.R., Alam M.J. and Khan A.A. 2008. Effect of Sulphur and Zinc on Growth, Yield and Nutrient Uptake of Boro Rice (cv. BRRI Dhan29). *J. Soil Nature*. **2**(3): 10-15.

Rahman, M.H., Khatun, M.M., Mamun, M.A.A., Islam, M.Z. and Islam, M.R. (2007). Effect of number of seedling hill$^{-1}$ and nitrogen levels on growth and yield of BRRI dhan32. *J. Soil Nature*. **1**(2): 01–07.

Rahman, R.S., Ahmed, M.U., Rahman, M.M., Islam, M.R. and Zafar, A. (2009). Effect of different levels of sulfur on the growth and yield of BBRI dhan41. *Bangladesh Res. Publ. J*., **3**(1): 846-852.

Roy, S.K., Ali, M.Y., Jahan, M.S., Saha, U.K., Ahmad–Hamdani, M.S., Hasan. M.M. and Alam, M.A. (2014). Evaluation of growth and yield attributing characteristics of indigenous Boro rice varieties. *Life Sci.J.***11**(4): 122–126.

Sarker, B.C., Zahan, M., Majumder, U.K., Islam, M.A. and Roy, B. (2013). Growth and yield potential of some local and high yielding Boro rice cultivars. *J.Agro. and Environ.*. **7**(1): 107–110.

Sen, P., Roy, P. and Bhattacharya, B. (2002). Effect of sulfur application on yield and nutrient uptake in rice mustard cropping system. Fertilizer Marketing Newsl., **33**(6): 9-15.

Shiyam, J.O., Binang, W.B. and Ittah, M.A. (2014). Evaluation of growth and yield attributes of some lowland chinese hybrid rice (*Oryza sativa* L.) varieties in the Coastal Humid Forest Zone of Nigeria. *J.Agri. and Veterinary Sci*. **7**(2): 70–73.

Singh, A.K. and Singh, N.P. (2002). Response of rice to zinc in the soils of Meghalya. Fertilizer Newsl., **47**(8): 53-54.

Singh, A.K., Meena, M.K., and Bharati, R.C. (2011). Sulphur and Zinc Nutrient Management in rice-lentil cropping system. International Conference on "Life Science Research for Rural and Agricultural Development" 27-29 December, 2011, CPRS Patna (Bihar). p. 66-67.

Singh, S.P. and Singh, M.P. (2014). Effect of Sulphur Fertilization on Sulphur Balance in Soil and Productivity of Wheat in a Wheat–Rice Cropping System. *Agric Res*., **3**(4): 284–292.

Sohel, M.A.T., Siddique, M.A.B., Asaduzzaman, M., Alam, M.N. and Karim, M.M. (2009). Varietal performance of transplant aman rice under differnt hill densities. *Bangladesh J.Agri. Res*. **34**(1): 33–39.

Sokoto, M.B. and Muhammad, A. (2014). Response of rice varieties to water stress in Sokoto, Sudan Savannah, Nigeria. *J.Bios. and Medicines.* **2**: 68–74.

Somani, L.L. (2008). Micronutrients for Soil and Plant Health. Agrotech Publishing Academy. p. 14-74.

Sritharan, N. and Vijayalakshmi, C. (2012). Physiological basis of rice genotypes under aerobic condition. Plant Archives. **12**(1): 209–214.

Tiwari, R.J. (1994). Response of gypsum on morphophysiochemical properties of cotton cultivars under salt affected vertisols of Madhya Pradesh. *Crop Res*., **7**: 197-200.

Wiangsamut, B.F., Umnat, P., Koolpluksee, M. and Kassakul, W. (2015). Effects of number of seedlings on growth, yield, cost and benefit of 2 rice genotypes in transplanted fields. *J. Agri. Tech*. **11**(2): 373–389.

Wirnas, D., Mubarrozzah, R.H., Noviarini, M., Marwiyah, S., Trikoesoemaningtyas, Aswidinnoor, H. andjahjo, S.H. (2015). Contribution of genetic x temperature interaction to performance and variance of rice yield in Indonesia. *Int. J. Agron. and Agri. Res. (IJAAR)*. **6**(4): 112–119.

Xue, Z., Meng, C.F., Lu, X., Wu, C.S. and Teng, C.Q. (2002). Effect of applying sulfur fertilizers on rice yield on paddy soils in red soil regions. Hangzhou, China: *Zhejiang Academy of Agril. Sci., Acta Agril. Sci*., **14**(3): 114-149.

Yoshihashi, T., Nguyen, T. T. H. and Kabaki, N. (2004).Area dependency of 2-acetyl-1- pyrroline content in an aromatic rice variety, *KhaoDawk Mali 105*.*JARQ-JPN Agr. Res*. **38**:105–109.

Yang, X. E., Liu, J. X., Wang, W. M., Ye, Z. Q., and Luo A. C. (2004). Potassium internal use efficiency relative to growth vigour potassium distribution and Krbohydrates alloKtion in rice cultivars. *J.Plant Nutrition*, **27**: 837-852.

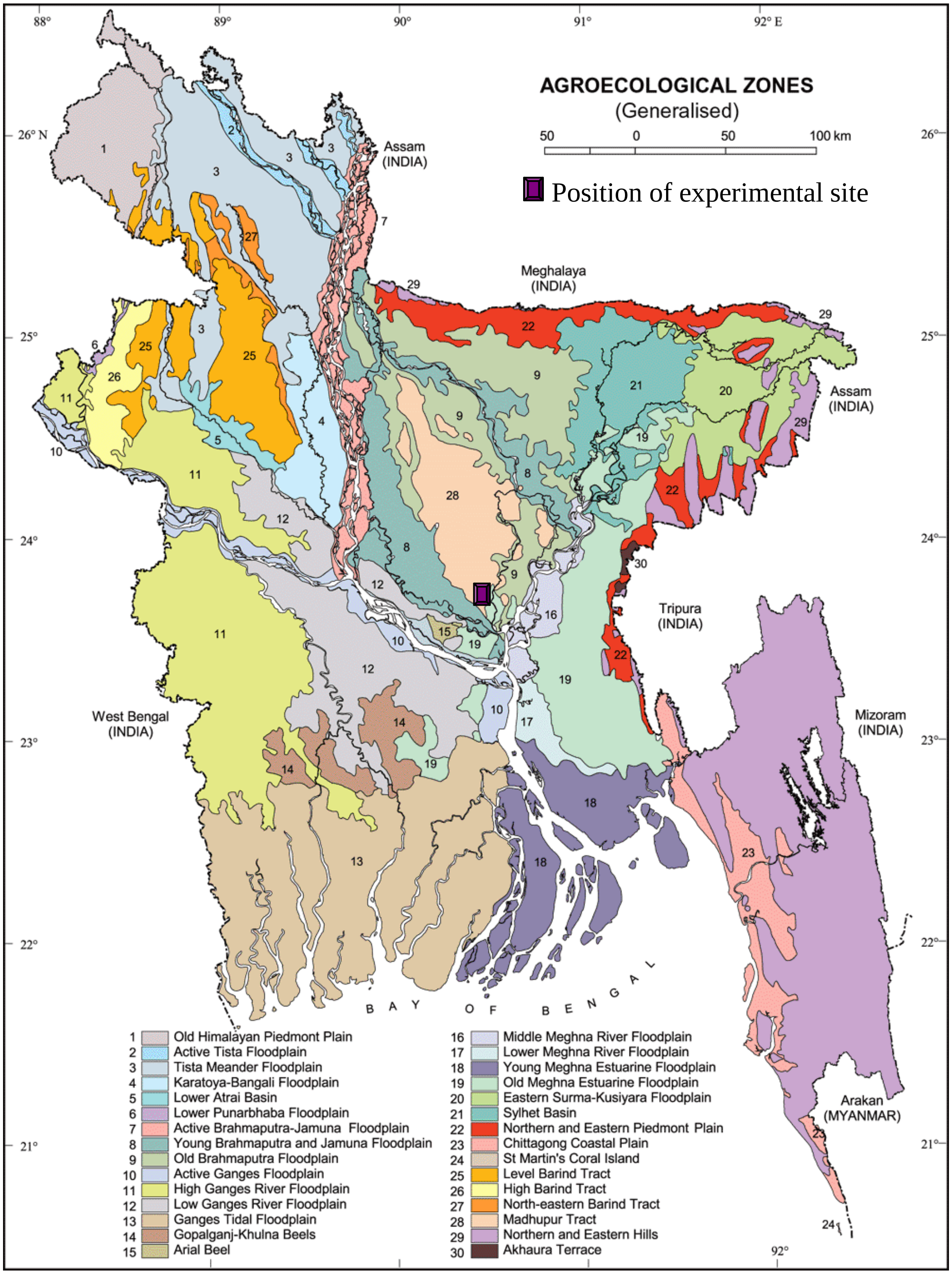
Yao, F., Huang, I., Cui, K., Nie, L., Xiang, I, Liu, X., Wu, W., Chen, M. and Peng, S. (2012). Agronomic performance of high–yielding rice variety grown under alternate wetting and drying irrigation. *Field Crops Research*. **126**: 16–22.

YiMing,L., Lizhong,X., ShenGang,P., Jun,L., Yuan,L. and XiangRu,T.(2014). Effect of Potassium Fertilizer on Aroma and Quality of Aromatic *Rice.Southwest China J.Agri. Sci.* .**27(**3). pp.1147-1153.

Zayed, B.A., Elkhoby, W.M., Shehata, S. . and A mmar, .H. (2007). Role of potassium application on the productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils. *African. Crop Sci. Con. Proc*. **8**: 53-60.

# APPENDICES

## Appendix I. Map showing the experimental site under study



**Appendix II. Weather data, 2019, Dhaka**

| Month | Average RH (%) | Average Temperature ( ºC ) | | Total Rainfall (mm) | Average Sunshine hours |
|---|---|---|---|---|---|
| | | Min. | Max. | | |
| June | 82 | 25.5 | 32.4 | 637 | 4.7 |
| July | 84 | 25.7 | 31.4 | 742 | 3.3 |
| August | 81 | 26.4 | 32.5 | 514 | 4.9 |
| September | 81 | 26.4 | 32.0 | 188 | 3.0 |
| October | 79 | 23.8 | 31.4 | 331 | 5.2 |
| November | 78 | 19.9 | 29.0 | 122 | 5.7 |
| December | 70 | 15.0 | 25.8 | 0 | 5.5 |

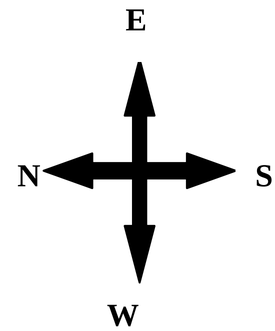
**Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.**

**Appendix III. Physiochemical properties of the initial soil**

| Characteristics | Value |
|---|---|
| Partical size analysis. | |
| % Sand | 26 |
| % Silt | 45 |
| % Clay | 29 |
| Textural class | silty-clay |
| pH | 5.6 |
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.78 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20.00 |
| Exchangeable K (me/100 g soil) | 0.10 |
| Available S (ppm) | 45 |

**Source: Soil Resources Development Institute (SRDI), Dhaka-1207**

**Appendix IV. Layout and design of the experimental plot**




| $R_1$ | | $R_2$ | | $R_3$ | |
|---|---|---|---|---|---|
| | | | | $I_1$ | $I_0$ |
| $K_1S_1V_1$ | $K_2S_2V_2$ | $K_2S_2V_1$ | $K_3S_3V_2$ | $K_1S_1V_1$ | $K_2S_2V_2$ |
| $K_1S_1V_2$ | $K_2S_3V_1$ | $K_3S_2V_2$ | $K_3S_3V_1$ | $K_1S_1V_2$ | $K_2S_3V_1$ |
| $K_1S_2V_1$ | $K_2S_3V_2$ | $K_2S_1V_1$ | $K_3S_2V_2$ | $K_1S_2V_1$ | $K_2S_3V_2$ |
| $K_1S_2V_2$ | $K_3S_1V_1$ | $K_2S_1V_1$ | $K_3S_2V_2$ | $K_1S_2V_2$ | $K_3S_1V_1$ |
| $K_1S_3V_1$ | $K_3S_1V_2$ | $K_1S_3V_2$ | $K_3S_2V_1$ | $K_1S_3V_1$ | $K_3S_1V_2$ |
| $K_1S_3V_2$ | $K_3S_2V_1$ | $K_1S_3V_1$ | $K_3S_1V_2$ | $K_1S_3V_2$ | $K_3S_2V_1$ |
| $K_2S_1V_1$ | $K_3S_2V_2$ | $K_1S_2V_2$ | $K_3S_1V_1$ | $K_2S_1V_1$ | $K_3S_2V_2$ |
| $K_3S_2V_2$ | $K_3S_3V_1$ | $K_1S_2V_1$ | $K_2S_3V_2$ | $K_3S_2V_2$ | $K_3S_3V_1$ |
| $K_2S_2V_1$ | $K_3S_3V_2$ | $K_1S_1V_1$ | $K_2S_2V_2$ | $K_2S_2V_1$ | $K_3S_3V_2$ |

Unit plot size:
1.25 m x 2 m

Factor A:
**Potassium level**
$K_1$= 60 kg MoP ha$^{-1}$ (recommended dose)
$K_2$= 65 kg MoP ha$^{-1}$
$K_3$= 70 kg MoP ha$^{-1}$

Factor B **Sulphur**
$S_1$= 45 kg Gypsum ha$^{-1}$ (recommended dose)
$S_2$= 50 kg Gypsum ha$^{-1}$\
$S_3$= 55 Gypsum ha$^{-1}$

**C. Variety (2)**

$V_1$= BRRI Dhan 80
$V_2$= BRRI Dhan 34

**Appendix V. Analysis of variance of the data on plant height of aman rice as influenced by variety, potassium and sulphur**

| Sources of Variation | Degrees of freedom | Mean Square | | | |
|---|---|---|---|---|---|
| | | plant height | | | |
| | | 20DAT | 40DAT | 60DAT | Harvest |
| Replication | 2 | 49.822 | 25.681 | 161.882 | 22.222 |
| A | 2 | 27.56 | 5.303 | 9.716 | 45.409 |
| Error | 4 | 19.476 | 32.845 | 10.504 | 28.2 |
| B | 2 | 0.684 | 14.725 | 26.196 | 16.915 |
| AB | 4 | 12.661 | 6.636 | 14.518 | 36.226 |
| C | 1 | 32.294 | 9.127 | 73.967 | 513.375 |
| AC | 2 | 35.61 | 12.02 | 136.323 | 3776.431 |
| BC | 2 | 1.27 | 1.509 | 12.181 | 4.181 |
| ABC | 4 | 14.733 | 8.442 | 4.803 | 12.986 |
| Error | 30 | 7.41 | 19.563 | 15.774 | 9.182 |

**Appendix VI. Analysis of variance of the data on total tiller production hill$^{-1}$, Dry weight hill$^{-1}$, Spade value, Effective tiller plant$^{-1}$, panicle length of aman rice as influenced by variety, potassium and sulphur**

| Sources of Variation | Degrees of freedom | Mean Square | | | | |
|---|---|---|---|---|---|---|
| | | Total number of tillers plant$^{-1}$ | Dry weight hill$^{-1}$ (g) | Spade value | Effective tiller plant$^{-1}$ | Panicle length (cm) |
| Replication | 2 | 1.106 | 98.767 | 0.111 | 1.25 | 0.108 |
| A | 2 | 3.007 | 76.847 | 0.093 | 0.062 | 1.553 |
| Error | 4 | 5.531 | 655.302 | 1.953 | 0.576 | 0.068 |
| B | 2 | 12.287 | 498.417 | 0.792 | 0.352 | 0.264 |
| AB | 4 | 4.505 | 424.109 | 3.81 | 4.663 | 0.7 |
| C | 1 | 5.415 | 1311.479 | 0.61 | 51.627 | 3.645 |
| AC | 2 | 46.641 | 111.466 | 5.073 | 97.305 | 1.573 |
| BC | 2 | 1.767 | 1731.303 | 0.231 | 6.587 | 1.042 |
| ABC | 4 | 9.784 | 395.449 | 0.304 | 9.419 | 0.429 |
| Error | 30 | 1.429 | 257.369 | 0.708 | 3.144 | 0.12 |

**Appendix VII. Analysis of variance of the data on Filled grain panicle$^{-1}$, Unfilled grain panicle$^{-1}$, 1000 grain weight and 1000 kernel weight of aman rice as influenced by variety, potassium and sulphur**

| Sources of Variation | Degrees of freedom | Mean Square | | | |
|---|---|---|---|---|---|
| | | Filled grain panicle$^{-1}$ | Unfilled grain panicle$^{-1}$ | 1000 grain weight | 1000 kernel weight |
| Replication | 2 | 15.519 | 14.241 | 0.031 | 0 |
| A | 2 | 105.485 | 135.398 | 4.864 | 1.474 |
| Error | 4 | 270.15 | 41.271 | 0.057 | 0.004 |
| B | 2 | 457.386 | 11.594 | 2.958 | 2.116 |
| AB | 4 | 1050.792 | 115.035 | 1.846 | 1.035 |
| C | 1 | 14048.91 | 603.338 | 363.637 | 270.861 |
| AC | 2 | 45170.87 | 1805.156 | 1367.283 | 1015.53 |
| BC | 2 | 730.189 | 68.476 | 0.792 | 2.691 |
| ABC | 4 | 586.85 | 168.885 | 3.712 | 1.821 |
| Error | 30 | 164.798 | 34.547 | 0.041 | 0.006 |

**Appendix VIII. Analysis of variance of the data on grain yield, straw weight hill$^{-1}$, harvest index, protein content and grain 2-AP of aman rice as influenced by variety, potassium and sulphur**

| Sources of Variation | Degrees of freedom | Grain yield (t ha$^{-1}$ ) | Straw weight hill$^{-1}$ (g) | Harvest index (%) | Protein content (%) | Grain 2-AP (µg g-1) |
|---|---|---|---|---|---|---|
| Replication | 2 | 149.051 | 0.28 | 12.931 | 0.002 | 0.05 |
| A | 2 | 104.917 | 0.026 | 14.845 | 0.442 | 0.018 |
| Error | 4 | 51.361 | 0.218 | 9.698 | 0.003 | 0 |
| B | 2 | 534.921 | 0.097 | 51.118 | 0.044 | 0.003 |
| AB | 4 | 164.601 | 0.253 | 15.87 | 0.052 | 0.003 |
| C | 1 | 437.476 | 0.807 | 5.684 | 0.004 | 0.004 |
| AC | 2 | 86.998 | 2.788 | 125.173 | 0.048 | 0.002 |
| BC | 2 | 78.625 | 0.763 | 2.689 | 0 | 0 |
| ABC | 4 | 192.563 | 0.288 | 15.276 | 0.001 | 0.001 |
| Error | 30 | 57.06 | 0.238 | 5.307 | 0.002 | 0 |