# EFFECT OF ARSENIC, NITROGEN AND PHOSPHORUS ON GROWTH AND YIELD OF RICE

**A Thesis**

**By**


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# CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF ARSENIC, NITROGEN AND PHOSPHORUS ON GROWTH AND YIELD OF RICE"** 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**IFTE SAM BIN QUADER,**Registration. No. 11-04634, 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.

**Dated:**
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***Dedicated***
***To***
***My Beloved Parents***
***&***
***Siblings***

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*The Author*

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## ABSTRACT

A pot experiment was conducted at soil science farm ofSher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2016 to March 2017 to evaluate the effect of arsenic, nitrogen and phosphorus on the growth and yield of rice (BRRI Dhan36). The experiment comprised four arsenic doses 0, 2, 4, 6 ppm with the recommended doses and with 50% more than the recommended doses of nitrogen and phosphorus fertilizers. The treatment combinations were $As_1T_1$= $As_1$+N &P recommended dose, $As_2T_1$= $As_2$+N & P recommended dose, $As_3T_1$=$As_3$+ N & P recommended dose, $As_4T_1$=$As_4$+ N & P recommended dose, $As_1T_2$= $As_1$+50% more N & P than recommended dose, $As_2T_2$= $As_2$+50% more N & P than recommended dose, $As_3T_2$=$As_3$+ 50% more N &P than recommended dose, $As_4T_2$=$As_4$+50% more N & P than recommended dose. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In the experiment, increased As showed adverse effect on plant height, effective tillers per plant, non-effective tillers per plant, filled grains per plant, unfilled grains per plant, grains per panicle, 1000-grain weight, grain and straw yield of rice. During harvest, highest plant height (80.30 cm), highest tiller (20), longest panicle (24cm), highest straw yield (28.03 gm) and grain yield (30.13 gm) were recorded in controlled As level. On the contrary, lowest plant height (58.37 cm), lowest tiller (5), shortest panicle (15.33 cm), lowest straw yield (11.7 gm) and grain yield (14.2 gm) were recorded in highest As level (6 ppm). Increased doses of phosphorus and nitrogen fertilizers may have effect in higher allocation of As in plant parts which reduces the yield of rice with the increased level of As.

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# LIST OF ACRONYMS

| | | |
|---|---|---|
| AEZ | = | Agro-Ecological Zone |
| BARI | = | Bangladesh Agricultural Research Institute |
| BRRI | = | Bangladesh 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*) is by far the most important cereals grown in Bangladesh. Bangladesh occupies third position in rice area and fourth position in rice production among the rice growing countries. 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. Rice alone contributes 11% of GDP and accounts for 55% labor employment in its production, processing, and marketing. More than 94% of population derives 76% of its daily calories and 66% of its protein needs from rice. Thus, rice plays a vital role in the livelihood of the people of Bangladesh but the national average rice yield (2.34 t $ha^{-1}$) is very low compared to that of other rice growing countries. In such condition, increasing rice production can play a crucial function to feed the steadily growing people of this country. These high-yielding rice variety has resulted in an increase in rice production but environmental pollution like arsenic presence in soil in several concentration makes it difficult to giving high yield.

Arsenic is one of the heavy metals which poses toxic impact on human health and it is drawing serious attention due to its area coverage and the number of people affected directly or indirectly. Naturally occurring element arsenic, widely distributed in the earth's crust. The risk of health hazard arises when groundwater is contaminated with the arsenic. Arsenic contaminated water using as the irrigation source leads the uptake of arsenic into the plant and enters to the food chain, affecting food safety. Exposure of arsenic also can be done with the drinking of arsenic water and food prepared with contaminated water. Groundwater resources contaminated with arsenic is becoming a serious issue in parts of Asia including Bangladesh, West Bengal (India), China, Vietnam and Taiwan and also in United States, Australia, Chile, Mexico and Argentina. Natural geologic process and the anthropogenic sources such as industrial wastes, mining and agricultural wastes are mainly responsible for the release of arsenic as well as the arsenic contamination.

Arsenic in groundwater and its conveying into the environment appears to be a superior problems in Bangladesh. Bangladesh has the highest percentage of contaminated shallow tubewells (~20 percent) and an estimated 30 million people are dependent on those wells for domestic purposes. Beside domestic purposes, large quantities of water are being used for irrigating boro rice especially in the dry season. About 80% of accumulated groundwater spent is secondhand for irrigating crops especially boro rice. Irrigated water with high arsenic concentrations causes the accelerated arsenic concentration in soil and ultimately in rice grain and straw.

Inorganic arsenic are more likely to be stored on the paddy than other crops and acts as the largest food source. There are three reasons responsible for the susceptibility of rice to arsenic contamination. Firstly, rice requires high amount of irrigation water and the irrigation water contaminated with arsenic increases the chance of direct contamination. Secondly, arsenic with the uptake of excessive groundwater, accumulates in the above ground which is actually used for rice cultivation. Thirdly, arsenic absorption from soil and water is higher in rice than the other food crops.

In Bangladesh, arsenic concentrations in agricultural soils have been reported to be between 4.0 and 758.0 mg $kg^{-1}$ where the underground irrigation water does not contaminated with high level of arsenic. However, about 83 mg of As$kg^{-1}$ has been reported in agricultural soils of those areas, where the underground irrigation water is contaminated with very high level of arsenic (Ullah, 2009). Kabata-Pendias and Pendias (1992) recommended 20 mg of As $kg^{-1}$ soil as the safe level of arsenic in agricultural soil for crops.

Consequently, widespread use of arsenic contaminated groundwater for irrigation in rice field could elevate its concentrations in surface soil and eventually into rice plant and rice grain (Abedin et al., 2002). Arsenic uptake and accumulation in rice plant from irrigation water and contaminated soil might depend on cultivars (Xie and Huang, 1998; Meharg and Rahman, 2002). The availability of arsenic to the rice plant might also be subjected to the geographic location, soil properties, redox condition and cropping season (Meharg and Rahman, 2002).

Nitrogen is an integral component of many compounds and associated with photosynthetic activity. It is an essential component of amino acids and related proteins. Nitrogen is essential for carbohydrates uses within rice and stimulates root and development as well as the uptake of other nutrients. When too much nitrogen is applied, excess vegetative growth occurs, and the plant lodges with slightest wind. Crop maturity is delayed, and the rice are more susceptible to disease and insect pests. Deficiency of nitrogen results in low plant growth which reduces the grain yield, leaf area index, leaf area duration and rate of photosynthesis. It imparts dark green color to rice. The application of N fertilizer seems to have a positive effect on the As concentration in groundwater. N fertilizer was confirmed to play a positive role in promoting the release of As from peat sediments into water even some extent. The concentration of As is positively related to the ammonium-N concentration in groundwater and the %N in sediments. Chemical N fertilizer including the combination of the fertilizer and other sources to be a plausible source of N in peat sediments and groundwater. The As release from sediments was done with the mechanism of the “reduction of iron hydroxides and release of adsorbed As from the sediment” based on the negative relationship with the As concentration of groundwater in the area. The peat sediment, containing a high amount of As, was thought to contribute greatly to the amount of As released under the mechanism. The reducing condition of groundwater was thought to become stronger by the microbial activity, where the increased ammonium-N served as a nutrient for microorganisms.

Phosphorus has many essential functions in plant life; its role in energy storage and transfer is singly the most important. Large quantity of Phosphorus is found in seed and it is considered essential for seed formation. Phosphorus is essential for inflorescence, grain formation; ripening and reproductive parts of plant. It is needed for growth, nucleus formation, photosynthesis, utilization of sugar and starch, cell division and fat and albumen formation. Phosphorus is readily translocated within the rice and it moves from older tissues to younger tissues.

Phosphorus in adequate amount is necessary for earlier maturity, rapid growth and improves the quality of vegetative growth. Phosphorus alone or high quantity did not increase the yield of rice. However, the combined application of Phosphorus with nitrogen increased the yield significantly. Phosphorus fertilization increased total As uptake in rice plant, but the increase was restricted to the root. P supply may effect in higher As allocation to the plant parts, which has practical application in soil crop systems. These findings could have important implications for human health and agricultural systems, since it may reduce As contamination through the consumption of crops grown on contaminated soils. Rice is a widely grown staple cereal with promising attributes of the potential for accumulating toxic heavy metals and metalloids like As.

However, there are limited literatures available on arsenic contamination in different rice varieties. Detail information is needed to make rice cultivation sustainable in an arsenic containing soil with the knowledge how different doses of nitrogen and phosphorus can contribute to the improvement of rice growth. Recently, arsenic has become an important subject to analysis as its concentration is increasing in underground water. Considering the facts, the present study has been carried out with the following objective:

- To assess the effects of arsenic on the growth and yield of rice in combination with nitrogen and phosphorus.

# CHAPTER II

# REVIEW OF LITERATURE

Rice yield and yield contributing factors are dependent on manipulation of basic ingredient of agriculture and basic ingredients include variety, environment, hazards factors and agronomic practices. As is now one of the major problem for rice production and health hazard. In this chapter 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 soil

Arsenic is a naturally occurring terrestrial element and its main source is the parent materials from which the soil is derived (Yan-Chu, 1994). Coal combustion, copper, smelting, pesticide use, agricultural chemicals, agricultural burning, food additives, cotton desiccants, herbicide and arsenic chemical used for wood treatment are major anthropogenic sources of arsenic contamination in the environment (Bhattacharya et al., 1998: Grant and Dobbs, 1997).

Smith et al., (1998) stated that, as a result of both natural and anthropogenic activities arsenic enters the environment. Mineral breakdown and translocation of the products as well as accessions from dust storms, volcanic eruptions and forest fires is led by the natural process of pedogenesis. The origin and nature of the parent material are largely related to the concentrations of As released into the soil system by pedogenic processes.

## 2.2 Forms of arsenic

Many inorganic and organic compounds in soils are formed by arsenic (Vaughan, 1993). Inorganic compounds is mainly formed with either As(V) or As(III) (Masscheleyen et al., 1991). Depending on redox conditions the inorganic arsenic species are soluble in water and may change valency states (Marin et al., 1993a). As (V) will predominate under moderately oxidized conditions (>100 mV) and As (III) will predominate under moderately reducing conditions (Onken and Hossner, 1995, Onken and Hossner, 1996). Methyl arsenic acid, dimethyl arsenic acid, trimethylarscnic oxide and arsenobetaine are the organic arsenic compounds in soils (Takamatsu et al., 1982; Jen-How and Matzner, 2007). Inorganic arsenic and arseniteAs(lII) is more toxic than organic arsenic and arsenate As(V) respectively. Ground water of As affected districts of West Bengal having an approximate ratio of 1: 1 of arsenate and arsenite (Samanta et al., 1999). As extraction from two contaminated soils (soil 1 & 2) at different pH values with 0.3 M ammonium oxalate (pH 3), mili-Q water (pH 5.8), 0.3 M sodium carbonate (pH8.0) and 0.3 M sodium bicarbonate (pH 11.0) was done by Bissen and Frimmel (2000). In the found extracts arsenic was not organically bound and As(V) was the major components. The extractable arsenite concentrations were highest in the surface horizons of all soils but it may represent up to 36% of total extractable As. Litter fall from the trees also acts as the organic As species in forest soils. (Jen-How and Matzner, 2007).

## 2.3 Causes of arsenic contamination in Bangladesh

The source of arsenic contamination in groundwater of Bangladesh is geological which is agreed by all (BGS, 2000). There are two hypotheses about the arsenic releases into the groundwater:

**2.3.1 Pyrite oxidation:** During the last two decades, domestic uses and irrigation purposes increased the need of water significantly. Concomitant release of soluble arsenic into the groundwater due to heavy groundwater withdrawal from the underground aquifer makes aerated and so allows the oxidation of the pyrite ($FeS_2$) rich in arsenic (Das et al., 1995. 1996; Roy Chowdhury et al., 1998).

**2.3.2 Oxyhydroxide reduction:** Another group of scientists (Ahmed et al., 1998; Bhattacharya, 1998: Nickson et al., 2000) believe that by desorption from iron or manganese oxyhydroxide minerals present as a dispersed phase (e.g. as a coating) on the aquifer sediments under reducing conditions, arsenic is derived mainly. It is increasingly accepted that the second concept is most likely explanation of groundwater pollution with arsenic in Bangladesh and there is little or no sulphides in groundwater in Bangladesh (WHO. 1999; UNICEF. 2001).

## 2.4 Arsenic effects in crops

The number of factors affect the bioavailability, uptake and phytotoxicity of arsenic including the source and concentration of the element (NAS. 1977), arsenic chemical form (Marin et al., 1992: Carbonell-Barrachina et al., 1998a), soil properties such as clay content, pH and redox conditions (Johnson and Hiltbold, 1969: Marin et al., 1993a), plant species (Walsh and Keeney, 1975), other ions (Khattak et al., 1991), type and amount of organic matter present

(Mitchell and Barr. 1995) and physico-chemical factors involving the soil-root and root-shoot interfaces (Mitchell and Barr. 1995).

Using neutron activation analysis Martin et al., (2000) studied the distribution of arsenic in the stems of fruit trees grown in soils exposed to arsenical pesticides in Canada. The results showed that it is generally confined to heartwood near the pith and active xylem tissue in the most recent annual growth rings.

A pot experiment was conducted by Tlustos et al., (1998) with three soils (fluvisol, chernozem and alvisol) differing in physical and chemical properties and in the total As soil content and As was applied as an aqueous solution into 5 kg of soil which was mixed with N, P and K fertilizers. Sodium arsenate, sodium arsenite and dimethyl arsenic acid were applied at rates of 10 and 100 mg/As pot. Radishes cv. Duo was sown twice at each pot in two consecutive seasons. By extraction of 0.01 mol $CaCl_2$ solution per liter after each harvest, the amount of available soil As was determined. Significant yield reduction is found for the higher As rate in all treatments. After application of dimethylarsenic acid, the most toxic effect was found. In the first growing period plants died in fluvisols and chernozems but in the second period plants died only in fluvisols. It was found that growing plants at the lower As rate accumulated more As in leaves than in roots. Probably due to protection of the assimilatory organs arsenic accumulation differed in plants treated with the higher rate of As. As contents found higher in roots than in leaves.

The effects caused by arsenite on the processes of uptake and accumulation of Ca, K, Mg, N and P in tomato plants (*Lycopersicumesculentum* cv. *Marmende*) was showed by Carbonell-Barrachina et al., (1998b). A nutrient solution (hydroponically) containing As (as sodium arsenite $NaAsO_2$ at 2, 5 or 10 mg/As/litre) were used to grow tomato plants. As concentration in the nutrient solution made an impact upon the vegetative growth and fruit yield. Plant growth was also significantly reduced by As. Fresh fruit production reduced to 60.7%, 47.3% and 23.3% at 2,5 and 10 mg/As/liter, respectively, compared to the control. Klose and Braun (1997) studied about the soil arsenic content and crops uptake of As by fodder plants, spring barley, potatoes, maize, winter rape, pasture brasses and clover. All the tested soil content over 50 mg As/kg. Arsenic content ranged from 0.04 to 1.31 mg As/kg into the dry matter in maize, rape, barley and potatoes, when grown on soil containing 60-362 mg As/kg soil. Soil As content ranged from 90 to 1050 mg As/kg and plant As content ranged from 0.18 to 6.7 mg As/kg dry matter in pasture grasses showed up by the experiments.

Arsenic concentration effects on the tomato cv. Marmande and bean (*Phaseolus vulgaris*) cv. BuenosAires grown in crushed volcanic rock stated Carbonell-Barrachina et al., (1997b). Nutrient solution containing 0, 2, 5 or 10 mg/L As was used for growing tomato and bean plants. Phytotoxicity for arsenite was found in both plant species: however, bean plants are more prone to damage than tomato plants. Bean plants showed symptoms of arsenic toxicity and the plants which were treated with the treatment of l0 mg As/L found dead after 36+ days of treatment. Tomato root tissue makes arsenic compartmentalized effectively which makes its impact minimal on plant growth and metabolism. However, As was readily transported to shoots and accumulated to high concentrations in leaf tissue in case of bean plants. The differences found on the experiment in absorption and translocation of arsenite or its metabolized species by tomato and bean plants were probably responsible for the difference in plant tolerance of As pollution.

A pot experiment was conducted by Yu GuoYing et al., (1995) to study the combined impact of Cd, Pb, Cu, Zn and As pollution on soybean cv. Liaofeng 241 growth. In response of combined pollution, the accumulation of heavy metals in soybean roots was in the order of As>Pb> Cu Cd>Zn and that in stem and leaf was in the order of Cd> Cu>Zn>As>Pb. Nutrients concentrations and relative proportions is responsible for the interactions between nutrients. For soybean growth, As and Cu were the main toxic elements. For indicating and controlling the integrated impact of combined pollution, the relative ionic intensity was an effective index.

Wetland plants accumulates arsenic in the rhizosphere which leads to precipitation of iron oxyhydraltes stated Otte et al., (1995). Arsenic and Zinc shows a high binding affinity for iron oxyhydroxides and accrue in iron plaque around the roots of *Aster tripolium*. Fe, Zn and As per unit volume in soil is higher under *Halimioneportulacoides* than under *Spartinaanglica*. Higher concentration of Zn and As found in the rhizosphere as expected. It is suggested that differences on the concentration of Fe, Zn and As happened due to the differences in redox characteristics. Enrichment of arsenic found in the iron plaque of *Spartinaanglica* but not in *Halimioneportulacoides*.

Two greenhouse experiments was conducted to investigate the effects of different sources of arsenic application on the yield of ryegrass (*Loliumperenne*) and barley (*Hordeumvulgare*) and the arsenic concentration in crop tissue grown in a sand and loam soil by Jiang and Singh (1994). In the first experiment (3yr), As application was done either as sodium arsenite or as disodium hydrogen arsenate at the rate of 0, 2, 10, 50 and 250 mg As/kg soil in year 1. The residual effect of 1$^{st}$ year's arsenic application was investigated in the 2$^{nd}$ and 3$^{rd}$ year. In the second experiment (5yr), a NPK (l6-7-12) fertilizer containing 10, 100 and 3000 mg As/ Kg as sodium arsenite was applied at rates of 750 and 600 mg/kg to ryegrass and barley, respectively with lime and without lime. Arsenite shows higher inhibiting effect on crop yield than arsenate. The residual effect of arsenic was dependent on As application rate, soil type and crop species and in this case it resisted up to 3 years. As application rates had a direct impact on the yield reduction and the increase of As concentration in crops. Significant yield reduction and marked increase of As concentration was found at 50 and 250 mg As/kg in both crops. These rates considered as the critical range for both crops. In both experiments, the yield reduction and the increase in As concentration in crop tissue were higher in the sand soil than in the loam and barley straw accumulates greater amount of As than barley grain, indicating that greater proportion of the As taken up by this crop was retained in the vegetative organs.

Kiss et al., (1992) conducted a pot experiment using sandy chernozem soil and As treatment was done through irrigation water as well as in soil on spring barley cv Spartan. He observed that due to the presence of As, plant growth was reduced and the leaves showed red or yellow discoloration. Plant As content increased more with the As treated irrigation water than the As treated soil. Similar trial with onions cvMakoi, also showed that uptake of As was greater in leaves than in roots and bulbs.

## 2.5Toxic effect of arsenic in rice

Milami et al., (1988) conducted a field experiment with rice cv. Mercury (susceptible to disorder) at Winnsboro, Louisiana in 1988. Permanently flooded or flooded plots were used to grow rice and the plots were drained during midseason. Applied arsenic rate was 0, 2, 4, or 6 lb/acre and Zn rate was 0 orl.5 lb/acre. Average grain yield with continuous flooding was 2641 lb/acre and midseason drainage was 3562 lb/acre. The higher number of panicles and greater dry weight were observed with midseason draining. Under continuous flooding, average grain yields were 3524 lb and 1571 lb/acre with the application of 0 and 6 lbAs/acre, respectively. With the application of 0 and 1.5 lb Zn/acre application the grain yields were 3729 and 3551 lb/acre, respectively under the midseason drainage.

To investigate the effect of pH in the movement of arsenic (As) in the plant-soil system pot and field experiments was conducted by Chen et al., (1995). Higher soil pH reduced As adsorption and thereby increased the As concentration in the soil solution. Therefore, increasing soil pH had risen an increased chance of As availability in rice and creates a serious problem of As toxicity.

Kang et al., (1996) conducted a pot experiment with rice in loamy soils having available arsenic contents of 1.3, 6.0 or 10.3 mg/kg and total arsenic of 13.3, 27.7 and 56.0 mg/kg, respectively. Decreased plant height, number of effective tillers, dry weight and 100- grain weight was observed due to the increasing As levels.

Yields reduced from 48.7 g/pot with the lowest arsenic rate to 17.9 g with the highest rate of arsenic.

Kang-Lijuan et al., (1996) observed that the growth of rice affected by arsenic and found that increasing level of arsenic application decreased plant height, effective tillers, dry weight of aboveground parts and 1000-grain weight.

Slancheva et al., (1999) conducted a pot experiment that rice (Oryza sativa) cv. Krasnodarski 424 grown on alluvial soil which were treated with 25, 50 or 100 mg As/kg soil (as $Na_3AsO_4$) with or without seed inoculation with *Azospirillumbrasilense*. As concentrations more than 50 mg/kg were toxic to the plants. Chlorophyll a and b, carotenoid concentrations in chloroplasts, panicle number, filled grains and grain yield reduced by As.

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

Montenegro and Mejia (2001) conducted field and greenhouse experiments in rice to investigate the effect of irrigation water containing Cd and As on soils and on the physiological parameters of rice growth, the amount of As accrued in different parts of rice plants, and the yield and other aspects of rice crop. The results showed that when none of the element was present in the irrigation waters rice reached its maximum height. Increasing As content of irrigation waters reduced 10% of grains per panicle. Significant yield reduction was found when irrigation waters contained the highest concentration of Cd and As. Accumulation of Cd and As was increased in rice plants with the increase of both elements in the irrigation waters and the presence of Cd and As in irrigation waters had no effect on the milling quality of rice.

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

## 2.6 Uptake and accumulation of arsenic in rice

Arsenic concentration in soil or nutrient media are mainly responsible for arsenic uptake and accumulation. This uptake and accumulation increased greatly with increasing levels of As (Marin et al., 1992, 1993b; Xie and Huang, 1998). In rice plant parts arsenic concentration generally follow the pattern: root>straw>husk>whole grain>husked rice (Xie and Huang, 1998). Odanaka et al., 1987 and Marin et al., (1992) also reported higher accumulation of arsenic occurs in roots than any other plant parts. Chemical form of arsenic (species) was found to be more important than arsenic concentration in growing media in determining the phytotoxic effect of arsenic on rice (Marin et al., 1992). Arsenite and MMAA were phytotoxic to rice among the four arsenicals. Accumulation of arsenite, arsenate (Odanaka et al., 1987; Marin et al., 1992) and MMAA (Marin et al., 1992) was found in the root while DMAA was readily mobilized to the shoot (Odanaka et al., 1987; Marin et al., 1992). Marin et al., (1993b) also observed easy and quick translocation of DMAA was done when rice plants were grown in DMAA solution at 0-1.6 mg As/L resulting in higher concentrations of arsenic in rice shoots than that of roots. Root arsenic concentration was 10.5 mg/kg with the treatment of 0.05 mg As/L treatment and increased up to 212.7 mg/kg with the 0.8 mg As/L treatment (Marin et al., 1992).

Tsutsumi (1980) observed that elevated arsenic concentration was found in rice straw (up to 149 mg As/kg dry weight) when soil amended with sodium arsenate at different levels (0-312.5 mg As $kg^{-1}$) used for rice cultivation. Lower concentration of arsenic generally found on rice grain (Schoof et al., 1999; Heitkemper et al., 2001) and the concentration did not exhibit the maximum permissible limit of 1 mg As/kg. However, Xie and Huang (1998) observed that some cultivars which were grown in contaminated fields, they exceed the maximum permissible limit (1 mg As/kg) of arsenic concentration in rice grain (husked rice). Reports on transformation of arsenic species in the rice plants is limited although there are reports of transformation of arsenic species in the plant system (Benson et al., 1981; Nissen and Benson, 1982). By chemical speciation study Odanaka et al., (1987) showed that very little transformation of arsenic species occurred in rice shoot and root. However, recent studies (Schoof et al., 1999; Heitkemper et al., 2001) on rice grain speciation shows that considerable proportion of organic arsenic species may be found in the rice grain. However, source of grain and methods of extraction are responsible for variation of the proportion of organic species (DMAA and MMAA) in rice grain. From market basket survey Schoof et al., (1999) found 56% of organic species in rice grain. But in another study, organic species (DMAA and MMAA) measured by the same group (Schoof et al., 1998) was 19%. Uptake, accumulation and phytotoxicity may also vary depending on the cultivars used. Xie and Huang (1998) observed that uptake and accumulation of arsenic in different plant parts significantly differs among the rice cultivars.

## 2.7 Influence of phosphorus on arsenic availability

Fertilizer application had a strong influence on plants arsenic uptake. Phosphorus fertilizer (e.g. TSP) is especially important among the fertilizers. The raw materials of TSP i.e. rock phosphate may contain arsenic and further the element may release arsenic from soil solid into the soil solution.

Koseki (1988) experimented on the suppression of arsenic injury of rice plants by the application of higher phosphate concentration in culture solution. Solution culture with 5, 20 or 60 ppm $P_20_5$ and 0.5, 1.0 or 2.5 ppm As (III) or 2.5, 5.0 or 10.0 ppm As (V) were used for growing rice. While increasing As rates increased the As concentration in root, stem, leaf and grain, especially as As (V) and As concentration decreased with increasing phosphorus rate. Significant arsenic × phosphorus interactions were found in the experiment.

Marin et al., (1993b) stated that induced dimethylarsenic acid concentration in solution increased As uptake and concentration in shoot and root. DMMA was readily translocated to the shoot after uptake by plants. Net photosynthesis and photosynthetic capacity were significantly decreased at the higher rates of DMMA application in response to tissue As concentration. Higher rates (0.8 and 1.6mg As/L sodium salt of dimethyarsenic acid) of DMMA also showed the significant reduction of leaf area and dry matter production. Lower rate (0.2%mg As/L) of DMMA application had no significant effect on reduction in photosynthesis or growth. At the levels used, DMMA application did not show any effect on nutritional disorders through affecting changes in mineral contents of P, K. Ca, Mg, Mn, Fe, Cu, Zn, Mo and Na in roots and shoots.

Melamedet at., (1995) conducted an experiment on the effect of adsorbed phosphate on transport of arsenic in an oxisol. They observed that ground water contamination can be increased by the mobility of toxic trace elements in soils which was led by competitive oxyanion adsorption. Laboratory soil columns constructed from an aggregated oxisol was used to investigate the competitive nature of sorbed phosphate on arsenic mobility. Treatment of increased amounts of phosphate greatly increased the mobility of arsenic.

Onken and Hossner (1995) found that the As content of rice plants was best correlated to the mean soil solution arsenic concentration in a clay and to the mean soil solution arsenic concentration in a silt loam soil. In both soils, plant P concentration was significantly correlated to the amount of As added to the soil rather thanany soil solution As concentration. The rate of As uptake by plants increased with the increased rate of plant growth. Plants grown in As treated soil showed higher rates of As uptake for similar rates of growth when compared with plants in untreated soils. Growth per unit of As uptake was lower for plants in As treated soil than plants in untreated soils.

Heeraman et al., (2001) conducted an experiment on the interactions of lime, N, P, and organic matter additions with respect to plant growth and As and Hg uptake. Strong relationship between As plant uptake, root length density and solution As was found. Soluble As showed positive correlation with P and inverse relationship with oxalate extractable Fe.

Abedin et al., (2002) conducted a greenhouse experiment where irrigation water with arsenate contaminated water containing arsenite, arsenate, dimethylarsinic acid, and monomethylarsinic acid used for growing rice (*Oryza sativa*). The short-term uptake kinetics for these four As species were observed in 7 day old excised rice roots. High affinity uptake (0-0.0532mM) for arsenite and arsenate with eight rice varieties, for two growing seasons, Boro rice (dry season) and T. Aman rice (wet season), showed that uptake of both arsenite and arsenate by aman varieties was more than that of boro varieties. The level of Arsenite and arsenate uptake was approximately active and the rate of uptake was same. Higher substrate concentration (low affinity uptake system) showed greater uptake of arsenite than arsenate. Arsenite and arsenate were taken up by different uptake systems and competed with phosphate uptake Presence of phosphate strongly suppressed arsenate uptake in the system, while arsenite transport was not affected by phosphate. Uptake of monomethylarsenic acid was occurred at a very slow rate, and limited uptake of dimethylarsinic acid by plants. Thus, the above literature gives a clear indication about the toxic effect of arsenic on rice and many other crops, and this toxicity is markedly increased in presence of high P.

# 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.

### 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 (Edris*et al.*, 1979). 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. $As_1$:Control (No arsenic)

ii. $As_2$: 2 ppm As

iii. $As_3$: 4 ppm As

iv. $As_4$: 6 ppm As

**Factor B:** Nitrogen and phosphorus levels(2 levels)

i. $T_1$: Recommended dose of N & P

ii. $T_2$: 50% more than recommended dose of N & P

As such there were 8 treatments combinations viz. $As_1T_1$, $As_2T_1$, $As_3T_1$, $As_4T_1$, $As_1T_2$, $As_2T_2$, $As_3T_2$, $As_4T_2$.

### 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 treatments combinations in each of 3 replications. The 8 treatment combinations of the experiment were assigned at random in 8 pots of each replication.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| As1T1 | As1T2 | As2T1 | As2T2 | As3T1 | As3T2 | As4T1 | As4T2 |
| As1T2 | As2T1 | As2T2 | As3T1 | As3T2 | As4T1 | As4T2 | As1T1 |
| As2T1 | As2T2 | As3T1 | As3T2 | As4T1 | As4T2 | As1T1 | As1T2 |

**Fig: Layout of experiment field**

$As_1T_1$= $As_1$+N&P recommended dose, $As_2T_1$= $As_2$+N& P recommended dose, $As_3T_1$=$As_3$+ N & P recommended dose, $As_4T_1$=$As_4$+ N & P recommended dose, $As_1T_2$= $As_1$+50% more N & P than recommended dose, $As_2T_2$= $As_2$+50% more N & P than recommended dose, $As_3T_2$=$As_3$+50% more N & P than recommended dose, $As_4T_2$=$As_4$+50% more N & P than recommended dose.

## 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 K, S, Zn and B in the form ofMOP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of MOP, gypsum, zinc sulphate and borax were applied during the final preparation of pot land. Different concentration of As and different doses of nitrogen and phosphorus fertilizers 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 | Doses(kg/ha) | Application(%) | | |
|---|---|---|---|---|
| | | Basal | 1st installment | 2nd installment |
| 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), nitrogen and phosphorous fertilizers. The results presented in tables and figures are discussed systematically under the following heads:

## 4.1 Effect of arsenic, nitrogen and phosphorous fertilizers on yield and yield contributing characters of rice plant

### 4.1.1 Plant height at harvest

The effects of arsenic (As), nitrogen and phosphorous fertilizers made a significant affect in plant height of BRRI dhan36. A significant ($p<0.05$) variation in plant height was observed in respect of different arsenic levels, nitrogen and phosphorous fertilizers (Table 1). The highest plant height (80.3**)** was found in $As_1T_1$ treated pot and lowest plant height (58.36**)** was found in $As_4T_2$ treated pot (Table 1). Due to increase in arsenic concentration in soil, plant height might be reduced.In the experiment, highest plant height was found when nitrogen and phosphorus fertilizers were in recommended doses with controlled arsenic level and lowest plant height was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers. It was reported by Abedin et al., (2002a) that As affect the root development and reduced the plant height of rice. Similar findings was also reported by some other researchers 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). Biswas et al., (2009), Abedin et al., (2002) and Azad et al., (2009) also agreed with these result by their previous research. In linear relationship, significant and negative correlation were observed in rice plant height ($R^2$= 0.298) (Fig. 1). And, also, in linear relationship, plant height were found statistically significant ($p<0.05$) and negatively correlated with straw yield ($R^2$= 0.018) in BRRI dhan36 (Fig. 9).

**Table 1. Effect of arsenic, nitrogen and phosphorus on the different growth parameters of rice**

| **Treatments** | **Plant height (cm)** | **Effective tiller plant$^{-1}$** | **Non-effective tiller plant$^{-1}$** | **Panicle length** |
|---|---|---|---|---|
| $As_1T_1$ | 80.30 a | 16.67 b | 5.67 a | 24.00 a |
| $As_2T_1$ | 70.13 c | 12.00 c | 3.67 b | 21.00 bc |
| $As_3T_1$ | 68.80 cd | 8.33 de | 2.67 bcd | 19.33 c |
| $As_4T_1$ | 62.13 de | 6.33 ef | 1.67 d | 16.00 d |
| $As_1T_2$ | 79.53 ab | 20.00 a | 6.00 a | 23.00 ab |
| $As_2T_2$ | 72.67 bc | 11.00 cd | 3.00 bc | 21.33 bc |
| $As_3T_2$ | 68.77 cd | 11.00 cd | 2.33 cd | 19.00 c |
| $As_4T_2$ | 58.37 e | 5.00 f | 1.67 d | 15.33 d |
| **$LSD_{(0.05)}$** | **6.911** | **3.048** | **1.114** | **2.487** |
| **CV(%)** | **5.63** | **15.42** | **19.09** | **7.15** |

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

($As_1T_1$= $As_1$+N& P recommended dose, $As_2T_1$= $As_2$+N& P recommended dose, $As_3T_1$=$As_3$+ N & P recommended dose, $As_4T_1$=$As_4$+ N & P recommended dose, $As_1T_2$= $As_1$+50% more N & P than recommended dose, $As_2T_2$= $As_2$+50% more N & P than recommended dose, $As_3T_2$=$As_3$+50% more N & P than recommended dose, $As_4T_2$=$As_4$+50% more N & P than recommended dose)

### 4.1.2 Effective tillers plant$^{-1}$

Arsenic concentration in soilshowed remarkable effect on the number of effective tillers per plants in rice variety BRRI dhan36. The number of effective tillers of rice plant decreased significantly ($p<0.05$) with increasing soil As concentration observed during study. Effective tillers plant$^{-1}$ was affected markedly due to the effects of different arsenic (As) levels in BRRI dhan36 (Table 1). The highest effective tillers per plant (20.00) was found in $As_1T_2$ treated pot and lowest effective tillers per plant (5.00) was found in $As_4T_2$ treated pot (Table 1). In the experiment, maximum effective tiller per plant was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and minimum effective per plant was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers. 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, reported by Islam and Jahiruddin (2010). In linear relationship, the effective tillers per plant of rice variety BRRI dhan36 were observed negatively and strongly correlated ($R^2= 0.257$) (Fig. 2).

### 4.1.3 Non-effective tillers plant$^{-1}$

The number of non-effective tillers plant$^{-1}$ in response different doses of arsenic (As), nitrogen and phosphorous were found statistically significant ($p<0.05$) variation in rice variety of BRRI dhan36. In respect of different arsenic levels and nitrogen, a significant ($p<0.05$) variation in non-effective tillers per plant was observed in table 1. The highest number of non-effective tillers per plant (6.00) were found in $As_1T_2$ treated pot and lowest number of non-effective tillers per plant (1.67) of rice was found in As4T1 and $As_4T_2$ treated pot (Table 1).In the experiment, maximum non-effective tiller per plant was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and minimumnon-effective tiller per plant was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers. Result is in agreement with research of 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; these together contributed reduced grain yield. Tillers number of rice plant was reduced significantly with increase of arsenic concentration in irrigation water up to 8 $mgL^{-1}$ also observed by Abedin et al., (2002). In linear relationship, the non-effective tillers per plant of rice variety BRRI dhan36 were observed negatively and strongly correlated ($R^2$=0 .185) (Fig. 3).

**4.1.4 Panicle length (cm)**

InBRRI dhan36, Panicle length were decreased significantly with increasing soil As levels in soils. Panicle length of rice plant was affected markedly due to the effects of arsenic (As), nitrogen and phosphorous fertilizers applications in BRRI dhan36 (Table 1). A significant ($p<0.05$) variation in panicle length was observed in respect of different arsenic levels, nitrogen and phosphorous fertilizer. In BRRI dhan36, each successive levels of soil arsenic concentration significantly decreased the panicle length of BRRI dhan36. The largest panicle length

(24.00cm) was found in $As_1T_1$ treatment and smallest panicle length (15.33cm) was found in $As_4T_2$ treatment (Table 1). It was reported by Vromman et al.,( 2013) that arsenic application in rice soils 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. The panicles number of rice plant were not affected at low doses of As in soil but significantly affected the panicles number at higher doses reported by (Azad et al., 2009). A positive and strong correlation of panicle length was found ($R^2$= 0.120) (Fig. 4)

**Table 2. Effect of arsenic, nitrogen and phosphoruson the different growth parameters of rice**

| Treatments | Filled grain plant$^{-1}$ | Unfilled grain plant$^{-1}$ | Filled grain panicle$^{-1}$ | Unfilled grain panicle$^{-1}$ |
|---|---|---|---|---|
| $As_1T_1$ | 700.33 a | 213.33 e | 47.66 a | 38.00 a |
| $As_2T_1$ | 628.33 a | 244.00 cd | 39.66 b | 36.67 a |
| $As_3T_1$ | 495.33 b | 267.67 bc | 34.00 c | 27.33 bc |
| $As_4T_1$ | 329.33 c | 306.67 a | 30.00 cd | 21.67 d |
| $As_1T_2$ | 683.67 a | 221.00 de | 49.33 a | 41.00 a |
| $As_2T_2$ | 628.00 a | 257.67 bc | 40.33 b | 40.33 a |
| $As_3T_2$ | 500.33 b | 282.67 ab | 32.33 c | 30.67 b |
| $As_4T_2$ | 362.67 c | 309.00 a | 25.00 d | 24.67 cd |
| **LSD$_{(0.05)}$** | **92.288** | **30.350** | **5.518** | **5.531** |
| **CV(%)** | **9.74** | **6.60** | **8.45** | **8.82** |

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

($As_1T_1$= $As_1$+N& P recommended dose, $As_2T_1$= $As_2$+N& P recommended dose, $As_3T_1$=$As_3$+ N & P recommended dose, $As_4T_1$=$As_4$+ N & P recommended dose, $As_1T_2$= $As_1$+50% more N & P than recommended dose, $As_2T_2$= $As_2$+50% more N & P than recommended dose, $As_3T_2$=$As_3$+50% more N & P than recommended dose, $As_4T_2$=$As_4$+50% more N & P than recommended dose)

### 4.1.5 Filled grain plant$^{-1}$

The number of filled grain per plant of rice plant was significantly reduced with increasing of soil As concentration. Filled grain per plant was affected markedly due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36. In respect of different arsenic levels, nitrogen and phosphorous fertilizers, a significant ($p<0.05$) variation in filled grain per plant was observed (Table 2). The highest filled grain per plant (700.33) was found in $As_1T_1$ treatment and lowest filled grain per plant (329.33) was found $As_4T_1$ treatment (Table 2).In the experiment, highest filled grain per plant was found when nitrogen and phosphorus fertilizers were in recommended doses with controlled arsenic level and lowest filled grain per plant was found in the highest arsenic level (6 ppm) with recommended doses of nitrogen and phosphorus fertilizers. This result is similar to the research of Hussain et al., (2005), Islam and Jahiruddin (2010). Strong and negative correlation were observed in filled grain per plant ($R^2$= 0.097).

### 4.1.6 Un-filled grain plant$^{-1}$

Increasing soil As concentration not only decrease the filled grain per plant but also increase the unfilled grain per plant of rice plant. Un-filled grain per plant was affected due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36 (Table 2). In respect of different arsenic levels, nitrogen and phosphorous fertilizer, a non-significant ($p<0.05$) in un-filled grain per plant was observed. The highest un-filled grain per plant (309.00) was found in $As_4T_2$ treated pot and lowest un-filled grain per plant (213.33) was found in $As_1T_1$ treated pot (Table 2). In the experiment, lowest un-filled grain per plant was found when nitrogen and phosphorus fertilizers were in recommended doses with controlled arsenic level and highest un-filled grain per plant was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers. In linear relationship, the un-filled grain per plant of rice variety BRRI dhan36 were observed negatively and strongly correlated ($R^2$= 0.327) (Fig. 6)

**4.1.7 Filled grain panicle$^{-1}$**

The number of filled grain per panicle of rice plant was reduced significantly with increasing of soil As concentration. Due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36, filled grain per panicle was affected markedly. A significant ($p<0.05$) variation in filled grain per panicle was observed in respect of different arsenic levels (Table 2). The highest filled grain per panicle (49.33) was found in $As_1T_2$ treatment and lowest filled grain per panicle (25.00) was found in $As_4T_2$ treatment (Table 2).In the experiment, highest filled grain per panicle was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and lowest filled grain per panicle was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers. This result is similar to the findings of Hussain et al., (2005), Islam and Jahiruddin (2010).

### 4.1.8 Un-filled grain panicle$^{-1}$

Increasing soil As concentration not only decrease the filled grain per panicle but also decrease the unfilled grain per panicle of rice plant. Un-filled grain per panicle was affected due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36 (Table 2). In respect of different arsenic levels, nitrogen and phosphorous fertilizer, a non-significant ($p<0.05$) in un-filled grain per plant was observed. The highest un-filled grain per panicle (41.00) was found in $As_1T_2$ treated pot and lowest un-filled grain per panicle (21.67) was found in $As_4T_1$ treated pot (Table 2).In the experiment highest un-filled grain per panicle was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and lowest un-filled grain per panicle was found in the highest arsenic level (6 ppm) with recommended doses of nitrogen and phosphorus fertilizers.

**Table 3. Effect of arsenic, nitrogen and phosphorus on the different growth parameters of rice**

| **Treatments** | **1000 Grain weight(g)** | **Grain yield(g)** | **Straw yield(g)** |
|---|---|---|---|
| $As_1T_1$ | 25.46 | 28.70 a | 27.76 a |
| $As_2T_1$ | 23.60 | 22.90 b | 23.63 b |
| $As_3T_1$ | 22.76 | 20.53 b | 18.80 c |
| $As_4T_1$ | 21.96 | 14.20 c | 11.73 d |
| $As_1T_2$ | 26.36 | 30.13 a | 28.03 a |
| $As_2T_2$ | 23.26 | 27.93 a | 22.93 b |
| $As_3T_2$ | 22.00 | 22.86 b | 16.83 c |
| $As_4T_2$ | 20.73 | 14.73 c | 11.70 d |
| **$LSD_{(0.05)}$** | **NS** | **4.110** | **2.955** |
| **CV(%)** | **3.87** | **10.32** | **8.36** |

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

($As_1T_1$= $As_1$+N&P recommended dose, $As_2T_1$= $As_2$+N& P recommended dose, $As_3T_1$=$As_3$+ N & P recommended dose, $As_4T_1$=$As_4$+ N & P recommended dose, $As_1T_2$= $As_1$+50% more N & P than recommended dose, $As_2T_2$= $As_2$+50% more N & P than recommended dose, $As_3T_2$=$As_3$+50% more N & P than recommended dose, $As_4T_2$=$As_4$+50% more N & P than recommended dose)

**4.1.9 1000 grain weight**

In As contaminated soils, increasing soil As concentration affected the 1000 grain weight of rice. Due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36, 1000-grain weight was affected markedly (Table 3). In respect of different arsenic levels, nitrogen and phosphorous fertilizer, a non-significant ($p<0.05$) variation in 1000-grain weight was observed because the grain weight is a stable characters of cereal crops. The highest 1000-grain weight (26.36g) was found in $As_1T_2$ treatment and lowest 1000-grain weight (20.73g) was found in $As_4T_2$ treatment (Table 3).In the experiment, highest 1000-grain weight was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and lowest 1000-grain weight was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers. This result is similar to the findings of Abedin (2002) that presence arsenic at a higher concentration in irrigation water significantly reduced the 1000 grain weight of rice plant.

**4.1.10 Straw yield**

The straw yield of rice was decreased with increasing soil As concentration in soils. Due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36, straw yield was affected markedly (Table 3). In respect of different arsenic levels, nitrogen and phosphorous fertilize, a non-significant ($p<0.05$) variation in straw weight was observed. The straw yield of rice plant was found reduced drastically in soil arsenic treatments. The highest straw yield (28.03g) was found in $As_1T_2$ treatment and lowest straw yield (11.70g) was found in $As_4T_2$ treatment (Table 3).In the experiment, highest straw yield was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and lowest straw yield was found in the highest arsenic level (6 ppm) with 50% more than recommended doses of nitrogen and phosphorus fertilizers.Recently reported by Hossain et al., (2005) and Kang et al., (1996) 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) that that soil arsenic concentration on irrigated rice-based cropping system may cause heavy depletion of straw yield of rice. The straw yield were also found negatively correlated significantly with effective tillers ($R^2$= 0.185) (Fig. 7).

**4.1.11 Grain yield**

InBRRI dhan36, Grain yield were decreased significantly with increasing soil As levels in soil. Due to the effects of arsenic (As), nitrogen and phosphorous fertilizer in BRRI dhan36, grain yield was affected markedly (Table 3). In respect of different arsenic levels, nitrogen and phosphorous fertilizer, a non-significant ($p<0.05$) variation in grain yield was observed. The highest grain yield (30.13g) was found in $As_1T_2$ treated pot and lowest grain yield (14.20) was found in $As_4T_1$ treated pot (Table 3). In the experiment, highest grain yield was found when nitrogen and phosphorus fertilizers were in 50% more than recommended doses with controlled arsenic level and lowest grain yield was found in the highest arsenic level (6 ppm) with recommended doses of nitrogen and phosphorus fertilizers.This result is similar to the result of Jahiruddin et al., (2004) stated that the highest grain yield reduction was observed with the maximum dose of irrigation arsenic treatment. These results are in good agreement with the findings of due to arsenic toxicity in rice plant, grain yield reduction was reported by Hossain et al. (2005); and Kang et al. (1996). Some other publisher also published same result such as, Panaullah et al., (2009); Carbonell-Barrachina et al., (1997); Abedin and Meharg (2002); and Tsutsumi (1980). It was stated by Abedin et al., (2002) that increasing the concentration in irrigation water significantly decreased plant height, grain yield, the number of filled grains, grain weight, and root biomass, while the arsenic concentrations in root, straw, and rice husk increased significantly. In linear relationship, the grain yield of BRRI dhan36 was observed negatively correlated ($R^2$= 0.018) (Fig. 8).

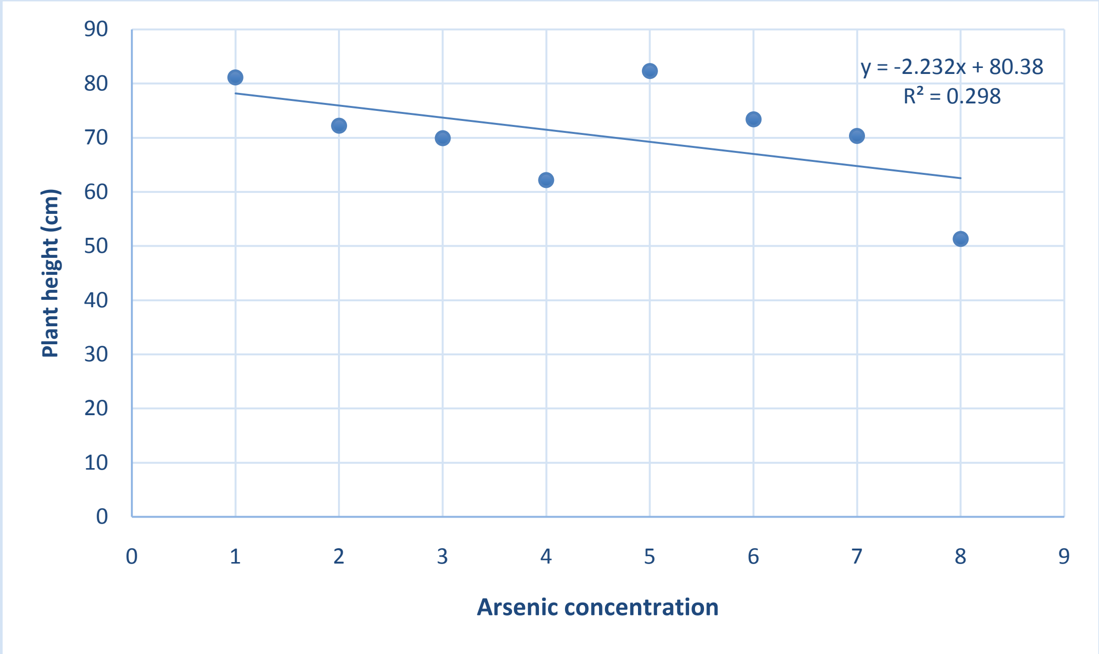


**Fig. 1 Linear relationship of plant height in response of arsenic, nitrogen & phosphorus fertilizers**

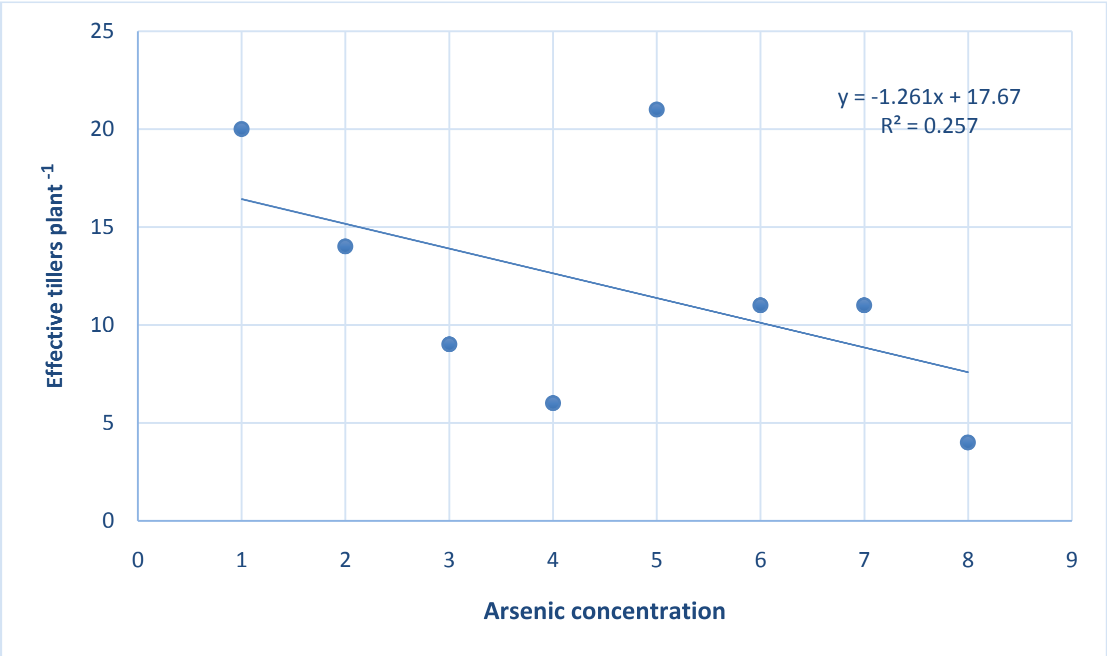


**Fig. 2 Linear relationship of effective tillers plant$^{-1}$ in response of arsenic, nitrogen & phosphorus fertilizers**

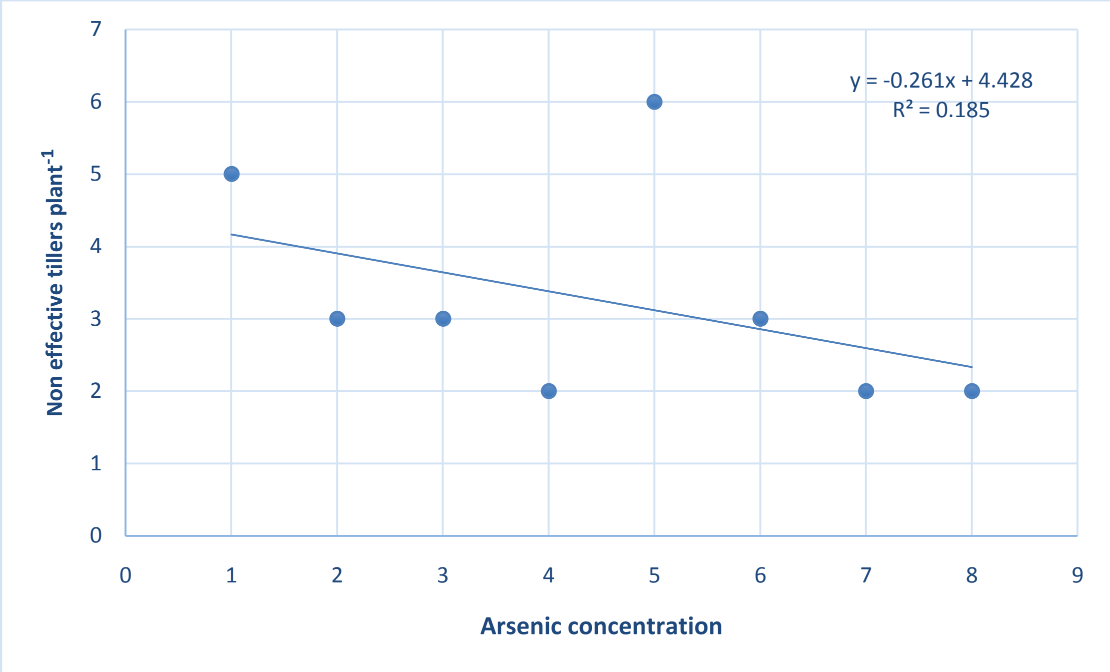


**Fig. 3 Linear relationship of non-effective tillers plant$^{-1}$ in response of arsenic, nitrogen & phosphorus fertilizers**

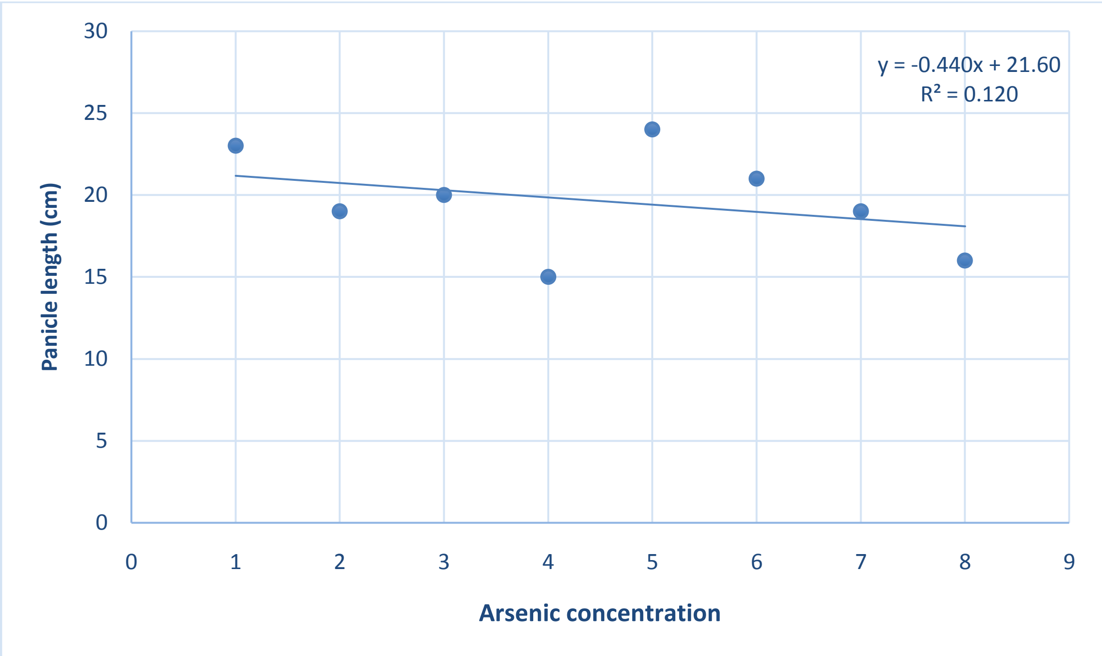


**Fig. 4 Linear relationship of panicle length in response of arsenic, nitrogen & phosphorus fertilizers**

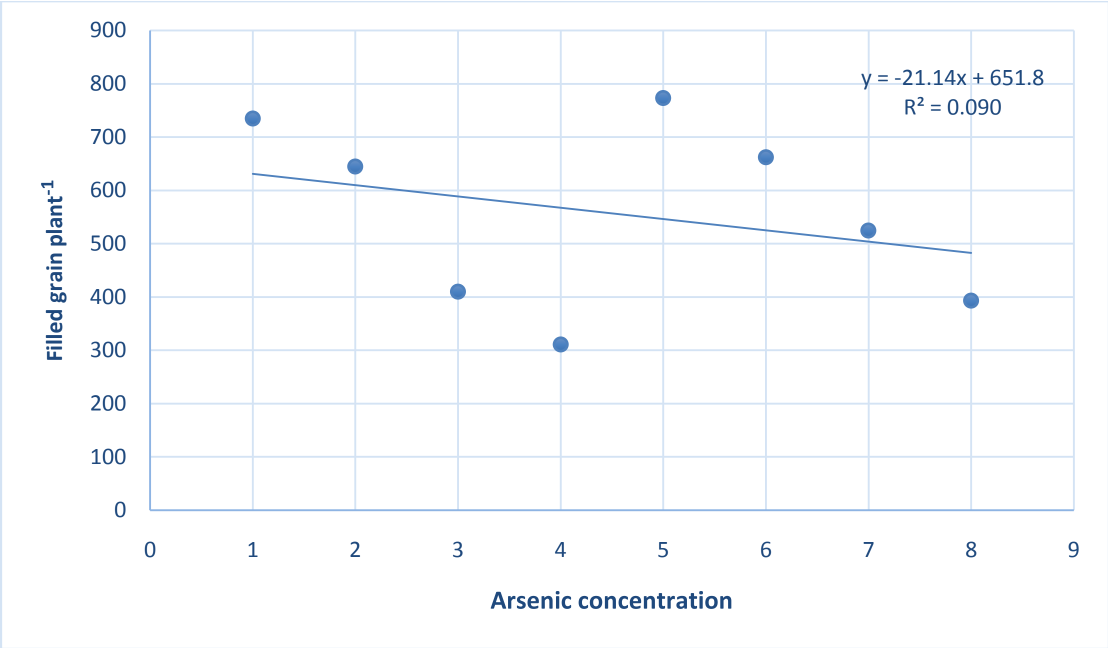


**Fig. 5 Linear relationship of filled grain plant$^{-1}$ in response of arsenic, nitrogen & phosphorus fertilizers**

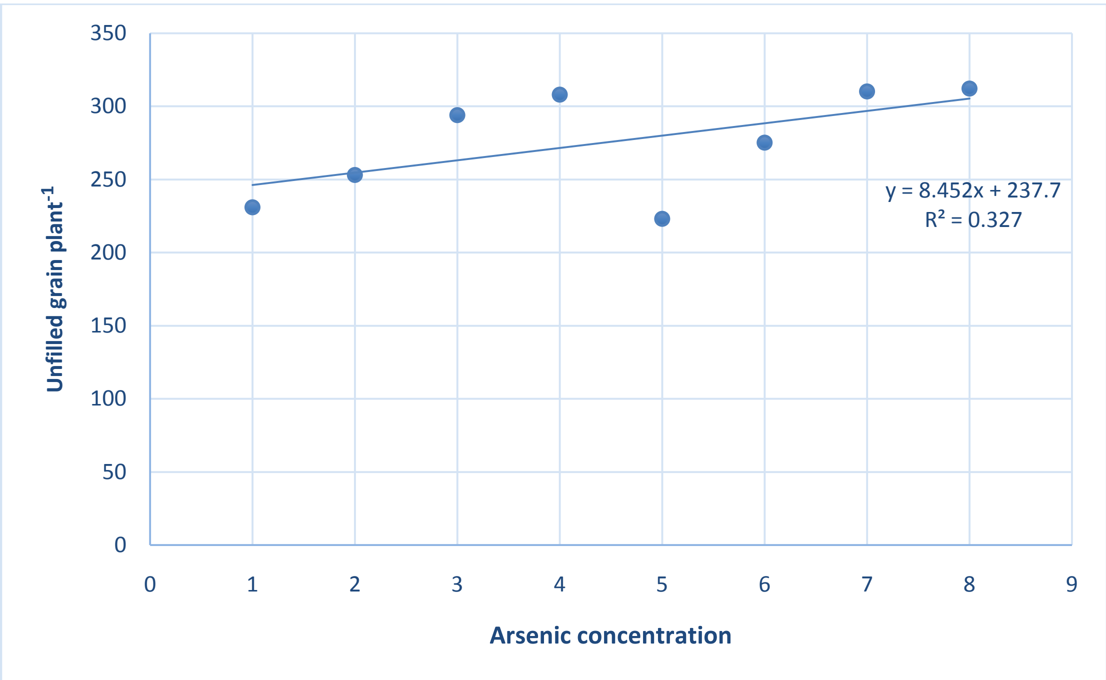


**Fig. 6 Linear relationship of un-filled grain plant$^{-1}$ in response of arsenic, nitrogen & phosphorus fertilizers**

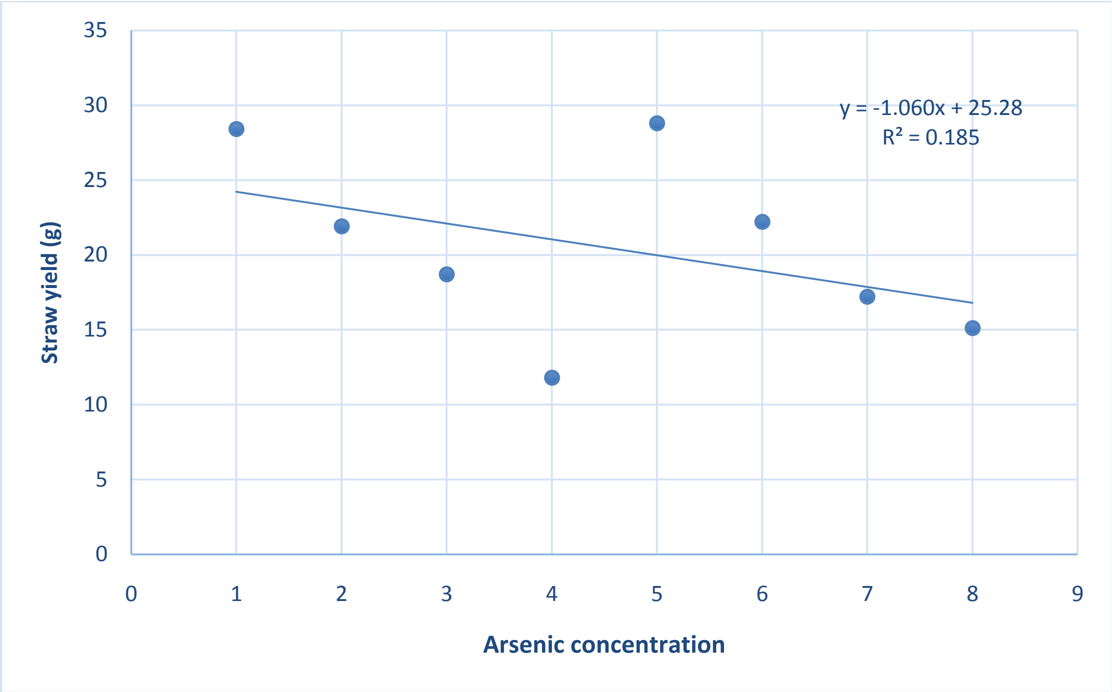


**Fig. 7 Linear relationship of straw yield in response of arsenic, nitrogen & phosphorus fertilizers**

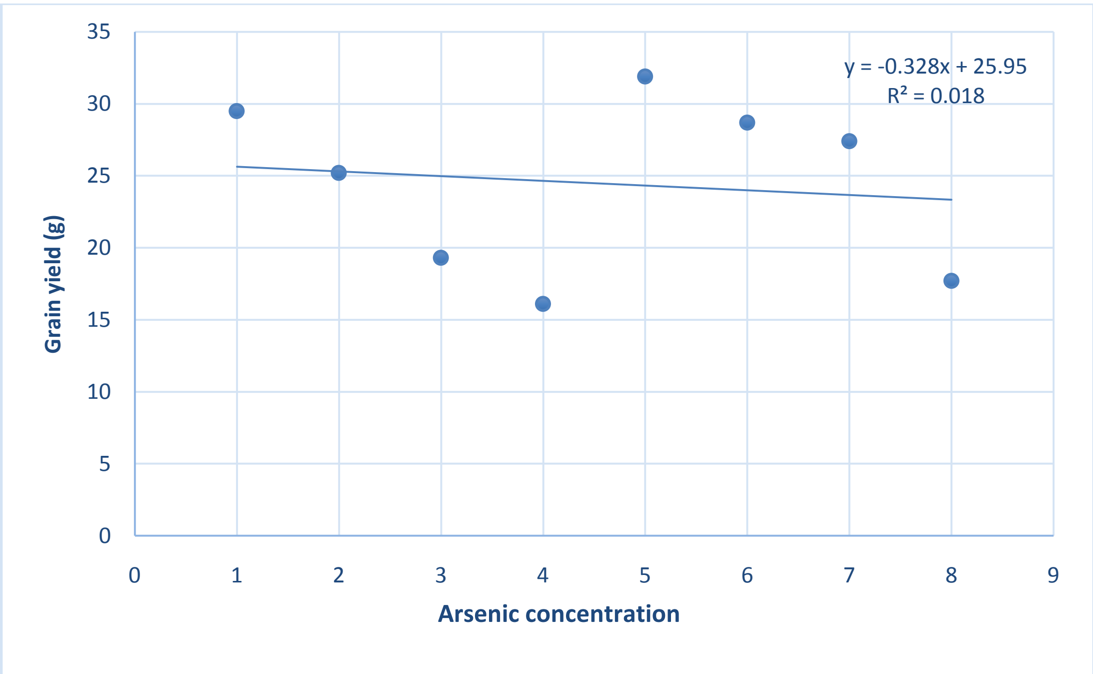


**Fig. 8 Linear relationship of grain yield in response of arsenic, nitrogen & phosphorus fertilizers**

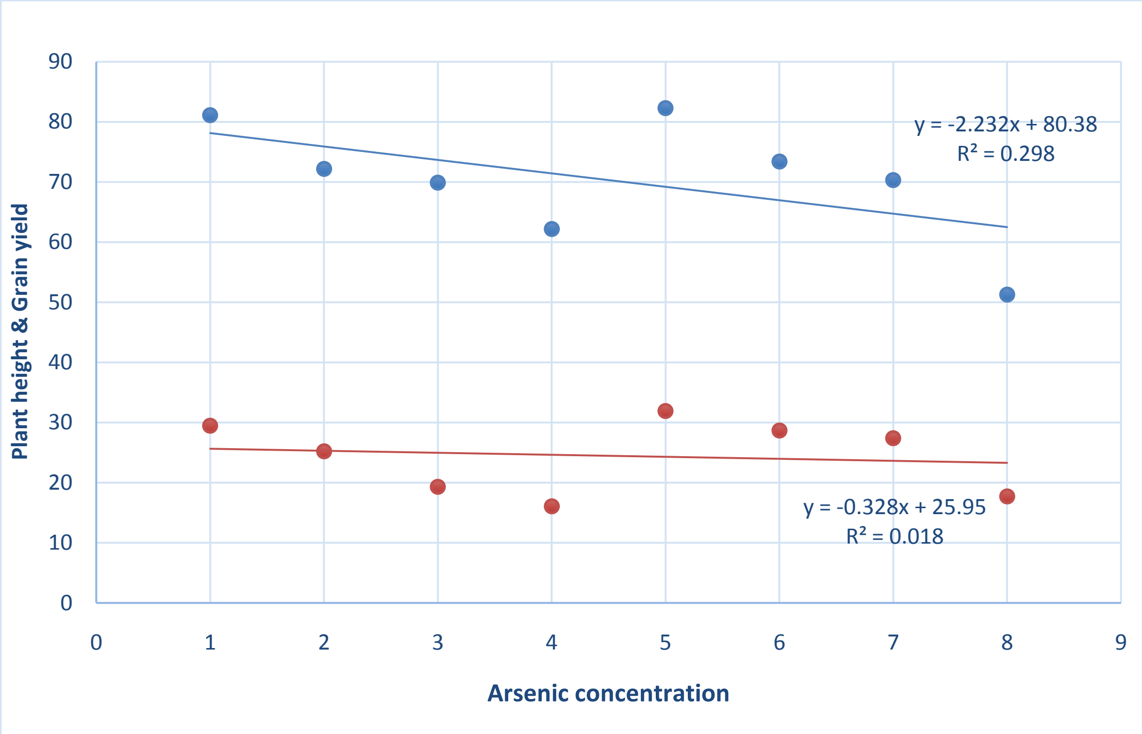


**Fig. 9 Linear relationship of plant height and grain yield in response of arsenic, nitrogen & phosphorus fertilizers**

# CHAPTER V

# SUMMARY AND CONCLUSIONS

Arsenic concentration increasing in the groundwater of Bangladesh soil is an alarming issue for the farmers as well as the consumers. Rice is the main crop of Bangladesh which is more susceptible to uptake arsenic from the groundwater which leads to the entrance of this toxic element to the food chain. So the experiment was conducted to demonstrate the effect of different doses of nitrogen and phosphorus fertilizers on the arsenic uptake by BRRI dhan36.

A pot experiment was conducted atSher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2016 to March 2017 to evaluate the effect of arsenic, nitrogen and phosphorus on the growth and yield of rice. The experiment comprised four arsenic doses 0, 2, 4, 6 ppm with the recommended dose of fertilizers and with 50% more than the recommended doses of nitrogen and phosphorus fertilizers. The treatment combinations were $As_1T_1$= $As_1$+N &P recommended dose, $As_2T_1$= $As_2$+N & P recommended dose, $As_3T_1$=$As_3$+ N & P recommended dose, $As_4T_1$=$As_4$+ N & P recommended dose, $As_1T_2$= $As_1$+50% more N & P than recommended dose, $As_2T_2$= $As_2$+50% more N & P than recommended dose, $As_3T_2$=$As_3$+50% more N & P than recommended dose, $As_4T_2$=$As_4$+50% more N & P than recommended dose. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The highest rice plant height (80.3**)** was found in $As_1T_1$ treated pot and lowest rice plant height (58.36**)** was found in $As_4T_2$ treated pot. Due to increase in arsenic concentration in soil, plant height might be reduced. The highest effective tillers per plant (20.00) was found in $As_1T_2$ treated pot and lowest effective tillers per plant (5.00) was found in $As_4T_2$ treated pot. The largest panicle length (24.00cm) was found in $As_1T_1$ treatment and smallest panicle length (15.33cm) was found in $As_4T_2$ treatment. The highest filled grain per plant (700.33) was found in $As_1T_1$ treatment and lowest filled grain per plant (329.33) was found $As_4T_1$ treatment. The highest filled grain per panicle (49.33) was found in $As_1T_2$ treatment and lowest filled grain per panicle (25.00) was found in $As_4T_2$ treatment. The highest 1000-grain weight (26.36g) was found in $As_1T_2$ treatment and lowest 1000-grain weight (20.73g) was found in $As_4T_2$ treatment. The straw yield of rice plant was found reduced drastically in soil arsenic treatments. The highest straw yield (28.03g) was found in $As_1T_2$ treatment and lowest straw yield (11.70g) was found in $As_4T_2$ treatment. The highest grain yield (30.13g) was found in $As_1T_2$ treated pot and lowest grain yield (14.20) was found in $As_4T_1$ treated pot.

Addition of nitrogen and phosphorus did not influence significantly the plant height, non-effective tillers per pot, panicle length, filled grains per panicle, un-filled grains per panicle, 1000-grain weight and straw yield.

The experiment showed that the addition of As to soil significantly and adversely affected the plant height, total tillers per pot, effective tillers per pot, non-effective tillers per pot, panicle length, filled grains per panicle, unfilled grains per panicle, 1000-grain weight, and grain and straw yield. Generally, the values for most of the parameters drastically decreased as the doses of As increased. The grain and straw yields were markedly affected by As addition to soil.

# CHAPTER VI

# RECOMMENDATION

The experiment showed that nitrogen and phosphorus fertilizers increase arsenic uptake and thus markedly reduced straw and grain yield of rice. So, the practice of using recommended dose of nitrogen and phosphorus fertilizer can be suggested in the arsenic affected area for rice cultivation. However, further research on different dose of fertilizer practices on rice 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 |