EFFECTS OF DIFFERENT LEVELS OF ARSENIC ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BR-14, BRRI dhan58, BRRI dhan67, BRRI dhan88 AND BRRI dhan92

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF DIFFERENT LEVELS OF ARSENIC ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BR-14, BRRI dhan58, BRRI dhan67, BRRI dhan88 AND BRRI dhan92"** submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL CHEMISTRY**, embodies the result of a piece of *bona fide* research work carried out by **MD. SHEHAB SARKER**, Registration No. 15-06759 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2022

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Dedicated to

My

Beloved Parents

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The Author

ABSTRACT

An experiment was conducted from November 2020 to April 2022 to study the effect of arsenic on the growth, yield and nutrients content of five boro rice varieties *viz*. V_1 (BR-14), V_2 (BRRI dhan58), V_3 (BRRI dhan67), V_4 (BRRI dhan88), and V_5 (BRRI dhan92) which were comprised of five arsenic treatments *viz*. As_0 (control; no arsenic added), As_1 (2 ppm), As_2 (10 ppm), As_3 (20 ppm), and As_4 (40 ppm). In case of single effect, the maximum growth (plant height, leaf length, leaves number, total tillers number) were found in V_3 (BRRI dhan67) variety whereas minimum growth parameters for plant height and leaf length were found in V_5, for leaves number V_4 and total tillers number were found in V_2. The control treatment As_0 (no arsenic) gave the maximum growth that was decreased by increasing of As level. Maximum yield parameters number of grains, number of filled grains, thousand grain weight and grain yield were found in V_2 variety whereas minimum yield parameters (panicle length, number of panicle) were found in V_5 but maximum straw yield was observed in V_1 variety. The control treatment As_0 (no arsenic produced) gave the maximum yield, which was decreased by increasing of As level. In case of combined effect maximum plant height, number of grains per panicle, number of filled grains per panicle, thousand grain weight and grain yield were found from V_3As_0 treatment whereas maximum straw yield obtained from V_1As_0. P and K content decreased with increasing arsenic level but S and As content showed opposite trend. Maximum arsenic content was observed in V_4As_4 treatment whereas minimum in controlled treatment. But considering everything it can be concluded that V_2 (BRRI dhan 58) performed best in terms of grain yield and As effect.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I
INTRODUCTION

The most extensively farmed cereal crop in the world is rice (*Oryza sativa* L.), which is a member of the *Poaceae* family. It is essential to the existence of billions of people worldwide. Rice is the staple food for over half of the world's population. Possibly it is the oldest domesticated grain (~10,000 years), rice approximately 480 million metric tons of milled rice is produced annually (Muthayya *et al*, 2014). About 10% of the planet's arable land is used to grow rice, making it the single greatest food crop. They directly supply more than 50% of all calories consumed by the entire human population. Rice provides 21% of global human per capita energy and 15% of per capita protein (Arya *et al*, 2017). A total of 23–25% of the total calories consumed by humans come through the consumption of rice alone (Ashikari and Ma 2015; Yu *et al*, 2020). Calories from rice are particularly important in Asia, especially among the poor. It is estimated that around 90% and 91% of the world's rice area and production respectively are present in Asia (Dey *et al*, 2019). It is essential to Bangladesh's economy, contributing significantly to GDP, creating jobs, and increasing food availability. Bangladesh can cultivate rice all year round due to ideal geographic, meteorological, and edaphic conditions. Bangladesh has clinched third place in global rice production with an increased output of 36 million metric tons in 2020-21 amid the pandemic situation and COVID-19-induced lockdown (Anonymous, 2020).

In Bangladesh, where there are 165 million people, rice is a basic diet. It provides over 48% of rural employment, about two-thirds of the nation's total calorie supply, and roughly 50% of the average person's protein intake. In Bangladesh, the rice industry generates one-sixth of the country's income and one-half of the agricultural GDP. Rice is the backbone of Bangladesh's agriculture; it alone contributes about 4.5% to the GDP (BBS, 2020). The crop, both politically- and culturally-sensitive, occupies about 78% of annual agricultural land (gross cropped area), and currently in production-surplus feeding about 165 million people (Kabir *et al*., 2015).

There are three distinct classes of rice in Bangladesh; Aus, Aman and Boro, which are cultivated during the period April to July, August to December and January to May, respectively. Among them, boro rice covers about 40.91% of total rice and it contributes to 52.87% of the total rice production (BBS, 2020). Thus, rice plays a vital role in the livelihood of the people of Bangladesh but the national average rice yield (3.21 t ha^{-1}) is very low compared to that of other rice growing countries. For instance, the average rice yield in China is about 6.50t ha^{-1}, Japan is 6.64t ha^{-1} and in Korea is 5.30t ha^{-1} (FAO, 2021).

Food security, specifically achieving self-sufficiency in rice production, is a pressing issue in Bangladesh right now. In such circumstances, increasing rice output can be essential to feed this nation's continually expanding population. The use of contemporary varieties and technologies has made it possible for rice production to increase significantly. The production of rice has increased as a result of these high-yielding rice varieties, but environmental pollution, such as the presence of arsenic in the soil in various concentrations, makes it challenging to produce high yields. Because of its long-term and widespread negative impacts on human health, arsenic is one of the hazardous environmental contaminants that has recently received significant media attention. Although arsenic naturally exists in water, soil, and rocks, some places may have higher concentrations than others. It easily moves up the food chain and can build up significantly in both plants and animals, some of which are consumed by humans. Arsenic's biggest threat to public health comes from tainted ground water. Arsenic is a potent environmental pollutant that has caused one of the largest public health poisonings in the history of human civilization (Islam and Hossain, 2019).

The most common rice cultivation practice is flooded irrigation, and in absence of rains, groundwater is used. The repeated use of As-laden groundwater has resulted in As build-up in soil through the years (Upadhyay et al., 2019). Rice can accumulate As in several-fold higher levels than other cereal crops such as wheat and maize (Williams et al., 2007; Upadhyay et al., 2019). In reducing conditions of flooded paddy fields, arsenite is present in higher concentrations than arsenate (Meharg and Jardine, 2003). Various factors such as pH, redox potential, dissolved organic carbon, organic matter, and biotic factors play a significant role in determining the bioavailability of various As species in the soil system (Majumdar et al., 2018). Rice roots release oxygen, which causes oxidation of Fe^{2+} to Fe^{3}+and leads to the formation of iron plaque at the rice root surface. The adsorption of As by iron plaque increases the rhizospheric concentration of As around rice roots (Zhao et al., 2010; Hu et al., 2019). Further, As itself affects iron plaque formation, and there are also varietal influences on iron plaque formation due to differences in root oxidation abilities of different varieties (Lee et al., 2013).

The transporters involved in the uptake of As and translocation from root to shoot and grains play a crucial role in As build-up in plants. The extensive research conducted to date has resulted in identification of several transporters (Awasthi et al., 2017), such as aquaglyceroporins for As(III) and organic As species (Ma et al., 2008), phosphate transporters for As(V) (Catarecha et al., 2007; Wang et al., 2016), ATP-binding cassette-type transporters for As-thiol complexes (Song et al., 2010, 2014), and inositol transporters and peptide transporter for grain/seed As accumulation (Duan et al., 2015). Furthermore, metabolites and genes/proteins involved in internal As metabolism in plants have also been discovered. To this end, the role of enzymes involved in As(V) to As(III) reduction is important, and these include high As content 1;1/1;2/4 (HAC1;1/1;2/4) (Shi et al., 2016; Xu et al., 2017) in rice. Significant progress has been made in understanding holistic biochemical, proteomic, and transcriptomic changes in response to As stress in plants (Chakrabarty et al., 2009; Srivastava et al., 2019). However, the development of low-As accumulating rice varieties through the use of genes/proteins by employing molecular techniques is not yet feasible. The As accumulation in rice grains varies significantly in different rice varieties (Norton et al., 2009).

Considering the above fact, the present study was carried out with the following objectives:

1. To evaluate the effect of different doses of Arsenic on the growth and yield and nutrient content of rice

2. To find out the effect of Arsenic on P, K, S and As content of BR14, BRRI dhan58, BRRI dhan67, BRRI dhan88, BRRI dhan92 rice varieties.

CHAPTER II

REVIEW OF LITERATURE

Varietal performance is one of the major reasons of yield reduction of rice. So, varieties are the most important factor needed to be considered in rice production. Again, arsenic (As) contamination in paddy soils is one of the most serious problems facing rice production in Asian countries. In Bangladesh, out of 64 districts, 61 districts are reported to have considerable levels of As in groundwater (BGS, 2001). Some of the important and informative works and research findings related to the variety and arsenic effect done at home and abroad have been reviewed under the following headings:

Abou-Khalif (2009) conducted an experiment for physiological evaluation of some hybrid rice varieties in different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were used. Results indicated that H1 hybrid rice variety surpassed other varieties for number of tillers m^{-2}, chlorophyll content, leaf area index, sink capacity, number of grains $panicle^{-1}$, panicle length (cm), 1000-grain weight (g), number of panicles m^{-1}, panicle weight (g) and grain yield (ton ha^{-1}).

According to Sahoo and Mukherjee (2014) arsenic is naturally present in the soil. Its average concentration in non-contaminated soils is 5 mg kg^{-1}; however, the concentration can increase up to 27,000 mg kg^{-1} or more than that in contaminated soil. Arsenic concentration in paddy field occurs naturally via. weathring processes, and/or by anthropogenic activities such as mining, pesticides use, fertilizer application and irrigation with arsenic contaminated groundwater. In the long term, use of this arsenic contaminated irrigation water can cause elevated arsenic concentration in soil and crops.

Ahsan and Del Valls (2011) studied the arsenic concentration of soil in different locations of Bangladesh and reported that arsenic concentration in noncontaminated soils range from 0.1 to 10 mg kg^{-1}. However, the arsenic content in some parts of Bangladesh soils are more than 30 mg kg^{-1}. In Srinagar thana, Bangaldesh, arsenic concentration in top soil layer of paddy field varied 7 to 27.5 mg kg^{-1} whereas at the Sonargaon area of Bangladesh arsenic concentration in the top soil layer of paddy field varied from about 3.2 to 19 mg kg^{-1}. Mean arsenic concentration in soils of two up-zilas (Daudkandi and Begumganj) of Bangladesh was 15.676 ppm which was 1.5 times higher than worldwide natural concentration of 10 ppm. On other hand, in Dhamrai region the level of soil arsenic is 6.10 mg kg^{-1} which is lower than world limit.

Alam and Islam (2011) reported that arsenic contamination resulted in less tillering, shorter plants, uneven plant growth and finally, decreased yield. Land degradation due to continued use of arsenic contaminated irrigation was reported. Due to the application of extra fertilizer and labour, the cost of modern Boro rice production in the more arsenic contaminated plots was 5% higher compared to that in less contaminated plots. Yields of MV (Modern variety) boro rice in more contaminated plots were significantly low resulting in lower gross return and profitability.

Alam and Rahman (2003) selected 21 field sites in Comilla district Bangladesh for analysis of arsenic content in groundwater, soil and rice plant samples. Arsenic content in irrigation groundwater was varied from 62 to 364 ppb while in soil it was ranged from 2.0 to 12.0 mg kg^{-1}. They also reported that arsenic accumulation in rice varies from variety to variety. Arsenic accumulation in rice Purbachi variety was more than the other varieties such as BR 28, BR 29, BR 14 and IR 50. Arsenic was detected in all the grain samples of Purbachi variety of rice tested (0.022 to 0.094 mg kg^{-1}) and in few samples of BR 28 and BR 29 varieties. But no arsenic accumulation was found in the grain samples of BR 14 and IR 50 rice varieties. Root samples were found to have the highest accumulation of arsenic.

Ali *et al*. (2005) analyzed the arsenic concentration in paddy plants collected from Srinagar and Sonargoan site of Bangladesh which were irrigated with arsenic rich irrigation water. They found that plants roots accumulated the higher amount of arsenic followed by stem and then grains. Arsenic concentration in roots of rice plant samples collected from the Srinagar site varied from 2.81 to 16.8 mg kg^{-1} while that in the rice grain varied from 0.05 to 1.52 mg kg^{-1}. For the samples collected from the Srinagar site, arsenic in root varied from 2.88 to 26.1 mg kg^{-1}, while that in the rice grain varied from 0.05 to 1.23 mg kg^{-1}.

Ali *et al*. (2005) studied the arsenic profile of the rice field and canal soil samples collected from Srinagar and Sonargoan site of Bangladesh which was irrigated with arsenic rich irrigation water. They found that arsenic accumulation is the canal samples were relatively high compared to the field samples. Field samples of Srinagar had mean arsenic concentration from 14.5 mg kg^{-1} in top layer and 4.9 mg kg^{-1} in sub soil layer. At the Sonargoan site, the mean arsenic concentration in the top soil layer was 8.9 mg kg^{-1}, while that at the bottom layer was 6.07 mg kg^{-1}. The higher accumulation of arsenic at the Srinagar site is probably partly related to higher arsenic concentration in the irrigation water in Srinagar site.

Anwar and Begum (2010) reported that time of tiller separation of rice significantly influenced plant height, total number of tiller hill^{-1}, number of bearing tillers and panicle length but grain and straw yields were unaffected. Therefore, Sonarbangla-1 appeared to be tolerant to tiller separation and separation should be done between 20 to 40 DAT without hampering grain yield.

Bhattacharya *et al*. (2011) conducted a green pot experiment on four widely cultivated varieties of rice (namely Ratna, IR 50, Gangakaveri and Tulsa) of West Bengal to investigate the uptake and distribution of arsenic phytotoxicity in different fractions of rice plant. 5.0, 10.0, 20.0, 30.0 and 40.0 mg kg^{-1} dry weight of arsenic dosing was applied to study the arsenic phyto toxicity in rice. The result showed that the uptake of arsenic in rice plant varied with the different rice varieties. With the increasing concentration of arsenic added to pot soil, the accumulation of arsenic in rice grain was found to increase, but on necessarily in the same rate. The high yielding rice varieties were found to be higher accumulator of arsenic as compared to the studied local rice variety, Tulsa. Irrespective of rice varieties, arsenic accumulated mostly in the root of the rice plant, followed by accumulation in the straw, husk and grain parts. In most of the rice varieties, the accumulation of arsenic in the rice grain was found to exceed the WHO recommendation permissible limit in rice (1 mg kg^{-1} of dry weight) at 20.0 mg kg^{-1} of arsenic dosing in pot.

Biswas *et al*. (2014) studied the arsenic concentration in rice plant parts grown in different season at West Bengal. The results showed that median arsenic concentration in rice starw grown in summer season was 0.96 mg kg^{-1}, while in winter it was 0.85. Similarly, the median arsenic concentration in rice husk was 0.75 mg kg1 and 0.72 mg kg^{-1} respectively, in summer and winter season. In rice grain arsenic concentration ranged from 0.23 to 0.61 mg kg^{-1} in the summer and 0.16 to 0.38 mg kg^{-1} in winter.

Chamely *et al*. (2015) conducted an experiment with three varieties *viz*., BRRI dhan28 (V_1), BRRI dhan29 (V_2) and BRRI dhan45 (V_3); and five rates of nitrogen to study the effect of variety and rate of nitrogen on the performance of Boro rice. The growth analysis results indicate that the tallest plant (80.88 cm) and the highest number of total tillers $hill^{-1}$ (13.80) were observed in BRRI dhan29 at 70 DATs and the highest total dry matter (66.41 g m^{-2}) was observed in BRRI dhan45. The shortest plant (78.15 cm) and the lowest number of tillers $hill^{-1}$ (12.41) were recorded from BRRI dhan45 and the lowest dry matter (61.24 g) was observed in BRRI dhan29. The harvest data reveal that variety had significant effect on total tillers $hill^{-1}$, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, panicle length, grain yield, straw yield and harvest index. The highest grain yield (4.84 t ha^{-1}) was recorded from BRRI dhan29.

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

Dilday *et al*. (2000) reported that physiological disorder of rice called straighthead is influenced by arsenic which results in blank florets and distorted lemma and palea and in extreme cases, can result in almost a total yield loss. Twelve cultivars were grown in the southern United States among them ten cultivars are more popular and used to observe arsenic responses (i.e. monosodium methanearsenate, MSMA). The most susceptible cultivars to straighthead were Cocodrie, Kaybonnet, Bengal, and Mars at the rate of 6 lb acre^{-1} level of MSMA based on a scale of low to high susceptibility. Arsenic (As) tolerant cultivars also showed strong tolerance against straight head.

Haque *et al.* (2013) conducted an experiment to evaluate some physiological traits and yield of three hybrid rice varieties (BRRI hybrid dhan 2, Heera 2, and Tia) in comparison to BRRI dhan48 in *Aus* season. Compared to BRRI dhan 48, hybrid varieties accumulated greater shoot dry matter at anthesis, higher flag leaf chlorophyll at 2, 9, 16 and 23 days after flowering (DAF), flag leaf photosynthetic rate at 2 DAF and longer panicles. Heera 2 and BRRI hybrid dhan 2 maintained significantly higher chlorophyll a, b ratio over Tia and BRRI dhan 48 at 2, 9, 16 and 23 DAF in their flag leaf. Shoot reserve remobilization to grain exhibited higher degree of sensitivity to rising of minimum temperature in the studied hybrids compared to the inbred. Inefficient photosynthetic activities of flag leaf and poor shoot reserve translocation to grain resulted poor grain filling percentage in the test hybrids. Consequently the studied hybrids showed significantly lower grain yield (36.7%) as compared to inbred BRRI dhan48, irrespective of planting date in *Aus* season.

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.

Howladar *et al*. (2019) carried out a pot experiment with arsenic (As) *viz*. 0, 0.1, 1 and 2 mg L^{-1} as sodium arsenite and phosphorus *viz*, 0, 15 and 30 µg L^{-1} as ammonium dihydrogen phosphate to evaluate their effects on dry matter yield and nutrients concentration in rice plants (*Oryza sativa* L.) in the net house. Arsenic toxicity caused more damage to root than to shoot. As reduced plant height and dry matter yields but lower level increased the same significantly. A maximum diminution of 26.70% shoot weight and 32.30% root weights were observed where 2 mg L^{-1}As and 0 µg L^{-1} P were applied. The lowest concentration of most of the nutrients were found at 2 mg L^{-1} As and 0 µg L^{-1} P.

Huang and Yan (2016) conducted a field test of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred variety. The only inbred Francis in this experiment was used as the check. Results showed that the yields of 7 hybrids were 25.7%-30.7% higher than check Francis. Hybrid 28s/BP23R had the highest yield, 10846.6 kg ha^{-1} and over check by 30.7%. The yield of hybrid 28s/PB-24, was 10628.9 kg ha^{-1} and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg ha^{-1} and over check by 27.1% and 27.0%, respectively. The sterile lines 28s, 29s, 30s and 33A have good combinability. PB2, PB5, PB12, PB22, PB23, PB24, and PB25 are good restorers and most of their hybrids were over check more than 17%.

Hue (2010) carried out a field study to study the total arsenic content in some soil orders, sediments and stream waters of Hawaii. According to him, arsenic levels in Hawaii soils are quite variable, ranging from 15 to 950 mg kg^{-1}. Andisols contains more arsenic (mean 163 mg kg^{-1}) than the other soil orders followed by Oxisols (mean 72 mg kg^{-1}) and Ultisols (mean 60 mg kg^{-1}). He also reported that arsenic level in some stream waters are likely relaetd to arsenic impacted soil.

Huq *et al*. (2006) studied the arsenic content in various rice varieties collected from different districts of Bangladesh. They found that rice variety BR-28 had the maximum arsenic content ranged from 0.1 to 1.8 mg kg^{-1} (mean, 0.81 mg kg^{-1}), depends on the arsenic content in irrigation water and soil. While the average arsenic content of BR-14, IRRI-532 and BR-76 were 0.24, 0.21 and 0.19 mg kg^{-1} of dry weight, respectively.

Islam *et al*. (2004) carried out a pot culture experiment at Bangladesh to see the effects of arsenic irrigation water on Boro rice and then residual effect on Aman rice. There were eight treatments consisting of control, 0.10, 0.25, 0.50, 0.75, 1.00, 1.50 and 2.00 ppm arsenic added through irrigation water. After the harvest of Boro rice, Aman rice (cv. BRRI dhan 33) was grown in the same pot with monsson rain. Nutreint such as N, P, K and S @ 100, 25, 40 and 25 ppm respectively were applied in both the season. Excluding the 0.25 ppm of arsenic concentration in irrigation water, further doses significantly depressed the plant growth, yield and yield components. The concentartion of arsenic in grain and straw in Boro rice increased significantly with increasing arsenic concentration in irrigation water. Application of arsenic added to the first crop also had significant residual effetc on the second crop in respect of growth and yield components. Arsenic concentration were always higher in Boro rice grain and straw compared to Aman rice.

Islam *et al*. (2009) conducted a pot experiments with Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan 31 and BRRI hybrid dhan-l to compare the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. BRRI dhan 3l had about 10-15% higher plant height, very similar tillers $hill^{-1}$, 15-25% higher leaf area compared to Sonarbangla-1. Sonarbangla-1 had about 40% higher dry matter production at 25 DAT but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher root dry weight at 25 DAT, but 5-10% lower root dry weight at 50 and 75 DAT compared to BRRI dhan31. The photosynthetic rate was higher (20 μ mol m^{-2} sec^{-1}) in BRRI dhan3l at 35 DAT (maximum tillering stage) but at 65 DAT, Sonarbangla-l had higher photosynthetic rate of 19.5 μ mol m^{-2} sec^{-1}. BRRI dhan3l had higher panicles $plant^{-1}$ than Sonarbangla-1, but Sonarbangla-1 had higher number of grains $panicle^{-1}$, 1000-grain weight and grain yield than BRRI dhan 31.

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

Jahan *et al*. (2020) conducted a study to elucidate the effect of soil As contamination on rice and its management through water regimes. Two water management practices *viz*. alternate wetting and drying (AWD) and continuous flooding (CF) in combination with different concentration of As (0, 20 and 40 mg kg^{-1}) were initiated as treatment using BRRI dhan47 rice variety. Pots were filled with 10 kg soil with background soil As 3.73 mg kg^{-1}. Results showed that As contamination significantly reduced growth and yield of rice. The grain and straw arsenic concentrations were 0.55 and 17.31 mg kg^{-1}, respectively in soil treated with As 40 mg kg^{-1} while 0.18 mg kg^{-1} grain As and 2.41 mg kg^{-1} straw As were found in As 0 mg kg^{-1} treatment.

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

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

Kabir *et al*. (2016) performed a study in shallow tube well command areas in Faridpur, Bangladesh, where both soil and irrigation water arsenic was high. Both arsenic contaminated irrigation water and the soils were responsible for accumulation of arsenic in rice straw, husk, and grain. The accumulation of arsenic was higher in water followed by soil, straw, husk, and grain. Arsenic concentration varied widely within command areas. The extent and propensity of arsenic concentration were higher in areas where high concentration of arsenic existed in groundwater and soils. The average arsenic content in grain was 0.08–0.45 mg kg^{-1} while in groundwater arsenic level it ranged from 138.0 to 191.3 ppb.

Kamal (2007) conducted an experiment to determine the effect of variety and planting method on the yield of *boro* rice. Four varieties *viz*., BINADHAN-5, BINADHAN-6, BRRI dhan28 and BRRI dhan29, and three planting methods *viz*., transplanting method, drum seeding and line sowing were included as experimental treatments. BINADHAN-5 produced the highest grain yield (4.61 t ha^{-1}) which was the consequence of highest number of effective tillers $hill^{-1}$ and highest number of grains $panicle^{-1}$. In case of effect of interaction of BINADHAN-5 and transplanting method produced the highest grain (5.20 t ha^{-1}) yield.

Khatun (2020) conducted a field experiment with six rice varieties to determine their growth and yield performance. Maximum number of filled spikelet observed in Binadhan-17 (164.89/ penical) and that was significantly different from other varieties. Percent of sterile spikelet was highest in BRRI dhan39 (12.9%) and that was statistically similar with Binadhan-16 (11.96%) and BRRI dhan33 (12.36%). Maximum 1000-seed weight was observed in Binadhan-17 (27.25 g). Highest grain yield was obtained from Binadhan-17 (6.13 t ha^{-1}) that was significantly different from other varieties. Lowest grain yield observed in BRRI dhan39 (4.49 t ha^{-1}) that was statistically similar to BRRI dhan33 (4.57 t ha^{-1}) and Binadhan-7 (4.86 t ha^{-1}).

Masum *et al*. (2014) conducted a study to investigate the influence of population density on growth and yield of inbred and hybrid boro rice. The effect of variety, population density $hill^{-1}$ and their interaction showed significant variation in respect of yield contributing parameters and yield. ACI Hybrid Dhan 2, 2 seedlings $hill^{-1}$ and their combination increased yield attributing parameters, grain and straw yield for *boro* season.

Meharg and Rahman (2002) investigated the arsenic level in rice grains from Bangladesh was done by Three rice grain samples were grown in the regions where arsenic is build up in the soil had high arsenic concentrations having levels above 1.7 µg g^{-1}. These typical grain arsenic levels contributed considerably to 0.1 mg L^{-1} arsenic. Arsenic accumulation in rice can be further elevated in rice growing on arsenic contaminated soils, potentially increasing the risk of arsenic exposure of the Bangladesh population.

Mia (2018) carried out a field experiment consisted of three rice varieties *viz*. (i) V_1 = BRRI dhan45, (ii) V_2 = BRRI dhan63 and (iii) V_3 = BRRI hybrid dhan3 with four Zn application methods *viz*. (i) F_0 = No zinc application, (ii) F_1 = Zn application through root soaking, (iii) F_2 = Zn application through foliar spray and (iv) F_3 = Zn application through soil application. The result revealed that BRRI hybrid dhan3 produced the highest yield (8.47 t ha^{-1}) because of its higher panicle length (23.48 cm), grains $panicle^{-1}$ (100.33), weight of 1000-

seeds (29.33g), straw yield (9.10 t ha^{-1}) and the lowest unfilled grains $panicle^{-1}$ (6.84).

Montenegro and Mejia (2001) conducted field and greenhouse experiments in rice to investigate the effect of irrigation water containing Cd and As on soils and on the physiological parameters of rice growth, the amount of As accrued in different parts of rice plants, and the yield and other aspects of rice crop. The results showed that when none of the element was present in the irrigation waters rice reached its maximum height. Increasing As content of irrigation waters reduced panicles $hill^{-1}$, panicle length and grains per panicle. Significant yield reduction was found when irrigation waters contained the highest concentration of Cd and As. Accumulation of Cd and As was increased in rice plants with the increase of both elements in the irrigation waters.

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

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

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

Patel *et al*. (2016) studied the arsenic concentration in Kaudikasa village of Ambagarh Chowki block, Rajnandgoan Chhattisgarh. They collected 20 ground water irrigation sources and 20 field soil samples and analyzed for arsenic content. They found that arsenic concentration in water varied from 34 to 90 mg L^{-1}. While in soil concentration of arsenic was ranged from 44 – 270 mg kg^{-1} with mean value 126 ± 28 mg kg^{-1}. The arsenic concentration in the soil of studied area was found to be higher than reported in other regions of the country and world (Brammer, 2009).

Patel *et al*. (2016) studied the Distribution of arsenic in rice grain, husk, straw and root. The concentration of arsenic in the rice grain, husk, straw and root (n = 20) was ranged from 0.17 - 0.72, 0.40 - 1.58, 2.5 - 5.9 and 204 - 354 mg kg^{-1} with mean value of 0.47 ± 0.07, 0.83 ± 0.15, 4.2 ± 0.5 and 276 ± 21 mg kg^{-1}, respectively. The arsenic content in husk was found to be higher than the rice grain, may be due to external contamination from the environment. The high yield rice varieties i.e. Kalinga, IR-64, G. Gurmatia, Shyamla, Ek Hazar Das, M2, etc. were found to be more sensitive to the As-accumulation. The concentration of arsenic in the rice of the studied area was found to be higher than reported in the other region of the country and World (Jayasumana *et al*. 2015).

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

Rahman *et al.* (2020) conducted an experiment to study the effects of crop establishment methods on the growth and yield of boro rice. Among the varieties the highest grain yield was obtain in BRRI hybrid dhan3 due to highest number of grains $panicle^{-1}$ and 1000-grain weight. The highest grain yield (6.21 t ha^{-1}) was found in puddle transplanting with BRRI dhan28, while the lowest grain yield (2.80 t ha^{-1}) was produced in dry direct seeding with BRRI dhan28. Therefore, puddle transplanting with BRRI dhan28 might be recommended due to best physiological performance and obtaining highest grain yield of *boro* rice.

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

Salam *et al*. (2019) carried out an experiment in Boro season in two experiment field with the objective of testing agronomic status and adaptability of four modern rice varieties in comparison with the popular mega variety BRRI dhan28. It was observed that germination rate, plant height, effective tiller number were significantly higher in BRRI dhan67 than the other varieties but insignificant with BRRI dhan28 ($p \leq 0.05$). All the yield components spikelets per panicle, filled grain and 1000-grain weight were also significantly higher in BRRI dhan67 in compared to the other varieties. The highest grain yield was observed in BRRI dhan67 in both plots (7.89 and 7.29 t ha^{-1}). Harvest Index of BRRI dhan67 (51.02±4.2, 57.84±8.6)% indicated that this variety is the best yielder among the varieties.

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

Sarkar *et al.* (2016) conducted an experiment to check the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 where inbred BRRI dhan 33 was used as check variety. The highest TDM hill^{-1} (84.0 g), maximum leaf area hill^{-1} (1787cm^2), average highest CGR and RGR (40.63 g m^{-2} d^{-1} and 17.9 mg g^{-1} d^{-1}) were observed Tia and lowest TDM hill^{-1} (70.10 g), minimum leaf area hill^{-1} (1198 cm^2), average lowest CGR and RGR (27.26 g m^{-2} d^{-1} and 13.35 mg g^{-1} d^{-1}) were observed in BRRI dhan 33. These hybrid varieties also showed higher yield attributes *viz.* effective tillers hill^{-1}, 1000-grain weight, biological yield and harvest index (HI) over the inbred. The highest grain yield was achieved from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two hybrid varieties produced 24.0% higher yield over the inbred BRRI dhan 33. Effective tillers hill^{-1} and higher filled grains panicle^{-1} mainly contributed to the higher grain yield of hybrid varieties.

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, Xudao151 came close to FARO 15 with grain yield of 2.987 t ha^{-1}.

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

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.

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

The impact of arsenic contaminated irrigation water on soil arsenic content and rice productivity was studied by Panaullah *et al*. (2009) in the commond area of a single tubewell in Faridpur district, Bangladesh. After 16-17 years of use of the tubewell, a spatially variable build up of arsenic and other chemical constituents of the water (Fe, Mn and P) was observed over the command area, with soil-arsenic levels ranging from about 10 to 70 mg kg^{-1}. A simple mass balance calculation using the current water arsenic level of 0.13 mg L^{-1} suggested that 96 percent of the added arsenic was retained in the soil.

Williams *et al*. (2006) studied the arsenic level in ground water and rice grains in different districts of Bangladesh. They reported that arsenic concentration in groundwater was ranges from 3 to 366 ppb and rice obtained from districts with more contaminated with water (>50 ppb) were more elevated with arsenic than rice from less contaminated districts (<50ppb). They also found that arsenic content in Boro rice (0.15 to 0.38 mg kg^{-1}) could be 1.5 times than higher than the Aman rice (0.11 to 0.32 mg kg^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of arsenic on the growth, yield and nutrients content in straw and grain of rice varieties. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses. The details of experimental materials and methods are described below:

3.1 Site description

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

3.2 Climate

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

3.3 Soil

The soil of the experimental area that used in the pot for rice grown belongs to “The Modhupur Tract”, AEZ 28. Pot soil was silty clay in texture. Soil pH was 5.6 and has organic carbon 0.45%. The experimental site is shown in Appendix III.

3.4 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Variety – 5 varieties of rice

1. V_1 = BR-14
2. V_2 = BRRI dhan58
3. V_3 = BRRI dhan67
4. V_4 = BRRI dhan88
5. V_5 = BRRI dhan92

Factor B: Arsenic (As) doses – 5 doses

1. As_0 = Control (No arsenic)
2. As_1 = 2 mg As kg^{-1} soil
3. As_2 = 10 mg As kg^{-1} soil
4. As_3 = 20 mg As kg^{-1} soil
5. As_4 = 40 mg As kg^{-1} soil

There were total 25 (5×5) combination as a whole *viz.*, V_1As_0, V_1As_1, V_1As_2, V_1As_3, V_1As_4, V_2As_0, V_2As_1, V_2As_2, V_2As_3, V_2As_4, V_3As_0, V_3As_1, V_3As_2, V_3As_3, V_3As_4, V_4As_0, V_4As_1, V_4As_2, V_4As_3, V_4As_4, V_5As_0,V_5As_1, V_5As_2, V_5As_3 and V_5As_4.

3.5 Experimental design and layout

The two factors experiment was laid out in Completely Randomized Design (CRD) with four replications. Thus, a total 100 experimental pots were assigned randomly at the experimental site.

3.6 Growing of crops

3.6.1 Seed collection and sprouting

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

3.6.2 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil.

3.6.3 Raising of seedlings

The sprouted seeds were sown on beds as uniformly as possible at 20 November, 2020. Irrigation was gently provided to the bed when needed. No fertilizer was used in the nursery bed.

3.6.4 Pot preparation

The pot for the experiment was filled up with 5 kg of soil at 20 December, 2020. Weeds and stubble were removed from the soil and finally obtained a desirable condition of soil for transplanting of seedlings.

3.6.5 Fertilizers and As application

The fertilizers N, P, K, S and B in the form of Urea, TSP, MoP, gypsum and borax, respectively were added into the pot. The following doses of fertilizer were applied for cultivation of crop as recommended by BRRI, 2020.

Fertilizer	Recommended doses ha^{-1}
Urea	**150 kg**
TSP	**100 kg**
MoP	**100 kg**
Gypsum	**60 kg**

The fertilizers N, P, K, and S in the form of urea, TSP, MoP, gypsum respectively were applied. The entire amount of TSP, MoP, gypsum were applied during the final pot preparation. Arsenic was applied to the soil during final pot preparation according to the treatment. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation.

3.6.6 Uprooting and transplanting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted in the pot on 6th January, 2021. One seedling was transplanted in each hill and two hills were in each pot. After one week of transplanting all pots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.7 Intercultural operations

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

3.7.1 Irrigation and drainage

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

3.7.2 Weeding

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

3.7.3 Insect and pest control

Furadan 57 EC was applied at the time of final land preparation and later on Malathion was applied as and when necessary.

3.8 Harvesting, threshing and cleaning

Depending on the variety, the crop was harvested after 80-90% of the grains had become straw in colour. The harvested crop was wrapped individually, correctly labelled, and sent to the threshing floor. For each pot, the grains were dried, washed, and weighed. The grains were cleaned and finally the weight was adjusted to a moisture content of 13%. The straw was sun dried and the yields of grain and straw pot^{-1} were recorded.

3.9 Recording of data

The following data were collected during the study period:

3.9.1. Growth characters

1. Plant height (cm)
2. Number of leaves
3. Leaf length (cm)
4. Number of total tillers
5. Number of effective tillers

3.9.2 Yield contributing parameters

1. Panicle length (cm)
2. Number of panicles hill^{-1}
3. Number of grain panicle^{-1}
4. Number of filled grains panicle^{-1}
5. Dry weight of straw hill^{-1} (g)

3.9.3 Yield parameters

1. 1000 grain weight (g)
2. Grain yield hill^{-1} (g)
3. Straw yield hill^{-1} (g)

3.9.4 Nutrient content

1. P, K, S, and As content in grain
2. P, K, S, and As content in straw

3.10 Procedures of recording data

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

3.10.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of harvest. The height was measured from the ground level to the tip of the plant.

3. 10.2 Number of leaves

The number of leaves was recorded at the time of harvest by counting total leaves in a hill.

3. 10.3 Leaf length

Leaf length hill^{-1} was measured in centimeter (cm) using meter scale. The length was measured from the base to the tip of the leaf.

3. 10.4 Number of total tillers

The number of tillers $^{-1}$ was recorded at the time of harvest by counting total tillers in a hill.

3. 10.5 Number of effective tillers

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers plant^{-1}. Data on effective tiller hill^{-1} were counted and value was recorded.

3. 10.6 Panicle length (cm)

The length of panicle was measured with a meter scale from 5 selected panicles and the average value was recorded.

3.10.7 Number of panicles

The number of total panicle per pot were counted.

3. 10.8 Number of grains panicle^{-1}

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

3.10.9 Number of filled grains panicle^{-1}

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

3.10.10 Dry weight hill^{-1}

Dry matter hill^{-1} was recorded at harvest. Collected hill were oven dried at 70°C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into dry matter content hill^{-1}.

3.10.11 Weight of 1000 grain (g)

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 13% moisture and the mean weight was expressed in gram.

3. 10.12 Grain yield

Grain yield was determined from each hill of each pot and expressed as g on 13% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.10.13 Straw yield

Straw obtained from each unit pot were sun-dried and weighed carefully. The dry weight of the straw of each pot was measured.

3.10.14 P, K, S and As content in grain and straw

P and S content in grain and straw were determined by Spectrophotometer. K content in grain and straw was determined by flame emission Spectrophotometer and As content in grain and straw was determined by ICP-MS (Agilent-7850). (BRiCM, Bangladesh Reference Institute for Chemical Measurements, 75 Laboratory Road, Dhaka).

Rice grain and straw were dried in an oven at 70°C to obtain constant weight. Oven-dried grain and straw samples were grounded in a Wiley Hammer Mill passed through 40 mesh screen, mixed well and stored in plastic vials. Exactly 1 g oven-dried samples of rice were taken in digestion tube. About 20 mL of di-acid mixture (2:1) ration of HNO_3 and $HClO_4$ digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at 100°C. The temperature was increased to 200°C gradually to prevent frothing (50°C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating source and allowed to cool to room temperature. About 40 mL of de-ionised water was carefully added to the digestion tubes and the contents filtered through Whatman no. 40 filter paper into a 100 ml volumetric flask and the volume was made up to the mark with de-ionised water. The samples were stored at room temperature in clearly marked containers. After digestion, approximately 100 mL of each digest samples was stored in a plastic bottle for determination of the P. K and S. After that, the percent values were also calculated from concentration of P. K and S. in the samples.

3.11 Statistical analysis

The data collected on different parameters were statistically analyzed with Completely Randomized Design (CRD) using the MSTAT computer package program. The significance of the difference among the treatment means was estimated by the Least Significant Difference Test (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation included the response of different rice varieties to different levels of arsenic (As). The results presented in tables and figures are discussed systematically under the following heads:

4.1 Growth parameters

4.1.1 Plant height

Effect of variety

Plant height was significantly varied due to the varietal difference of rice (Table 4.1). The highest plant height (97.42 cm) was recorded from the variety V_3 (BRRI dhan67) whereas the lowest plant height (85.4 cm) was recorded from the variety V_4 (BR-88). Similar result was also observed by Salam *et al*. (2019) and Singh *et al*. (2019) who observed variation on plant height of rice in varietal difference.

Effect of arsenic

Significant variation was observed on plant height of rice as influenced by different arsenic levels (Table 4.1). Results showed that lower levels of arsenic gave higher plant height and the control treatment As_0 (no arsenic added) gave the maximum plant height (97.43 cm) whereas maximum arsenic level As_4 (40 ppm) showed minimum plant height (83.88 cm). Jahan *et al*. (2020) and Howladar *et al*. (2019) showed similar result with the present study and reported that As contamination significantly reduced plant height of rice.

Table 4.1. **Effect of variety and arsenic on growth parameters of rice**

Treatments	Growth parameters				
	Plant height (cm)	Leaf length (cm)	Number of leaves hill^{-1}	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}
Effect of variety					
V_1	89.97 b	49.08 b	46.45 b	9.90 a	9.73 a
V_2	92.57 ab	41.87 c	44.90 b	7.86 b	7.86 c
V_3	97.42 a	51.07 a	49.10 a	9.00 a	8.90 b
V_4	85.40 c	44.66 b	46.90 b	9.25 a	8.95 b
V_5	83.81 c	39.08 c	46.05 b	9.55 a	8.85 b
$LSD_{0.05}$	8.41	1.39	2.6	2.04	2.04
CV(%)	12.33	14.56	13.21	11.41	12.24
Effect of arsenic					
As_0	97.43 a	51.07 a	49.20 a	19.20 a	10.70 a
As_1	92.57 ab	49.68 a	49.10 a	9.90 b	9.75 a
As_2	89.97 abc	44.67 b	46.45 a	9.55 b	8.95 a
As_3	85.45 bc	41.88 bc	46.05 a	9.25 b	8.90 a
As_4	83.88 c	39.08 c	44.90 a	9.00 b	8.85 a
$LSD_{0.05}$	8.411	4.329	6.621	2.67	2.85
CV(%)	12.33	14.56	13.21	11.41	12.24

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

Combined effect of variety and arsenic

There was a significant variation on plant height of rice due to treatment combination of different rice varieties and arsenic levels (Table 4.2). Data showed that the highest plant height (100.0 cm) was observed from the treatment combination of V_3As_0 which is statistically identical to the treatment combination of V_1As_0, V_3As_1, V_3As_2, V_3As_3, V_5As_0 whereas the lowest plant height (71.25 cm) was observed from the treatment combination of V_4As_4.

Table 4.2. **Combined effect of variety and arsenic on growth parameters of rice**

Treatment combination	Growth parameters				
	Plant height (cm)	Leaf length (cm)	Number of leaves	Number of total tillers	Number of effective tillers
V_1As_0	99.63 a	57.38 a	64.00 a	11.25 ab	11.25abc
V_1As_1	94.25 ab	52.50 abc	52.50 abcd	11.00 ab	10.25 bc
V_1As_2	93.38 abc	49.63 abcde	48.25 bcde	10.00 bc	10.00 bc
V_1As_3	89.00 abcde	46.45 cdef	44.25 defg	8.750 bcd	8.750 bc
V_1As_4	73.63 de	42.45 defg	23.25 h	8.500 bcd	8.500 bc
V_2As_0	95.50 ab	49.75 abcde	63.00 cde	9.250 bcd	9.250 bc
V_2As_1	94.75 ab	47.75 abcdef	47.75 cdef	8.750 bcd	8.25abc
V_2As_2	92.25 abcd	41.00 efgh	43.50 defg	7.750 def	7.750 bc
V_2As_3	90.38 abcd	39.50 fgh	37.25 efgh	7.250 cde	7.00 bc
V_2As_4	90.00 abcde	31.38 hi	33.00 fgh	6.300 cde	6.150 bc
V_3As_0	100.0 a	52.42 abc	62.75 ab	10.00 bcd	10.00 bc
V_3As_1	98.75 a	52.08 abcd	51.75 abcde	10.00 bcd	9.750 bc
V_3As_2	97.25 a	51.95 abcd	48.75 bcde	8.750 cde	8.750 bc
V_3As_3	96.88 a	51.50 abcd	45.25 cdefg	8.250 cde	8.250 bc
V_3As_4	94.25 ab	47.40 bcdef	37.00 efgh	8.000 cde	7.750 bc
V_4As_0	95.13 ab	53.45 abc	64.75 a	12.75 a	12.25ab
V_4As_1	94.50 ab	52.70 abc	59.50 abc	12.25 a	12.25ab
V_4As_2	84.25 abcde	49.38 abcde	42.25 defg	8.750 bcd	8.500 bc
V_4As_3	82.13 abcde	36.05 ghi	32.75 gh	6.750 de	6.750 bc
V_4As_4	71.25 e	31.75 hi	31.00 gh	5.750 e	5.000 c
V_5As_0	96.75 a	56.30 ab	65.00 a	14.25 cde	12.75 ab
V_5As_1	95.38 ab	53.17 abc	51.25 abcde	10.25 bcd	10.00 bc
V_5As_2	77.50 bcde	32.58 hi	45.75 cdefg	8.750 bcd	7.250 bc
V_5As_3	75.00 cde	27.00 i	42.50 defg	7.250 cde	7.250 bc
V_5As_4	74.75 cde	26.38 i	41.50 defg	7.250 cde	7.000 bc
$LSD_{0.05}$	18.81	9.68	14.81	5.97	6.39
CV(%)	12.33	14.56	13.21	11.41	12.24

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

4.1.2 Leaf length

Effect of variety

Significant variation was recorded for leaf length which was influenced by different of rice varieties (Table 4.1). The maximum leaf length (51.07 cm) was recorded from the variety V_3 (BRRI dhan67) whereas the minimum leaf length (39.08 cm) was recorded from the variety V_5 (BRRI dhan92). Similar result was also observed by Mahmood (2019) who found variation in leaf area among the varieties.

Effect of arsenic

Different arsenic levels showed significant variations in the leaf length of rice (Table 4.1). The maximum leaf length (51.07 cm) was found from the control treatment As_0 (no arsenic produced) whereas the minimum leaf length (39.08 cm) was found from the maximum arsenic level As_4 (40 ppm). The lowest amount of arsenic shows the highest length and the highest amount of arsenic content shows the lowest leaf length.

Combined effect of variety and arsenic

Treatment combination of different rice varieties and arsenic levels gave significant influence on leaf length of rice (Table 4.2). Results showed that the maximum leaf length (57.38 cm) was observed from the treatment combination of V_1As_0 and the minimum leaf length (26.38 cm) was observed from the treatment combination of V_5As_4.

4.1.3 Number of leaves

Effect of variety

Different varieties of rice showed a significant variation on number of leaves (Table 4.1). Results showed that the variety V_3 (BRRI dhan67) gave the maximum number of leaves (49.10) whereas the variety V_5 (BRRI dhan92) gave the minimum number of leaves (46.05). The result obtained from the present study was reported significant variation of leaf number due to varietal difference.

Effect of arsenic

Significant differences was observed on number of leaves of rice as influenced by different arsenic levels (Table 4.1). The control treatment As_0 (no arsenic produced) gave the maximum number of leaves (49.20) whereas the lowest number of leaves (44.05) was given by the treatment As_4. This type of result also found in Sarker *et al.* (2013). The lowest amount of arsenic showed the highest number of leaf and the highest amount of arsenic content showed the lowest number of leaf.

Combined effect of variety and arsenic

Significant influence was achieved on number of leaves of rice due to treatment combination of different rice varieties and arsenic levels (Table 4.2). Results indicated that the highest number of leaves (65.00) was observed from the treatment combination of V_5As_0 which was statistically identical to the treatment combination of V_4As_0 and V_1As_0 whereas the lowest number of leaves (23.25) was observed from the treatment combination of V_1As_4.

4.1.4 Number of total tillers

Effect of variety

Significant variation was recorded for number of total tillers which was influenced by different of rice varieties (Table 4.1). Results revealed that the maximum number of total tillers (9.90) was recorded from the variety V_1 (BR-14) whereas the minimum number of total tillers (7.86) was recorded from the variety V_2 (BRRI dhan58). Present study results was also supported by the findings of Rashid *et al*. (2017) and Haque *et al.* (2013); they reported that variety had significant variation on number of tillers $hill^{-1}$.

Effect of arsenic

Different arsenic levels showed a significant variations on a number of total tillers of rice (Table 4.1). The maximum number of total tillers (19.20) was found from the control treatment As_0 (no arsenic produced) and the minimum number of total tillers (9.00) was found from the treatment As_4. The lowest amount of arsenic showed the highest number of total tillers and highest amount of arsenic content showed the lowest number of tillers.

Combined effect of variety and arsenic

Treatment combination of different rice varieties and arsenic levels gave significant influence on number of total tillers of rice (Table 4.2). The maximum number of total tillers (14.25) was observed from the treatment combination of V_5As_0 whereas the minimum number of total tillers (5.75) was observed from the treatment combination of V_4As_4.

4.1.5 Number of effective tillers

Effect of variety

Number of effective tillers was significantly varied due to the varietal differences of rice (Table 4.1). Results indicated that the highest number of effective tillers (9.75) was recorded from the variety V_1 (BR-14) which was followed by V_4 (BRRI dhan88) whereas the lowest number of effective tillers (7.68) was recorded from the variety V_2 (BRRI dhan58). This type of result was also observed by the findings of Chamely *et al*. (2015), Sarker *et al.* (2013) and Abou-Khalif (2009).

Effect of arsenic

Significant variation was observed in a number of effective tillers of rice as influenced by different arsenic levels (Table 4.1). It was observed that the highest number of effective tillers (10.70) was found from the control treatment

As_0 (no arsenic produced) and gradually decreased effective tillers was found with increasing arsenic levels. The lowest number of effective tillers (8.85) was found from the maximum levels of arsenic As_4. Present study results was also supported by the result which also observed by Alam and Islam (2011) who found decreased tillering due to As contamination.

The combined effect of variety and arsenic

There was a significant variation on number of effective tillers of rice due to treatment combination of different rice varieties and arsenic levels (Table 4.2). The highest number of effective tillers hill^{-1} (12.75) was observed from the treatment combination of V_4As_0 which was statistically identical to the treatment combination of V_4As_0 and V_4As_1 whereas V_4As_4 gave the least number of effective tillers (5.00) compared to other treatment combinations.

4.2 Yield contributing parameters

4.2.1 Panicle length (cm)

Effect of variety

Different varieties of rice showed significant variation on panicle length (Table 4.3). Results showed that the variety V_1 (BR-14) and V_3 (BRRI dhan67) gave the maximum panicle length (24.90 cm) and the variety V_5 (BRRI dhan92) gave the minimum panicle length (22.80 cm). Chamely *et al*. (2015) and Islam *et al*. (2013) found similar result, which supported the present study.

Effect of arsenic

Significant variation was observed on panicle length of rice as influenced by different arsenic levels (Table 4.3). The control treatment As_0 (no arsenic produced) gave the maximum panicle length (24.93 cm) which was significantly identical to the arsenic dose of As_2. The lowest panicle length (22.80 cm) was given by the treatment As_4. Montenegro and Mejia (2001) also found reduced panicle length due to As contamination through irrigation water.

Combined effect of variety and arsenic

Significant influence was achieved on panicle length of rice due to treatment combination of different rice varieties and arsenic levels (Table 4.4). Results indicated that the highest panicle length (27.50 cm) was observed from the treatment combination of V_1As_0. The lowest panicle length (21.25 cm) was observed from the treatment combination of V_5As_4.

Table 4. 3. **Effect of variety and arsenic on yield contributing parameters of rice**

Treatments	Yield contributing parameters			
	Panicle length (cm)	Number of panicles	Number of grains panicle^{-1}	Number of filled grain panicle^{-1}
Effect of variety				
V_1	24.90 a	10.00 a	142.64 a	98.27 b
V_2	23.65 b	9.20 a	143.42 a	99.98 a
V_3	24.90 a	8.20 bc	129.66 b	93.55 b
V_4	23.49 a	8.20 bc	127.02 b	83.64 b
V_5	22.80 c	8.35 b	99.48 c	34.69 c
$LSD_{0.05}$	2.07	0.89	13.76	12.61
CV(%)	5.93	7.27	12.12	10.14
Effect of arsenic				
As_0	24.93 a	10.00 a	143.4 a	99.97 a
As_1	24.90 a	9.20 ab	142.6 a	98.28 a
As_2	23.79 ab	8.35 ab	129.7 a	93.57 ab
As_3	23.65 b	8.20 b	127.1 a	83.65 b
As_4	22.80 b	8.20 b	99.47 b	34.69 c
$LSD_{0.05}$	1.157	1.78	17.79	12.61
CV(%)	5.93	7.27	12.12	10.14

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

Table 4.4. **Combined effect of variety and arsenic on yield contributing parameters of rice**

Treatment combination	Yield contributing parameters			
	Panicle length (cm)	Number of panicles	Number of grain panicle^{-1}	Number of filled grain panicle^{-1}
V_1As_0	27.50 a	11.50 ab	153.7 ab	117.0 abc
V_1As_1	26.00 abcd	11.25 abc	147.7 abcd	115.1 abc
V_1As_2	24.13 cdefgh	10.25 abcd	146.2 abcd	108.5 bcd
V_1As_3	23.88 cdefgh	9.000 abcde	137.1 abcd	103.4 cde
V_1As_4	23.00 efghi	8.000 bcde	128.5 abcde	47.38 h
V_2As_0	27.00 ab	11.25 abc	159.7 a	135.7 ab
V_2As_1	23.50 defghi	11.25 abc	156.0 ab	131.6 ab
V_2As_2	23.00 efghi	9.000 abcde	147.8 abcd	103.2 cde
V_2As_3	22.75 fghi	7.500 cdef	145.4 abcd	81.54 def
V_2As_4	22.00 hi	7.000 def	108.2 defgh	47.88 h
V_3As_0	26.25 abc	10.25 abcd	165.7 a	140.4 a
V_3As_1	25.25 abcdef	9.000 abcde	163.6 a	139.2 a
V_3As_2	24.88 bcdefg	9.000 abcde	137.2 abcd	79.35 efg
V_3As_3	24.38 cdefgh	7.250 def	112.0 cdefg	54.96 fgh
V_3As_4	23.75 cdefghi	5.500 ef	69.81 hi	53.85 fgh
V_4As_0	25.50 abcde	9.750 abcd	149.8 abc	128.5 abc
V_4As_1	24.13 cdefgh	9.500 abcd	143.1 abcd	125.8 abc
V_4As_2	23.75 cdefghi	8.250 bcde	133.8 abcde	56.60 fgh
V_4As_3	23.00 efghi	6.750 def	119.3 bcdef	54.50 fgh
V_4As4	22.58 ghi	6.750 def	89.44 fgh	52.83 gh
V_5As_0	25.50 abcde	12.25 a	154.1 ab	131.9 ab
V_5As_1	22.63 ghi	8.750 abcde	135.4 abcde	28.46 hi
V_5As_2	22.50 ghi	8.500 abcde	97.29 efgh	7.642 i
V_5As_3	22.13 hi	8.250 bcde	72.39 ghi	4.505 i
V_5As_4	21.25 i	4.000 f	38.22 i	0.9625 i
$LSD_{0.05}$	2.58	4	39.79	28.19
CV (%)	5.93	7.27	12.12	10.14

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

4.2.2 Number of panicles

Effect of variety

Significant variation was recorded for number panicles which was influenced by different of rice varieties (Table 4.3). Results revealed that the maximum number of panicles (10.00) was recorded from the variety V_1 (BR-14) which was significantly different from others variety whereas the minimum number panicles (8.20) was recorded from the variety V_3 (BRRI dhan67) and V_4 (BRRI dhan88) which also the significantly different from others variety. Islam *et al*. (2009) also observed variation on panicles hill^{-1} due to varietal difference.

Effect of arsenic

Different arsenic levels showed significant variation on number panicles of rice (Table 4.3). It was observed that lower levels of arsenic showed comparatively higher number panicles and gradually decreased panicle number was observed due to higher arsenic levels. The maximum number of panicles (10.00) was found from the control treatment As_0 (no arsenic produced). The minimum number of panicles (8.20) was found from the treatment As_4 which was identical to As_3.

Combined effect of variety and arsenic

Treatment combination of different rice varieties and arsenic levels gave significant influence on number of panicles of rice (Table 4.4). The maximum number of panicles (12.25) was observed from the treatment combination of V_5As_0 which was statistically identical to the treatment combinations of V_1As_0 whereas the minimum number of panicles (4.00) was observed from the treatment combination of V_5As_4. Similar result was also observed by Montenegro and Mejia (2001).

4.2.3 Number of grains panicle^{-1}

Effect of variety

Number of grains panicle^{-1} was varied due to varietal difference of rice (Table 4.3). Results indicated that the highest number of grains panicle^{-1} (143.42) was recorded from the variety V_2 (BRRI dhan58) which was significantly different to other varieties whereas the lowest number of grains panicle^{-1} (99.48) was recorded from the variety V_5 (BRRI dhan92) which also different to other varieties.

Effect of arsenic

Variation was observed in a number of grains panicle^{-1} of rice as influenced by different arsenic levels (Table 4.3). It was observed that the highest number of grains panicle^{-1} (143.3) was found from the control treatment, As_0 (no arsenic produced) which was statistically identical to arsenic dose As_1, As_2 and As_3, and gradually decreased number of grains panicle^{-1} was found with increasing arsenic levels. The lowest number of grains panicle^{-1} (99.47) was found from the maximum levels of arsenic As_4, which was significantly different from other arsenic levels. Similar result was also observed by Montenegro and Mejia (2001).

Combined effect of variety and arsenic

There was a variation on number of grains panicle^{-1} of rice due to treatment combination of different rice varieties and arsenic levels (Table 4.4). The highest number of grains panicle^{-1} (165.20) was observed from the treatment combination of V_3As_0 that was statistically identical to the treatment combination of V_2As_1 and V_3As_1 whereas V_5As_4 gave the least number of grains panicle^{-1} (38.22), which was significantly different to other treatment combinations.

4.2.4 Number of filled grains panicle^{-1}

Effect of variety

Number of filled grains panicle^{-1} was varied due to the varietal different of rice (Table 4.3). Results indicated that the highest number of filled grains panicle^{-1} (99.98) was recorded from the variety V_2 (BRRI dhan-58) which was significantly different to other varieties whereas the lowest number of filled grains panicle^{-1} (34.69) was recorded from the variety V_5 (BRRI dhan92) that was also significantly different to other varieties. The result obtained from the present study was similar with the findings of Rashid *et al*. (2017) and Sarker *et al.* (2013).

Effect of arsenic

Variation was observed on number of filled grains panicle^{-1} of rice as influenced by different arsenic levels (Table 4.4). It was observed that the highest number of filled grains panicle^{-1} (140.4) was found from the control treatment As_0 (no arsenic produced) followed by As_1 (98.28) and gradually decreased number of filled grains panicle^{-1} was found with increasing arsenic levels. The lowest number of filled grains panicle^{-1} (0.96) was found from the maximum levels of arsenic $S_{4,}$ which was significantly different from other arsenic levels. Montenegro and Mejia (2001) also found reduced grains per panicle due to contamination through irrigation water.

The combined effect of variety and arsenic

There was a variation on number of filled grains panicle^{-1} of rice due to the treatment combination of different rice varieties and arsenic levels (Table 4.4). The highest number of filled grains panicle^{-1} (140.40) was observed from the treatment combination of V_3As_0 that was statistically identical to the combination of V_3As_1 whereas V_5As_4 gave the least number of filled grains panicle^{-1} (0.9625), which was statistically identical to the combination of V_5As_2 and $V_5As_{3.}$

4.3 Yield parameters

4.3.1. 1000 grain weight (g)

Effect of variety

1000 grain weight (g) was varied due to varietal difference of rice (Table 4.5). The highest 1000 grain weight (g) (15.69 g) was recorded from the variety V_3 (BRRI dhan67) whereas the lowest 1000 grain weight (g) (6.94 g) was recorded from the variety V_5 (BRRI dhan92).

Effect of arsenic

Variation was observed on straw yield of rice as influenced by different arsenic levels (Table 4.5). It was observed that the highest 1000 grain weight (g) (15.69 g) was found from the control treatment As_0 (no arsenic produced). The lowest number 1000 grain weight (g) (6.943 g) was found in As_4.

The combined effect of variety and arsenic

There was a variation on rice 1000-grain weight (g) due to treatment combination of different rice varieties and arsenic levels (Table 4.6). The highest 1000 grain weight (g) (19.89 g) was observed from the treatment combination of V_3As_0 whereas the treatment combination of V_5As_4 showed minimum 1000 grain weight (g) (3.150 g).

4.3.2 Grain yield

Effect of variety

Grain yield was varied due to varietal different of rice (Table 4.5). Results indicated that the highest grain yield (20.81 g) was recorded from the variety V_2 (BRRI dhan58) whereas the lowest grain yield (10.79 g) was recorded from the variety V_5 (BRRI dhan92).

Effect of arsenic

Variation was observed on grain yield of rice as influenced by different arsenic levels (Table 4.5). It was observed that the highest grain yield (15.69 g) was found from the control treatment As_0 (no arsenic produced). The lowest grain yield 6.943 g) was found in the arsenic level of As_4. Grain yield is decreasing by increasing of arsenic level.

The combined effect of variety and arsenic

There was a variation on rice grain yield due to treatment combination of different rice varieties and arsenic levels (Table 4.6). The highest grain yield hill^{-1} (30.96 g) was observed from the treatment combination of V_3As_0 which was statistically identical to the treatment combination of V_1As_0 whereas the treatment combination of V_1As_4 showed minimum grain yield hill^{-1} (6.25 g) that was significantly different compared to other treatment combinations.

Table 4.5. **Effect of variety and arsenic on yield parameters of rice**

Treatments	Yield parameters		
	1000 grain weight (g)	Grain Yield (g hill^{-1})	Straw yield (g hill^{-1})
Effect of variety			
V_1	14.81 b	16.90 b	34.29 a
V_2	15.52 a	20.81 a	29.01 b
V_3	15.69 a	17.23 ab	21.71 d
V_4	14.03 b	14.65 c	30.80 b
V_5	6.94 d	10.79 c	26.43 c
LSD0.05	1.66	3.58	3.49
CV(%)	6.23	6.23	11.28
Effect of arsenic			
As_0	15.69 a	15.69 a	34.29 a
As_1	15.53 a	15.53 a	30.81 a
As_2	14.81 ab	14.81 ab	29.02 ab
As_3	14.03 b	14.03 b	26.44 ab
As_4	6.943 c	6.943 c	21.71 b
LSD0.05	1.31	4.2	18.85
CV(%)	6.23	3.5	11.28

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

4.3.3 Straw yield hill^{-1}

Effect of variety

Straw yield hill^{-1} was varied due to varietal difference of rice (Table 4.5). Results indicated that the highest straw yield hill^{-1} (34.29 g) was recorded from the variety V_1 (BR-14) whereas the lowest straw yield hill^{-1} (21.71 g) was recorded from the variety V_3 (BRRI dhan67). Similar result was also observed by Chamely *et al*. (2015).

Effect of arsenic

Variation was observed on straw yield of rice as influenced by different arsenic levels (Table 4.5). It was observed that the highest straw yield hill^{-1} (34.29 g) was found from the control treatment As_0 (no arsenic produced). The lowest number straw yield hill^{-1} (21.71 g) was found in As_4. Similar result was also observed by Jahan *et al*. (2020).

The combined effect of variety and arsenic

There was a variation on rice straw yield $hill^{-1}$ due to treatment combination of different rice varieties and arsenic levels (Table 4.6). The highest straw yield $hill^{-1}$ (74.50 g) was observed from the treatment combination of V_1As_0 which was statistically identical to the treatment combination of V_2As_0 and V_4As_0 whereas the treatment combination of V_4As_4 showed minimum straw yield $hill^{-1}$ (9.45 g) that was significantly different compared to other treatment combinations.

Table 4.6. **Combined effect of variety and arsenic on yield parameters of rice**

Treatment combination	Yield parameters		
	1000 grain weight (g)	Grain Yield (g $hill^{-1}$)	Straw Yield (g $hill^{-1}$)
V_1As_0	18.13 abcd	30.17 a	74.50 a
V_1As_1	17.22 abcde	28.21 b	41.00 bcd
V_1As_2	15.65 def	10.8 hij	23.53 defg
V_1As_3	14.75 efg	9.11 hij	21.40 efg
V_1As_4	8.300 ijk	6.25 k	11.05 g
V_2As_0	19.38 ab	25.97 b	69.00 a
V_2As_1	18.71 abc	22.61 cde	34.00 cdef
V_2As_2	17.02 abcde	21.73 cde	18.65 fg
V_2As_3	13.97 fg	19.86 cde	12.27 g
V_2As_4	8.550 ij	13.90 efg	11.16 g
V_3As_0	19.89 a	30.96 a	40.00 bcde
V_3As_1	16.90 bcde	30.36 a	19.15 fg
V_3As_2	15.90 cdef	9.85 hij	18.50 fg
V_3As_3	15.13 ef	8.30 j	17.20 fg
V_3As_4	10.63 hi	6.72 k	13.70 g
V_4As_0	16.56 bcde	22.74 cde	72.50 a
V_4As_1	15.90 cdef	20.27 cde	44.00 bc
V_4As_2	15.55 def	14.54 efg	16.73 fg
V_4As_3	11.89 gh	9.58 hij	11.35 g
V_4As_4	10.27 hi	6.12 k	9.450 g
V_5As_0	16.35 cdef	20.87 cde	58.00 ab
V_5As_1	5.800 jkl	13.64 efg	23.70 defg
V_5As_2	5.403 kl	7.56 k	18.75 fg
V_5As_3	4.012 l	5.31 kl	18.00 fg
V_5As_4	3.150 l	4.59 l	13.75 g
$LSD_{0.05}$	1.31	4.2	18.85
CV(%)	6.23	3.5	11.28

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

4.4 Nutrient content in grain and straw

4.4.1 Phosphorus (P) content in grain

Effect of variety

Different variety showed significant variation on P content in grain (Table 4.7). However, the maximum P content (0.3009%) was found in V_1 (BR-14) whereas the lowest P content (0.2297%) was recorded in V_3 (BRRI dhan67) variety.

Effect of arsenic

Different arsenic levels showed significant variation on P content in rice grain (Table 4.7). However, the maximum P content (0.3069%) was found from the control treatment As_0 (no arsenic produced) followed by As_1 whereas the lowest P content (0.2058%) was recorded in arsenic level of As_4. The phosphorus content was decreasing by increasing amount of arsenic.

Table 4.7 **Effect of variety and arsenic on nutrient content of rice grain**

Treatments	Nutrient content parameters			
	P%	K%	S%	As(mg/kg)
Effect of variety				
V_1	0.3009 a	0.1164 a	0.1517 ab	2.836 a
V_2	0.2865 a	0.1164 a	0.1620 a	1.202 e
V_3	0.2297 c	0.1070 a	0.1463 ab	1.947 c
V_4	0.2413 bc	0.1258 a	0.1155 c	1.325 d
V_5	0.2551 b	0.1070 a	0.1352 bc	2.327 b
$LSD_{0.05}$	0.02	0.02	0.02	0.02
CV(%)	2.72	1.87	3.82	5.10
Effect of arsenic				
As_0	0.3160 a	0.1447 a	0.1227 c	0. 00 e
As_1	0.2795 b	0.1259 ab	0.1320 bc	1.156 d
As_2	0.2653 bc	0.1072 bc	0.1435 ab	1.572 c
As_3	0.2472 c	0.09775 c	0.1522 a	1.757 b
As_4	0.2058 d	0.09700 c	0.1603 a	4.952 a
$LSD_{0.05}$	0.02	0.02	0.02	0.02
CV(%)	2.72	1.87	3.82	5.10

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

Combined effect of variety and arsenic

Significant variation was found on P content in rice grain due to treatment combination of different rice varieties and arsenic levels (Table 4.8). The highest P content (0.4527%) was observed from the treatment combination of V_1As_0 while the treatment combination of V_5As_4 gave the least performance of P content (0.1567%). The phosphorus content was decreasing by increasing of arsenic amount.

Table 4.8. **Combined effects of variety and arsenic on nutrient content of rice grain**

Treatment combination	Nutrient content of grain			
	%P	%K	%S	As (mg/kg)
V_1As_0	0.4527 a	0.1447 a	0.1028 h	0 m
V_1As_1	0.3117 bc	0.1447 a	0.1137 gh	1.001 kl
V_1As_2	0.2757 def	0.1447 a	0.1137 gh	2.01 c
V_1As_3	0.2707 efg	0.1447 a	0.1377 def	2.016 c
V_1As_4	0.2688 efg	0.1447 a	0.1458 cde	7.87 a
V_2As_0	0.3257 b	0.1447 a	0.1137 gh	0 m
V_2As_1	0.2918 cd	0.1447 a	0.1187 fgh	1.009 k
V_2As_2	0.2667 efg	0.1447 a	0.1217 fgh	1.314 h
V_2As_3	0.2567 fgh	0.0977 b	0.1488 cd	1.687 e
V_2As_4	0.2567 fgh	0.0977 b	0.1567 bcd	1.812 d
V_3As_0	0.2847 de	0.1447 a	0.1157 gh	0 m
V_3As_1	0.2847 de	0.0977 b	0.1458 cde	1.113 j
V_3As_2	0.2617 fg	0.0977 b	0.1488 cd	1.428 f
V_3As_3	0.2548 gh	0.0977 b	0.1507 bcd	1.676 e
V_3As_4	0.2407 h	0.0977 b	0.1567 bcd	5.001 b
V_4As_0	0.2757 def	0.0977 b	0.1187 fgh	0 m
V_4As_1	0.2728 defg	0.0977 b	0.1458 cde	1.33 g
V_4As_2	0.2527 gh	0.0977 b	0.1567 bcd	1.336 g
V_4As_3	0.2158 i	0.0977 b	0.1698 ab	1.487 f
V_4As_4	0.2158 i	0.0977 b	0.1698 ab	2.071 c
V_5As_0	0.2688 efg	0.0970 b	0.1267 efg	0 m
V_5As_1	0.2407 h	0.0970 b	0.1488 cd	1.221 i
V_5As_2	0.1937 j	0.0970 b	0.1648 abc	1.338 g
V_5As_3	0.1688 k	0.0970 b	0.1807 a	1.725 d
V_5As_4	0.1567 k	0.0970 b	0.1807 a	7.023 a
$LSD_{0.05}$	0.02	0.02	0.02	0.02
CV(%)	2.72	1.87	3.82	5.10

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

4.4.2 Potassium (K) content in grain

Effect of variety

Different variety showed significant variation on Potassium (K) content in grain (Table 4.7). However, the maximum K content (0.1164%) was found in both V_1 (BR-14) and V_2 (BRRI dhan58) varieties whereas the lowest K content (0.0981%) was recorded in V_3 (BRRI dhan67) and V_5 (BRRI dhan92) variety.

Effect of arsenic

Different arsenic levels showed significant variation on K content in rice grain (Table 4.7). However, the maximum K content (0.1447%) was found from the control treatment As_0 (no arsenic produced) whereas the lowest K content (0.0970%) was recorded in arsenic level of As_4 which was statistically identical to the As_3. Potassium content was the highest in control treatment (no arsenic produced) and K content was gradually decreased by increasing amount of arsenic.

Combined effect of variety and arsenic

Significant variation was found on K content in rice grain due to treatment combination of different rice varieties and arsenic levels (Table 4.8). The highest K content (0.1447%) was found in the treatment combination of V_1As_0 which was statistically identical to the V_1As_1, V_1As_2, V_1As_3, V_1As_4, V_2As_0, V_2As_1, V_2As_2, V_3As_0. The treatment combination of V_5As_0 gave the least performance of K content (0.0970%), which was statistically identical to the V_5As_1, V_5As_2, V_5As_3, V_5As_4.

4.4.3 Sulphur (S) content in grain

Effect of variety

Different variety showed significant variation on S content in grain (Table 4.7). However, the maximum S content (0.1620%) was found in V_2 (BR-14) whereas the lowest S content (0.1155%) was recorded in V_4 (BRRI dhan88) variety.

Effect of arsenic

Different arsenic levels showed significant variation on S content in rice grain (Table 4.7). However, the maximum S content (0.1603%) was found from the arsenic level of As_4 which was statistically identical to the As_3 whereas the lowest S content (0.1227%) was recorded in control treatment As_0. Sulphur content was the lowest in control treatment (no arsenic produced) and S content was gradually increased by increasing of the arsenic amount.

Combined effect of variety and arsenic

Significant variation was found on S content in rice grain due to treatment combination of different rice varieties and arsenic levels (Table 4.8). The highest S content (0.1807%) was observed from the treatment combination of V_5As_4 which was statistically identical to the V_5As_3 whereas the lowest performance of S content (0.1028%) in the treatment combination of V_1As_0.

4.4.4 Arsenic (As) content in grain

Effect of variety

Different varieties showed a significant variation on As content in grain (Table 4.7). The maximum As content (2.836 mg/kg) was found in the variety V_1 (BR-14) whereas the V_2 (BRRI dhan58) showed the minimum As content (1.202%). Bhattacharya *et al*. (2010) and Patra *et al*. (2016) also observed similar result as the present study.

Effect of arsenic

Different arsenic levels showed significant variation on As content in rice grain (Table 4.7). The maximum As content (4.952 mg/kg) was found from the arsenic level of As_4 whereas the treatment As_0 showed lowest As content (0.2007%). Arsenic content is the lowest in control treatment (no arsenic produced) which is gradually increased by increasing of the arsenic amount.

Combined effect of variety and arsenic

Significant variation was found on As content in rice grain due to treatment combination of different rice varieties and arsenic levels (Table 4.8). The highest As content (7.870 mg/kg) was observed from the treatment combination of V_1As_4 which was statistically identical to the treatment combination of V_5As_4. The treatment combination of V_1As_0, V_2As_0, V_3As_0, and V_3As_0 showed same the lowest (0.000 mg/kg) As content.

4.4.5 Phosphorus (P) content in straw

Effect of variety

Different variety showed significant variation on P content in straw (Table 4.9). The maximum P content (0.2189%) was found in V_1 (BR-14) whereas the lowest P content (0.1187%) was recorded in V_3 (BRRI dhan 67).

Effect of arsenic

Different arsenic levels showed significant variation on P content in rice straw (Table 4.9). However, the maximum P content (0.1989%) was found from the control treatment As_0 (no arsenic produced) whereas the lowest P content (0.1141%) was recorded in the arsenic level of As_4. The P content is highest in control treatment (no arsenic produced) and gradually decreases by increasing the arsenic amount.

Table 4.9. **Effect of variety and arsenic on nutrient content of rice straw**

Treatments	Nutrient content parameters			
	P%	K%	S%	As (mg/kg)
Effect of variety				
V1	0.2189 a	0.2479 a	0.2085 c	6.717 d
V2	0.1419 bc	0.2292 a	0.2955 a	4.750 e
V3	0.1187 d	0.1918 b	0.2144 bc	7.240 c
V4	0.1296 cd	0.1638 c	0.2290 b	11.13 a
V5	0.1542 b	0.1638 c	0.2252 bc	8.705 b
LSD0.05	0.02	0.02	0.02	0.02
CV(%)	3.43	2.46	3.68	5.72
Effect of arsenic				
As0	0.1989 a	0.2479 a	0.1944 d	1.304 e
As1	0.1725 b	0.2293 a	0.2183 c	4.259 d
As2	0.1488 c	0.1825 b	0.2339 bc	7.459 c
As3	0.1292 cd	0.1824 b	0.2479 b	11.18 b
As4	0.1141 d	0.1544 c	0.2781 a	14.34 a
$LSD_{0.05}$	0.02	0.02	0.02	0.02
CV(%)	3.43	2.46	3.68	5.72

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

V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

Combined effect of variety and arsenic

Significant variation was found on P content in rice straw due to treatment combination of different rice varieties and arsenic levels (Table 4.10). The highest P content (0.2759%) was observed from the treatment combination of V_1As_0 whereas the lowest performance of P content (0.0959%) was found in the treatment combination of V_5As_4. Presence of lower arsenic content shows highest P content and high arsenic component shows lower P content.

Table 4.10. **Combined effects of variety and arsenic on nutrient content of rice straw**

Treatment combination	Nutrient content of straw			
	%P	%K	%S	As (mg/kg)
V_1As_0	0.2759 a	0.3320 a	0.1447 l	0.000 n
V_1As_1	0.2144 c	0.2386 c	0.1690 k	3.101 l
V_1As_2	0.1984 cd	0.2853 b	0.1825 jk	4.129 k
V_1As_3	0.1665 fg	0.1918 d	0.2096 hi	11.131 e
V_1As_4	0.1392 hi	0.1918 d	0.2663 cd	14.251 b
V_2As_0	0.2485 b	0.2853 b	0.1906 ij	0.000 n
V_2As_1	0.1779 ef	0.2853 b	0.1909 ij	3.012 l
V_2As_2	0.1620 fg	0.1921 d	0.2123 h	3.087 l
V_2As_3	0.1483 gh	0.1918 d	0.2204 gh	6.981 i
V_2As_4	0.1255 ij	0.1918 d	0.2771 c	8.273 h
V_3As_0	0.2144 c	0.2386 c	0.2123 h	0.000 n
V_3As_1	0.1529 gh	0.1918 d	0.2123 h	1.612 m
V_3As_2	0.1392 hi	0.1918 d	0.2206 gh	6.354 i
V_3As_3	0.1187 jk	0.1454 e	0.2258 fgh	12.101 d
V_3As_4	0.1187 jk	0.1451 e	0.2988 b	13.893 c
V_4As_0	0.1893 de	0.2386 c	0.2285 fgh	0.000 n
V_4As_1	0.1164 jkl	0.1918 d	0.2228 gh	5.132 j
V_4As_2	0.1164 jkl	0.1916 d	0.2366 efg	12.122 d
V_4As_3	0.1141 jklm	0.1451 e	0.2447 ef	14.325 b
V_4As4	0.1096 jklm	0.1451 e	0.3069 b	20.961 a
V_5As_0	0.1665 fg	0.1918 d	0.2526 de	0.000 n
V_5As_1	0.1096 jklm	0.1451 e	0.2661 cd	5.124 j
V_5As_2	0.1005 klm	0.1451 e	0.2663 cd	9.122 g
V_5As_3	0.0982 lm	0.1449 e	0.2771 c	10.211 f
V_5As_4	0.0959 m	0.1449 e	0.3285 a	13.133 c
$LSD_{0.05}$	0.02	0.02	0.02	0.02
CV(%)	3.43	2.46	3.68	5.72

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability V_1 = BR-14, V_2 = BRRI dhan58, V_3 = BRRI dhan67, V_4 = BRRI dhan88, V_5 = BRRI dhan92

As_0 = Control (No arsenic), As_1 = 2 ppm, As_2 = 10 ppm, As_3 = 20 ppm, As_4 = 40 ppm

4.4.6 Potassium (K) content in straw

Effect of variety

Different varieties showed variation on K content in straw (Table 4.9). The maximum K content (0.2479%) was found in V_1 (BR-14) variety whereas the lowest K content (0.1638%) was recorded in V_4 (BR-88) and V_5 (BRRI dhan 92),

Effect of arsenic

Different arsenic levels showed variation on K content in rice straw (Table 4.9). The highest K content (0.2479%) was found from the control treatment As_0 (no arsenic produced) whereas the lowest K content (0.1544%) was recorded in arsenic level of As_4. The K content is highest in control treatment (no arsenic produced) and gradually decreases by increasing the arsenic amount.

Combined effect of variety and arsenic

Variation was found on K content in rice straw due to treatment combination of different rice varieties and arsenic levels (Table 4.10). The highest K content (0.3320%) was observed from the treatment combination of V_1As_0. The treatment combination of V_5As_4 gave least performance of K content (0.1449%) which is statistically identical to the treatment combination of V_3As_3 , V_5As_4 ,V_4As_3 ,V_4As_4 ,V_5As_1, V_5As_2 and V_5As_3.

4.4.7 Sulphur (S) content in straw

Effect of variety

Different variety showed variation on S content in straw (Table 4.9). The maximum S content (0.2955%) was found in V_2 (BRRI dhan58) whereas the lowest S content (0.2085%) was recorded in V_1 (BR-14).

Effect of arsenic

Different arsenic levels showed variation on S content in rice straw (Table 4.9). However, the maximum S content (0.2781%) was found from the arsenic level of As_4 whereas the lowest S content (0.1944%) was recorded in control treatment As_0 (no arsenic produced). The S content is lowest in control treatment (no arsenic produced) and gradually increases by increasing the arsenic amount.

Combined effect of variety and arsenic

Variation was found on S content in rice straw due to treatment combination of different rice varieties and arsenic levels (Table 4.10). The highest S content (0.3285%) was observed from the treatment combination of V_5As_4. The treatment combination V_1As_0 gave least performance of S content (0.1447%).

4.4.8 Arsenic (As) content in straw

Effect of variety

Different variety showed variation on As content in straw (Table 4.9). The maximum As content (11.13 mg/kg) was found in the variety V_4 (BRRI dhan88) whereas the variety V_2 (BRRI Dhan58) showed a minimum As content (4.750 mg/kg). Bhattacharya *et al*. (2010) and Patra *et al*. (2016) also observed similar result with the present study.

Effect of arsenic

Different arsenic levels showed variation on As content in rice straw (Table 4.9). The maximum As content (14.34 mg/kg) was found from the arsenic level of As_4 whereas the control treatment As_0 (no arsenic produced) showed minimum As content in straw (1.304 mg/kg). Patra *et al*. (2016) found similar result with present study and observed higher concentration of As in straw with higher dose applied of As in the soil.

Combined effect of variety and arsenic

Variation was found on As content in rice straw due to treatment combination of different rice varieties and arsenic levels (Table 4.10). The highest As content (20.961 mg/kg) was observed from the treatment combination of V_4As_4. The treatment combination of V_1As_0, V_2As_0 V_3As_0, and V_4As_0 showed minimum As content (0.000 mg/kg)

CHAPTER V
SUMMARY AND CONCLUSION

An experiment was conducted at the net house of the Agro-environmental Chemistry Laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from January 2020 to May 2022 to study the effect of arsenic on the growth, yield and nutrients content in straw and grain of rice varieties. Five rice varieties *viz*. V_1 (BR-14), V_2 (BRRI dhan58), V_3 (BRRI dhan67), V_4 (BRRI dhan88), and V_5 (BRRI dhan92) were comprised of five arsenic treatments *viz*. As_0 (control; no arsenic added), As_1 (2 ppm), As_2 (10 ppm), As_3 (20 ppm), and As_4 (40 ppm) for the present study. Among different rice varieties, V_3 (BRRI dhan67) showed better performance on growth and yield contributing parameters. Maximum plant height, leaf length, leaves number, penicle length, 1000 grain weight were found in V_3 (BRRI dhan67) variety. But maximum number of grains, number of filled grain and grain yield were found from V_2 (BRRI dhan58) whereas minimum growth and yield parameters were found in V_5 (BRRI dhan92) except number of total tillers, effective tillers, number of penicles. The highest plant height (100.0 cm) was observed from the treatment combination of V_3As_0 which was statistically identical to the combination of V_1As_0, V_3As_1, V_3As_2, V_3As_3, V_5As_0 whereas the lowest plant height (71.25 cm) was observed from the treatment combination of V_4As_4. The maximum leaf length (57.38 cm) was observed from the combination of V_1As_0 and the minimum leaf length (26.38 cm) was observed from the combination of V_5As_4. The highest number of leaves (65.00) was observed from the treatment combination of V_5As_0 which was statistically identical to the combination of V_4As_0 and V_1As_0 whereas the lowest number of leaves (23.25) was observed from the combination of V_1As_4. The maximum number of total tillers (14.25) was observed from the treatment combination of V_5As_0 whereas the minimum number of total tillers (5.75) was observed from the combination of V_4As_4. The highest panicle length (27.50 cm) was observed from the combination of V_1As_0. The lowest panicle length (21.25 cm) was observed from the combination of V_5As_4. The maximum number of panicles (12.25) was observed from the combination of V_5As_0 which was statistically identical to the combinations of V_1As_0 whereas the minimum number of panicles (4.00) was observed from the treatment combination of V_5As_4. The highest number of grains panicle^{-1} (165.20) was observed from the treatment combination of V_3As_0 that was statistically identical to the treatment combination of V_2As_1 and V_3As_1 whereas V_5As_4 gave the least number of grains panicle^{-1} (38.22). The highest number of filled grains panicle^{-1} (140.40) was observed from the treatment combination of V_3As_0 that was statistically identical to the combination of V_3As_1 whereas V_5As_4 gave the least number of filled grains panicle^{-1} (0.9625) which was statistically identical to the combination of V_5As_2 and V_5As_3. The highest straw yield hill^{-1} (74.50 g) was observed from the treatment combination of V_1As_0 which was statistically identical to the treatment combination of V_4As_0 whereas the treatment combination of V_4As_4 showed minimum straw yield hill^{-1} (9.45 g). The highest 1000 grain weight (g) (19.89 g) was observed from the treatment combination of V_3As_0 whereas the combination of V_5As_4 showed minimum value (3.150 g). In the case of the effect on the variety of nutrient content in grain, the maximum P, K, S, and As content was found in the V_1 (BR-14), V_4 (BRRI dhan88), V_2 (BRRI dhan58), and V_5 (BRRI dhan92) variety respectively. It was observed that the highest number of growth and yield parameters of rice was found from the control treatment As_0 (no arsenic produced) and gradually decreased with increasing of arsenic levels. In the case of the effect on the arsenic of nutrient content in grain, the maximum P, K content was found in the treatment of As_0 and the amount of nutrient content of P and K decreases with the increase of arsenic dose. On the other hand, the minimum S and As nutrient content was found in the treatment dose of As_0, and the nutrient content of S and As is increasing by increasing of arsenic doses. In the case of the effect on the variety of nutrient content in straw, the maximum P, K, S, and As content was found in the V_1 (BR-14), V_1 (BR-14), V_2 (BRRI dhan58), and V_4 (BRRI dhan88), variety respectively. In the case of the effect on the arsenic of nutrient content in straw, the maximum P, K content was found in the treatment of As_0 and the amount of nutrient content of P and K decreases with the increase of arsenic dose. On the other hand, the minimum S and As nutrient content was found in the treatment dose of As_0, and the nutrient content of S and As is increasing with increasing of arsenic doses. In case of the nutrient content of grain, the highest P content (0.4527%) was observed from the treatment combination of V_1As_0 while the treatment combination of V_5As_4 gave least performance of P content (0.1567%). The highest K content (0.1447%) was found in the treatment combination of V_1As_0 which is statistically identical to the V_1As_1, V_1As_2, V_1As_3, V_1As_4, V_2As_0, V_2As_1, V_2As_2, V_3As_0. The treatment combination of V_5As_0 gave the least performance of K content (0.0970%) which is statistically identical to the V_5As_1, V_5As_2, V_5As_3, V_5As_4. The highest S content (0.1807%) was observed from the treatment combination of V_5As_4 which is statistically identical to the V_5As_3 whereas the lowest performance of S content (0.1028%) in the treatment combination of V_1As_0. The highest As content (7.870 mg/kg) was observed from the treatment combination of V_1As_4. The treatment combination of V_1As_0, V_2As_0, V_3As_0, and V_3As_0 showed same lowest (0.000%) As content. The highest P content (0.2759%) was observed from the treatment combination of V_1As_0 whereas the lowest performance of P content (0.0959%) was found in the treatment combination of V_5As_4. Presence of lower arsenic content shows highest P content and high arsenic component shows lower P content. The highest K content (0.3320%) was observed from the treatment combination of V_1As_0. The treatment combination of V_5As_4 gave least performance of K content (0.1449%) which is statistically identical to the treatment combination of V_3As_3, V_5As_4, V_4As_3, V_4As_4 ,V_5As_1, V_5As_2 and V_5As_3. The highest S content (0.3285%) was observed from the treatment combination of V_5As_4. The treatment combination V_1As_0 gave least performance of S content (0.1447%). The highest As content (20.961 mg/kg) was observed from the treatment combination of V_4As_4. The treatment combination of V_1As_0, V_2As_0 V_3As_0, and V_4As_0 showed minimum As content (0.000 mg/kg).

It can be concluded that with the increasing doses of As, growth and yield contributing characters were decreased. But among the varieties V_2 (BRRI dhan 58) showed higher grain yield, less affected by the As and minimum As content was obtained in this variety.

CHAPTER VI

REFERENCES

Abedin, M. J., Cotter-Howells, J., & Meharg, A. A. (2002). Arsenic uptake and accumulation in rice (*Oryza sativa* L.) irrigated with contaminated water. *Plant and soil*, 240, 311-319.

Abedin, M.J. and Meharg, A.A. (2002). Relative toxicity of arsenite and arsenate on germination and early seedling growth of rice (Oryz*a sativa* L.). *Plant Soil*. **243**: 57-66.

Abou-Khalif, A.A.B. (2009). Evaluation of some hybrid rice varieties in under different sowing times. *Afr. J. Plant Sci.* 3(4): 053-058.

Ahsan, D.A. and Del Valls, T.A. (2011). Impact of arsenic contaminated irrigation water in food chain: An overview from Bangladesh. *Int. J. Environ. Res*., 5(3): 627-638.

Alam, A. and Rahman, A. (2003). Accumulation of arsenic from arsenic contaminated irrigation water and effect on nutrient content. Fate of arsenic in environment. Proceeding of the international symposium on the fate of arsenic in the environment, ITN centre, BUET, Dhaka.

Alam, M.S. and Islam, M.A. (2011). Assessing the effect of arsenic contamination on modern rice production: evidences from a farm level study. *Bangladesh J. Agric. Econs*. **34**(1&2): 15-28.

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. Agron. Agric. Res*. **2**(12): 10–15.

Ali, M.A., Badruzzaman, A.B.M., Jalil, M.A., Hossain, M.D., Ahmed, M.F., Masud, A.A. and Rahman, A. (2005). Arsenic in plants-soil environment in Bangladesh. *Environ. Sci. Technol*., **34**: 85-110.

Anonymous (2020) Annual Report of Bangladesh Rice Research Institute 2019-2020 BRRI, Gazipur 1701, Bangladesh, 496 pp.

Anwar, M. P., & Begum, M. (2010). Tolerance of hybrid rice variety Sonarbangla-1 to tiller seperation. Bangladesh j. crop sci, 13(15), 39-44.

Arya, N. N., Mahaputra, I. K., & Suharyanto, S. (2017). The efforts for productivity and income improvement of rice farming through the use new superior variety (Case Study). *J Agrib. and R. Dev. Res.,* 3(1): 33-38.

Ashikari, M., & Ma, J. F. (2015). Exploring the power of plants to overcome environmental stresses. Rice, 8:1-1.

Awasthi, S., Chauhan, R., Srivastava, S., & Tripathi, R. D. (2017). The journey of arsenic from soil to grain in rice. Frontiers in Plant Science, 8, 1007.

BBS. (2020). Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of Peoples Republic of Bangladesh.

BGS and DPHE. Kinniburgh DG, PL Smedley. Arsenic Contamination of Ground Water in Bangladesh. 1&2. Keyworth: British Geological Survey; 2001

Bhattacharya, P., Samal, A.C., Majumdar, J. and Santra, S.C. (2010). Uptake of arsenic in rice plant varieties cultivated with arsenic-rich groundwater. *Environ. Asia*. **3**: 34-37.

Bhattacharya, P., Samal, A. C., Majumdar, J., Banerjee, S., & Santra, S. C. (2011, February). Arsenic toxicity in four different varieties of Rice (Oryza sativa L.) of West Bengal. In Proceedings of UGC Sponsored National Seminar on Advances in Environmental Science and Technology, Vivekanandan College, Kolkata, India (pp. 5-6).

Biswas, A., Biswas, S. and Santra, S.C. 2014. Arsenic in irrigated water, soil and rice: perspective of the cropping season. *Paddy Water Environ*. **12**: 407- 412.

Brammer, H. (2009). Mitigation of arsenic contamination in irrigated paddy soils in South and South-East Asia. *Environ. Int*. **35**: 856-863.

Calpe, C. and Prakash, A. (2007). Sensitive and Special Products-a rice perspective. Commodity Market Review, FAO. p. 49-71.

Catarecha, P., Segura, M. D., Franco-Zorrilla, J. M., García-Ponce, B., Lanza, M., Solano, R., et al. (2007). A mutant of the Arabidopsis phosphate transporter PHT1;1 displays enhanced arsenic accumulation. *Plant Cell,* 19: 1123–1133.

Chakrabarty, D., Trivedi, P. K., Misra, P., Tiwari, M., Shri, M., Shukla, D., et al. (2009). Comparative transcriptomic analysis of arsenate and arsenite stresses in rice seedlings. *Chemosphere* 74, 688–702. doi: 10.1016/j.chemosphere.2008.09.082

Chamely, S.G., Islam, N., Hoshain, S., Rabbani, M.G., Kader, M.A. and Salam, M.A. (2015). Effect of variety and nitrogen rate on the yield performance of boro rice. *Progressive Agric*. **26** (1): 6-14.

Chowdhury, M. T. A., C. M. Deacon, G. D. Jones, S. M. I. Huq, P. N. Williams, L. H. E. Winkel, A. H. Price, G. J. Norton and A. A. Meharg. (2017). Arsenic in Bangladesh soils related to physiographic region, paddy management, and micro- and macro-elemental status. *Sci. Total Environ*. pp. 406- 415.

Chowdhury,U. M.J., Sacker,U.A., Sarkar, R.M.A.and Kashem,A.M. (2005). Effect of variety and number of seedlings hill's on the yield and its components on late transplanted *Aman* rice. *Bangladesh J. Agril. Sci.* **20**(2): 311-316.

Chowhan, S., Ali, M.K.J., Nahar, K., Rahman, M.M., Ali, M.I. and Islam, M. (2021). Yield and morpho physical characters of some modern aus rice varieties at Khagrachari. *Plant Sci. Today*. **8**(1): 155-160.

Cubadda F, Raggi A, Zanasi F, Carcea M (2003) From durum wheat to pasta: effect of technological processing on the levels of arsenic, cadmium, lead and nickel a pilot study. Food Addit Contam 20(4):353–360.

Dilday, R.H., Slaton, N.A., Gibbhons, J.W., Moldenhouer, k.A., and Yan, W.G. 2000. Straightheadot rice as influenced by arsenic and nitrogen. Research Series Arkansas Agricultural Experiment Station. **476**: 201-214.

Dey, S., Badri, J., Ram, K., Chhabra, A. K., & Janghel, D. K. (2019). Current status of rice breeding for sheath blight resistance. Int J Curr Microbiol Appl Sci, 8(2), 163-175.

Duan, G. L., Hu, Y., Schneider, S., McDermott, J., Chen, J., Sauer, N., et al. (2015). Inositol transporters AtINT2 and AtINT4 regulate arsenic accumulation in Arabidopsis seeds. *Nat. Plants* 2:15202. doi: 10.1038/nplants.2015.202

FAO (2011). Directorate of economics and statistics: Ministry of Agriculture.

FAO (Food and Agriculture Organization). (2021). Retrieved from: http://www.fao.org/faostat/en/#data/QCL.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research (2nd edn.). Int. Rice Res. Inst., *A Willey Int. Sci*,. 28-192.

Haque, M. M., Pramanik, H. R. and Biswas, J. K. (2015). Physiological behavior and yield performances of hybrid rice at different planting dates in *Aus* Season. *Bangladesh Rice J.* **17**(1&2): 7-14.

Haque, M.M., Pramanik, H.R. and Biswas, J.K. (2013). Physiological behavior and yield performances of hybrid rice at different planting dates in *Aus* Season. *Bangladesh Rice J.* **17**(1&2): 7-14.

Howladar, M.M., Uddin, M.J., Islam, M.M., Parveen, Z. and Rahman, M.K. (2019). Effects of arsenic and phosphorus on the growth and nutrient concentration in rice plant. *J. Biodivers. Conserv. Bioresour. Manag*. **5**(1): 31-38.

Hu, M., Sun, W., Krumins, V. and Li, F., 2019. Arsenic contamination influences microbial community structure and putative arsenic metabolism gene abundance in iron plaque on paddy rice root. Science of the Total Environment, 649: 405-412.

Huang, B. and Yan, Z. (2016). Performance of 32 Hybrid Rice Varieties at Pine Bluff of Arkansas. *American J. Plant Sci*. **7**: 2239-2247.

Hue, V.N. (2010). Arsenic levels, chemistry and bioavailabilty in Hawaii soils. World Congress of Soil Science, soil solution for a changing world. Brisbane, Austrilia, 9-12.

Huq, S. M. I. and R. Naidu. (2003). Arsenic in ground water of Bangladesh: contamination in the food chain. In: M. F. Ahmed (ed.). Arsenic contamination: Bangladesh perspective. ITN-Bangladesh; Centre for water supply and management. BUET, Dhaka, Bangladesh.

Huq, S.M.I., Joardar, J.C. Parvin, S., Corell, R. and Naidu, R. (2006). Arsenic contamination in food-chain: Transfer of arsenic into food material through groundwater irrigation. *J. Health Popul Nutr*. **24**(3): 305-316.

Islam, K. and K. Hossain. (2019). Association between arsenic exposure and organ dysfunction- a population based study in Bangladesh. Abstract. 1st International Conference on Environmental Science and Resource Management. 2019: Safe Environment for Better Living, February 08- 09, 2019. Mawlana Bhashani Science and Technology Universitry, ICESRM 2019. 43-44.

Islam, M. S., Parvin, S. and Sarkar, M. A. R. (2009). Yield of fine rice varieties as influenced by integrated management of poultry manure, urea super granules and prilled urea. *J. Environ. Sci. Nat. Res.,* **5**(1): 203-212.

Islam, M. S., Parvin, S. and Sarkar, M. A. R. (2009). Yield of fine rice varieties as influenced by integrated management of poultry manure, urea super granules and prilled urea. *J. Environ. Sci. Nat. Res.,* **5**(1): 203-212.

Islam, M.R., Islam, S., Jahiruddin, M. and Islam, M.A. (2004). Effect of irrigation water arsenic in rice-rice cropping system. *J. Biol. Sci*. **4**(4): 542-556.

Islam, N., Kabir, M.Y., Adhikary, S. K. and Jahan, M.S. (2013). Yield Performance of Six Local Aromatic Rice Cultivars. *IOSR J. Agric. Vet. Sci. (IOSR-JAVS).* **6**(3): 58-62

Jahan, I., Islam, M.R., Hoque, T.S., Hossain, M., Abedin, M.A. (2020). Influence of Soil arsenic in Rice and its Mitigation Through Water Management. *J. Bangladesh Agric. Univ*. **18**(3): 1–6.

Jahan, I., S. M. Ullah, S. Hoque and T. K. Ullah. (2003). Effects of arsenic on the mineral nutrition of rice plant. Dhaka. *Univ. J. Biol. Sci*. **12**(2): 165-175.

Jisan, M. T., Paul, S. K. and Salim, M. (2014). Yield performance of some transplant aman rice varieties as influenced by different levels of nitrogen. *J. Bangladesh Agril. Univ*. **12**(2): 321–324.

Julfiquar, W.A., Haque, M.M., Haque, E.K.G.M.A. and Rashid, A.M. (2009). Current status of Hybrid Rice Research and Future Program in Bangladesh. Proc. Workshop on use and development of hybrid rice in Bangladesh, held at BARC, 18-19, May, 2009.

Julfiquar,W.A., Haque, M.M., Haque, E.K.G.M.A. and Rashid, A.M. (1998). Current status of Hybrid Rice Research and Future Program in Bangladesh. Proc. Workshop on use and development of hybrid rice in Bangladesh, held at BARC, 22-23, April, 1998.

Kabir, M S, M U Salam, A Chowdhury, N M F Rahman, K M Iftekharuddaula, M S Rahman, M H Rashid, S S Dipti, A Islam, M A Latif and A S Islam. (2015). Rice vision for Bangladesh: 2050 and beyond. *Bangladesh Rice Journal*, 19(2): 1-18.

Kabir, M.S., Salam, M.A., Paul, D.N.R., Hossain, M.I., Rahman, N.M.F., Aziz, A., and Latif, M.A. (2016). Spatial variation of arsenic in soil, irrigation water, and plant parts: A Microlevel Study. *The Sci. World J*. pp. 1-12.

Kamal, M.M. (2007). Performance of modern boro rice varieties under different planting methods. *J. Bangladesh Agril. Univ*. **5**(1): 43-47, 2007.

Khan, M. A., J. Stroud, Y. G. Zhu, S. P. McGrath and F. J. Zhao. (2010). Arsenic bioavailability to rice is elevated in Bangladeshi paddy soils. *Environ. Sci. Technol*. **44**: 8515-8521.

Khatun, S. (2020). Growth and Yield Performance of Six Aman Rice Varieties of Bangladesh. *Asian Res. J. Agric*. **12**(2): 1-7

Lee, C. H., Hsieh, Y. C., Lin, T. H., and Lee, D. Y. (2013). Iron plaque formation and its effect on arsenic uptake by different genotypes of paddy rice. *Plant Soil* 363: 231–241.

Lu, Y., Adomako, E. E., Solaiman, A. R. M., Islam, M. R., Deacon, C., Williams, P. N., ... & Meharg, A. A. (2009). Baseline soil variation is a major factor in arsenic accumulation in Bengal Delta paddy rice. Environmental Science & Technology, 43(6): 1724-1729.

Ma, J. F., Yamaji, N., Mitani, N., Xu, X. Y., Su, Y. H., McGrath, S. P., & Zhao, F. J. (2008). Transporters of arsenite in rice and their role in arsenic accumulation in rice grain. PNAS, 105(29): 9931-9935.

Mahmood, R., Howlader, M.H.K. and Haque, M.Z. (2019). Performance of hybrid Boro rice in coastal area of Bangladesh. *Prog. Agric*. **30** (2): 186-193.

Majumdar, A., Barla, A., Upadhyay, M. K., Ghosh, D., Chaudhuri, P., Srivastava, S., et al. (2018). Vermiremediation of metal(loid)s via *Eichornia crassipes* phytomass extraction: a sustainable technique for plant amelioration. *J. Environ. Manage.* 220: 118–125.

Masum, S.M., Ali, M.H., Hasanuzzaman, M., Chowdhury, I.F., Mandal, M.S.H. and Jerin, R. (2014). Response of variety and population density on yield attributes and yield of boro rice (*Oryza sativa*). *Ann. Agric. Res. New Series*. **35**(4): 355-361.

Meharg, A. A., & Jardine, L. (2003). Arsenite transport into paddy rice (Oryza sativa) roots. New phytologist, 157(1), 39-44.

Meharg, A.A., and Rahman, M.M. (2002). Arsenic Contamination of Bangladesh Paddy Field Soils: Implications for Rice Contribution to Arsenic Consumption. *Environ. Sci. Technol*. pp. 42-47.

Mia, M. B. (2018). Influence of zinc application methods on growth and yield of *Boro* rice. M.S. thesis, Dept. Agronomy, Sher-e-bangla Agricultural University, Dhaka-1207.

Montenegro, O. and Mejia, L. 2001. Contamination of rice (*Oryza sativa* L.) with cadmium and arsenic by irrigation with water of the Bogota River in rice soils of the lower basin. *Suelos Ecuatoriales*. **31**(1): 26-31.

Montenegro, O. and Mejia, L. 2001. Contamination of rice (*Oryza sativa* L.) with cadmium and arsenic by irrigation with water of the Bogota River in rice soils of the lower basin. *Suelos Ecuatoriales*. 31(1): 26-31.

Murshida, S., Uddin, M.R., Anwar, M.P., Sarker, U.K., Islam, M.M. and Haque, M.M.I. (2017). Effect of variety and water management on the growth and yield of Boro rice. *Prog. Agric*. **28** (1): 26-35.

Murthy, K.N.K., Shankaranarayana, V., Murali, K., Jayakumar, B.V. (2004). Effect of different dates of planting on spikelet sterility in rice genotypes *(Oryza sativa* L.). *Res. Crops.* **5**(2/3): 143-147.

Muthayya, S., Sugimoto, J.D., Montgomery, S. and Maberly, G.F., (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences*, *1324*(1): 7-14.

Norton, G. J., Islam, M. R., Deacon, C. M., Zhao, F. J., Stroud, J. L., McGrath, S. P., et al. (2009). Identification of low inorganic and total grain arsenic rice cultivars from Bangladesh. Environ. Sci. Technol. 43, 6070–6075.

Panaullah, G. M., T. Alam, M. B. Hossain, R. H. Loppert, J. G. Lauren, C. A. Meisner, Z. U. Ahmed and J. M. Duxbury. (2009). Arsenic toxicity to rice (Oryza sativa L.) in Bangladesh. *Plant Soil*. **317**(1-2): 31-39.

Patel, J.R. (2000). Effect of water regime, variety and blue green algae on rice *(Oryza sativa). Indian J. Agron.* 45(1): 103-106.

Patel, K.S., Sahu, B.L., Ramteke, S. and Bontempi, E. (2016). Contamination of paddy soil and rice with arsenic. *J. Environ. Protec*. **7**: 689-698.

Patra, P.K., Sarkar, S., Pal, S., Roy, A. and Dhara, M.C. (2016). Interim progress report on "Screening of low arsenic accumulating rice varieties and hybrids for West Bengal", Government of West Bengal, 1-47.

Pinson, S.R., Tarpley, L., Yan, W., Yeater, K., Lahner, B., Yakubova, E. and Salt, D.E. (2015). Worldwide genetic diversity for mineral element concentrations in rice grain. *Crop Sci*. **55**: 294-311.

Rahman, A., Salam, M.A., Kader, M.A., Islam, M.S. and Perveen, S. (2020). Growth and yield of boro rice (Oryza sativa L.) in response to crop establishment methods and varieties. Arch. Agric. Environ. Sci. 5(2): 137-143.

Rahman, M. A., M. M. Rahman, M. A. M. Miah and H. M. Khaled. (2004). Influence of soil arsenic concentrations in rice (Oryza sativa L.). J. Sub-trop. *Agric. Res. Dev*. **2**: 24-31.

Rahman, M.A., Hasegawa, H., Rahman, M.M., Rahman, M.A. and Miah, M.A.M. (2007) Accumulation of arsenic in tissues of rice plant (Oryza sativa L.) and its distribution in fractions of rice grain. Chemosphere, **69**: 942-948.

Rahman, M.A., Hossain, S.M.A., Sarkar, N.A.R., Hossain, M.S. and Islam, M.S. (2002). Effect of variety and structural arrangement of rows on the yield and yield components of transplant *Aman* rice. *Bangladesh .J. Agril. Sci.* **29**(2): 303-307.

Rashid, M.M., Ghosh, A.K., Roni, M.N., Islam, M.R and Alam, M.M. (2017). Yield performance of seven aromatic rice varieties of Bangladesh. *Int. J. Agric. Environ. Res.* **3**(2): 2637.

Razzaque, M.A., Talukder, N.M., Islam, M.S., Bhadra, A.K. and Dutta, R.K. (2009). The effect of salinity on morphological characteristics of seven rice (Oryza sativa) genotypes differing in salt tolerance. *Pak. J. Biol. Sci*. **12**(5): 406-412.

Sahoo, P.K. and Mukherjee, A. (2014). Arsenic fate and transport in groundwatersoil-plant system: An understanding of suitable rice paddy cultivation arsenic enriched areas. Treands in Modelling of Environmental Contaminants, **10**: 21-32.

Salam, T. B., Karmakar, B., Hossain, S. M. T., Robin, M. H., Mariam, M. Z. and Hossain, M. (2019). Agronomic Performance of Modern Rice Varieties in South-west Bangladesh. *Plant Sci. Today*. **6**(4): 528-532.

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

Sarkar, S.C., Akter, M., Islam, M.R. and Haque, M.M. (2016). Performance of Five Selected Hybrid Rice Varieties in *Aman* Season. *J. Plant Sci.,* **4**(2): 72-79.

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. Journal of Agronomy and Environment, 7(1): 107-110.

Shi, S., Wang, T., Chen, Z., Tang, Z., Wu, Z., Salt, D. E & Zhao, F. J. (2016). OsHAC1; 1 and OsHAC1; 2 function as arsenate reductases and regulate arsenic accumulation. Plant Physiology, 172(3), 1708-1719.

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. Agric. Veterinary Sci.* **7**(2): 70-73.

Shrivastava, A., Barla, A., Majumdar, A., Singh, S., and Bose, S. (2019). Arsenic mitigation in rice grain loading via alternative irrigation by proposed water management practices. *Chemosphere* 238:124988.

Siddiquee, M.A., Biswas, S.K., Kabir, K. A., Mahbub, A.A., Dipti, S.S., Ferdous, N., Biswas, J.K. and Banu, B. (2002). A Comparative Study Between Hybrid and Inbred Rice in Relation to Their Yield and Quality. *Pakistan J. Biol. Sci.* 5: 550-552.

Singh, S., Singh, V., Khanna, R., Kumar, P. and Shukla, R. (2019). Effect of nitrogen and sulphur fertilization on growth and yield of rice (*Oryza sativa* L.). *Prog. Res. Int. J. Soc. Sci. Dev*. 14 (Special-I): 526-530.

Song, W. Y., Park, J., Mendoza-Cózatl, D. G., Suter-Grotemeyer, M., Shim, D., Hörtensteiner, S., et al. (2010). Arsenic tolerance in Arabidopsis is mediated by two ABCC-type phytochelatin transporters. *Proc. Nat. Acad. Sci. U. S. A.* 107: 21187–21192.

Song, W. Y., Yamaki, T., Yamaji, N., Ko, D., Jung, K. H., Fujii-Kashino, M., et al. (2014). A rice ABC transporter, OsABCC1, reduces arsenic accumulation in the grain. *Proc. Nat. Acad. Sci. U. S. A.* 111,15699–15704. doi: 10.1073/pnas.1414968111

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

Sumit, C; Pyare, L; Singh, A.P. and Tripathi, M.K. (2004). Agronomic and morpho-physiological analysis of growth and productivity in hybrid rice *(Oryza sativa* L.). *Ann. Biol.* 20 (2): 233-238.

Upadhyay, M. K., Majumdar, A., Barla, A., Bose, S., & Srivastava, S. (2019). An assessment of arsenic hazard in groundwater–soil–rice system in two villages of Nadia district, West Bengal, India. Environmental geochemistry and health, 41, 2381-2395.

Wang, P., Zhang, W., Mao, C., Xu, G., and Zhao, F. J. (2016). The role of OsPT8 in arsenate uptake and varietal difference in arsenate tolerance in rice. *J. Exp. Bot*. 67: 6051–6059

Williams, P.N., Islam, M.R., Adomokao, E.E., Raab, A., Hossain, S.A., Zhu, Y.G., Feldman, J. and Mehrag, A.A. (2006). Increase in rice grain arsenic for regions of Bangladesh irrigating paddies with elevated arsenic in ground waters. Environ. Sci. Technol., 40: 4903-4908.

Williams, P.N., Raab, A., Feldmann, J. and Meharg, A.A. (2007). Market basket survey shows elevated levels of As in South Central US processed rice compared to California: consequences for human dietary exposure. Environmental Science and Technology, 41: 2178-2183.

Xu, J., Shi, S., Wang, L., Tang, Z., Lv, T., Zhu, X., et al. (2017). OsHAC4 is critical for arsenate tolerance and regulates arsenic accumulation in rice. *New Phytol.* 215: 1090–1101

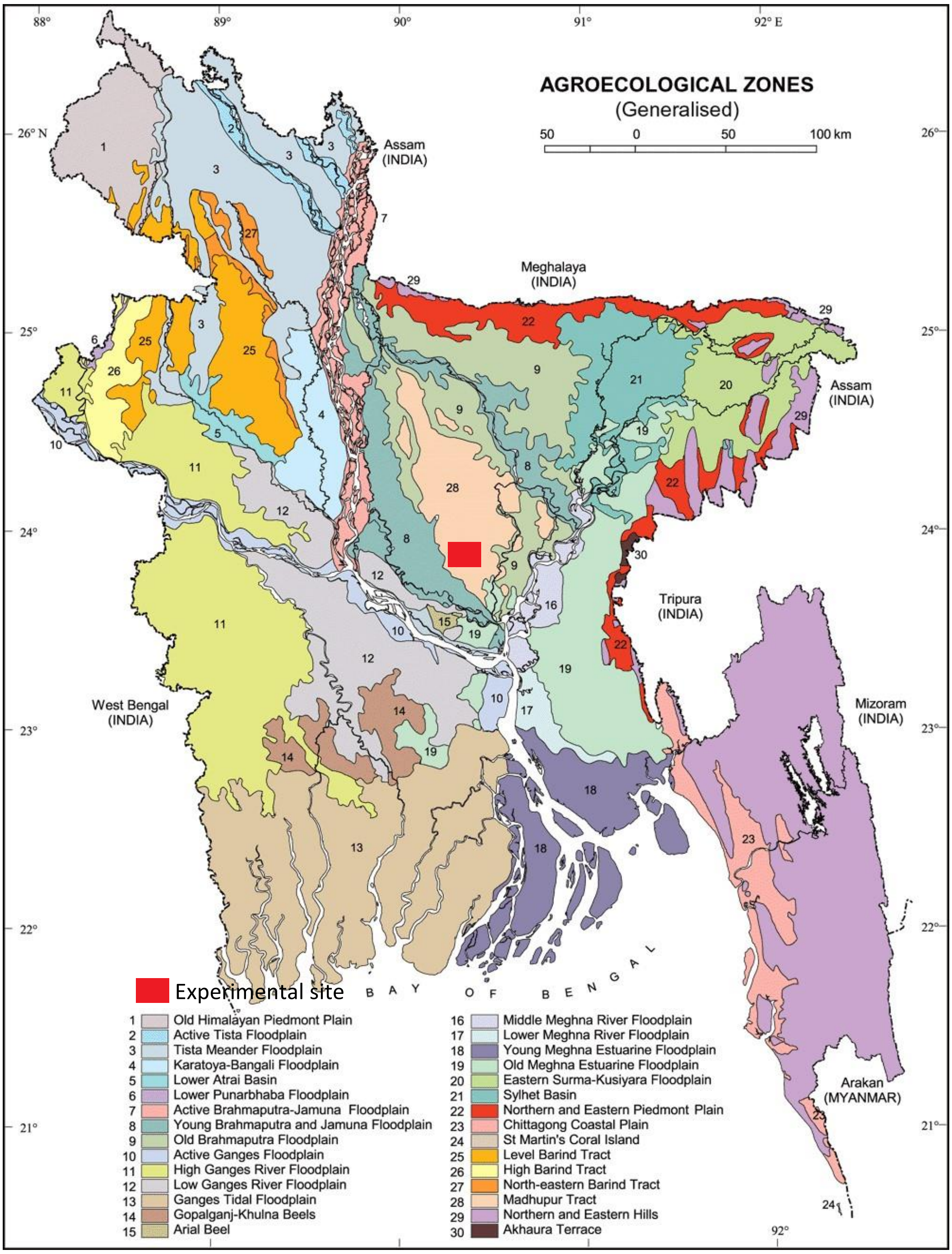
Yu S, Ali J, Zhang C et al (2020) Genomic breeding of green super rice varieties and their deployment in Asia and Africa. *Theor Appl Genet* 133:1427–1442

Zhao, F. J., McGrath, S. P., and Meharg, A. A. (2010). Arsenic as a food chain contaminant: mechanisms of plant uptake and metabolism and mitigation strategies. *Annu. Rev. Plant Biol.* 61, 535–559.

CHAPTER VII

APPENDICES

Appendix I. Map showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from December 2020 to May 2021.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2020	December	25.50	6.70	16.10	54.80	0.0
2021	January	23.80	11.70	17.75	46.20	0.0
2021	February	22.75	14.26	18.51	37.90	0.0
2021	March	35.20	21.00	28.10	52.44	20.4
2021	April	34.70	24.60	29.65	65.40	165.0
2021	May	32.64	23.85	28.25	68.30	182.2

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

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

A. Morphological characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

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

Source: Soil Resource Development Institute (SRDI)