# EFFECT OF TEXTILE WASTEWATER ON PHYSIOLOGICAL ATTRIBUTES, GRAIN QUALITY AND YIELD OF RICE

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## *CERTIFICATE*

*This is to certify that thesis entitled* ***"EFFECT OF TEXTILE WASTEWATER ON PHYSIOLOGICAL ATTRIBUTES, GRAIN QUALITY AND YIELD OF RICE"*** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN AGRICULTURAL BOTANY*** *embodies the result of a piece of bona fide research work carried out by* ***BILKISH AKHTER BULY, Registration no. 18-09132*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

**Dated: December, 2020**
**Place: Dhaka, Bangladesh**

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**DEDICATED**
**TO**
**MY BELOVED**
**PARENTS**

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***Dated: June, 2021*** ***The Author***

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## ABSTRACT

The present investigation to study the effect of textile wastewater on physiological attributes, grain quality and yield of rice" was conducted from February, 2019 to June, 2019 at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factors A: Two rice varieties (BRRI dhan29 and BRRI Hybrid dhan2) and Factor B: Five different concentration of textile waste water (80%, 60%, 40%, 20% industrial wastewater and no wastewater (0%)). The pot experiment was laid out in 2 factors Randomized Complete Block Design with three replications. Different treatment combinations expressed significant differences due to their interaction effect on morphological, physiological parameters, yield attributing traits and yield. In case of varietal performance, the taller plant (90.40 cm) and more sterile spikelet panicle$^{-1}$ (30.13) were observed in BRRI dhan29 variety. Grater total dry mater (14.84 g), absolute grain growth rate (6.91), leaf area (34.31cm$^2$), SPAD value (46.13), number of spikelet panicle$^{-1}$ (200.6), weight of 1000 grain (24.60 g), grain yield (3.91 t ha$^{-1}$), straw yield (4.12 t ha$^{-1}$) and harvest index (48.42%) were found in BRRI Hybrid dhan2 variety. Among the waste water treatments, the tallest plant (91.33 cm), the maximum total number of tillers hill$^{-1}$ (27.00), number of leaves hill$^{-1}$ (28.00), dry mater (19.97 g), absolute grain growth rate (7.10), leaf area (38.53 cm$^2$), SPAD value (48.13), total number of spikelet panicle$^{-1}$ (283.5), weight of 1000 grain (26.63 g), grain yield (5.26 t ha$^{-1}$), straw yield (5.40 t ha$^{-1}$), harvest index (49.35%) were recorded from $T_0$ (no waste water). Whereas, maximum sterile spikelet panicle$^{-1}$ (37.68) was recorded from $T_1$ (using 80% industrial waste water for irrigation). The tallest plant (93.33 cm), the maximum number of total tillers hill$^{-1}$ (27.67), number of leaves hill$^{-1}$ (29.33), dry mater (21.41 g), absolute grain growth rate (8.24), leaf area (39.47 cm$^2$), SPAD value (49.13), total number of spikelet panicle$^{-1}$ (335.5), weight of 1000 grain (28.00g), grain yield (5.40 t ha$^{-1}$), straw yield (5.58 t ha$^{-1}$) and harvest index (49.52%) were recorded from the treatment combination $V_2T_0$ (BRRI Hybrid dhan2 + no waste water). Whereas, maximum sterile spikelet panicle$^{-1}$ (39.42) was recorded from the treatment combination $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation).

## LIST OF ABBREVIATIONS AND ACRONYMS

| **Abbreviation** | **Full meaning** |
|---|---|
| % | Percent |
| $^{o}$C | Degree Celsius |
| AEZ | Agro-ecological Zone |
| AVOVA | Analysis of variance |
| AS | Aroma Scoring |
| BARI | Bangladesh Agricultural Research Institute |
| BBS | Bangladesh Bureau of Statistics |
| BRRI | Bangladesh Rice Research Institute |
| CD | Cooking Duration |
| cm | Centimeter |
| CV | Coefficient of variation |
| DAS | Days after sowing |
| DAT | Days after transplanting |
| d.f. | Degrees of freedom |
| *et al.* | And others |
| ER | Elongation ratio |
| FAO | Food and Agriculture Organization |
| G | Gram |
| Ha | Hectare |
| J. | Journal |
| Kg | Kilogram |
| L/B | Length-breadth ratio |
| LSD | Least Significant Difference |
| Mg | Milligram |
| Ml | Milliliter |
| MP | Muriate of Potash |
| SAU | Sher-e-Bangla Agricultural University |
| SPAD | The Soil Plant Analysis Development |
| TSP | Triple Super Phosphate |

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# CHAPTER I

# INTRODUCTION

Bangladesh is one of the top most rice producing countries covering an area of about 7.85 million hectares arable lands where 70% is used for rice production. Rice is not only the foremost staple food but it also provides nearly 48% of the rural employment, about two-third of the total calories supply and about one-half of the protein intake of an average person in the country (Julfiquar *et al*., 2002). There is no doubt that rice has been continued to be the staple food crop in Bangladesh. For achieving higher rice productivity, hybrid rice technology has been introduced in Bangladesh during last 10 years. Human population consumed about 23% of calories from rice (Subudhi *et al*., 2006). In Asia largest amount of rice is grown and also utilize it as an energy source (Rabbani *et al*., 2010; Raza *et al*., 2006).

Rice is normally cultivated in anaerobic condition and it requires huge amount of freshwater. Enhance industrialization and urbanization in the last few decades, resulted in pollution in air, water, soil and food. Industrial effluents is one of the major factors that responsible for low productivity of crops (Sarma, 2002). The major contribution of heavy metals are wastes from industry, effluents from paper mill, agrochemicals and anthropogenic activities pose a threat to ecosystem (Samual *et al*., 2014). Industrial effluents contain high contents of chemicals, considerable amount of chloride, sulphate, calcium, magnesium and heavy metals such as zinc, copper and lead (Baskaran *et al*., 2009). The use of wastewater from industries and urban center in agriculture has received considerable attention in recent years and each type of effluent has a specific character, it may or may not be beneficial to crop-soil-animal subsystem (Padhan and Sahu, 2011).

Different international research articles indicated that textile wastewater may be a good source of nutrients in addition to meet the crop requirement. Textile wastewater contains heavy load of pollutants, exhibiting high total dissolved solids (TDS), total suspended solids (TSS), and many other organic and inorganic compounds (heavy metals) (Siddique *et al*., 2012 and Pathak *et al*., 2009). Presence of these toxic substances limits its application for irrigation purposes (Khan *et al*., 2013). However, availability of some vital nutrients like copper, zinc, iron, and manganese in textile wastewater (Begum *et al*., 2011) may offer a possibility to use it for irrigational purpose after proper treatment (Khan *et al*., 2015). For this reason, some of the small land holders are using wastewater for irrigation purposes in dry season (Shah, 2009; Girsha and Raju, 2008 and Ahmad *et al*. 2003).

Direct application of textile effluents may cause inhibitory effect on growth of some plants (Wins and Murgan, 2010), but on dilution can impart positive effects (Rahman *et al*., 2015). It has been reported that dilution of wastewater has significantly increased growth and germination of black gram, green gram, rice, groundnut, sunflower and maize (Wins and Murgan, 2010 and Elarajan and Bupathi, 2006). Thus for beneficial cultivation, farmers can use textile effluent for irrigation with lower concentrations of effluent like 25% dilution (Kumar *et al*., 2016). Zn, Fe, Mn Cu and S contents in rice seedlings were significantly increased on application of textile wastewater in comparison to good quality irrigation water (Begum *et al*., 2011).

In Bangladesh, industrial wastes and effluents are being discharged at random without treatments directly to soil, canals and rivers. They contain heavy metals like Cu, Zn, Pb, Cr, Cd, As, Hg, Mn, and Fe. Some of them are toxic to plants and some others to both plants and animals. In areas where irrigation water is scarce, the use of industrial wastewater is an important source for supplementing water resources. Furthermore, reuse may help alleviate industrial disposal problems by reducing the volume of industrial wastewater involved. The uptake of heavy metals by plants from contaminated soils is of great concern because an excess of dietary intake of some of these heavy metals (e.g. Pb and Cd) might be hazardous to consumers (Begum *et al*., 2011). This in turn, directly or indirectly, it is affecting the soil and crop productivity and quality of agricultural products because Cd, As, Cr, and Hg are extremely poisonous (Hellawell, 1986). Their uptake and accumulation in plant have been known to result in negative effects on plant growth (Breekle and Kahle, 1992). The nature and extent of damage caused by industrial effluents are very alarming. Farmers of different industrial areas of Bangladesh cultivate rice around vicinity of different industries, which discharge effluents directly to the rice field. Research on the effect of textile effluents on modern inbred and hybrid rice cultivation is very little in Bangladesh. Considering the above statement, the present research work has been designed to evaluate the effects of different diluted textile wastewater on morphological and physiological characteristics as well as in grain yield of rice.

The major objectives for this study are given bellow:

1. To study the effect of textile wastewater on rice morphology, physiology and yield of rice.
2. To evaluate the varietal response due to textile wastewater.

# CHAPTER II

# REVIEW OF LITERATURE

Rice is major crop in Bangladesh and due to increasing industries and textile mills and industries, the scarcity of fresh irrigation water is become a threat for agriculture. As a result, use of textile wastewater as irrigation water for rice cultivation increase day by day mostly those areas where textile industries are located. So, the effect of textile wastewater for rice production and grain quality increased day by day. For this reason, some literatures are presented bellow in some sub-headings:

## 2.1. Effect of waste water in agriculture

Dash (2012) reported that, the use of municipal sewage water in plant growth is a useful alternative resource to fresh water, while waste water of different industries like textile, garments, mills etc. consist of anion which can be useful for plant growth but its large amount could be toxic.

At lower dilutions of wastewater germination percentage increased due to wastewater that adds nutrients in the soil and increased fertility to sustain plant growth (Rehmani, 2007). It has been reported that heavy metal form complex between chemicals and pollutants when discharge and protect their entrance into the root and plant the body (Yousaf *et al*., 2010; Akbar *et al*., 2007).

Inhibition of seed germination at higher concentration of municipal sewage water (MSW) and sugar mill effluent (SME), result in dissolved solids that enhanced the salt content and conductivity of solute before germination of seed. The osmotic potential of effluent also changes thereby decreasing the absorbed water content in seeds that cause decrease in germination. Oil and grease may act with salt and organic compound to increase osmotic potential and reducing the amount of water and oxygen availability for germination (Ogunwenma *et al*., 2010).

Chung *et al*. (2011) noted that the agricultural use of domestic wastewater helps to preserve environmental quality, and concurrently furthers other national goals such as providing sustainable agriculture while preserving scarce water sources.

The usage of municipal water with physical treatment could raise water resources for irrigation which may prove to be advantageous for agricultural production as municipal water has a higher amount of organic matter, nutrients, and some heavy metals which are toxic to plants beyond a certain limit (Singh *et al*., 2012). The macro- and micro-nutrients in the sewage sludge assist as a good basis of plant nutrients and the organic constituents furnish helpful soil conditioning properties (Singh and Agrawal, 2008).

At 25%, increase in chlorophyll content may be due to the absence of heavy metals and the presence of iron and magnesium that are necessary for the synthesis of chlorophyll (Borale and Patil, 2004).

**2.2. Effect of textile wastewater on morphological attributes of rice**

Gassama *et al*. (2015) conducted a study and reported that, the utilization of wastewater for irrigation purposes has developed an important way to exploit the nutrients it contains. The study indicated a significant ($P < 0.05$) difference between untreated and treated wastewater for seedling length (SL), root volume (RV), root surface area (RSA), seedling vigor index (SVI), and root: shoot ratio (R:S) while no significant different was observed between untreated and treated wastewater for germination percentage (GP) and percentage phytotoxicity (PPT). The wastewaters had stimulatory effect on the rice seeds at lower wastewater concentrations (<25%)

while inhibitory effect was observed at higher wastewater concentrations (>50%). N, P, K, Ca, Mg, Zn, Fe, Cu, and Mn were high in the untreated wastewater compare to treated wastewater. Seedlings irrigated with untreated wastewater have high seed germination, seedling performance with high nutrient uptake compare to treated wastewater. The wastewaters showed inhibitory effect on chlorophyll content. The inhibition effect was observed at >50% concentration of both untreated and treated wastewater while promoting effects were observed at lower (<25%) concentration. The rice MR220 variety showed better growth resistance, tolerance, and adaptability to wastewater. This can be due to its excellent genetic makeup and capacity to sustain the toxicity. Conclusively, wastewater could be recommended as a good source of water and nutrient for seed germination and seedling performance.

Higher concentration of wastewater primarily affected the physiological parameters of rice varieties including root and shoot length while diluted concentration overcome the effect of toxicity to some extent. Organic and inorganic chemicals restrict energy supply, retard growth and development of germinated seeds while the toxicity of effluent cause reduction in leaf area, cell size and decrease in inter cellular spaces, reduce oxygen, increase carbon dioxide, harder the soil, reduced the root/shoot length, fresh and dry weight and total leaf area (Baskaran *et al*., 2009).

Pandey and Neralia (2002) observed that, cell membrane injury may be occurs, when the toxic metals uptake increase and causing low water uptake by the plant and accumulation of metal by cell injury. Elevated electric conductivity and osmotic pressure cause retardation of germination and plant growth.

Singh *et al*. (2007) observed a significant decrease in the percentage germination and seedling vigor of rice and wheat with an increase in spent wash concentration. The decrease may be due to the adverse effect of high toxicity of the wastewater at a higher concentration (Yousaf *et al*., 2010 and Ramana *et al*., 2002). The 50% and 100% wastewater concentrations were inhibitory to seed germination as the reduction was observed by a previous study (Irwin, 1978).

Behera and Misra (1982) studied the impact of industrial wastewater on growth and advance of rice seedlings and reported that the germination per cent, number of roots, shoot and root length, fresh and dry weight of the seedlings showed an opposite relationship with effluent concentration.

Rajaram and Janardhanam (1988) conducted the study with textile wastewater and concluded the effect of distillery effluent on seed germination and early seedling growth of rice and reported that the processed effluents were rich in inorganic constituents like ammonia, calcium, nitrogen, chemicals and traces of heavy metals and these markedly suppressed the germination per cent and early growth of the seedling as the concentration of the effluent increase.

Rajannan, *et al.* (1998) also studied the effects of textile effluent at different concentrations (25, 50, 75 and 100%) on seed germination of *Oryza sativa* and found that the germination was inhibited by 25 and 50% effluent and fully dormant by 75 and 100% effluent. Even the chlorophyll and protein contents of plants were found to reduce with the effluent concentration of 75 and 100%.

Chinnusamy, *et al.* (2001) studied the effect of treated distillery effluent on two cultivars of *Oryza sativa* L. Cv. Saka-4 and Pusa 44 after diluted with tap water viz., 100, 50 and 25% in Petri plates over the control. It was observed that root length, shoot length fresh weight root and shoot, dry weight of root and shoot germination relative index, vigour index, emergence index and chlorophyll content were higher in 25% than 50% over control.

Rani and Alikhan (2007) also noticed that the percentage germination and seedling energy of rice and wheat reduced significantly with a raise in spent wash concentration.

Cell membrane injury may be occurs, when the toxic metals uptake increase and causing low water uptake by the plant and accumulation of metal by cell injury. Elevated electric conductivity and osmotic pressure cause retardation of germination and plant growth (Pandey and Neralia, 2002).

The highest ammonium concentration in effluents increases the root length of *Cicer arietinum* but toxic in higher concentration of effluents (Nawaz *et al*., 2006).

Akhtar *et al*. (2018), conducted the study and observed that fresh weights of root and shoot decreased in raw form while increased at 25%, however, dry weights of root and shoot increased at raw water. This may due the increased uptake of undissolved metals which remains in the root and shoot, when it became dry (Nath *et al*., 2007).

Wastewater irrigation have both beneficial and damaging effects on crop growth. For agriculture attractive practice, irrigation of wastewater with dilutions provides N and P that helps in water conservations, recycling of nutrients in the wastewater, reducing the direct fertilizer inputs and minimizing pollution loads (Huma *et al*., 2012). In Pakistan where treatment and disposal facilities are limited, diluted water is utilized to irrigate the crops (Ensink *et al*., 2004).

Kaur *et al*. (2019) revealed that, the use of industrial waste water for irrigation through drip system has emerged a very important way to utilize its nutrients and removal of its pollutants load by cultivating various crops. An experiment was conducted to evaluate the impact of textile factory effluents (0, 10, 35, 75 and 100% concentration) on germination and some physiological parameters like biomass production, root development in rice. Plants were raised in small pots in triplicate and irrigated with various concentrations (0, 10, 35, 75 and 100%) of effluent. Germination %, biomass production and various attributes of root development were determined in plants grown under different treatments. Plants exhibited a reduction in percentage germination, root and shoot dry weight, number of root branches/plants grown with higher concentration (75 and 100% concentration) of textile effluents. However, the effect of textile effluents was promotive rather than inhibitory on these parameters when applied in low concentrations (10 and 35%). It was concluded that the effect of textile effluent was crop specific depending on the concentration and stage of growth. It was suggested that waste water from textile industry could be utilized for irrigation purposes through drip irrigation after proper treatment and may contribute, at least in part towards solving the problem of disposal of textile effluent.

Kaur *et al*. (2019) revealed that, percent germination, root and shoot dry weight, numbers of root branches/plants were found to be minimum under treatment textile effluents with 75% concentration and textile effluents with 100% concentration which, shows overall reduction in percentage germination and physiological parameters for both crops. Similar, results was reported by Khan *et al*., (2011).

Begum *et al*. (2011) reported that, textile industrial waste water had significant effect on plant height and effective tillers per hill of boro rice. In uncontaminated field, the highest plant height, effective tillers per hill and panicle length were obtained with fresh water irrigation followed by mixed water irrigation in both the years. The lowest plant height and effective tillers per hill were observed with polluted water irrigation. Similarly, in effluent contaminated soil, the highest plant height and effective tillers per hill were noted when fresh water was used followed by mixed water. Fresh water irrigation gave the tallest plants because it contained considerable amount of macro and micro- nutrients and contained heavy metals within permissible limit. Adequate nutrients supply and presence of heavy metals within permissible limit in irrigation water enhanced root and shoot growth and thereby resulted the highest plant height, and tillers per hill.

Begum *et al*. (2011) also revealed that, Textile industrial waste water exerted significant negative influence on the number of filled grains per panicle and 1000-grain weight of boro rice in both uncontaminated and contaminated soil. In both the seasons, the fresh soil showed the maximum number of filled grains/panicle and 1000-grain weight followed by mixed water and the minimum number of filled grains per panicle and 1000-grain weight were obtained by using polluted water for irrigation. Similarly in contaminated soil, the maximum number of filled grains per panicle, and 1000-grain weight were obtained by using fresh water as irrigation followed by mixed water, and minimum number of filled grains per panicle, and 1000- grain weight was obtained due to polluted water used for irrigation.

On the contrary, effluent of textile industry used for irrigation contained Cu, Mn, C1, and Cr beyond the maximum permissible limit (MPA). These elements particularly Cr might have exerted toxic effects on rice plants leading to decrease plant height and effective tillers per hill (Yamaguchi and Aso, 1977).

**2.3. Effect of textile wastewater on quality of rice grain**

Akhtar *et al*. (2018) showed that, raw water reduced $K^+$ and $Ca^{+2}$ ions while $Na^+$ ions were increased. High concentration of salinity result in number of effects on plant growth. Ionic stress interrupt the uptake of nutrients, and result in direct toxicity in plant. Secondly, $Na^{+}$ inhibits their absorption and competes with useful ions like $K^{+}$ and $Ca^{+2}$. Alkalinity increased due to high sodium content in effluent that affect soil permeability and texture and act as a deflocculating agent and displaces the divalent cations like calcium and magnesium (Medhi *et al*., 2008).

Thambavani *et al*. (2011) revealed that treatment of effluents may have some role in reducing the formation of toxic ions, and so increasing the absorption of useful ions like $K^{+}$ and $Ca^{+2}$. It also reported that, biosynthesized of pigments optimum quantity of magnesium and potassium present in lower concentration of effluent.

The excess amount of metals in contaminated soil decreased the magnesium, potassium, calcium and phosphorous which result in poor growth and yield of rice so heavy metals inhibited the primary productivity of rice (Konwar and Jha, 2010).

Phosphorus and potassium contents of rice were found to decrease depending on the concentration of textile effluents. The decrease in phosphorous and potassium contents of the crop might be attributed to the presence of higher amount of Pb, Zn, and Cu in the textile effluents that have antagonistic relationship with P and K (Muchrimsyah and Mercado, 1990 and Khan and Khan, 1983).

Strand *et al*. (1990), Dahiya *et al*. (1990), and Osawa and Tazuke (1990) reported that, textile polluted water used for irrigation contained Pb and Cu above the permissible limit, which probably reduced the N content of rice grain.

Begum *et al*. (2011) showed that, the maximum S and Zn content of the soil was recorded in the plots where industrial effluent was applied and the soil was also polluted as compared to the fresh water irrigated plots having uncontaminated soil. Waste water of textile industries resulted in higher S and Zn content by the rice grain and plant. The reason might be due to the higher S and Zn concentration in the waste water. Tripathi *et al*., (1988) also reported raw sewage irrigation increased S and Zn content in the soil.

The Mg and Fe concentration increased significantly with the concentration of waste water of the textile industry. Lee and Kim, (1991) reported increased concentration and uptake of Mg and Fe by rice due to the use of waste water.

The increase in Cu and Mn content in rice crop at all levels and rice grain due to use textile wastewater as irrigation source for rice cultivation and this was found by Khalid and Tinsley (1980).

Chen *et al*. (1991) noticed that, textile waste water that contained Pb might influence lead content in rice crops as well as rice grain.

**2.4. Effect of textile wastewater on yield of rice**

Begum *et al*. (2011) reported that, fresh water gave the highest grain yield (5.23 t/ha in 1999 and 5.40 t/ha in 2000) followed by mixed water (4.19 t/ha in 1999 and 4.24 t/ha in 2000). The lowest grain yield (2.89 t/ha in 1999 and 2.91 t/ha in 2000) was obtained from polluted water used for irrigation. Results revealed that fresh water irrigation always gave the highest yield, even in the polluted soil compared to polluted water. On the contrary, polluted water had negative influence on grain yield of rice and displayed significantly lowest grain yield. The grain yield reduction due to mixed and polluted water irrigations varied from 19.88 to 76.29 % in the year 1998 and 21.48 to 78.52% in the year 1999. The highest grain yield reduction over fresh water irrigation of 76.29 and 78.52% was observed in the year 1999 and 2000, respectively, in polluted soil irrigated with polluted water in comparison to fresh soil irrigated with fresh water.

Markedly reduced grain yield with textile industrial waste water irrigation in both fresh and polluted soils was remarkable since this water had contained high concentration of toxic elements like Cu, Mn, Cl, and Cr. These elements particularly Cr might have exerted toxic effects to rice plants leading to decrease root elongation (Yamaguchi and Aso, 1977), decreased net photosynthesis (Austenfeld, 1979) and hampered physiological function in rice plants leading to reduced plant height, reduced number of effective tillers per hill, and very poor straw yield and ultimately resulted in drastic reduction of grain yield.

Begum *et al*. (2011) showed the results clearly indicate that textile industrial waste water was detrimental to rice growth and always gave the poor straw yield of boro rice even in the fresh soil. Fresh and textile waste water had significant effect on grain yield of boro rice in both fresh and polluted soils. This finding again agrees with the findings of Yagdi *et al*. (2000) where they observed that toxicity of heavy metals (As, Cu, Hg, Zn, Cd, Cr, Pb, Mo, Ni, and Se) decreased plant growth and development.

The excess amount of metals in contaminated soil decreased the magnesium, potassium, calcium and phosphorous which result in poor growth and yield of rice so heavy metals inhibited the primary productivity of rice (Konwar and Jha, 2010).

Yagdi *et al*. (2000) and Lee and Kim (1991) found that, fresh soil and fresh water always gave significantly higher uptake of N. The maximum decrease in N, P, and K uptake of the crop was recorded in the plots where textile industrial waste water was applied. The lowest and very poor uptake of N, P, and K with polluted water in industrially polluted soil was likely, since polluted water and soil contained toxic level of heavy metals like Zn, Cu, Mn, Cd, and Pb which depressed the yield significantly. It is to be noted here that nutrient uptake is the function of biomass yield and nutrient concentration in plant. As the yield decreased significantly in polluted soil irrigated with polluted water, N uptake also reduced significantly.

Begum *et al*. (2011) concluded that, heavy metal had antagonistic effects on essential plant nutrient uptake. Plant did not uptake adequate amount of nutrients from waste water, which was on the growth and yield of rice.

# CHAPTER III

# MATERIALS AND METHOD

The experiment was conducted to observe the effect of textile wastewater on physiological attributes, grain quality and yield of rice. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatments and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

## 3.1 Experimental period

The field experiments were conducted during the period of February to June, 2019.

## 3.2 Description of the experimental site

### 3.2.1 Location of the experimental field

The experiment was carried out on the research field of Sher-e-Bangla Agricultural University, Dhaka. The location of the site is 23º74'N latitude and 90º35'E longitude with an elevation of 8.2 meter from sea level.

### 3.2 2 Characteristics of the soil

The experimental site belongs to the agro-ecological zone of Modhupur Tract (AEZ-28). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land.

### 3.2.3 Climate

Subtropical in nature, characterized by three distinct seasons. The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix 2.

### 3.3 Plant material

In this experiment, two rice varieties namely BRRI dhan29 and BRRI Hybrid dhan2 were used. The seeds were collected from Bangladesh Rice Research Institution (BRRI), Joydeppur, Gazipur.

### 3.4 Experimental design

The experiment was conducted in two factors RCBD (Randomized Complete Block Design) with three replications. The unit plot size was 3 m x 3 m. Each plot contains 15 pots.

### 3.5 Treatments

The experiment consisted of two factors-

**Factor A: Variety (2 Rice varieties)**

(i) BRRI dhan29 ($V_1$)

(ii) BRRI Hybrid dhan2 ($V_2$)

**Factor B: Textile wastewater (5 Concentrations)**

(i) No wastewater ($T_0$).

(ii) Using 80% industrial water for irrigation ($T_1$)

(iii) Using 60% industrial water for irrigation ($T_2$)

(iv) Using 40% industrial water for irrigation ($T_3$)

(v) Using 20% industrial water for irrigation ($T_4$)

**Treatment Combinations (10):**

1. $V_1T_0$: BRRI dhan29 + No waste water

2. $V_1T_1$: BRRI dhan29 + Using 80% industrial water for irrigation

3. $V_1T_2$: BRRI dhan29 + Using 60% industrial water for irrigation

4. $V_1T_3$: BRRI dhan29 + Using 40% industrial water for irrigation

5. $V_1T_4$: BRRI dhan29 + Using 20% industrial water for irrigation

6. $V_2T_0$: BRRI Hybrid dhan2 + No waste water

7. $V_2T_1$: BRRI Hybrid dhan2 + Using 80% industrial water for irrigation

8. $V_2T_2$: BRRI Hybrid dhan2 + Using 60% industrial water for irrigation

9. $V_2T_3$: BRRI Hybrid dhan2 + Using 40% industrial water for irrigation

10. $V_2T_4$: BRRI Hybrid dhan2 + Using 20% industrial water for irrigation

### 3.6 Preparation of waste water

Textile wastewater is a waste of textile mill. Textile wastewater has a variable and complex mixture of pollutants, such as inorganic compounds, polymers, organic products, and color. Textile wastewater can be treated using biological treatment processes, chemical precipitation, adsorption, and membrane technology. For preparing waste water, at first, black, blue, green, violet and brown color mixed in a dram and then this mixture were mixed with Hydrose (200gm) and Kostic soda (200 gm). And made this solution where total amount was 1400 gm. After that, 20 lit water added with this mixture (1400 gm) and boiled it throughly, so that, the color became permanent color. Then the solution was dilute and kept it into four container. At last this solution was storage and use it when needed. Per pot needed 2 liter of water.

### Procedure of experiment

### 3.6.1 Raising seedling

#### 3.6.1.1 Seed collection

Vigorous and healthy seeds of BRRI dhan29 and BRRI Hybrid dhan2 were collected from BRRI (Bangladesh Rice Research Institute), Gazipur, Bangladesh.

#### 3.6.1.2 Seed sprouting

Healthy seeds were kept in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

#### 3.6.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on 20 February, 2019 in order to transplant the seedlings in the main field.

### 3.6.2 Preparation of the pot

The pot was selected for the experiment and placed in the open field at the 2nd week of March, 2019 with a well mixture field soil. Field soil was mixture with well decomposed cowdung and fertilizers. After that, mixture soil filed pots were irrigated by the irrigating can. Then keep it in the open air for transplanting.

### 3.6.3 Fertilizers and manure application

The fertilizers N, P, K, S and Zn in the form of Urea, TSP, MoP, Gypsum and Zinc Sulphate, respectively were applied. All fertilizers except urea were applied at the time of final land preparation and urea was top-dressed into three equal splits each at 15, 30 and 45 days after transplanting (DAT) (BARC, 1997). The dose and method of application are shown in Table 1.

**Table 1.** Dose and method of application of fertilizers in rice field

| **Fertilizers** | **Dose (kg/ha)** | **Application (%)** | | | |
|---|---|---|---|---|---|
| | | **Basal** | **1st installment** | **2nd installment** | **3rd installment** |
| Urea | 120 | 0 | 33.33 | 33.33 | 33.33 |
| TSP | 100 | 100 | - | - | - |
| MoP | 70 | 70 | - | - | - |
| Gypsum | 60 | 60 | - | - | - |
| Zinc Sulphate | 10 | 10 | - | - | - |

### 3.6.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 15 March, 2019 without causing much mechanical injury to the roots.

### 3.6.5 Transplanting of seedlings in the pot

Thirty (30) days old seedlings were transplanted in the experimental pots using three seedlings per hill and 4 hills per pot on 15 March, 2019.

### 3.6.6 Intercultural operations

After establishment of seedlings, all intercultural operations were accomplished for better growth and development of the rice seed lings as and whenever necessary.

#### 3.6.6.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 3 cm in the early stages to enhance tillering and 4-5 cm in the later stage to discourage late tillering. The plots were finally dried out at 15 days before harvesting.

#### 3.6.6.2 Gap filling

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

#### 3.6.6.3 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the pots during the period of experiment. Weeding was done after 15, 32 and 52 days of transplanting.

#### 3.6.6.4 Top dressing

The urea fertilizer was top-dressed in 3 equal installments at 15, 30 and 45 days after transplanting (DAT).

#### 3.6.6.5 Plant protection

There were some incidence of insects specially grasshopper, stem borer, rice ear cutting caterpillar, thrips and rice bug which was controlled by spraying Curator 5G and Smithton. The disease, Brown spot of rice was controlled by spraying Tilt.

### 3.7 Harvesting, threshing and cleaning

Five hills were randomly selected from the fifteen pots per plot at maturity (when 80% of the grains became golden yellow) and uprooted from each unit plot prior to harvest for recording data. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. The grains were threshed, cleaned and sun dried (adjusted to 12% moisture con-tent) to record grain yield plot$^{-1}$. Straws were also sun-dried to record its yield plot$^{-1}$ and both grain and straw yields plot$^{-1}$ were then converted to t ha$^{-1}$.

### 3.8 Data recording

The following data were collected during the study period:

**Growth characteristics**

1. Plant height (cm)

2. Total tillers hill$^{-1}$

3. Leaves hill$^{-1}$

**Morphological parameters**

1. Leaf area ($cm^2$)

**Physiological parameters**

1. SPAD value

2. Stomatal conductance

3. Absolute grain growth rate

4. Total dry matter hill$^{-1}$ (g)

5. Dry mater distribution

**Yield contributing parameters**

1. Total grain panicle$^{-1}$

2. Filled grain panicle$^{-1}$

3. Unfilled grain panicle$^{-1}$

4. Grain sterility (%)

5. 1000 seed weight (g)

**Yield parameters**

1. Grain yield (t ha$^{-1}$)

2. Straw yield (t ha$^{-1}$)

3. Biological yield (t ha$^{-1}$)

4. Harvest index

**3.9 Procedure of recording data**

**3.9.1 Plant height (cm)**

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of same 5 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

### 3.9.2 Number of total tillers hill$^{-1}$

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers.

### 3.9.3 Number of leaves hill$^{-1}$

The total number of leaves hill$^{-1}$ was counted from 5 selected hills at harvest and average value was recorded.

### 3.9.4 Leaf area (cm$^2$)

Leaf area (cm$^2$) was estimated manually at the time of 55, 75 DAT and at harvest. Data were collected as the average of 5 plants selected. Final data were calculated multiplying by a correction factor 0.75.

Leaf area = Leaf length × leaf breadth × 0.75

### 3.9.5 Absolute grain growth rate (AGGR)

During anthesis, different main panicles were tagged; some were sampled and packed in separate brown paper packet as per treatment. Then the packets were kept in oven at 70ºC for 72 hrs. The tagged panicles were collected after 10 days interval from anthesis to maturity. Then the panicles were packed and oven dried at the same procedure. After drying 20 grains were randomly collected from each panicles and the weight of one grain was calculated. The average values were taken from each treatment for analysis.

$$AGGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \text{ mg grain}^{-1} \text{ day}^{-1}$$

Where,

$W_1$ = Grain dry weight at initial time

$W_2$ = Grain dry weight at final time

$T_1$ = Initial time

$T_2$ = Final time

### 3.9.6 Total dry matter hill$^{-1}$ (g)

Total dry matter per hill was measured in gram (g) at harvest from 5 randomly selected plant of each plot from inner rows leaving the boarder row. Collected plant were oven dried at 70°C for 72 hours then transferred into desecrator and allowed to cool down at room temperature, then final weight was taken.

### 3.9.7 Total grains panicle$^{-1}$

The total number of grains was calculated by adding filled and unfilled grains and then average number of total grains panicle$^{-1}$ was recorded.

### 3.9.8 Filled grain panicle$^{-1}$

The number of filled grains was collected from the randomly selected 5 panicles from each plot and then average number of filled grains panicle$^{-1}$ was calculated.

### 3.9.9 Unfilled grains panicle$^{-1}$

The number of unfilled grains was collected randomly from selected 5 plants of a plot and then average number of unfilled grains panicle$^{-1}$ was recorded.

### 3.9.10 Grain sterility (%)

The grain sterility percentage was calculated by dividing number of unfilled grains with number of total grains and multiply by 100.

Grain sterility percentage= (Number of unfilled grains/ Number of total grains) x 100

### 3.9.11 1000 seed weight

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

### 3.9.12 Grain yield ha$^{-1}$

Grains obtained from each unit plot were sun-dried and weighed carefully. The central 3 lines from each plot were harvested, threshed, dried, weighed and finally converted to t ha$^{-1}$ basis.

### 3.9.13 Straw yield ha$^{-1}$

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 3 lines were harvested, threshed, dried and weighed and finally converted to t ha$^{-1}$ basis.

### 3.9.14 Biological yield

The biological yield was calculated by adding total grain yield and straw yield.

Biological yield = Grain yield + Straw yield

### 3.9.15 Harvest index

The harvest index was calculated with the following formula:

Harvest index = (Grain yield / Biological yield) x 100

### 3.10 Statistical Analysis

All the data collected on different parameters wear statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C computer package program and the mean difference were adjudged by least significant (LSD) test at 5% level of significance.

# CHAPTER IV

# RESULTS AND DISCUSSION

The present investigation entitled “Effect of textile wastewater on morphological attributes and yield of rice”. The findings obtained from the study have been presented, discussed and compared in this chapter through different tables and figures. The analyses of variance (ANOVA) and other table on different parameters have been presented in Appendices. The results have been presented and discussed with the help of tables and graphs and possible interpretations have been given under the following sub-headings.

## 4.1 Growth performances

### 4.1.1 Plant height (cm) at harvesting stage

#### 4.1.1.1 Effect of variety

Statistically significant variation was recorded between the rice varieties for plant height (cm) (Figure 1). Data revealed that the tallest plant (90.4 cm) was observed from BRRI Hybrid dhan2, which was statistically different from other variety, whereas the shortest plant (90.07 cm) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that plant height differed from variety to variety. Plant height was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

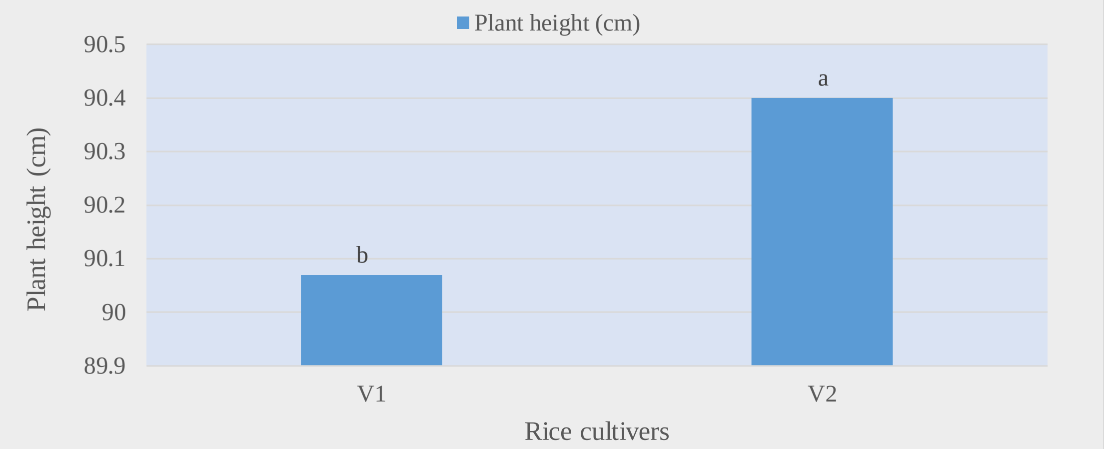


Figure 1: The effect of varieties on plant height (cm) of rice

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

#### 4.1.1.2 Effect of textile wastewater

Significantly different variation in plant height of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 2). Among the different treatments, the maximum plant height (91.33 cm) was observed from $T_0$ (no waste water) which was significantly similar with $T_4$ (using 20% industrial water for irrigation) followed by others and minimum plant height (89.00 cm) was recorded from $T_1$ (using 80% industrial water for irrigation). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

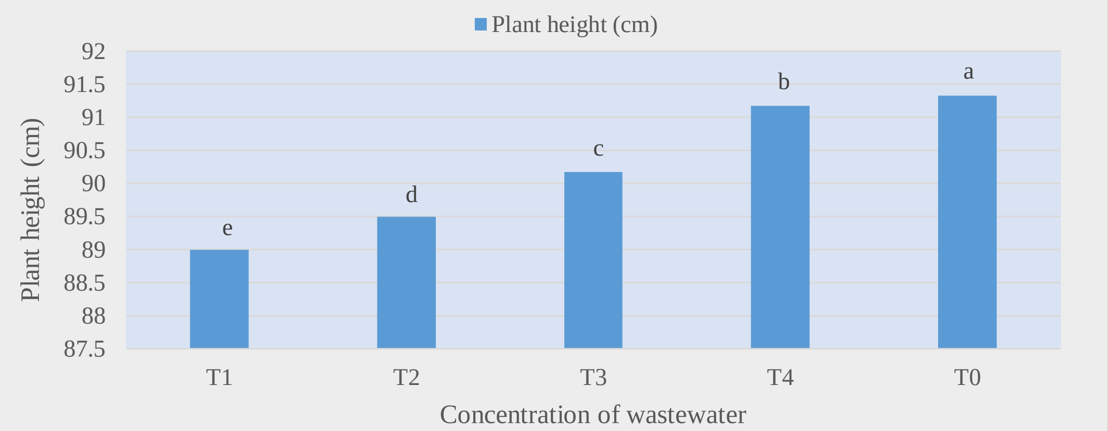


Figure 2: The effect of concentration of textile wastewater on plant height (cm) of rice

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.1.1.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on plant height of rice (Table 2). The maximum plant height (93.33 cm) was recorded from the $V_1T_0$ (BRRI dhan29 + no waste water) which was statistically similar with the other combinations. The shortest plant (84.67 cm) was obtained from the $V_2T_1$ (BRRI Hybrid dhan2 + using 80% industrial water for irrigation).

**Table 2:** Interaction effect of varieties and concentration of wastewater on plant height (cm) of rice at harvesting stage

| Varieties | Waste water concentrations | Plant height (cm) |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 93.33 a |
| | $T_1$ | 89.67 a |
| | $T_2$ | 90.33 a |
| | $T_3$ | 92.00 a |
| | $T_4$ | 90.67 a |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 92.33 a |
| | $T_1$ | 84.67 a |
| | $T_2$ | 89.67 a |
| | $T_3$ | 90.33 a |
| | $T_4$ | 92.33 a |
| CV (%) | | 8.08 |
| $LSD_{(0.05)}$ | | 12.18 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.1.2 Tillers hill$^{-1}$ at anthesis stage

#### 4.1.2.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for number of tillers hill$^{-1}$ (Figure 3). Data revealed that, the maximum tiller hill$^{-1}$ (25.00) was observed from BRRI Hybrid dhan2, which was statistically different from other variety, whereas the shortest plant (21.33) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that plant height differed from variety to variety. Plant height was greatly influenced by different varieties possibly due to the

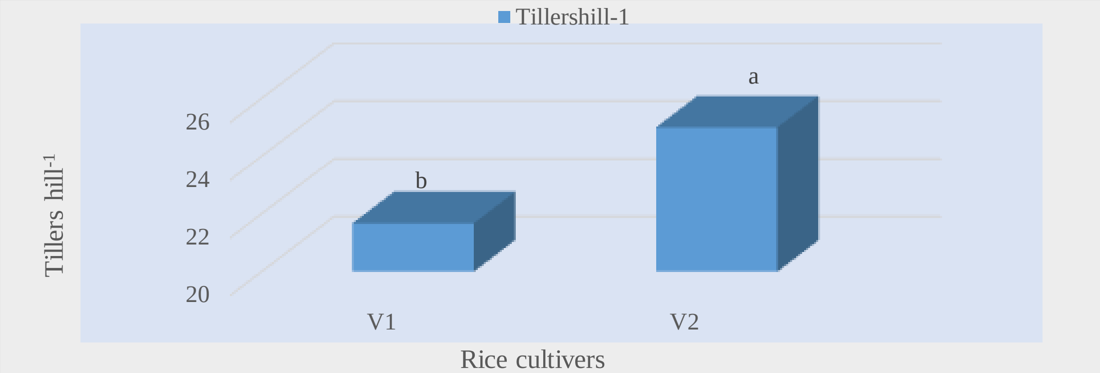



Figure 3: The effect of varieties on tillers hill$^{-1}$ of rice

reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

**4.1.2.2 Effect of textile wastewater**

Significantly different variation in number of tillers hill$^{-1}$ of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 4). Among the different treatments, the maximum number of tillers hill$^{-1}$ (27.00) was observed from $T_0$ (no waste water) which was significantly different and followed by others. Minimum number of tillers hill$^{-1}$ (19.83) was recorded from $T_1$ (using 80% industrial water for irrigation). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

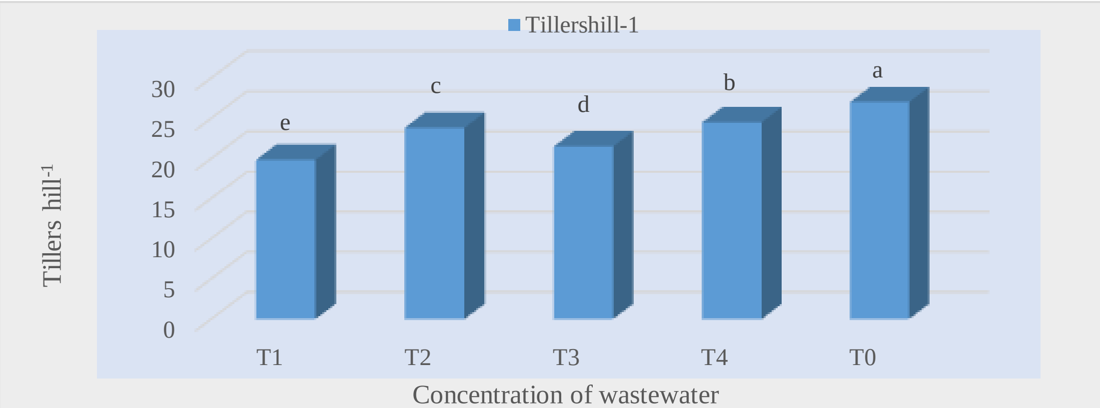



Figure 4: The effect of concentration of wastewater on tillers hill$^{-1}$ of rice

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.1.2.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on number of tillers hill$^{-1}$ of rice (Table 3). The maximum number of tillers hill$^{-1}$ (27.67) was recorded from the $V_1T_0$ (BRRI dhan29 + no waste water) which was statistically similar with $V_2T_0$ (26.33) and $V_2T_4$ (26.33) and followed by $V_1T_3$ (25.33) and $V_1T_4$ (24.33). The minimum number of tillers hill$^{-1}$ (18.33) was obtained from the $V_2T_1$ (BRRI Hybrid dhan2 + using 80% industrial water for irrigation) which was statistically similar with $V_2T_2$ (18.67) and followed by $V_1T_1$ (21.33), $V_1T_2$ (22.33) and $V_2T_3$ (22.67).

**Table 3:** Interaction effect of varieties and textile wastewater on tillers hill$^{-1}$ at anthesis stage

| Varieties | Waste water concentration | Tillers hill$^{-1}$ |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 27.67 a |
| | $T_1$ | 21.33 d |
| | $T_2$ | 22.33 d |
| | $T_3$ | 25.33 bc |
| | $T_4$ | 24.33 c |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 26.33 ab |
| | $T_1$ | 18.33 e |
| | $T_2$ | 18.67 e |
| | $T_3$ | 22.67 d |
| | $T_4$ | 26.33 ab |
| CV (%) | | 4.02 |
| LSD $_{(0.05)}$ | | 1.57 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.1.3 Leaves hill$^{-1}$ at anthesis stage

#### 4.1.3.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for number of leaves hill$^{-1}$ (Figure 5). Data revealed that, the maximum number of leaves hill$^{-1}$

(26.60) was observed from BRRI Hybrid dhan2, which was statistically different from other variety, whereas the minimum number of leaves hill$^{-1}$ (24.93) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that the number of leaves hill$^{-1}$ differed from variety to variety. The number of leaves hill$^{-1}$ was greatly influenced by different varieties possibly due to the reason that the height of the plant

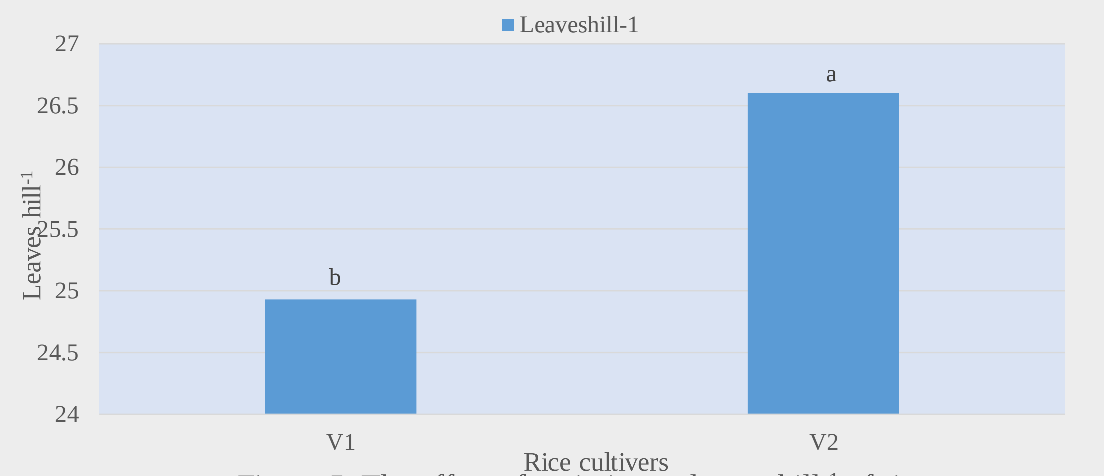


Figure 5: The effect of varieties on leaves hill$^{-1}$ of rice

is a varietal trait which is primarily influenced by genetic makeup.

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

**4.1.3.2 Effect of textile wastewater**

Significantly different variation in number of leaves hill$^{-1}$ of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 6). Among the different treatments, the maximum number of leaves hill$^{-1}$ (28.00) was observed from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (26.50) and $T_3$ (25.83). Minimum number of leaves hill$^{-1}$ (24.00) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (24.50). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

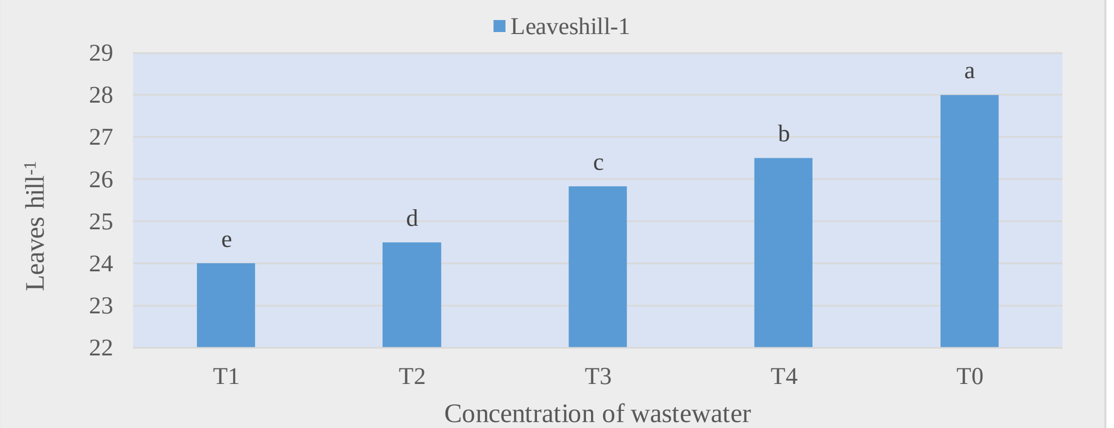



Figure 6: The effect of concentration of wastewater on leaves hill$^{-1}$ of rice

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.1.3.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on number of leaves hill$^{-1}$ of rice (Table 4). The maximum number of leaves hill$^{-1}$ (29.33) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was statistically different from others and followed by $V_1T_0$ (28.33), $V_1T_4$ (27.67), $V_1T_3$ (27.33) and $V_2T_4$ (26.67). The minimum number of leaves hill$^{-1}$ (21.33) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (22.67), $V_2T_2$ (23.33), $V_2T_3$ (25.67) and $V_1T_2$ (25.33).

**Table 4:** Interaction effect of varieties and textile wastewater on leaves hill$^{-1}$ of rice at anthesis stage

| Varieties | Waste water concentration | Leaves hill$^{-1}$ |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 28.33 b |
| | $T_1$ | 21.33 g |
| | $T_2$ | 25.33 e |
| | $T_3$ | 27.33 cd |
| | $T_4$ | 27.67 bc |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 29.33 a |
| | $T_1$ | 22.67 f |
| | $T_2$ | 23.33 f |
| | $T_3$ | 25.67 e |
| | $T_4$ | 26.67 d |
| CV (%) | | 2.20 |
| LSD $_{(0.05)}$ | | 0.95 |

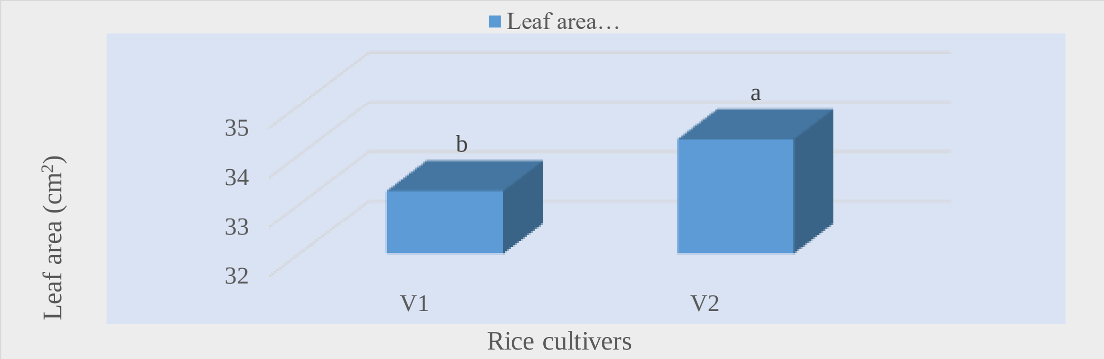
Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

## 4.2 Morphological parameter

### 4.2.1 Leaf area (cm$^2$)

#### 4.2.1.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for leaf area (cm$^2$) (Figure 7). Data revealed that, the maximum leaf area (34.31 cm$^2$) was observed from BRRI Hybrid dhan2, which was statistically different from other variety. Whereas the minimum leaf area (33.27 cm$^2$) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that the leaf area differed from variety to variety. The leaf area was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.



Figurre 7: The effect of vaieties on leaf area of rice

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

#### 4.2.1.2 Effect of textile wastewater

Significantly different variation in leaf area of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 8). Among the different treatments, the maximum leaf area (38.53 cm$^2$) was observed from $T_0$ (no wastewater) which was significantly different from others and followed by $T_4$ (34.47 cm$^2$) and $T_3$ (32.55 cm$^2$). Minimum leaf area (31.00 cm$^2$) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (32.40 cm$^2$). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

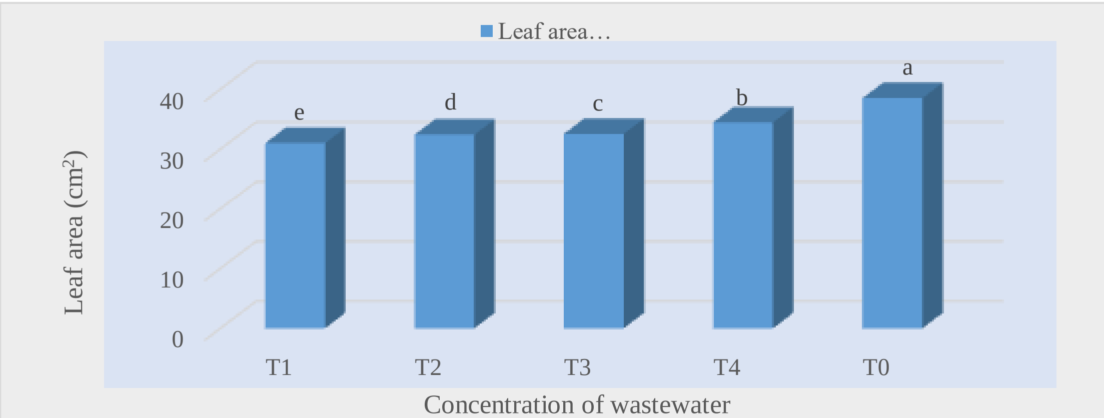


Figure 8: The effect of concentration of textile wastewater on leaf area (cm$^2$) of rice

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.3.1.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on leaf area of rice (Table 5). The maximum leaf area (39.47 $cm^2$) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was similar with $V_1T_0$ (39.40 $cm^2$) and followed by $V_1T_4$ (37.60 $cm^2$), $V_1T_3$ (36.47 $cm^2$) and $V_2T_4$ (33.57 $cm^2$). The minimum leaf area (28.33 $cm^2$) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (29.50 $cm^2$), $V_2T_2$ (29.53 $cm^2$), $V_2T_3$ (31.53 $cm^2$) and $V_1T_2$ (32.50 $cm^2$).

**Table 5:** Interaction effect of varieties and textile wastewater on leaf area of rice at grain filling stage

| Varieties | Waste water concentration | Leaf area ($cm^2$) |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 39.40 a |
| | $T_1$ | 28.33 h |
| | $T_2$ | 32.50 e |
| | $T_3$ | 36.47 c |
| | $T_4$ | 37.60 b |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 39.47 a |
| | $T_1$ | 29.50 g |
| | $T_2$ | 29.53 g |
| | $T_3$ | 31.53 f |
| | $T_4$ | 33.57 d |
| CV (%) | | 0.82 |
| LSD $_{(0.05)}$ | | 0.46 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

## 4.3 Physiological parameters

### 4.3.1 SPAD value at grain filling stage

#### 4.3.1.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for SPAD value at grain filling stage (Figure 9). Data revealed that, the maximum SPAD value (46.13) was observed from BRRI Hybrid dhan2, which was statistically different from other variety. Whereas the minimum SPAD value (41.37) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that the SPAD value differed from variety to variety. The SPAD value was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

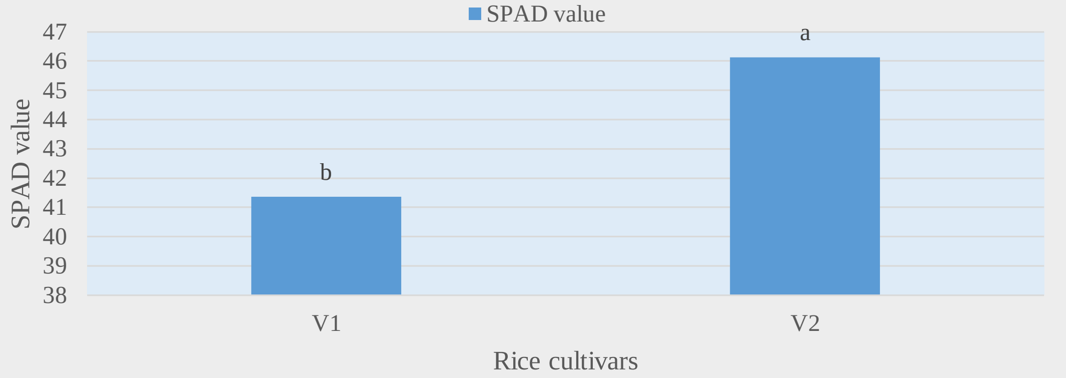



Figure 9: The effect of varieties on SPAD value of rice life at grain filling stage

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

#### 4.3.1.2 Effect of textile wastewater

Significantly different variation in SPAD value of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 10). Among the

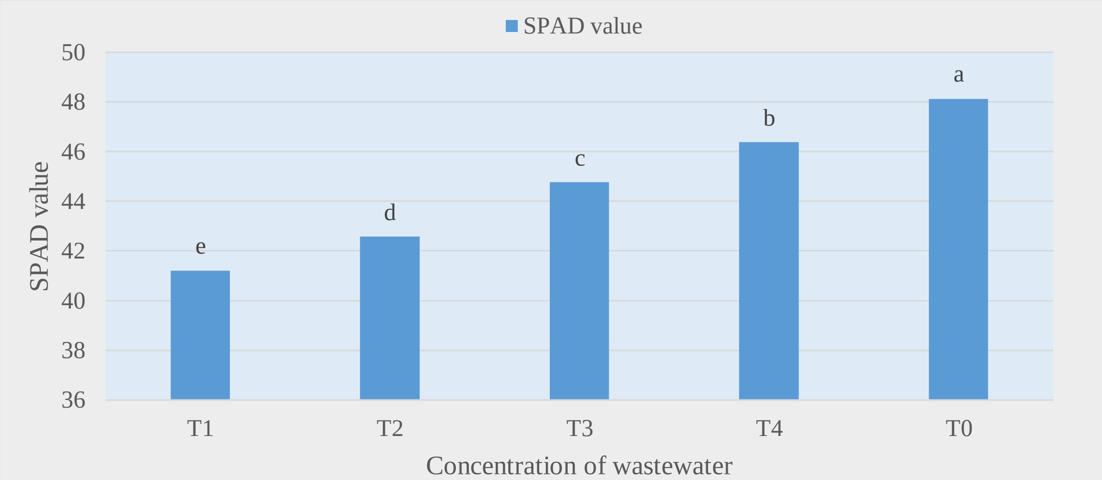


Figure 10: The effect of concentration of wastewater on SPAD value of rice leaf at grain filling stage

different treatments, the maximum SPAD value (48.13) was observed from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (46.37) and $T_3$ (44.76). Minimum SPAD value (41.21) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (42.57). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.3.1.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on SPAD value of rice at grain filling stage (Table 6). The maximum SPAD value (49.13) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was statistically different from others and followed by $V_1T_0$ (47.37), $V_1T_4$ (46.33), $V_1T_3$ (45.17) and $V_2T_4$ (44.87). The minimum SPAD value (41.21) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (41.76) and followed by $V_2T_2$ (42.13), $V_2T_3$ (42.89) and $V_1T_2$ (43.26).

**Table 6:** Interaction effect of varieties and textile wastewater on SPAD value of rice at grain filling stage

| Varieties | Waste water concentration | SPAD value |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 47.37 b |
| | $T_1$ | 41.21 g |
| | $T_2$ | 43.26 e |
| | $T_3$ | 45.17 cd |
| | $T_4$ | 46.33 c |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 49.13 a |
| | $T_1$ | 41.76 g |
| | $T_2$ | 42.13 f |
| | $T_3$ | 42.89 e |
| | $T_4$ | 44.87 d |
| CV (%) | | 0.79 |
| $LSD_{(0.05)}$ | | 0.05 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.3.2 Stomatal conductance at grain filling stage

#### 4.3.2.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for stomatal conductance (Table 7). Data revealed that, the maximum stomatal conductance (0.48 mol $CO_2$ $m^{-2}$ $s^{-1}$) was observed from BRRI Hybrid dhan2, which was statistically different from other variety, whereas the minimum stomatal conductance (0.42 mol $CO_2$ $m^{-2}$ $s^{-1}$) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that the stomatal conductance differed from variety to variety.

**Table 7:** The effect of varieties on stomatal conductance of rice leaf at grain filling stage

| Varieties | Stomatal conductance (mol $CO_2$ $m^{-2}$ $s^{-1}$) |
|---|---|
| $V_1$ | 0.42 b |
| $V_2$ | 0.48 a |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $V_1$= BRRI dhan29; and $V_2$= BRRI hybrid dhan2.

#### 4.3.2.2 Effect of textile wastewater

Significantly different variation in stomatal conductance of rice was observed in case of different amount of textile wastewater as irrigation water (Table 8). Among the different treatments, the maximum stomatal conductance (0.53 mol $CO_2$ $m^{-2}$ $s^{-1}$) was observed from $T_0$ (no waste water) which was significantly similar with $T_4$ (0.51 mol $CO_2$ $m^{-2}$ $s^{-1}$) and followed by others. Minimum stomatal conductance (0.41 mol $CO_2$ $m^{-2}$ $s^{-1}$) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly similar with $T_2$ (0.44 mol $CO_2$ $m^{-2}$ $s^{-1}$) and $T_3$ (0.48 mol $CO_2$ $m^{-2}$ $s^{-1}$). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

**Table 8:** The effect of concentration of wastewater on stomatal conductance of rice leaf at grain filling stage

| Waste water concentration | Stomatal conductance (mol $CO_2$ $m^{-2}$ $s^{-1}$) |
|---|---|
| $T_0$ | 0.53 a |
| $T_1$ | 0.41 b |
| $T_2$ | 0.44 b |
| $T_3$ | 0.48 b |
| $T_4$ | 0.51 a |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.3.2.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on stomatal conductance of rice at grain filling stage (Table 9). The maximum stomatal conductance (0.56 mol $CO_2$ $m^{-2}$ $s^{-1}$) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was statistically similar with $V_1T_0$ (0.53 mol $CO_2$ $m^{-2}$ $s^{-1}$), $V_1T_4$ (0.52 mol $CO_2$ $m^{-2}$ $s^{-1}$) and $V_1T_3$ (0.51 mol $CO_2$ $m^{-2}$ $s^{-1}$) and followed by $V_2T_4$ (0.48 mol $CO_2$ $m^{-2}$ $s^{-1}$) and $V_1T_2$ (0.47 mol $CO_2$ $m^{-2}$ $s^{-1}$). The minimum stomatal conductance (0.41 mol $CO_2$ $m^{-2}$ $s^{-1}$) was obtained from the

$V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically similar with $V_2T_1$ (0.42 mol $CO_2$ $m^{-2}$ $s^{-1}$) and followed by $V_2T_2$ (0.43 mol $CO_2$ $m^{-2}$ $s^{-1}$) and $V_2T_3$ (0.45 mol $CO_2$ $m^{-2}$ $s^{-1}$).

**Table 9:** Interaction effect of varieties and textile wastewater on stomatal conductance of rice at grain filling stage

| Varieties | Waste water concentration | Stomatal conductance (mol $CO_2$ $m^{-2}$ $s^{-1}$) |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 0.53 a |
| | $T_1$ | 0.41 e |
| | $T_2$ | 0.47 b |
| | $T_3$ | 0.51 ab |
| | $T_4$ | 0.52 a |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 0.56 a |
| | $T_1$ | 0.42 e |
| | $T_2$ | 0.43 d |
| | $T_3$ | 0.45 c |
| | $T_4$ | 0.48 b |
| CV (%) | | 1.69 |
| $LSD_{(0.05)}$ | | 0.05 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.3.3 Absolute grain growth rate at grain filling stage

#### 4.3.3.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for absolute grain growth rate (Figure 11). Data revealed that, the maximum absolute grain growth rate (6.91) was observed from BRRI Hybrid dhan2, which was statistically different from other variety. Whereas the minimum absolute grain growth rate (3.33) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that the absolute grain growth rate differed from variety to variety. Absolute grain growth rate was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

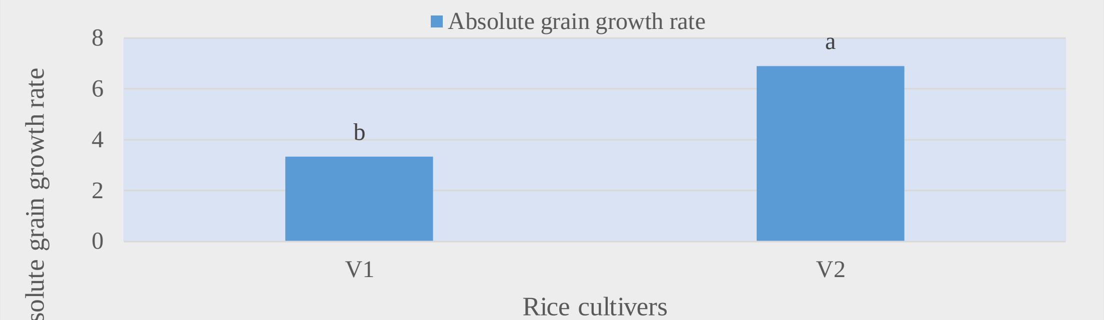



Figure 11: The effect of varieties on absolute grain growth rate of rice

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

#### 4.3.3.2 Effect of textile wastewater

Significantly different variation in absolute grain growth rate of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 12). Among the different treatments, the maximum absolute grain growth rate (7.10) was observed from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (5.94) and $T_3$ (5.07). Minimum absolute grain growth rate (3.28) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (4.23). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

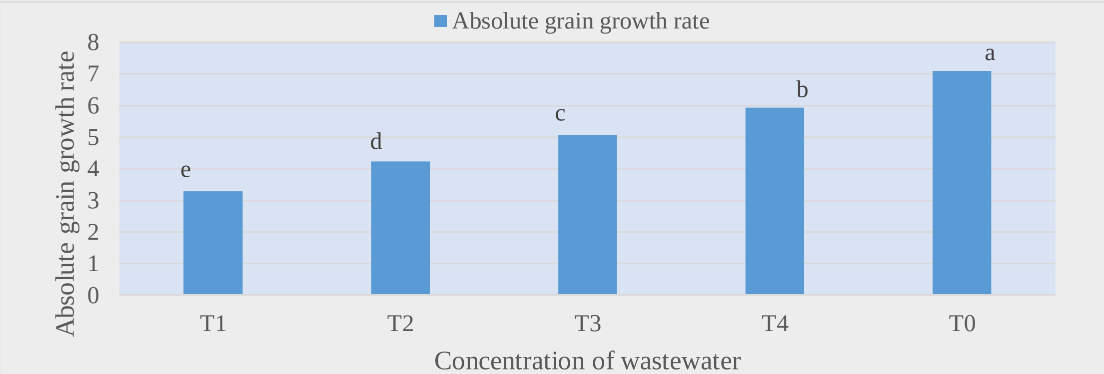



Figure 12: The effect of concentration of wastewater on absolute grain growth rate of rice

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.3.3.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on absolute grain growth rate of rice (Table 10). The maximum absolute grain growth rate (8.24) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was similar with $V_1T_0$ (8.21) and followed by $V_1T_4$ (7.75), $V_1T_3$ (6.00) and $V_2T_4$ (5.99). The minimum absolute grain growth rate (2.21) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (2.38), $V_2T_2$ (2.46), $V_2T_3$ (3.63) and $V_1T_2$ (4.35).

**Table 10:** Interaction effect of varieties and textile wastewater on absolute grain growth rate of rice

| Varieties | Waste water concentration | Absolute grain growth rate |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 8.21 a |
| | $T_1$ | 2.21 h |
| | $T_2$ | 4.35 d |
| | $T_3$ | 6.00 c |
| | $T_4$ | 7.75 b |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 8.24 a |
| | $T_1$ | 2.38 g |
| | $T_2$ | 2.46 f |
| | $T_3$ | 3.63 e |
| | $T_4$ | 5.99 c |
| CV (%) | | 0.35 |
| $LSD_{(0.05)}$ | | 0.05 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.3.4 Total dry mater (g) at harvesting stage

#### 4.3.4.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for total dry mater $hill^{-1}$ (Figure 13). Data revealed that, the maximum dry mater $hill^{-1}$ (14.84 g) was observed from BRRI Hybrid dhan2, which was statistically different from other variety, whereas the minimum dry mater hill$^{-1}$ (12.27 g) was recorded from BRRI dhan29. This confirms the report of Hossain *et al.* (1991) that the total dry mater hill$^{-1}$ differed from variety to variety. The total dry mater hill$^{-1}$ was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

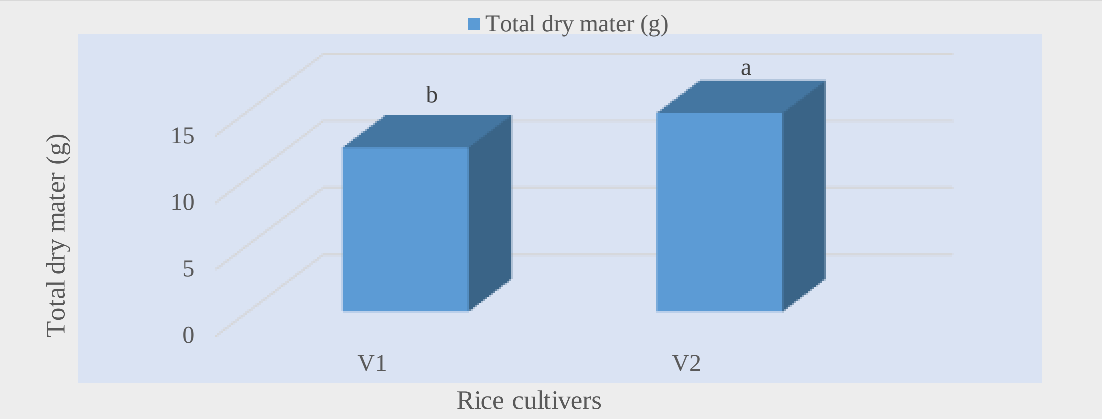



Figure 13: The effect of varieties on total dry mater (g) of rice

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

### 4.3.4.2 Effect of textile wastewater

Significantly different variation in total dry mater hill$^{-1}$ of rice was observed in case of different amount of textile wastewater as irrigation water (Figure 14). Among the different treatments, the maximum dry mater hill$^{-1}$ (19.97 g) was observed from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (17.43 g) and $T_3$ (13.43 g). Minimum dry mater hill$^{-1}$ (6.99 g) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (9.98 g). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

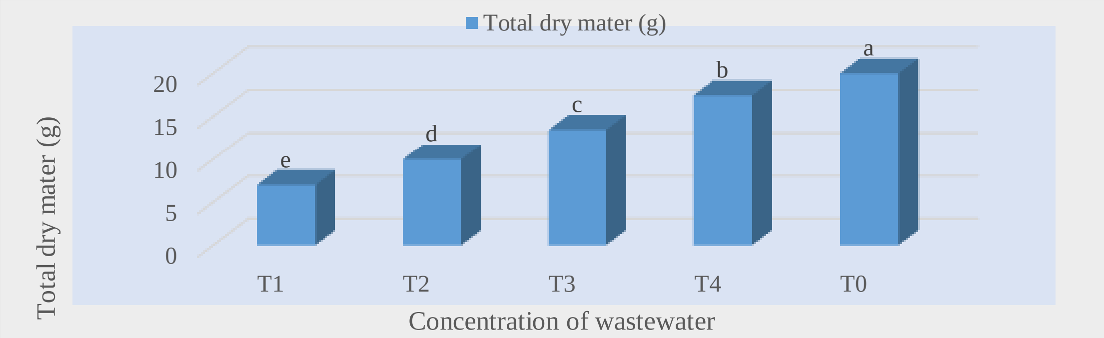


Figure 14: The effect of concentration of wastewater on total dry mater (g) of rice

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.3.4.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on total dry mater hill$^{-1}$ of rice (Table 11). The maximum dry mater hill$^{-1}$ (21.41 g) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was statistically different from others and followed by $V_1T_0$ (18.53 g), $V_1T_4$ (18.37 g), $V_1T_3$ (16.49 g) and $V_2T_4$ (15.49 g). The minimum dry mater hill$^{-1}$ (66.40 g) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (7.58 g), $V_2T_2$ (8.57 g), $V_2T_3$ (11.37 g) and $V_1T_2$ (11.39 g).

**Table 11:** Interaction effect of varieties and textile wastewater on total dry mater (g) of rice at harvesting stage

| Varieties | Waste water concentration | Total dry mater (g) |
|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 18.53 b |
| | $T_1$ | 6.40 h |
| | $T_2$ | 11.39 e |
| | $T_3$ | 16.49 c |
| | $T_4$ | 18.37 b |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 21.41 a |
| | $T_1$ | 7.58 g |
| | $T_2$ | 8.57 f |
| | $T_3$ | 11.37 e |
| | $T_4$ | 15.49 d |
| CV (%) | | 0.88 |
| $LSD_{(0.05)}$ | | 0.20 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.3.5 Dry mater distribution at harvesting stage

#### 4.3.5.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for dry mater distribution (g) (Table 12). In case of grain dry weight (g), there was statistically significant variations among the rice cultivars. The maximum weight (10.47 g) was observed from BRRI Hybrid dhan2, which was statistically different from other variety. Whereas the minimum weight (9.13 g) was recorded from BRRI dhan29 (Table 12).

On the other hand, straw dry weight (g), there was statistically significant variations among the rice cultivars. The maximum weight (4.37 g) was observed from BRRI Hybrid dhan2, which was statistically different from other variety. Whereas the minimum weight (3.14 g) was recorded from BRRI dhan29 (Table 12). This confirms the report of Hossain *et al.* (1991) that the dry matter distribution differed from variety to variety. Dry matter distribution was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

**Table 12:** The effect of varieties on dry matter distribution of rice plants at harvesting stage

| Varieties | Dry matter distribution | | |
|---|---|---|---|
| | Total dry matter (g) | Total grain dry weight (g) | Dry straw weight (g) |
| $V_1$ | 12.27 b (100%) | 9.13 b (74.41%) | 3.14 b (25.59%) |
| $V_2$ | 14.84 a (100%) | 10.47 a (70.55%) | 4.37 a (29.45%) |

Values followed by same letter(s) did not differ significantly a 5% level of probability. Values inside the parenthesis indicate the value relative to total dry matter.
Here, $V_1$= BRRI dhan29; and $V_2$= BRRI hybrid dhan2.

#### 4.3.5.2 Effect of textile wastewater

Significantly different variation in dry mater distribution of rice was observed in case of different amount of textile wastewater as irrigation water (Table 13). In case of grain dry weight (g), there was statistically significant variations among different amount of textile wastewater as irrigation water. The maximum weight (14.85 g) was observed from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (13.76 g) and $T_3$ (9.30 g). Minimum weight (4.16 g) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (6.41 g).

On the other hand, straw dry weight (g), there was statistically significant variations among different amount of textile wastewater as irrigation water. The maximum weight (5.12 g) was observed from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (3.67 g) and $T_3$ (4.13 g). Minimum weight (2.83 g) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (3.57 g) (Table 13). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

**Table 13:** The effect of concentration of wastewater on dry matter distribution of rice plant at harvesting stage

| **Waste water concentration** | **Dry matter distribution** | | |
|---|---|---|---|
| | **Total dry matter (g)** | **Total grain dry weight (g)** | **Dry straw weight (g)** |
| $T_0$ | 19.97 a (100%) | 14.85 a (74.36%) | 5.12 a (25.64%) |
| $T_1$ | 6.99 e (100%) | 4.16 e (59.51%) | 2.83 d (40.49%) |
| $T_2$ | 9.98 d (100%) | 6.41 d (64.23%) | 3.57 c (35.77%) |
| $T_3$ | 13.43 c (100%) | 9.30 c (69.25%) | 4.13 b (30.75%) |
| $T_4$ | 17.43 b (100%) | 13.76 b (78.95%) | 3.67 b (21.05%) |

Values followed by same letter(s) did not differ significantly a 5% level of probability. Values inside the parenthesis indicate the value relative to total dry matter.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.2.1.3 Interaction effect of different varieties and textile wastewater

Different varieties and textile wastewater expressed no significant differences due to their interaction effect on dry matter distribution of rice (Table 14). In case of grain dry weight (g), there was statistically significant variations among different a varieties and textile wastewater. The maximum weight (15.74 g) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was statistically different from others and followed by $V_1T_4$ (13.50 g), $V_1T_0$ (13.46 g), $V_1T_3$ (12.16 g) and $V_2T_4$ (11.37 g). The minimum weight (3.86 g) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (4.60 g), $V_2T_2$ (5.20 g), $V_1T_2$ (7.61 g) and $V_2T_3$ (8.48 g) (Table 14).

On the other hand, straw dry weight (g), there was statistically significant variations among different a varieties and textile wastewater. The maximum weight (5.67 g) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was statistically different from others and followed by $V_1T_0$ (5.07 g), $V_1T_4$ (4.87 g), $V_1T_3$ (4.33 g), and $V_2T_4$ (4.12 g). The minimum weight (2.54 g) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (2.98 g), $V_2T_2$ (3.37 g), $V_1T_2$ (3.78 g) and $V_2T_3$ (3.89 g) (Table 14).

**Table 14:** Interaction effect of varieties and textile wastewater on dry matter distribution of rice plant at harvesting stage

| **Varieties** | **Waste water concentration** | **Dry matter distribution** | | |
|---|---|---|---|---|
| | | **Total dry matter (g)** | **Total grain dry weight (g)** | **Dry straw weight (g)** |
| BRRI dhan29 ($V_1$) | $T_0$ | 18.53 b (100%) | 13.46 b (72.64%) | 5.07 a (27.36%) |
| | $T_1$ | 6.40 h (100%) | 3.86 I (60.31%) | 2.54 f (39.69%) |
| | $T_2$ | 11.39 e (100%) | 7.61 f (66.81%) | 3.78 c (33.19%) |
| | $T_3$ | 16.49 c (100%) | 12.16 c (73.74%) | 4.33 b (26.26%) |
| | $T_4$ | 18.37 b (100%) | 13.50 b (73.49%) | 4.87 b (26.51%) |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 21.41 a (100%) | 15.74 a (73.52%) | 5.67 a (26.48%) |
| | $T_1$ | 7.58 g (100%) | 4.60 h (60.69%) | 2.98 e (39.31%) |
| | $T_2$ | 8.57 f (100%) | 5.20 g (60.68%) | 3.37 d (39.32%) |
| | $T_3$ | 11.37 e (100%) | 8.48 e (74.58%) | 2.89 c (25.42%) |
| | $T_4$ | 15.49 d (100%) | 11.37 d (73.40%) | 4.12 b (26.60%) |
| CV (%) | | 1.72 | 1.13 | 0.87 |
| $LSD_{(0.05)}$ | | 0.37 | 0.21 | 0.16 |

Values followed by same letter(s) did not differ significantly a 5% level of probability. Values inside the parenthesis indicate the value relative to total dry matter.

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

## 4.4. Yield contributing parameters

### 4.4.1 Effect of variety

#### 4.4.1.1 Total spikelet panicle$^{-1}$ at harvesting stage

Different varieties expressed significant differences due to the effect on the total number of spikelet panicle$^{-1}$ of rice at harvesting stage (Table 15). The maximum total number of spikelet panicle$^{-1}$ (200.6) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum total number of spikelet panicle$^{-1}$ (156.9) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that the total number of spikelet panicle$^{-1}$ differed from variety to variety. The total number of spikelet panicle$^{-1}$ was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

#### 4.4.1.2 Filled spikelet panicle$^{-1}$ at harvesting stage

Different varieties expressed significant differences due to the effect on the number of filled spikelet panicle$^{-1}$ of rice at harvesting stage (Table 15). The maximum number of filled spikelet panicle$^{-1}$ (171.32) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum number of filled spikelet panicle$^{-1}$ (126.77) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that the number of filled spikelet panicle$^{-1}$ differed from variety to variety. The number of filled spikelet panicle$^{-1}$ was greatly influenced by different varieties possibly due to the reason that the filled spikelet panicle$^{-1}$ is a varietal trait which is primarily influenced by genetic makeup.

#### 4.4.1.3 Unfilled spikelet panicle$^{-1}$ at harvesting stage

Different varieties expressed significant differences due to the effect on the number of unfilled spikelet panicle$^{-1}$ of rice at harvesting stage (Table 15). The maximum number of unfilled spikelet panicle$^{-1}$ (30.13) was recorded from the $V_1$ (BRRI dhan29) which was statistically different from other. Whereas the minimum number of unfilled spikelet panicle$^{-1}$ (29.28) was obtained from the $V_2$ (BRRI Hybrid dhan2). This confirms the report of Hossain *et al.* (1991) that the number of unfilled spikelet panicle$^{-1}$ differed from variety to variety. The number of unfilled spikelet panicle$^{-1}$ was greatly influenced by different varieties possibly due to the reason that the number of unfilled spikelet panicle$^{-1}$ is a varietal trait which is primarily influenced by genetic makeup.

#### 4.4.1.4 Spikelet fertility (%) at harvesting stage

Different varieties expressed significant differences due to the effect on spikelet fertility of rice at harvesting stage (Table 15). The maximum spikelet fertility (83.27%) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum spikelet fertility (80.39%) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that grain sterility differed from variety to variety.

**Table 15:** The effect of varieties on yield attribution characteristics of rice at harvesting stage

| Varieties | Total spikelet panicle$^{-1}$ | Filled spikelet panicle$^{-1}$ | Unfilled spikelet panicle$^{-1}$ | Spikelet fertility (%) |
|---|---|---|---|---|
| $V_1$ | 156.9 b | 126.77 b | 30.13 a | 80.39 b |
| $V_2$ | 200.6 a | 171.32 a | 29.28 b | 83.27 a |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $V_1$= BRRI dhan29; and $V_2$= BRRI hybrid dhan2.

### 4.4.2 Effect of textile wastewater

#### 4.4.2.1 Total spikelet panicle$^{-1}$ at harvesting stage

Different treatments expressed significant differences due to the effect on the total number of spikelet panicle$^{-1}$ of rice at harvesting stage (Table 16). The maximum total number of spikelet panicle$^{-1}$ (283.5) was recorded from the $T_0$ (no waste water) which was statistically different from other and followed by $T_4$ (215.4) and $T_3$ (171.0). Whereas the minimum total number of spikelet panicle$^{-1}$ (108.4) was obtained from the $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (115.5). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

#### 4.4.2.2 Filled spikelet panicle$^{-1}$ at harvesting stage

Different treatments expressed significant differences due to the effect on the number of filled spikelet panicle$^{-1}$ of rice at harvesting stage (Table 16). The maximum number of filled spikelet panicle$^{-1}$ (260.41) was recorded from the $T_0$ (no waste water) which was statistically different from other and followed by $T_4$ (189.56) and $T_3$ (141.85). Whereas the minimum number of filled spikelet panicle$^{-1}$ (70.72) was obtained from the $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (82.73). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

#### 4.4.2.3 Unfilled spikelet panicle$^{-1}$ at harvesting stage

Different treatments expressed significant differences due to the effect on the number of unfilled spikelet panicle$^{-1}$ of rice at harvesting stage (Table 16). The maximum number of unfilled spikelet panicle$^{-1}$ (37.68) was recorded from the $T_1$ (using 80%

industrial water for irrigation) which was significantly different from others and followed by $T_2$ (32.77). Whereas the minimum number of unfilled spikelet panicle$^{-1}$ (23.09) was obtained from the $T_0$ (no waste water) which was statistically different from other and followed by $T_4$ (25.84) and $T_3$ (29.15). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

### 4.4.2.4 Spikelet fertility (%) at harvesting stage

Different treatments expressed significant differences due to the effect on spikelet fertility of rice at harvesting stage (Table 16). The maximum spikelet fertility (91.86%) was recorded from the $T_0$ (no waste water) which was statistically different from other and followed by $T_4$ (88.00%) and $T_3$ (82.95%). Whereas the minimum spikelet fertility (65.24%) was obtained from the $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (71.63%). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

**Table 16:** The effect of concentration of wastewater on yield attribution characteristics of rice at harvesting stage

| Waste water concentration | Total spikelet panicle$^{-1}$ | Filled spikelet panicle$^{-1}$ | Unfilled spikelet panicle$^{-1}$ | Spikelet fertility (%) |
|---|---|---|---|---|
| $T_0$ | 283.5 a | 260.41 a | 23.09 e | 91.86 a |
| $T_1$ | 108.4 e | 70.72 e | 37.68 a | 65.24 e |
| $T_2$ | 115.5 d | 82.73 d | 32.77 b | 71.63 d |
| $T_3$ | 171.0 c | 141.85 c | 29.15 c | 82.95 c |
| $T_4$ | 215.4 b | 189.56 b | 25.84 d | 88.00 b |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.4.3 Interaction effect of different varieties and concentration of textile wastewater

#### 4.4.3.1 Total spikelet panicle$^{-1}$ at harvesting stage

Different varieties and treatments expressed significant differences due to their interaction on the total number of spikelet panicle$^{-1}$ of rice at harvesting stage (Table 17). The maximum total number of spikelet panicle$^{-1}$ (335.5) was recorded from $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (267.4), $V_1T_4$ (231.4), $V_1T_3$ (187.3) and $V_2T_4$ (163.4). The minimum number of spikelet panicle$^{-1}$ (102.3) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (110.4), $V_2T_2$ (114.4), $V_2T_3$ (120.6) and $V_1T_2$ (154.7).

#### 4.4.3.2 Filled spikelet panicle$^{-1}$ at harvesting stage

Different varieties and treatments expressed significant differences due to their interaction effect on the number of filled spikelet panicle$^{-1}$ of rice at harvesting stage (Table 17). The maximum number of filled spikelet panicle$^{-1}$ (313.07) was recorded from $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (243.65), $V_1T_4$ (206.06), $V_1T_3$ (160.97) and $V_2T_4$ (134.56). The minimum number of filled spikelet panicle$^{-1}$ (62.88) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_2$ (80.54), $V_2T_1$ (84.45), $V_2T_3$ (88.92) and $V_1T_2$ (125.23).

#### 4.4.3.3 Unfilled spikelet panicle$^{-1}$ at harvesting stage

Different varieties and treatments expressed significant differences due to their interaction effect on the number of unfilled spikelet panicle$^{-1}$ of rice at harvesting stage (Table 17). The maximum number of unfilled spikelet $panicle^{-1}$ (39.42) was recorded from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (35.95), $V_2T_2$ (33.86), $V_2T_3$ (31.68) and $V_1T_2$ (29.47). The minimum number of unfilled spikelet $panicle^{-1}$ (22.43) was obtained from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (23.75), $V_1T_4$ (25.34), $V_1T_3$ (26.33) and $V_2T_4$ (28.84).

**4.4.3.4 Spikelet fertility (%) at harvesting stage**

Different varieties and treatments expressed significant differences due to their interaction effect on spikelet fertility of rice (Table 17). The maximum spikelet fertility (93.32%) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (90.52%), $V_1T_4$ (89.05%), $V_1T_3$ (85.94%) and $V_2T_4$ (82.81%). The minimum spikelet fertility (61.17%) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (67.44%), $V_2T_2$ (70.40%), $V_2T_3$ (73.73%) and $V_1T_2$ (81.05%).

**Table 17:** Interaction effect of varieties and treatments on yield attribution characteristics of rice at harvesting stage

| Varieties | Waste water concentration | Total spikelet panicle$^{-1}$ | Filled spikelet panicle$^{-1}$ | Unfilled spikelet panicle$^{-1}$ |
|---|---|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 267.4 b | 243.65 b | 23.75 i |
| | $T_1$ | 102.3 j | 62.88 j | 39.42 a |
| | $T_2$ | 154.7 f | 125.23 f | 29.47 e |
| | $T_3$ | 187.3 d | 160.97 d | 26.33 g |
| | $T_4$ | 231.4 c | 206.06 c | 25.34 h |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 335.5 a | 313.07 a | 22.43 j |
| | $T_1$ | 110.4 i | 84.45 h | 35.95 b |
| | $T_2$ | 114.4 h | 80.54 i | 33.86 c |
| | $T_3$ | 120.6 g | 88.92 g | 31.68 d |
| | $T_4$ | 163.4 e | 134.56 e | 28.84 f |
| CV (%) | | 0.73 | 0.17 | 0.08 |
| LSD $_{(0.05)}$ | | 1.40 | 0.50 | 0.05 |

Values followed by same letter(s) did not differ significantly a 5% level of probability. Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for

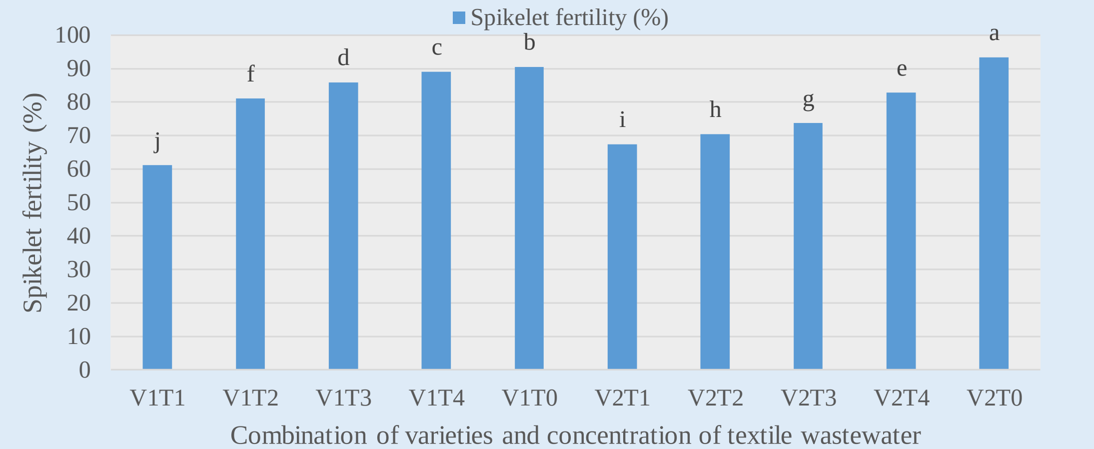



Figure 15: Interaction effect of varieties and concentration of textile wastewater on spikelet fertility of rice at harvesting stage

irrigation.

Here, $V_1$= BRRI hybrid dhan2, $V_2$= BRRI dhan29, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.5. Yield parameters

#### 4.5.1 1000 grain weight (g) at harvesting stage

##### 4.5.1.1 Effect of variety

Different varieties expressed significant differences due to the effect on 1000 grain weight of rice at harvesting stage (Table 18). The maximum weight of 1000 grain

(24.60 g) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum weight of 1000 grain (23.10 g) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that 1000 grain weight differed from variety to variety. The weight of 1000 grain was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

**Table 18:** The effect of varieties on 1000 grain weight at harvesting stage

| **Varieties** | **1000 grain weight (g)** | |
|---|---|---|
| | **Actual** | **Relative** |
| $V_1$ | 23.10 b | 93.90% |
| $V_2$ | 24.60 a | 100% |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $V_1$= BRRI dhan29; and $V_2$= BRRI hybrid dhan2.

### 4.5.1.2 Effect of textile water

Different treatments expressed significant differences due to the effect on 1000 grain weight of rice at harvesting stage (Table 19). The maximum weight of 1000 grain (26.63 g) was recorded from the $T_0$ (no waste water) which was statistically different from other and followed by $T_4$ (24.48 g) and $T_3$ (23.97 g). Whereas the minimum weight of 1000 grain (21.43 g) was obtained from the $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (22.73 g). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

**Table 19:** The effect of concentration of wastewater on 1000 grain weight of rice at harvesting stage

| **Waste water concentration** | **1000 grain weight (g)** | |
|---|---|---|
| | **Actual** | **Relative** |
| $T_0$ | 26.63 a | 100% |
| $T_1$ | 21.43 d | 80.47% |
| $T_2$ | 22.73 c | 85.36% |
| $T_3$ | 23.97 b | 90.01% |
| $T_4$ | 24.48 b | 91.93% |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 5.4.1.3 Effect of combination of varieties and concentration of textile wastewater

Different varieties and concentration of textile wastewater expressed significant differences due to their interaction effect on 1000 grain weight of rice at harvesting stage (Table 20). The maximum weight of 1000 grain (28.00 g) was recorded from the $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (25.27 g), $V_1T_4$ (25.10 g), $V_1T_3$ (24.33 g) and $V_2T_4$ (23.87 g). The minimum 1000 grain weight (20.57 g) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (22.20 g), $V_2T_2$ (22.30 g), $V_2T_3$ (23.27 g) and $V_1T_2$ (23.60 g).

**Table 20:** Interaction effect of varieties and concentration of textile wastewater on 1000 grain weight of rice at harvesting stage

| Varieties | Waste water concentration | 1000 grain weight (g) | |
|---|---|---|---|
| | | Actual | Relative |
| BRRI dhan29 ($V_1$) | $T_0$ | 25.27 b | 100% |
| | $T_1$ | 20.57 g | 81.40% |
| | $T_2$ | 23.60 de | 93.39% |
| | $T_3$ | 24.33 cd | 96.28% |
| | $T_4$ | 25.10 bc | 99.33% |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 28.00 a | 100% |
| | $T_1$ | 22.20 f | 79.29% |
| | $T_2$ | 22.30 f | 79.64% |
| | $T_3$ | 23.27 e | 83.11% |
| | $T_4$ | 23.87 de | 85.25% |
| CV (%) | | 2.19 | - |
| LSD (0.05) | | 0.87 | - |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.5.2 Effect of varieties on yield

#### 4.5.2.1 Grain yield (t $ha^{-1}$) at harvesting stage

Different varieties expressed significant differences due to the effect on the grain yield at harvesting stage (Table 21). The maximum grain yield (3.91 t $ha^{-1}$) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum grain yield (3.44 t $ha^{-1}$) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that the grain yield differed from variety to variety. The yield of grain was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

#### 4.5.2.2 Straw yield (t ha$^{-1}$)

Different varieties expressed significant differences due to the effect on the straw yield of rice at harvesting stage (Table 21). The maximum straw yield (4.12 t ha$^{-1}$) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum straw yield (3.73 t ha$^{-1}$) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that the straw yield differed from variety to variety. The yield of straw was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

#### 4.5.2.3 Biological yield (t ha$^{-1}$)

Different varieties expressed significant differences due to the effect on the biological yield of rice at harvesting stage (Table 21). The maximum biological yield (8.03 t ha$^{-1}$) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum biological yield (7.17 t ha$^{-1}$) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that the biological yield differed from variety to variety. The biological yield was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

**Table 21:** The effect of varieties on yield of rice at harvesting stage

| Varieties | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| $V_1$ | 3.44 b | 3.73 b | 7.17 b |
| $V_2$ | 3.91 a | 4.12 a | 8.03 a |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $V_1$= BRRI dhan29; and $V_2$= BRRI hybrid dhan2.

#### 4.5.2.4 Harvest index (%)

Different varieties expressed non-significant differences due to the effect on the harvest index of rice (Figure 16). The maximum harvest index (48.42%) was recorded from the $V_2$ (BRRI Hybrid dhan2) which was statistically different from other. Whereas the minimum harvest index (47.28%) was obtained from the $V_1$ (BRRI dhan29). This confirms the report of Hossain *et al.* (1991) that the harvest index differed from variety to variety. The harvest index was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

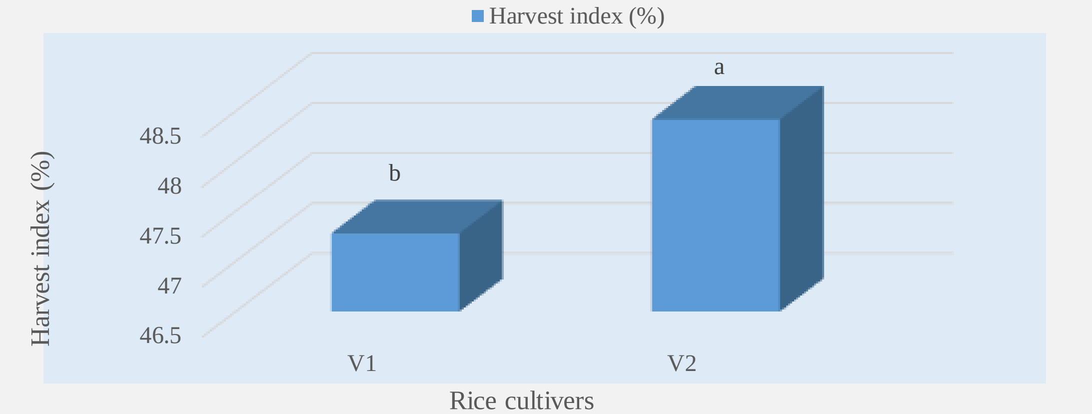



Figure 16: The effect of varieties on harvest index (%) of rice plant at harvesting stage

Here, $V_1$= BRRI hybrid dhan2 and $V_2$= BRRI dhan29

### 4.5.3 Effect of textile wastewater on yield

#### 4.5.3.1 Grain yield (t $ha^{-1}$) at harvesting stage

Different treatments expressed significant differences due to the effect on the grain yield of rice at harvesting stage (Table 22). The maximum grain yield (5.26 t $ha^{-1}$) was recorded from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (5.05 t $ha^{-1}$) and $T_3$ (3.66 t $ha^{-1}$). Minimum grain yield (1.64 t $ha^{-1}$) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (2.77 t $ha^{-1}$). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

#### 4.5.3.2 Straw yield (t $ha^{-1}$) at harvesting stage

Different treatments expressed significant differences due to the effect on the straw yield of rice at harvesting stage (Table 22). The maximum straw yield (5.40 t $ha^{-1}$) was recorded from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (5.24 t $ha^{-1}$) and $T_3$ (3.99 t $ha^{-1}$). Minimum number of straw per panicle (1.95 t $ha^{-1}$) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (3.04 t $ha^{-1}$). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

#### 4.5.3.3 Biological yield (t $ha^{-1}$) at harvesting stage

Different treatments expressed significant differences due to the effect on the biological yield of rice at harvesting stage (Table 22). The maximum biological yield (10.66 t $ha^{-1}$) was recorded from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (10.29 t $ha^{-1}$) and $T_3$ (7.65 t $ha^{-1}$). Minimum biological yield (3.59 t $ha^{-1}$) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (5.81 t $ha^{-1}$). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

**Table 22:** The effect of concentration of wastewater on yield of rice at harvesting stage

| Waste water concentration | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) |
|---|---|---|---|
| $T_0$ | 5.26 a | 5.40 a | 10.66 a |
| $T_1$ | 1.64 e | 1.95 e | 3.59 e |
| $T_2$ | 2.77 d | 3.04 d | 5.81 d |
| $T_3$ | 3.66 c | 3.99 c | 7.65 c |
| $T_4$ | 5.05 b | 5.24 b | 10.29 b |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

#### 4.5.3.4 Harvest index (%) at harvesting stage

Different treatments expressed significant differences due to the effect on the straw yield of rice at harvesting stage (Figure 17). The maximum harvest index (49.35 %) was recorded from $T_0$ (no waste water) which was significantly different from others and followed by $T_4$ (49.09%) and $T_3$ (47.70%). Minimum harvest index (45.47%) was recorded from $T_1$ (using 80% industrial water for irrigation) which was significantly different from others and followed by $T_2$ (47.65%). It might be due to the fact that polluted textile/industrial wastewater effect on the development of rice plant. Similar results were also reported by Nazneen *et al*. (2018).

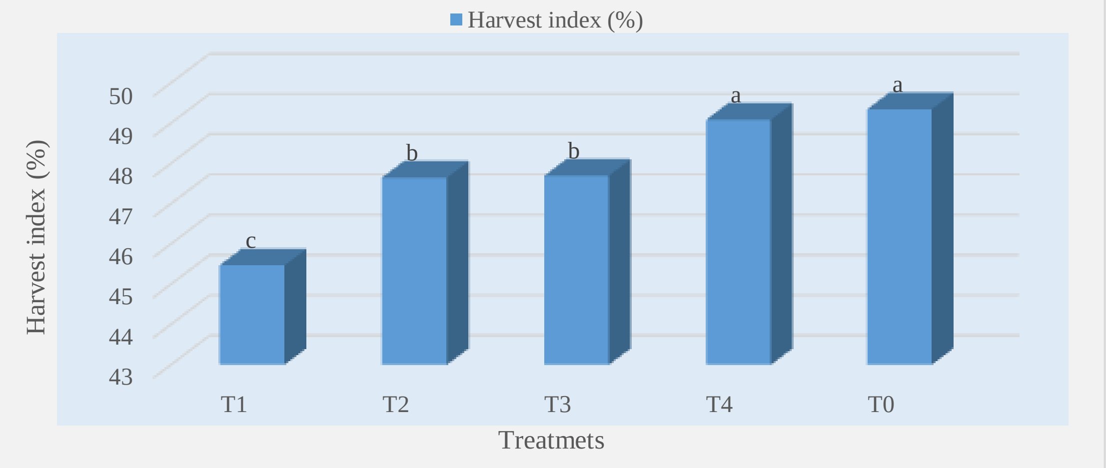



Figure 17: The effect of concentration of wastewater on harvest index (%) of rice plant at harvesting stage

Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.5.4 Interaction effect of different varieties and concentration of textile wastewater

#### 4.5.4.1 Grain yield (t $ha^{-1}$) at harvesting stage

Different varieties and concentration of textile wastewater expressed significant differences due to their interaction effect on the grain yield of rice at harvesting stage (Table 23). The maximum grain yield (5.40 t $ha^{-1}$) was recorded from $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (5.24 t $ha^{-1}$), $V_1T_4$ (5.14 t $ha^{-1}$), $V_1T_3$ (4.87 t $ha^{-1}$) and $V_2T_4$ (4.19 t $ha^{-1}$). The minimum grain yield (1.44 t $ha^{-1}$) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (1.83 t $ha^{-1}$), $V_2T_2$ (2.65 t $ha^{-1}$), $V_2T_3$ (2.89 t $ha^{-1}$) and $V_1T_2$ (3.13 t $ha^{-1}$).

#### 4.5.4.2 Straw yield (t $ha^{-1}$) at harvesting stage

Different varieties and concentration of textile wastewater expressed significant differences due to their interaction effect on the straw yield of rice at harvesting stage (Table 23). The maximum straw yield (5.58 t $ha^{-1}$) was recorded from $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (5.43 t $ha^{-1}$), $V_1T_4$ (5.23 t $ha^{-1}$), $V_1T_3$ (5.05 t $ha^{-1}$) and $V_2T_4$ (4.42 t $ha^{-1}$). The minimum straw yield (1.84 t $ha^{-1}$) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (2.06 t $ha^{-1}$), $V_2T_2$ (2.96 t $ha^{-1}$), $V_2T_3$ (3.12 t $ha^{-1}$) and $V_1T_2$ (3.56 t $ha^{-1}$).

#### 4.5.4.3 Biological yield (t $ha^{-1}$) at harvesting stage

Different varieties and concentration of textile wastewater expressed significant differences due to their interaction effect on the biological yield of rice at harvesting stage (Table 23). The maximum biological yield (5.58 t $ha^{-1}$) was recorded from $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly different from others and followed by $V_1T_0$ (5.43 t $ha^{-1}$), $V_1T_4$ (5.23 t $ha^{-1}$), $V_1T_3$ (5.05 t $ha^{-1}$) and $V_2T_4$ (4.42 t $ha^{-1}$). The minimum biological yield (1.84 t $ha^{-1}$) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_1$ (2.06 t $ha^{-1}$), $V_2T_2$ (2.96 t $ha^{-1}$), $V_2T_3$ (3.12 t $ha^{-1}$) and $V_1T_2$ (3.56 t $ha^{-1}$).

**Table 23:** Effect of combination of varieties and concentration of textile wastewater on yield of rice at harvesting stage

| Varieties | Waste water concentration | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) |
|---|---|---|---|---|
| BRRI dhan29 ($V_1$) | $T_0$ | 5.24 b | 5.43 b | 10.67 b |
| | $T_1$ | 1.44 j | 1.84 j | 3.28 j |
| | $T_2$ | 3.13 f | 3.56 f | 6.69 f |
| | $T_3$ | 4.87 d | 5.05 d | 9.92 d |
| | $T_4$ | 5.13 c | 5.23 c | 10.36 c |
| BRRI hybrid dhan2 ($V_2$) | $T_0$ | 5.40 a | 5.58 a | 10.98 a |
| | $T_1$ | 1.83 i | 2.06 i | 3.89 i |
| | $T_2$ | 2.65 h | 2.96 h | 5.61 h |
| | $T_3$ | 2.89 g | 3.12 g | 6.01 g |
| | $T_4$ | 4.19 e | 4.42 e | 8.61 e |
| CV (%) | | 2.19 | 0.33 | 0.55 |
| LSD (0.05) | | 0.05 | 0.05 | 1.24 |

Values followed by same letter(s) did not differ significantly a 5% level of probability.
Here, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

### 4.5.4.4 Harvest index (%)

Different varieties and treatments expressed significant differences due to their interaction effect on the harvest index of rice at harvesting stage (Figure 18). The maximum harvest index (49.52%) was recorded from $V_2T_0$ (BRRI Hybrid dhan2 + no waste water) which was significantly similar with $V_2T_4$ (49.18%), $V_1T_0$ (49.11%), $V_2T_3$ (49.07%) and $V_2T_1$ (48.66%). The minimum harvest index (43.86%) was obtained from the $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation) which was statistically different from others and followed by $V_2T_2$ (46.74%), $V_1T_3$ (47.09%), $V_1T_2$ (47.21%) and $V_1T_4$ (48.09%).

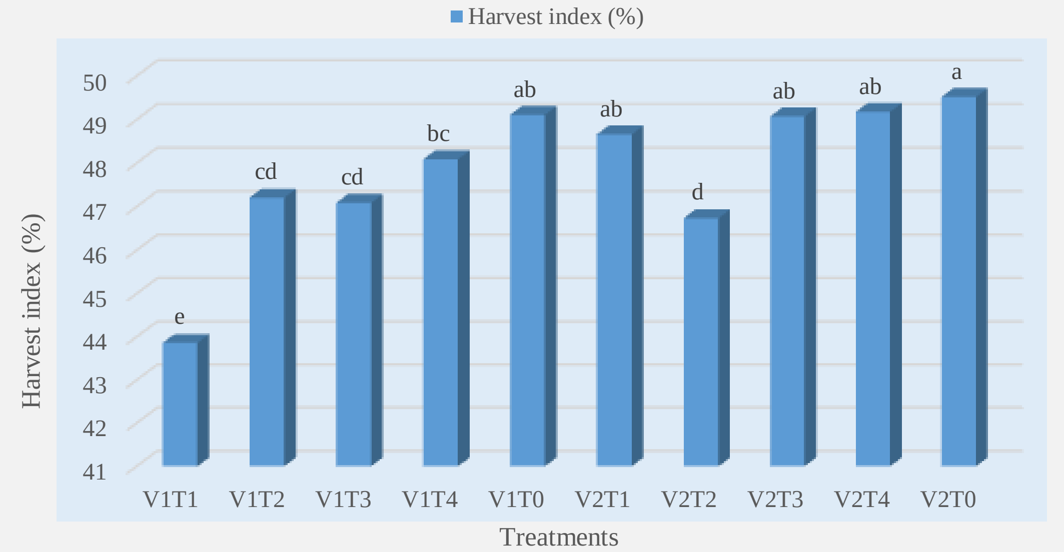



Figure 18: Interaction effect of varieties and concentration of textile wastewater on harvest index (%) of rice plant at harvesting stage

Here, $V_1$= BRRI hybrid dhan2, $V_2$= BRRI dhan29, $T_0$= No wastewater; $T_1$= Using 80% industrial water for irrigation; $T_2$= Using 60% industrial water for irrigation; $T_3$= Using 40% industrial water for irrigation; and $T_4$= Using 20% industrial water for irrigation.

# CHAPTER V

# SUMMARY AND CONCLUSION

The present investigation entitled "Effect of textile wastewater on morpho-phygiological attributes and yield of rice" was conducted during the period from February to June, 2019 at the Agricultural research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factors A: rice varieties (BRRI dhan29 and BRRI Hybrid dhan2) and Factor B: textile water (Using 80% industrial water for irrigation, Using 60% industrial water for irrigation, Using 40% industrial water for irrigation, Using 20% industrial water for irrigation and no waste water). The experiment was laid out in a Randomized Complete Block Design (RCBD) 2 factor with three replications. There were 10 treatment combinations and total numbers of unit plots were 30. The size of unit plot was 9 $m^2$ (3 m × 3 m). Each plot contains 15 pots. The pots were fertilized with nitrogen, phosphate, potash, sulphur and zinc at the rate of 120, 100, 70, 60 and 10 kg/ha, respectively in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc-sulphate. Results revealed that variety, textile wastewater and their interactions had significant effect on plant growth determinants, yield attributing traits and yields detailed below:-

The tallest plant (90.4 cm at harvest) and maximum sterile spikelet $panicle^{-1}$ (30.13) were observed from BRRI dhan29 variety. Whereas the maximum number of tillers $hill^{-1}$ (25.00), maximum number of leaves $hill^{-1}$ (26.60), maximum total dry mater (14.84 g), maximum absolute grain growth rate (6.91), maximum leaf area (34.31$cm^2$), maximum SPAD value (46.13), maximum number of spikelet $panicle^{-1}$ (200.6), maximum weight of 1000 grain (24.60 g), maximum grain yield (3.91 t $ha^{-1}$), maximum straw yield (4.12 t $ha^{-1}$) and maximum harvest index (48.42%) were found from BRRI Hybrid dhan2 variety.

Among the treatments, the tallest plant (91.33 cm), the maximum total number of tillers $hill^{-1}$ (27.00), maximum number of leaves $hill^{-1}$ (28.00), maximum dry mater (19.97 g), maximum absolute grain growth rate (7.10), maximum leaf area (38.53 $cm^2$), maximum SPAD value (48.13), maximum total number of spikelet $panicle^{-1}$ (283.5), maximum weight of 1000 grain (26.63 g), grain yield (5.26 t $ha^{-1}$), straw yield (5.40 t $ha^{-1}$), harvest index (49.35%) were recorded from $T_0$ (no waste water). Whereas, maximum sterile spikelet $panicle^{-1}$ (37.68) was recorded from $T_1$ (using 80% industrial waste water for irrigation).

In case of different combinations, the tallest plant (93.33 cm), the maximum number of total tillers $hill^{-1}$ (27.67), maximum number of leaves $hill^{-1}$ (29.33), maximum dry mater (21.41 g), maximum absolute grain growth rate (8.24), maximum leaf area (39.47 $cm^2$), maximum SPAD value (49.13), maximum total number of spikelet $panicle^{-1}$ (335.5), maximum weight of 1000 grain (28.00g), maximum grain yield (5.40 t $ha^{-1}$), maximum straw yield (5.58 t $ha^{-1}$) and harvest index (49.52%) were recorded from the combination of $V_2T_0$ (BRRI Hybrid dhan2 + no waste water). Whereas, maximum sterile spikelet $panicle^{-1}$ (39.42) was recorded from the combination of $V_1T_1$ (BRRI dhan29 + using 80% industrial water for irrigation).

## Conclusion

The results of the present experiment lead to conclude that-

1. Different morphological, physiological and yield characters were seriously affected due to waste water treatment in rice.

2. Plant height, number of tiller hill$^{-1}$, number of leaves hill$^{-1}$, number of spikelet panicle$^{-1}$, total dry matter, absolute grain growth rate, SPAD value, leaf area, 1000 grain weight, straw yield, grain yield and harvest index were adversely affected due to waste water in both rice varieties.

3. The rice variety BRRI Hybrid dhan2 perform better under textile waste water treatment compared to BRRI dhan29.

# CHAPTER VI

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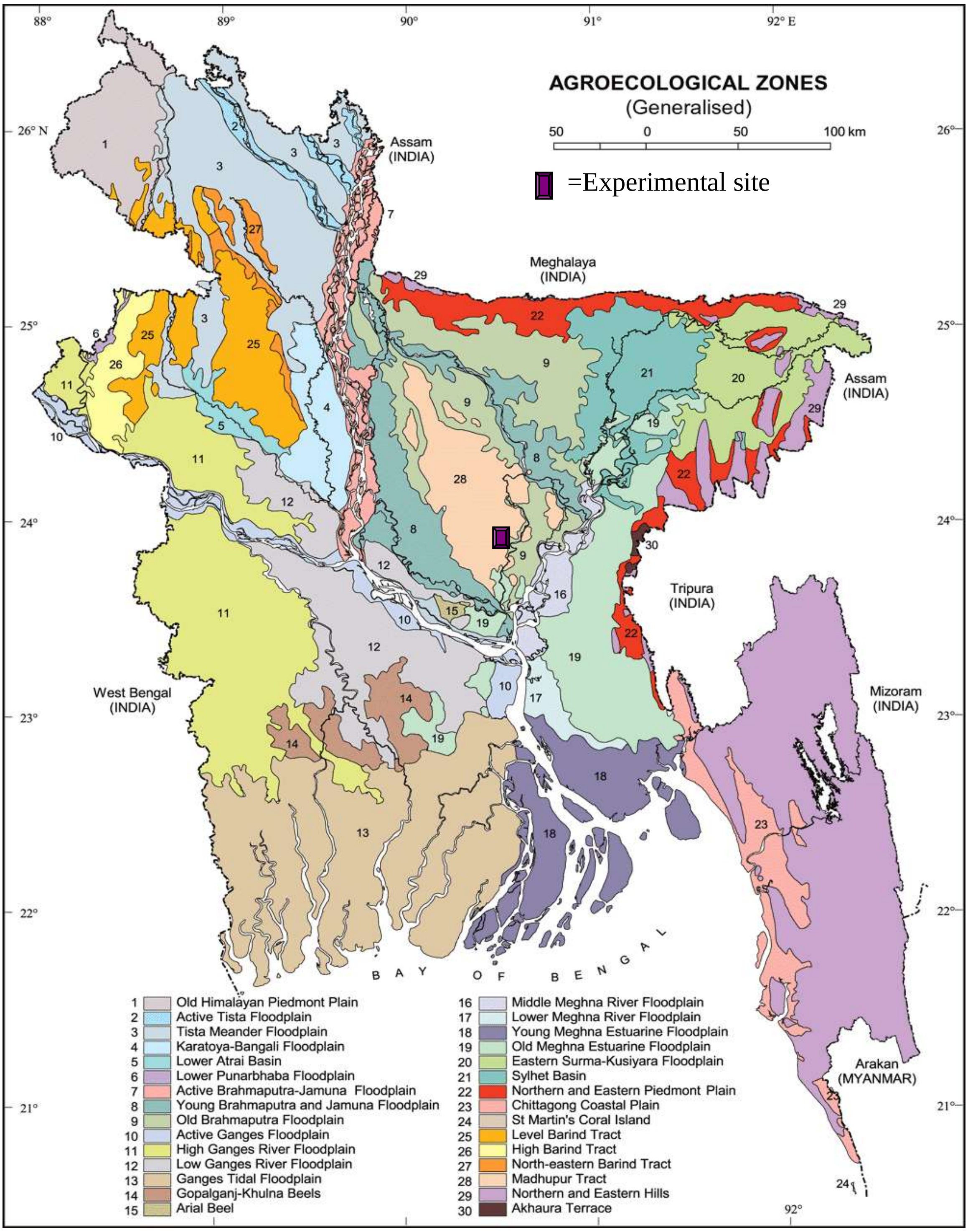
# CHAPTER VII

# APPENDIXES

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



**Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)**

| Constituents | Percent |
|---|---|
| Sand | 26 |
| Silt | 45 |
| Clay | 29 |
| Textural class | Silty clay |

**Chemical composition:**

| Soil characters | Value |
|---|---|
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.54 |
| Total nitrogen (%) | 0.027 |
| Phosphorus | 6.3 µg/g soil |
| Sulphur | 8.42 µg/g soil |
| Magnesium | 1.17 meq/100 g soil |
| Boron | 0.88 µg/g soil |
| Copper | 1.64 µg/g soil |
| Zinc | 1.54 µg/g soil |
| Potassium | 0.10 meg/100g soil |

**Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka**

**Appendix III: Analysis of variance of the data on plant height of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 80.033 |
| Factor A | 1 | 0.833 |
| Factor B | 4 | 6.217 |
| A×B | 4 | 42.917 |
| Error | 18 | 53.219 |

**Appendix IV: Analysis of variance of the data on tillers hill$^{-1}$ of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 1.433 |
| Factor A | 1 | 83.333 |
| Factor B | 4 | 46.00 |
| A×B | 4 | 3.667 |
| Error | 18 | 0.878 |

**Appendix V: Analysis of variance of the data on leaf area of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.016 |
| Factor A | 1 | 8.008 |
| Factor B | 4 | 51.316 |
| A×B | 4 | 65.543 |
| Error | 18 | 0.076 |

**Appendix VI: Analysis of variance of the data on effective tillers hill$^{-1}$ of rice as varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.233 |
| Factor A | 1 | 76.80 |
| Factor B | 4 | 53.383 |
| A×B | 4 | 1.217 |
| Error | 18 | 0.344 |

**Appendix VII: Analysis of variance of the data on total dry matter of rice as varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.82 |
| Factor A | 1 | 49.614 |
| Factor B | 4 | 168.144 |
| A×B | 4 | 1.859 |
| Error | 18 | 0.014 |

**Appendix VIII: Analysis of variance of the data on unfilled spikelet panicle$^{-1}$ of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.00 |
| Factor A | 1 | 5.359 |
| Factor B | 4 | 198.07 |
| A×B | 4 | 6.117 |
| Error | 18 | 0.001 |

**Appendix IX: Analysis of variance of the data on percent spikelet fertility of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.001 |
| Factor A | 1 | 62.352 |
| Factor B | 4 | 77.692 |
| A×B | 4 | 22.296 |
| Error | 18 | 0.003 |

**Appendix X: Analysis of variance of the data on 1000 grain weight of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.189 |
| Factor A | 1 | 16.875 |
| Factor B | 4 | 22.873 |
| A×B | 4 | 0.908 |
| Error | 18 | 0.273 |

**Appendix XI: Analysis of variance of the data on 1000 grain weight of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.001 |
| Factor A | 1 | 1.629 |
| Factor B | 4 | 14.105 |
| A×B | 4 | 0.171 |
| Error | 18 | 0.001 |

**Appendix XII: Analysis of variance of the data on 1000 grain weight of rice as influenced by varieties and concentration of textile wastewater**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.00 |
| Factor A | 1 | 1.141 |
| Factor B | 4 | 12.90 |
| A×B | 4 | 0.113 |
| Error | 18 | 0.00 |

**Appendix XIII: Analysis of variance of the data on 1000 grain weight of rice as influenced by varieties and concentration of textile wastewater SPAD value**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.11 |
| Factor A | 1 | 110.208 |
| Factor B | 4 | 321.373 |
| A×B | 4 | 24.181 |
| Error | 18 | 0.067 |

**Appendix XIV: Analysis of variance of the data on 1000 grain weight of rice asinfluenced by varieties and concentration of textile wastewater on SPAD value**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.00 |
| Factor A | 1 | 96.087 |
| Factor B | 4 | 13.133 |
| A×B | 4 | 3.073 |
| Error | 18 | 0.00 |

**Appendix XV: Analysis of variance of the data on grain yield of rice as influenced by varieties and cultivation method**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.206 |
| Factor A | 1 | 0.308 |
| Error | 2 | 0.051 |
| Factor B | 5 | 2.369 |
| A×B | 5 | 0.309 |
| Error | 20 | 0.073 |

**Appendix XVI: Analysis of variance of the data on straw yield of rice as influenced by varieties and cultivation method**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.104 |
| Factor A | 1 | 2.507 |
| Error | 2 | 0.079 |
| Factor B | 5 | 15.80 |
| A×B | 5 | 0.228 |
| Error | 20 | 0.068 |

**Appendix XVII: Analysis of variance of the data on harvest index of rice as influenced by varieties and cultivation method**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 23.344 |
| Factor A | 1 | 4.23 |
| Error | 2 | 2.714 |
| Factor B | 5 | 28.092 |
| A×B | 5 | 16.737 |
| Error | 20 | 5.45 |

**Appendix XVIII: Analysis of variance of the data on length-breadth ratio of rice as influenced by varieties and cultivation method**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.013 |
| Factor A | 1 | 0.034 |
| Error | 2 | 0.058 |
| Factor B | 5 | 4.575 |
| A×B | 5 | 0.101 |
| Error | 20 | 0.024 |

**Appendix XIX: Analysis of variance of the data on cooking duration of rice as influenced by varieties and cultivation method**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.016 |
| Factor A | 1 | 1.21 |
| Error | 2 | 0.016 |
| Factor B | 5 | 4.065 |
| A×B | 5 | 0.045 |
| Error | 20 | 0.013 |

**Appendix XX: Analysis of variance of the data on ER of rice as influenced by varieties and cultivation method**

| Source of variance | Degrees of freedom | Mean square |
|---|---|---|
| Replication | 2 | 0.004 |
| Factor A | 1 | 0.063 |
| Error | 2 | 0.023 |
| Factor B | 5 | 0.07 |
| A×B | 5 | 0.023 |
| Error | 20 | 0.008 |

**Appendix XXI: Analysis of variance of the data on SPAD value of rice as influenced by varieties and cultivation method**

| **Source of variance** | **Degrees of freedom** | **Mean square** |
|---|---|---|
| Replication | 2 | 0.123 |
| Factor A | 1 | 196.00 |
| Error | 2 | 0.016 |
| Factor B | 5 | 352.747 |
| A×B | 5 | 25.595 |
| Error | 20 | 0.063 |