EFFECTS OF ARSENIC ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BRRI dhan29 AND Binadhan-8

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CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF ARSENIC ON THE GROWTH, YIELD AND NUTRIENTS CONTENT OF BRRI dhan29 AND Binadhan-8" submitted to the DEPARTMENT OF AGRICULTURAL CHEMISTRY, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of bona fide research work carried out by BILASH CHANDRA PAUL, Registration. No. 10-04166, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

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MY

BELOVED PARENTS

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The Author

ABSTRACT

The experiment was conducted in the net house and the Laboratory of Agro-Environmental Chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 and Department of Agricultural Chemistry, BAU during the Boro season (December-June) of the year 2014-15 to evaluate the effects of arsenic on growth, yield and nutrients content of two different Boro rice cultivars. The two factorial experiment was laid out in a CRD design with three replications. Factor A: two varieties [V_1- BRRI dhan29 and V_2-Binadhan-8] and Factor B: different arsenic doses [**As_0** = No arsenic applied, **As_1**=10 ppm As, **As_2**=20 ppm As, **As_3**=40 ppm As, **As_4**=60 ppm As, **As_5**=80 ppm As]. Arsenic (As) was added from Sodium Arsenate ($Na_2HAsO_4.7H_2O$). However, Binadhan-8 showed better performance than BRRI dhan29. Treatment with no arsenic (**$As_{0)}$** gave higher results in most growth, yield and yield related parameters. In case of interaction, Binadhan-8 and the treatment **As_0** gave longer panicle, higher number of filled grains panicle^{-1}, 1000-grain weight, grain yield and straw yield. K, Na, and As content in grain showed statistically significant difference due to the varietal effect in most cases except Cu. The treatment As_1 gave higher Na and Cu content whereas the lowest from As_3. The maximum As content in grain, straw and root was found in As_5 whereas the minimum from As_0 treatment. In interaction, the maximum As content in grain, straw and root was found in V_1As_5 whereas the minimum As content in grain, straw and root was observed from V_2As_0 treatment. Arsenic contamination significantly decreased almost all the growth, yield contributing character and nutrient contents. However, the effect was quite varied with the rice varieties. The As concentration in grain, straw and root of these rice varieties increased with increasing rate of As addition. Binadhan-8 had the lowest As concentration and BRRI dhan29 showed the highest As concentration in grain, straw and root. Therefore, it suggests that arsenic reduces the yield of rice. Therefore it is needed to screen out tolerant or resistant varieties as well as find any possible ways to obliterate arsenic uptake in rice.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL WORD
%	Percent
@	At the rate of
^0C	Degree Celsius
AEZ	Agro-Ecological Zone
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CRD	Completely Randomized Design
$CuSO_4.5H_2O$	Green vitriol
CV%	Percentage of Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DMRT	Duncan's Multiple Range Test
dS/m	Deci Semens per meter
EC	Electrical Conductivity
e.g.	As for example
et al	and others
g	Gram
i.e.	that is
K	Potassium
kg	Kilogram
kg ha^{-1}	kg per hectare
KCl	Potassium Chloride
LSD	Least Significant Difference
m	Meter
MoP	Muriate of Potash
N	Nitrogen
NaOH	Sodium Hydroxide
NS	Not Significant
OM	Organic Matter
P	Phosphorus
pH	Hydrogen ion concentration
S	Sulphur
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate
Zn	Zinc

CHAPTER I

INTRODUCTION

Arsenic is one of the toxic environmental pollutants which has recently attract attention because of its chronic and epidemic effects on human health through widespread water and crop contamination due to the natural release of this toxic element from aquifer rocks in Bangladesh (Fazal *et al.,* 2001; Smith *et al.,* 2000; Ahmed, 2000; Hopenhayn, 2006), West Bengal, India (Chakraborti and Das, 1997; Banerjee, 2000). Geogenic contamination of arsenic in aquifer rocks has also been reported in Thailand (Visoottiviseth *et al*., 2002), Vietnam, Inner Mongolia, Greece, Hungary, USA, Ghana, Chile, Argentina and Mexico (O'Neill, 1995; Smedley and Kinniburgh, 2002).

Arsenic ranked the first in a list of 20 hazardous substances by the Agency for Toxic Substances and Disease Registry (Goering *et al.,* 1999). The main source of air and soil contamination with arsenic compounds is the mining of coal and oil as well as mining and metallurgy of non-ferrous metals (Ozna and Biernat, 2008) and in drinking water the source is arsenic-rich rocks through which the water has filtered. Bangladesh is a delta of high As contamination in groundwater. The people in Bangladesh are suffering due to the arsenic contamination. At present 80 million people in out of 64 districts across the country are exposed to arsenic poisoning and 10,000 people have already shown the symptoms of arsenicosis (Chowdhury, 2001). As far recorded, twenty countries including Bangladesh have been suffering from groundwater contamination by arsenic, which is the most severe problem occurring in Asia namely Bangladesh (Biswas *et al*.,1998). In Bangladesh, groundwater is the primary source of drinking water for up to 90% of a total population of 130 million (Khan *et al*.,1997;WHO, 2001). In some areas of Bangladesh, groundwater arsenic concentrations are as much as 2 mg L^{-1}(School of Environmental Studies and Dhaka Community Hospital, 2000) whereas the WHO provisional guideline is 0.05 mgL^{-1} (WHO, 2001). An estimated population of 25 million is exposed to arsenic concentrations of more than 0.05 mg L^{-1}, Bangladesh-permissible limit, and the number would be approximately doubled if WHO limit of 0.01 mg L^{-1} was adopted (School of Environmental Studies and Dhaka Community Hospital, 2000). It is estimated that arsenic in drinking water might cause 200,000 to 270,000 deaths from cancer in Bangladesh alone (WHO, 2001).

Bangladesh is one of the major rice growing countries. The people of Bangladesh are not only drink the arsenic contaminated groundwater but also irrigate their crops. In Bangladesh, irrigation is mostly dependent on groundwater. About 33% of total arable land of the country is under irrigation facilities (BBS, 1996). Presently, 75% of the total cropped area and 83% of the total irrigated area are used for rice cultivation. Irrigation is principally performed in dry season for Boro rice cultivation. About 86% of the total groundwater withdrawn is used for irrigating crops mainly Boro rice (WRI, 2000). In Bangladesh, a large number of shallow tubewell (STW) and deep tubewell (DTW) have been installed to irrigate about 4.3 million hectors of crop land which contributes to the food grain production of the country significantly (Rashid *et al.*, 2004). A large number of tube wells in at least 61 districts out of 64 have been identified to have arsenic concentration above the national recommended limit of 0.05 mgL^{-1}. Long term irrigation with arsenic contaminated groundwater is likely to increase its concentration in crops (Ullah, 1998; Imamul, H. *et al*., 2003). The agricultural soil of arsenic non-contaminated areas of Bangladesh contain 4.0 to 8.0 mg of As kg^{-1} while that irrigated with arsenic contaminated groundwater, contain up to 83 mg of As kg^{-1} (Ullah, 1998). The maximum acceptable concentration of arsenic in agricultural soil is 20 mg kg^{-1} (Kabata and Pendias, 1992).

Arsenic (As) is not essential for plant growth because of chemical similarities to P, As is able to replace P in many cell reactions and it shows many harmful toxicities to plants including wilting of new-cycle leaves and retardation of root and top growth. All the growth and yield parameters of Boro rice responded positively at lower concentrations of up to 0.25 mg As L^{-1} in irrigation water but decreased sharply at concentrations more than 0.5 mg As L^{-1}. At higher concentration, arsenic is toxic to most plants. It interferes with metabolic processes and inhibits plant growth and development through arsenic induced phytotoxicity (Marin *et al.*, 1993). When plants are exposed to excess arsenic either in soil or in solution culture, they exhibits toxicity symptoms such as: inhibition of seed germination (Abedin *et al*., 2002a),decrease in plant height (Marin *et al.*, 1992; Carbonell *et al.*, 1995; Abedin *et al.*, 2002b; Jahan *et al.*, 2003), depress in tillering (Kang *et al.*, 1996; Rahman *et al.*, 2004), reduction in root growth (Abedin *et al*., 2002a), decrease in shoot growth (Cox *et al*., 1996) lower fruit and grain yield (Carbonell *et al*., 1995; Abedin *et al.*, 2002b; Kang *et al.*, 1996) and sometimes, leads to death (Marin *et al*., 1992; Baker *et al.*, 1976).

Rice is more susceptible to arsenic toxicity compared to upland crops, because of an increase in both the bioavailability and toxicity of arsenic under the submerged soil of paddy fields (Horswell and Speir, 2006). Rahman *et al.* (2008) investigated the severity of straight head in rice (cv. BRRI dhan29) which was increased significantly up to 50 mg of As kg^{-1} soil treatments. Straight head resulted in sterile florets with distorted lemma and palea, reduced plant height, tillering, panicle length and grain yield. Straight head caused approximately 17-100% sterile florets/spikelet formation and about 16-100% loss of grain yield. No rice plant survived up to maturity stage in soil treated with 60 and 90 mg As kg^{-1} was reported by Rahman *et al.*, (2007). Wang *et al*. (2006) reported that As (roxarsone or arsanilic acid) could significantly reduce plant height, number of effective tiller, straw yield and grain yield. Arsenic significantly reduced Phosphorus concentration in rice (Zhu, 2003). Kiss *et al*. (1992) reported red/yellow discoloration of rice leaf due to arsenic poisoning. Also there are a few arsenic induced diseases of rice, most remarkable is “Straight head” disease (Martin *et al*., 1992) or ‘parrot beak’ (because of misshaped grains)(Williams, 2003). Arsenic uptake and accumulation in rice plant from irrigation water may differ depending on cultivars used (Xie and Huang, 1998). It is therefore, apparent that the use of arsenic contaminated irrigation waters in Bangladesh may cause accumulation of arsenic in rice and rice plants, which needs to be examined.

Arsenic may enter into human body directly through drinking water and indirectly through foods, chiefly rice for Bangladeshi people. Nowadays it suggests that widespread use of groundwater for irrigation is another route of arsenic which enter the food chain. Duxbury *et al.* (2002) mentioned the presence of arsenic in food chain. Arsenic is transported by the blood to different organs in the body, mainly in the form of monomethyl arsonic acid. After acute and chronic exposure arsenic causes a wide variety of adverse health effects to humans (Mandal and Suzuki, 2002). Indirect effect of arsenic poisons is disrupting the digestive system, change in skin color, formation of skin patches, stomach pains, vomiting and gangrene. (Islam, 2013).

Variety is the most important factor in rice production. Yield components are directly related to the variety and neighboring environments in which it grows. Variety is the key component to produce higher yield of rice depending upon their differences in genotypic characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season. The growth process of rice plants under a given agro-climatic condition differs with variety. In the year 2015-2016 among the Boro rice varieties modern varieties covered 98.29% and yield was 2.44 t ha^{-1} on the other hand local varieties covered 1.71% and yield was 1.37 t ha^{-1} (BBS, 2016). It was the farmers who have gradually replaced the local indigenous low yielding rice varieties by HYV of rice developed by BRRI only because of getting 20% to 30 % more yield $unit^{-1}$ land area (Shahjahan, 2007). This variety however, needs further test under different adaptive condition to interact with different environmental conditions and hazards materials. Considering these matters this research work was under taken with the following objectives:

- To compare the growth yield and yield component of the two rice varieties under different As treatments,

- To find out the effect of As on the nutrient content of two selected rice cultivars.

CHAPTER-II

REVIEW OF LITERATURE

Growth and yield of rice plants are greatly influenced by the environmental factors i.e. air, day length or photoperiod, temperature, variety and agronomic practices like transplanting time, spacing, number of seedlings, depth of planting, fertilizer management etc. and abiotic stresses like salinity, drought, flood, contamination by heavy metals etc. Yield and yield contributing characters of rice are considerably influenced by different levels of contamination by heavy metals like Arsenic, Cadmium, Lead etc. Arsenic is one the most widespread and toxic heavy metals in several parts of the world. It is one of the main pollutants in paddy fields near industrial areas and highly toxic to plant growth and development. But the available relevant reviews related to As and variety in respect of their performance is very limited in the context of Bangladesh as well as the World. Some of the recent past information on As and variety performance on rice have been reviewed under the following headings:

2.1. Sources of arsenic in the environment

Arsenic is found in natural and anthropogenic sources (Hughes, 2002). It occurs naturally in rocks and soil, water, air, plants and animals. Volcanic activity, erosion of rocks and minerals, and forest fires are natural sources. The terrestrial abundance of arsenic is around 1.5-3.0 mg/kg (Mandal and Suzuki, 2002).

The amount of arsenic that occurs in soil varies considerably from country to country from 0.1 to 50 mg/kg at an average concentration of about 5-6 mg/kg (Colbourn *et al.*, 1975). Arsenic concentrations in soils are mostly present in sulphide ores of metals including sodium, copper, lead, silver and gold (BGS, 1999). Arsenic in soils may originate from parent materials (Tanaka, 1988), but it is present in soils in higher concentrations than those in rocks (Peterson *et al.*, 1981). Uncontaminated soils usually contain 1.0-40.0 mg/kg of arsenic with the lowest concentrations in sandy soils and those derived from granites, whereas larger concentrations are found in alluvial and organic soils (Mandal and Suzuki, 2002).

Arsenic concentrations in soils enriched in these ores are often higher than in normal soil (BGS, 1999). The parent materials of soil are usually sedimentary rocks. During the formation of these rocks, arsenic is carried down by precipitation of iron hydroxides and sulphides. Therefore, iron deposits and sedimentary iron ores are rich in arsenic (Maclean and Langille, 1981).

Arsenic occurs mainly as inorganic species, but it also can bind to organic material in soils (BGS, 1999 and Mandal and Suzuki, 2002). Arsenic may accumulate in soils through the use of arsenical pesticides, herbicide, fertilizer etc. Inorganic arsenic may be converted to arsenic compounds by soil microorganisms (Wei *et al.*, 1991). The total amount of arsenic in soils and its chemical forms has an important influence on plant, animal and human health (Nriagu and

Azcue, 1994). Accumulation of arsenic can cause toxic effects to plants and enter the human food chain.

Arsenic retention and release by sediments depends on the chemical properties of the sediments, especially on the amount of iron and aluminium oxides and hydroxides they contain (BGS, 1999). The amount of sedimentary iron is an important factor that influences arsenic retention in sediments (Mandal and Suzuki, 2002).

The concentrations of arsenic in unpolluted fresh waters typically range between 0.001 mg/L and 0.01 mg/L, rising to 0.1-5.0 mg/L in areas of sulphide mineralization and mining (Smedley *et al.*, 1996).

Apart from this, arsenic and arsenic compounds (arsenicals) are used for a variety of industrial purposes. The burning of fossil fuels, combustion of wastes, mining and smelting, pulp and paper production, glass manufacturing, and cement manufacturing can result in emissions of arsenic to the environment (EPA, 1998).

Uddin (1998) reported that the mean As concentration in uncontaminated agricultural soils in some districts of Bangladesh varied between 2.6 and 7.6 mg As kg^{-1} (mean 4.64 mg As kg-1) which is comparable to the standard level of As in other uncontaminated soils from various countries ranging from 0.1 to 40 mg kg-1 (mean 6 mg kg-1) (Mandal and Suzuki, 2002). A similar range of 0.5–25 mg kg^{-1} was reported by Kabata and Pendis (1992) for As content of surface soils from different countries.

In contrast, soil As in some Bangladesh areas where irrigation is carried out with As contaminated groundwater, soil As level can reach up to 83 mg kg-1 (Ullah, 1998). This As content falls in the reported range of 10– 2470 mg As kg-1 for soils contaminated by pesticides wastes or industrial activity (Kabata and Pendias, 1992; Mandal and Suzuki, 2002).

Alam and Sattar (2000) reported that elevated As concentrations up to 57 mg kg-1 in Bangladesh soils collected from different locations could lead to elevated concentrations of As in rice grain and rice straw, which is used to feed cattle's and cows. A detailed As survey in soils of Bangladesh has been done by BGS (1999).

As is an element of most plants, which is found to be cumulative in living tissue, i.e., once ingested by any organism it is passed out of the organism only very slowly if at all. The amount of As in a plant, depends almost solely on the amount of As. Its concentration varies from less than 0.01 to about 5 mg g^{-1} (dry weight basis) (Mandal and Suzuki, 2002). There appears to be little chance that animals will be poisoned by consuming plants which absorb As residues from contaminated soils, because plant injury occurs before toxic concentrations can appear. The As taken up by various plant species, that As was translocated within the plant since its concentration in the grain was detectable. With increasing soil As concentrations, however, the highest As concentrations were always recorded in old leaves and in roots (Kabata and Pendias, 1992). Concentrations of as in plants grown on uncontaminated soils vary from 0.009 to 1.5 mg kg^{-1}, with leafy vegetables having the higher concentrations, and fruits the lower concentrations.

2.2 Arsenic availability to plants

Huq *et al.* (2005) found green algae accumulate arsenic at a significantly high concentration while grown in boro rice field in Bangladesh. This accumulation of arsenic by green algae from irrigation water may cause lower accumulation of arsenic by rice plant, which would be beneficial to the people of Bangladesh.

In case of rice, Ghani *et al.*, (2004) also observed higher accumulation of As in rice roots (121.56 x117.03 ppm) followed by straw (13.01 x 3.57 ppm) and least in grain (0.12 x 0.05).

Hiromi and Ahmad (2003) collected rice samples from different part of the country and conducted test for arsenic and found arsenic contamination range from 0.1 to 0.3 ppm which was similar to that of Japan's rice. But the limitations of the study were samples collected from farmer's house and market so there was no perfect indication of arsenic in soil and water.

Das *et al.,* (2003) conducted test for arsenic in rice grown on the soils adjacent to arsenic contaminated water source. They found roots of paddy accumulated the highest arsenic concentration followed by shoot and rice grain (0.23 ppm). The ratio of As concentration in root, shoot and grain is 1: 6:10. But they didn't show the level of As in soil.

In another study conducted by Ali *et al.*, (2003), the highest concentration of arsenic was found in the roots (2.81-16.8 mg/kg) of rice plant, and the comparatively a lower concentration in stem and leaves and the lowest concentrations were found in rice grain (0.05 - 1.52 mg/kg with a mean of OA 8 mg/kg).

Duxbury *et al.*, (2002) collected 150 samples of paddy grains from Barisal, Comilla, Dinajpur, Rajshahi and Rangpur districts in Bangladesh and determined the arsenic concentration in the grain. He found arsenic concentration in the range from 0.01 to 00415 mg/kg dry weight. As expected grain arsenic concentrations were higher for Boro rice (mean value 183 µg/kg dry wt.) compared to Aman rice (mean value 117 µg/kg dry weight).

Recent studies by Meharg *et al.,* (2002) demonstrate significant uptake of As by rice grown in Bangladesh.

Abedin *et al.*, (2002) found arsenic, arsenate, DMAA and MMAA in soil solution where rice (8 Bangladesh Varieties) was irrigated with arsenic (arsenate, arsenite, DMAA, MMAA) contaminated water having arsenic concentration 0 to 8 mgL-1 in greenhouse experiment. Uptake of both arsenite and arsenate by Boro varieties was less than that of Aman varieties. Arsenite uptake was carrier-mediated, and was taken up at approximately the same rate as arsenate. In presence of phosphate arsenate uptake strongly suppressed while arsenite transport was not affected. However, at a slow rate, there was a hyperbolic uptake of MMAA and limited uptake of DMAA. They found accumulation of arsenic in rice grain was limited and was less than the maximum permissible limit of 1mg/kg (National Food Authority, Australia, 1993). The presence of very high concentrations of arsenic in rice straw could pose a potential health hazard to the cattle population as rice straw is used as cattle feed in Bangladesh and in other countries.

Huq *et al.,* (2001) reported 0.11 to 0.35 mg/kg As found in cooked rice collected from Munshigonj, Bangladesh.

Chakraborti *et al.*, (2001) showed 95% inorganic and 5% organic As species in rice. Irrespective of arsenic chemical forms root arsenic concentration was 10.5 mg/kg in the 0.05 mg As/L. treatment, which increased to 212.7 mg/kg in the 0.8 mg As L^{-1} treatment (Marin *et al.*, 1992).

Xie *et al.,* (2001) determined As contents of roots, flag leaf, grain and husked rice of II new cultivars of rarely rice variety cultivated in paddy soils polluted from tailingat an abandoned lead-zinc-silver mine at Xhoxing, Zhejang, China. They found As concentrations in husked rice exceeded the hygienic standard (0.7 mg As/kg) when they grew in the soil having total As content 70-100 mg/kg.

Bennett *et al.,* (2000) tested wild rice collected from Seely, Willow Flowage, Crandon and Port Edwards area of Northern Wisconsin, USA and found arsenic concentrations (ppm) 12.00, 0.34, 0.81 and 0.11 in root (36), stem (27), leaf (30) and seed (4) respectively and average concentration 4.82 ppm. The mean for As is almost double that of Nriagu and Lin's value of 0.066 ppm for store-bought wild rice (Nriagu and Lin, 1994).

Rice grain generally has lower arsenic concentration (Schoof *et al.*, 1999; Heitkemper *et al.*, 2001) and the concentration remain much below maximum permissible limit of 1 mg As kg^{-1}.

Accumulation of arsenic is affected by arsenic concentration in soil or nutrient media and increased greatly with increasing arsenic levels (Xie and Huang 1998).

Arsenic concentration pattern in rice plant parts generally follow the pattern: root> straw> husk> whole grain >husked rice (Xie and Huang, 1998). However, a study conducted Yan Chu (1994) has posed a relationship between arsenic concentration in soil solution and rice also tested to quantify the effect of arsenic level uptake into rice. The regression equation found between the amount of arsenic present in the rice plant, Y, and the amount of arsenic in aqueous solution, X, to be: $Y = 0.042X - 0.0413$.

Marin *et al.,* (1992) also reported higher accumulation of arsenic in roots than any other plant parts.

2.3 Performance of As on rice

Bhattacherjee *et al.,* (2014) investicated to higher levels of As adversely affected the nutrient content and their uptake by rice except N contents. Nitrogen content increased with the increase of As level. Higher amount of nutrient content and uptake was recorded in BRRI dhan48 and flood condition enhanced higher nutrient content as well as uptake by rice. This study suggests the possible management of moisture regime and considering less As susceptible variety, which might reduce the toxic effects of As on nutrient uptake.

Talukder *et al.*, (2011) examined that the effects of water management (WM) and Phosphorus (P) rates on As uptake, rice growth, yield and yield attributes of winter (boro) and monsoon (aman) rice in an As contaminated soil-water. Significantly, the highest average grain yields (6.88+or-0.07 t ha-1 in boro 6.38+or-0.06 t ha-1 in aman) were recorded in permanent raised bed (PRB; aerobic WM: Eh=+360 mV) plus 100% P amendment. There was a 12% yield increase over conventional till on flat (CTF; anaerobic WM: Eh=-56 mV) at the same P level. In boro, the As content in grain and As content in straw were about 3 and 6 times higher in CTF compared to PRB, respectively. The highest total As content (0.646+or-0.01 ppm in grain and 10.93+or-0.19 ppm in straw) was recorded under CTF, and the lowest total As content (0.247+or-0.01 and 1.554+or-0.09 ppm in grain and straw, respectively) was recorded under PRB (aerobic WM). The results suggest that grain and straw As are closely associated in boro rice. The furrow irrigation approach of the PRB treatments consistently reduced irrigation input by 29-31% for boro and 27-30% for aman rice relative to CTF treatments in 2004 and 2005, respectively, thus reducing the amount of As added to the soil from the As-contaminated irrigation water.

Khan *et al.*, (2010a) reported that relatively low mobility of applied As and the likely continued detrimental accumulation of As within the rooting zone. Arsenic addition in either irrigation water or as soil-applied As resulted in yield reductions from 21 to 74% in Boro rice and 8 to 80% in T. Aman rice, the latter indicating the strong residual effect of As on subsequent crops. The As concentrations in rice grain (0.22 to 0.81 micro g^{-1}), straw (2.64 to 12.52 micro g^{-1}) and husk (1.20 to 2.48 micro g^{-1}) increased with increasing addition of As. A critical need exists for the development of crop and water management strategies to minimize potential As hazard in wetland rice production.

Rahman (2010) observed that application of arsenic, at 30, 50, 70, 90 DAT and harvest the longest plant (17.59 cm, 32.53 cm, 56.64 cm, 77.04 and 84.09 cm), maximum length of panicle (23.10 cm), highest number of filled grains panicle^{-1} (92.52), highest grain yield (3.91 t ha^{-1}) and highest straw yield (7.52 t ha^{-1}) was recorded in As, whereas the shortest plant (16.44 cm, 28.88 cm, 53.40 cm, 72.53 cm and 80.85 cm), minimum length of panicle (22.05), lowest number of filled grains panicle^{-1} (79.35), lowest grain yield (3.39 t ha^{-1}) and lowest straw yield (7.16 t ha^{-1}) was recorded in As.

Bhattacharya *et al.*, (2010) found that the arsenic uptake in rice to vary with different rice varieties; the maximum accumulation was in White minikit (0.31+or-0.005 mg/kg) and IR 50 (0.29+or-0.001 mg/kg) rice varieties and minimum was found to be in the Jaya rice variety (0.14+or-0.002 mg/kg). In rice plant maximum arsenic accumulation occurred in the straw part (0.89+or-0.019-1.65+or-0.021 mg/kg) compared to the accumulation in husk (0.31+or-0.011-

0.85+or-0.016 mg/kg) and grain (0.14+or-0.002-0.31+or-0.005 mg/kg) parts. For any rice sample concentration of arsenic in the grain did not exceed the WHO recommended permissible limit in rice (1.0 mg/kg).

Arsenic (As) is now regarded as one of the most serious contaminants as a typical noxious element-especially inorganic arsenic reported by Wang *et al.,* (2010). Indeed, arsenic has a chronic poisoning effect in human body. Recent studies have shown that rice is much more efficient in assimilating arsenic into its straw and grains than other staple cereal crops, and consumption of rice constitutes a large proportion of dietary intake of arsenic. Therefore, scientists pay a high degree of attention to arsenic in rice. In rice total As content varies from 0.005 to 0.710 mg/kg. Arsenic speciation in rice grain is dominated by inorganic As (III+V) and dimethylarsinic (DMA). The inorganic As content in rice varies from 10% to 90% of total As.

The study was conducted by Dittmar *et al.,* (2010) investigated that straw and grain As concentrations were elevated in the field and highest near the irrigation water inlet, where As concentrations in both soil and irrigation water were highest. On the basis of a recently published scenario of long-term As accumulation at the study site, it was estimated that, under unchanged irrigation practice, average grain As concentrations increase from currently ~0.15 mg As kg^{-1} to 0.25-0.58 mg As kg^{-1} by the year 2050. This translates to a 1.5-3.8 times higher As intake by the local population via rice, possibly exceeding the provisional tolerable As intake value defined by FAO/WHO.

Khan *et al.,* (2010b) reported that some paddy soils in the Bengal delta are contaminated with arsenic (As) due to irrigation of As-laden groundwater, which may lead to yield losses and elevated As transfer to the food chain. Whether these soils have a higher As bioavailability than other soils containing either geogenic As or contaminated by mining activities was investigated in a pot experiment. Fourteen soils varying in the source and the degree (4-138 mg As kg^{-1}) of As contamination were collected, 10 from Bangladeshi paddy fields (contaminated by irrigation water) and two each from China and the UK (geogenic or mining impacted), for comparison. Bangladeshi soils had higher percentages of the total As extractable by ammonium phosphate (specifically sorbed As) than other soils and also released more As into the porewater upon flooding. Porewater As concentrations increased with increasing soil As concentrations more steeply in Bangladeshi soils, with arsenite being the dominant As species. Rice growth and grain yield decreased markedly in Bangladeshi soils containing >13 mg As kg^{-1}, but not in the other soils.

Begum *et al.,* (2008) reported that the grain yield of Boro rice was reduced by 20.6 % for 15 ppm As treatment and 63.8 % due to 30 ppm As. Such reductions for straw yield were 21.0 and 65.2 % with these two As treatments, respectively. Residual effect of arsenic was also significant and negative in T. Aman rice. The grain-As concentration in all cases was below 1 ppm, and the straw-As content was well above 1 ppm. The arsenic concentrations of both grain and straw were lower in T. Aman rice than in Boro rice. N content in grain and straw increased with increasing addition of arsenic.

Panaullah *et al.,* (2009) showed that increasing soil As levels resulted in significant decrease in rice yield, raising serious concern about phytotoxicity of As. After 16–17 years of use of the tubewell, a spatially variable build up of As and other chemical constituents of the water (Fe, Mn and P) was observed over the command area, with soil-As levels ranging from about 10 to 70 mg kg^{-1}. When BRRI dhan 29 rice was grown in two successive years across this soil-As gradient, yield declined progressively from 7–9 to 2–3 t ha^{-1} with increasing soil-As concentration. The average yield loss over the 8 ha commands area was estimated to be 16%. Rice-straw As content increased with increasing soil-As concentration; however, the toxicity of As to rice resulted in reduced grain-As concentrations in one of the 2 years.

Hossain *et al.,* (2008) investicated to the effects of different concentrations of arsenic (As) in irrigation water on Boro (dry-season) rice (Oryza sativa) and their residual effects on the following Aman (wet-season) rice. All the growth and yield parameters of Boro rice responded positively at lower concentrations of up to 0.25 mg As L^{-1} in irrigation water but decreased sharply at concentrations more than 0.5 mg As L^{-1}. Arsenic concentrations in grain and straw of Boro rice increased significantly with increasing concentration of Asin irrigation water. The grain As concentration was in the range of 0.25 to 0.97 ug g^{-1} and its concentration in rice straw varied from 2.4 to 9.6 mg g^{-1} over the treatments. Residual As from previous Boro rice showed a very similar pattern in the following Aman rice, although As concentration in Aman rice grain and straw over the treatments was almost half of the As levels in Boro rice grain.

Duxbury and Panaullah (2007) reported that rice yields in conventional paddy fields decreased from 8.92 to 2.99 t/ha as soil-As levels increased from 26.3 to 57.5 mg/kg. Complementary pot studies showed greater yield reductions at higher soil-As levels than in the field. In both trials, the popular modern rice variety BR29 was used. The practical limit for paddy cultivation might lie at soil-As levels between 25 and 50 mg/kg. However, differences in varietal tolerance described above need to be kept in view, and so do differences in soil management. Also reported results from rice grown on raised beds, in which yields decreased from 8.24 t/ha at a soil As level of 26.3 mg/kg to 5.21 t/ha at 57.5 mg/kg As (i.e., 2.22 t/ha higher than in the flooded field at the highest As concentration).

Rahman *et al.,* (2007) conducted an experiment on the effect of soil arsenic on photosynthetic pigments, Chlorophyll-a and -b, and their correlations with rice yield and growth. Arsenic concentration in initial soil, to which the above mentioned concentrations of arsenic were added, was 6.44±0.24 mg kg^{-1}. Both chlorophyll-a and -b contents in rice leaf decreased significantly ($p < 0.05$) with the increase of soil arsenic concentrations. No rice plant survived up to maturity stage in soil treated with 60 and 90 mg of As kg^{-1}. The highest chlorophyll-a and -b contents were observed in control treatment (2.62±0.24 and 2.07±0.14 mg g^{-1}) were the average values of (chlorophyll-a and -b, respectively of the five rice varieties) while 1.50±0.20 and 1.04±0.08 mg g^{-1} (average of five rice varieties) of chlorophyll-a and -b, respectively were the lowest. The content of photosynthetic pigments in these five rice varieties did not differ significantly ($p > 0.05$) from each other in control treatment though they differed significantly ($p < 0.05$) from each other in 30 mg of As kg^{-1} soil treatment. Among the five rice varieties, chlorophyll content in BRRI dhan35 was found to be mostly affected with the increase of soil arsenic concentration while BRRI hybrid dhan1 was least affected. Well correlations were observed between chlorophyll content and rice growth and yield that arsenic toxicity affects the photosynthesis which ultimately results in the reduction of rice growth and yield.

Hossain *et al.,* (2005) also found yield reductions of more than 40 and 60% for two popular rice varieties (BRRI Dhan-28 and Iratom-24) when 20 mg/kg of arsenic was added to soils, compared to the control.

Guo *et al.,* (2005) investigated to the effect of silicate on the yield and arsenate uptake by rice. Rice seedlings (*Oryza sativa* L. cv. Weiyou 77) were cultured in modified Hoagland nutrient solution containing three arsenate levels (0, 0.5 and 1.0 mg L^{-1} As) and four silicate levels (0, 14, 28 and 56 mg L^{-1} Si). Addition of Si significantly increased shoot dry weight (P=0.001) but had little effect on root dry weight (P=0.43). Addition of As had no significant effect on shoot dry weight (P=0.43) but significantly increased root dry weight (P=0.01). Silicon concentrations in shoots and roots increased proportionally to increasing amounts of externally supplied Si (P<0.001). The presence of As in the nutrient solution had little effect on shoot Si concentration (P=0.16) but significantly decreased root Si concentration (P=0.005).Increasing external Si concentration significantly decreased shoot and root As concentrations and total As uptake by rice seedlings (P<0.001).

Delowar *et al.,* (2005) reported that extent of accumulation of arsenic in rice plants and its effects on growth and yield of rice. Arsenic concentrations in paddy soils (irrigated with 0, 2.5, 5, 10, 15 and 20 mg L^{-1} of arsenic water) were 0-0.2, 0-0.95 and 0-0.27 mg kg^{-1} at tillering, heading and ripening stages. Rice grains accumulated arsenic from soil/water and arsenic accumulation varied greatly in the two rice varieties studied. Arsenic concentrations in rice grains were 0-0.07 and 0-0.14 mg kg^{-1} dry weight in rice varieties BRRI dhan28 and Iratom 24, respectively. The growth and yield of rice plants were reduced significantly with increased doses of arsenic but the grain weight was not affected. Among the different yield components, the number of tillers per pot, number of effective tillers per pot and grain yield per pot reduced greatly with the higher dose (20 mg L^{-1}) of arsenic applied. Yield reduction of more than 60 and 40% for Iratom-24 and BRRI dhan28, was found with 20 mg L^{-1} of arsenic as compared to control. The reduction in straw yield was also significantly higher for both of rice varieties with the 20 mg L^{-1} arsenic application.

Williams *et al.,* (2005) observed that 64% of European, 80% of Bangladeshi and 81% of Indian rice arsenic were inorganic, with As(III) predominating. Arsenic from groundwater affects people in Bangladesh via seed grains and forages. Samples of rice (Oryza sativa L) and rice straw were collected from arsenic-contaminated areas and arsenic concentration was measured using Flow Injection Hidride Generator Atomic Absorption Spectrophotometer (FI-HG-AAS) method. The concentrations in rice and rice straw were 0.235 ± 0.014 ppm (n = 48) and 1.149 ± 0.119 ppm (n = 51), respectively. Both were greater than the maximum permissible concentration in drinking water (0.05 ppm; WHO).

The Cornell group found significant correlations between arsenic contents of soil, grain and straw. Average arsenic concentrations in rice grain and rice straw were 0.45 and 2.00 ppm, respectively (Farid *et al.*, 2005).

Alam (2005) reported that the highest amount of arsenic accumulated in the stem of a rice plant and the trend found is Stem> Leaf> Husk> Rice grain. The ratio of total arsenic in Stem, Leaf, Husk and Rice grain in BRRI dhan-28 and BRRI dhan-29 varieties rice plants are 71 : 26 : 2 : 1 and 65 : 31 : 3 : 1, respectively. Maximum deficiency of protein content found was in BRRI dhan-28 (27.9%) variety followed by Purbaehi, BR-14 and BRRI dhan-29. Deficiency of amylase content in the four tested varieties varies as BRRI dhan-29 > BRRIdhan-28 >Purbaehi> BR-14.

Jahiruddin *et al.,* (2004) studied the effects of As contamination on crop yield and as accumulation under control conditions. The levels of soil added arsenic were 0, 5, 10, 15, 20, 30, 40 and 50 ppm, and that of irrigation water As were 0, 0.1, 0.25, 0.5, 0.75, 1.0, 1.5 and 2 ppm. The effect of added as (plus 2.6 ppm soil as) was tested directly on Boro rice (cv. BRRI dhan 29) and its residual effect on T. Arnan rice (cv. BRRI dhan 33). The pots for both crops received an equal amount of fertilizers. They found that the grain protein was adversely affected due to arsenic contamination. 40% grain yield reduction for 10 mg kg^{-1} arsenic addition to BAU farm soil.

Islam *et al.,* (2004) observed an adverse effect of irrigation water arsenic (As) on Boro rice (February to June) and the residual effect on T. Aman rice (August-November). There were eight treatments consisting of Control, 0.10, 0.25, 0.50, 0.75, 1.00, 1.50 and 2.00 ppm As added through irrigation water. A total of 56 L of irrigation water having different concentrations of As was needed for the Boro rice (cv. BRRI dhan29). After harvest of Boro rice, T. Aman rice (cv. BRRI dhan 33) was grown in the same pots with monsoon rain. Nutrients such as N, P, K and S @ 100, 25, 40 and 25 ppm, respectively were added to sustain normal growth of both Boro and T. Aman rice. The irrigation water added As up to 0.25 ppm enhanced the plant height, panicle length, filled grains/panicle, 1000-grain weight and finally the grain yield of Boro rice and the further doses of depressed the plant growth, yield and yield components. The concentration of As in rice grain or straw of Boro rice increased significantly with increasing As concentrations in the irrigation water, the values for grain As for every As treatment were below the Maximum permissible level (1.0 ppm).

Shah *et al.,* (2004) has reported the level of arsenic in soil having concentration above 20 ppm may affect rice yield of Bangladesh variety.

Ghoshal *et al.,* (2003) examined the effect of irrigation water, contaminated with arsenic, on the uptake of phosphorus and arsenic by the different parts of the crop. The treatments comprised irrigation with arsenic-free deionized water and arsenic-contaminated irrigation water containing 0.29 ppm arsenic. Each treatment was divided into two series, namely, uncovered and covered (glazed black polythene sheet). Arsenic accumulation and concentration significantly increased in the straw and roots of the plants grown on soil irrigated with arsenic-contaminated water. Similar results were obtained with covered treatments. Arsenic concentration and accumulation was greater in the root than the straw. Phosphorus uptake was reduced with the increase in soil arsenic concentration and covering further reduced the same, indicating a significant arsenic-phosphorus interaction.

Elevated soil arsenic levels resulting from long-term use of arsenic contaminated ground for irrigation in Bangladesh may inhibit seed germination and seedling establishment of rice, the country's main food crop was reported by Abedin and Meharg (2002). A germination study on rice seeds and a short-term toxicity experiment with different concentrations of arsenite and arsenate on rice seedlings were conducted. Percent germination over control decreased significantly with increasing concentrations of arsenite and arsenate. Arsenite was found to be more toxic than arsenate for rice seed germination. There were varietal differences among the test varieties in response to arsenite and arsenate exposure. The performance of the dry season cultivar Purbachi was the best among the cultivars. Germination of Purbachi was not inhibited at up to 4 mg L^{-1} arsenite and 8 mg L^{-1} arsenate treatment. Root tolerance index (RTI) and relative shoot height (RSH) for rice seedlings decreased with increasing concentrations of arsenite and arsenate. Reduction of RTI caused by arsenate was higher than that of arsenite. In general, dry season varieties have more tolerance to arsenite or arsenate than the wet season varieties.

Abedin *et al.,* (2002) conducted an experiment to cheek the tolerance to germination of some Bangladesh HYV rice varieties to arsenic and found that most of the varieties showed tolerance upto 2 mg As L^{-1}. Percentage germination decreased considerably at 4 mg As L^{-1} and at the highest concentration of 8 gm As L^{-1} treatment germination was completely halted for all the varieties except purbachi. Purbachi was the only variety that showed tolerance up to 4 mg As L^{-1} treatment for arsenite and up to 8 mg As L^{-1} treatment for arsenate. Because of the tolerance of rice seeds for germination up to 2 mg As L^{-1} which is equivalent to highest reported concentration in Bangladesh groundwater, the use of contaminated groundwater might have little impact on germination.

Merakchiyska (2002) reported that arsenic concentrations of 25 mg kg^{-1} soil did not have negative effect on the photosynthetic process in bean plants (Phaseolus vulgaris L.) while the higher doses (50 and 100 mg of As kg^{-1} soil) inhibit the photosynthesis by 42 and 32%, respectively.

Increased arsenic concentrations caused an alternation of the chloroplast shape, manifested in its rounding and shortening of the longitudinal axis of plant cell. Other manifestations are concaving membrane, bending and partial destruction as well as changes in the accumulation and flow of assimilates which results in the decrease of chlorophyll content in rice leaf (Miteva and Merakchiyska, 2002).

Field and greenhouse experiments were simultaneously carried out by Montenegro and Mejia (2001) in rice (Oryza sativa cv. Oryzica) planted in soils of the Bogota river (Colombia) lower basin, to evaluate the effect of the Cd and As content in irrigation waters on soils, and on: (1) the physiological parameters of rice growth; (2) the amount of Cd and As accumulated in the different parts of rice plants; and (3) the yield and other aspects and properties of rice crop. The results of the experiment led to the following conclusions: (1) rice reached its maximum height when neither element was present in the irrigation waters; (2) the gradual increase of Cd in the irrigation waters decreased by 12.5% the number of grains per panicle, while an increase in As content induced a 10% reduction in the same parameter; (3) when irrigation waters used contained the highest concentration of Cd and As, yields were significantly reduced; maximum yield were obtained when Cd and As were absent from the irrigation waters; (4) at any concentration of As in irrigation waters, the highest concentration of Cd accumulated in the rice leaves when the concentration of Cd in irrigation water was 2 mg/litre; above this value, Cd accumulation in leaves decreased with the gradual increase of As concentration; (5) accumulation of Cd and As in rice grains increased with the gradual increment in concentration of both elements in the irrigation waters; amounts of Cd and As accumulated in the rice grains were 50 and 150 times, respectively, higher than the maximum critical levels.

Kang *et al.,* (1996) reported that increasing the level of arsenic decreased plant height, number of effective tillers, dry weight of aboveground parts and 1000-grain weight. Yields decreased from 48.7 g/pot with the lowest rate of arsenic to 17.9 g with the highest rate. Content of arsenic was higher in roots than in stems plus leaves or in grain, but in all parts the content increased as soil arsenic increased. The contents of arsenic in stems plus leaves were more closely related to soil total and available arsenic than those of roots or grain.

Onken and Hossner (1995) also reported rice yield reduction by 66% when mean soil solution arsenic concentration reached 1.5 mg/L. The arsenic concentration at which rice yield is decreased by 10% is judged tobe the maximum allowable limit or critical content of arsenic in soil (Yan-chu, 1994). Nriagu and Lin (1994) reported rice yield decreases by 10% at 25 ppm of arsenic in soil. While reviewing soil arsenic concentration effect on rice yield. Yan-chu (1994) reported a reduction of yield by 10% at 12.5-29 mg As kg L^{-1}, 50% at 47-52 mg As kg^{-1}, no yield leading to death of plants occurred at 109-157 mg As kg L^{-1}.

Chen and Liu (1993) investigated that the effect of pH in the movement of arsenic (As) in the plant-soil system. Increasing the soil pH decreased As adsorption and thereby increased the As concentration in the soil solution. Therefore as the soil pH rose As availability to rice increased and toxicity problems became more serious. They also reported that from a pot experiments, low levels of arsenite (As3+) added to the soil increased growth due to inhibition of photorespiration unnecesary for growth, which led to less depletion of photosynthates. High levels of arsenite caused phytotoxicity due to inhibition of necessary respiration.

Kabata and Pendias (1992) recommended the safe level of arsenic in agricultural soil as 20 mg As kg^{-1}. the reduction of rice plant growth, in terms of tillering, plant height and shoot biomass production, was the ultimate result of arsenic phytotoxicity at high soil arsenic concentrations (Jahan *et al.*, 2003; Rahman *et al.*, 2004; Xie and Huang, 1998) though the phytotoxicity at lower soil arsenic concentrations was not significant.

Higher soil arsenic concentrations decrease the nitrogen content in garden pea (Paivoke, 1983) and silver bet (Merry *et al.*, 1986).Tsutsumi (1980) and Marin *et al.* (1992) reported about reduced plant height, Tang and Miller (1991) and Marin *et al.* (1993) reported about reduced root and Tsutsumi (1980), Milam *et al.* (1988), Tang and Miller (1991), Marin *et al.* (1992, 1993) reported reduced shoot biomass and/or growth in rice grown either in soil or in solution culture with arsenic. However, improved tillering (Xie and Huang 1994) and no reduction in dry matter production (Marin *et al.,* 1993) have also been reported while arsenic concentrations in the growing media were low. Significant reduction in dry biomass (root and shoot), leaf area and net photosynthesis was observed with increasing concentration of DMAA (0 - 1.6 mg As L-1) by Marin *et al.* (1993). A physiological disease, straight head has been reported to be associated with arsenic (Wells and Gilmour, 1977; Gilmour and Wells, 1980). It was also found that 7 ppm of arsenic causes injury to rice plant and would affect farm output productivity (Yan- Chu,1994).

2.4 Performance of rice cultivars

The successful production of any crop depends on manipulation of basic ingredients of crop culture. The variety of crop is one of the basic ingredients. Variety itself is the genetic factor which contributes a lot in improving yield and yield components. Different scientists reported on the effect of rice varieties on grain yields. Some available information and literature related to the effect of variety on the yield and yield contributing characters of rice are furnished here.

Chamely *et al.*, (2015) observed variety exerted significant effect on all the yield and yield contributing characters of boro rice except plant height. The highest number of total tillers $hill^{-1}$ was recorded in the variety BRRI dhan29 which was statistically similar with the variety BRRI dhan28 and the lowest number of total tillers $hill^{-1}$ was observed in BRRI dhan45. The highest number of effective tillers $hill^{-1}$ was recorded in the variety BRRI dhan29 and the lowest one was observed in BRRI dhan45. The reasons for differences in producing bearing tillers $hill^{-1}$ might be due to the variation in genetic make-up of the variety that might be influenced by heredity.

Roy *et al.,* (2014) evaluated that the plant height and number of tillers $hill^{-1}$ at different days after transplanting varied significantly among the varieties up to harvest. At harvest, the tallest plant (123.80 cm) was recorded in Bapoy and the shortest (81.13 cm) was found in GS one. The maximum number of tillers hill^{-1} (46.00) was observed in Sylhetyboro and the minimum (19.80) in Bereratna. The maximum number of effective tillers hill^{-1} (43.87) was recorded in the variety Sylhetyboro while Bereratna produced the lowest effective tillers hill^{-1} (17.73). The highest (110.57) and the lowest (42.13) number of filled grains panicle^{-1} was observed in the variety Koijore and Sylhetyboro, respectively. Thousand grain weight was the highest (26.35 g) in Kali boro and the lowest (17.83 g) in GS one. Grain did not differ significantly among the varieties but numerically the highest grain yield (5.01 t ha^{-1}) was found in the variety Koijore and the lowest in GS one (3.17 t ha^{-1}).

Islam *et al.*, (2014) showed that urea fertilizer application method significantly influenced plant height, tillering production, leaf area index, effective tillers hill^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panicle^{-1}, 1000-grain weight, grain yield, straw yield, and biological yield. Application of USG N as at 7 DAT gave highest yield (7.82 t ha-1) while application of 15 kg N ha^{-1} as PU 30 DAT+ 15 kg N ha^{-1} as PU at 50 DAT gave lowest yield (4.88 t ha^{-1}). Varietal influence were significant on tillering pattern, leaf area index, effective tillers hill^{-1}, filled grains panicle^{-1},1000-grain weight, grain yield, straw yield and biological yield. BR11 gave the highest yield (8.17 t ha^{-1}) which was statistically similar with BRRI dhan46 (7.3 t ha^{-1}) while the lowest yield obtained from BRRI dhan33 (2.87 t ha^{-1}).

Zohra *et al.*, (2013) found that grain yield was highest (5.46 t ha^{-1}) in BRRI dhan46 and straw yield was highest (6.58 t ha^{-1}) in Kalizira. It was observed that in most of the cases, all the varieties performed better for their yield contributing characters with 2 pellets of USG/4 hills compared to any other levels. The findings suggest that BRRI dhan46 can be cultivated to obtain high rice yield in transplant aman season.

Alam *et al.*, (2012) conducted an experiment to evaluate the effect of variety, spacing and number of seedlings hill^{-1} on the yield potentials of transplant aman rice. Variety had significant effects on almost all the yield component characters and yield. Among the varieties BRRI dhan33 gave significantly the tallest plant (113.17 cm), which is statistically identical with BR11 (111.25 cm). The highest number of total tillers hill^{-1} (12.23) was produced by BR11 and the lowest number of total tillers hill^{-1} (10.17) was produced by BRRI dhan32. All the yield components characters (tillers hill^{-1}, effective tillers hill^{-1}, panicle length, weight of 1000-grain and grain yield) except number of fertile spikelets panicle^{-1} were highest in case of variety BR11 and hence it produced the highest grain yield (5.92 t ha^{-1}).

Debnath *et al.*, (2012) observed that variety had significant effect on all the agronomic parameters except number of effective tillers, ineffective tillers, total tillers, grain straw ratio and biological yield. BRRI hybrid dhan2 produced the highest dry grain yield (5.92 t ha^{-1}) and the lowest straw yield (4.97 t ha^{-1}), whereas, BRRI dhan29 produced the lowest grain yield (4.16 t ha^{-1}) and the highest straw yield (6.70 t ha^{-1}).

Ashrafuzzaman *et al.,* (2009) found that Kalizira was the tallest (107.90 cm) of all the studied varieties. It had shown no significant difference with BRRI dhan38 (107.80 cm) and BRRI dhan34 (106.70 cm). BRRI dhan34 showed the highest number of panicles per hill (11.67) followed by Kalizira (11.33).The rice varieties differed significantly ($P<0.05$) with respect to leaf chlorophyll content, plant height, internode length, thousand grain weight and grain and straw yields. Varieties differed in morphological and yield and yield contributing traits. Thousand grain weight and grain yield both was highest in BRRI dhan38. Basmati required shorter days to maturity and Kalizira longest days to maturity.

Takita (2009) reported that Nerica rice has erect panicles even after maturity which can favor high canopy photosynthesis with less light interception by these panicles than droopy panicles.

Hasanuzzaman *et al.,* (2009) in a study found that the length of panicle in late transplanted Aman rice ranged from 23.59 to 21.30 cm.

Number of panicles was the result of the number of tillers produced and the proportion of effective tillers, which survived to produce panicle (Hossain *et al.*, 2008).

Kabir *et al.,* (2009) was carried an experiment in transplant Aman season 2008 to find out the effect of urea super granules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield attributes of transplant Aman rice varieties. Two transplant Aman rice varieties viz. BRRI dhan41 and BRRI dhan46 and ten levels of integrated nutrient management encompassing USG, PU and PM were tested. In case of varietal effect plant height, total tillers hill^{-1}, effective tillers hill^{-1}, length of panicle, grains panicle^{-1}, unfilled spikelets panicle^{-1}, grain yield, straw yield and harvest index were significantly influenced at different levels of significance. Variety BRRI dhan41 produced higher grain and straw yield and harvest index than that of BRRI dhan46. Higher grain yield in BRRI dhan41was due mainly to higher of effective tillers hill^{-1} and grains panicle^{-1}.

Sultana (2008) observed that number total of tillers hill^{-1} was not significantly affected by variety. Apparently more number (11.07) of total tillers was produced by the variety BR14 than BR26 (10.90).

Obaidullah (2007) stated that variety significantly influenced panicle length, number of total grains panicle1, filled grains panicle1, 1000 grains weight, grain yield and straw yield but not for effective tillers hill1 and harvest index. The varietal effects on yield and other yield attributes where hybrid variety gave numerically maximum tillers hill^{-1} (10.08), and significantly highest panicle length (27.36 cm), grains panicle^{-1} (196.75), filled grains panicle^{-1} (156.84), 1000 grain weight (27.40 g) which eventually elevated the grain yield (5.58 t ha^{-1}). These parameters were 9.8, 25.17 cm, 112.83, 86.77, 20.09 g and 3.88 t ha^{-1}, respectively as lowest measurements from inbred varieties.

Jesy (2007) observed that weight of 1000-grains was not significantly affected by variety. Apparently BRRI dhan4l produced the higher weight of 1000-grains (23.42 g) than BRRI dhan40 (23.39 g).

BRRI (2006) studied the performance of BR14, Pajam, BR5 and Tulsimala and reported that Tulsimala produced the highest number of filled grains panicle^{-1} and BR14 produced the lowest number of filled grains panicle^{-1}.

Hossan (2005) observed that grain yield was significantly differed due to variety. It was evident from the result that BRRI dhan4l produced the higher grain yield (5.02 t ha^{-1}) than BRRI dhan31.

BRRI (2004) reported that the filled grains panicle^{-1} of different modern varieties were 95-100 in BR3, 125 in BR4, 120-130 in BR22 and 110-120 in BR23 when they were cultivated in transplant Aus season. They reported that three modern upland rice varieties namely, BR20, BR21 and BR24 were suitable for high rainfall belts of Bangladesh. Under proper management, the grain yield was 3.5 ton for BR 20, 3.0 ton for BR21 and 3.5 ton for BR24 ha^{-1}. They also reported that grain yields of the modern rice varieties in Aus season under transplant condition ranged from 4.0-4.5 t ha^{-1} for BR3, 5.5 - 6.5 t ha^{-1} for BR4, 2.5-5.5 t ha^{-1} for BR23 and 4.0-4.5 t ha^{-1} for IR20.

Akbar (2004) stated that variety, seedling age and their interaction exerted significant influence on almost all the studied crop characters of rice. Among the varieties, BRRI dhan4l performed the best in respect of number of bearing tillers hill^{-1}, panicle length, total spikelets panicle^{-1}, and number of grains panicle^{-1}. BRRI dhan41 also produced the maximum grain and straw yields, Sonarbangla-1 ranked first in respect of total tillers hill^{-1} and 1000 grain weight but produced the highest number of non-bearing tillers hill and sterile spikelets panicle^{-1}. Grain, straw and biological yields were found highest in the combination of BRRI dhan41 x 15 day-old seedlings. Therefore, BRRI dhan4l may be cultivated using 15 day-old seedlings in aman season following the SRI technique to better grain and straw yields.

Bhuiya (2000) reported that plant height varied variety to variety viz. Binasail, Binadhan-4 and Binadhan-19 with different plant spacing viz. 20 cm x 10 cm, 20 cm x 15 cm and 20 cm x 20 cm.

Japanese group and 48.8% is in high yielding group. Yield ranged from 22.6 g plant^{-1}. The mean value of yield in Japanese group was 22.8 g plant^{-1}, and that in high yielding group was 34.1 g plant^{-1}. They also reported that a positive correlation was found between harvest index and yield in the yielding group (Cui *et al.*, 2000).

Diaz *et al.*, (2000) also reported that panicle length varied among varieties. The highest number of grains panicle^{-1} (159.55) was recorded in the variety BRRI dhan29 which was about double compare to the variety BBRI dhan45 and about 1.5 fold more than the variety BRRI dhan28.

Om *et al.,* (1999) conducted a field experiment with four varieties (3 hybrids: ORI 161, PMS 2A, PMS 10A and one inbred variety HKR 126) during rainy season and observed that hybrid ORI 161 exhibited superiority to other varieties in grain yield and straw yield.

Improving rice (Oryza sativa L.) grain yield per unit land area is the only way to achieve increased rice production because of the reduction in area devoted to rice production (Cassman, 1999).

Tac *et al.,* (1998) conducted an experiment with two varieties, Akitakomachi and Hitombore in tohoku region of Japan. It was found that Hitombore yielded the higher (710 g m-2) and Akitakomachi the lowest (660 g m-2).

Mishra and Pandey (1998) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties.

WenXiong *et al.,* (1996) showed significant grain yield increase over Minhui 63 of 35.2 and 48%, respectively, in China in 1993. The higher number of productive tillers plant-1 had the largest direct effect on grain yield, resulting in increased sink capability. The higher tiller number and number of grains panicle-1 were attributable to higher leaf areas, higher net photosynthesis in individual leaves (particularly in the later stages) and favorable partitioning of photosynthesis to plant organs. Compared with Minhui 63, hybrids showed slight heterosis in relative growth rate but significant heterosis in crop growth rate, especially at later growth stages, with increases of 160.52 and 97.62% in shanyou 63 and Teyou 63, respectively.

Islam (1995) in an experiment with four rice cultivars viz. BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

Leenakumari *et al.,* (1993) found higher grain yield from the hybrid varieties over the modern varieties. They evaluated eleven hybrids of varying duration against controls Jaya, Rasi, 1R20 and Margala, and concluded that hybrid OR 1002 gave the highest yield (7.9 t ha^{-1}) followed by IR 1000 (6.2 t ha^{-1}).

BINA (1993) evaluated the performance of four varieties- IRATOM 24, BR 14, Binadhan-13 and Binadhan-9. It was found that the varieties differed significantly in respect of plant height, number of unproductive tillers hill^{-1}, panicle length and sterile spikelets panicle^{-1}.

BRRI (1991) reported that the number of effective tillers produced by some transplant aman rice ranged from 7 to 14 tillers hill^{-1} and it significantly differed from variety.

Rice tillering is a major determinant for panicle production (Miller *et al.,* 1991) and as a consequence affects total yield. The high tillering capacity is considered as a desirable trait in rice production, since number of tillers per plant is closely related to number of panicles per plant. To some extent, yield potential of a rice variety may be characterized by tillering capacity. On the other hand, it was reported that the plants with more tillers showed a greater inconsistency in mobilizing assimilates and nutrients among tillers. Moreover, grain quality could be also affected by tillering ability due to different grain development characteristics. It has been well documented that either excessive or insufficient tillering is unfavorable for high yield. Hossain and Alam (1991) also found that the growth characters like total tillers hill-1 differed significantly among BR3, BR11, Pajam and Jaguli varieties in boro season.

Idris and Matin (1990) reported that number of total tillers hill-1 was identical among the varieties studied.

Miah *et al.,* (1990) conducted an experiment where rice cv. Nizersail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizersail.

Refey *et al.,* (1989) reported that weight of 1000-grains differed among the cultivars studied.

Shamsuddin *et al.,* (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among varieties.

Sawant *et al.,* (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

Ghosh and Hossain (1988) reported that effective tillers/plant, number of grains/panicle and grain weight as the major contributory characters for grain yield it had positive correlations with number of productive tillers/plant.

Kamal *et al.,* (1988) observed that among three rice varieties BR3 produced the highest the grain yield and pajam yielded the lowest. The superiority of promising line over the high yielding varieties in respect of grain yield was recorded.

BRRI (1985) concluded that BR4 and BR10 were higher yielders than Rajasail and Kajalsail.

In addition, grain yield also related with other characters such as plant type, growth duration, and yield components (Yoshida, 1981). Rice yield is a product of number of panicles per unit area, number of spikelets per panicle, percentage of filled grains and weight of 1000 grains (Yoshida, 1981; De Datta, 1981).

Miller (1978) from a study of 14 rice cultivars observed that grain yields ranged from 5.6 to 7.7 t ha^{-1}. He also reported that grain yield was significantly influenced by rice cultivars.

Chang and Vergara (1972) stated that the tillering pattern of rice varied with the varieties. In general tall cultivars showed a tendency to have small number of tillers and shorts on showed a large number. Tiller number and panicle number were positively correlated. Japonica cultivars that produced few tillers under tropical conditions were vigorous and produced more tillers when grown under temperate conditions. Indica cultivars, which were vigorous under tropical conditions, showed few tillers under temperate conditions.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the net house of the Laboratory of Agro-Environmental Chemistry lab of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season (December-June) of the year 2014-15. This chapter deals with a detail description of the site, pot preparation, intercultural operations, data recording and procedure of statistical analysis etc.

3.1 Description of experimental site

The pot experiment was carried out during the boro season of 2014-15 to evaluate the effect of arsenic on growth, yield and nutrient contents of boro rice.

3.1.1. Location and site

The growth and performance was carried out in the net house of the Department of Agricultural Chemistry of Sher-e-Bangla Agricultural University (SAU), Dhaka.

3.1.2 Climate

It has sub-tropical humid climate and is characterized by high temperature accompanied by moderately high rainfall during kharif season (April-September) and low temperature in rabi season (October-March). Geographically, the net house stands at 23º41' N latitude and 90º22' E longitude at an altitude of 8.6 meter above the sea level.

3.2 Collection and preparation of soil

A bulk volume of soil was collected at a depth of 0-l5 cm from the experimental field of Sher-e-Bangla Agricultural University. After collection, the soils were made free from the plant roots and unnecessary materials and dried under sunlight for 2 weeks. Then the soil sieved and mixed up thoroughly and ready for potting.

3.3 Pot preparation

An amount of 8 kg soil was taken in a series of pots. The required number of plastic pots having 24 cm top, 18 cm bottom diameter and 22 cm depth were collected from the local market and cleaned before use. There were altogether 36 pots comprising 6 different treatments to two different boro rice varieties with 3 replications. Water was added to the pot to bring the soil up to saturation.

3.4 Treatments of the experiment

Six rates of arsenic *viz.* 0, 10, 20, 40, 60 and 80 ppm As (on soil weight basis) were applied on two boro rice varieties. The source of As was Sodium Arsenate ($Na_2HAsO_4.7H_2O$). The rice varieties were *viz,* V_1=BRRI dhan29, V_2= Binadhan-8. Treatment consisted of six concentrations of arsenic. The experiment was carried out in a Completely Randomized Design (CRD). Each pot contained three hills.

The treatments included in the experiment were two factorials.

Design: CRD with two factorials

Factor A: Variety: 02

V_1 = BRRI dhan29

V_2 = Binadhan-8

Factor B: Different doses of arsenic: 06

As_0= (No arsenic applied)

As_1= (10 ppm arsenic on soil weight basis)

As_2= (20 ppm arsenic on soil weight basis)

As_3= (40 ppm arsenic on soil weight basis)

As_4= (60 ppm arsenic on soil weight basis)

As_5= (80 ppm arsenic on soil weight basis)

Treatment combinations = 2 x 6 = 12

Replications: 3

3.5 Description of rice varieties under study

3.5.1 BRRI dhan29

BRRI dhan29 was developed by the scientists of BRRI (Bangladesh Rice Research Institute) and was officially released by National Seed Board of Bangladesh in 1994. It is a high yielding variety which can yield up to 7.5 ton/ha. Its crop duration is 160 days. (Bangladesh Rice Knowledge Bank , BRRI, 2017)

3.5.2 Binadhan-8

Binadhan-8 was developed by the scientists of BINA (Bangladesh Institute of Nuclear Agriculture) and was officially released by National Seed Board of Bangladesh in 2010. It is a salt tolerant high yielding variety which can yield up to 5.5 ton/ha (average 4.5-5.5 ton/ha) under salt stress and in non saline area, maximum yield up to 9 ton/ha (average 7.5-8.5 ton/ha). Its crop duration is 130-135 days.

3.6 Raising of seedlings

Seeds of BRRI dhan29 and Binadhan8 were collected from BRRI (Bangladesh Rice Research Institute), Gazipur and BINA (Bangladesh Institute of Nuclear Agriculture), Mymensingh, respectively. The seedlings were raised at the wet seed bed in SAU farm. The seeds were sprouted by soaking for 72 hours. The sprouted seeds were sown uniformly in the well-prepared seed bed in 9^{th} December 2014.

3.7 Fertilizer application

All the pot received fertilizers according to BRRI's recommended fertilizer dose (BRRI-Adhunic Dhaner Chash, 2015). The amounts of nitrogen, phosphorus, potassium and sulphur required for each pot were calculated as per their rates of application. Except nitrogen, full dose of P, K were added at the time of final pot preparation. Nitrogen was added in three equal splits at 7, 30 and 45 days after transplanting (DAT). Arsenic was added to soil before transplanting.

3.8 Transplanting of seedlings

The seedlings were uprooted carefully from the seedbed in the morning and transplanted in the same day. Three healthy seedlings of fourty days age were transplanted in the pots on 1^{st} January 2015.

3.9 Intercultural operations

Weeding and loosening of soils around the hills were done when felt necessary. Top dressing of urea was done when felt necessary. At the grain filling stage, the pots were covered with net to protect the grains from the attack of birds. Observation was regularly made. All the stages of plants and plants response as per treatments were observed carefully.

3.10 Irrigation

Six cm water was added after transplanting and maintained for 15 days after transplanting. Then water was added following saturation system and allowed to dry until where hair cracking was observed. This process was continued up to panicle initiation stage.

3.11 Harvesting

The crop was harvested at two rice varieties' full maturity. Plants of each pot was bundled separately with tag mark indicating the respective treatment combinations and brought to the laboratory for recording data on yield and yield parameters.

3.12 Sampling threshing and processing

The plant samples were dried in an oven at 60 ^{0}C for 48 hours and then cut into small pieces using clean scissors. The plant materials were stored in desiccators to analyze total As, Cu, K and Na concentrations.

3.13 Sampling and data collection

Data collections from the experiment on different growth stages were done under the following heads as per experimental requirements.

3.13.1 Plant height

The heights (cm) of the pre-selected 10 hills were taken by measuring the distance from base of the plant to the tip of the flag leaf at 30, 45, 60, 75 and 90 DAT. The collected data were finally averaged.

3.13.2 Number of tillers

Number of tillers hill^{-1} was counted from every hills at 30, 45, 60, 75 and 90 DAT and finally averaged.

3.13.3 Number of leaves

Number of leaves plant^{-1} was counted three times at 30, 45, 60, 75 and 90 DAT. Mean value of data were calculated and recorded.

3.13.4 Number of effective and ineffective tillers

Number of effective and ineffective tillers hill^{-1} was counted from the plants of the pots after harvesting and finally averaged.

3.13.5 Panicle length

The panicle length (cm) was measured with a meter scale from the plants of the pots and the average value was recorded as per plant.

3.13.6 Number of filled grains and unfilled grains

Number of filled grains and unfilled grains panicle^{-1} were counted from 5 panicles from each pot. Lack of any food materials inside the spikelets were denoted as unfilled grains.

3.13.7 Weight of 1000 grains

One hundred grains (g) were randomly collected from each plot and were sun dried and weighed by an electronic balance and then multiplied by 10.

3.13.8 Grain yield

Grains from each pot were harvested. The grains were threshed, cleaned, dried and then weighed in kg. Thereafter it was converted as ton per hectare (t ha^{-1}).

3.13.9 Straw yield

Straw obtained from each pot were sun-dried and weighed carefully. The dry weight of straw of the respective pot yield was converted to ton per hectare (t ha^{-1}).

3.14 Chemical Analysis

3.14.1 Preparation of plant extract:

Rice plants were separated into roots and shoots after uprooting and rinsed repeatedly with tap water and finally with distilled water and then dried in an oven at 70^0C to obtain constant weight.

Oven-dried shoot samples, root samples and grain samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. Exactly 1g oven-dried samples of rice plant were taken in digestion tube. About 10 mL of concentrated percloric acid in a digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at 100^0C. The temperature was increased to 365^0C gradually to prevent frothing (50^0C 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 10 ml of each digest samples was stored in a plastic bottle for determination of the Na^+ and K^+. Content of Na^+ and K^+ were determined by Flame Photometer. After that, the percent of Na^+ and K^+ values were also calculated from concentration of Na^+ and K^+ in the plant tissues.

3.14.2 Determination of Arsenic

Total Arsenic concentration was determined from the digest by Analytik Jena novAA 400P Atomic Absorption Spectrotometer (Analytik Jena, 2017)

3.14.3 Determination of Potassium

The amount of potassium (K) was estimated from prepared sample with the help of a flame photometer at 766 nm.

3.14.4 Determination of Copper

The amount of cupper (Cu) was estimated from prepared sample with the help of a flame photometer at 766 nm.

3.14.5 Determination of Sodium

The amount of sodium (Na) was estimated from prepared sample with the help of a flame photometer at 589 nm.

3.15 Statistical Analysis

The data were compiled and tabulated in proper form and were subjected to statistical analysis. Analysis of variance was done following the computer package MSTAT-C program developed by Russel, (1986). The mean differences among the treatments were adjusted by least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

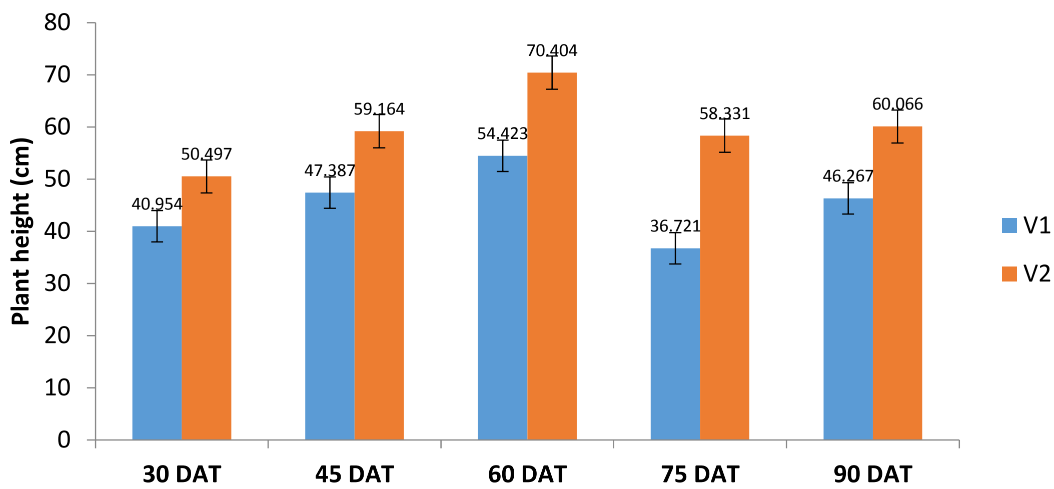
RESULTS AND DISCUSSION

A study was undertaken during the Boro season of December-June (2014-15) to evaluate the effect of arsenic on two boro rice cultivars. The experiment was conducted in the net house of the Department of Agricultural Chemistry of Sher-e-Bangla Agricultural University (SAU), Dhaka. The results of the study regarding the effect of arsenic on growth, yield and nutrients content of BRRI dhan29 and Binadhan-8 have been presented with possible interpretations under the following headings:

4.1 Plant Height

Effect of variety

The plant height (cm) of Boro rice was significantly influenced by varieties at 30, 45, 60, 75 and 90 days after transplanting (DAT) (Figure 1 and Appendix IV). The results revealed that at 30, 45, 60, 75 and 90 DAT, the variety Binadhan-8 produced the tallest plant (50.497cm, 59.164 cm, 70.404 cm, 58.331 cm and 60.066 cm respectively) and the variety BRRI dhan29 gave the shortest plant (40.954 cm, 47.387 cm, 54.423 cm, 36.721 cm and 46.267 cm respectively). Probably the genetic makeup of varieties was responsible for the variation in plant height. This confirms the reports of Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.



V_1 – BRRI dhan29, V_2 – Binadhan-8

Figure 1. Effect of variety on plant height at different days after transplanting

Effect of arsenic

Soil application of As showed distinct negative effect on the plant height of BRRI dhan29 and Binadhan-8. Different doses of arsenic had significant effect on plant height of rice at 30, 45, 60, 75 and 90 DAT (Table 1). At 30 DAT, the highest plant height (48.773cm) was observed from the As_1 treatment which is statistically similar with As_0 (47.318 cm) and As_2 (46.942 cm) and the lowest (42.162 cm) was observed from As_5 treatment which is statistically similar with As_4 (44.553 cm) and As_3 (44.607 cm). At 45 DAT, the highest plant height (58.193 cm) was observed from the As_1 treatment which is statistically similar with As_0 (56.608 cm) and the lowest (47.968 cm) was observed from As_5 treatment which is statistically similar with As_4 (49.887 cm). At 60 DAT, the highest plant height (81.275 cm) was observed from the As_0 treatment and the lowest (44.997 cm) was observed from As_5 treatment. At 75 DAT, the highest plant height (72.332 cm) was observed from the As_1 treatment which is statistically similar with As_0 (69.828 cm) and As_2 (66.5 cm) and the lowest (0 cm) was observed from As_5 treatment. At 90 DAT, the highest plant height (83.832 cm) was observed from the As_0 treatment which is statistically similar with As_1 (81.275 cm) and As_2 (76.145 cm) and the lowest (0cm) was observed from As_5 treatment. Holmgren *et al*., (1993) and Das *et al*., (1997), all the growth parameters tested in their experiment viz. plant height were affected by the application of As.

Table 1. Effect of different doses of arsenic on plant height at different days after transplanting

Treatments	Plant height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
As_0	47.318 a	56.608 ab	81.275 a	69.828 a	83.832 a
As_1	48.773 a	58.193 a	75.387 b	72.332 a	81.275 a
As_2	46.942 ab	55.5 b	69.387 c	66.5 a	76.145 a
As_3	44.607 bc	51.497 c	53.108 d	46.885 b	55.413 b
As_4	44.553 bc	49.887 cd	50.33 d	29.608 c	22.333 c
As_5	42.162 c	47.968 d	44.997 e	0 d	0 d
LSD $_{(0.05)}$	2.536	2.498	4.313	10.548	14.681
CV (%)	4.63	3.92	5.77	8.54	9.06
Significant level	*	*	*	*	*

* - Significant at 5% level

As_0 = No As applied, As_1= 10 ppm As, As_2= 20 ppm As, As_3= 40 ppm As, As_4= 60 ppm As and As_5= 80 ppm As on soil weight basis

Combined effect of variety and arsenic

Interaction of varieties and different arsenic doses showed significant variation on plant height of rice at 30 DAT, 45 DAT, 60 DAT, 75 DAT and 90 DAT (Table 2). At 30 DAT, the highest plant height (54.22 cm) was observed from the V_2As_1 treatment which was statistically similar withV_2As_2 (52.777 cm) and V_2As_0 (51.883 cm) whereas, the lowest (38.663 cm) was observed from V_1As_4 treatment which was statistically similar with V_1As_2 (41.107 cm), V_1As_3 (39.55 cm) and V_1As_5 (40.327 cm). At 45 DAT, the highest plant height (62.333 cm) was observed from the V_2As_1treatment which was statistically similar to V_2As_0 (61.997 cm), V_2As_2 (61.5 cm) whereas, the lowest (41.777 cm) was observed from V_1As_4 treatment which was statistically similar with V_1As_3 (44.33 cm). At 60 DAT, the highest plant height (85.33 cm) was observed from the V_2As_0 treatment which was statistically similar withV_2As_1 (82.997 cm) whereas, the lowest (38.887 cm) was observed from V_1As_5 treatment which was statistically similar withV_1As_4 (41.107 cm) and V_1As_3 (41.22 cm). At 75 DAT, the highest plant height (75.887 cm) was observed from the V_2As_1 treatment which was statistically similar with V_2As_0 (75.773 cm), V_2As_2 (73cm) and V_2As_3 (66.107 cm) whereas, the lowest (0 cm) was observed from V_2As_5, V_1As_4 and V_1As_5 treatment. At 90 DAT, the highest plant height (85.553 cm) was observed from the V_1As_0 treatment which was statistically similar withV_2As_1 (82.663 cm), V_2As_0 (82.11 cm), V_1As_1 (79.887 cm), V_1As_2 (75.107 cm) whereas, the lowest (0 cm) was observed from V_2As_5 treatment which was statistically similar withV_1As_4, and V_1As_5. Hossain *et al.,* (2008) found that plant height significantly varied with different concentrations of As.

Table 2: Interaction effect of variety and different doses of arsenic on plant height at different days after transplanting

Treatments		Plant height (cm)				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
V_1	As_0	42.753 cde	51.22 de	77.22 b	63.883 ab	85.553 a
	As_1	43.327 cd	54.053 d	67.777 c	68.777 ab	79.887 a
	As_2	41.107 cdef	49.5 e	60.33 d	60 b	75.107 a
	As_3	39.55 ef	44.33 f	41.22 f	27.663 c	37.053 b
	As_4	38.663 f	41.777 f	41.107 f	0 d	0 c
	As_5	40.327 def	43.44 f	38.887 f	0 d	0 c
V_2	As_0	51.883 ab	61.997 ab	85.33 a	75.773 a	82.11 a
	As_1	54.22 a	62.333 a	82.997 ab	75.887 a	82.663 a
	As_2	52.777 ab	61.5 abc	78.443 b	73 ab	77.183 a
	As_3	49.663 b	58.663 bc	64.997 cd	66.107 ab	73.773 a
	As_4	50.443 b	57.997 c	59.553 d	59.217 b	44.667 b
	As_5	43.997 c	52.497 de	51.107 e	0 d	0 c
$LSD_{(0.05)}$		3.587	3.532	6.101	14.917	20.762
CV (%)		4.63	3.92	5.77	8.54	9.06
Significant level		*	*	*	*	*

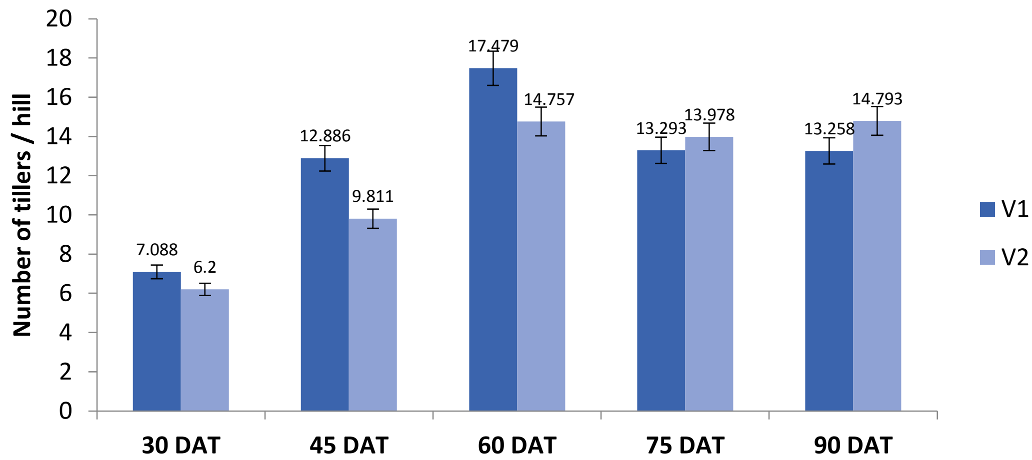
* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.2 Number of tillers

Effect of variety

The number of tillers hill^{-1} of boro rice was significantly influenced by different varieties at 30, 45 and 60 days after transplanting (DAT) and The number of tillers hill^{-1} of boro rice was not significantly influenced by different varieties at 75 and 90 DAT (Figure 2 and Appendix V). The result revealed that at 30, 45 and 60 DAT, the variety BRRI dhan29 produced the highest number of tillers hill^{-1} (7.088, 12.886 and 17.479 respectively) and the variety Binadhan-8 gave the lowest number of tiller hill^{-1} (6.200, 9.811 and 14.757 respectively). At 75 and 90 DAT, there were no significant difference between the variety BRRI dhan29 and Binadhan-8. But numerically Binadhan-8 produced the highest number of tillers hill^{-1} (13.978 and 14.793 respectively) whereas the lowest number of tillers hill^{-1} was found in BRRI dhan29 (13.293 and 13.258 respectively). Number of tillers hill^{-1} can be different in different varieties due to genetical build-up. Roy *et al.*, (2014) found that, number of tillers hill^{-1} at different days after transplanting varied significantly among the varieties up to harvest where maximum number of tillers hill^{-1} was observed in Sylhety boro and minimum in Bereratna.



V_1 – BRRI dhan29, V_2 – Binadhan-8

Figure 2. Effect of variety on number of tillers hill^{-1} at different days after transplanting

Effect of arsenic

Different doses of arsenic had significant effect on number of tillers hill^{-1} of rice at 30, 45, 60,75, 90 days after transplanting (DAT) (Table 3). At 30 DAT, the highest number of tillers hill^{-1} (7.1083) was observed from the As_1 treatment which was statistically similar with As_0 (6.4967), As_2 (6.9417), As_4 (6.94), As_5 (6.385) and the lowest (5.9967) was observed from As_3 treatment which was statistically similar with As_5 (6.385), As_0 (6.4967), As_4 (6.94), As_2 (6.941). At 45 DAT, the highest number of tillers hill^{-1} (14.942) was observed from the As_0 treatment which was statistically similar with As_1(14.885) and the lowest (7.828) was observed from As_5 treatment which was statistically similar with As_4 (8.553) and As_3 (10.108). At 60 DAT, the highest number of tillers hill^{-1} (22.497) was observed from the As_0 treatment which was statistically similar with As_2 (22.165) and As_1 (19.83) and the lowest (8.442) was observed from As_5 treatment which was statistically similar with As_4 (8.942). At 75 DAT, the highest number of tillers hill^{-1} (22.885) was observed from the As_1 treatment which was statistically similar with As_0 (21.328) and As_2 (20.607) and the lowest (0) was observed from As_5 treatment which was statistically similar with As_4 (4.775). At 90 DAT, the highest number of tillers hill^{-1} (22.498) was observed from the As_2 treatment which was statistically similar with As_0 (22.33) and As_1 (19.942) and the lowest (0) was observed from As_5 treatment.

Table 3. Effect of different doses of arsenic on number of tillers hill^{-1} at different days after transplanting

Treatments	Number of tillers hill^{-1}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
As_0	6.4967 ab	14.942 a	22.497 a	21.328 a	22.33 a
As_1	7.1083 a	14.885 a	19.83 a	22.885 a	19.942 a
As_2	6.9417 ab	11.775 b	22.165 a	20.607 a	22.498 a
As_3	5.9967 b	10.108 bc	14.832 b	12.218 b	14.22 b
As_4	6.94 ab	8.553 c	8.942 c	4.775 c	5.165 c
As_5	6.385 ab	7.828 c	8.442 c	0 c	0 d
LSD $_{(0.05)}$	1.004	2.819	3.564	4.879	3.667
CV (%)	12.62	10.75	8.47	11.88	9.84
Significant level	*	*	*	*	*

* - Significant at 5% level

Combined effect of variety and arsenic

Interaction of varieties and different arsenic doses showed significant variation on number of tillers hill^{-1} of rice at 30, 45, 60, 75 and 90 days after transplanting (DAT) (Table 4). At 30 DAT, the highest number of tillers hill^{-1}(7.6633) was observed from the V_1As_2 treatment which was statistically similar to V_1As_1 (7.5533), V_1As_4 (7.44), V_1As_5 (7.216), V_2As_1 (6.6633), V_2As_4 (6.44) whereas, the lowest (5.553) was observed from V_2As_5 treatment which was statistically similar to V_2As_3 (5.997). At 45 DAT, the highest number of tillers hill^{-1}(18.887) was observed from the V_1As_1 treatment which was statistically similar to V_1As_0 (17.22) whereas, the lowest (7.327) was observed from V_2As_5 treatment which was statistically similar to V_2As_4 (7.443), V_2As_3 (9.997) and V_2As_1 (10.883). At 60 DAT, the highest number of tillers hill^{-1}(25.107) was observed from the V_1As_0 treatment which was statistically similar to V_1As_1 (23.33) whereas, the lowest (7.663) was observed from V_2As_4 treatment which was statistically similar to V_2As_5 (8.22). At 75 DAT, the highest number of tillers hill^{-1}(25.107) was observed from the V_1As_0 treatment which was statistically similar to V_1As_1 (23.883) whereas, the lowest (0) was observed from V_2As_5 treatment which was statistically similar to V_1As_4 and V_1As_5. At 90 DAT, the highest number of tillers hill^{-1} (24.443) was observed from the V_1As_0 treatment which was statistically similar to V_1As_2 (23.443) and V_1As_1 (23.22) whereas, the lowest (0) was observed from V_2As_5 treatment which was statistically similar to V_1As_4 and V_1As_5.

Table 4: Interaction effect of variety and different doses of arsenic on number of tillers hill^{-1} at different days after transplanting

Treatments		Number of tillers hill^{-1}				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
V_1	As_0	6.6633 a-d	17.22 a	25.107 a	25.107 a	24.443 a
	As_1	7.5533 ab	18.887 a	23.33 abc	23.883 ab	23.22 a
	As_2	7.6633 a	12.997 b	24.777 ab	22.773 abc	23.443 a
	As_3	5.9967 cd	10.22 bc	12.777 ef	7.9967 e	8.4433 c
	As_4	7.44 ab	9.663 bc	10.22 fg	0 f	0 d
	As_5	7.216 abc	8.33 c	8.663 fg	0 f	0 d
V_2	As_0	6.33 abcd	12.663 b	19.887 bcd	17.55 bc	20.217 ab
	As_1	6.663 a-d	10.883 bc	16.33 de	21.887 abc	16.663 b
	As_2	6.22 bcd	10.553 bc	19.553 cd	18.44 abc	21.553 ab
	As_3	5.997 cd	9.997 bc	16.887 de	16.44 cd	19.997 ab
	As_4	6.44 abcd	7.443 c	7.663 g	9.55 de	10.33 c
	As_5	5.553 d	7.327 c	8.22 fg	0 f	0 d
LSD $_{(0.05)}$		1.419	3.988	5.041	6.900	5.186
CV (%)		12.62	10.75	8.47	11.88	9.84
Significant level		*	*	*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.3 Number of leaves

Effect of variety

The total number of leaves hill^{-1} of boro rice showed significant variation among the two varieties (Figure 3 and Appendix VI). The maximum number of leaves hill^{-1} at 30, 45, 60, 75 and 90 days after transplanting (DAT) was observed in V_2 (50.497, 59.164, 70.404, 58.331 and 60.066 respectively) and the minimum number of leaves hill^{-1} at 30, 45, 60, 75 and 90 days after transplanting (DAT) was observed in V_1 (40.954, 47.387, 54.423, 36.721 and 46.267 respectively).

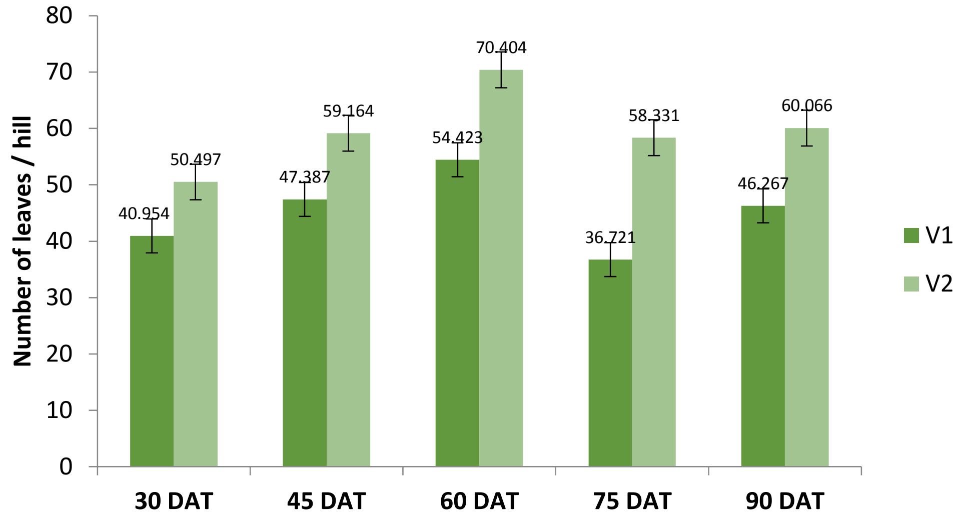


Figure 3. Effect of variety on number of leaves hill^{-1} at different days after transplanting

Effect of arsenic

Different arsenic doses showed significant variation on number of leaves hill^{-1} of rice at 30, 45, 60, 75 and 90 days after transplanting (DAT) (Table 5). At 30 DAT, the highest number of leaves hill $^{-1}$ (48.773) was observed from the As_1 treatment whereas, the lowest (42.162) was observed from As_5 treatment. At 45 DAT, the highest number of leaves hill $^{-1}$ (58.193) was observed from the As_1 treatment whereas, the lowest number (47.968) was observed from As_5 treatment. At 60 DAT, the highest number of leaves hill $^{-1}$ (81.275) was observed from the As_0 treatment whereas, the lowest number (44.997) was observed from As_5 treatment. At 75 DAT, the highest number of leaves hill $^{-1}$ (72.332) was observed from the As_1 treatment whereas, the lowest number (0) was observed from As_5 treatment. At 90 DAT, the highest number of leaves hill $^{-1}$ (83.832) was observed from the As_0 treatment whereas, the lowest number (0) was observed from As_5 treatment.

Table 5. Effect of different doses of arsenic on number of leaves hill^{-1} at different days after transplanting

Treatments	Number of leaves hill^{-1}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
As_0	47.318 a	56.608 ab	81.275 a	69.828 a	83.832 a
As_1	48.773 a	58.193 a	75.387 b	72.332 a	81.275 a
As_2	46.942 ab	55.5 b	69.387 c	66.5 a	76.145 a
As_3	44.607 bc	51.497 c	53.108 d	46.885 b	55.413 b
As_4	44.553 bc	49.887 cd	50.33 d	29.608 c	22.333 c
As_5	42.162 c	47.968 d	44.997 e	0 d	0 d
LSD $_{(0.05)}$	2.536	2.498	4.313	10.548	14.681
CV (%)	11.47	9.01	11.47	12.16	9.44
Significant level	*	*	*	*	*

* - Significant at 5% level

Combined effect of variety and arsenic

Interaction of varieties and different arsenic doses showed significant variation on number of leaves hill^{-1} of rice at 30, 45, 60, 75 and 90 days after transplanting (DAT). At 30 DAT, the highest number of leaves hill^{-1} (54.22) was observed from the V_2As_1 treatment which was statistically similar to V_2As_2 (52.777), V_1As_0 (51.883) whereas, the lowest (38.663) was observed from V_1As_4 treatment which was statistically similar to V_1As_5 (40.327). At 45 DAT, the highest number of leaves hill^{-1}(62.333) was observed from the V_2As_1 treatment whereas, the lowest (41.777) was observed from V_1As_4 treatment. At 60 DAT, the highest number of leaves hill^{-1}(85.33) was observed from the V_2As_0 treatment whereas, the lowest (38.887) was observed from V_1As_5 treatment. At 75 DAT, the highest number of leaves hill^{-1}(75.887) was observed from the V_2As_1 treatment whereas, the lowest (0) was observed from V_2As_5 treatment which was statistically similar to V_1As_4, V_1As_5. At 90 DAT, the highest number of leaves hill^{-1} (85.553) was observed from the V_1As_0 treatment whereas, the lowest (0) was observed from V_2As_5 treatment which was statistically similar to V_1As_4 and V_1As_5.

Table 6: Interaction effect of variety and different doses of arsenic on number of leaves hill^{-1} at different days after transplanting

Treatments		Number of leaves hill^{-1}				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
V_1	As_0	42.753 cde	51.22 de	67.22 c	68.883 ab	85.553 a
	As_1	43.327 cd	54.053 d	67.777 c	68.777 ab	79.887 a
	As_2	41.107 cdef	49.5 e	60.33 d	60 b	75.107 a
	As_3	39.55 ef	44.33 f	41.22 f	27.663 c	37.053 b
	As_4	38.663 f	41.777 f	41.107 f	0 d	0 c
	As_5	40.327 def	43.44 f	38.887 f	0 d	0 c
V_2	As_0	51.883 ab	61.997 ab	85.33 a	75.773 a	82.11 a
	As_1	54.22 a	62.333 a	82.997 ab	75.887 a	82.663 a
	As_2	52.777 ab	61.5 abc	78.443 b	73 ab	77.183 a
	As_3	49.663 b	58.663 bc	64.997 cd	66.107 ab	73.773 a
	As_4	50.443 b	57.997 c	59.553 d	59.217 b	44.667 b
	As_5	43.997 c	52.497 de	51.107 e	0 d	0 c
LSD $_{(0.05)}$		3.587	3.532	6.100	14.917	20.762
CV (%)		11.47	9.01	11.47	12.16	9.44
Significant level		*	*	*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.4 Number of effective tillers

Effect of variety

The number of effective tillers hill^{-1} of boro rice was significantly influenced by the two varieties (Table 7). The result revealed that the variety Binadhan-8 produced the highest number of effective tillers hill^{-1} (11.406) and the variety BRRI dhan29 gave the lowest number of effective tillers hill^{-1} (6.499). The result is similar to that of Nahar *et al.*, (2009) who reported that BRRI dhan46 had significantly higher effective tillers hill^{-1} than the BRRI dhan31 in late transplanted conditions. BRRI (1991) and Lockard (1958) also reported similar views that the number of effective tillers differed among different varieties.

Table 7: Effect of variety on effective tillers hill^{-1}, non-effective tillers hill^{-1} and panicle length

Treatments	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Panicle length (cm)
V_1	6.499 b	2.128	8.082 b
V_2	11.406 a	2.441	16.064 a
LSD $_{(0.05)}$	1.816	0.923	0.431
CV (%)	9.35	8.46	5.17
Significant level	*	NS	*

* - Significant at 5% level, NS – Non Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

Effect of arsenic

Different arsenic doses had significant effect on the number of effective tillers hill^{-1} of rice (Table 8). The highest number of effective tillers hill^{-1} (20.832) was observed from the As_0 treatment and the lowest (0) was observed from As_5 treatment. Arsenic is a poisonous and toxic heavy metal which exerts hampering and hindering effect on plant physiology. Kang *et al.*, (1996) reported that when the level of arsenic increased, the number of effective tillers hill^{-1} decreased.

Table 8: Effect of arsenic on effective tillers hill^{-1}, non-effective tillers hill^{-1} and panicle length

Treatments	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Panicle length (cm)
As_0	20.832 a	2.7733 b	25.62 a
As_1	15.885 b	4.995 a	23.99 b
As_2	8.4983 c	2.22 b	12.275 c
As_3	8.4983 c	3.72 ab	10.555 d
As_4	0 d	0 c	0 e
As_5	0 d	0 c	0 e
LSD $_{(0.05)}$	3.145	1.599	0.746
CV (%)	9.35	8.46	5.17
Significant level	*	*	*

* - Significant at 5% level

Combined effect of variety and arsenic

Interaction of varieties and different doses of arsenic showed significant variation on the number of effective tillers hill^{-1} of rice (Table 9). The highest number of effective tillers hill^{-1} (22.887) was observed from the V_1As_0 treatment whereas, the lowest (0) was observed from V_2As_4 treatment which was statistically similar with V_2As_5, V_1As_3, V_1As_4 and V_1As_5 (0). Number of effective tillers hill^{-1} can vary from cultivar to cultivar. Hossain *et al.*, (2005) also found that by increasing As concentrations, the number of effective tillers hill^{-1} reduced.

Table 9: Interaction effect of variety and different doses of arsenic on effective tillers hill^{-1}, non-effective tillers hill^{-1} and panicle length

Treatments		Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Panicle length (cm)
V_1	As_0	22.887 a	4.33 b	24.78 b
	As_1	16.107 b	8.44 a	23.713 c
	As_2	0 c	0 c	0 e
	As_3	0 c	0 c	0 e
	As_4	0 c	0 c	0 e
	As_5	0 c	0 c	0 e
V_2	As_0	18.777 ab	1.2167 c	26.46 a
	As_1	15.663 b	1.55 c	24.267 bc
	As_2	16.997 b	4.44 b	24.55 bc
	As_3	16.997 b	7.44 a	21.11 d
	As_4	0 c	0 c	0 e
	As_5	0 c	0 c	0 e
LSD $_{(0.05)}$		4.448	2.261	1.056
CV (%)		9.35	8.46	5.17
Significant level		*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.5 Number of non-effective tillers

Effect of variety

The non-effective tillers hill^{-1} of boro rice was not statistically significant among the two varieties (Table 7). Numerically maximum number of non-effective tillers hill^{-1} was observed in the V_2 (Binadhan-8) and the minimum number of non-effective tillers hill^{-1} was obtained from the variety V_1 (BRRI dhan29). Tyeb *et al.*, (2013) observed that maximum number of total tillers hill^{-1} (16.02) and effective tillers hill^{-1} (13.19) were obtained from BRRI dhan52 followed by BRRI dhan51 while BRRI dhan41 produced the minimum number of total tillers hill^{-1} (13.08) and effective tillers hill^{-1} (9.29). Debnath (2010) and Ashrafuzzman (2006) observed that varieties differed insignificantly in respect of number of ineffective tillers m^{-2} though Ahmed (2006) found significant effect between inbred and hybrid varieties in respect of number of non-effective tillers m^{-2}.

Effect of arsenic

Number of non-effective tillers hill^{-1} was significantly varied due to arsenic doses at all growth stages (Table 8). The highest number of non-effective tillers hill^{-1} (4.995) was recorded from As_1 treatment which was statistically similar with As_3 (3.72). In contrast, the lowest number of non-effective tillers hill $^{-1}$ (0) was recorded from As_4 treatment which was statistically similar with As_5 treatment.

Combined effect of variety and arsenic

Number of non-effective tillers hill $^{-1}$ was significantly varied due to interaction of varieties and different arsenic doses at all growth stages (Table 9). The highest number of non-effective tillers hill^{-1} (8.44) was recorded from treatment combination V_1As_1 which was statistically similar with V_2As_3 (7.44). In contrast, the lowest number of non-effective tillers hill^{-1} (0) was recorded from the treatment combination V_1As_2 which was statistically similar with V_1As_3, V_1As_4, V_1As_5, V_2As_4 and V_2As_5.

4.6 Panicle length

Effect of variety

It is very obvious that panicle length can vary from variety to variety. The panicle length (cm) of boro rice was statistically significant and hence was influenced by different varieties (Table 7). The longest panicle was observed in the V_2 (Binadhan-8) and the shortest was obtained from the variety V_1 (BRRI dhan29). This finding is in contradiction with Ashrafuzzaman (2006) and Main (2006) who observed that varieties differed insignificantly in respect of panicle length.

Effect of arsenic

Different doses of arsenic had significantly influenced the panicle length of rice (Table 8). The highest length of panicle (25.62 cm) was obtained from As_0 treatment whereas, the lowest (0 cm) was observed from As_5 treatment. This also supports the report of Das *et al*., (1997). He has marked Arsenic as poisonous heavy metal both for plants and animals. Like all other parameter, panicle length was affected by the application of As in his experiment. Islam *et al.*, (2004) found that the irrigation water added As up to 0.25 ppm enhanced the panicle length and finally the grain yield of Boro rice and the further doses of depressed the plant growth, yield and yield components.

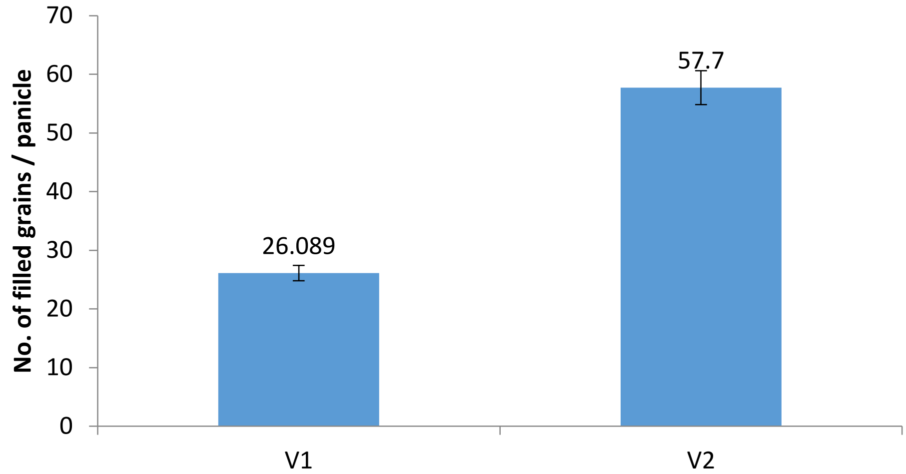
Combined effect of variety and arsenic

Significant influence was observed on panicle length (cm) due to the different interaction of varieties and different arsenic doses (Table 9). The highest length of panicle (26.46 cm) was obtained from V_2As_0. In contrast the lowest number of panicle length (0 cm) was recorded from the treatment combination V_2As_5 which was statistically similar with$V_1As_{2,}$ $V_1As_{3,}$ $V_1As_{4,}$ V_1As_5 and V_2As_5 (0 cm). Holmgren *et al*., (1993) and Das *et al*., (1997), all the growth parameters tested in their experiment viz. panicle length were affected by the application of As.

4.7 Number of filled grains

Effect of variety

The number of filled grains panicle^{-1} of boro rice was significantly influenced by different varieties (Figure 4 and Appendix VII). The result revealed that the highest number of filled grain panicle^{-1} was observed in variety V_2 (Binadhan-8) and the lowest number of filled grain panicle^{-1} was observed in variety V_1 (BRRI dhan29). Singh *et al*., (1990) found that number of filled spikelets panicle^{-1} significantly differed among the varieties. BRRI (2006) studied the performance of BR14, Pajam, BR5 and Tulsimala and reported that Tulsimala produced the highest number of filled grains panicle^{-1} and BR14 produced the lowest number of filled grains panicle^{-1}.



V_1 – BRRI dhan29, V_2 – Binadhan-8

Figure 4. Effect of variety on number of filled grains panicle^{-1}

Effect of arsenic

Different doses of arsenic had significantly influenced the number of filled grain panicle^{-1} (Table 10). The highest number of filled grain (94.633) was observed in As_1 treatment which was statistically similar with As_0 and the lowest was observed in As_5 treatment which was statistically similar with As_4. As the number of filled grain panicle^{-1} is a growth contributing character, increase in the number of filled grain panicle^{-1} increase the yield. The yield of rice grain was highly affected by arsenic treatments; the highest values of grain was recorded at with control and sharply decreased with increasing arsenic concentration. Similarly Islam *et al.*, (2004) reported that the irrigation water added As up to 0.25 ppm enhanced unfilled grains panicle^{-1} and finally the grain yield of Boro rice and the further doses of depressed the plant growth, yield and yield components.

Table 10: Effect of arsenic on number of filled grain panicle^{-1}, unfilled grain panicle^{-1} and 1000 grains weight

Treatments	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000 grains weight (g)
As_0	94.567 a	51.167 ab	17.113 a
As_1	94.633 a	51.767 a	12.677 b
As_2	32 b	33.767 c	10.568 c
As_3	30.167 b	40.25 bc	2.0417 d
As_4	0 c	0 d	0 e
As_5	0 c	0 d	0 e
LSD $_{(0.05)}$	8.609	11.494	1.616
CV (%)	7.16	12.55	9.10
Significant level	*	*	*

* Significant at 5% level

Combined effect of variety and arsenic

Interaction of variety and different doses of arsenic had significant influence on number of filled grains panicle^{-1}. In respect of the number of filled grain panicle^{-1}, the highest number of filled grains panicle^{-1} was V_2As_1 (113.47) and the lowest number of filled grains panicle^{-1} was V_1As_2 (0) (Table 11). This result agreed with Hossain *et al.*, (2008) who reported that number of filled grain panicle^{-1} decreased with increasing the concentration of As.

Table 11: Interaction effect of variety and different doses of arsenic on number of filled grain panicle^{-1}, unfilled grain panicle^{-1} and 1000 grains weight

Treatments		No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	1000 grains weight (g)
V_1	As_0	80.733 b	84.733 a	13.36 b
	As_1	75.8 bc	87.733 a	3.9533 c
	As_2	0 e	0 d	0 d
	As_3	0 e	0 d	0 d
	As_4	0 e	0 d	0 d
	As_5	0 e	0 d	0 d
V_2	As_0	108.4 a	17.6 c	20.867 a
	As_1	113.47 a	15.8 cd	21.4 a
	As_2	64 cd	67.533 b	21.137 a
	As_3	60.333 d	80.5 ab	4.0833 c
	As_4	0 e	0 d	0 d
	As_5	0 e	0 d	0 d
LSD $_{(0.05)}$		12.175	16.255	2.285
CV (%)		7.16	12.55	9.10
Significant level		*	*	*

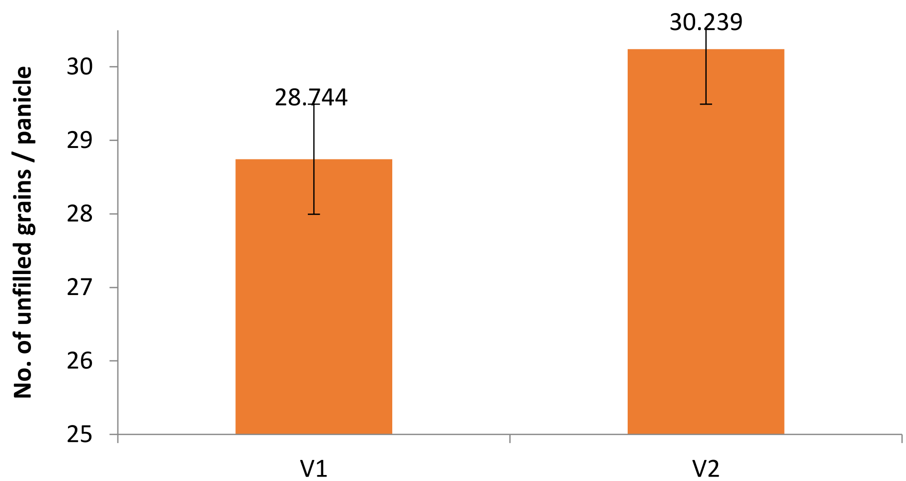
* Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.8 Number of unfilled grains

Effect of variety

The highest number of unfilled grains panicle^{-1} was observed in V_2 (Binadhan-8) and the lowest number of unfilled grains panicle^{-1} was observed in variety V_1 (BRRI dhan29) (Figure 5 and Appendix VII). Tyeb *et al.*, (2013) observed that BRRI dhan4l produced the highest number of unfilled grains panicle^{-1} (28.71) followed by BRRI dhan51 (24.88) and BRRI dhan46 (19.50). The lowest number of unfilled grains panicle^{-1} produced by BRRI dhan52 (14.17).



V_1 – BRRI dhan29, V_2 – Binadhan-8

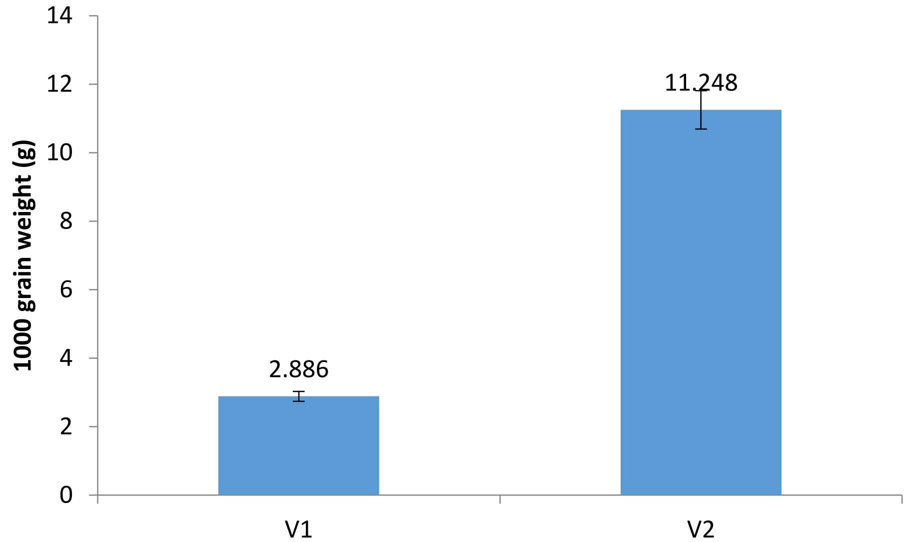
Figure 5. Effect of variety on number of unfilled grains panicle^{-1}

Different doses of arsenic had also significantly influenced the number of unfilled grain panicle^{-1}. The highest number of unfilled grain was observed in As_1 (51.767) treatment which was statistically similar with As_0 and the lowest was observed in As_5 (0) treatment (Table 10).

Interaction of variety and different doses of arsenic had significant influence on number of unfilled grains panicle^{-1}. In respect of the number of unfilled grain panicle^{-1}, the highest number of unfilled grains panicle^{-1} was V_1As_1 (87.733) and the lowest number of filled grains panicle^{-1} was V_1As_5 (0) (Table11).

4.9 Weight of 1000 grains

The 1000-Grain weight of two different boro rice varieties were significantly influenced by different varieties (Figure 6 and Appendix VII). The result revealed that the highest 1000-Grain weight was showed by V_2 (Binadhan-8) and the lowest 1000-grain weight was observed in variety V_1(BRRI dhan29) which was 19.41 g. M. B. Islam *et al.*, (2013) observed that the highest 1000 grain weight recorded from BRRI dhan46 (28.17 g) and the lowest from BRRI dhan33 (24.19 g).



V_1 – BRRI dhan29, V_2 – Binadhan-8

Figure 6. Effect of variety on number of 1000-grain weight

Different doses of applied arsenic had significant effect on 1000-grain weight of the boro rice varieties (Table 10). The highest 1000-grain weight was observed in arsenic dose As_0 (17.113 g) and the lowest 1000-grain weight was observed in arsenic As_5 (0 g). Islam *et al.,* (2004) showed that As up to 0.25 ppm increased 1000-grain weight and finally the grain yield of Boro rice and the further doses of depressed the plant growth, yield and yield components.

Interaction of variety and different doses of arsenic had significant influence on 1000-grain weight. In respect of the 1000-grain weight, the highest 1000-grain weight was recorded in V_2As_2 (21.137) which was statistically similar with V_2As_0 and the lowest 1000-grain weight was found from V_1As_5 (0) which was statistically similar with V_2As_5 (Table11).

This result is contradictory with Delowar *et al.,* (2005) who reported that the grain weight was not affected by different concentration of As. According to Holmgren *et al*., (1993) and Das *et al*., (1997), all the growth parameters tested in their experiment viz. 1000-grain weight were affected by the application of As. Arsenic has been marked as poisonous heavy metal both for plants and animals.

4.10 Grain Yield

Effect of variety

Grain yield (t ha^{-1}) of boro rice was significantly influenced by different varieties (Table 12). The result revealed that the variety Binadhan-8 produced the highest grain yield (3.239 t ha^{-1}) and the variety BRRI dhan29 gave lowest grain yield (1.316t ha^{-1}). Zohra *et al.*, (2013) observed that the highest number of effective tillers $hill^{-1}$ (11.42) which eventually contributed to higher grain yield (5.46 t ha^{-1}) of BRRI dhan46 compared to (4.44 t ha^{-1}) BINA dhan7 .

Table 12: Effect of variety on grain and straw yield

Treatments	Grain (t ha^{-1})	Straw (t ha^{-1})
V_1	1.316 b	1.705 b
V_2	3.239 a	3.282 a
LSD $_{(0.05)}$	0.490	0.787
CV (%)	9.18	5.66
Significant level	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

Effect of arsenic

Different doses of arsenic had significant influence on grain yield (Table 13). The highest grain yield (7.583t ha^{-1}) was obtained from As_0 treatment while the lowest result (0 t ha^{-1}) was recorded from As_5. It clearly indicates the poisonous and detrimental effect of arsenic on plant. This result agreed with Hossain *et al.* (2005) who found that yield reductions of more than 40 and 60% for two popular rice varieties (BRRI Dhan-28 and Iratom-24) when 20 mg/kg of arsenic was added to soils, compared to the control.

Table 13: Effect of arsenic on grain and straw yield

Treatments	Grain (t ha^{-1})	Straw (t ha^{-1})
As_0	7.583 a	7.422 a
As_1	3.875 b	5.118 b
As_2	1.766 c	0.940 c
As_3	0.441 d	0.526 c
As_4	0 d	0.401 c
As_5	0 d	0.553 c
LSD $_{(0.05)}$	0.850	1.363
CV (%)	9.18	5.66
Significant level	*	*

* - Significant at 5% level

Combined effect of variety and arsenic

Grain yield of boro rice was significantly influenced by the interaction effect of variety and different arsenic doses (Table 14). The highest grain yield (9.027 t ha^{-1}) was recorded from V_2As_0 treatment. On the other hand, V_2As_5 showed the lowest result (0 t ha^{-1}) which was statistically similar with V_2As_3 (0.883 t ha^{-1}). This result is similar with Begum *et al.*, (2008) who reported that the grain yield of Boro rice was reduced by 20.6 % for 15 ppm As treatment and 63.8 % due to 30 ppm As.

Table 14: Interaction effect of variety and different doses arsenic on grain yield and straw yield

Treatments		Grain (t ha^{-1})	Straw (t ha^{-1})
V_1	As_0	6.14 b	5.293 b
	As_1	1.756 d	2.543 c
	As_2	0 e	0.703 cd
	As_3	0 e	0.583 d
	As_4	0 e	0.330 d
	As_5	0 e	0.777 cd
V_2	As_0	9.027 a	9.550 a
	As_1	5.993 b	7.693 a
	As_2	3.533 c	1.177 cd
	As_3	0.883 de	0.470 d
	As_4	0 e	0.473 d
	As_5	0 e	0.330 d
$LSD_{(0.05)}$		1.202	1.928
CV (%)		9.18	5.66
Significant level		*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.11 Straw Yield

Straw yield (t ha^{-1}) of boro rice was significantly influenced by different varieties (Table 12). The result revealed that the variety Binadhan-8 produced the highest straw yield (3.282 t ha^{-1}) and the variety BRRI dhan29 gave lowest straw yield (1.705t ha^{-1}). M.B. Islam *et al.*, (2013) observed that the highest straw yield was found from BR11 and lowest from BRRI dhan33. BRRI dhan46 showed statistically similar result with BR11 for all cases. This result was in agreement with the finding of Patel (2000) who reported that yield performance varied with variety.

Different arsenic doses had significant influence on straw yield (Table 13). The highest straw yield (7.422 t ha^{-1}) was obtained from As_0 treatment while the lowest result (0.553 t ha^{-1}) was recorded from As_5 treatment. Results showed that higher doses of arsenic gave lower yield. This may be due to toxic effect of arsenic.

Interaction of variety and different arsenic doses has significant effect on straw yield of rice (Table 14). The highest straw yield (9.550 t ha^{-1}) was obtained from V_2As_0 treatment. On the other hand, V_1As_4 showed the lowest result (0.330 t ha^{-1}) treatment. Here we can see the lowest dose of arsenic resulted in the maximum yield and the highest dose of arsenic produced the minimum yield. This may be due to the toxic effect of the heavy metal-As. Similarly Begum *et al.*, (2008) showed that the straw yield of Boro rice was reduced by 21.0 % for 15 ppm As treatment and 65.2 % due to 30 ppm As.

4.12 Chemical Composition

4.12.1 Sodium (Na) content in grain

Effect of variety

Na content in grain showed statistically insignificant difference due to the varieties (Table 15). Numerically the highest Na content (0.1186 %) was observed in grain from the variety Binadhan-8(V_2) and the lowest amount of Na (0.0599 %) found in grain for the variety BRRI dhan29 (V_1).

Table 15: Effect of variety on Na, K, Cu and As content in grain

Treatments	Grain			
	% Na	%K	Cu (ppm)	As (ppm)
V_1	0.0599 b	0.5736 b	0.0833	5.6756 a
V_2	0.1186 a	1.0236 a	0.0671	0.0946 b
LSD $_{(0.05)}$	0.013	0.075	0.102	0.4839
CV (%)	6.22	6.71	9.99	4.26
Significant level	*	*	NS	*

* - Significant at 5% level, NS – Not Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

Effect of arsenic

Na content in grain showed statistically significant difference due to the arsenic (Table 16). The highest Na content (0.1821 %) was observed in grain from the treatment As_1 which was statistically similar with As_0 (0.1792 %) and the lowest amount of Na (0%) found in grain from the treatment As_4 and As_5.

Table 16: Effect of arsenic on Na, K, Cu and As content in grain

Treatments	Grain			
	% Na	%K	Cu (ppm)	As (ppm)
As_0	0.1792 a	1.6042 a	0.1009 ab	0 d
As_1	0.1821 a	1.5708 a	0.2495 a	0 d
As_2	0.0917 b	0.7958 b	0.0505 b	2.953 c
As_3	0.0825 b	0.8208 b	0.0503 b	3.764 bc
As_4	0 c	0 c	0 b	4.469 b
As_5	0 c	0 c	0 b	6.125 a
LSD $_{(0.05)}$	0.023	0.131	0.178	0.8381
CV (%)	6.22	6.71	9.99	4.26
Significant level	*	*	*	*

* - Significant at 5% level

Combined effect of variety and arsenic

Interaction of variety and different arsenic doses has significant effect on %Na of grain in rice (Table 17). The highest Na content (0.1833 %) was obtained from V_2As_1 treatment which was statistically similar with V_2As_0, V_2As_2, V_2As_3, V_1As_0 and V_1As_1 treatment. On the other hand, V_1As_5 and V_2As_5 showed the lowest result (0%).

Table 17: Interaction effect of variety and different doses of arsenic on Na, K, Cu and As content in grain

Treatments		Grain			
		% Na	%K	Cu (ppm)	As (ppm)
V_1	As_0	0.1783 a	1.7417 a	0.1014 b	0 d
	As_1	0.1808 a	1.7 a	0.3983 a	0 d
	As_2	0 b	0 d	0 b	5.907 c
	As_3	0 b	0 d	0 b	7.527 b
	As_4	0 b	0 d	0 b	8.594 b
	As_5	0 b	0 d	0 b	12.03 a
V_2	As_0	0.18 a	1.4667 bc	0.1004 b	0 d
	As_1	0.1833 a	1.4417 c	0.1008 b	0 d
	As_2	0.1833 a	1.5917 abc	0.101 b	0 d
	As_3	0.165 a	1.6417 ab	0.1006 b	0 d
	As_4	0 b	0 d	0 b	0.3436 d
	As_5	0 b	0 d	0 b	0.2239 d
$LSD_{(0.05)}$		0.033	0.185	0.252	1.231
CV (%)		6.22	6.71	9.99	4.26
Significant level		*	*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.12.2 Potassium (K) content in grain

K content in grain showed statistically significant difference due to the varieties (Table 15). The highest K content (1.0236 %) was observed in grain from the variety Binadhan-8(V_2) and the lowest amount of K (0.5736 %) found in grain for the variety BRRI dhan29 (V_1).

K content in grain showed statistically significant difference due to the arsenic (Table 16). The highest K content (1.6042%) was observed in grain from the treatment As_0 which was statistically similar with As_1 (1.5708 %) and the lowest amount of K (0%) was found in grain from the treatment As_4 and As_5.

Interaction of variety and different arsenic doses has significant effect on %K of grain in rice (Table 17). The highest K content (1.7417 %) was obtained from V_1As_0 treatment which was statistically similar with V_2As_2, V_2As_3, and V_1As_1 treatment. On the other hand, V_1As_5 and V_2As_5 showed the lowest result (0%).

4.12.3 Copper (Cu) content in grain

Cu content in grain showed statistically insignificant difference due to the varieties (Table 15). Numerically the highest Cu content (0.0833 ppm) was observed in grain from the variety BRRI dhan29 (V_1) and the lowest amount of Cu (0.0671 ppm) was found in grain for the variety Binadhan-8 (V_2).

Cu content in grain showed statistically significant difference due to the arsenic (Table 16). The highest Cu content (0.2495 ppm) was observed in grain from the treatment As_1 which was statistically similar with As_0 (0.1009 ppm) and the lowest amount of Cu (0 ppm) was found in grain from the treatment As_4 and As_5.

Interaction of variety and different arsenic doses has significant effect of Cu on grain in rice (Table 17). The highest Cu content (0.3983 %) was obtained from V_1As_1 treatment. On the other hand, V_1As_5, V_1As_4, V_1As_3, V_2As_4 and V_2As_5 showed the lowest result (0 ppm).

4.12.4 Arsenic (As) content in grain

As content in grain showed statistically significant difference due to the varieties (Table 15). The highest As content (5.6756 ppm) was observed in grain from the variety BRRI dhan29 (V_1) and the lowest amount of As (0.0946 ppm) found in grain for the variety Binadhan-8 (V_2).

As content in grain showed statistically significant difference due to the different concentration of arsenic (Table 16). The highest As content (6.125 ppm) was observed in grain from the treatment As_5 and the lowest amount of As (0 ppm) was found in grain from the treatment As_0 and As_1.

Interaction of variety and different arsenic doses has significant effect of As on grain in rice (Table 17). The highest As content (12.03 ppm) was obtained from V_1As_5 treatment. On the other hand, V_1As_0, V_1As_1, V_2As_0, V_2As_1, V_2As_2 and V_2As_3 showed the lowest result (0 ppm). Delowar *et al.*, (2005) reported that Arsenic concentrations in rice grains were 0-0.07 and 0-0.14 mg kg^{-1} dry weight in rice varieties BRRI dhan28 and Iratom 24, respectively.

4.12.5 Sodium (Na) content in straw

Effect of variety

Na content in straw showed statistically in-significant difference due to the varieties (Table 18). Numerically the highest Na content (1.7681 %) was observed in straw from the variety Binadhan-8 (V_2) and the lowest amount of Na (1.575%) found in straw or the variety BRRI dhan29 (V_1).

Table 18: Effect of variety on Na, K, Cu and As content in straw

Treatments	Straw			
	% Na	%K	Cu (ppm)	As (ppm)
V_1	1.575	2.6715	0.098	20.85 a
V_2	1.7681	2.9097	0.0972	13.52 b
LSD $_{(0.05)}$	0.245	0.416	1.24	0.8520
CV (%)	11.22	10.61	6.84	7.17
Significant level	NS	NS	NS	*

* - Significant at 5% level, NS – Not Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

Effect of arsenic

Na content in straw showed statistically significant difference due to the arsenic (Table 19). The highest Na content (2.1917 %) was observed in straw from the treatment As_0 which was statistically similar with As_3 (1.95 %) and the lowest amount of Na (1.1708 %) was found in straw from the treatment As_4.

Table 19: Effect of arsenic on Na, K, Cu and As content in straw

Treatments	Straw			
	% Na	%K	Cu (ppm)	As (ppm)
As_0	2.1917 a	2.4917	0.0983	0.79 e
As_1	1.5667 bcd	2.6354	0.0962	9.27 d
As_2	1.7167 bc	3.2	0.0979	16.46 c
As_3	1.95 ab	2.7917	0.0978	17.31 c
As_4	1.1708 d	3.1417	0.0979	19.11 b
As_5	1.4333 cd	2.4833	0.0975	23.15 a
LSD $_{(0.05)}$	0.424	0.722	2.16	1.843
CV (%)	11.22	10.61	6.84	7.17
Significant level	*	NS	NS	*

* - Significant at 5% level, NS – Not Significant

Combined effect of variety and arsenic

Interaction of variety and different arsenic doses has significant effect on % Na of straw in rice (Table 20). The highest Na content (2.3 %) was obtained from V_1As_0 treatment which was statistically similar with V_2As_2 and V_2As_0 treatment. On the other hand, V_1As_4 showed the lowest result (1.0833%).

Table 20: Interaction effect of variety and different doses of arsenic on Na, K, Cu and As content in straw

Treatments		Straw			
		% Na	%K	Cu (ppm)	As (ppm)
V_1	As_0	2.3 a	2.5167 b	0.0992 a	0.46 ef
	As_1	1.35 de	2.2792 b	0.0954 b	7.51 de
	As_2	1.475 cde	3.1333 ab	0.099 a	20.18 c
	As_3	1.7083 abcd	2.9833 ab	0.0982 ab	20.72 c
	As_4	1.0833 e	2.6417 ab	0.098 ab	23.20 b
	As_5	1.5333 bcde	2.475 b	0.0984 ab	27.01 a
V_2	As_0	2.0833 ab	2.4667 b	0.0975 ab	0.118 j
	As_1	1.7833 abcd	2.9917 ab	0.0969 ab	11.02 ij
	As_2	1.9583 abc	3.2667 ab	0.0968 ab	12.73 hi
	As_3	2.1917 a	2.6 b	0.0975 ab	13.91 gh
	As_4	1.2583 de	3.6417 a	0.0978 ab	15.02 fg
	As_5	1.3333 de	2.4917 b	0.0966 ab	19.29 cd
$LSD_{(0.05)}$		0.600	1.021	3.05	2.607
CV (%)		11.22	10.61	6.84	7.17
Significant level		*	*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.12.6 Potassium (K) content in straw

K content in straw showed statistically insignificant difference due to the varieties (Table 18). Numerically the highest K content (2.9097 %) was observed in straw from the variety Binadhan-8(V_2) and the lowest amount of K (2.6715 %) found in straw for the variety BRRI dhan29 (V_1).

K content in straw showed statistically insignificant difference due to the arsenic (Table 19). Numerically the highest K content (3.2 %) was observed in straw from the treatment As_2 which was statistically similar with As_4, As_3, As_1, As_o, As_5.

Interaction of variety and different arsenic doses has significant effect on % Na of straw in rice (Table 20). The highest K content (3.6417 %) was obtained from V_2As_4 treatment which was statistically similar with V_2As_2 and V_2As_1 treatment. On the other hand, V_1As_5 showed the lowest result (2.475 %).

4.12.7 Copper (Cu) content in straw

Cu content in straw showed statistically insignificant difference due to the varieties (Table 18). Numerically the highest Cu content (0.098 ppm) was observed in straw from the variety BRRI dhan29 (V_1) and the lowest amount of Cu (0.0972 ppm) found in straw for the variety Binadhan-8 (V_2).

Cu content in straw showed statistically insignificant difference due to the arsenic (Table 19). Numerically the highest Cu content (0.0983 ppm) was observed in straw from the treatment As_0 which all are statistically similar.

Interaction of variety and different arsenic doses has significant effect on Cu on straw in rice (Table 20). The highest Cu content (0.0992 ppm) was obtained from V_1As_0 treatment. On the other hand, V_1As_1 treatment showed the lowest result (0.0954 ppm).

4.12.8 Arsenic (As) content in straw

As content in straw showed statistically significant difference due to the varieties (Table 18). The highest As content (20.85 ppm) was observed in straw from the variety BRRI dhan29 (V_1) and the lowest amount of As (13.52 ppm) found in straw for the variety Binadhan-8 (V_2).

As content in straw showed statistically significant difference due to the arsenic (Table 19). The highest As content (23.15 ppm) was observed in straw from the treatment As_5 and the lowest amount of As (0.79 ppm) found in straw from the treatment As_0.

Interaction of variety and different arsenic doses has significant effect on As on straw in rice (Table 20). The highest As content (27.01 ppm) was obtained from V_1As_5 treatment. On the other hand, V_2As_0 showed the lowest result (0.118 ppm).

4.12.9 Sodium (Na) content in root

Effect of variety

Na content in root showed statistically insignificant difference due to the varieties (Table 21). Numerically the highest Na content (0.9236 %) was observed in root from the variety Binadhan-8(V_2) and the lowest amount of Na (0.9194 %) found in root for the variety BRRI dhan29 (V_1).

Table 21: Effect of variety on Na, K, Cu and As content in root

Treatments	Root			
	% Na	%K	Cu (ppm)	As (ppm)
V_1	0.9194	0.7333	0.1504	15.61 a
V_2	0.9236	0.7056	0.0993	11.45 b
LSD $_{(0.05)}$	0.229	0.278	0.103	0.378
CV (%)	12.99	13.00	9.80	4.04
Significant level	NS	NS	NS	*

* - Significant at 5% level, NS – Not Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

Effect of arsenic

Na content in root showed statistically significant difference due to the arsenic (Table 22). The highest Na content (1.3042 %) was observed in root from the treatment As_5 which was statistically similar with As_0 (1.1208 %) and the lowest amount of Na (0.6333 %) found in root from the treatment As_3.

Table 22: Effect of arsenic on Na, K, Cu and As content in root

Treatments	Root			
	% Na	%K	Cu (ppm)	As (ppm)
As_0	1.1208 ab	0.7958	0.0998	1.219 f
As_1	0.875 bc	0.6417	0.1005	8.549 e
As_2	0.7708 bc	0.6917	0.1002	10.59 d
As_3	0.6333 c	0.8333	0.1002	15.81 c
As_4	0.825 bc	0.5458	0.1002	19.67 b
As_5	1.3042 a	0.8083	0.2483	20.36 a
LSD $_{(0.05)}$	0.397	0.482	0.179	0.813
CV (%)	12.99	13.00	9.80	4.04
Significant level	*	NS	NS	*

* - Significant at 5% level, NS – Not Significant

Combined effect of variety and arsenic

Interaction of variety and different arsenic doses has significant effect on % Na of root in rice (Table 23). The highest Na content (1.425 %) was obtained from V_2As_5 treatment which was statistically similar with V_1As_5, V_1As_1, V_1As_2, V_1As_0 and V_2As_0 treatment. On the other hand, V_2As_3 showed the lowest result (0.5083 %).

Table 23: Interaction effect of variety and different doses of arsenic on Na, K, Cu and As content in root

Treatments		Root			
		% Na	%K	Cu (ppm)	As (ppm)
V_1	As_0	0.8833 abc	0.8583	0.1005 b	1.585 g
	As_1	1.0417 abc	0.775	0.1013 b	7.977 g
	As_2	0.8667 abc	0.7667	0.1008 b	9.171 f
	As_3	0.7583 bc	0.7667	0.1006 b	19.35 b
	As_4	0.7833 bc	0.6	0.1006 b	26.02 a
	As_5	1.1833 ab	0.6333	0.3985 a	26.31 a
V_2	As_0	1.3583 a	0.7333	0.099 b	0.854 h
	As_1	0.7083 bc	0.5083	0.0996 b	9.121 f
	As_2	0.675 bc	0.6167	0.0996 b	12.01 e
	As_3	0.5083 c	0.9	0.0998 b	12.26 e
	As_4	0.8667 abc	0.4917	0.0997 b	13.31 d
	As_5	1.425 a	0.9833	0.0981 b	14.40 c
$LSD_{(0.05)}$		0.561	0.682	0.253	0.9259
CV (%)		12.99	13.00	9.80	4.04
Significant level		*	NS	*	*

* - Significant at 5% level, NS – Not Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

4.12.10 Potassium (K) content in root

K content in root showed statistically insignificant difference due to the varieties (Table 21). Numerically the highest K content (0.7333 %) was observed in root from the variety BRRI dhan29 (V_1) and the lowest amount of K (0.7056 %) found in root for the variety Binadhan-8 (V_2).

K content in root showed statistically insignificant difference due to the arsenic (Table 22). Numerically the highest K content (0.833%) was observed in root from the treatment As_3 which was statistically similar with As_4, As_2, As_1, As_o, As_5.

Interaction of variety and different arsenic doses has no significant effect on % Na of root in rice (Table 23). Numerically the highest K content (0.8583 %) was obtained from V_1As_0 treatment and the lowest K content (0.4917 %) was obtained from V_2As_4.

4.12.11 Copper (Cu) content in root

Cu content in root showed statistically insignificant difference due to the varieties (Table 21). Numerically the highest Cu content (0.1504 ppm) was observed in root from the variety BRRI dhan29 (V_1) and the lowest amount of Cu (0.0993 ppm) found in root for the variety Binadhan-8 (V_2).

Cu content in root showed statistically insignificant difference due to the arsenic (Table 22). Numerically the highest Cu content (0.1005 ppm) was observed in root from the treatment As_1 and the lowest Cu content (0.1005 ppm) was observed in root from the treatment As_0.

Interaction of variety and different arsenic doses has significant effect on Cu of root in rice (Table 23). The highest Cu content (0.3985 ppm) was obtained from V_1As_5 treatment. On the other hand, all treatments showed the lowest same result.

4.12.12 Arsenic (As) content in root

As content in root showed statistically significant difference due to the varieties (Table 21). The highest As content (15.61 ppm) was observed in root from the variety BRRI dhan29 (V_1) and the lowest amount of As (11.45 ppm) found in root for the variety Binadhan-8 (V_2).

As content in root showed statistically significant difference due to the arsenic (Table 22). Numerically the highest As content (20.36 ppm) was observed in root from the treatment As_5 and the lowest amount of As (1.219 ppm) found in root from the treatment As_0.

Interaction of variety and different arsenic doses has significant effect on As of root in rice (Table 23). The highest As content (26.31 ppm) was obtained from V_1As_5 treatment which is statistically similar with V_1As_4 (26.02 ppm). On the other hand, V_2As_0 showed the lowest result (0.854 ppm).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the net house of the Laboratory of Agro-Environmental Chemistry lab of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season (December-June) of the year 2014-15 to find out the effect of arsenic on growth, yield and nutrients content of two different boro rice varieties (BRRI dhan29 and Binadhan-8). The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: two varieties [V_1- BRRI dhan29 and V_2- Binadhan-8] and Factor B: different arsenic doses on soil weight basis [**As_0**=(No arsenic applied), **As_1**=10 ppm As, **As**$_2$=20 ppm As, **As_3**=40 ppm As, **As_4**=60 ppm As, **As_5**=80 ppm As]. Different growth and yield parameters varied significantly due to varietal difference.

At 30, 45, 60, 75 and 90 DAT, the variety Binadhan-8 produced the tallest plant (50.497cm, 59.164 cm, 70.404 cm, 58.331 cm and 60.066 cm respectively) and the variety BRRI dhan29 gave the shortest plant (40.954 cm, 47.387 cm, 54.423 cm, 36.721 cm and 46.267 cm respectively). At 30, 45 and 60 DAT, the variety BRRI dhan29 produced the highest number of tillers hill^{-1} (7.088, 12.886 and 17.479 respectively) and the variety Binadhan-8 gave the lowest number of tiller hill^{-1} (6.200, 9.811 and 14.757 respectively). At 75 and 90 DAT, the variety Binadhan-8 produced the maximum number of tillers hill^{-1} (13.978 and 14.793 respectively) than BRRI dhan29. The total number of leaves hill^{-1} of boro rice showed variation among the two varieties. At 30, 45, 60, 75 and 90 days after transplanting (DAT) the maximum number of leaves hill^{-1} were observed in V_2 (50.497, 59.164, 70.404, 58.331 and 60.066 respectively) whereas the minimum number of leaves hill^{-1} were observed in V_1 (40.954, 47.387, 54.423, 36.721 and 46.267 respectively). Among two varieties Binadhan-8 produced the longest panicle, the highest number of effective tillers hill^{-1}, non-effective tillers hill^{-1}, 1000-grain weight, filled grains panicle^{-1} and unfilled grains panicle^{-1}. The maximum grain and straw yield (3.239 and 3.282 t ha^{-1} respectively) were recorded from Binadhan-8 whereas the minimum grain and straw yield (1.316 and 1.705 t ha^{-1} respectively) were found in the variety of BRRI dhan29. Na, K and As content in grain showed statistically significant difference due to the varietal effect except Cu. BRRI dhan29 gave the highest As content in grain, straw and root.

Different doses of arsenic had significant effect on growth and yield of rice. At 30, 45 and 75 DAT, the highest plant height (48.773 cm, 58.193 cm and 72.332 cm respectively) were in the As_1 treatment and the lowest (42.162 cm, 0 cm and 47.968 cm respectively) were in As_5 treatment. At 60 and 90 DAT, the highest plant height (81.275 cm and 83.832 cm respectively) were observed from the As_0 treatment and the lowest (44.997 cm and 0 cm respectively) were observed from As_5 treatment. At 30 DAT, the highest number of tillers hill^{-1} was found from the As_1 treatment and the lowest (5.9967) was observed from As_3 treatment. At 45 and 60 DAT, the highest number of tillers hill^{-1} (14.942 and 22.497 respectively) was observed from the As_0

treatment and the lowest (7.828 and 8.442 respectively) was observed from As_5 treatment. At 75 DAT, the highest number of tillers hill^{-1}(22.885) was observed from the As_1 treatment and the lowest (0) was observed from As_5 treatment. At 90 DAT, the highest number of tillers hill^{-1} (22.498) was observed from the As_2 treatment and the lowest (0) was observed from As_5 treatment. At 30, 45 and 75 DAT, the highest number of leaves hill $^{-1}$ was observed from the As_1 treatment whereas, the lowest was observed from As_5 treatment. At 60 and 90 DAT, the highest number of leaves hill $^{-1}$ was observed from the As_0 treatment whereas, the lowest number was observed from As_5 treatment.

The highest number of effective tillers hill^{-1} (20.832) was observed from the As_0 treatment and the lowest (0) was observed from As_5 treatment. Arsenic is a poisonous and toxic heavy metal which exerts hampering and hindering effect on plant physiology. The highest number of non-effective tillers hill^{-1} (4.995) was recorded from As_1 treatment. In contrast, the lowest number of non-effective tillers hill $^{-1}$ (0) was recorded from As_4 treatment. The highest length of panicle (25.62 cm) was obtained from As_0 treatment whereas, the lowest (0 cm) was observed from As_5 treatment. The highest number of filled grains and unfilled grains (94.633 and 51.767) were observed in As_1 treatment and the lowest (0) were observed in As_5 treatment. The highest 1000-grain weight, grain yield and straw yield were observed in arsenic dose As_0 (17.113 g, 7.583 t ha^{-1} and 7.422 t ha^{-1} respectively) and the lowest 1000-grain weight was observed in arsenic As_5 (0 g, 0 t ha^{-1} and 0.553 t ha^{-1} respectively).

The highest Na content (0.1821 %) was observed in grain from the treatment As_1 and the lowest amount of Na (0 %) found in grain from the treatment As_4 and As_5. The highest Na content (2.1917 %) was observed in straw from the treatment As_0 and the lowest amount of Na (1.1708 %) found in straw from the treatment As_4. The highest Na content was observed in root from the treatment As_5 and the lowest amount of Na found in root from the treatment As_3. The maximum K content (1.6042 %) was observed in grain from As_0 and the lowest amount (0 %) of K found in grain in As_5. The highest K content (3.2 %) was observed in straw from the treatment As_2. The highest K content (0.833 %) was observed in root from the treatment As_3. The highest Cu content (0.2495 ppm) was observed in grain from the treatment As_1 and the lowest amount of Cu (0 ppm) found in grain from the treatment As_4 and As_5. The highest Cu content was observed in straw from the treatment As_0. The highest Cu content (0.1005 ppm) was observed in root from the treatment As_1. The highest As content (6.125 ppm) was observed in grain from the treatment As_5 and the lowest amount of As (0 ppm) found in grain from the treatment As_0 and As_1. The highest As content (23.15 ppm) was observed in straw from the treatment As_5 and the lowest amount of As (0.79 ppm) found in straw from the treatment As_0. The highest As content (20.36 ppm) was observed in root from the treatment As_5 and the lowest amount of As (1.219 ppm) found in root from the treatment As_0.

At 30, 45 and 75 DAT the highest plant height (54.22 cm, 62.333 cm and 75.887 cm respectively) were observed from the V_2As_1 treatment whereas, the lowest (38.663 cm, 41.777 cm and 0 cm respectively) were observed from V_1As_4 treatment. At 60 and 90 DAT, the highest plant height (85.33 cm and 85.553 cm respectively) were observed from the V_2As_0 treatment whereas, the lowest (38.887 cm and 0 cm respectively) were observed from V_1As_5 and V_2As_5 treatment respectively. At 30 DAT, the highest number of tillers hill^{-1}(7.6633) was observed from the V_1As_2 treatment whereas, the lowest (5.5533) was observed from V_2As_5 treatment. At 45 DAT, the highest number of tillers hill^{-1}(18.887) was observed from the V_1As_1 treatment whereas, the lowest (7.327) was observed from V_2As_5 treatment. At 60 DAT, the highest number of tillers hill^{-1}(25.107) was observed from the V_1As_0 treatment whereas, the lowest (7.663) was observed from V_2As_4 treatment. At 75 and 90 DAT, the maximum number of tillers hill^{-1}(25.107 and 24.443) was observed from the V_1As_0 treatment whereas, the lowest (0) was observed from V_2As_5 treatment.

The highest 1000-grain weight was found from the V_2As_2 treatment whereas, the lowest was found from V_2As_5 treatment. The highest grain yield (9.027 t ha^{-1}) was recorded from V_2As_0 treatment. On the other hand, V_2As_5 showed the lowest result (0 t ha^{-1}). The highest straw yield (9.550 t ha^{-1}) was obtained from V_2As_0 treatment. On the other hand, V_1As_4 showed the lowest result (0.330 t ha^{-1}) treatment.

The highest Na content (0.1833 %) in grain was obtained from V_2As_1 treatment. On the other hand, V_1As_5 and V_2As_5 showed the lowest result (0 %). The highest K content (1.7417 %) in grain was obtained from V_1As_0 treatment. On the other hand, V_1As_5 and V_2As_5 showed the lowest result (0 %). The highest Cu content (0.3983 ppm) in grain was obtained from V_1As_1 treatment. On the other hand, V_1As_5, V_1As_4, V_1As_3, V_2As_4 and V_2As_5 showed the lowest result (0 ppm). The highest As content (12.03 ppm) in grain was obtained from V_1As_5 treatment. On the other hand, V_1As_0, V_1As_1, V_2As_0, V_2As_1, V_2As_2 and V_2As_3 showed the lowest result (0 ppm). The highest Na content (2.3 %) in straw was obtained from V_1As_0 treatment. On the other hand, V_1As_4 showed the lowest result (1.0833 %). The highest K content in straw (3.6417 %) was obtained from V_2As_4 treatment. On the other hand, V_1As_5 showed the lowest result (2.475 %). The highest Cu content (0.0992 ppm) in straw was obtained from V_1As_0 treatment. On the other hand, V_1As_1 treatment showed the lowest result (0.0954 ppm). The highest As content (27.01 ppm) in straw was obtained from V_1As_5 treatment. On the other hand, V_2As_0 showed the lowest result (0.118 ppm). The highest Na content (1.425 %) in root was obtained from V_2As_5 treatment. On the other hand, V_2As_3 showed the lowest result (0.5083 %). The highest K content (0.8583 %) in root was obtained from V_1As_0 treatment. The highest Cu content (0.3985 ppm) in root was obtained from V_1As_5 treatment. On the other hand, all treatments showed the lowest same result. The highest As content (26.31 ppm) in root was obtained from V_1As_5 treatment. On the other hand, V_2As_0 showed the lowest result (0.854 ppm).

From the above results it can be concluded that,

- Binadhan-8 had better yield potential than BRRI dhan29 in Boro season.
- Binadhan-8 had comparatively lower arsenic accumulation in grain, straw and root than BRRI dhan29.
- Binadhan-8 with controlled treatments gave the better result than other treatments. Yield and yield contributing parameters was decreased with increased level of As accumulation.

CHAPTER VI

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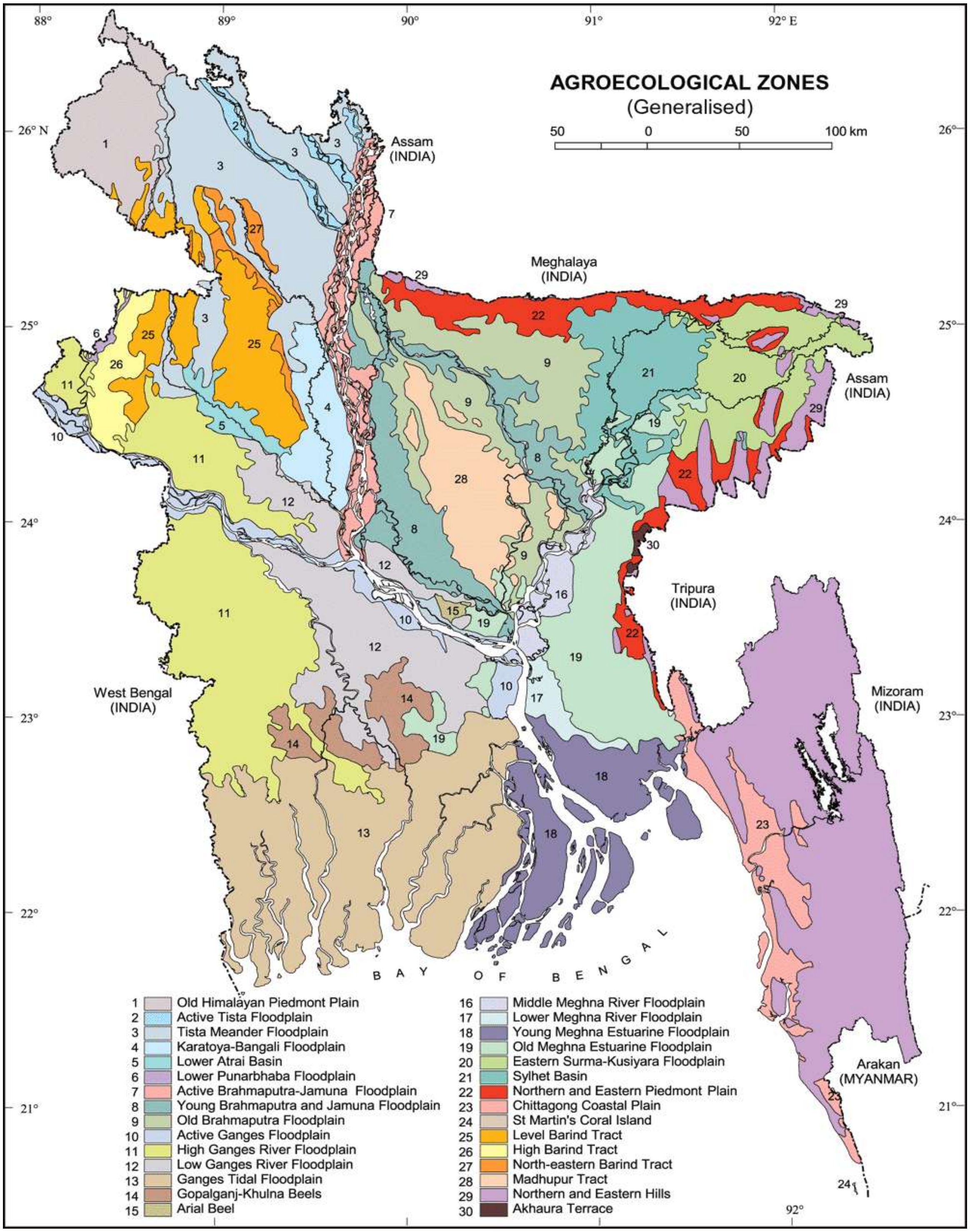
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka.
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace.
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(SAU Farm, Dhaka)

Appendix III. Initial physical and chemical characteristics of the soil

Characteristics	Value
Mechanical fractions: % Sand (2.0-0.02 mm) % Silt (0.02-0.002 mm) % Clay (<0.002 mm)	 22.26 56.72 20.75
Textural class	Silt Loam
pH (1: 2.5 soil- water)	5.9
Organic Matter (%)	1.09
Total N (%)	0.028
Available K (ppm)	15.625
Available P (ppm)	7.988
Available S (ppm)	2.066

(SAU Farm, Dhaka)

Appendix IV. Effect of variety on plant height (cm) at different days after transplanting

Treatment	Plant height (cm)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
V_1	40.954 b	47.387 b	54.423 b	36.721 b	46.267 b
V_2	50.497 a	59.164 a	70.404 a	58.331 a	60.066 a
LSD $_{(0.05)}$	1.464	1.442	2.490	6.09	8.476
CV (%)	4.63	3.92	5.77	8.54	9.06
Significant level	*	*	*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

Appendix V. Effect of variety on number of tillers hill^{-1} at different days after transplanting

Treatment	Number of tillers hill^{-1}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
V_1	7.0889 a	12.886 a	17.479 a	13.293	13.258
V_2	6.2006 b	9.811 b	14.757 b	13.978	14.793
LSD $_{(0.05)}$	0.579	1.628	2.058	2.817	2.117
CV (%)	12.62	10.75	8.47	11.88	9.84
Significant level	*	*	*	NS	NS

* - Significant at 5% level, NS= Not Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

Appendix VI. Effect of variety on number of leaves hill^{-1} at different days after transplanting

Treatment	Number of leaves hill^{-1}				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
V_1	40.954 b	47.387 b	54.423 b	36.721 b	46.267 b
V_2	50.497 a	59.164 a	70.404 a	58.331 a	60.066 a
LSD $_{(0.05)}$	1.464	1.442	2.490	6.09	8.476
CV (%)	11.47	9.01	11.47	12.16	9.44
Significant level	*	*	*	*	*

* - Significant at 5% level

V_1 – BRRI dhan29, V_2 – Binadhan-8

Appendix VII. Effect of variety on number of filled grains panicle^{-1}, number unfilled grains panicle^{-1} and 1000 grains weight

Treatments	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	1000 grains weight (g)
V_1	26.089 b	28.744	2.886 b
V_2	57.7 a	30.239	11.248 a
LSD $_{(0.05)}$	4.970	6.636	0.933
CV (%)	7.16	12.55	9.10
Significant level	*	NS	*

* - Significant at 5% level, NS= Not Significant

V_1 – BRRI dhan29, V_2 – Binadhan-8

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