# INFLUENCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON MITIGATION OF ARSENIC STRESS IN BRRI dhan47

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**INFLUENCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON MITIGATION OF ARSENIC STRESS IN BRRI dhan47**

**A Thesis**
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# CERTIFICATE

This is to certify that the thesis entitled "**INFLUENCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON MITIGATION OF ARSENIC STRESS IN BRRI dhan47''**submitted to the department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRICULTURAL CHEMISTRY**, embodies the results of a piece of *bona fide* research work carried out by **MOHAMMAD ASHIK ELAHI SHOHEL**, Registration No. **11-04560**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

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**INFLUENCE OF VERMICOMPOST AND INORGANIC FERTILIZERS ON MITIGATION OF ARSENIC STRESS IN BRRI dhan47**

## ABSTRACT

An experiment was conducted in the net house and the agro-environmental chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 during the Boro season of the year 2016-17 to evaluate the influence of vermicompost and inorganic fertilizers on the mitigation of arsenic stress in BRRI dhan47. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: different doses of arsenic on soil weight basis [$As_0$=No arsenic applied, $As_1$= 10 ppm arsenic, $As_2$= 20 ppm arsenic, $As_3$= 30 ppm arsenic] and Factor B: different doses of vermicompost and inorganic fertilizers [$T_o$= Recommended doses of vermicompost + inorganic fertilizers, $T_1$= Recommended doses of inorganic fertilizers without vermicompost, $T_2$= Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$= Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers]. Arsenic was added from Sodium Arsenate ($Na_2HAsO_4.7H_2O$). In case of fertilizers, $T_2$ gave higher results in most growth, yield and yield contributing parameters (height, tiller number, effective tiller, filled grain, 1000 grain weight, grain and straw yield) and $T_1$ gave lower results; whereas for arsenic, maximum results were recorded from $As_0$ and minimum from $As_3$. In interaction, $As_0T_2$ produced higher results and $As_3T_1$ produced lower results in most cases. The treatment $T_2$ gave higher N, P and K content in grain, straw and root whereas, $T_1$ gave lower content; highest As content by $T_1$ and lowest by $T_2$. In case of arsenic content in grain, shoot and root, maximum results were recorded from $As_3$ and minimum from $As_0$. In interaction, the maximum N, P and K content in grain, straw and root were found in $As_0T_2$ and the minimum were observed from $As_3T_1$ treatment; whereas, highest As by $As_3T_1$ and lowest by $As_0T_0$. Therefore, the treatment $T_2$ showed lower arsenic in grain, shoot and root and $T_1$ showed the highest content.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| % | Percent |
| @ | At the rate of |
| $^0C$ | Degree Celsius |
| AEZ | Agro-Ecological Zone |
| As | Arsenic |
| BRRI | Bangladesh Rice Research Institute |
| cm | Centimeter |
| CRD | Completely Randomized Design |
| CV% | Percentage of Coefficient of Variance |
| DAT | Days After Transplanting |
| e.g. | As for example |
| *et al.* | and others |
| g | Gram |
| ha | Hectare |
| i.e. | that is |
| K | Potassium |
| kg | Kilogram |
| kg $ha^{-1}$ | kg per hectare |
| LSD | Least Significant Difference |
| L | Liter |
| m | Meter |
| ml/L | Milliliter per Liter |
| mg/L | Milligram per Liter |
| MoP | Muriate of Potash |
| N | Nitrogen |
| nm | Nano Meter |
| ng | Nano Gram |

## LIST OF ABBREVIATIONS (Cont'd)

| | |
|---|---|
| P | Phosphorus |
| pH | Hydrogen ion concentration |
| ppm | Parts Per Million |
| S | Sulphur |
| SAU | Sher-e-Bangla Agricultural University |
| t $ha^{-1}$ | Ton per hectare |
| TSP | Triple Super Phosphate |
| µg/kg | Microgram per kg |
| Zn | Zinc |

# CHAPTER I

# INTRODUCTION

Rice (*Oryza sativa* L.) is the principle cereal staple food under the family Poaceae for 160 million people of Bangladesh. Rice sector contributes to 70% of the agricultural GDP and one-sixth of the national income of Bangladesh. Rice covers about 81% of the total cropped area and provides nearly 48% of rural development (BBS, 2012). It is the main source of food for more than 60% of the world's population and the second most important crop in the world after wheat, more than 90% of which is produced in Asia. In Bangladesh, over 80% of the irrigated area and about 75% of the total cropped area is planted to rice (BRKB, 2017).

The total rice production in our country is about 34.00 million tons to feed her 149.69 million people (Mandal and Choudhury, 2014). The increase in rice production becomes possible largely due to adoption of rice modern rice varieties on around 66% of the rice land which contributes to about 73% of the country's total rice production (BRKB, 2017). BBS (2010) reported that the population will have possibly increased to 230 million by the year 2030 which need more cereal crops for meet their demand. The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. Horizontal expansion of rice area, rice yield unit$^{-1}$ area should be increased to meet this ever-increasing demand of food in the country. Management practices also can help for horizontal expansion of rice area and yield unit$^{-1}$ area.

Bangladesh is one of the major rice growing countries. Rice plays a vital role in the livelihood of the people of Bangladesh. But cultivation is always vulnerable to unfavorable weather events and abiotic stresses. Growth and development of the crops including rice depend on environmental factors such as atmosphere, temperature, light, humidity, nutrients etc. Many abiotic factors such as heat, cold, drought, salinity and heavy metal contamination reduce the growth and development of the crops. Arsenic (As) stress is one kind of heavy metal stress with generally alters the morpho-physiology, yield contributing characters and yield of agricultural crops. It inhibits the growth with fresh and dry biomass accumulation (Stoeva and Bineva, 2003) and causes physiological disorders (Wells and Gillmor, 1997) as well as reduction of the crop productivity (Stepanok, 1998).

Long-term exposure to inorganic arsenic, mainly through drinking of contaminated water, eating of food prepared with this water and eating food irrigated with arsenic rich water can lead to chronic arsenic poisoning. Rai *et al*. (2015) reported that accumulation of arsenic (As) in grain is a serious concern worldwide which affects nutritional status in rice grain and is associated with higher rates of skin, bladder, lung cancer and heart disease.

Singh *et al*. (2006) stated that arsenic reduces the rate of photosynthesis by damage mechanism of different cell organelles such as plasma membrane, chloroplast which causing electrolyte leakage and an increase in malondialdehyde ($C_3H_4O_2$), a product of lipid per-oxidation, pointing to the role of oxidative stress in arsenic toxicity. Flora (1999) stated that the exposure of plants to inorganic arsenic does result in the generation of reactive oxygen species (ROS), which is linked with arsenic valence change, a process that readily, occur in plants. ROS has the capacity to directly damage proteins, amino acids and nucleic acids and also cause per-oxidation of membrane lipids. To combat these effects, enzymatic and non enzymatic antioxidants are mobilized to quench ROS. Enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT), glutathione-S-transferase (GST) etc. and non enzymatic antioxidants include glutathione and ascorbate (Dat *et al*., 2000).

Arsenic in Bangladesh has attracted much attention since its recognition in the 1990s of its wide occurrence in well-water in the country. The people in Bangladesh are suffering due to the arsenic contamination. At present 80 million people in 59 out of 64 districts across the country are exposed to arsenic poisoning and 10000 people have already shown the symptoms of arsenicosis (Chowdhury, 2001).

Now-a-days, twenty countries including Bangladesh have been suffering from groundwater contamination by arsenic, which is the most severe problem occurring in Asia (Biswas *et al.*, 1998). According to WHO recommendation the permissible limit of arsenic in rice is 1mg/kg. The As contaminated areas in Bangladesh have shown as more than 20 mg As/kg soil. People are exposed to elevated level of arsenic through contaminated drinking water. Using contaminated water in food preparations, irrigation, and industrial processes and eating contaminated food (Ali *et al*., 2003). A significant loss of crop production due to high concentration (20 ppm) arsenic in plant body was recorded by a number of researchers (Davis and De Wiest, 1998).

Duxbury *et al*. (2013) mentioned the presence of arsenic in food chain. Arsenic (As), a naturally occurring metalloid, is very mobile in the environment. It enters into farming systems through a variety of means which include natural geochemical processes (Smedley and Kinniburgh, 2002), use of arsenic-based pesticides, mining operations, irrigation with arsenic contaminated groundwater, and also fertilization with municipal solid wastes (Mehrag and Rahman, 2002). For Bangladesh perspective, groundwater contamination of arsenic is a pressing issue for various districts. Up to various levels, most of the districts of Bangladesh have arsenic contaminated groundwater and 17 of them have exceeded the safety level of WHO recommendation for safety including Chandpur, Comilla, Noakhali, Feni, Munshiganj, Brahmanbaria, Faridpur, Madaripur, Laxmipur, Gopalganj, Shariatpur, Narayanganj, Narail, Satkhira and Chapainawabganj (Haque *et al.*, 2007).

A number of mitigation approaches have been tried to control arsenic accumulation in plants like chemical precipitation, ion-exchange, reverse osmosis, solvent extraction, and bioremediation by microbes which include the removal of heavy metals by microorganisms (bacteria, fungi, yeast and algae) as absorbents. Phyto-remediation that the removal of contaminants with the help of green plants and organic soil amendments such as cow dung, vermicompost etc. also includes the mitigation of arsenic accumulation in plants which is eco-friendly and available to farmers. Incorporation of organic manures significantly reduced the arsenic uptake by different plant parts of rice is more pronounced and consistent with FYM and vermicompost (Sinha and Bhattacharyya, 2011).

During last decade, arsenic pollution has been considered an important environmental issue in many countries worldwide. However, the environment route of exposure causing arsenic contamination in the general population has not been fully determined. Recently, the most significant concern related to human health risks from arsenic toxicity is thought to be transported through drinking water, worldwide food distribution, smoking, and global cosmetics.

Considering the above facts, the present study was under taken with the following objectives:

- To assess the effects of arsenic stress on the growth and yield of BRRI dhan47.
- To analyze the role of vermicompost and inorganic fertilizers on mitigation of arsenic stress in BRRI dhan47 with reference to growth, yield and nutrient content of rice.
- To find out the suitable combination of vermicompost and inorganic fertilizers to mitigate the detrimental effects of arsenic stress for rice production in Bangladesh.

# CHAPTER II

# REVIEW OF LITERATURE

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

## 2.1 Sources of arsenic in the environment

Arsenic, a metalloid and naturally occurring element, is one of the most abundant elements in the earth's crust and is found throughout our environment. Arsenic can attach to very small particles in the air, stay in the air for many days, and travel long distances. Arsenic is primarily used as an insecticide and herbicide or preservatives for wood due to its germicidal power and resistance to rotting and decay respectively. Arsenic is also pISSN 1975-8375 eISSN 2233-4521 used in medicine, electronics, and industrial manufacturing (Nriagu and Azcue, 1990).

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

Ferguson (1990) reported that in the environment, arsenic and its compounds are mobile and cannot be destroyed. However, interaction with oxygen or other molecules present in air, water, or soil, as well as with bacteria that live in soil or sediment can cause arsenic to change form, attach to different particles, or separate from these particles. Elevated concentrations of arsenic have primarily resulted from natural sources, such as erosion and leaching from geological formations or anthropogenic sources. In addition, arsenic use for industrial purposes, mining activities, metal processing, and pesticides and fertilizers are other major sources of contamination.

Gibb *et al*. (2011) and Argos *et al*. (2010) stated that many common arsenic compounds can dissolve in water, thus arsenic can contaminate lakes, rivers, or underground water by dissolving in rain, snow, or through discarded industrial wastes. Therefore, arsenic contamination in groundwater is a serious public health threat worldwide. In addition, the effect of chronic arsenic exposure from ingested arsenic-contaminated food and water or inhaled contaminated air has been investigated in various countries and found to be associated with detrimental health effects such as hyperpigmentation, keratosis, various types of cancer and vascular diseases.

Arsenic is a crystal-shaped metalloid element which is brittle in nature and grayish white in color. It is a naturally occurring poisonous chemical compounds and widely distributed in the soil profile as component of minerals and found in nominal amounts in all organisms. Arsenic can be found as a compound of oxygen, chlorine, sulfur, carbon, hydrogen, lead, mercury, gold and iron. There are as many as 150 species of arsenic-bearing minerals that exist on the earth. However, only few of them are considered as arsenic ore, because the amount of arsenic is higher in these compounds and also they are more available. These compounds are realgar or arsenic disulphide (AsS), orpiment or arsenic trisulphide ($As_2S_3$) and arsenopyrite or ferrous arsenic sulphide (FeAsS) (Nordstrom, 2002).

Hughes (2002) stated that arsenic is found in natural and anthropogenic sources. It occurs naturally in rocks and soil, water, air, plants and animals. Volcanic activity, erosion of rocks and minerals, and forest fires are natural sources. Arsenic occurs naturally in soil, water, air, plants and animals. There are two forms of arsenic: organic and inorganic. Both are easily absorbed, but the inorganic form is more harmful. It accumulates in body organ, is classified as a carcinogen and may affect different chemical and metabolic processes in the body.

Mandal and Suzuki (2002) reported that the terrestrial abundance of arsenic is around 1.5-3.0 mg/kg. Colbourn *et al*. (1975) stated that the quantity of arsenic in soil varies considerably from country to country from 0.1 to 50 mg/kg with an average concentration of about 5-6 mg/kg. Arsenic may originate in soils from parent material (Tanaka, 1988), but in soils it present in higher concentrations than those in rocks (Peterson *et al*., 1981). Mandal and Suzuki (2002) stated that uncontaminated soils usually contain 1.0-40.0 mg/kg of arsenic with the lowest concentrations in sandy soils and those derived from granites, whereas larger concentrations are found in alluvial and organic soils. In soils, the concentrations of arsenic are mostly present in sulphide ores of metals including sodium, copper, lead, silver and gold (BGS, 1999).

Lu (1990) stated that arsenic used in industrial processes is used to produce antifungal wood preservatives lead to soil contamination. Incineration of preserved wood products, pressure treated with chromate copper arsenate was found to be a source of environmental arsenic contamination. Arsenic used in sheep dips, glass industries, pharmaceuticals, antifouling paints, leather preservatives, poison baits and arsenic-containing pigments, and are also employed in optical industries and microelectronics.

USDA (1970) reported that arsenic compounds are used in insecticides and pesticides due to its germicidal power. The inorganic arsenic compounds, primarily, sodium arsenite, have been widely used as a weed killer, and non-selective soil sterilant.

EPA (1983) reported that methylated arsenic is a minor component in the air of suburban, urban and industrial areas, and that the major inorganic portion of air is composed of the trivalent and pentavalent compounds.

Arsenic occurs mainly as inorganic species, but it also can bind to organic material in soils (BGS, 1999; Mandal and Suzuki, 2002). Arsenic may accumulate in soils through the use of arsenical pesticides, herbicide, fertilizer etc. Inorganic arsenic may be converted to arsenic compounds by soil microorganisms (Wei *et al.*, 1991). The total amount of arsenic in soils and its chemical forms has an important influence on plant, animal and human health (Nriagu and Lin, 1994). Accumulation of arsenic can cause toxic effects to plants and enter the human food chain.

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

### 2.2 Pathways of arsenic exposure in humans

Bhattacharya *et al*. (2002) stated that groundwater is a major source of drinking water, and elevated concentration of arsenic in groundwater has been associated with various negative health effects in humans. Arsenic in drinking water is one of the most significant environmental causes of cancer. In 1963, WHO has recommended limits to the maximum concentrations of arsenic in drinking water and their recommendation was of 50 µg/L, but after new evidence relating low arsenic concentrations with cancer risk, WHO further reduced their recommendation to 10 µg/L in 1992 (WHO, 2001).

Akter *et al*. (2005) reported that once arsenic compounds are absorbed, they are generally processed via the liver's metabolic pathway, and then converted into many different types of inorganic and organic species including arsenite ($As^{3+}$), arsenate ($As^{5+}$), dimethylarsinate (DMA), and monomethylarsonate (MMA). Inorganic arsenic and organic arsenic are absorbed quickly into the blood and circulated to the human gastrointestinal tract. Organic arsenic species are generally considered innocuous since they are poorly absorbed into cells. In contrast, inorganic arsenic species are highly reactive and affect a series of intercellular reactions (Drobna *et al*., 2010).

Groundwater contamination is one of the major pathways of human exposure to inorganic arsenic and the risk of arsenic contamination is generally much higher in groundwater than that in surface water (Argos *et al*., 2012). Chowdhury *et al*. (2000) reported the elevated concentrations of arsenic in groundwater of Bangladesh, Vietnam (Berg *et al*., 2001), China (Lianfang and Jianzhong, 1994), Taiwan (Chen *et al.*, 1994), Argentina (Smedley *et al.*, 2005), and Canada (Grantham and Jones, 1977).

Chakraborti *et al*. (2001) reported that contaminated used to cultivate rice and vegetables for human consumption is an important pathway of arsenic ingestion. Le *et al*. (1994) stated that some crustaceans contain arsenobetaine and some seaweed contains arsenosugar, but seafood usually contains organic arsenic compounds that are less toxic than inorganic counterparts are.

Cigarette smokers have a significantly higher total urinary arsenic concentration than non-smokers do because some chemicals in cigarettes compete for different enzymes or co-factors involved in the arsenic methylation process (Tseng, 2005). Ferreccio *et al*. (2000) found that cigarette smoking and ingesting arsenic in drinking water had a synergistic effect. Cigarette smokers exposed to high concentrations of arsenic in drinking water (200 µg/L) had a higher risk of bladder cancer than smokers exposed to low concentrations of arsenic did (Morales *et al*., 2000 and Steinmaus *et al*., 2003).

Cosmetics are also considered an unlikely source of arsenic exposure and as a simple impurity, but are a leading cause of direct exposure among a many individuals. Assessing the amount of dermal absorption from a single component in a cosmetic product is complex and depends on many factors such as the concentration of arsenic in the product, the amount of product applied, the length of time left on the skin and the presence of emollients and penetration enhancers in the cosmetic products (Hostynek, 2014).

EPA (2004) reported that human exposure to arsenic through the air generally occurs at very low concentrations ranging from 0.4 to 30 $ng/m^3$. They also estimated that approximately 40 to 90 ng of arsenic per day are typically inhaled by humans. In unpolluted areas, approximately 50 ng or less arsenic is inhaled per day.

Duxbury and Panaullah (2007) reported that the most severe effects have been found in Bengal Delta region in Bangladesh and West Bengal, India where the groundwater has been widely developed to supply drinking and irrigation water. An estimated 30 million people drink water from arsenic contaminated Shallow Tube Wells (STWs) and approximately 900000 STWs are used in irrigating 2.4 million out of 4 million ha under irrigation in Bangladesh, mainly paddy fields. Also, about 95% of the groundwater extracted is used for irrigation.

FAO (2007) reported that the problem originated from the arsenic-rich bedrock of the Brahmaputra river basin that filters drinking water pumped to the surface through millions of tube wells. High concentrations of arsenic enter the food chain via absorption by crops from roots to straw and grain contaminated from irrigated water.

It was also estimated that water pumping from shallow aquifers for irrigation adds one million kilogram of arsenic per year to the arable soil in Bangladesh, mainly in the paddy fields.

Stroud *et al*. (2011); Brammer and Ravenscroft (2009) reported that arsenic pollution in groundwater has been reported in over 70 countries and population of about 150 million people worldwide with heavy concentration discovered in 10 countries in south and south-east Asia namely, Bangladesh, Cambodia, China, India, Laos, Myanmar, Nepal, Pakistan, Taiwan and Vietnam with over 110 million people living in these areas have serious health hazards due to their dependence on As-contaminated water for drinking and irrigation purposes.

Mirdar-Ul-Haq *et al*. (2005) reported that among many other factors responsible for heavy metal such as arsenic contamination in soils are long term usage of sewage or effluents for irrigation purposes which in turn will have adverse effects on plants, animals and human health.

Islam and Islam (2007) reported that arsenic is a poison. It is a significant health risk to millions of people worldwide when it is there in food and drink. It is highly poisonous at higher doses but chronic exposure to lower levels increases the risk of cancer of skin, bladder, lungs, kidney, liver, colon, prostrate; cardiac disease, pulmonary disease, cardiovascular disease, diabetes; diseases of arteries and capillaries; increased sensitivity to Hepatitis B infection, infertility, and other ailments. Observable symptoms to the arsenic poisoning can be thickening and discoloration of skin, stomach pain, nausea, vomiting, diarrhea, paralysis and blindness.

**2.3 Arsenic availability to plants**

Arsenic accumulation by green algae at a significantly high concentration while grown in Boro rice field in Bangladesh. This arsenic accumulation by green algae from irrigation water may cause lower arsenic accumulation by rice plant which would be beneficial to the people of Bangladesh (Huq *et al*., 2001).

A test was conducted by Das *et al.* (2003) for arsenic in rice grown on the soils adjacent to water source contaminated with arsenic. They found that highest concentration of arsenic accumulated by roots of paddy followed by shoot and rice grain (0.23 ppm).

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

A test was conducted by Duxbury *et al.* (2002) to determine the concentration of arsenic in rice grain of 150 samples collected from different districts of Bangladesh including Barisal, Comilla, Dinajpur, Rajshahi and Rangpur. Arsenic concentration was found in the range from 0.01 to 00415 mg/kg dry weight. As expected boro rice grain contained higher arsenic concentrations (mean value 183 μg/kg dry weight.) compared to aman rice (mean value 117 μg/kg dry weight).

Heitkemper *et al.* (2001) concluded that rice grain has lower concentration of arsenic and the concentration remain much below than maximum permissible limit of 1 mg/kg.

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

Xie and Huang (1998) reported that the pattern of arsenic concentration in rice plant parts generally follow the pattern: root> straw> husk> whole grain >husked rice.

Yan Chu (1994) posed a relationship between concentrations of arsenic in soil solution and rice tested to quantify the effect of level of arsenic uptake into rice. The regression equation found between the amount of arsenic present in the rice plant, Y, and the amount of arsenic in aqueous solution, X, to be: $Y = 0.042X - 0.0413$.

**2.4 Performance of arsenic on rice**

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 (Brammer, 2008).

Abedin *et al*. (2002a) reported that irrigation water contaminated with arsenic decrease seed germination, plant height, root growth and yield of rice. In Bangladesh, groundwater of 61 out of 64 districts is contaminated with arsenic in different concentrations. Concentration of arsenic exceeding 1.00 mg per liter of water is observed in 17 districts including Chandpur, Comilla, Noakhali, Feni, Munshiganj, Brahmanbaria, Faridpur, Madaripur, Laksmipur, Gopalganj, Shariatpur, Narayenganj, Narail, Satkhira and Chapainawabganj.

Duxbury and Panaullah (2007) reported that rice yield decreased from 8.9 t/ha at 26.3 ppm soil arsenic to 3 t/ha at 57.5 ppm arsenic. The results indicated that the practical limit for paddy production might lie between 25-50 mg/kg soil arsenic.

Panaullah *et al*. (2009) reported that irrigation water contaminated with arsenic reduce yield from 7-9 to 2-3 t/ha with increasing soil arsenic content and the average yield loss was 16 percent. They also reported that growth inhibition of rice was associated with straw arsenic concentrations of >5-10 mg/kg.

Huq and Joardar (2008) reported that the yield of BRRI dhan28 and BRRI dhan29 decreased 16 percent from control at higher dose (2.0 mg/L).

Abedin *et al*. (2002b) reported that increase in the content of arsenic in irrigation water led to increasing arsenic content in rice plants and consequent decrease in plant yield. Islam *et al*. (2004) reported that household survey on dietary habits revealed women consumed on an average 3.1 liter of water, 1.1 kg of cooked rice and 42 g of dry weight of curry per day. The total ingestion rates ranged from 31.1-129.3 µg/day (mean 63.5 µg/day) and the result indicated that the major route of arsenic in Bangladesh is rice followed by water and curry.

Higher level of arsenic adversely affected the nutrient uptake in rice and nutrient content except N. Nitrogen content increased with the increase of arsenic level. Higher amount of nutrient uptake and nutrient content was recorded in BRRI dhan48 and flooding enhanced higher nutrient content and uptake in rice. This study suggests the possible management of moisture regime and considering less arsenic susceptible variety, which might reduce the toxic effects of arsenic on nutrient uptake (Bhattacherjee *et al.*, 2014).

Khan *et al*. (2010) stated that low mobility of applied arsenic and the likely continued detrimental accumulation of arsenic within the rooting zone. Arsenic present in irrigation water or in soil resulted in reduction of yield from 21-74% in Boro rice and 8-80% in T. Aman rice, the later indicating the strong residual effect of arsenic on subsequent crops. The concentrations of arsenic in rice grain (0.22-0.81 µ/g), straw (2.64-12.52 µ/g) and husk (1.20-2.48 µ/g) increased with increasing addition of arsenic. In pot experiment, the growth of rice was inhibited when soil contained >15 mg As/kg, and severe toxicity symptoms were apparent when soil contained 60 mg As/kg.

Bhattacharya *et al.* (2010) reported that the arsenic uptake in rice varies with different rice varieties; the maximum accumulation was recorded in White Minikate (0.31+or-0.005 mg/kg) and IR 50 (0.29+or-0.001 mg/kg) rice varieties and minimum was found in the Jaya rice variety (0.14+or-0.002 mg/kg). In rice plant, maximum arsenic accumulation found in the straw part (0.89+or-0.019-1.65+or-0.021 mg/kg) compared to the accumulation in husk (0.31+or-0.011-0.85+or-0.016 mg/kg) and grain (0.14+or-0.002-0.31+or-0.005 mg/kg) parts. For any rice sample concentration of arsenic in the grain did not exceed the WHO recommended permissible limit in rice (1.0 mg/kg).

Wang *et al.* (2010) reported that arsenic is one of the most serious contaminants as noxious element-especially inorganic arsenic and it has a chronic poisoning effect in human body. Several studies have shown that rice is much more efficient accumulator of arsenic into its straw and grains than other staple cereal crops, and rice consumption constitute a large proportion of dietary intake of arsenic. The total arsenic content in rice varies from 0.005-0.710 mg/kg. The content of inorganic arsenic in rice varies from 10-90% of total arsenic.

Jahan *et al*. (2003); Rahman *et al*. (2004); Xie and Huang (1998) reported that plant height and shoot biomass production decreased with the increase of soil arsenic concentrations. Reduction in growth of rice plant in terms of tillering, plant height and shoot biomass production due to the result of arsenic phytotoxicity at high soil arsenic concentrations.

Duel and Swoboda (1972) and Jacobs *et al*. (1970) stated that displacement of soil phosphate by arsenate at low soil arsenic concentration increased the availability of phosphate to the plant resulted in the increase of plant growth.

Schoof *et al*. (1999) stated that rice has higher inorganic arsenic concentrations than most other food, and consequently, diets that rely heavily on rice may contain the most inorganic arsenic.

Meharg *et al*. (2009) reported that about 80% inorganic arsenic contamination in rice was reported in Bangladesh which is far more toxic than organic species. This was in sharp contrast to 58% Arsenic in U.S. rice, 64% in rice from Europe and 81% contamination in rice from India. However, basmati rice imported from India and Pakistan and jasmine rice from Thailand were found to contain the least arsenic.

Islam *et al*. (2005); Delowar *et al*. (2005) and Bhattacharya *et al*. (2009) reported that rice accumulates up to 2 mg/kg which is much above the permissible limit of 1.0 mg/kg, according to the WHO recommendation. Mehrag and Rahman (2002) concluded that the average contribution to total arsenic intake from drinking water was 13%, whereas from cooked rice, it was 56%, thus making it clear that rice contributed most to the daily arsenic uptake.

Van Geen *et al*. (2006) reported that the health risks due to ingestion of arsenic contained in rice therefore appear to be dwarfed in countries such as Bangladesh. Several studies observe that rice (*Oryza sativa* L.) in different growth stages accumulates arsenic in different levels but at maturing stage uptakes highest amount significantly than at other stages (Wang *et al*., 2006).

Abedin *et al*. (2002a) reported that percent of rice seed germination over control decreased significantly with the increasing concentrations of arsenite (As-III) and arsenate (As-V) and found that arsenite was more toxic than arsenate for rice seed germination.

Dahal *et al*. (2008) reported that the significant presence of arsenic contaminated irrigation water on alkaline soils and arsenic uptake in agricultural plants at field level in Nepal. He concluded his study by giving the mean arsenic content of edible plant material (dry weight) in the order of onion leaves (0.55 mg As $kg^{-1}$>onion bulb (0.45 mg As $kg^{-1}$>cauliflower (0.33 mg As $kg^{-1}$>rice (0.18 mg As $kg^{-1}$>brinjal (0.09 mg As $kg^{-1}$>potato (<0.01 mg As $kg^{-1}$ indicating that in Nepal, onion leaves had highest and rice (fourth in order of concentration) As uptake.

Khan *et al*. (2010); Panaullah *et al*. (2009) and Islam *et al*. (2005) reported that the gradual transfer of Arsenic in irrigation water from contaminated shallow tube-wells to the soils, where it was potentially available for uptake by plants.

Bhattacharya *et al*. (2009) and Nahar (2009) reported that over 1000 tons of arsenic is transferred to arable land each year from irrigation by groundwater contaminated with arsenic in Bangladesh. Long term use of arsenic contaminated groundwater for irrigation purposes may result in further increase in arsenic concentration in agricultural soil and eventually led to hyper-accumulation in crops, including rice.

Abedin *et al*. (2002a); Delowar *et al*. (2005); Islam *et al*. (2004) and Rauf *et al*. (2011) reported that elevated levels of arsenic in irrigation water or soil either naturally or artificially can reduce growth and productivity of rice due to its toxicity. Arsenic impairs metabolic processes and thus reduces plant growth and development (Marin *et al*., 1993). Soil arsenic, decreases plant height (Carbonell-Barrachina *et al*., 1995; Abedin *et al*., 2002b; Jahan *et al*., 2003 and Karimi *et al*., 2010); reduces tillering ability (Kang *et al*., 1996 and Rahman *et al*., 2004); lessen shoot growth (Cox *et al*., 1996 and Carbonell-Barrachina *et al*., 1998); lowers fruit and grain yield (Carbonell-Barrachina *et al*., 1995; Abedin *et al*., 2002c and Kang *et al*., 1996) and sometimes leads to death (Marin *et al*., 1992 and Baker *et al*., 1976).

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

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

Hossain (2005) reported that reduction of yield more than 40% and 60% for two popular rice varieties (BRRI Dhan28 and Iratom-24) when 20 mg/kg of arsenic was added to soils, compared to the control.

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

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

Williams (2003) observed that 64% of European, 80% of Bangladeshi and 81% of Indian rice arsenic were inorganic, with As (III) predominating. Arsenic present in ground water affects people in Bangladesh via seed grains and forages. Samples of rice and rice straw were collected from arsenic-contaminated areas and arsenic concentration was measured using Flow Injection Hydride Generator Atomic Absorption Spectrophotometer (FI-HG-AAS) method. The concentrations in rice and rice straw were 0.235 ± 0.014 ppm (n = 48) and 1.149 ± 0.119 ppm (n = 51), respectively. Both were greater than the maximum permissible concentration in drinking water (0.05 ppm; WHO).

Jahiruddin *et al.* (2004) studied the effects of arsenic contamination on crop yield and arsenic accumulation under control conditions. The levels of soil added arsenic were 0, 5, 10, 15, 20, 30, 40 and 50 ppm, and that of irrigation water arsenic were 0, 0.1, 0.25, 0.5, 0.75, 1.0, 1.5 and 2 ppm. The effect of added arsenic (plus 2.6 ppm soil arsenic) was tested directly on Boro rice (BRRI dhan29) and its residual effect on T. Aman rice (BRRI dhan33). The pots for both crops received an equal amount of fertilizers. They found that the grain protein was adversely affected due to arsenic contamination. 40% grain yield reduction for 10 mg/kg addition of arsenic to BAU farm soil.

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

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

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

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

### 2.5 Arsenic mitigation processes

Brown *et al*. (2003) and Hartley *et al*. (2009) reported that organic soil amendments such as compost, manures and sludges are now established amongst *in-situ* alternatives to expensive and/or disruptive hard engineered removal or capping of contaminated substrates to reduce contaminant-associated risk.

Agrafioti *et al*. (2014) and Samsuri *et al*. (2013) reported that biochars had high efficiency to remove inorganic As (III) and As (V) from aqueous solution, especially for the activated biochars produced from agricultural wastes.

Warren *et al*. (2003) and Tighe *et al*. (2005) reported that the combination of biochar with iron-oxides can reduce arsenic mobility in soil by anion exchange.

Mench *et al*. (2003) found good synergisms between compost and iron-rich materials to decrease available fractions of metals and arsenic in soils.

Epps and Sturgis (1939) stated that application of sulfur exerted a depressive effect on arsenic toxicity to paddy rice.

Leupin and Hug (2005) and Ghurye *et al*. (2004) stated that oxidation/precipitation is very effective technology for the removal of arsenic from water.

Lara *et al*. (2006) reported that instead of UV-light, solar-light can also remove arsenic from natural water upon addition of iron and citrate.

Katsoyiannis and Zouboulis (2006) reported that iron oxidizing bacteria remove arsenic more efficiently than those of manganese oxidizing bacteria.

Saalfield and Bostick (2009) demonstrated a process in the laboratory, where the mobility of arsenic was affected by biologically mediated redox processes by binding it to iron oxides through dissimilatory sulphate reduction and secondary iron reduction processes in reducing aquifers.

Appelo *et al*. (1999) stated that in-situ oxidation can reduce the arsenic content in the pumped groundwater by pumping the oxygenated water into the groundwater aquifer. The dissolved oxygen content in water oxidizes As (III) to less mobile As (V) in the aquifer causing the reduction in the content of arsenic.

Ma *et al*. (2001) reported that the *Pteris vittata* (Chinese brake fern) was found to be resistant to arsenic, having the capability of hyper accumulating large amounts of arsenic in its fronds by area contaminants are picked up by the roots of plants and transported to their over ground parts, and then removed together with the crops (phytostabilization, phytoextraction and phytovolatilization).

Baig *et al*. (2010) reported that the use of native biomasses (powdered) removed arsenic from surface water. For example, biomass from the stem of a thorny *Acacia nilotica* was used for the removal of arsenic from arsenic contaminated water bodies.

Takamatsu *et al*. (1982) reported that water management practices influenced the physio-chemical properties of the paddy soils through reduction-oxidation process, which reduce the availability of arsenic to the soil solution through transformation of less toxic and available (arsenate) form, and subsequent entry to plant systems.

Das *et al*. (2008) stated that the addition of organic matter in paddy field reduced the arsenic availability through the formation of an insoluble and stable arseno-organic complexes and their adsorption on to organic colloids of soil solutions.

Walker *et al*. (2004) reported that the addition of organic amendments to the soils reduce the heavy metal bioavailability by changing them from bioavailable forms to the fractions associated with organic matter or metal oxides or carbonates.

Cao *et al*. (2003) reported that when bio solid was added to either acidic or neutral soil the adsorption of arsenic was increased and reduce water soluble arsenic.

Shiralipour *et al*. (1992) reported that the application of organic matter to soil would increase soil anion and cation exchange capacity, which may increase arsenic adsorption by increasing the amount of positive charge on the oxide surface and/or forming a positively charged surface and enhanced sorption capacity of the soil matrix.

Mukhopadhyay and Sanyal (2004) reported that the combined application of manures and compost have significant effect in reducing the plant and soil arsenic content, due to the release of higher amount of organic acid (humic/falvic acid), binding site of the arsenic in the soil rather than release of nutrients and change the physiochemical properties of soil-water.

Wang and Muligan (2006) stated that humic acid (HA) and falvic acids (FA) from organic matter compete strongly with arsenic for active adsorption sites on mineral surfaces result in lowering the levels of arsenic retention, mobility and bioavailability of arsenic.

Redman *et al*. (2002) stated that the formation of humic acid (HA)/falvic acid (FA)-metal complexes strongly bind arsenate and arsenite anions through metal-bridging mechanism contribute to immobilization of arsenic.

Chen *et al*. (2000) reported that organic amendments such as manures and compost which contain a high amount of humified organic matter can decrease the bioavailability of heavy metals through adsorption and by forming stable complexes with humic substances.

Jones *et al*. (2000) reported that the reduced accumulation of arsenic in plants are due to low availability of the toxicant from soil due to amended through compost, manures etc.

Rahman *et al*. (2008) showed that the combined application of lathyrus + vermicompost + poultry manure reduced arsenic transport in plant parts (root, straw, husk, whole grains and milled grain).

## CHAPTER III

## MATERIALS AND METHODS

This chapter presents a brief description about the materials and methods those were utilized when researching and writing this work. It describes the key methods, use of different parameters to correlate with establishing rice plant. It further covers the data collection procedure, source of data and ways of data were analyzed.

### 3.1 Experimental site

The experiment was conducted under pot-culture at the net house and the agro-environmental chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 during the Boro season of 2016-17 to evaluate the influence of vermicompost and inorganic fertilizers on the mitigation of arsenic stress in Boro rice.

### 3.2 Climate

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

### 3.3 Description of soil

The soil of the experiment was collected from the field of Sher-e-Bangla Agricultural University (SAU) Farm. The soil was Shallow Red Brown Terrace soil under Tejgaon series belonging to the Agro-Ecological Zone 28 (Modhupur Tract). The soil was clay loam in texture with common fine medium distinct dark yellowish brown mottles. The collected soil was pulverized and inert materials, visible insect pest and propagules were removed. The soil was dried in the sun, crushed carefully and thoroughly mixed.

### 3.4 Collection and preparation of soil

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

### 3.5 Pot preparation

An amount of 8 kg soil was taken in a series of pots. The required number of plastic pots having 24 cm top, 18 cm bottom diameter and 22 cm depth were collected from the local market and cleaned before use. There were altogether 60 pots comprising 4 different treatments of arsenic to 5 different treatments of vermicompost and inorganic fertilizers with 3 replications. Water was added to the pot to bring the soil up to saturation.

### 3.6 Treatments of the experiment

Four rates of arsenic *viz.* 0, 10, 20, and 30 ppm arsenic (on soil weight basis) and five rates of vermicompost and inorganic fertilizers were applied on BRRI dhan47. The source of arsenic was Sodium Arsenate ($Na_2HAsO_4.7H_2O$).

Design: CRD with two factorials

Factor A: Different doses of arsenic: 04

$As_0$= (No arsenic applied)

$As_1$= (10 ppm arsenic on soil weight basis)

$As_2$= (20 ppm arsenic on soil weight basis)

$As_3$= (30 ppm arsenic on soil weight basis)

Factor B: Different doses of vermicompost and inorganic fertilizers: 05

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers

$T_1$ = Recommended doses of inorganic fertilizers without vermicompost

$T_2$ = Recommended doses of vermicompost without inorganic fertilizers

$T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

$T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

Treatment combinations = 4 x 5 = 20

Replications: 3

**3.7 Description of rice variety under study**

**3.7.1 BRRI dhan47**

BRRI dhan47 was developed by the scientists of BRRI (Bangladesh Rice Research Institute) and was officially released by National Seed Board of Bangladesh in 2007. It is a high yielding variety which can yield up to 6.0 t/ha. Its crop duration is 152 days (BRKB, 2017).

**3.8 Collection of seed**

Seeds of BRRI dhan47 was collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur-1701, Dhaka.

**3.9 Sterilization of seed**

Prior to germination test seeds were surface sterilized with 1% sodium hypochlorite solution. The glass vials containing distilled water for seed rinsing was sterilized for 20 minutes in an auto clave at $121\pm1^0$ C and at 15 bar air pressure.

**3.10 Raising of seedlings**

The seedlings were raised at the wet seed bed in SAU farm. The seeds were sprouted by soaking for 72 hours. The sprouted seeds were sown uniformly in the well-prepared seed bed in $15^{th}$ December 2016.

**3.11 Fertilizer application**

All the pot received fertilizers according to BRRI's recommended fertilizer dose (BRRI, 2016). The amounts of nitrogen, phosphorus, potassium and sulphur required for each pot were calculated as per their rates of application. Except nitrogen, full dose of P, K and vermicompost were added at the time of final pot preparation.

Nitrogen was added in three equal splits at 7, 30 and 45 days after transplanting (DAT). Arsenic was added to soil before transplanting.

### 3.12 Transplanting of seedlings

The seedlings were uprooted carefully from the seedbed in the morning and transplanted in the same day. Healthy seedlings of 45 days age were transplanted in the pots on 29$^{th}$ January 2017. One hill in each pot with two seedlings were maintained.

### 3.13 Intercultural operations

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

### 3.14 Irrigation

Three cm water was added above ground after transplanting and maintained for 15 days after transplanting. Then water was added following saturation system and continued up to panicle initiation stage.

### 3.15 Harvesting

The crop was harvested at full maturity on 18$^{th}$ May 2017. Plants of each pot was bundled separately with tag mark indicating the respective treatment combinations and brought to the laboratory for recording data on yield and yield contributing parameters.

### 3.16 Sampling and data collection

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

### 3.16.1 Plant height

The heights (cm) of the plants were taken by measuring the distance from base of the plant to the tip of the flag leaf at 30, 50, 70 and 90 DAT and finally averaged.

### 3.16.2 Number of tillers hill$^{-1}$

Number of tillers hill$^{-1}$ was counted from each pot at 30, 50, 70 and 90 DAT and finally averaged.

### 3.16.3 Number of effective and non-effective tillers hill$^{-1}$

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

### 3.16.4 Number of filled grains and unfilled grains panicle$^{-1}$

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

### 3.16.5 Weight of 1000 grain

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

### 3.16.6 Grain yield (g/pot)

Grains obtained from each pot were sun-dried and weighed carefully. The dry weight of grain of the respective pot was recorded carefully.

### 3.16.7 Straw yield (g/pot)

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

## 3.17 Sample threshing and processing

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

### 3.18 Chemical Analysis

#### 3.18.1 Preparation of plant extract for P and K determination

The samples were dried in an oven at $70^0$C to obtain constant weight. Oven-dried grain, straw and root samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. Exactly 1g oven-dried samples of rice plants were taken in digestion tube. About 10 mL of di-acid mixture (nitric acid : perchloric acid = 2:1) was taken in a digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at $100^0$C. The temperature was increased to $365^0$C gradually to prevent frothing ($50^0$C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating source and allowed to cool to room temperature. About 40 ml of distilled water was carefully added to the digestion tubes and the contents filtered through Whatman No. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with distilled water. The samples were then stored at room temperature in clearly marked containers.

After digestion, approximately 100 mL of each digest samples was stored in a plastic bottle for determination of the P and K. Content of P was determined by Spectrophotometer and content of K was determined by Flame Photometer. After that, the percent of P and K values were also calculated from the concentration of P and K in the plant tissues.

#### 3.18.2 Determination of Arsenic

**Sample information:** Digest sample, pH<2 with HCl 5 mL/L

**Sample storage**: Refrigerator, <$4^0$C

**Instrument:** Flame Atomic Absorption Spectrophotometer with HVG, Ar gas (99.999%) as carrier of sample. HCl 5M and 0.4% $NaBH_4$ as reagent for HVG. Sample flow rate 5 mL/min.

**Reagents used:** (i) KI (ii) Conc. $HNO_3$ (iii) Conc. HCl (iv) De-ionized water (DI water) (v) 1000 ppm standard solution of As (vi) $NaBH_4$ (vii) 5M HCl

**Preparation of reagents**

**Preparation of $NaBH_4$ solution (0.4% w/v):** 2.5 g Sodium Hydroxide and 2.0 g Sodium Borohydrate were dissolved in 500 mL volumetric flask and marked up to volume with DI water.

**Preparation of KI (20% w/v):** 20 g KI was taken in 100 mL water then dissolved in water and marked up to volume.

**Preparation of 5M HCl:** 200 mL DI water was taken in a volumetric flask and then 208 mL of HCl (37%) was added and volume was marked up to with DI water.

**Preparation of calibration standard from 1000 ppm standard solution of As:** 1 mL of As (1000 ppm standard solution) was taken in 100 mL volumetric flask and then mark up with DI water. Then 1mL from 10 ppm solution was taken in 100 mL volumetric flask and marked up to volume with DI water. Then dilutions were as follows from the 100 ppb solution:

0 mL= 100 mL water (o ppb, blank)

2.5 mL= 100 mL water (2.5 ppb)

5 mL= 100 mL water (5 ppb)

10 mL= 100 mL water (10 ppb)

After that, 40 mL from each solution was taken in individual 50 mL volumetric flask and then 4 mL of 37% HCl and 2 mL of freshly prepared 20% (w/v) KI were added to each and left to dark for 15 minutes.

**Preparation of blank:** 40 mL DI water was taken in 50 mL volumetric flask and 4 mL of 37% HCl and 2 mL of freshly prepared 20% (w/v) KI were added and left to dark for 15 minutes.

**Treatment and preparation of sample:** 1 g well-mixed sample was taken in a beaker. About 10 mL conc. $HNO_3$ was added. The sample was covered with a watch glass and heated on hot plate at $90^0$ to $95^0$C until the volume reduced to 15-20 mL. The beaker was removed and allowed to cooling. The beaker walls and watch glass were washed down with DI water when necessary filter or centrifuge the sample to remove silicates or other insoluble material. Then the final volume to 50 mL was with diluent. After that, 40 mL of this was taken in 50 mL volumetric flask and 4 mL of 37% HCl and 2 mL of freshly prepared 20% (w/v) KI were added and left to dark for 15 minutes.

**Procedure:** For grain, straw and root arsenic analysis, 1 mL of each samples were taken in a 100 mL conical flask and 50 mL of 0.5 mol/L $NaHCO_3$ solution was added. Then the whole materials were shaken for 1 hr in a "to and fro'' horizontal shaker and after completion of shaking, the suspensions were filtered through Whatman filter paper No. 42. The filtered were collected for arsenic analysis with Atomic Absorption Spectrophotometer coupled with Hydride Vapor Generator (HVG) unit after reducing with 2 mL of 10% KI solution and 2 mL of 35% HCl, $NaBH_4$ solution and 4 mol/L HCl solution separately from three containers were allowed passing to a mixing manifold by a peristaltic pump. From the mixing manifold by argon (inert gas), carrier, $AsH_3$ (arsine) generated in the reaction loop. The arsenic was then atomized in a flame of air-acetylene and the direct arsenic concentrations in the sample were measured.

### 3.18.3 Determination of Nitrogen

The Macro Kjeldahl method was used to determine the total Nitrogen in root, shoot and grain of plant samples. Three steps were followed in this method. These are as follows:-

A. Digestion: In this step the organic nitrogen was converted to ammonium sulphate by sulphuric acid and digestion accelerators (Catalyst Mixture) at a temperature of 360-440º C.

$$N + H_2SO_4 = (NH_4)_2SO_4$$

B. Distillation: In this step, the solution was made alkaline from the distillation of ammonia. The distilled ammonia was received in boric acid solution.

$$(NH_4)_2SO_4 + NaOH = Na_2SO_4 + NH_3 + H_2O$$

$$2NH_3 + H_3BO_3 = (NH_4)_3BO_3$$

C. Titration: To determine the amount of $NH_3$, ammonium borate was titrated with standard sulfuric acid.

$$(NH_4)_3BO_3 + H_2SO_4 = (NH_4)_2SO_4 + H_3BO_3$$

**Reagents**: 4% Boric Acid solution, Mixed indicator (Bromocresol green and Methyl red), 40% Sodium Hydroxide solution, Standard Sulphuric Acid solution 0.05 N and 0.05 N $Na_2CO_3$ solution.

**Procedure:** About 1.0g of oven dried sample was weighed and then taken into a 250 mL Kjeldahl flask. Then 5g catalysts mixer ($K_2SO_4$:$CuSO_4.5H_2O$: Se=100:1:1) was added in to flask. Then about 25mL concentrated $H_2SO_4$ was also added o the flask. The flask was heated until the solution become clear and then allowed to cool and then about 120 mL of distilled water was added and 5-6 glass bead into the flask. After digestion, 40% NaOH 125mL was added to the conical flask and attached quickly to the distillation set. Then the flask was heated continuously. In the meantime, 25mL of 4% boric acid solution and 2-4 drops of mixed indicator was taken in a 500mL receiver conical flask. After distillation, about 150ml distillate was collected into receiver conical flask. The distillate was then titrated with standard $H_2SO_4$ taken from a burette until the green color completely turns to pink color at the end point. The same procedure was followed for a blank sample. The result was calculated using the following formula-

$$\%N = (T-B) \times N \times 1.4/S$$

Where, T= Titration value for sample (mL), B= Titration value for blank (mL), N= Normality of $H_2SO_4$ (N), S= Weight of the sample (g), 1.4= conversion factor

### 3.18.4 Determination of Phosphorus

The amount of Phosphorus (P) was estimated from the plant extract by ascorbic acid blue color method with the help of a Spectrophotometer at 660 nm.

**Reagents required**

A. Mixed reagent: 12.0 g ammonium molybdate $(NH_4)_6Mo_7O_{24}.4H_20$ was dissolved in 250 mL distilled water. About 0.2908 g antimony potassium tartarate $K_2Sb_2(C_4H_2O_6)_2.3H_2O$ was dissolved in 1000 mL $H_2SO_4$. Two solutions were mixed together and volume was made up to 2000 mL with distilled water and stored in a pyrex bottle in a dark cool place.

B. Color developing reagent: 0.53 g ascorbic acid was added to 100 mL of the mixed reagent.

C. Standard Phosphorus solution (100 ppm): 0.439 g potassium dihydrogen phosphate ($KH_2PO_4$) was weighed into a 1L volumetric flask. About 500 mL distilled water was added and shaked the contents until the salt dissolved. Then the volume was made up to 1L with distilled water.

**Procedure**

A. Color development: About 20 mL of the extract was pipetted out in a 100 mL volumetric flask. About 20 mL color developing reagent was added slowly and carefully to prevent the loss of sample due to excessive foaming. After the evolution of $CO_2$ had ceased, the flask was shaked gently to mixed the contents. The volume was made up to the mark with distilled water.

B. Preparation of working standard P solution: About 20 mL of the standard P solutions (100 ppm) was pipetted to a 1L volumetric flask and volume was made up to the mark by distilled water. This solution contained 2 ppm P. About 0, 5, 10, 15, 20 and 25 mL aliquot were pipetted out from 2 ppm solution in 100 mL volumetric flask respectively. About 20 mL color developing reagent was added to each flask, mixed and volume was made with distilled water. These solutions gave 0, 0.1, 0.2, 0.3, 0.4 and 0.5 ppm of P solution respectively. The solution was allowed to stand for 15 minutes and then color intensity (% absorbance) was measured at 660 nm. A standard curve was prepared from the spectrophotometer reading and concentrations of plant samples were calculated from the curve.

### 3.18.5 Determination of Potassium

The amount of Potassium (K) was determined from the plant extract with the help of a Flame photometer.

**Preparation of primary potassium standard solution (1000 ppm):** 1.918 g potassium chloride was taken in a 1L volumetric flask. About 200-300 mL distilled water was added and the flask was shaked thoroughly until a clear solution was obtained. The volume was made up to the mark with distilled water. Thus, 1000 ppm K solution was prepared.

**Preparation of secondary potassium solution (100 ppm and 10 ppm):** About 10 mL of the 1000 ppm K solution was taken in a 100 mL volumetric flask. The volume was made up to mark with distilled water and shaked thoroughly. Thus, 100 ppm K solution was prepared. From 100 ppm solution, 10 mL was taken in a 100 mL volumetric flask. The volume was made up to the mark with distilled water and shaked thoroughly. Thus, 10 ppm solution was obtained.

**Preparation of potassium standard series solution:** A series of standard solution containing 1 ppm, 2 ppm, 3 ppm, 4 ppm, 5 ppm and 6 ppm were prepared by pipetting 10 mL, 20 mL, 30 mL, 40 mL, 50 mL and 60 mL of 10 ppm K solution in six different 100 mL volumetric flask respectively. The volume was made up to the mark by distilled water and shaked thoroughly. Then, the reading (% emission) were taken from flame emission spectrophotometer and a standard curve was prepared from the reading taken. Plant samples were taken in volumetric flask and volume was made up to the mark by distilled water. Then the samples reading were taken and concentrations were calculated from the standard curve.

### 3.19 Statistical Analysis

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

# CHAPTER IV

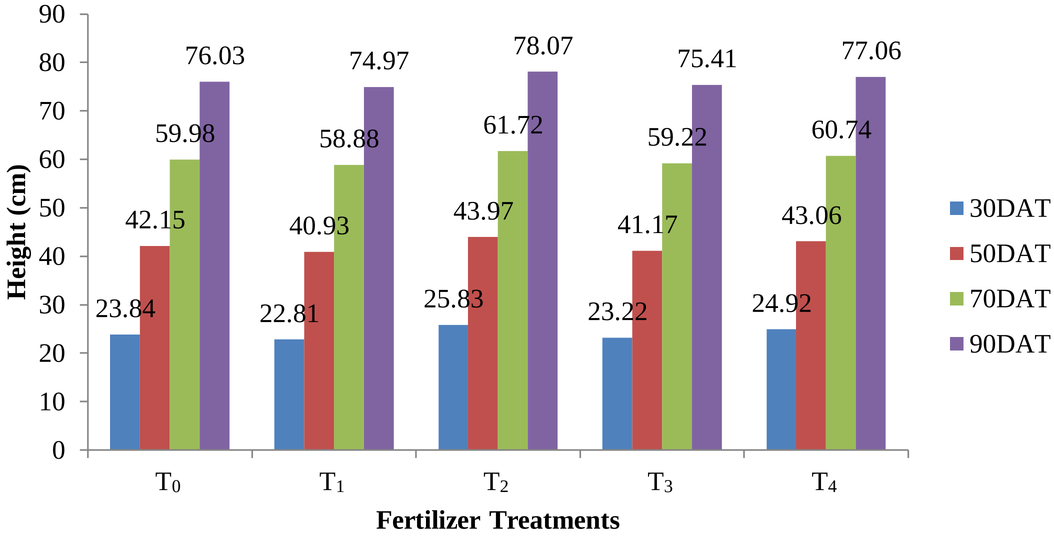
# RESULTS AND DISCUSSION

A study was undertaken during the Boro season of December-June (2016-17) to evaluate the influence of vermicompost and inorganic fertilizers on mitigation of arsenic in BRRI dhan47. The results of the study regarding the influence of vermicompost and inorganic fertilizers on mitigation of arsenic in BRRI dhan47 has been presented with possible interpretations under the following headings:

## 4.1 Plant Height

### Effect of fertilizer

The plant height (cm) of BRRI dhan47 was significantly influenced by different doses of fertilizers (vermicompost and inorganic) at 30, 50, 70 and 90 DAT (Figure 1 and Appendix IV). The results revealed that at 30, 50, 70 and 90 DAT, the treatment $T_2$ produced the tallest plant (25.83 cm, 43.97 cm, 61.72 cm and 78.07 cm respectively)



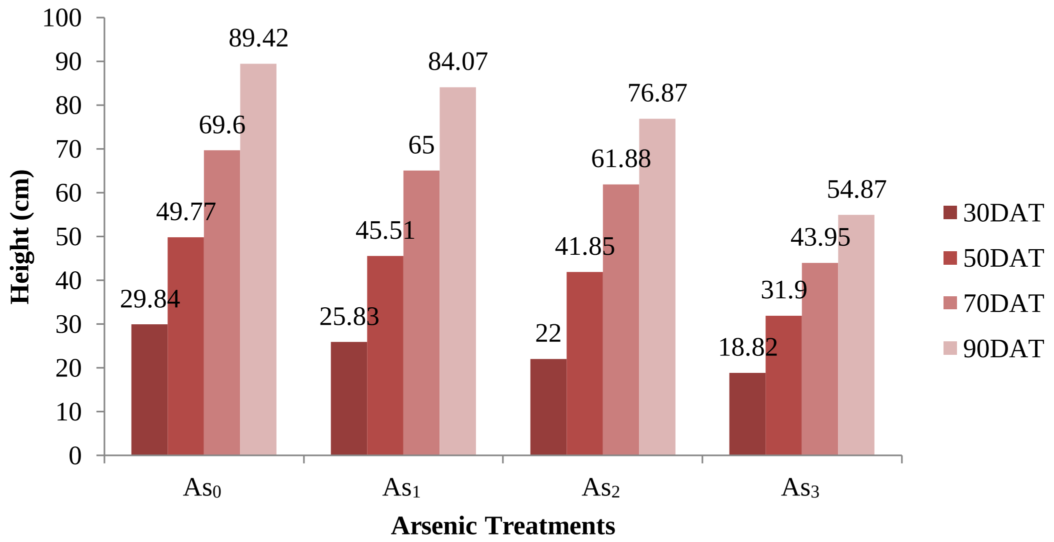

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 1. Effect of different doses of fertilizers (vermicompost and inorganic) on plant height at different days after transplanting**

and the treatment $T_1$ produced the shortest plant (22.81 cm, 40.93 cm, 58.88 cm and 74.97 cm respectively). The doses of organic manure had positive effect on plant height. This confirms the reports of Kobayashi *et al*. (1989).

### Effect of arsenic

Different levels of arsenic application showed distinct negative effect on the plant height of BRRI dhan47 at 30, 50, 70, and 90 DAT (Figure 2 and Appendix V). The result revealed that at 30, 50, 70 and 90 DAT, the highest plant height (29.84 cm, 49.77 cm, 69.6 cm and 89.42 cm respectively) were recorded from the treatment $As_0$ and, the lowest height (18.82 cm, 31.9 cm, 43.95 cm and 54.87 cm respectively) were recorded from the treatment $As_3$. Holmgren *et al*. (1993) and Das *et al*. (1997), all the growth parameters tested in their experiment viz. plant height were affected by the application of arsenic.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 2. Effect of different doses of arsenic on plant height at different days after transplanting**

### Interaction effect of fertilizer and arsenic

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant variation on plant height of BRRI dhan47 at 30, 50, 70 and 90 DAT (Table 1). At 30 DAT, the highest plant height (31.77 cm) was observed from the $As_0T_2$ treatment and the lowest plant height (18.37 cm) was observed from $As_3T_1$ treatment which was statistically similar with $As_3T_0$ (18.57 cm), $As_3T_3$ (18.43 cm) and $As_3T_4$ (18.67 cm). At 50 DAT, the highest plant height (50.77 cm) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_0$ (50.37 cm) and $As_0T_4$ (50.67 cm) whereas, the lowest plant height (31.37 cm) was observed from the treatment $As_3T_1$ which was statistically similar with $As_3T_3$ (31.37 cm), $As_3T_0$ (31.50 cm) and $As_3T_4$ (31.63 cm). At 70 DAT, the highest plant height (70.80 cm) was observed from the $As_0T_2$ treatment and the lowest plant height (43.27

**Table 1: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on plant height at different days after transplanting**

| Treatments | | Plant height (cm) | | | |
|---|---|---|---|---|---|
| | | 30 DAT | 50 DAT | 70 DAT | 90 DAT |
| $As_0$ | $T_0$ | 29.83 c | 50.37 a | 70.10 b | 89.80 a |
| | $T_1$ | 28.33 d | 48.43 bc | 68.47 c | 88.47 b |
| | $T_2$ | 31.77 a | 50.77 a | 70.80 a | 90.23 a |
| | $T_3$ | 28.63 d | 48.63 b | 68.50 c | 88.77 b |
| | $T_4$ | 30.63 b | 50.67 a | 70.13 b | 89.83 a |
| $As_1$ | $T_0$ | 25.20 f | 45.17 e | 64.57 f | 83.33 e |
| | $T_1$ | 24.03 g | 43.40 f | 63.23 g | 81.57 g |
| | $T_2$ | 28.23 d | 48.07 c | 67.37 d | 87.13 c |
| | $T_3$ | 24.37 g | 43.60 f | 63.43 g | 82.10 f |
| | $T_4$ | 27.33 e | 47.33 d | 66.40 e | 86.20 d |
| $As_2$ | $T_0$ | 21.77 i | 41.57 h | 61.67 i | 76.50 j |
| | $T_1$ | 20.50 j | 40.53 i | 60.53 j | 75.47 k |
| | $T_2$ | 23.23 h | 43.43 f | 63.13 gh | 78.47 h |
| | $T_3$ | 21.43 i | 41.10 h | 61.40 i | 76.37 j |
| | $T_4$ | 23.07 h | 42.60 g | 62.67 h | 77.57 i |
| $As_3$ | $T_0$ | 18.57 k | 31.50 k | 43.60 lm | 54.50 m |
| | $T_1$ | 18.37 k | 31.37 k | 43.27 m | 54.40 m |
| | $T_2$ | 20.07 j | 33.63 j | 45.57 k | 56.43 l |
| | $T_3$ | 18.43 k | 31.37 k | 43.53 lm | 54.40 m |
| | $T_4$ | 18.67 k | 31.63 k | 43.77 l | 54.63 m |
| $LSD_{(0.05)}$ | | 0.6476 | 0.4783 | 0.4951 | 0.5086 |
| CV (%) | | 1.63 | 0.69 | 0.50 | 0.40 |
| Significant level | | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

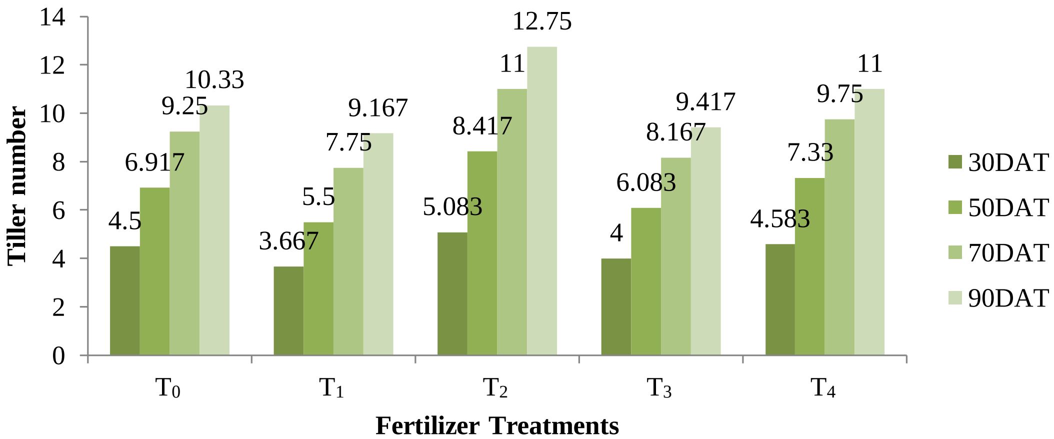
$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

cm) was observed from $As_3T_1$ which was statistically similar with $As_3T_3$ (43.53cm), $As_3T_0$ (43.60 cm) and $As_3T_4$ (43.77 cm). At 90 DAT, the highest plant height (90.23 cm) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_4$ (89.83 cm) and $As_0T_0$ (89.80 cm) whereas, the lowest plant height (54.40 cm) was observed from $As_3T_1$ treatment which was statistically similar with $As_3T_3$ (54.40 cm), $As_3T_0$ (54.50 cm) and $As_3T_4$ (54.63 cm). Hossain *et al.* (2008) found that plant height significantly varied with different concentrations of arsenic.

## 4.2 Number of tillers hill$^{-1}$

### Effect of fertilizer

The number of tillers hill$^{-1}$ of BRRI dhan47 were significantly influenced by different doses of fertilizers (vermicompost and inorganic) at 30, 50, 70 and 90 DAT (Figure 3 and Appendix IV). The results revealed that at 30, 50, 70 and 90 DAT, the treatment $T_2$ produced the highest number of tillers hill$^{-1}$ (5.083, 8.417, 11 and 12.75 respectively) and the treatment $T_1$ produced the lowest number of tillers hill$^{-1}$ (3.667, 5.5, 7.75 and 9.617 respectively). This confirms the reports of Nayak *et al*. (2007) that a significant increase in number of tillers hill$^{-1}$ due to the application of organic manure with chemical fertilizers.

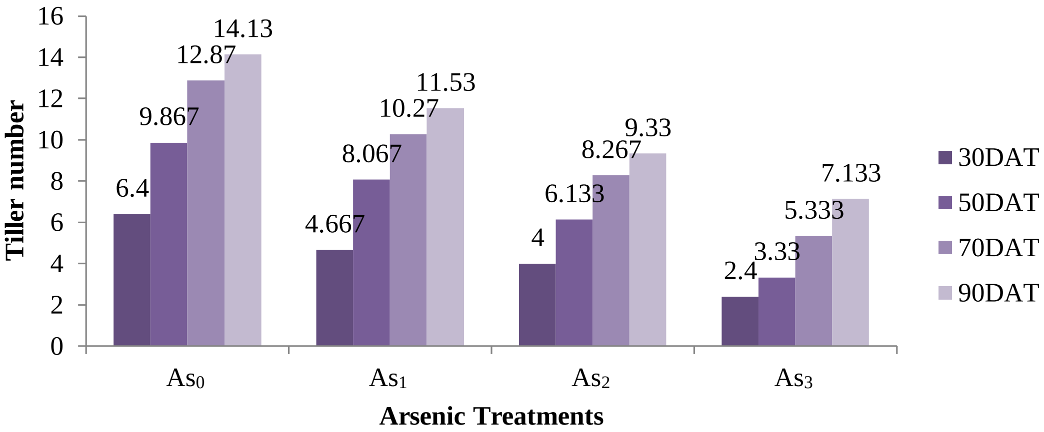



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 3. Effect of different doses of fertilizers (vermicompost and inorganic) on number of tillers hill$^{-1}$ at different days after transplanting**

### Effect of arsenic

Different doses of arsenic had significant effect on number of tillers hill$^{-1}$ of BRRI dhan47 at 30, 50, 70 and 90 DAT (Figure 4 and Appendix V). At 30, 50, 70 and 90 DAT, the highest number of tillers hill$^{-1}$ (6.4, 9.867, 12.87 and 14.13 respectively) were observed from the $As_0$ treatment and the lowest number of tillers hill-1 (2.4, 3.333, 5.333 and 7.133) were observed from the $As_3$ treatment. Holmgren *et al*. (1993) and Das *et al*. (1997) reported that all the growth parameters tested in their experiment viz. tiller numbers were affected by the application of arsenic.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 4. Effect of different doses of arsenic on number of tillers hill$^{-1}$ at different days after transplanting**

### Interaction effect of fertilizer and arsenic

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant variation on number of tillers hill$^{-1}$ of BRRI dhan47 at 30, 50, 70 and 90 DAT (Table 2). At 30 DAT, the highest number of tillers hill$^{-1}$ (7.333) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_4$ (6.667), $As_0T_0$ (6.333), $As_0T_3$ (6.000) and $As_0T_1$ (5.667) and the lowest number of tillers hill$^{-1}$ (1.333) was observed from $As_3T_1$ treatment which was statistically similar with $As_3T_3$ (2.333), $As_3T_4$ (2.667) and $As_3T_0$ (2.667). At 50 DAT, the highest number of tillers hill$^{-1}$ (11.67) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_4$ (10.67) and $As_0T_0$ (10.33) and the lowest number of tillers hill$^{-1}$ (2.00) was observed from $As_3T_1$ treatment which was statistically similar with $As_3T_3$ (3.00) and $As_3T_0$ (3.333). At 70 DAT, the highest number of tillers hill$^{-1}$ (14.67) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_4$ (13.67) and $As_0T_0$ (13.33) whereas, the lowest number of tillers hill$^{-1}$ (4.00) was observed from $As_3T_1$ treatment which was statistically similar with $As_3T_3$ (4.667) and $As_3T_0$ (5.00). At 90 DAT, the highest number of tillers hill$^{-1}$ (16.33) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_4$ (15.00) and the lowest number of tillers hill$^{-1}$ (6.00) observed from $As_3T_1$ treatment which was statistically similar with $As_3T_3$ (6.33) and $As_3T_0$ (7.00).

**Table 2: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on number of tillers hill$^{-1}$ at different days after transplanting**

| Treatments | | Number of tillers hill$^{-1}$ | | | |
|---|---|---|---|---|---|
| | | 30 DAT | 50 DAT | 70 DAT | 90 DAT |
| $As_0$ | $T_0$ | 6.333 abc | 10.33 ab | 13.33 ab | 14.33 bc |
| | $T_1$ | 5.667 a-e | 8.00 def | 11.00 cd | 12.67 cd |
| | $T_2$ | 7.333 a | 11.67 a | 14.67 a | 16.33 a |
| | $T_3$ | 6.000 a-d | 8.667 cd | 11.67 bc | 12.33 de |
| | $T_4$ | 6.667 ab | 10.67 ab | 13.67 a | 15.00 ab |
| $As_1$ | $T_0$ | 5.000 b-g | 8.00 def | 10.33 c-f | 11.00 d-g |
| | $T_1$ | 4.333 d-i | 7.00 efg | 9.00 e-h | 10.00 f-i |
| | $T_2$ | 5.333 b-f | 9.667 bc | 11.33 cd | 14.33 bc |
| | $T_3$ | 4.000 e-j | 7.333 d-g | 9.667 d-g | 10.67 e-h |
| | $T_4$ | 4.667 c-h | 8.333 cde | 11.00 cd | 11.67 def |
| $As_2$ | $T_0$ | 4.000 e-j | 6.00 ghi | 8.33 g-j | 9.00 h-k |
| | $T_1$ | 3.333 g-j | 5.00 ij | 7.00 ijk | 8.00 j-m |
| | $T_2$ | 4.667 c-h | 7.667 def | 10.67 cde | 11.67 def |
| | $T_3$ | 3.667 f-j | 5.333 hi | 6.667 jkl | 8.333 i-l |
| | $T_4$ | 4.333 d-i | 6.667 fgh | 8.667 f-i | 9.667 g-j |
| $As_3$ | $T_0$ | 2.667 ijk | 3.333 klm | 5.00 lm | 7.00 lmn |
| | $T_1$ | 1.333 k | 2.000 m | 4.00 m | 6.00 n |
| | $T_2$ | 3.000 h-k | 4.667 ijk | 7.333 h-k | 8.667 i-l |
| | $T_3$ | 2.333 jk | 3.000 lm | 4.667 m | 6.33 mn |
| | $T_4$ | 2.667 ijk | 3.667 jkl | 5.667 klm | 7.667 k-n |
| $LSD_{(0.05)}$ | | 1.770 | 1.492 | 1.941 | 1.999 |
| CV (%) | | 24.56 | 13.19 | 12.81 | 11.50 |
| Significant level | | * | * | * | * |

* - Significant at 5% level

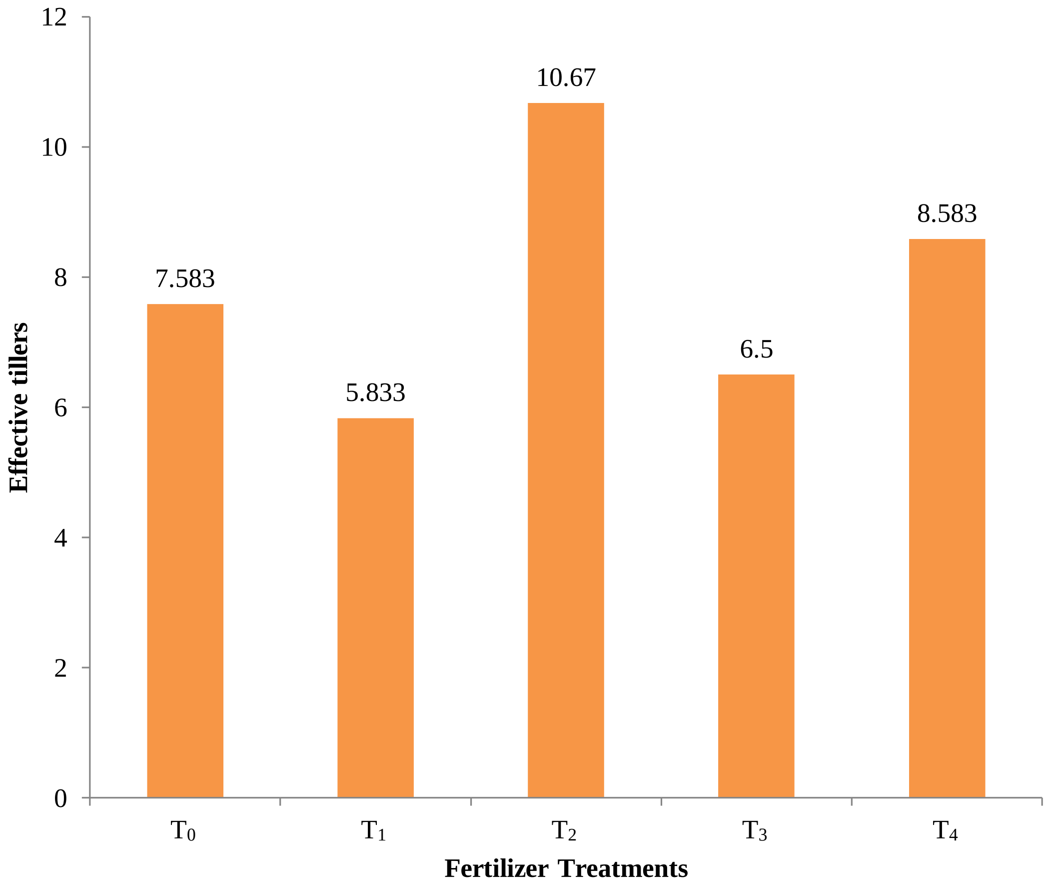
$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

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

### Effect of fertilizer

The number of effective tillers $hill^{-1}$ of BRRI dhan47 were significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 5 and Appendix VI). The results revealed that the treatment $T_2$ produced the highest number of effective tillers $hill^{-1}$ (10.67) and the treatment $T_1$ produced the lowest number of effective tillers (5.833). Nayak *et al*. (2007) reported that a significant increase in number of effective tillers $hill^{-1}$ due to the application of organic manure with chemical fertilizers.

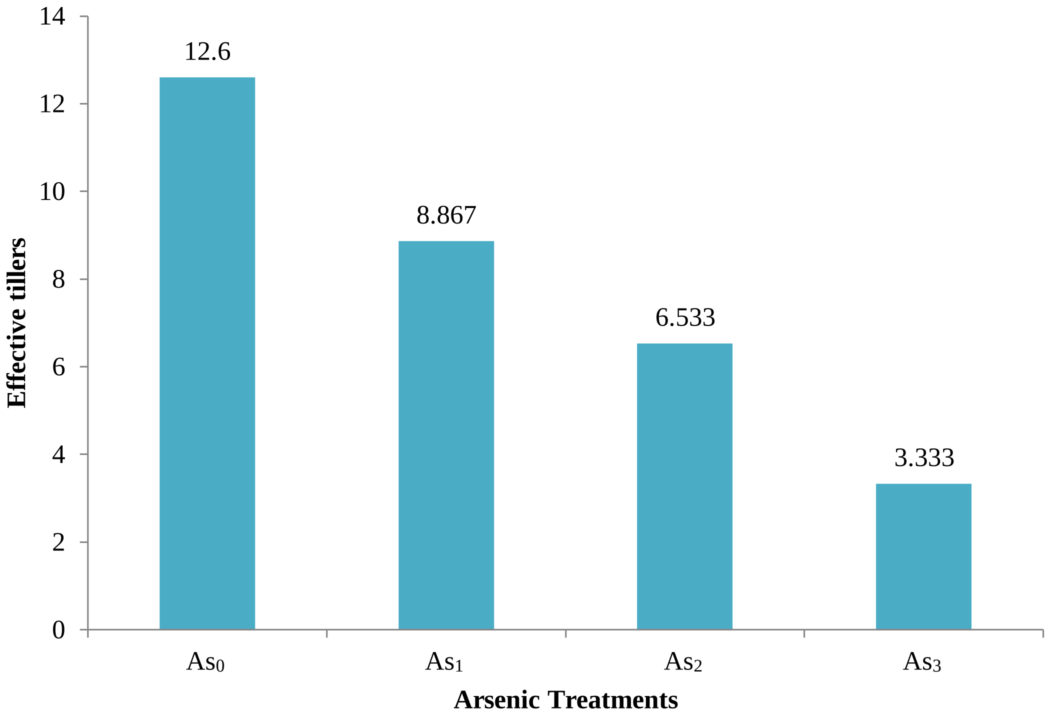



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 5: Effect of different doses of fertilizers (vermicompost and inorganic) on number of effective tillers $hill^{-1}$**

### Effect of arsenic

Different doses of arsenic had significant effect on the number of effective tillers hill$^{-1}$ of BRRI dhan47 (Figure 6 and Appendix VII). The highest number of effective tillers hill$^{-1}$ (12.60) was observed from the $As_0$ treatment and the lowest (3.333) was observed from $As_3$ treatment. Arsenic is a poisonous and toxic heavy metal which exerts hampering and hindering effect on plant physiology. Kang *et al.* (1996) reported that when the level of arsenic increased, the number of effective tillers hill$^{-1}$ decreased.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 6: Effect of different doses of arsenic on number of effective tillers hill$^{-1}$**

### Interaction effect of fertilizer and arsenic

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant variation on number of effective tillers hill$^{-1}$ of BRRI dhan47 (Table 3). The highest number of effective tillers hill$^{-1}$ (15.33) was observed from the $As_0T_2$ treatment which was statistically similar with $As_0T_4$ (13.67), whereas, the lowest (1) was observed from $As_3T_1$ treatment which was statistically similar with $As_3T_3$ (2.333). Hossain *et al.* (2008) found that by increasing arsenic concentrations, the number of effective tillers hill$^{-1}$ reduced.

**Table 3: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on number of effective tillers hill$^{-1}$**

| Treatments | | Number of effective tillers hill$^{-1}$ |
|---|---|---|
| $As_0$ | $T_0$ | 12.67 bc |
| | $T_1$ | 10.33 cde |
| | $T_2$ | 15.33 a |
| | $T_3$ | 11.00 cd |
| | $T_4$ | 13.67 ab |
| $As_1$ | $T_0$ | 8.333 efg |
| | $T_1$ | 6.667 g-j |
| | $T_2$ | 12.33 bc |
| | $T_3$ | 7.667 fgh |
| | $T_4$ | 9.333 def |
| $As_2$ | $T_0$ | 6.000 g-j |
| | $T_1$ | 5.333 h-k |
| | $T_2$ | 9.333 def |
| | $T_3$ | 5.00 ijk |
| | $T_4$ | 7.00 f-i |
| $As_3$ | $T_0$ | 3.33 klm |
| | $T_1$ | 1.00 m |
| | $T_2$ | 5.667 h-k |
| | $T_3$ | 2.333 lm |
| | $T_4$ | 4.333 jkl |
| LSD $_{(0.05)}$ | | 2.363 |
| CV (%) | | 18.28 |
| Significant level | | * |

* - Significant at 5% level

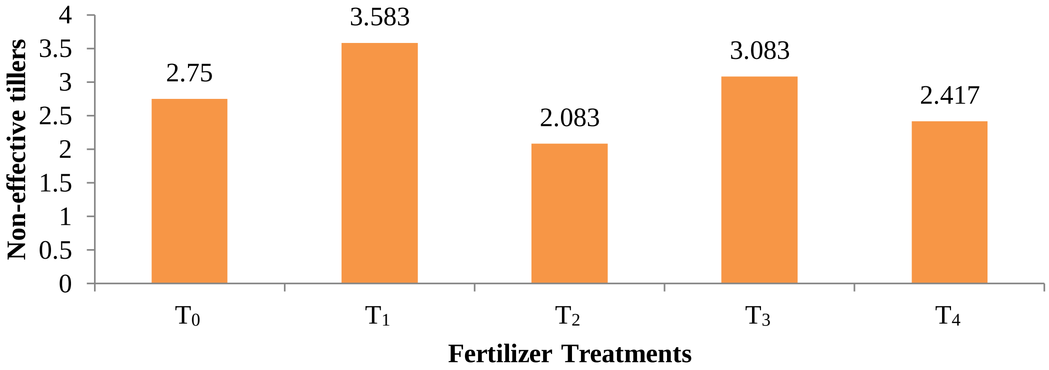
$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

## 4.4 Number of non-effective tillers hill$^{-1}$

### Effect of fertilizer

The number of non-effective tillers hill$^{-1}$ of BRRI dhan47 were significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 7 and Appendix VI). The results revealed that the treatment $T_1$ produced the highest number of non-effective tillers hill$^{-1}$ (3.583) and the treatment $T_2$ produced the lowest number of non-effective tillers (2.083).

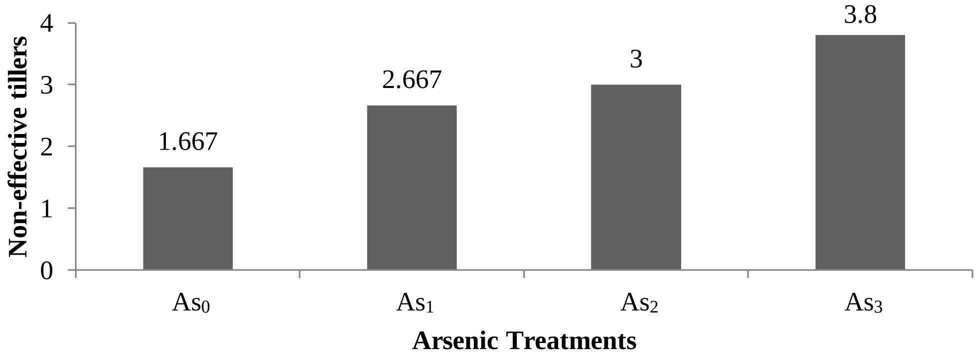



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 7: Effect of different doses of fertilizers on number of non-effective tillers hill$^{-1}$**

### Effect of arsenic

Number of non-effective tillers hill$^{-1}$ was significantly varied due to arsenic doses at all growth stages (Figure 8 and Appendix VII). The highest number of non-effective tillers hill$^{-1}$ (3.80) was recorded from $As_3$ treatment and the lowest number of non-effective tillers hill$^{-1}$ (1.667) was recorded from $As_0$ treatment.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 8: Effect of different doses of arsenic on number of non-effective tillers hill$^{-1}$**

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant variation on number of effective tillers hill$^{-1}$ of BRRI dhan47 (Table 4). The highest number of non-effective tillers hill$^{-1}$ (5.00) was

**Table 4: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on number of non-effective tillers hill$^{-1}$**

| Treatments | | Number of non-effective tillers hill$^{-1}$ |
|---|---|---|
| $As_0$ | $T_0$ | 1.667 fgh |
| | $T_1$ | 2.333 d-g |
| | $T_2$ | 1.000 h |
| | $T_3$ | 2.000 e-h |
| | $T_4$ | 1.333 gh |
| $As_1$ | $T_0$ | 2.667 c-f |
| | $T_1$ | 3.333 bcd |
| | $T_2$ | 2.000 e-h |
| | $T_3$ | 3.000 b-e |
| | $T_4$ | 2.333 d-g |
| $As_2$ | $T_0$ | 3.000 b-e |
| | $T_1$ | 3.667 bc |
| | $T_2$ | 2.333 d-g |
| | $T_3$ | 3.333 bcd |
| | $T_4$ | 2.667 c-f |
| $As_3$ | $T_0$ | 3.667 bc |
| | $T_1$ | 5.000 a |
| | $T_2$ | 3.000 b-e |
| | $T_3$ | 4.000 ab |
| | $T_4$ | 3.333 bcd |
| $LSD_{(0.05)}$ | | 1.278 |
| CV (%) | | 27.83 |
| Significant level | | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

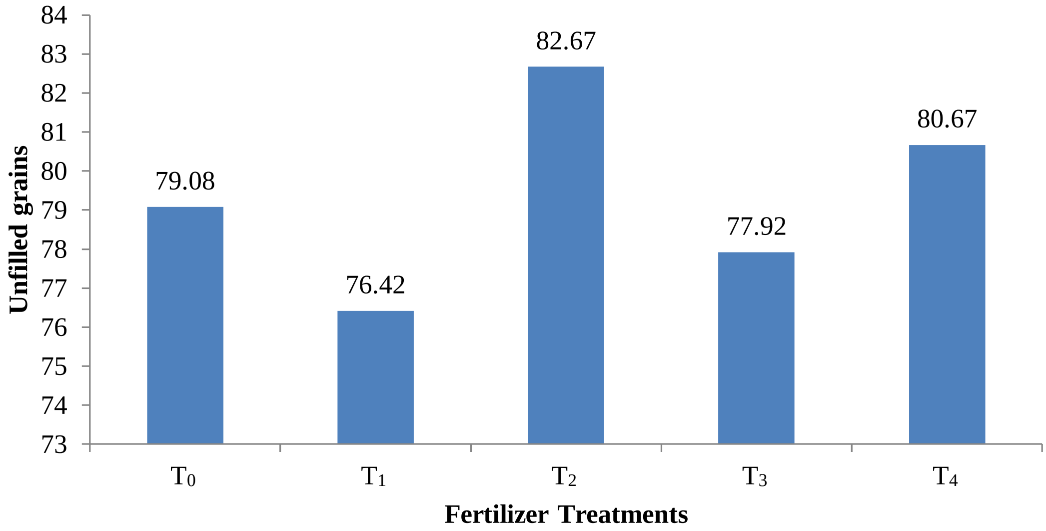
$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

recorded from $As_3T_1$ which was statistically similar with $As_3T_3$ (4.00) whereas, the lowest number of non-effective tillers hill$^{-1}$ (1.00) was recorded from $As_0T_2$ which was statistically similar with $As_0T_4$ (1.333).

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

### Effect of fertilizer

The number of filled grains panicle$^{-1}$ of BRRI dhan47 were significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 9 and Appendix VI). The results revealed that the treatment $T_2$ produced the highest number of filled grains (82.67) which was statistically similar with $T_4$ (80.67) and the lowest (76.42) was recorded from the treatment $T_1$.

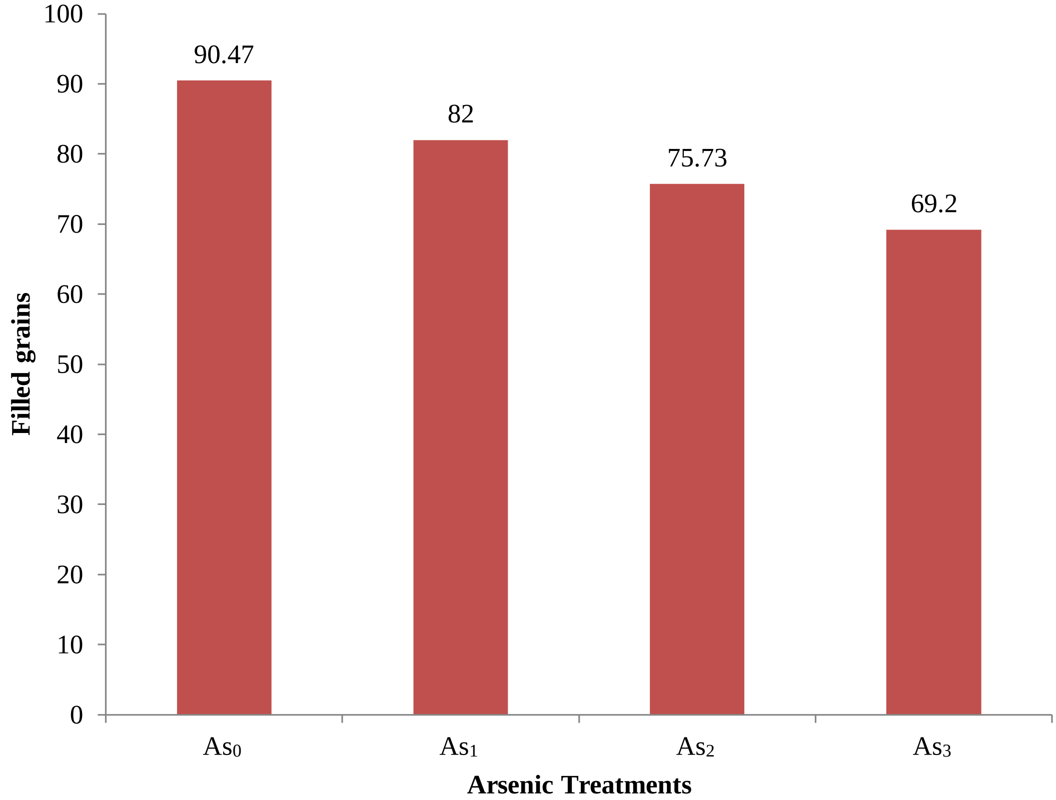



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 9: Effect of different doses of fertilizers on number of filled grains panicle$^{-1}$**

### Effect of arsenic

Different doses of arsenic had significantly influenced the number of filled grains panicle$^{-1}$ (Figure 10 and Appendix VII). The highest number of filled grains (90.47) was observed in $As_0$ treatment and the lowest (69.20) was observed in $As_3$ treatment. As the number of filled grains panicle$^{-1}$ is a growth contributing character, increase in the number of filled grains panicle$^{-1}$ increase the yield. The yield of rice grain was highly affected by arsenic treatments; the highest value of grains was recorded at control and sharply decreased with increasing arsenic concentration. Similarly, Islam *et al.* (2004) reported that the irrigation water added arsenic up to 0.25 ppm enhanced unfilled grains panicle$^{-1}$ and finally the grain yield of Boro rice and the further doses of arsenic depressed the plant growth, yield and yield components.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 10: Effect of different doses of arsenic on number of filled grains panicle$^{-1}$**

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant influence on number of filled grains panicle$^{-1}$. In respect of the number of filled grains, the highest number (94.67) of filled grains was recorded from $As_0T_2$ which was statistically similar with $As_0T_4$ (92.33) and $As_0T_0$ (90.00) whereas, the lowest number (66.33) of filled grains panicle$^{-1}$ recorded from $As_3T_1$ which was statistically similar with $As_3T_3$ (68.33) and $As_3T_0$ (69.33) (Table 5). This result agreed with Hossain *et al.* (2008) who reported that number of filled grain panicle$^{-1}$ decreased with increasing the concentration of arsenic.

**Table 5: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on number of filled grains panicle$^{-1}$**

| Treatments | | Number of filled grains panicle$^{-1}$ |
|---|---|---|
| $As_0$ | $T_0$ | 90.33 abc |
| | $T_1$ | 86.33 cde |
| | $T_2$ | 94.67 a |
| | $T_3$ | 88.67 bcd |
| | $T_4$ | 92.33 ab |
| $As_1$ | $T_0$ | 81.33 efg |
| | $T_1$ | 79.33 fgh |
| | $T_2$ | 85.67 cde |
| | $T_3$ | 80.00 fgh |
| | $T_4$ | 83.67 def |
| $As_2$ | $T_0$ | 75.33 h-k |
| | $T_1$ | 73.67 i-m |
| | $T_2$ | 78.67 f-i |
| | $T_3$ | 74.67 h-l |
| | $T_4$ | 76.33 g-j |
| $As_3$ | $T_0$ | 69.33 lmn |
| | $T_1$ | 66.33 n |
| | $T_2$ | 71.67 j-n |
| | $T_3$ | 68.33 mn |
| | $T_4$ | 70.33 k-n |
| LSD $_{(0.05)}$ | | 5.551 |
| CV (%) | | 4.24 |
| Significant level | | * |

* - Significant at 5% level

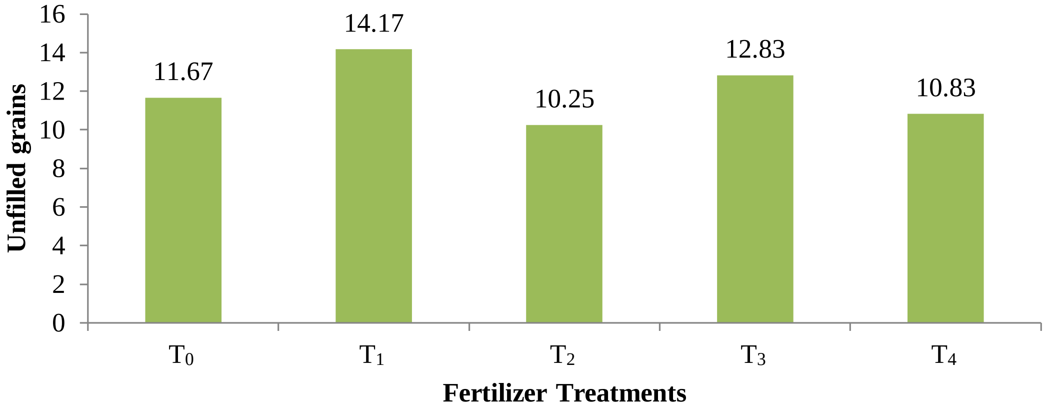
$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

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

### Effect of fertilizer

The number of unfilled grains panicle$^{-1}$ of BRRI dhan47 were significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 11 and Appendix VI). The results revealed that the treatment $T_1$ produced the highest number of unfilled grains (14.17) which was statistically similar with $T_3$ (12.83) and the lowest (10.25) was recorded from the treatment $T_2$ which was statistically similar with $T_0$ (11.67) and $T_4$ (10.83).

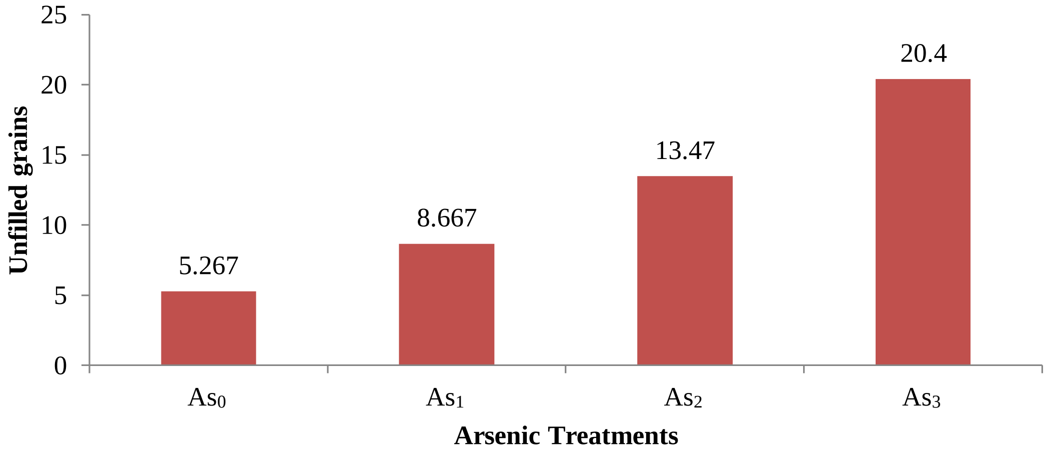



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 11: Effect of different doses of fertilizers (vermicompost and inorganic) on number of unfilled grains panicle$^{-1}$**

### Effect of arsenic

Different doses of arsenic had significantly influence on the number of unfilled grains panicle$^{-1}$ (Figure 15 and Appendix VII). The highest number of unfilled grains (20.4) was observed in $As_3$ treatment and the lowest (5.267) was observed in $As_0$ treatment.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 12: Effect of different doses of arsenic on number of unfilled grains panicle$^{-1}$**

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant influence on number of unfilled grains panicle$^{-1}$. The highest number of unfilled grains panicle$^{-1}$ (23.33) was recorded from $As_3T_1$ which was statistically similar with $As_3T_3$ (21.33), $As_3T_0$ (20.67) and $As_3T_4$ (19.33).

**Table 6: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on number of unfilled grains panicle$^{-1}$**

| Treatments | | Number of unfilled grains panicle$^{-1}$ |
|---|---|---|
| $As_0$ | $T_0$ | 5.667 ijk |
| | $T_1$ | 6.667 ijk |
| | $T_2$ | 3.667 k |
| | $T_3$ | 6.000 ijk |
| | $T_4$ | 4.333 jk |
| $As_1$ | $T_0$ | 8.333 g-j |
| | $T_1$ | 11.33 e-h |
| | $T_2$ | 6.333 ijk |
| | $T_3$ | 9.667 f-i |
| | $T_4$ | 7.667 h-k |
| $As_2$ | $T_0$ | 13.33 def |
| | $T_1$ | 15.33 cde |
| | $T_2$ | 11.33 e-h |
| | $T_3$ | 14.67 de |
| | $T_4$ | 12.67 efg |
| $As_3$ | $T_0$ | 20.67 ab |
| | $T_1$ | 23.33 a |
| | $T_2$ | 17.33 bcd |
| | $T_3$ | 21.33 ab |
| | $T_4$ | 19.33 abc |
| LSD $_{(0.05)}$ | | 4.402 |
| CV (%) | | 22.32 |
| Significant level | | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

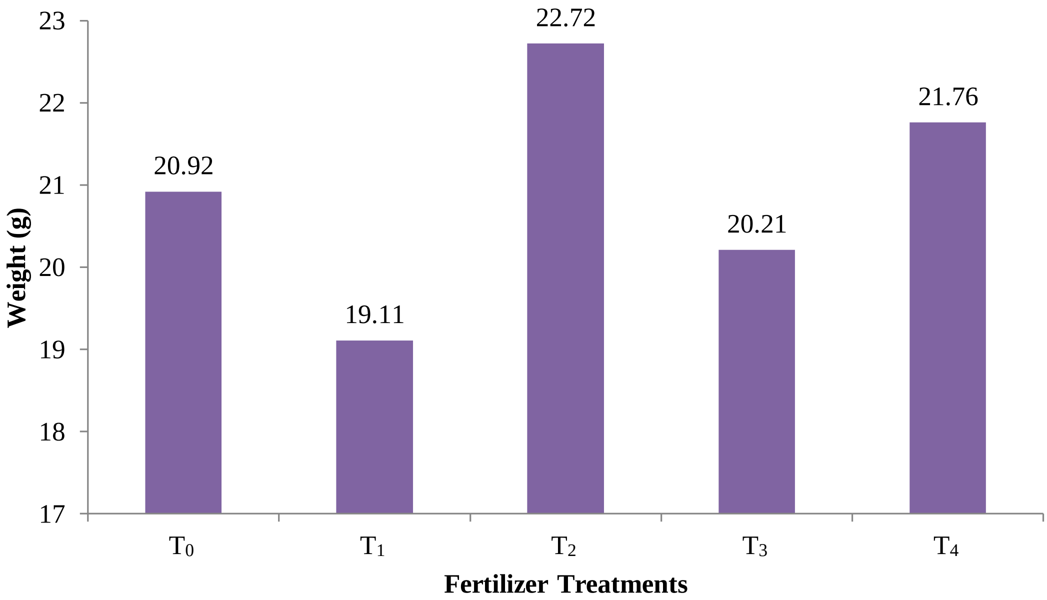
$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

The lowest number of unfilled grains panicle$^{-1}$ was recorded from $As_0T_2$ (3.667) which was statistically similar with $As_0T_4$ (4.333), $As_0T_0$ (5.667), $As_0T_3$ (6.000) and $As_1T_2$ (6.333) (Table 6).

## 4.7 Weight of 1000 grain

### Effect of fertilizer

The 1000 grain weight of BRRI dhan47 was significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 13 and Appendix VI). The results revealed that the highest 1000 grain weight (g) was recorded from the treatment $T_2$ (22.72) which was statistically similar with $T_0$ (21.76) whereas, the lowest (19.11) was recorded from the treatment $T_1$ which was statistically similar with $T_3$ (20.21). Yang *et al*. (2004) recorded that 1000 grain weight was increased by the application of organic manure with chemical fertilizers.

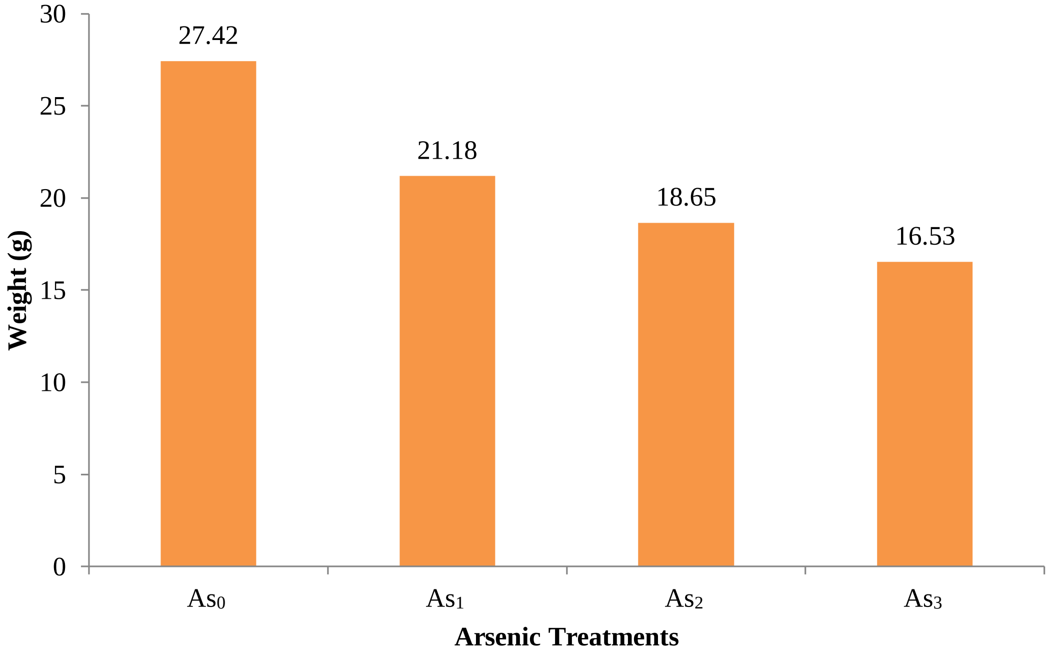



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 13: Effect of different doses of fertilizers (vermicompost and inorganic) on 1000 grain weight (g)**

### Effect of arsenic

Different doses of arsenic had significantly influenced on 1000 grain weight of BRRI dhan47 (Figure 14 and Appendix VII). The results revealed that the highest 1000 grain weight (g) was recorded from the treatment $As_0$ (27.42) and the lowest (16.53) was recorded from the treatment $As_3$.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 14: Effect of different doses of arsenic on 1000 grain weight (g)**

### Interaction effect of fertilizer and arsenic

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic showed significant influence on 1000 grain weight (g) of BRRI dhan47. The results revealed that the highest 1000 grain weight (g) was recorded from the treatment $As_0T_2$ (29.40) which was statistically similar with $As_0T_4$ (28.30) and $As_0T_0$ (27.60) whereas, the lowest (15.17) was recorded from the treatment $As_3T_1$ which was statistically similar with $As_3T_3$ (16.28), $As_3T_0$ (16.49) and $As_3T_4$ (17.23) (Table 7).

**Table 7: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on 1000 grain weight (g)**

| Treatments | | 1000 grain weight (g) |
|---|---|---|
| $As_0$ | $T_0$ | 27.60 ab |
| | $T_1$ | 25.30 cd |
| | $T_2$ | 29.40 a |
| | $T_3$ | 26.50 bc |
| | $T_4$ | 28.30 ab |
| $As_1$ | $T_0$ | 21.20 efg |
| | $T_1$ | 19.11 ghi |
| | $T_2$ | 23.20 de |
| | $T_3$ | 20.10 fgh |
| | $T_4$ | 22.30 ef |
| $As_2$ | $T_0$ | 18.40 hij |
| | $T_1$ | 16.88 jk |
| | $T_2$ | 20.80 fg |
| | $T_3$ | 17.95 hij |
| | $T_4$ | 19.20 ghi |
| $As_3$ | $T_0$ | 16.49 jk |
| | $T_1$ | 15.17 k |
| | $T_2$ | 17.48 ij |
| | $T_3$ | 16.28 ijk |
| | $T_4$ | 17.23 ijk |
| LSD $_{(0.05)}$ | | 2.216 |
| CV (%) | | 6.41 |
| Significant level | | * |

* - Significant at 5% level

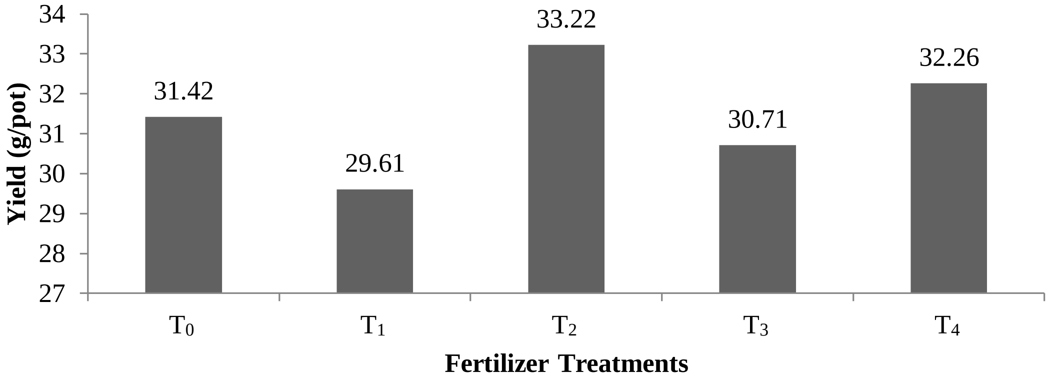
$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

## 4.8 Grain yield (g/pot)

### Effect of fertilizer

Grain yield (g/pot) of BRRI dhan47 was significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 15 and Appendix VI). The highest grain yield (33.22 g/pot) was produced from $T_2$ treatment and the lowest (29.61 g/pot) was recorded from $T_1$. Rahman *et al.* (2009) reported that the application of organic manure and chemical fertilizers increased the grain yield of rice.

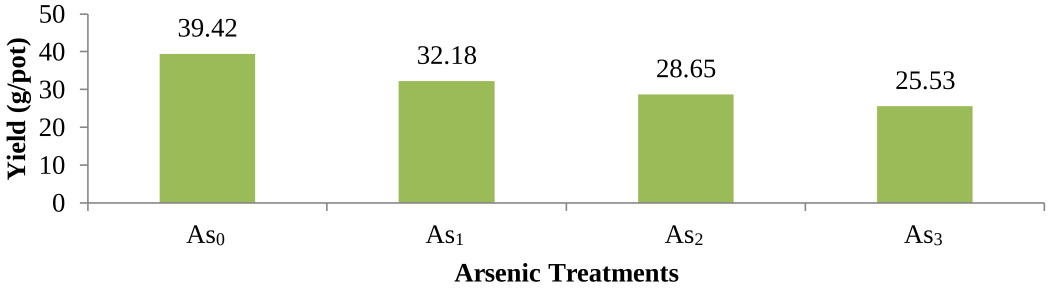



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 15: Effect of different doses of fertilizers (vermicompost and inorganic) on grain yield (g/pot)**

**Effect of arsenic**

Different doses of arsenic had significant influence on grain yield (Figure 16 and Appendix VII). The highest grain yield (39.42 g/pot) was obtained from $As_0$ treatment and the lowest (25.53 g/pot) from $As_3$ treatment. This result agreed with Hossain (2005) who found that yield reductions of more than 40% and 60% for two popular rice varieties (BRRI dhan28 and Iratom-24) when 20 mg/kg of arsenic was added to soils, compared to the control.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 16: Effect of different doses of arsenic on grain yield (g/pot)**

## Interaction effect of fertilizer and arsenic

Grain yield of BRRI dhan47 was significantly influenced by the interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic (Table 8). The highest grain yield (41.40 g/pot) was recorded from $As_0T_2$ and the lowest yield (24.17 g/pot) was recorded from the treatment $As_3T_1$.

**Table 8: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on grain yield (g/pot)**

| Treatments | | Grain yield (g/pot) |
|---|---|---|
| $As_0$ | $T_0$ | 39.60 c |
| | $T_1$ | 37.30 e |
| | $T_2$ | 41.40 a |
| | $T_3$ | 38.50 d |
| | $T_4$ | 40.30 b |
| $As_1$ | $T_0$ | 32.30 h |
| | $T_1$ | 30.11 j |
| | $T_2$ | 34.20 f |
| | $T_3$ | 31.10 i |
| | $T_4$ | 33.30 g |
| $As_2$ | $T_0$ | 28.40 l |
| | $T_1$ | 26.88 n |
| | $T_2$ | 30.80 i |
| | $T_3$ | 27.95 m |
| | $T_4$ | 29.20 k |
| $As_3$ | $T_0$ | 25.49 p |
| | $T_1$ | 24.17 q |
| | $T_2$ | 26.48 o |
| | $T_3$ | 25.28 p |
| | $T_4$ | 26.23 o |
| $LSD_{(0.05)}$ | | 0.3259 |
| CV (%) | | 0.63 |
| Significant level | | * |

* - Significant at 5% level

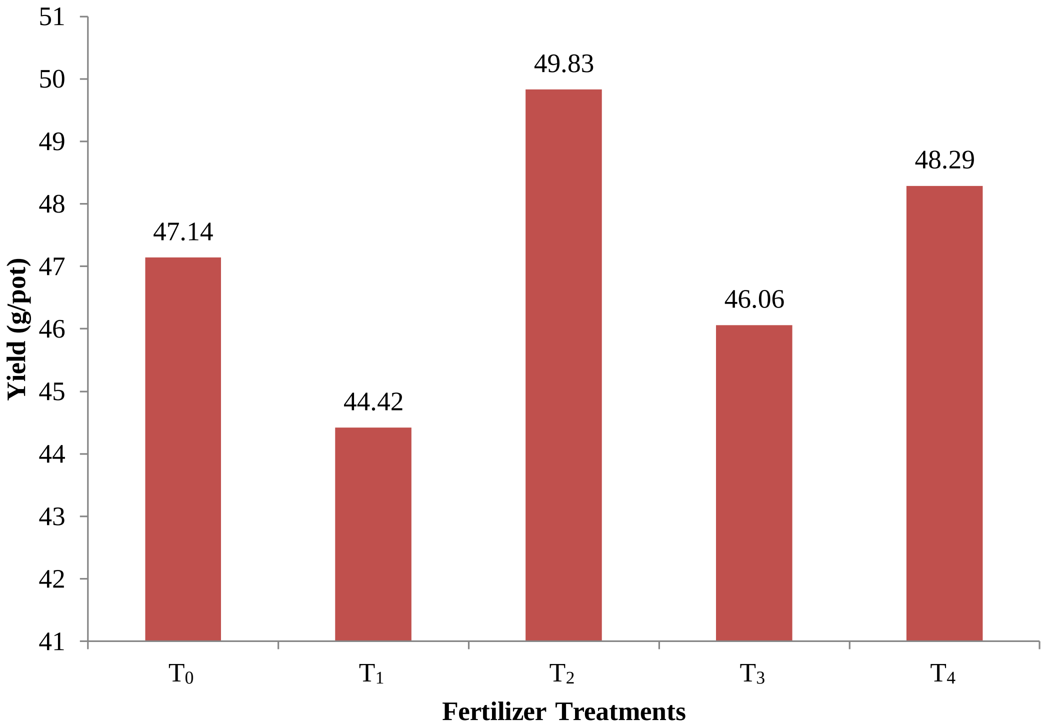
$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

## 4.9 Straw yield (g/pot)

## Effect of fertilizer

Straw yield (g/pot) of BRRI dhan47 was significantly influenced by different doses of fertilizers (vermicompost and inorganic) (Figure 17 and Appendix VI). The highest straw yield (49.83 g/pot) was recorded from $T_2$ and the lowest (44.42 g/pot) was recorded from the treatment $T_1$.

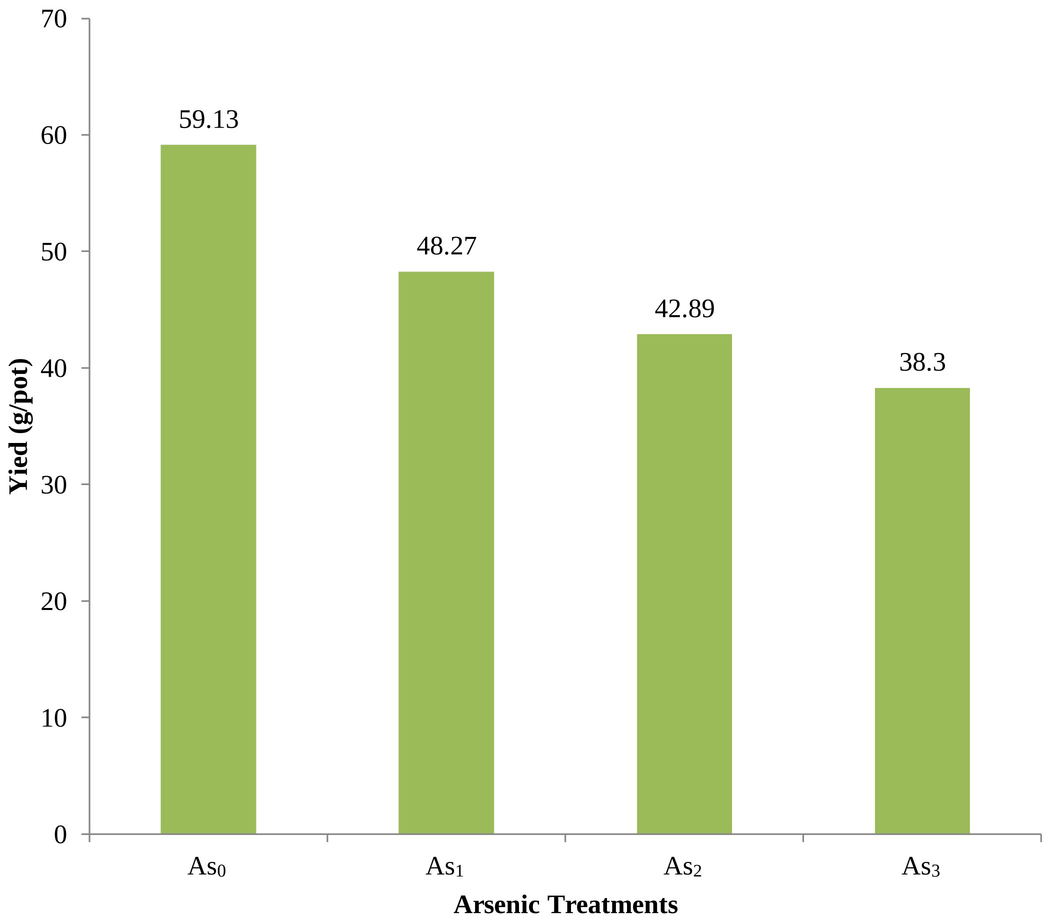



$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Figure 17: Effect of different doses of fertilizers (vermicompost and inorganic) on straw yield (g/pot)**

### Effect of arsenic

Different arsenic doses had significant influence on straw yield (Figure 18 and Appendix VII). The highest straw yield (59.13 g/pot) was obtained from $As_0$ treatment and the lowest (38.3 g/pot) was recorded from $As_3$ treatment. Results showed that higher doses of arsenic gave lower yield. This may be due to toxic effect of arsenic. Begum *et al.* (2008) showed that the straw yield of Boro rice was reduced by 21.0 % for 15 ppm As treatment and 65.2 % due to 30 ppm As.




$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Figure 18: Effect of different doses of arsenic on straw yield (g/pot)**

**Interaction effect of fertilizer and arsenic**

Straw yield of Boro rice was significantly influenced by the interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic (Table 9). The highest straw yield (62.10 g/pot) was recorded from the treatment $As_0T_2$ and the lowest yield (39.72 g/pot) was recorded from the treatment $As_3T_1$.

**Table 9: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on straw yield (g/pot)**

| Treatments | | Straw yield (g/pot) |
|---|---|---|
| $As_0$ | $T_0$ | 59.40 c |
| | $T_1$ | 55.95 e |
| | $T_2$ | 62.10 a |
| | $T_3$ | 57.75 d |
| | $T_4$ | 60.45 b |
| $As_1$ | $T_0$ | 48.30 h |
| | $T_1$ | 45.16 k |
| | $T_2$ | 51.30 f |
| | $T_3$ | 46.65 i |
| | $T_4$ | 49.95 g |
| $As_2$ | $T_0$ | 42.60 m |
| | $T_1$ | 40.32 o |
| | $T_2$ | 46.20 j |
| | $T_3$ | 41.93 n |
| | $T_4$ | 38.24 l |
| $As_3$ | $T_0$ | 36.26 r |
| | $T_1$ | 39.72 t |
| | $T_2$ | 37.92 p |
| | $T_3$ | 39.35 s |
| | $T_4$ | 38.70 q |
| $LSD_{(0.05)}$ | | 0.2609 |
| CV (%) | | 0.34 |
| Significant level | | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

## 4.10 Chemical Composition

### 4.10.1 Nitrogen (N) content in grain

**Effect of fertilizer**

Nitrogen (N) content in grain showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 10). The highest N content (1.445 %) was observed in grain from the treatment $T_2$ and the lowest amount of N (1.235 %) found in grain from treatment $T_1$. Khatik and Dikshit (2001) reported that the increasing concentration of N in grain, straw and root of organic manure treated plots indicate that organic manures increased the availability of N in the soil which in-turn increased the N contents in grain, straw and root of rice.

**Table 10: Effect of different doses of fertilizers (vermicompost and inorganic) on N, P, K and As content in grain**

| Treatments | Grain | | | |
|---|---|---|---|---|
| | % N | % P | % K | As (ppm) |
| $T_0$ | 1.332 c | 0.4950 c | 0.2998 a | 1.360 c |
| $T_1$ | 1.235 d | 0.4050 d | 0.2645 a | 1.707 a |
| $T_2$ | 1.445 a | 0.5875 a | 0.3340 a | 1.222 e |
| $T_3$ | 1.300 c | 0.4400 d | 0.2850 a | 1.472 b |
| $T_4$ | 1.390 b | 0.5375 b | 0.3173 a | 1.290 d |
| LSD $_{(0.05)}$ | 0.03690 | 0.03690 | 0.08251 | 0.02609 |
| CV (%) | 3.32 | 8.23 | 2.39 | 2.35 |
| Significant level | * | * | NS | * |

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

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

### Effect of arsenic

Nitrogen (N) content in grain was significant due to different doses of arsenic (Table 11). The highest N content (1.748 %) was observed in grain from the treatment $As_0$ and the lowest amount of N (0.9520 %) found in grain from the treatment $As_3$.

**Table 11. Effect of different doses of arsenic on N, P, K and As content in grain**

| Treatments | Grain | | | |
|---|---|---|---|---|
| | % N | % P | % K | As (ppm) |
| $As_0$ | 1.748 a | 0.872 a | 0.4384 a | 0.000 d |
| $As_1$ | 1.474 b | 0.600 b | 0.3512 b | 0.972 c |
| $As_2$ | 1.188 c | 0.364 c | 0.2464 c | 1.896 b |
| $As_3$ | 0.9520 d | 0.136 d | 0.1644 d | 2.774 a |
| LSD $_{(0.05)}$ | 0.0330 | 0.0330 | 0.0738 | 0.02334 |
| CV (%) | 3.32 | 8.23 | 2.39 | 2.35 |
| Significant level | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

### Interaction effect of fertilizer and arsenic

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on nitrogen (N) content in grain (Table 12). The highest N (1.860 %) in grain was observed from the treatment $As_0T_0$ which was statistically similar with $As_0T_4$ (1.810 %) and the lowest N (0.860 %) in grain was observed from $As_3T_1$ which was statistically similar with $As_0T_0$ (0.930 %).

**Table 12: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on N, P, K and As content in grain**

| Treatments | | Grain | | | |
|---|---|---|---|---|---|
| | | % N | % P | % K | As (ppm) |
| $As_0$ | $T_0$ | 1.740 bc | 0.880 bc | 0.438 ab | 0.000 o |
| | $T_1$ | 1.630 de | 0.770 de | 0.404 a-d | 0.000 o |
| | $T_2$ | 1.860 a | 0.970 a | 0.470 a | 0.000 o |
| | $T_3$ | 1.700 cd | 0.820 cd | 0.425 abc | 0.000 o |
| | $T_4$ | 1.810 ab | 0.920 ab | 0.454 a | 0.000 o |
| $As_1$ | $T_0$ | 1.470 gh | 0.610 g | 0.352 a-g | 0.940 l |
| | $T_1$ | 1.360 ij | 0.510 h | 0.316 a-i | 1.390 j |
| | $T_2$ | 1.590 ef | 0.710 ef | 0.384 a-e | 0.610 n |
| | $T_3$ | 1.430 hi | 0.520 h | 0.336 a-h | 1.150 k |
| | $T_4$ | 1.520 fg | 0.650 fg | 0.368 a-f | 0.770 m |
| $As_2$ | $T_0$ | 1.190 lm | 0.360 jk | 0.246 d-j | 1.810 g |
| | $T_1$ | 1.090 no | 0.270 lm | 0.212 f-j | 2.310 e |
| | $T_2$ | 1.290 jk | 0.460 hi | 0.281 b-j | 1.660 i |
| | $T_3$ | 1.130 mn | 0.320 kl | 0.231 e-j | 1.960 f |
| | $T_4$ | 1.240 kl | 0.410 ij | 0.262 c-j | 1.740 h |
| $As_3$ | $T_0$ | 0.930 qr | 0.130 op | 0.163 ij | 2.690 c |
| | $T_1$ | 0.860 r | 0.070 p | 0.126 j | 3.130 a |
| | $T_2$ | 1.040 op | 0.210 mn | 0.200 g-j | 2.620 d |
| | $T_3$ | 0.940 q | 0.100 op | 0.148 j | 2.780 b |
| | $T_4$ | 0.990 pq | 0.170 no | 0.185 hij | 2.650 cd |
| $LSD_{(0.05)}$ | | 0.07380 | 0.07380 | 0.1650 | 0.05218 |
| CV (%) | | 3.32 | 8.23 | 2.39 | 2.35 |
| Significant level | | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

### 4.10.2 Phosphorus (P) content in grain

**Effect of fertilizer**

Phosphorus (P) content in grain showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 10). The highest P content (0.5875 %) was observed in grain from the treatment $T_2$ and the lowest amount of P (0.4050 %) found in grain for the treatment $T_1$ which was statistically similar with $T_3$ (0.440 %). Guan (1989) reported that organic manures increased the P concentrations in grain, straw and root of rice.

**Effect of arsenic**

Phosphorus (P) content in grain showed statistically significant difference due to different doses of arsenic (Table 11). The highest P content (0.872 %) was observed in grain from the treatment $As_0$ and the lowest amount of P (0.512 %) found in grain from the treatment $As_3$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (organic and inorganic) and different doses of arsenic had significant influence on phosphorus (P) content in grain (Table 12). The highest P (0.970 %) in grain was observed from the treatment $As_0T_2$ which was statistically similar with $As_0T_4$ (0.920 %) and the lowest P (0.070 %) in grain was observed from $As_3T_1$ which was statistically similar with $As_3T_3$ (0.100 %) and $As_3T_0$ (0.130 %).

### 4.10.3 Potassium (K) content in grain

**Effect of fertilizer**

Effect of different doses of fertilizers (vermicompost and inorganic) on Potassium (K) content in grain was insignificant (Table 10).

**Effect of arsenic**

Potassium (K) content in grain showed statistically significant difference due to different doses of arsenic (Table 11). The highest K content (0.4384 %) was observed in grain from the treatment $As_0$ and the lowest amount of K (0.1644 %) found in grain from the treatment $As_3$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on potassium (K) content in grain (Table 12). The highest K (0.470 %) in grain was observed from the treatment $As_0T_2$ which was statistically similar with $As_0T_4$ (0.454 %), $As_0T_0$ (0.438 %) and $As_0T_3$ (0.425 %). whereas, the lowest K (0.126 %) in grain was observed from $As_3T_1$ which was statistically similar with $As_3T_3$ (0.148 %), $As_3T_0$ (0.163 %) and $As_3T_4$ (0.185 %).

**4.10.4 Arsenic (As) content in grain**

**Effect of fertilizer**

Arsenic (As) content in grain showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 10). The highest As content (1.707 ppm) was observed in grain from the treatment $T_1$ and the lowest amount of As (1.222 ppm) found in grain for the treatment $T_2$. The As content in grain was lower by the treatment ($T_2$) containing more vermicompost because worms reduced the arsenic availability through the formation of an insoluble and stable arseno-organic complexes. Das *et al*. (2008) stated that the addition of organic matter in paddy field reduced the arsenic availability through the formation of an insoluble and stable arseno-organic complexes and their adsorption on to organic colloids of soil solutions.

**Effect of arsenic**

Arsenic (As) content in grain showed statistically significant difference due to different doses of arsenic (Table 11). The highest As content (2.774 ppm) was observed in grain from the treatment $As_3$ and the lowest amount of As (0 ppm) found in grain from the treatment $As_0$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on arsenic (As) content in grain (Table 12). The highest As (3.130 ppm) in grain was observed from the treatment $As_3T_1$ whereas, the lowest As (0 ppm) in grain was observed from $As_0T_0$ which was statistically similar with $As_0T_1$ (0 ppm), $As_0T_2$ (0 ppm), $As_0T_3$ (0 ppm) and $As_0T_4$ (0 ppm).

### 4.10.5 Nitrogen (N) content in straw

**Effect of fertilizer**

Nitrogen (N) content in straw showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 13). The highest N content (0.9450 %) was observed in straw from the treatment $T_2$ and the lowest amount of N (0.7350 %) found in straw for the treatment $T_1$.

**Table 13: Effect of different doses of fertilizers (vermicompost and inorganic) on N, P, K and As content in straw**

| Treatments | Straw | | | |
|---|---|---|---|---|
| | % N | % P | % K | As (ppm) |
| $T_0$ | 0.8325 c | 0.4450 c | 1.043 c | 2.747 c |
| $T_1$ | 0.7350 d | 0.3550 e | 0.9225 e | 3.510 a |
| $T_2$ | 0.9450 a | 0.5375 a | 1.163 a | 2.457 e |
| $T_3$ | 0.790 c | 0.3900 d | 0.9925 d | 2.932 b |
| $T_4$ | 0.890 b | 0.4875 a | 1.105 b | 2.587 d |
| LSD $_{(0.05)}$ | 0.04519 | 0.02609 | 0.02609 | 0.03690 |
| CV (%) | 6.73 | 6.73 | 2.58 | 1.40 |
| Significant level | * | * | * | * |

* - Significant at 5% level

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Effect of arsenic**

Nitrogen (N) content in straw showed statistically significant difference due to different doses of arsenic (Table 14). The highest N content (1.248 %) was observed in straw from the treatment $As_0$ and the lowest amount of N (0.440 %) found in straw from the treatment $As_3$.

**Table 14. Effect of different doses of arsenic on N, P, K and As content in straw**

| Treatments | Straw | | | |
|---|---|---|---|---|
| | % N | % P | % K | As (ppm) |
| $As_0$ | 1.248 a | 0.822 a | 1.582 a | 0.000 d |
| $As_1$ | 0.974 b | 0.550 b | 1.232 b | 2.410 c |
| $As_2$ | 0.688 c | 0.314 c | 0.8320 c | 3.638 b |
| $As_3$ | 0.440 d | 0.086 d | 0.5340 d | 5.340 a |
| LSD $_{(0.05)}$ | 0.04042 | 0.02334 | 0.02334 | 0.03300 |
| CV (%) | 6.73 | 6.73 | 2.58 | 1.40 |
| Significant level | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on nitrogen (N) content in straw (Table 15). The highest N (1.360 %) in straw was observed from the treatment $As_0T_0$ which was statistically similar with $As_0T_4$ (1.310 %) and the lowest N (0.360 %) in straw was observed from $As_3T_1$ which was statistically similar with $As_3T_3$ (0.400 %) and $As_3T_0$ (0.430 %).

**4.10.6 Phosphorus (P) content in straw**

**Effect of fertilizer**

Phosphorus (P) content in straw showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 13). The highest P content (0.5375 %) was observed in straw from the treatment $T_2$ which was statistically similar with the treatment $T_4$ (0.4875 %) and the lowest amount of P (0.3550 %) found in straw for the treatment $T_1$.

**Effect of arsenic**

Phosphorus (P) content in straw showed statistically significant difference due to different doses of arsenic (Table 14). The highest P content (0.822 %) was observed in straw from the treatment $As_0$ and the lowest amount of P (0.086 %) found in straw from the treatment $As_3$.

**Table 15: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on N, P, K and As content in straw**

| Treatments | | Straw | | | |
|---|---|---|---|---|---|
| | | % N | % P | % K | As (ppm) |
| $As_0$ | $T_0$ | 1.240 bc | 0.830 b | 1.580 c | 0.000 n |
| | $T_1$ | 1.130 de | 0.720 c | 1.460 d | 0.000 n |
| | $T_2$ | 1.360 a | 0.920 a | 1.700 a | 0.000 n |
| | $T_3$ | 1.200 cd | 0.770 c | 1.530 c | 0.000 n |
| | $T_4$ | 1.310 ab | 0.870 ab | 1.640 b | 0.000 n |
| $As_1$ | $T_0$ | 0.970 g | 0.560 e | 1.230 g | 2.350 k |
| | $T_1$ | 0.860 hi | 0.460 fg | 1.110 h | 3.410 h |
| | $T_2$ | 1.090 ef | 0.660 d | 1.350 e | 1.550 m |
| | $T_3$ | 0.930 gh | 0.470 f | 1.180 g | 2.810 j |
| | $T_4$ | 1.020 fg | 0.600 e | 1.290 f | 1.930 l |
| $As_2$ | $T_0$ | 0.690 kl | 0.310 ij | 0.830 k | 3.430 h |
| | $T_1$ | 0.590 m | 0.220 k | 0.710 l | 4.610 f |
| | $T_2$ | 0.790 ij | 0.410 gh | 0.950 i | 3.260 i |
| | $T_3$ | 0.630 lm | 0.270 jk | 0.780 k | 3.570 g |
| | $T_4$ | 0.740 jk | 0.360 hi | 0.890 j | 3.320 i |
| $As_3$ | $T_0$ | 0.430 op | 0.080 mn | 0.530 n | 5.210 c |
| | $T_1$ | 0.360 p | 0.020 o | 0.410 o | 6.020 a |
| | $T_2$ | 0.540 mn | 0.160 l | 0.650 m | 5.020 e |
| | $T_3$ | 0.400 op | 0.050 no | 0.480 n | 5.350 b |
| | $T_4$ | 0.490 no | 0.120 lm | 0.600 m | 5.100 d |
| $LSD_{(0.05)}$ | | 0.09039 | 0.05218 | 0.05218 | 0.07380 |
| CV (%) | | 6.73 | 6.73 | 2.58 | 1.40 |
| Significant level | | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

### Interaction effect of fertilizer and arsenic

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on phosphorus (P) content in straw (Table 15). The highest P (0.920 %) in straw was observed from the treatment $As_0T_2$ which was statistically similar with $As_0T_4$ (0.870 %) and the lowest P (0.020 %) in straw was observed from $As_3T_1$ which was statistically similar with $As_3T_3$ (0.050 %).

### 4.10.7 Potassium (K) content in straw

**Effect of fertilizer**

Potassium (K) content in straw showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 13). The highest K content (1.163 %) was observed in straw from the treatment $T_2$ and the lowest amount of K (0.9225 %) found in straw for the treatment $T_1$.

**Effect of arsenic**

Potassium (K) content in straw showed statistically significant difference due to different doses of arsenic (Table 14). The highest K content (1.582 %) was observed in straw from the treatment $As_0$ and the lowest amount of K (0.534 %) found in straw from the treatment $As_3$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on potassium (K) content in straw (Table 15). The highest K (1.700 %) in straw was observed from the treatment $As_0T_2$ and the lowest K (0.410 %) in straw was observed from $As_3T_1$.

### 4.10.8 Arsenic (As) content in straw

**Effect of fertilizer**

Arsenic (As) content in straw showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 13). The highest As content (3.510 ppm) was observed in straw from the treatment $T_1$ and the lowest amount of As (2.457 ppm) found in straw for the treatment $T_2$.

**Effect of arsenic**

Arsenic (As) content in straw showed statistically significant difference due to different doses of arsenic (Table 14). The highest As content (5.340 ppm) was observed in straw from the treatment $As_3$ and the lowest amount of As (0 ppm) found in straw from the treatment $As_0$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on arsenic (As) content in straw (Table 15). The highest As (6.020 ppm) in straw was observed from the treatment $As_3T_1$ and the lowest As (0 ppm) in straw was observed from $As_0T_0$ which was statistically similar with $As_0T_1$ (0 ppm), $As_0T_2$ (0 ppm), $As_0T_3$ (0 ppm) and $As_0T_4$ (0 ppm).

### 4.10.9 Nitrogen (N) content in root

**Effect of fertilizer**

Nitrogen (N) content in root showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 16). The highest N content (0.6550 %) was observed in root from the treatment $T_2$ and the lowest amount of N (0.435 %) found in root for the treatment $T_1$.

**Table 16: Effect of different doses of fertilizers (vermicompost and inorganic) on N, P, K and As content in root**

| Treatments | Root | | | |
|---|---|---|---|---|
| | % N | % P | % K | As (ppm) |
| $T_0$ | 0.5325 c | 0.5450 c | 0.7525 c | 4.230 c |
| $T_1$ | 0.435 e | 0.4550 e | 0.6625 e | 4.735 a |
| $T_2$ | 0.6550 a | 0.6375 a | 0.8400 a | 4.128 d |
| $T_3$ | 0.490 d | 0.4900 d | 0.7250 d | 4.347 b |
| $T_4$ | 0.580 b | 0.5875 b | 0.7975 b | 4.155 d |
| LSD $_{(0.05)}$ | 0.03690 | 0.02609 | 0.02609 | 0.03690 |
| CV (%) | 7.72 | 6.80 | 4.12 | 0.95 |
| Significant level | * | * | * | * |

* - Significant at 5% level

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Effect of arsenic**

Nitrogen (N) content in root showed statistically significant difference due to different doses of arsenic (Table 17). The highest N content (0.940 %) was observed in root from the treatment $As_0$ and the lowest amount of N (0.144 %) found in root from the treatment $As_3$.

**Table 17. Effect of different doses of arsenic on N, P, K and As content in root**

| Treatments | Root | | | |
|---|---|---|---|---|
| | % N | % P | % K | As (ppm) |
| $As_0$ | 0.940 a | 0.922 a | 1.052 a | 0.000 d |
| $As_1$ | 0.674 b | 0.650 b | 0.878 b | 4.894 c |
| $As_2$ | 0.388 c | 0.414 c | 0.640 c | 5.710 b |
| $As_3$ | 0.144 d | 0.186 d | 0.452 c | 6.672 a |
| $LSD_{(0.05)}$ | 0.0330 | 0.02334 | 0.02334 | 0.03300 |
| CV (%) | 7.72 | 6.80 | 4.12 | 0.95 |
| Significant level | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on nitrogen (N) content in root (Table 18). The highest N (1.060 %) in root was observed from the treatment $As_0T_2$ and the lowest N (0.060 %) in root was observed from $As_3T_1$.which was statistically similar with $As_3T_3$ (0.100 %) and $As_3T_0$ (0.130 %).

**4.10.10 Phosphorus (P) content in root**

**Effect of fertilizer**

Phosphorus (P) content in root showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 16). The highest P content (0.6375 %) was observed in root from the treatment $T_2$ and the lowest amount of P (0.455 %) found in root for the treatment $T_1$.

**Table 18: Interaction effect of different doses of arsenic and different doses of fertilizers (vermicompost and inorganic) on N, P, K and As content in root**

| Treatments | | Root | | | |
|---|---|---|---|---|---|
| | | % N | % P | % K | As (ppm) |
| $As_0$ | $T_0$ | 0.940 b | 0.930 b | 1.050 bc | 0.000 j |
| | $T_1$ | 0.830 cd | 0.820 c | 0.970 de | 0.000 j |
| | $T_2$ | 1.060 a | 1.020 a | 1.130 a | 0.000 j |
| | $T_3$ | 0.900 bc | 0.870 c | 1.020 cd | 0.000 j |
| | $T_4$ | 0.970 b | 0.970 ab | 1.090 ab | 0.000 j |
| $As_1$ | $T_0$ | 0.670 fg | 0.660 e | 0.880 fg | 4.810 h |
| | $T_1$ | 0.560 hi | 0.560 fg | 0.790 h | 5.280 f |
| | $T_2$ | 0.790 de | 0.760 d | 0.960 e | 4.710 i |
| | $T_3$ | 0.630 gh | 0.570 f | 0.840 gh | 4.920 g |
| | $T_4$ | 0.720 ef | 0.700 e | 0.920 ef | 4.750 hi |
| $As_2$ | $T_0$ | 0.390 kl | 0.410 ij | 0.640 jk | 5.570 e |
| | $T_1$ | 0.290 mn | 0.320 k | 0.550 lm | 6.470 c |
| | $T_2$ | 0.490 ij | 0.510 gh | 0.730 i | 5.320 f |
| | $T_3$ | 0.330 lm | 0.370 jk | 0.600 kl | 5.840 d |
| | $T_4$ | 0.440 jk | 0.460 hi | 0.680 ij | 5.350 f |
| $As_3$ | $T_0$ | 0.130 pq | 0.180 mn | 0.440 n | 6.540 c |
| | $T_1$ | 0.060 q | 0.120 o | 0.340 o | 7.190 a |
| | $T_2$ | 0.240 no | 0.260 l | 0.540 m | 6.480 c |
| | $T_3$ | 0.100 q | 0.150 no | 0.440 n | 6.630 b |
| | $T_4$ | 0.190 op | 0.220 lm | 0.500 m | 6.520 c |
| $LSD_{(0.05)}$ | | 0.07380 | 0.05218 | 0.05218 | 0.07380 |
| CV (%) | | 7.72 | 6.80 | 4.12 | 0.95 |
| Significant level | | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

### Effect of arsenic

Phosphorus (P) content in root showed statistically significant difference due to different doses of arsenic (Table 17). The highest P content (0.922 %) was observed in root from the treatment $As_0$ and the lowest amount of P (0.186 %) found in root from the treatment $As_3$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on phosphorus (P) content in root (Table 18). The highest P (1.020 %) in root was observed from the treatment $As_0T_2$ which was statistically similar with $As_0T_4$ (0.970 %) and the lowest P (0.120 %) in root was observed from $As_3T_1$ which was statistically similar with $As_3T_3$ (0.150 %).

### 4.10.11 Potassium (K) content in root

**Effect of fertilizer**

Potassium (K) content in root showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 16). The highest K content (0.8400 %) was observed in root from the treatment $T_2$ and the lowest amount of K (0.6625 %) found in root from the treatment $T_1$.

**Effect of arsenic**

Potassium (K) content in root showed statistically significant difference due to different doses of arsenic (Table 17). The highest K content (1.052 %) was observed in root from the treatment $As_0$ and the lowest amount of K (0.452 %) found in root from the treatment $As_3$ which was statistically similar with $As_2$ (0.640 %).

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on potassium (K) content in root (Table 18). The highest K (1.130 %) in root was observed from the treatment $As_0T_2$ which was statistically similar with $As_0T_4$ (1.090 %) and the lowest K (0.340 %) in root was observed from $As_3T_1$.

### 4.10.12Arsenic (As) content in root

**Effect of fertilizer**

Arsenic (As) content in root showed statistically significant difference due to different doses of fertilizers (vermicompost and inorganic) (Table 16). The highest As content (4.735 ppm) was observed in root from the treatment $T_1$ and the lowest amount of As (4.128 ppm) found in root from the treatment $T_2$ which was statistically similar with $T_4$ (4.155 ppm).

**Effect of arsenic**

Arsenic (As) content in root showed statistically significant difference due to different doses of arsenic (Table 17). The highest As content (6.672 ppm) was observed in root from the treatment $As_3$ and the lowest amount of As (0 ppm) found in root from the treatment $As_0$.

**Interaction effect of fertilizer and arsenic**

Interaction of different doses of fertilizers (vermicompost and inorganic) and different doses of arsenic had significant influence on arsenic (As) content in root (Table 18). The highest As (7.190 ppm) in root was observed from the treatment $As_3T_1$ and the lowest As (0 ppm) in root was observed from $As_0T_0$ which was statistically similar with $As_0T_1$ (0 ppm), $As_0T_2$ (0 ppm), $As_0T_3$ (0 ppm) and $As_0T_4$ (0 ppm).

# CHAPTER V

# SUMMARY AND CONCLUSION

The experiment was conducted in the net house and the agro-environmental chemistry laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season of the year 2016-17 to evaluate the influence of vermicompost and inorganic fertilizers on mitigation of arsenic in BRRI dhan47. The two factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. Factor A: different doses of arsenic on soil weight basis [**$As_0$**=No arsenic applied, **$As_1$**= 10 ppm arsenic, **$As_2$**= 20 ppm arsenic, **$As_3$**= 30 ppm arsenic] and Factor B: different doses of vermicompost and inorganic fertilizers [**$T_o$**= Recommended doses of vermicompost + inorganic fertilizers, **$T_1$**= Recommended doses of inorganic fertilizers without vermicompost, **$T_2$**= Recommended doses of vermicompost without inorganic fertilizers, **$T_3$** = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, **$T_4$**= Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers].

Different growth and yield parameters varied significantly due to difference in the doses of fertilizers (vermicompost and inorganic). At 30, 50, 70 and 90 DAT, the treatment $T_2$ produced the tallest plant (25.83 cm, 43.97 cm, 61.72 cm and 78.07 cm respectively) and the treatment $T_1$ produced the shortest plant (22.81 cm, 40.93 cm, 58.88 cm and 74.97 cm respectively). At 30, 50, 70 and 90 DAT, the treatment $T_2$ produced the highest number of tillers hill$^{-1}$ (5.083, 8.417, 11 and 12.75 respectively) and the treatment $T_1$ produced the lowest number of tillers hill$^{-1}$ (3.667, 5.5, 7.75 and 9.167 respectively). Among the treatments, the treatment $T_2$ produced the highest number of effective tillers hill$^{-1}$ (10.67) and the treatment $T_1$ produced the lowest number of effective tillers (5.833) whereas, the treatment $T_1$ produced the highest number of non-effective tillers hill$^{-1}$ (3.583) and the treatment $T_2$ produced the lowest number of non-effective tillers hill$^{-1}$ (2.083). The highest number of filled grains panicle$^{-1}$ (82.67) produced by the treatment $T_2$ and the lowest number (76.42) produced by $T_1$. The maximum number of unfilled grains panicle$^{-1}$ (14.17) produced by the treatment $T_1$ and the lowest number (10.25) produced by $T_2$. The maximum value of 1000 grain weight was produced by the treatment $T_2$ (22.72 g) and the lowest by $T_1$ (19.11 g). The maximum grain yield (33.23 g/pot) was recorded from the treatment $T_2$ and the minimum (29.61 g/pot) from the $T_1$. The highest straw yield (49.83 g/pot) was found in the treatment $T_2$ and the lowest (44.42 g/pot) from the $T_1$.

The highest N (1.445 %) in grain was recorded from$T_2$ and the lowest (1.235 %) from $T_1$. The highest P (0.5875 %) in grain was recorded from$T_2$ and the lowest (0.4050 %) from $T_1$. The value of K (%) in grain was insignificant. The highest As content (1.707 ppm) in grain was recorded from$T_1$ and the lowest (1.222 ppm) from $T_2$.

The highest N (0.9450 %) in straw was recorded from $T_2$ and the lowest (0.7350 %) from $T_1$. The highest P (0.5375 %) in straw was recorded from $T_2$ and the lowest (0.3550 %) from $T_1$. The maximum value (1.163 %) of K in straw was recorded from $T_2$ and the lowest (0.9225 %) from $T_1$. The highest As content (3.510 ppm) in straw was recorded from $T_1$ and the lowest (2.457 ppm) from $T_2$.

The highest N (0.6550 %) in root was recorded from $T_2$ and the lowest (0.435 %) from $T_1$. The highest P (0.6375 %) in root was recorded from $T_2$ and the lowest (0.4550 %) from $T_1$. The maximum value (0.8400 %) of K in root was recorded from $T_2$ and the lowest (0.6625 %) from $T_1$. The highest As content (4.735 ppm) in root was recorded from $T_1$ and the lowest (4.128 ppm) from $T_2$.

Different doses of arsenic had significant effect on growth and yield of BRRI dhan47. At 30, 50, 70 and 90 DAT, the highest plant height (29.84 cm, 49.77 cm and 69.60 cm and 89.42 cm respectively) from the $As_0$ treatment and the lowest (18.82 cm, 31.90 cm, 43.95 cm and 54.87 cm respectively) from $As_3$ treatment. At 30, 50, 70 and 90 DAT, the treatment $As_0$ produced the highest number of tillers hill$^{-1}$ (6.4, 9.867, 12.87 and 14.13 respectively) and the treatment $As_3$ produced the lowest number of tillers hill$^{-1}$ (2.4, 3.33, 5.333 and 7.133 respectively). The highest number of effective tillers hill$^{-1}$ (12.6) was observed from the $As_0$ treatment and the lowest (6.533) was observed from $As_3$ treatment. The highest number of non-effective tillers hill$^{-1}$ (3.8) was recorded from $As_3$ treatment and the lowest number of non-effective tillers hill $^{-1}$ (1.667) was recorded from $As_0$ treatment. The highest number of filled grains panicle$^{-1}$ (90.47) was observed from the $As_0$ treatment and the lowest (69.20) was observed from $As_3$ treatment. The highest number of unfilled grains panicle$^{-1}$ (20.4) was observed in $As_3$ treatment and the lowest (5.267) in $As_0$ treatment. The maximum value of 1000 grain weight was produced by the treatment $As_0$ (27.42 g) and the lowest by $As_3$ (16.53 g). The maximum grain yield (39.42 g/pot) was recorded from the treatment $As_0$ whereas the minimum (25.53 g/pot) from the $As_3$. The highest straw yield (59.13 g/pot) was found in the treatment $As_0$ and the lowest (38.3 g/pot) from the $As_3$.

The highest N (1.748 %) in grain was recorded from $As_0$ and the lowest (0.9520 %) from $As_3$. The highest P (0.872 %) in grain was recorded from $As_0$ and the lowest (0.136%) from $As_3$. The maximum value (0.4384 %) of K in grain was recorded from $As_0$ and the lowest (0.1644 %) from $As_3$. The highest As content (2.774 ppm) in grain was recorded from $As_3$ and the lowest (0 ppm) from $As_0$.

The highest N (1.248 %) in straw was recorded from $As_0$ and the lowest (0.440 %) from $As_3$. The highest P (0.822 %) in straw was recorded from $As_0$ and the lowest (0.086 %) from $As_3$. The maximum value (1.582 %) of K in straw was recorded from $As_0$ and the lowest (0.5340 %) from $As_3$. The highest As content (5.340 ppm) in straw was recorded from $As_3$ and the lowest (0 ppm) from $As_0$.

The highest N (0.940 %) in root was recorded from $As_0$ and the lowest (0.144 %) from $As_3$. The highest P (0.922 %) in root was recorded from $As_0$ and the lowest (0.186 %) from $As_3$. The maximum value (1.052 %) of K in root was recorded from $As_0$ and the lowest (0.452 %) from $As_3$. The highest As content (6.672 ppm) in root was recorded from $As_3$ and the lowest (0 ppm) from $As_0$.

At 30, 50, 70 and 90 DAT the highest plant height (31.77 cm, 50.77 cm, 70.80 cm and 90.23cm respectively) were observed from the $As_0T_2$ treatment and the lowest (18.37 cm, 31.37 cm, 43.27 cm and 54.40 cm respectively) were observed from $As_3T_1$ treatment. At 30, 50, 70 and 90 DAT, the highest number of tillers hill$^{-1}$ (7.333, 11.67, 14.67 and 16.33) was observed from the $As_0T_2$ treatment and the lowest (1.333, 2, 4 and 6) was observed from $As_3T_1$ treatment. The highest number of effective tillers hill$^{-1}$ (15.33) was observed from the $As_0T_2$ treatment and the lowest (1) was observed from $As_3T_1$ treatment. The highest number of non-effective tillers hill$^{-1}$ (5.000) was recorded from $As_3T_1$ treatment and the lowest number of non-effective tillers hill$^{-1}$ (1.000) was recorded from $As_0T_2$ treatment. The highest number of filled grains panicle$^{-1}$ (94.67) was observed from the $As_0T_2$ treatment and the lowest (66.33) was observed from $As_3T_1$ treatment. The highest number of unfilled grains panicle$^{-1}$ (23.33) was observed in $As_3T_1$ treatment and the lowest (3.667) in $As_0T_2$ treatment. The maximum value of 1000 grain weight was produced by the treatment $As_0T_2$ (29.40 g) and the lowest by $As_3T_1$ (15.17 g). The maximum grain yield (41.40 g/pot) was recorded from the treatment $As_0T_2$ whereas the minimum (24.17 g/pot) from the $As_3T_1$. The highest straw yield (62.10 g/pot) was found in the treatment $As_0T_2$ and the lowest (39.72 g/pot) from the $As_3T_1$.

The highest N (1.860 %) in grain was recorded from $As_0T_2$ and the lowest (0.860 %) from $As_3T_1$. The highest P (0.970 %) in grain was recorded from $As_0T_2$ and the lowest (0.070 %) from $As_3T_1$. The maximum value (0.470 %) of K in grain was recorded from $As_0T_2$ and the lowest (0.126 %) from $As_3T_1$. The highest As content (3.130 ppm) in grain was recorded from $As_3T_1$ and the lowest (0 ppm) from $As_0T_0$.

The highest N (1.360 %) in straw was recorded from $As_0T_2$ and the lowest (0.360 %) from $As_3T_1$. The highest P (0.920 %) in straw was recorded from $As_0T_2$ and the lowest (0.020 %) from $As_3T_1$. The maximum value (1.700 %) of K in straw was recorded from $As_0T_2$ and the lowest (0.410 %) from $As_3T_1$. The highest As content (6.020 ppm) in straw was recorded from $As_3T_1$ and the lowest (0 ppm) from $As_0T_0$.

The highest N (1.060 %) in root was recorded from $As_0T_2$ and the lowest (0.060 %) from $As_3T_1$. The highest P (1.020 %) in root was recorded from $As_0T_2$ and the lowest (0.120 %) from $As_3T_1$. The maximum value (1.130 %) of K in root was recorded from $As_0T_2$ and the lowest (0.340%) from $As_3T_1$. The highest As content (7.190 ppm) in root was recorded from $As_3T_1$ and the lowest (0 ppm) from $As_0T_0$.

From the above results it can be concluded that,

- Arsenic toxicity adversely affects all the growth and yield related attributes of BRRI dhan47.
- Treatment $T_2$ gave the better yield and yield contributing characters among all the combinations of vermicompost and inorganic fertilizers**.**
- Treatment $T_2$ has lower arsenic accumulation in grain, straw and root.
- Use of vermicompost with inorganic fertilizers decreased the adverse effects of high arsenic toxicity on rice plant and improved all the traits mentioned above.

From the above conclusions, the following recommendations can be made:

- ✓ Farmers can adopt the use of vermicompost to reduce the toxicity of arsenic.
- ✓ Such studies should be carried out to different arsenic prone areas of the country.

# CHAPTER VI

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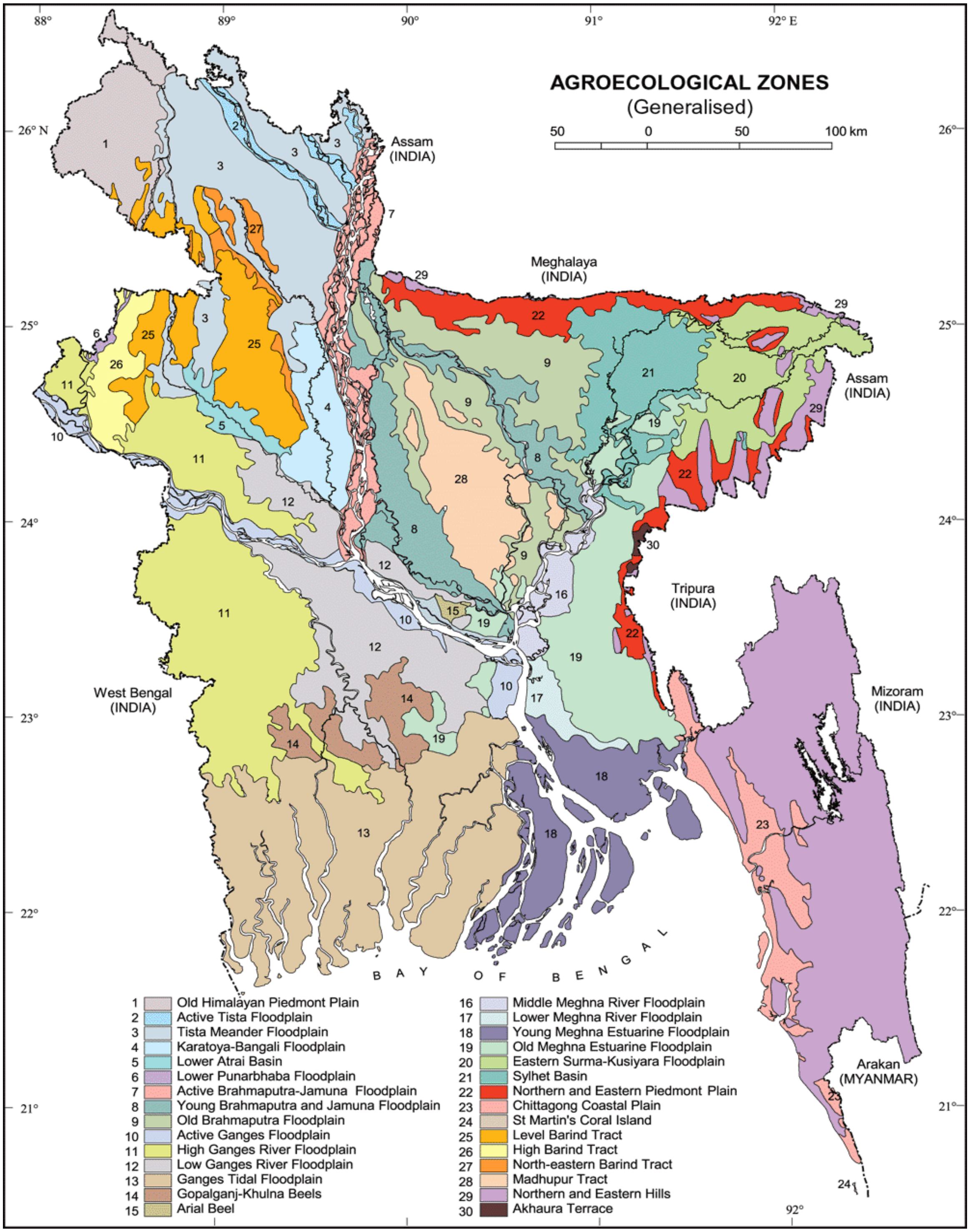
## APPENDICES

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



**Appendix II. Morphological characteristics of the experimental field**

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

**(SAU Farm, Dhaka)**

**Appendix III. Initial physical and chemical characteristics of the soil**

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

**(SAU Farm, Dhaka)**

**Appendix IV. Effect of different doses of fertilizers (vermicompost and inorganic) on plant height and number of tillers hill$^{-1}$ at different days after transplanting**

| Treatments | Plant height (cm) | | | | Number of tillers hill$^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | 30DAT | 50DAT | 70DAT | 90DAT | 30DAT | 50DAT | 70DAT | 90DAT |
| $T_0$ | 23.84 c | 42.15 c | 59.98 c | 76.03 c | 4.500abc | 6.917 b | 9.250 b | 10.33bc |
| $T_1$ | 22.81 e | 40.93 e | 58.88 e | 74.97 e | 3.667 c | 5.500 c | 7.750 c | 9.167 d |
| $T_2$ | 25.83 a | 43.97 a | 61.72 a | 78.07 a | 5.083a | 8.417 a | 11.00 a | 12.15 a |
| $T_3$ | 23.22 d | 41.17 d | 59.22 d | 75.41 d | 4.00bc | 6.083 c | 8.167 c | 9.417cd |
| $T_4$ | 24.92 b | 43.06 b | 60.74 b | 77.06 b | 4.583 ab | 7.333 b | 9.750 b | 11.00 b |
| LSD $_{(0.05)}$ | 0.3238 | 0.2391 | 0.2475 | 0.2543 | 0.8848 | 0.7458 | 0.9703 | 0.9994 |
| CV (%) | 1.63 | 0.69 | 0.50 | 0.40 | 24.56 | 13.19 | 4.10 | 11.50 |
| Significant level | * | * | * | * | * | * | * | * |

* - Significant at 5% level

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Appendix V. Effect of different doses of arsenic on plant height and number of tillers hill$^{-1}$at different days after transplanting**

| Treatments | Plant height (cm) | | | | Number of tillers hill$^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|
| | 30DAT | 50DAT | 70DAT | 90DAT | 30DAT | 50DAT | 70DAT | 90DAT |
| $As_0$ | 29.84 a | 49.77 a | 69.60 a | 89.42 a | 6.400 a | 9.867 a | 12.87 a | 14.13 a |
| $As_1$ | 25.83 b | 45.51 b | 65.00 b | 84.07 b | 4.667 b | 8.067 b | 10.27 b | 11.53 b |
| $As_2$ | 22.00 c | 41.85 c | 61.88 c | 76.87 c | 4.000 c | 6.133 c | 8.267 c | 9.333 c |
| $As_3$ | 18.82 d | 31.90 d | 43.95 d | 54.87 d | 2.400 d | 3.133 d | 5.333 d | 7.133 d |
| LSD $_{(0.05)}$ | 0.2896 | 0.2139 | 0.2214 | 0.2275 | 07914 | 0.6671 | 0.8679 | 0.8939 |
| CV (%) | 1.63 | 0.69 | 0.50 | 0.40 | 24.56 | 13.19 | 4.10 | 11.50 |
| Significant level | * | * | * | * | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

**Appendix VI. Effect of different doses of fertilizers (vermicompost and inorganic) on number of effective tillers hill$^{-1}$, non-effective tillers hill$^{-1}$, number of filled grains panicle$^{-1}$, number of unfilled grains panicle$^{-1}$, 1000 grain weight (g), grain yield (g/pot) and straw yield (g/pot)**

| Treatments | Effective tillers hill$^{-1}$ | Non-effective tillers hill$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ | 1000 grain wt. (g) | Grain yield (g/pot) | Straw yield (g/pot) |
|---|---|---|---|---|---|---|---|
| $T_0$ | 7.583 bc | 2.750 bc | 79.08 bc | 11.67 bc | 20.92bc | 31.72 c | 47.14 c |
| $T_1$ | 5.833 d | 3.583 a | 76.42 c | 14.17 a | 19.11 d | 29.61 e | 44.42 e |
| $T_2$ | 10.67 a | 2.083 d | 82.67 a | 10.25 c | 22.72 a | 33.22 a | 49.83 a |
| $T_3$ | 6.500 cd | 3.083 ab | 77.92 bc | 12.83 ab | 20.21cd | 30.71d | 46.06 d |
| $T_4$ | 8.583 b | 2.417cd | 80.67 ab | 10.83 bc | 21.76ab | 32.26 b | 48.29 b |
| LSD $_{(0.05)}$ | 1.181 | 0.6391 | 2.776 | 2.201 | 1.108 | 0.1629 | 0.1305 |
| CV (%) | 18.28 | 27.83 | 4.24 | 22.32 | 6.41 | 0.63 | 0.34 |
| Significant level | * | * | * | * | * | * | * |

* - Significant at 5% level

$T_o$ = Recommended doses of vermicompost + inorganic fertilizers, $T_1$ = Recommended doses of inorganic fertilizers without vermicompost, $T_2$ = Recommended doses of vermicompost without inorganic fertilizers, $T_3$ = Reduction of 40% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers, $T_4$ = Reduction of 60% of recommended doses of inorganic fertilizers + Addition of vermicompost to supplement the reduction of inorganic fertilizers

**Appendix VII. Effect of different doses of arsenic on number of effective tillers hill$^{-1}$, non-effective tillers hill$^{-1}$, number of filled grains panicle$^{-1}$, number of unfilled grains panicle$^{-1}$, 1000 grain weight (g), grain yield (g/pot) and straw yield (g/pot)**

| Treatments | Effective tillers hill$^{-1}$ | Non-effective tillers hill$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ | 1000 grain wt. (g) | Grain yield (g/pot) | Straw yield (g/pot) |
|---|---|---|---|---|---|---|---|
| $As_0$ | 12.60 a | 1.667 c | 90.47 a | 5.267 d | 27.42 a | 39.42 a | 59.13 a |
| $As_1$ | 8.867 b | 2.667 b | 82.00 b | 8.667 c | 21.18 b | 32.18 b | 48.27 b |
| $As_2$ | 6.533 c | 3.000 b | 75.73 c | 13.47 b | 18.65 c | 28.65 c | 42.89 c |
| $As_3$ | 3.333 d | 3.800 a | 69.20 d | 20.40 a | 16.53 d | 25.53 d | 38.30 d |
| LSD $_{(0.05)}$ | 1.057 | 0.5716 | 2.483 | 1.969 | 0.9909 | 0.1457 | 0.1167 |
| CV (%) | 18.28 | 27.83 | 4.24 | 22.32 | 6.41 | 0.63 | 0.34 |
| Significant level | * | * | * | * | * | * | * |

* - Significant at 5% level

$As_0$ = No As applied, $As_1$= 10 ppm As, $As_2$= 20 ppm As, $As_3$= 30 ppm As on soil weight basis

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