EFFECT OF DIFFERENT DOSES OF ARSENIC AND WATER MANAGEMENT ON GROWTH AND YIELD OF BRRI Dhan36

A Thesis

By

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CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF DIFFERENT DOSES OF ARSENIC AND WATER MANAGEMENT ON GROWTH AND YIELD OF BRRI dhan36”** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN SOIL SCIENCE,** embodies the results of a piece of *bonafide* research work carried out by **MD. SAFAYET HOSSAIN,** Registration. No. 11-04568, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

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Dedicated
To
My Beloved Parents
&
Siblings

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EFFECT OF DIFFERENT DOSES OF ARSENIC AND WATER MANAGEMENT ON GROWTH AND YIELD OF BRRI Dhan36

ABSTRACT

In the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, a pot experiment was conducted during the period from December 2016 to March 2017 to study the effects of water management practices on growth, yield and arsenic content of BRRI Dhan36 at different levels of soil added arsenic. Four levels of As viz. 0, 2, 4 and 6 ppm were added to soil collected from Sher-e-Bangla Agricultural University field. After two weeks of transplanting, two water management practices viz. saturated condition and unsaturated condition were imposed to the rice plants grown in pots which was continued till harvesting. There were 8 treatment combinations such as As_0W_1= As_0+ Unsaturated condition, As_1W_1=As_1+ Unsaturated condition, As_2W_1=As_2+ Unsaturated condition, As_3W_1=As_3+ Unsaturated condition, As_0W_2= As_0+ saturated condition, As_1W_2= As_1+ saturated condition, As_2W_2=As_2+ saturated condition, As_3W_2=As_3+ saturated condition. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Addition of As adversely affected the plant height, effective tillers per plant, non-effective tillers per plant, filled grain per plant, unfilled grain per plant, grains per panicle, 1000-grain weight, grain and straw yield of rice. The grain yield due to 0-6 ppm As treatments were found to vary from 14.7 to 29.5 gm pot^{-1}, the highest grain yield being recorded by As control (0 ppm As) and the lowest yield by 6 ppm As. Similarly, the highest straw yield of 30.30 g pot^{-1} was found in As control with unsaturated conditions and the lowest yield of 12.33 g pot^{-1} was in 6 ppm As treated pot with saturated conditions. Again the highest plant height (81.67cm) during harvest was found in control As whereas the lowest plant height (51.33cm) was found in As_3. The adverse effect of As on crop was aggravated due to the saturated condition of soil. Yield is comparatively lower in saturated condition than unsaturated condition.

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LIST OF ACRONYMS

AEZ = Agro-Ecological Zone
BARI = Bangladesh Agricultural Research
BRRI = InstituteBangladesh Rice Research Institute
BBS = Bangladesh Bureau of Statistics
DAS = Days after sowing
et al. = And others
N = Nitrogen
TSP = Triple Superphosphate
MoP = Muriate of Potash
Ca = Calcium
Mg = Magnesium
K = Potassium
P = Phosphorous
Fe = Iron
DAT = Days after transplanting
ha^{-1} = Per hectare
g = Gram
kg = Kilogram
SAU = Sher-e-Bangla Agricultural University
SRDI = Soil Resource Development Institute
HI = Harvest Index
No. = Number
Wt. = Weight
LSD = Least Significant Difference
^{0}C = Degree Celsius
NS = Non-significant
% = Percent
CV = Coefficient of variance
T = Ton
viz. = Videlicet (namely)

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa L.)* belongs to the family Poaceae is the most widely cultivated cereal crop in the world. It is central to the lives of billions of people around the world. Rice is harvested around 180 million hectares of land in the world. Rice provides 21% of global human per capita energy and 15% of per capita protein. Although rice protein ranks high in nutritional quality among cereals, protein content is modest. Rice also provides minerals, vitamins, and fiber, although all constituents except carbohydrates are reduced by milling. The dominant food crop of Bangladesh is rice, accounting for about 75 percent of agricultural land use (and 28 percent of GDP).Rice production increased every year in our country except FY 1981, but the annual increases have generally been modest, barely keeping pace with the population. Rice production exceeded 15 million tons for the first time in FY 1986. Rice alone contributes 95% of food production in Bangladesh (Julfiquar et al., 1998).

About 77.07% of total cropped area of Bangladesh is used for rice production, with annual production of 33.54 million tons from 11.52 million ha of land (BBS, 2003). Rice alone contributes 11% of GDP and accounts for 55% labor employment in its production, processing, and marketing (BBS, 2013). More than 94% of the population derives 76% of its daily calories and 66% of its protein needs from rice (BBS, 2013). In the mid-1980s, Bangladesh was the fourth largest rice producer in the world, but its productivity was low compared with other Asian countries, such as Malaysia and Indonesia. It is currently the world's sixth-largest producer.

The cultivation of rice in Bangladesh varies according to seasonal changes in the water supply. The largest harvest is aman, occurring in November and December and accounting for more than half of annual production. Some rice for a man harvest is sown in the spring through the broadcast method, matures during the summer rains, and is harvested in the fall. The higher yielding method involves starting the seeds in special beds and transplanting during the summer monsoon. The second harvest is aus, involving traditional strains but more often including high-yielding, dwarf varieties. Rice for the aus harvest is sown in March or April, benefits from April and May rains, matures during in the summer rains, and is harvested during the summer. With the increasing use of irrigation, there has been a growing focus on another rice-growing season extending during the dry season from October to March. The production of this boro rice, including high-yield varieties, expanded rapidly until the mid-1980s, when production leveled off at just below 4 million tons. Where irrigation is feasible, it is normal for fields throughout Bangladesh to produce rice for two harvests annually. Between rice-growing seasons, farmers will do everything possible to prevent the land from lying fallow and will grow vegetables, peanuts, pulses, or oilseeds if water and fertilizer are available.

But, nowadays, rice production is in great danger due to arsenic. Arsenic is one of the toxic environmental pollutants which have recently attracted mass attention because of its chronic and epidemic effects on human health. Arsenic naturally occurs in water, soil, and rocks, but its levels may be higher in some areas than others. It readily enters the food chain and may accumulate in significant amounts in both animals and plants, some of which are eaten by humans. The greatest threat to public health from arsenic originates from contaminated ground water. Inorganic arsenic is naturally present at high levels in the groundwater of a number of countries, including Argentina, Bangladesh, Chile, China, India, Mexico, and the United States of America. Drinking water, crops irrigated with contaminated water and food prepared with contaminated water are the sources of exposure. Bangladesh is the World's 4th largest producer of rice. Since Arsenic-polluted water is being used majorly for its production, the effect on yield reduction is tremendous due to As intake by the rice crop. About 80% inorganic arsenic contamination in rice was reported in Bangladesh which is far more toxic than organic species.

Arsenic uptake in rice can be reduced by switching from a program of saturated conditions to unsaturated conditions. Irrigating with surface water will reduce arsenic loading to soils, over time, yet arsenic uptake will continue if rice is produced in anaerobic conditions. Switching from flooded paddies to aerobic production can substantially reduce arsenic uptake. When rice is grown under saturated condition, arsenic is primarily found as As(III), which is highly mobile. In this form, As is easily absorbed by rice plants, whose capacity to accumulate As is greater than most other crops, such as wheat or barley concentrations of inorganic arsenic in rice grain were up to two times higher on continuously flooded plots than on those that were aerobic condition. A greatly increased bioavailability of As under the flooded conditions is the main reason for an enhanced As accumulation by flooded rice, and growing rice aerobically can dramatically decrease the As transfer from soil to grain. Water management also influence the yield of rice variety. In a field water generally remains in two conditions. Those are saturated conditions and unsaturated conditions. During a rain shower or irrigation application, the soil pores fill with water. If all soil pores are filled with water the soil is said to be saturated. There is no air left in the soil. It is easy to determine in the field if a soil is saturated. Plants need air and water in the soil. At saturation, no air is present and the plant will suffer. Many crops cannot withstand saturated soil conditions for a period of more than 2-5 days. Rice is one of the exceptions to this rule. The period of saturation of the topsoil usually does not last long. After the rain or the irrigation has stopped, part of the water present in the larger pores will move downward. This process is called drainage or percolation. In saturated conditions water remains in reduced form. A reducing atmosphere is an atmospheric condition in which oxidation is prevented by removal of oxygen and other oxidizing gases or vapors, and which may contain actively reducing gases such as hydrogen, carbon monoxide, and gases such as hydrogen sulphide that would be oxidized by any present oxygen.Unsaturated soils contain both air and fluid phases in their pores. In unsaturated conditions water remains in oxidized form. Oxidation is a process in which a chemical substance changes because of the addition of oxygen.

Recently, arsenic has become an important subject to analysis as its concentration is increasing in underground water. Thus, it gets to enter into the food chain through rice grain.

Considering the above fact, the present study is carried out with the following objective:

-To assess the effect of arsenic (As) on growth and yield of BRRI dhan36 in saturated and unsaturated conditions of soil.

CHAPTER II

REVIEW OF LITERATURE

Many basic ingredient manipulate rice yield and yield contributing factor and those factors are environment, agronomic practices and hazards factors. Arsenic is now a major concern for rice cultivation so an attempt was made to present a brief review about arsenic, its occurrence in soil and its effect on yield, growth and nutrition concentration in rice.

2.1 Occurrence of Arsenic in soils

Arsenic is a steel gray, brittle, crystalline metalloid with three allotropic forms that are yellow, black and gray and it is the 20th most abundant component in earth crust. Chemically, arsenic is found as compounds with oxygen, chlorine, sulphur, carbon and hydrogen on one hand and with lead, gold and iron on the other hand. On an average of 2-5 mg kg^{-1} arsenic is present in the earth's crust. Arsenopyrite (FeAsS), Onargite (Cu_3AsS_4) and Orpiment (As_2S_3) are the most common As bearing minerals.

A variety of inorganic and organic compounds in soils is formed by arsenic (Vaughan, 1993) and is present mainly as inorganic species, either As (v) or As (III)(Masscheleyn et al., 1991). Depending on redox conditions the inorganic arsenic species are soluble in water and may change valency states (Marin et al., 1993a). Under moderately reducing conditions As (III) will predominate (Masscheleyn et al.,1991,Marin et al., 1993a, Onken and Hossner, 1996) , whereas under moderately oxidized conditions (>100mV), As(v) will predominate. In soil (Johnson and Hiltbold, 1969) and in soil solution (Onken and Hossner, 1996) inorganic arsenic is the predominant form of arsenic and the available (extractable) arsenic concentration of soil is a better indicator of phytotoxicity than the total concentration are methyl arsenic acid [$CH_3AsO(OH)_2$] and dimethyl arsenic acid [$(CH_3)_2AsO(OH)_2$] are the principal organic arsenic compounds in soils (Takamatsu etal., 1982).

In virgin soils native As ranges from 0.2 to 40 µg g^{-1}, with an average content of about 5 µg g^{-1}(Mridha, 1998) also reported that arsenic in soils is highly mobile and any retention of arsenic in soils would occur by adsorption, especially if the soils contained iron or aluminum oxides. Agricultural soils in which pesticide and herbicide is applied may contain upward of 550 µg g^{-1}(NRC, 1977).In few rare cases it have been reported that natural elevated soil have a values up to 800 µg (Kabata-Pendias and Pendias, 1992). Nuruzzman (1995) had reported thatindustrial polluted soilsarsenic status around Dhaka City are higher particularly near Tannery industry. The Brahmaputra soils had As level below 20 µg g^{-1}, the maximum acceptable limit for agricultural soils, whereas Soils of Gangetic alluvium had As more than 20 µg g^{-1}(Jahiruddin et al., 2000). It is reported by Ullah (1998) that arsenic concentration in Bangladesh soils ranged from 4-8 µg^{1}.However, soil As level can reach up to 83 µg g^{-1} in some area where irrigation is performed with arsenic contaminated ground water.

The amount of soluble/potentially soluble/arsenic varies with soil which is depended on the capacity to adsorb arsenic. Soil adsorption capacity is also dependent on many factors, such as hydration, pH, changes in cation co-ordination, isomorphism substitution and crystallinity of the colloidal materials (Sadiq, 1997). Arsenic is more abundant in sandy soil than clay soil (Sheppard, 1992). In surface soils some investigators found a significant correlation between clay content and arsenic sorption (Johnson and Hiltbold, 1969; Nightingale, 1987). In both acidic and alkaline soils, Fe oxides / hydroxides are most commonly involved with As adsorption and the surfaces of Aloxides or hydroxides in some acidic soils can also play an important role in As adsorption. In calcareous soils the carbonate minerals are thought to be responsible for As adsorption (Sadiq, 1997).

2.2 Arsenic concentration in groundwater

Recommended arsenic concentration for drinking water is 0.01 mg L^{-1} while for Bangladesh the standard of arsenic concentration in drinking water is 0.05 mg L^{-1}.It was stated by (Das et al., 1996) thatAs in groundwater above the WHO’s maximum permissible limit of 0.05 mg L^{-1} was found in 6 districts of West Bengal, India. At present 37 administrative blocks by the side of the River Ganga and adjoining areas are affected by arsenic. The areas which are affected by groundwater contamination of arsenic are all located in the upper delta plain and thousands of samples of tube-well water in these six districts have been analyzed for arsenic. It was said that the source of As in the groundwater of these districts is geological. The concentration of As in all water samples collected from MithapukurUpazila under the district of Rangpur to be in trace quantities (<0.05 mg As L^{-1}) and these waters might not be toxic for irrigation and drinking purposes reported by (Shamsuzzman, 1997).

1,987 water sampled from 37 districts of Bangladesh are tested by Amin and Islam (1997) and 475 samples were found to have arsenic >0.05 mg $L^{-1}$and 243 samples between 0.01 and 0.05 mg L^{-1} and the rest samples had As level below 0.05 mg L^{-1}. Groundwater As level exceeding the recommended value of WHO (0.01 mg L^{-1}) has been found in 52 districts out of total 64 districts of Bangladesh stated by (Dhar et al., 1997) and by surveying of 60 districts they also stated that arsenic has been found above WHO’s maximum permissible limit (0.05 mg L^{-1}) in 41 districts.

Mandal et al., (1998) reported that Fakirpara, a village in Dangora block in 24 Pargana district of West Bengal was chosen for micro level study and all the tubewellsotFakirpara had been analyzed and 89% tubewells contain As above 0.05 mg L^{-1}(4.3% having <0.01 mg L^{-1}, 6.5% having 0.1-0.05 mg L^{-1}, 12.9% having 0.05-0.099 mg L^{-1}, 26.1% having 0.10-0.299 mg L^{-1}, 21.7% having 0.3-0.499 mg L^{-1}, 17.4% having 0.5-0.699 mg L^{-1} and 11.0% having 0.7-1.0 mg L^{-1}).

Ahmad (1998) reported that almost all over the country a total of 13,452 water samples from tube wells were tested by field kits covering and he found that 2,562 water samples hadAscontent more than 0.05 mg L^{-1}.As concentration in groundwater samples collected from ChapaiNawabganj district was below the recommendedlimit (<0.05 mg L^{-1}) found by Zaman et al., (1999).

The groundwater in Bangladesh is heavily contaminated with arsenic (DPHE-BGS, 2000) and 40-60% of the tube wells passed above the Bangladesh Standard (0.05 mg L^{-1}) whereas the permissible level of arsenic in drinking water is only 0.01 mg L^{-1}as per WHO recommendation (WHO, 1993).

Khan et al., (2000) conducted an experiment on the environment impacts of groundwater abstraction in Barind area and they found that out of 30 water samples collected from BagmaraUpazila, only three samples had As levels of 0.05, 0.19 and 0.35 mg L^{-1}, respectively.

2.3 Causes of Arsenic Contamination in Bangladesh

By weathering, burning or smelting of arsenic containing minerals, arsenic is released in the environment and may be deposited in soils, fresh and salt waters and in sediments. From several thousand years the release of arsenic to the environment has been occurring through the use of arsenic compounds by the human. It is generally agreed that the source of arsenic contamination in groundwater of Bangladesh is geological (BGS report, 1999) and there are two hypotheses of arsenic release into the groundwater and those are-

2.3.1 Pyrite Oxidation

A number of (non-hydrogeological) studies e.g. Das et al., (1994 and 1996)in West Bengal went to suggest that extensive seasonal pumping of groundwater for irrigation is responsible, although they did not put forward any direct evidence to support the idea. This idea is known ‘pyrite oxidation’ hypothesis. The idea is based on the assumption that arsenic is present in the sulfide mineral pyrite and arsenopyrite. According to the theory, lowering of the water table due to pumping introduces oxygen, which causes the breakdown of pyrite and releases arsenic, iron and sulphate into the water.

2.3.2 Oxy-hydroxide reduction

Field evidence in Bangladesh is not consistent with the pyrite oxidation theory. In the alternative explanation it is believed that arsenic is transported and deposited in the adsorbed form on fine-grained iron or manganese oxides (amorphous iron oxyhydroxide, which is the potential arsenic-bearing mineral, retained as the source of arsenic, is well known for its ability to adsorb arsenic under oxidizing conditions during sediment-water interactions and to readily release adsorbed arsenic under reducing conditions). This arsenic-bearing mineral, after burial, slowly breaks down as the pore water of the organic-rich sediments become more reducing over time (i.e., once the dissolved oxygen has been consumed in the decomposition of organic matter present in the sediments and once all other sources of oxygen such as nitrates and sulphates are consumed as well), releasing the arsenic. In support of this theory, various studies have shown that the water is rich in ferrous iron indicating that anaerobic conditions had existed that led to the reduction of the ferric iron. Also uniformly low sulphate concentrations were found, which is contrary to the expectations of the pyrite oxidation theory. Mineralogical and sedimentological studies showed insignificant amounts of pyrite in the aquifer sands but the conspicuous presence of hard coatings on sand grains that were rich in adsorbed arsenic.

2.4 Level of arsenic in soil

Generally arsenic present in soil at a very low level (Nlatschullat, 2000). In a typical uncontaminated agricultural soils the concentration of As are <20 mg Askg^{-1} (Wauchope, 1983), but contaminated soils may contain concentration of arsenic as high as 2600 mg As kg^{-1} (Pendias and Pendias, 1992; NRC, 1997; Meharg*and*Rahman.,1994).

A polluted site located in the vicinity of a former arsenical pesticide factory at Auzon in France examined by (Cances et al., 2003) and they said that arsenic concentrations were very high at the top (>7000 mg kg^{-1}) and decreased downward soil profile to the water table zone where it slightly increased. In trace area arsenic concentration in Bangladesh soils ranged from up to 64 mg kg^{-1}(Islam el al., 2005; lmamulHuq and Naidu., 2005); Panaullah et al., 2006).

In southwest and south of Bangladesh the concentration of As is higher than the rest portion of the country. This variation is mainly occur due to difference in sediment composition and also the composition of the ground water used for irrigating the crops. As concentration have a wide micro level variations of a STW command area even the size of which may be several acres (Hossain, 2007). Rapid precipitation of arsenate with iron in the course of the flowing water through the irrigation channel this variation is occur.

394 soil samples was collected by (Panaullah et al., 2006) (both rice and non-rice crops) from 184 unions of 92 thana across the country and analyzed for total As contents using the HG-AAS procedure. They found that theAs content in the soils ranged from negligible to 64 mgkg^{-1}, with an average of 6.5 mg kg^{-1}. In a typical uncontaminated agricultural soils the concentration of As are <20 mg As kg^{-1}(Wauchope, 1983), but contaminated soils may contain concentrations as high as 2600 mg As kg^{-1} (Pendias and Pendias, 1992; NRC, 1997; Meharg et al., 1994)

A surveywas carried out by Haq*et al*., (2006) to examine the status of As in soils of five intensive vegetable growing of ChapaiNawabganj district of Bangladesh. In different vegetable growing areas the level of heavy metal varied widely. Over the locations, with a mean value to 8.73 mg kg^{-1}As concentration in soils ranged from 4.22 to 15.47 mg kg^{-1}.

Green et al., (2006) reported that during the wet growing season (May-November), soil and soil-water As profiles were obtained from 4 rice paddies in Bangladesh specially when surface water with little arsenic is used for irrigation, or during the dry season (January-May), when groundwater elevated in arsenic is used instead. Accumulation of 13 ± 12 mg kg^{-1} acid-leachable As (n = 11) was observed in the upper 5 cm of paddy soil from 3 sites irrigated with groundwater containing 80-180 µg L^{-1} As, whereas only 3±2 mg kg^{-1} acid-leachable As (n = 8) was measured at a control site. Dissolved As concentrations averaged 370 ± 340 µg L^{-1}(n = 7) in the upper 5 cm of the soil at the 3 sites irrigated with groundwater containing 80-180 µg L^{-1} As, contrasting with soil water As concentrations of only 18 ± 7 µg L^{-1} (n =4) over the same depth interval at the control site., there is no evidence of a proportional transfer to rice grains collected from the same sites, despite the accumulation of As in soil and in soil water attributable to irrigation with groundwater containing elevated

As levels. After the digestion and analysis of individual grains of boro winter rice from the 2 sites irrigated with groundwater containing 150 and 180 µg L^{-1} As yielded concentrations of 0.28 ± 0.13 mg kg^{-1}(n = 12) and 0.44 ± 0.25 mg kg^{-1}(n = 12), respectively. They finally came with a result that the As content of winter rice from the control site was not significantly different though less variable (0.30 ± 0.07; n= 12).

A survey carried out byMeharg and Rahman (2003) aboutAs in rice and soil from Bangladesh and a total of 71 soil samples were collected throughout the country. The lowest measured soil concentration was10 mg kg^{-1}, whereas the highest measure soil concentration was 46 mg $kg^{-1}$was found in areas with low As in irrigation water. In Bangladesh the western part have the highest soil concentrations (>30 mg kg^{-1}), followed by the central belt, which is in agreement with groundwater concentrations.

A study was conducted by Islam et al. (2004) aboutAs levels in water, soil and crops at 456 locations in five upazilas. Soil average As concentration was 12.3 (ranging from 0.3 to 49 mg kg^{-1}) and the upazilas were classified according to soil concentrations: Faridpur>Tala>Brahmanbaria>Paba>Senbag53 percent contained less than 10 mg kg^{-1}, 26 percent contained between 10.1 and 20 mg kg^{-1}, and 18 percent contained more than 20 mg kg^{-1} of all soil samples. Total As concentrations of 5-33 mg kg^{-1} with an average of 17 mg kg^{-1} for some soil samples from Nawabganj, Rajarampur, Jessore, Jhenidah and Comilla. It was reported by Islam *et al.,* (2004) and Sattar*et al.,* (2009) that soil concentrations of As ranged from below detection limit to 56.7 mg kg^{-1}. Ten out of 25 locations contained As concentrations of more than 20 mg kg^{-1}. The levels of As in irrigation water, soils in five districts viz. Pabna, ChapaiNawabganj. Rajbari. Faridpur and Gopalganj of the Gangetic floodplains of Bangladesh was invested by (Islam el al., 2004b). In this study, there was a good correlation between water-As and soil-As over the locations. The levels of As in soils over five districts ranged from 2.09-11.37 mg kg^{-1} and among the five districts, the soils of the Pabna and Gopalganj districts had relatively lower levels of As compared to other three districts. Soil highest As concentrationwas found in soil sample from Rajbari which is 11.37 mg kg^{-1} followed by 10.44 mg kg^{-1}in soil sample from Faridpur. Soil samples was collected from arable lands (n = 18) in three upazilas: Kachua, Hajiganj (both in Chandpur district) and Sharishabari (in Jamalpur district) by Das el al., (1994). They found As concentrations ranged from 7.3 to 27.3 mg kg^{-1} with an average of 15.7±6.6 mg kg^{-1}.

35 soil samples from Bangladesh was collected by Biswas et al., (1988) at different depths (0-15, 15-30 cm) and they found that arsenic concentration insoils varied from 0.48 to 23 mg kg^{-1} in the surface soils and from 0.32-14.8 mg kg^{-1} in the subsurface soils.

An experiment was conducted by Kim et al., (2007) to determine the lateral and vertical distribution and accumulation of arsenic in soils collected from CCA-treated wood structures in Korea. He collected a total of fifty-five composite soil samples from four CCA-treated wood structures of approximately one year in age. Compared to background soil samples having 6.27 mg kg^{-1}, the arsenic concentrations in soil samples adjacent to the structures were as high as 128 mg kg^{-1}.Over 450 samples of Louisiana agricultural soils was analyzed by OnkenandHossner (1996) revealing a mean As level of 23.2 mg kg^{-1} with minimum and maximum values of <2.8 and 73 mg kg^{-1}, respectively.

2.5 Extent of As contamination

The arsenic contamination is extending all over the country. The southeast area of Bangladesh is the severely affected areas around the Meghna Estuary and also some parts of the southwest. A report from the British Geological Survey (BGS Report, 1999) suggested that, ground waters of 41 districts (out of 64) are believed to be affected by As contamination and the worst affected districts (percentage of sampled wells greater than 50 mg L^{-1} are Chandpur (96%), Gopalgonj (94%), Madaripur (93%).Munshigonj (83%), Shariatpur (80%). Noakhali (79%), Satkhira (75%), I.aksmipur (68%). Faridpur (66%), Bagerhat (66%), Comilla (65%) (60%). 51% of the samples were above 0.01 mg L^{-1} (the WHO Guideline Value) and 35% above 0.05 mg L^{-1} (the Bangladesh Drinking Water Standard), by an analysis of 2022 water samples (analyzed by the BGS laboratory). They also observed a characteristics of ground water typical to reduced condition: high dissolved iron (median 1.3 mg L^{-1}) and manganese (0.3 mg L^{-1}), low sulphate (median 0.7 mg L^{-1}) and high phosphate (median 0.6 mg L^{-1}) concentrations and also high ammonium and boron and low nitrate concentrations.

2.6 Effect of arsenic contamination

About 40% people in Bangladesh are at a risk of groundwater contamination by arsenics. The major routes of arsenic entry into the body are drinking water and foods, especially rice of this country's people. The gastrointestinal tract absorbed arsenic element into the bloodstream and then distributed to many organs including lungs, liver, kidneys and skin (Karim, 2000). Under national screening program, a total of 38.430 cases of arsenicosis have been identified (Ahmed*et al.*,2005). The most commonly observed symptoms are melanosis, hyperkeratosis and conjunctival congestion, although there are many clinical manifestations of arsenic poisoning (Das et al., 1996). Rice is the staple food (70% of total calorie intake) of Bangladeshi people so rice could be an important source of exposure to arsenic. Rice is cultivated in 75% of the total cropped areas and above 80% of the total irrigated area.

Approximately, for boro rice (dry season) production 95% of groundwater is extracted and remaining 5% is used for domestic purposes including drinking. A report from FAO, (2006) indicated that soil concentration of arsenic is increasing over time because of irrigation. Arsenic is a heavy metalloid which is toxic to plant and animal and also for human. Countries like UK and Australia, use a 1 µg As g^{-1} limit for arsenic in food and this is often cited as safe level for rice, however this value is too high for the Bangladesh level of rice consumption and the country should establish its own safety standard for foods and soil viewed by Duxbury and Zavala (2005). Consumption of arsenic contaminated water and foods poses a significant threat to public health and predicted inorganic arsenic intake from rice is modeled with the equivalent intake from drinking water for a typical Bangladesh diet.

Duxbury *et al.,*(2003) reported that human exposure to As through rice would be equivalent to half of that in water containing 50 µg L^{-1} for 14% of the paddy rice samples at rice and water intake levels of 400 g and 4 LVcap/day, respectively. a drinking water As level of 10 µg As L^{-1} would be equivalent to Daily consumption of rice with a total arsenic level of 0.08 µg Asg^{-1} (Williams et al., 2006).Rice is a big concern in Bangladesh for assessing risk of arsenic contamination to human health and crop yield. Authentic and representative data on arsenic concentrations (both inorganic and organic) and food consumption patterns are needed for a reliable, quantitative risk assessment for arsenic in food (Williams et al., 2006).

2.7 Water and Arsenic availability

As accumulation by rice plants under continuous flooded and aerobic conditions in the green house was investigated by Li et al., (2009). The least As accumulation was resulted in Growing rice aerobically during the entire rice growth duration. As accumulation in rice straw and grain is decreased significantly compared with rice grown under flooded conditionsby maintaining aerobic conditions during either vegetative or reproductive stage of rice growth, the concentrations of inorganic Asremained in the flooded rice although aerobic treatments decreased the percentage of inorganic As in grain. The water regime, and by implication of soil reduction and associated mobility of As and its availability to the plants could be important factors regulating As uptake and its impact on plant growth reported by Panaullah et al., (2006) . It was seen that soil As have no consistent effect on rice yield but maturity was greatly delayed in the high-As plots and about 40-50% of the grains in the high-As plots remained green, at the milk stage. Grain yield was very poor, which is only 2.0-2.5 t ha^{-1}(rough rice), which was much less than about 4.0-5.0 t ha^{-1} and high As in the soil across the country was suspected for this low yield of rice.

An experiment was conducted by Daum et al., (2001) to investigate the influence of different water management strategies on the uptake of As by paddy rice, since the redox potential in the soil affects their phytoavailability. An experiment was conducted in a farmer's field in the Po area of Italy with different irrigation strategies.

As concentration in rice plants and grains is decreased by two additional drainage periods during the growth stages of internode elongation and grain filling compared to the usual strategy with continuous flooding until shortly before harvest. Additional drainage periods caused the lower availability of As and it is happened due to the re-oxygenation of soil after removing the water as indicated by redox potential measurements.

2.8 Performance of As on rice

Talukder et al., (2011) conducted a field experiments to examine 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 at Gobindagonj, Gaibandha, Bangladesh in 2004 and 2005. In permanent raised bed (PRB; aerobic WM: Eh=+360 mV) plus 100% P amendment the highest average grain yields were recorded in (6.88+or-0.07 t ha^{-1} in boro 6.38+or-0.06 t ha^{-1} in aman). 12% yield increase over conventional till on flat was recorded (CTF; anaerobic WM: Eh=-56 mV) at the same P level. Compared to PRB in boro, the As content in grain and As content in straw were about 3 and 6 times higher in CTF. 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) and 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. According to the result grain and straw As are closely associated in boro rice. Irrigation input was reduced to 29-31% for boro and 27-30% for aman rice relative to CTF treatments in 2004 and 2005, respectively, by the furrow irrigation approach of the PRB treatments and thus reducing the amount of As added to the soil from the As-contaminated irrigation water.

Khan et al., (2010b) reported that due to irrigation of As-laden groundwater, some paddy soils in the Bengal delta are contaminated with arsenic (As), which may lead to yield losses and elevated As transfer to the food chain. In a pot experiment, it was investigated that soils have a higher As bioavailability than other soils containing either geogenic As or contaminated by mining activities. There are fourteen soils varying in the source and the degree (4-138 mg As kg^{-1}) of As contamination were collected, among those two each from China and the UK (geogenic or mining impacted) and 10 from Bangladeshi paddy fields (contaminated by arsenic) for comparison. Higher percentages of the total As extractable by ammonium phosphate (specifically absorbed As) was found in Bangladesh soil than any other soil and more As also released into the pore water upon flooding. Soils containing >13 mg As kg^{-1} reduced rice growth and grain yield markedly in Bangladesh than other countries soil.

Guo et al., (2005) conducted a solution culture experiment to investigate the effect of silicate on the yield and arsenate uptake by rice. In a 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) rice seedlings (*Oryza sativa L. cv. Weiyou 77*) were cultured. Si addition increased shoot dry weight (P=0.001) significantly but had little effect on root dry weight (P=0.43). Addition of As significantly increased root dry weight (P=0.01) but had no significant effect on shoot dry weight.

To ensure food security, the Bangladesh government has supported the cultivation of a number of high yielding rice varieties which require a large volume of irrigation water reported by Delowar et al., (2005). Over the last couple of decades the use of groundwater for irrigation has increased abruptly and about 80% of pumped groundwater is utilized in the agricultural sector, but the groundwater in many areas of Bangladesh is severely contaminated with arsenic. So, there is a huge chance of arsenic accumulation in rice and rice plants from arsenic contaminated water. Assessing the extent of accumulation of arsenic in rice plants and its effects on growth and yield of rice was the main aim of this study. The concentrations of Arsenic in rice soils (irrigated with 0, 2.5, 5, 10, 15 and 20 mgL^{-1} of arsenic water) were 0-0.2, 0-0.95 and 0-0.27 mg kg^{-1} at tillering, heading and ripening stages. It was found that arsenic was accumulated by rice grains from soil/water and arsenic accumulation varied greatly in the two rice varieties studied. In rice varieties BRRI dhan28 and Iratom24 arsenic concentrations in rice grains were 0-0.07 and 0-0.14 mg kg^{-1} dry weight.

Although the grain weight was not affected but the growth and yield of rice plants were reduced significantly with increased doses of arsenic. The number of tillers per pot, number of effective tillers per pot and grain yield per pot reduced greatly with the higher dose (20 mgL^{-1}) of arsenic applied among the different yield components. In Iratom-24 and BRRI dhan28, yield reduction was more than 60% and 40% with 20 $mg\ L^{-1}$ of arsenic as compared to control. Straw yield reduction was also significantly higher for both of rice varieties with the 20 $mg\ L^{-1}$ arsenic application.

Islam et al., (2004) carried out a pot culture experiment at Bangladesh Agricultural University (BAU), Mymensingh to see the effects irrigation water arsenic (As) on Boro rice (February to June) and the residual effect on T. Aman rice (August-November). The experiment was conducted with 8 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 and a total of 56 L of irrigation water having different concentrations of As was needed for the Boro rice (cv. BRRI dhan29). After harvesting of Boro rice, T. Aman rice (cv. BRRI dhan33) was grown in the same pots with monsoon rain after the harvest of Boro rice. To sustain normal growth of both Boro and T. Aman rice, nutrients such as N, P, K and S @ 100, 25, 40 and 25 ppm were added respectively. The values for grain As for every As treatment were below the Maximum permissible level (1.0 ppm) but The concentration of As in rice grain or straw of Boro rice increased significantly with increasing As concentrations in the irrigation water.

Ghoshal et al., (2003) carried out a pot culture experiment to study the effect of irrigation water, contaminated with arsenic, on the uptake of phosphorus and arsenic by the different parts of the crop. The treatments conducted with arsenic-free deionized irrigated water and arsenic-contaminated irrigated water containing 0.29 ppm arsenic. Each treatment have two series, namely uncovered and covered (glazed black polythene sheet). Soil irrigated with arsenic-contaminated water have shown significantly increased arsenic accumulation and concentration in the straw and roots of the plants grown. Arsenic concentration and accumulation was less in the straw than the root and Phosphorus uptake was reduced with the increase in soil arsenic concentration and covering further reduced the same, indicating a significant arsenic-phosphorus interaction.

Abedin and Meharg (2002) conducted an experiment on rice seed germination and a short-term toxicity experiment with different concentrations of arsenite and arsenate on rice seedlings were conducted. Germination percentage was decreased significantly with increasing concentrations of arsenite and arsenate. Arsenate was found to be less toxic than arsenite for rice seed germination. It was suggested that there were varietal differences among the test varieties in response to arsenite and arsenate exposure but the performance of the dry season cultivar Purbachi was the best among the cultivars. With increasing concentrations of arsenite and arsenate, root tolerance index (RTI) and relative shoot height (RSH) for rice seedlings decreased significantly. In general the wet season varieties have less tolerance to arsenite or arsenate than the dry season varieties.

Montenegro and Mejia (2001) carried out a field and greenhouse experiments 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 result of the experiments are (1) Whenneither element was present in the irrigation waters, rice reached its maximum height. (2) An increase in As content induced a 10% reduction in grains per panicle while the gradual increase of Cd in the irrigation waters decreased by 12.5% the number of grains per panicle.

Kang et al., (1996) grown rice in a pot experiment on loam paddy soil with available arsenic contents of 1.3, 6.0, 7.8 or 10.3 mg/kg and total arsenic contents of 1.3, 27.7, 36.6 and 56.0 mg/kg, respectively. Plant height, number of effective tillers, dry weight of aboveground parts and 1000-grain weight was decreased due to the increasing the level of arsenic. He found that Content of arsenic was higher in roots than in stems, leaves or in grain.

Chen and Liu (1993) carried out a pot and field experiments to investigate the effect of pH in the movement of arsenic (As) in the plant-soil system. They suggested that As adsorption decreased by increasing soil pH and thereby increased the As concentration in the soil solution. Therefore as the soil pH increased, As availability to rice increased and toxicity problems became more serious than before. They also reported that high levels of arsenite caused phytotoxicity due to inhibition of necessary respiration.

CHAPTER III

MATERIALS AND METHODS

The pot experiment was conducted at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2016 to April 2017 to study the effect of different doses of arsenic on yield of rice. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work in pot was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^{0}74'$ N latitude and $90^{0}35'$ E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Soil

The soil of the experimental area that used in the pot for rice grown belongs to “The Modhupur Tract”, AEZ 28.Pot soil was silty clay in texture. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system. The details of the pot soil have been presented in Appendix I.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatments

The experiment comprised of two factors.

Factor A: Arsenic level (4 levels):

i. As_0: Control (No arsenic)

ii. As_1: 2 ppm As

iii. As_2: 4 ppm As

iv. As_3: 6 ppm As

Factor B: Water condition

i. W_1: Unsaturated water condition

ii. W_2: Saturated water condition

As such there were 8 treatments combinations viz. As_0W_1, As_0W_2, As_1W_1, As_1W_2, As_2W_1, As_2W_2, As_3W_1, As_3W_2.

3.2.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were 24 pots for 8 treatment combination in each of 3 replications. The 8 treatment combinations of the experiment were assigned at random in 8 pots of each replication.

As0W1	As0W2	As1W1	As1W2	As2W1	As2W2	As3W1	As3W2
As0W2	As1W1	As1W2	As2W1	As2W2	As3W1	As3W2	As0W1
As1W1	As1W2	As2W1	As2W2	As3W1	As3W2	As0W1	As0W2

Fig: Layout of the experiment field

As_0W_1= As_0+ Unsaturated condition, As_1W_1= As_1+ Unsaturated condition, As_2W_1=As_2+ Unsaturated condition, As_3W_1=As_3+ Unsaturated condition, As_0W_2= As_0+ saturated condition, As_1W_2= As_1+ saturated condition, As_2W_2=As_2+ saturated condition, As_3W_2=As_3+ saturated condition.

3.3 Growing of crops

3.3.1 Raising seedlings

3.3.1.1 Seed collection

The seeds of the test crop i.e. BRRI dhan36 is collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur.

3.3.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then they were kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.3.1.3 Preparation of seedling nursery bed and seed sowing

According to BRRI recommendation seed bed was prepared with 1 m wide seed bed adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on December 8, 2016, in order to transplant the seedlings in the pot as per experimental treatment.

3.3.2 Preparation of the pot

The pot for the experiment was filled up with soil at 2 January, 2017. Weeds and stubble were removed from the soil and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.3.3 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MoP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of TSP, MoP, gypsum, zinc sulphate and borax were applied during the final preparation of pot land. Urea was applied in three equal installments -as basal dose, at tillering and before panicle initiation. Different concentration of As was mixed the soil as per treatment. The dose and method of application of fertilizers are shown in Table 1.

Table 1. Dose and method of application of fertilizers

Fertilizers	Dose (kg/ha)	Application(%)		
		Basal	1st installment	2nd installment
Urea	150	33.33	33.33	33.33
TSP	100	100	-	-
MoP	100	100	-	-
Gypsum	60	100	-	-
Borax	10	100	-	-

Source: Anon., 2010, BRRI, Joydebpur, Gazipur

3.3.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting of the seedlings. The seedlings were uprooted on January 8, 2017 without causing much mechanical injury to the roots.

3.3.5 Transplanting of seedlings in the pots

The rice seedlings were transplanted in the pot at 9 January, 2017 and 2 healthy seedlings were transplanted in the pot in a hill.

3.3.6After care

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

3.3.6.1 Irrigation and drainage

Sprinkler irrigation was provided to maintain a constant level of standing water upto 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The pot was finally dried out at 15 days before harvesting.

3.3.6.2 Gap filling

First gap filling was done for all of the pots at 10 days after transplanting (DAT) by planting same aged seedlings.

3.3.6.3 Weeding

Weeding were done to keep the pots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by manual means.

3.3.6.4 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 2 equal installments in the soil.

3.3.6.5 Plant protection

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

3.4 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each pot. The harvested crop of each pot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded pot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 13%. The straw was sun dried and the yields of grain and straw pot^{-1} were recorded and converted to t/ ha.

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 90 DAT (Days after transplanting) and at harvest. The height was measured from the ground level to the tip of the tiller.

3.5.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at the time of 90 DAT by counting total tillers in a hill.

3.5.3 Total tillers hill^{-1} (at harvest)

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

3.5.4 Effective tillers hill^{-1}

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

3.5.5 Length of panicle

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

3.5.6 Number of panicle

The number of total panicle per pot are counted.

3.5.7 Filled grain hill^{-1}

The total number of filled grain per hill are counted manually.

3.5.8 Un-filled grain hill^{-1}

The total number of unfilled grain per hill are counted manually.

3.5.9 Filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 3 panicles of a pot on the basis of grain in the spikelet and then average number of filled grains panicle^{-1} was recorded.

3.5.10 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from the same 3 panicles where filled grains were counted of a pot on the basis of no grain in the spikelet and then average number of unfilled grains panicle^{-1} was recorded.

3.5.11 Weight of 1000 seeds

One thousand seeds were counted randomly from the total cleaned harvested seeds of each individual pot and then weighed in grams and recorded.

3.5.12 Grain yield

Grains obtained from each unit pot were sun-dried and weighed carefully. The dry weight of grains of each pot was measured and grain yield pot^{-1}.

3.5.13 Straw yield

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

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed using Statistix 10 software to observe the significant difference among the treatments. The mean values of all the characters were calculated and factorial analysis of variance was performed. The significance of the difference among the treatment means was estimated by the

Least Significant Difference Test (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSIONS

The present investigation included the response of rice variety (BRRI dhan36, susceptible to arsenic) to different levels of arsenic (As) and saturated and unsaturated condition. The results presented in tables and figures are discussed systematically under the following heads:

4.1 Effect of arsenic, saturated and unsaturated water condition on yield and yield contributing characters of rice plant

4.1.1 Plant height at harvest

Due to the effects of arsenic (As), saturated and unsaturated condition in BRRI dhan36, plant height was affected significantly. A significant ($p<0.05$) variation in plant height was observed in respect of different arsenic levels, saturated and unsaturated condition of soil (Table 1). The highest rice plant (81.67 cm) was found in As_0W_2 treated pot and the lowest rice plant (51.00cm) was found in As_3W_2 treated pot (Table 1). In the experiment,the highest plant height was observed in saturated condition with controlled arsenic level and the lowest plant height was found in saturated condition with the highest arsenic level (6 ppm). This plant height reduction might be happened due to increase in arsenic concentration in soil and in saturated condition, As can be uptaken by rice plant due to available and also oxidation of As occur in saturated condition of soil. As affected the root development and reduced the plant height of rice which was reported by Abedin et al., (2002a). Some researcher also reported similar findings and they have also reported that plant roots are unable to accumulate the essential nutrients from soil in presence of excess arsenic because As

(III) reacts with sulfhydryl groups of proteins (Speer, 1973) causing disruption of root functions of plants (Orwick et al., 1976). In linear relationship, significant and negative correlation were observed in rice plant height (R^2= 0.303) (Fig. 1). And, also, in linear relationship, plant height were found statistically significant ($p<0.05$) and negatively correlated with straw yield (R^2= 0.430) in BRRI dhan36 (Fig. 9).

Table 1. Effect of arsenic, saturated and unsaturated water condition on the different growth parameters of rice

Treatments	**Plant height (cm)**	**Effective tiller plant^{-1}**	**Non-effective tiller plant^{-1}**	**Panicle length**
As_0W_1	70.33 abc	12.33 ab	5.67 a	24.00 ab
As_1W_1	67.00 abc	9.00 bcd	3.33 bc	21.33 bc
As_2W_1	66.67 abc	7.00 cde	2.33 cd	20.67 c
As_3W_1	51.33 c	3.00 e	1.67 d	14.00 e
As_0W_2	81.67 a	16.00 a	5.33 a	24.67 a
As_1W_2	71.67 ab	9.67 bc	3.67 b	20.67 c
As_2W_2	58.00 bc	5.00 de	2.67 bcd	20.67 c
As_3W_2	51.00 c	3.00 e	1.67 d	17.33 d
LSD	**19.422**	**4.082**	**1.122**	**3.154**
CV(%)	**17.14**	**28.69**	**19.47**	**8.82**

Means in a column followed by same letter (s) are not significantly different at 5% level of significance

(As_0W_1= As_0+ Unsaturated condition, As_1W_1= As_1+ Unsaturated condition, As_2W_1=As_2+ Unsaturated condition, As_3W_1=As_3+ Unsaturated condition, As_0W_2= As0+ saturated condition, As_1W_2= As_1+ saturated condition, As_2W_2=As_2+ saturated condition, As_3W_2=As_3+ saturated condition)

4.1.2 Effective tillers plant^{-1}

The application of different doses of arsenic(As), saturated and unsaturated condition had significant effect on thetillering of rice variety BRRI dhan36. It was observed that number of effective tillers of rice plant decreased significantly ($p<0.05$) with increasing soil As concentration. Effective tillers plant^{-1}was affected significantly in

BRRI dhan36 with increasing levels of arsenic concentration in soil(Table 1). The highest effective tillers per plant (16.00) was found in As_0W_2 treated pot and the lowest effective tillers per plant (3.00) was found in As_3W_2 treated pot (Table 1). In the experiment, maximum effective tiller per plant was observed in saturated conditions with controlled arsenic level and minimum effective tiller was found in saturated conditions with the highest arsenic level (6 ppm). This result is similar to the findings of Islam and Jahiruddin (2010), who reported that arsenic treatment resulted in a marked decrease in effective tillers per pot, filled grains per panicle and 1000-grain weight; these together contributed reduced grain yield. Rice grain yield was reduced by 20.6% for 15 $mgkg^{-1}$As treatment and 63.8% due to 30 $mgkg^{-1}$As. In linear relationship, the effective tillers per plant of rice variety BRRI dhan36 were observed negatively and strongly correlated (R^2= 0.086) (Fig. 2).

4.1.3 Non-effective tillers plant^{-1}

In response different doses ofarsenic(As), saturated and unsaturated condition, the number of non-effective tillers plant^{-1} were found statistically significant ($p < 0.05$) variation in rice variety of BRRI dhan36. A significant ($p<0.05$) variation in non-effective tillers per plant was observed(Table 1). The highest number of non-effective tillers per plant (5.66) were found in As_0W_1 treated pot and the lowest number of non-effective tillers per plant (1.66) of rice was found in As_3W_2 treated pot (Table 1).In the experiment maximum non-effective tiller per plant was observed in unsaturated conditions with controlled arsenic level and minimum non-effective tiller per plant was found in saturated conditions with the highest arsenic level (6 ppm). Islam and Jahiruddin (2010), who reported that 15 $mgkg^{-1}$ As treated rice soils significantly reduced the effective tillers per pot, filled grains per panicle and 1000-grain weight. Khan et al., (2010) also reported that the addition of arsenic significantly reduced tillering in rice plant. In linear relationship, the non-effective tillers per plant of rice variety BRRI dhan36 were observed negatively and strongly correlated (R^2= 0.098) (Fig. 3).

4.1.4 Panicle length (cm)

The panicle length was significantly affected by As addition to soil of rice variety BRRI dhan36. As levels in soils. Panicle length of rice plant was affected markedly due to the effects of arsenic (As), saturated and unsaturated condition applications in BRRI dhan36 (Table 1). It was observed that number of panicle length of rice plant decreased significantly ($p<0.05$) with increasing soil As concentration. The largest panicle length (24.66cm) was found in As_0W_2 treatment and smallest panicle length (1.66cm) was found in As_3W_1 and As_3W_2 treatment (Table 1). In the experiment the largest panicle length was observed in saturated conditions with controlled arsenic level and smallest panicle length was found in both saturated and unsaturated conditions with the highest arsenic level (6 ppm). This findings is similar to the findings of Vromman et al., 2013 who reported that the panicles number of rice plant were not affected at low doses of Asin soil but significantly affected the panicles number at higher doses. A positive and strong correlation of panicle length was found (R^2= 0.204) (Fig. 4).

Table 2. Effect of arsenic, saturated and unsaturated water condition on the different growth parameters of rice

Treatments	**Filled grain plant^{-1}**	**Unfilled grain plant^{-1}**	**Filled grain panicle^{-1}**	**Unfilled grain panicle^{-1}**
As_0W_1	616.33 a	243.33 e	47.33 a	39.00 a
As_1W_1	335.00 b	306.67 bc	39.33 b	33.67 b
As_2W_1	294.33 b	332.67 b	36.67 bc	29.67 b
As_3W_1	154.00 c	450.33 a	32.33 cd	21.00 c
As_0W_2	551.33 a	258.33 de	44.67 a	39.33 a
As_1W_2	348.67 b	314.67 bc	39.67 b	33.00 b

As$_2$W$_2$	320.33 b	284.33 cd	35.00 bc	32.00 b
As$_3$W$_2$	167.33 c	419.00 a	28.00 d	24.33 c
LSD	**77.28**	**31.628**	**4.841**	**4.765**
CV(%)	**12.67**	**5.54**	**7.30**	**8.64**

Means in a column followed by same letter (s) are not significantly different at 5% level of significance

(As$_0$W$_1$= As$_0$+ Unsaturated condition, As$_1$W$_1$= As$_1$+ Unsaturated condition, As$_2$W$_1$=As$_2$+ Unsaturated condition, As$_3$W$_1$=As$_3$+ Unsaturated condition, As$_0$W$_2$= As0+ saturated condition, As$_1$W$_2$= As$_1$+ saturated condition, As$_2$W$_2$=As$_2$+ saturated condition, As$_3$W$_2$=As$_3$+ saturated condition)

4.1.5 Filled grain plant^{-1}

With increasing of soil As concentration, the number of filled grain per panicle of rice plant was varied significantly. A significant ($p<0.05$) variation in filled grain per plant was observed in respect of different arsenic levels,saturated and unsaturated condition(Table 2). The highest filled grain per plant (616.33) was found in As$_0$W$_1$ treatment and lowest filled grain per plant (154.00) was found in As$_3$W$_1$ treatment (Table 2). In the experiment, highest filled grain per plant was observed in unsaturated conditions with controlled arsenic level and lowest filled grain per plant was found in unsaturated conditions with the highest arsenic level (6 ppm). This results were found similar with the findings from Hussain (2005), Islam and Jahiruddin (2010). Strong and negative correlation were observed in filled grain per plant (R^2= 0.299). (Fig. 5)

4.1.6 Un-filled grain plant^{-1}

Increasing soil As concentration not only decrease the filled grain per plant but also the unfilled grain per plant of rice plant. Un-filled grain per plant was affected due to the effects of arsenic (As), saturated and unsaturated condition in BRRI dhan36 (Table 2). A non-significant ($p<0.05$) variation in filled grain per plant was observed in respect of different arsenic levels,saturated and unsaturated condition(Table 2). The highest un-filled grain per plant (450.33) was found in As$_3$W$_1$ treated pot and lowest un-filled grain per plant (243.33) was found in As_0W_1 treated pot (Table 2).In the experiment, lowest un-filled grain per plant was observed in unsaturated conditions with controlled arsenic level and highest un-filled grain per plant was found in unsaturated conditions with the highest arsenic level (6 ppm). In linear relationship, the un-filled grain per plant of rice variety BRRI dhan36 were observed negatively and strongly correlated (R^2= 0.124) (Fig. 6).

4.1.7 Filled grain panicle^{-1}

The number of filled grain per panicle of rice variety BRRI dhan36 was varied significantly with increasing of soil As concentration. A significant effect was found in rice variety due to the effects of arsenic (As), saturated and unsaturated condition. A significant ($p<0.05$) variation in filled grain per plant was observed in respect of different arsenic levels,saturated and unsaturated condition(Table 2). The highest filled grain per panicle (47.33) was found in As_0W_1 treatment and the lowest filled grain per panicle (28.00) was found in As_3W_2 treatment (Table 2).In the experiment, the highest filled grain per panicle was observed in unsaturated conditions with controlled arsenic level and the lowest filled panicle per plant was found in saturated conditions with the highest arsenic level (6 ppm).

4.1.8 Un-filled grain panicle^{-1}

Increasing soil As concentration not only decrease the filled grain per panicle but also the unfilled grain per panicle of rice plant. The number of unfilled grain per panicle of rice variety BRRI dhan36 was varied significantly with increasing of soil As concentration. A significant ($p<0.05$) variation in filled grain per plant was observed in respect of different arsenic levels saturated and unsaturated condition(Table 2). The highest un-filled grain per panicle (39.33) was found in As_0W_2 treated pot and the lowest un-filled grain per panicle (21.00) was found in As_3W_1 treated pot (Table 2).In the experiment, highest un-filled grain per panicle was observed in saturated conditions with controlled arsenic level and lowest un-filled grain per panicle was found in unsaturated conditions with the highest arsenic level (6 ppm).

Table 3. Effect of arsenic, saturated and unsaturated water condition on the different growth parameters of rice

Treatments	**1000 Grain weight(g)**	**Grain yield(g/pot)**	**Straw yield(g/pot)**
As_0W_1	22.10	29.07 a	30.30 a
As_1W_1	21.36	27.33 ab	25.27 bc
As_2w_1	20.07	14.70 d	20.77 cd
As_3W_1	19.69	17.87 cd	12.33 e
As_0W_2	21.23	29.50 a	26.50 ab
As_1W_2	20.30	25.37 abc	20.37 d
As_2W_2	19.77	24.13 abc	20.57 d
As_3W_2	19.27	18.73 bcd	13.30 e
LSD	**NS**	**9.117**	**4.676**
CV(%)	**1.64**	**22.67**	**12.61**

Means in a column followed by same letter (s) are not significantly different at 5% level of significance

(As_0W_1= As_0+ Unsaturated condition, As_1W_1= As_1+ Unsaturated condition, As_2W_1=As_2+ Unsaturated condition, As_3W_1=As_3+ Unsaturated condition, As_0W_2= As0+ saturated condition, As_1W_2= As_1+ saturated condition, As_2W_2=As_2+ saturated condition, As_3W_2=As_3+ saturated condition)

4.1.9 1000 grain weight

Increasing soil As concentration influenced the 1000 grain weight of rice in As contaminated soils. 1000 grain per plant was affected due to the effects of arsenic (As), saturated and unsaturated condition in BRRI dhan36 (Table 3). A non-significant ($p<0.05$) variation in 1000 grain weight per plant was observed in respect of different arsenic levels,saturated and unsaturated condition(Table 3). The highest 1000-grain weight (22.10g) was found in As_0W_1 treatment and the lowest 1000-grain weight (19.27g) was found in As_3W_2 treatment (Table 3). In the experiment, the highest 1000-grain weight was observed in unsaturated condition with controlled arsenic level and lowest 1000-grain weight was found in saturated conditions with the highest arsenic level (6 ppm). Some researchers found similar kind of relationship, such as, Abedin and Meharg (2002) found that presence arsenic at a higher concentration in irrigation water significantly reduced the 1000 grain weight of rice plant. Vromman et al., (2013) reported that arsenic application in rice significantly reduced yield and different yield-contributing parameters including the number of panicles per plant, panicle dry weight, the number of spikelets and full grains per plant and 1000-grain weight.

4.1.10 Straw yield

The straw yield of BRRI dhan36 was found negatively affected with increasing soil As concentration in soils. Straw yield per plant was affected due to the effects of arsenic (As), saturated and unsaturated condition in BRRI dhan36 (Table 3). A significant ($p<0.05$) variation in straw yield per plant was observed in respect of different arsenic levels,saturated and unsaturated condition(Table 3). The highest straw yield (30.30g) was found in As_0W_1 treatment and lowest straw yield (12.33g) was found in As_3W_2 treatment (Table 3).In the experiment, highest straw yield was observed in unsaturated conditions with controlled arsenic level and lowest straw yield was found in saturated conditions with the highest arsenic level (6 ppm). Hossain et al., (2005); and Kang et al., (1996) reported that soil test-based soil arsenic concentration which could be reduced the grain yield of rice. Abedin et al., (2002); Yan et al., (2005); Hossain et al., (2005) and Islam et al., (2004) reported that soil arsenic concentration on irrigated rice-based cropping system may cause heavy depletion of straw yield of rice. This result is similar to the findings of some researchers such as, Islam and Jahiruddin (2010) found that the grain yield of rice was reduced by 20.6 % for 15 mg kg^{-1} As treatment and 63.8 % due to 30 mgkg^{-1} As. Such reductions for straw yield were 21.0 and 65.2 % with these two As treatments, respectively. The straw yield were also found negatively correlated significantly with effective tillers (R^2= 0.457) (Fig. 7).

4.1.11 Grain yield

The yield of rice variety BRRI dhan36 were found adversely affected with different levels of soil As concentration in soils. With increasing arsenic level, saturated and unsaturated condition, grain yield of BRRI dhan36 was affected significantly. A significant ($p<0.05$) variation in grain yield per plant was observed in respect of different arsenic levels,saturated and unsaturated condition(Table 3). The highest grain yield (29.5g) was found in As_0W_2 treated pot and lowest grain yield (14.7g) was found in As_2W_1 treated pot (Table 3).In the experiment, highest grain yield was observed in saturated condition with controlled arsenic level and lowest grain yield was found in unsaturated condition with the highest arsenic level (6 ppm). Hossain et al. (2005); Hossain et al. (2008) and Kang et al. (1996) reported that due to arsenic toxicity in rice plant, grain yield reduce. Similar results were published by some another researchers, such as, Panaullah et al., (2009); Carbonell-Barrachina et al., (1997); Abedin and Meharg (2002); and Tsutsumi (1980). Islam et al., (2004) reported that higher doses of arsenic with irrigation water significantly reduced of plant height, panicle length, grains panicle^{-1}, grain and straw yields of rice in boro season. In linear relationship, the grain yield of BRRI dhan36 was observed negatively correlated (R^2= 0.278) (Fig. 8).

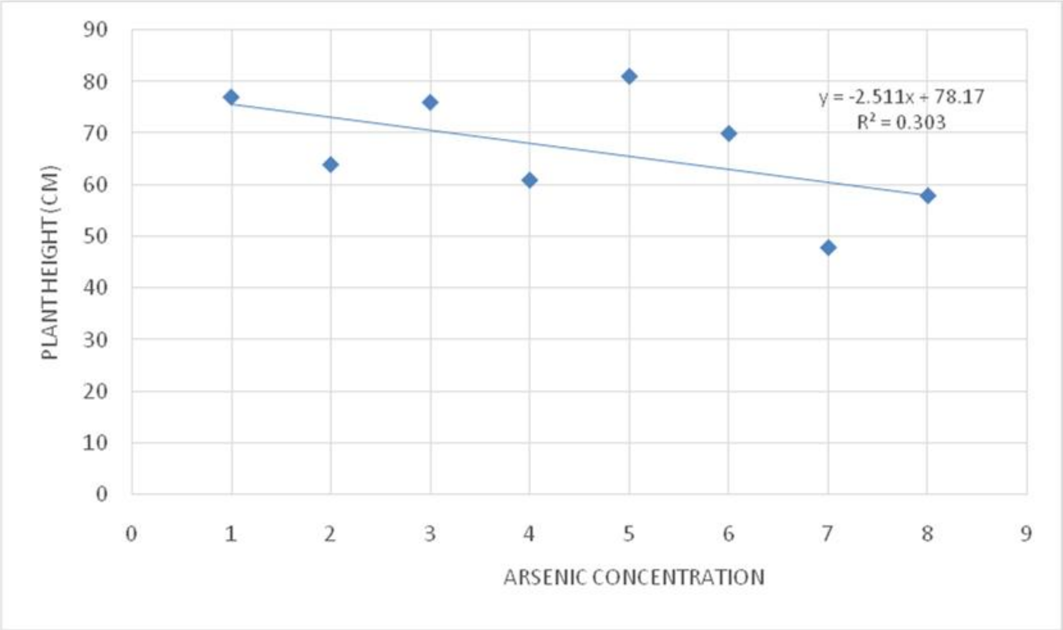

Fig. 1 Linear relationship of plant height in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

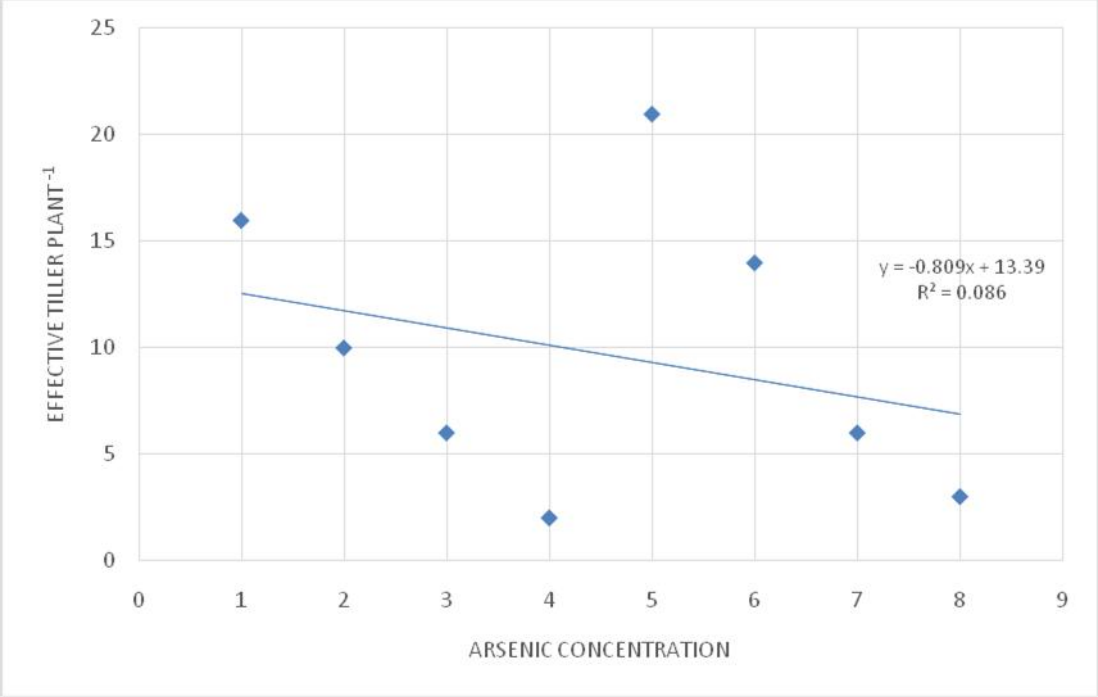

Fig. 2 Linear relationship of effective tillers plant^{-1} in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

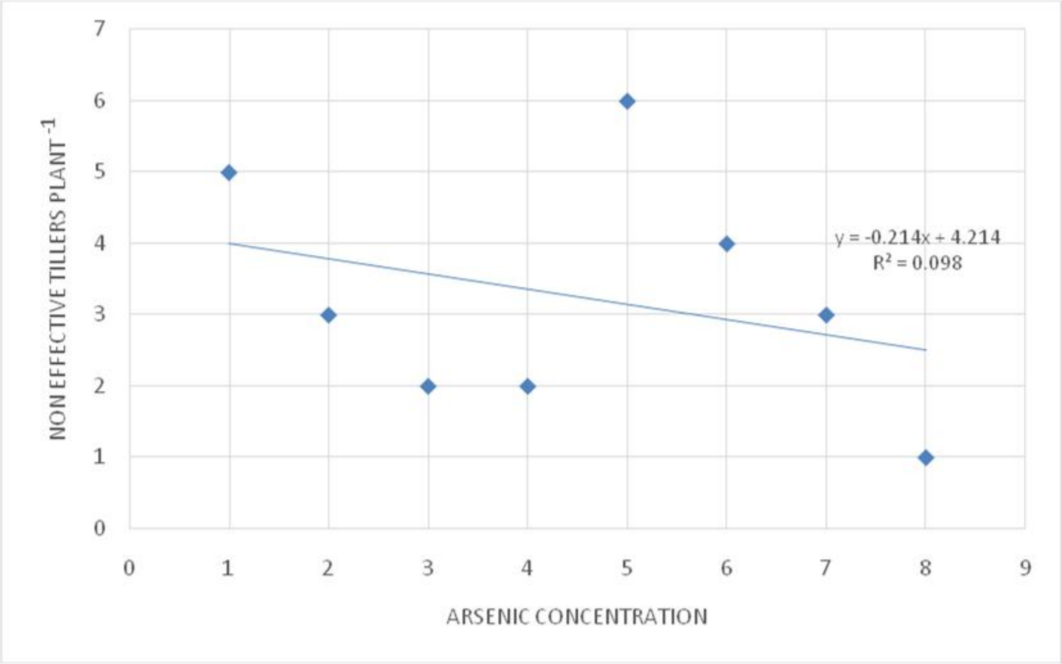

Fig. 3 Linear relationship of non-effective tillers plant^{-1} in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

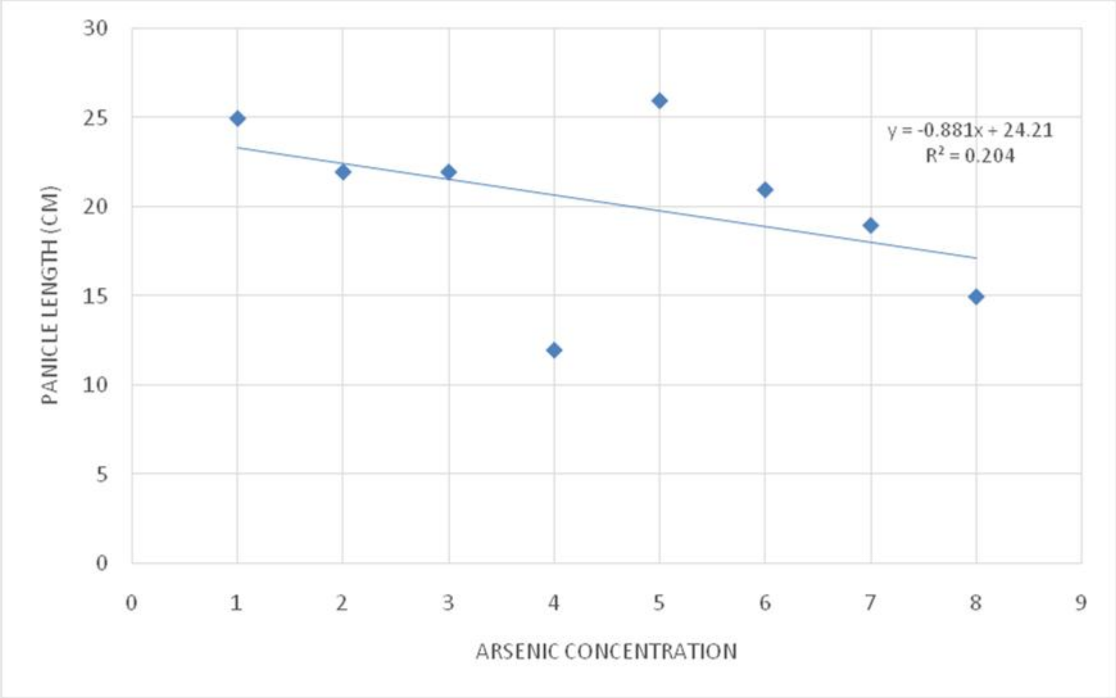

Fig. 4 Linear relationship of panicle length in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

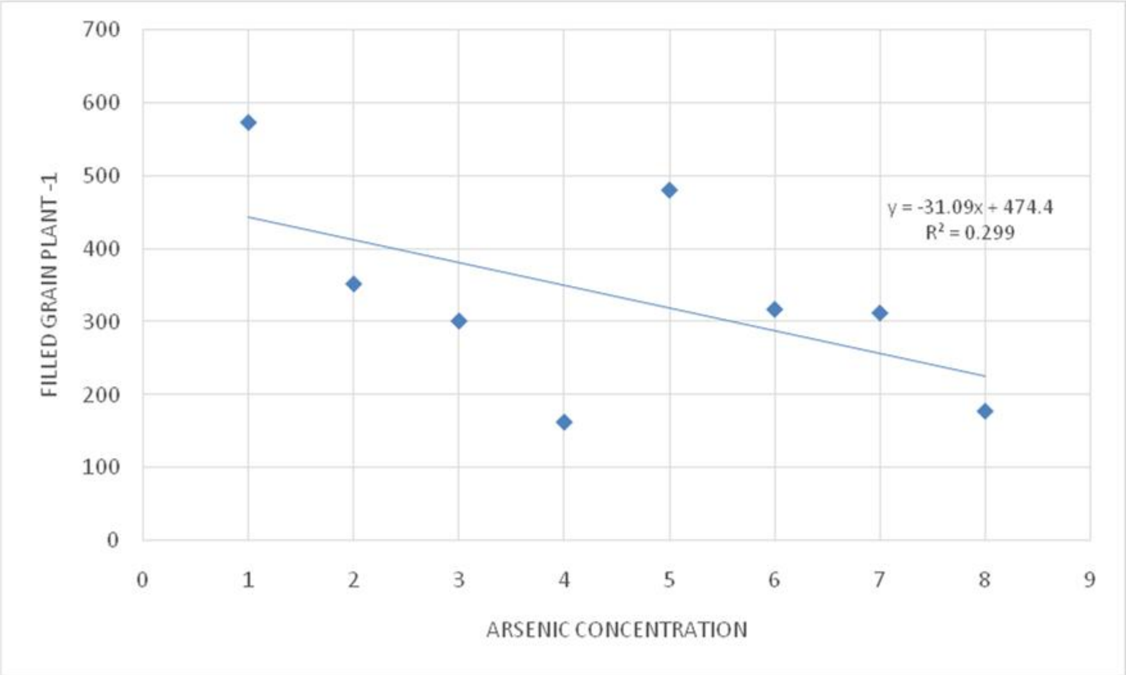

Fig. 5 Linear relationship of filled grain plant^{-1} in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

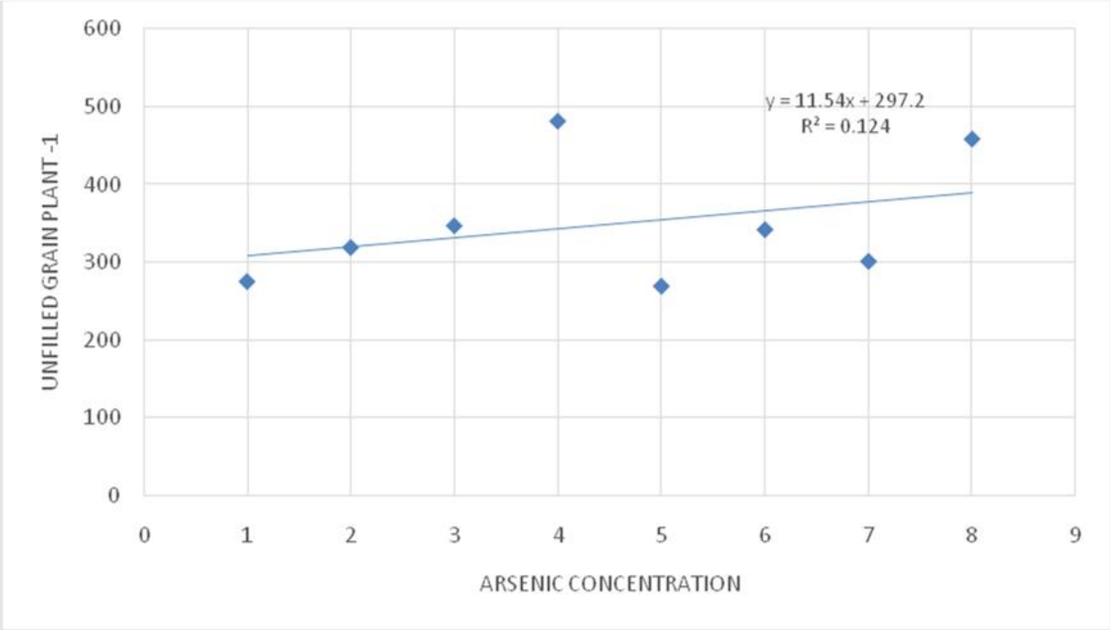

Fig. 6 Linear relationship of un-filled grain plant^{-1} in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

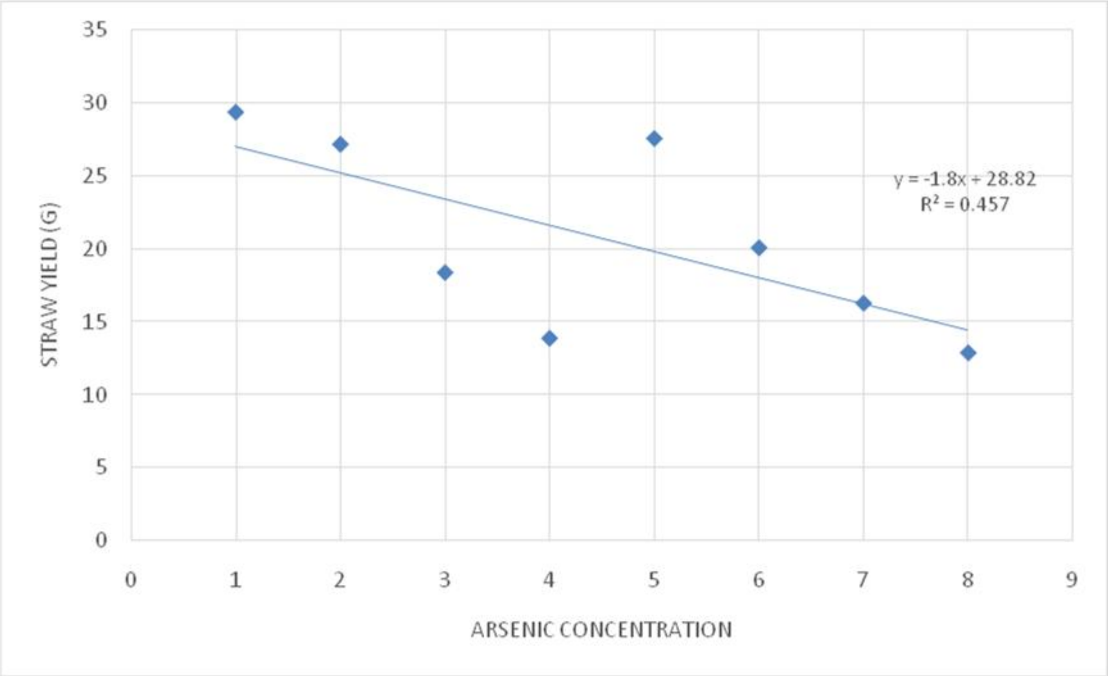

Fig. 7 Linear relationship of straw yield in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

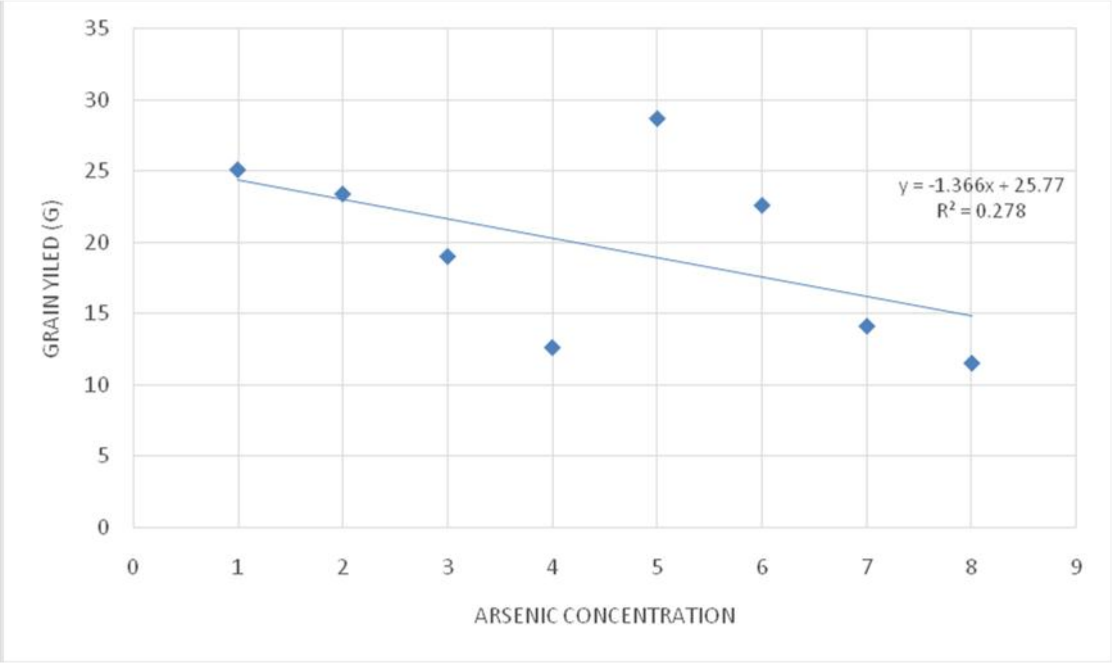

Fig. 8 Linear relationship of grain yield in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

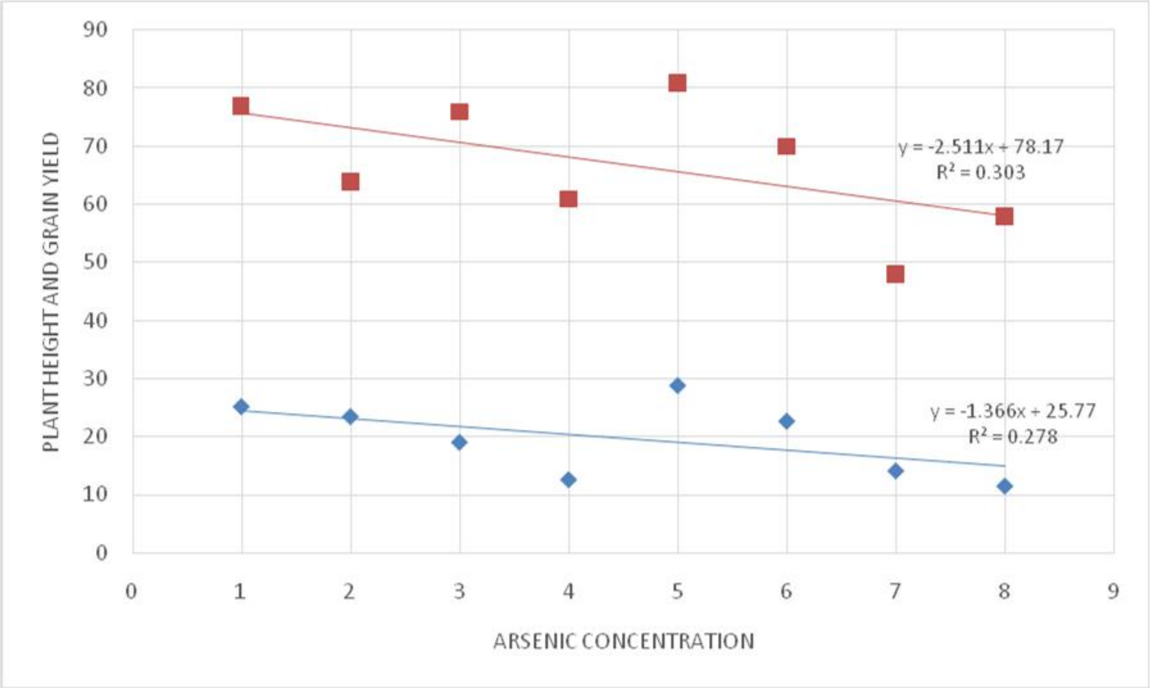

Fig. 9 Linear relationship of plant height and grain yield in response of arsenic, saturated and unsaturated water condition of BRRI dhan36

CHAPTER V

SUMMARY AND CONCLUSIONS

Rice is very efficient in taking up arsenic, because it is grown in water-flooded situation. That reduces the binding of arsenic by soil. It makes arsenic more available to rice. The semi-aquatic nature of rice plant and grain gives the option to pull arsenic up from readily available sources. It is a fact that arsenic is a naturally occurring contaminant and because it is in soil and water, so it is going to get into food. Rice takes more arsenic from the soil than other crops. This is because of the way rice is grown. Rice is grown in flooded areas which charge the soil readily releasing arsenic from the soil. Rice is most affected by arsenic uptake. The flooded soil is anaerobic and strongly reduced. In this situation arsenic is readily available to rice plants roots. Moreover, huge amount of water is used for irrigated rice than is used for aerobic culture. Different varieties of rice differ in arsenic tolerance. Seriously affected varieties develop straight head disease, empty panicle at maturity.

In Sher-e-Bangla Agricultural University, Dhaka, Bangladesh**,** a pot experiment was conducted during the period from December 2016 to March 2017 to study the effects of water management practices on growth, yield and arsenic content of BRRI dhan36 at different levels of soil added arsenic. Four levels of As viz. 0, 2, 4 and 6 mg g^{-1} were added to soil collected from Sher-e-Bangla Agricultural University field. After two weeks of transplanting, two water management practices viz. saturated condition and unsaturated condition were imposed to the rice plants grown in pots which was continued till harvesting. There were 8 treatment combinations such as As_0W_1= As_0+ Unsaturated condition, As_1W_1= As_1+ Unsaturated condition, As_2W_1=As_2+

Unsaturated condition, As_3W_1=As_3+ Unsaturated condition, As_0W_2= As_0+ saturated condition, As_1W_2= As_1+ saturated condition, As_2W_2=As_2+ saturated condition, As_3W_2=As_3+ saturated condition. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

From the experiment we recorded,the highest rice plant (81.66 cm) was found in As_0W_2 treated pot and the lowest rice plant (51.00cm) was found in As_3W_2 treated pot. The highest effective tillers per plant (16.00) was found in As_0W_2 treated pot and the lowest effective tillers per plant (3.00) was found in As_3W_2 treated pot. The largest panicle length (24.66cm) was found in As_0W_2 treatment and the smallest panicle length (1.66cm) was found in As_3W_1 and As_3W_2 treatment. The highest filled grain per plant (616.33) was found in As_0W_1 treatment and the lowest filled grain per plant (154.00) was found in As_3W_1 treatment. The highest filled grain per panicle (47.33) was found in As_0W_1 treatment and lowest filled grain per panicle (28.00) was found in As_3W_2 treatment. The highest 1000-grain weight (22.10g) was found in As_0W_1 treatment and the lowest 1000-grain weight (19.27g) was found in As_3W_2 treatment. The highest straw yield (30.30g) was found in As_0W_1 treatment and the lowest straw yield (12.33g) was found in As_3W_2 treatment. The highest grain yield (29.5g) was found in As_0W_2 treated pot and the lowest grain yield (14.7g) was found in As_2W_1 treated pot.

The exposure of As in children are higher whose origin is in and around the rural areas of Bangladesh. The accumulation of heavy metals due to human activities usually affects the topsoil layer sand due to piece meal cultivation processes, it contaminates the surrounding water level which in turn are absorbed by the plant system leading to the venomous effect on our biodiversity on a larger scale.

CHAPTER VI

RECOMMENDATION

Our result indicates that in saturated conditions, arsenic uptake by BRRI dhan36 is more in saturated condition than in unsaturated condition so straw and grain yield is comparatively lower in saturated condition. For rice cultivation in arsenic affected area we can suggest to keep unsaturated condition for better production. However, further research on water management practices on rice cultivation in arsenic contaminated areas is needed for its validation.

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Appendix I. Characteristics of the soil of experimental field

Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100g soil)	0.10
Available S (ppm)	23
Arsenic (ppm)	4.8