# STUDY ON NITROGEN DOSES IN BORO RICE GROWN WITH VARIABLE LEVELS OF FLOATING DUCKWEED


**ALIF HOSSAIN**

**REGISTRATION NO. : 13-05401**

**DEPARTMENT OF AGRONOMY**

**SHER-E-BANGLA AGRICULTURAL UNIVERSITY**
**DHAKA -1207**


**JUNE, 2020**

# STUDY ON NITROGEN DOSES IN BORO RICE GROWN WITH VARIABLE LEVELS OF FLOATING DUCKWEED

**BY**

**ALIF HOSSAIN**

**REGISTRATION NO. : 13-05401**

A Thesis
*Submitted to the Faculty of Agriculture,*
*Sher-e-Bangla Agricultural University, Dhaka*
*In partial fulfillment of the requirements*
*for the degree of*
**MASTER OF SCIENCE**

**IN**

**AGRONOMY**

**SEMESTER: JANUARY- JUNE, 2020**

**Approved by:**

**Dr. H. M. M. Tariq Hossain**
**Professor**
Department of Agronomy
SAU, Dhaka
**Supervisor**

**Dr. A. K. M. Ruhul Amin**
**Professor**
Department of Agronomy
SAU, Dhaka
**Co-Supervisor**

**Prof. Dr. Md. Shahidul Islam**
**Chairman**
Examination Committee

**DEPARTMENT OF AGRONOMY**
**Sher-e-Bangla Agricultural University**
**Sher-e-Bangla Nagar, Dhaka-1207**

# *CERTIFICATE*

This is to certify that the thesis entitled **"STUDY ON NITROGEN DOSES IN BORO RICE GROWN WITH VARIABLE LEVELS OF FLOATING DUCKWEED"** submitted to the Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **Alif Hossain**, Registration No. **13-05401** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

**June, 2020**

**Dhaka, Bangladesh**

**(Dr. H. M. M. Tariq Hossain)**
**Professor**
Department of Agronomy
SAU, Dhaka

# Dedicated to

# My

# Beloved Mother

#### *ACKNOWLEDGEMENTS*

*The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.*

*The author wishes to express his gratitude and best regards to his respected Supervisor,* ***Dr. H. M. M. Tariq Hossain****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

*The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor,* **Dr. A. K. M. Ruhul Amin***, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

*The author feels to express his heartfelt thanks to the honorable Chairman, Prof***. Dr. Md. Shahidul Islam***, Department of Agronomy along with all other teachers and staff members of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.*

*The author feels proud to express his deepest and endless gratitude to all of his course mates and friends to cooperate and help him during taking data from the field and preparation of the thesis. The author wishes to extend his special thanks to his class mates and friends for their keen help as well as heartiest co-operation and encouragement.*

*The author expresses his heartfelt thanks to his beloved parents, Elder Sister and Brother and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.*

***The Author***

**STUDY ON NITROGEN DOSES IN BORO RICE GROWN WITH VARIABLE LEVELS OF FLOATING DUCKWEED**

## ABSTRACT

An experiment was carried out at the Agronomy Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2018 to June 2019 to study on nitrogen requirement of boro rice grown with floating duckweed. Four duckweed treatment *viz*. $D_0$ = Control (0 g duckweeds $m^{-2}$), $D_1$ = 200 g duckweeds $m^{-2}$, $D_2$ = 400 g duckweeds $m^{-2}$ and $D_3$ = 600 g duckweeds $m^{-2}$ and three nitrogen treatment *viz*. $N_1$ = 45 kg N $ha^{-1}$, $N_2$ = 90 kg N $ha^{-1}$ and $N_3$ = 180 kg N $ha^{-1}$ were applied for this experiment. The experiment was laid out in a Randomized Complete Block Design with three replications where duckweed treatment (Factor A) and was for nitrogen treatment (Factor B). Data on different growth and yield parameters were recorded and analyzed using MSTAT software. Different doses of duckweeds showed significant influence on most of the parameters and $D_2$ (400 g duckweeds $m^{-2}$) treatment the best performance on growth and yield parameters of rice. Among different doses of nitrogen, $N_2$ (90 kg N $ha^{-1}$) gave the best results on growth and yield parameters of rice. In case of combined effect, $D_2N_2$ showed the best results on growth and yield parameters and gave the highest number of tillers $hill^{-1}$ (16.40), dry weight $hill^{-1}$ (48.97 g), number of effective tillers $hill^{-1}$ (14.73) and number of grains $panicle^{-1}$ (189.50). This treatment combination also showed the highest number of filled grains $panicle^{-1}$ (183.90), panicle length (25.83 cm), 1000 grain weight (25.13 g), seed yield (7.24 t $ha^{-1}$), straw yield (8.47 t $ha^{-1}$), biological yield (15.71 t $ha^{-1}$) and harvest index (46.09%). On the other hand, $D_0N_3$ gave the least results on these parameters. Findings revealed that application of 400 g duckweeds $m^{-2}$ with 90 kg N $ha^{-1}$ showed the superiority over other treatment combinations to produce higher grain yield of boro rice.

# LIST OF CONTENTS

# LIST OF CONTENTS (Cont'd)

## LIST OF TABLES

# LIST OF PLATES

# LIST OF APPENDICES

## ABBREVIATIONS AND ACRONYMS

| | | |
|---|---|---|
| AEZ | = | Agro-Ecological Zone |
| BBS | = | Bangladesh Bureau of Statistics |
| BCSIR | = | Bangladesh Council of Scientific and Industrial Research |
| cm | = | Centimeter |
| CV % | = | Percent Coefficient of Variation |
| DAS | = | Days After Sowing |
| DMRT | = | Duncan's Multiple Range Test |
| *et al.*, | = | And others |
| e.g. | = | exempli gratia (L), for example |
| etc. | = | Etcetera |
| FAO | = | Food and Agriculture Organization |
| g | = | Gram (s) |
| i.e. | = | id est (L), that is |
| Kg | = | Kilogram (s) |
| LSD | = | Least Significant Difference |
| $m^2$ | = | Meter squares |
| ml | = | Millilitre |
| M.S. | = | Master of Science |
| No. | = | Number |
| SAU | = | Sher-e-Bangla Agricultural University |
| var. | = | Variety |
| $^oC$ | = | Degree Celsius |
| % | = | Percentage |
| NaOH | = | Sodium hydroxide |
| GM | = | Geometric mean |
| mg | = | Milligram |
| P | = | Phosphorus |
| K | = | Potassium |
| Ca | = | Calcium |
| L | = | Litre |
| µg | = | Microgram |
| USA | = | United States of America |
| WHO | = | World Health Organization |

# Chapter I

# Introduction

# CHAPTER I

# INTRODUCTION

Globally, agriculture is currently facing unprecedented challenges for nourishing the increasing population without devastating the environment (Chen *et al*., 2014; Zhang *et al*., 2015). On the one hand, crop production needs to be doubled by 2050 to meet global food demand.

The population of our country is increasing but the cultivable land is decreasing due to urbanization and industrialization resulting in more shortage of food. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. Since it is not possible to have horizontal expansion of rice area, rice yield should be increased to meet this ever increasing demand of food. The rainfed Aus, the rainfed Aman and irrigated Boro rice are cultivated in 10%, 51% and 39% in the total cropped area in Bangladesh, respectively (BADC, 2016).

Rice contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh. In Bangladesh, area covered by rice was 11.39 million hectares with the production of 35.05 million metric tons [BBS, 2018]. Bangladesh ranks as fourth largest producer country in the world through increasing yield of rice. According to BBS Report 2016 Aus, Aman and Boro produced 1.51, 9.66 and 17.76 million metric tons of rice. Therefore, Boro rice is one of the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production.

Nitrogen is a major essential plant nutrient and a key input for increasing crop yield. Rice plants require a large amount of nitrogen at the early and mid tillering stage to maximize the number of panicles. In order to exploit the full yield potential of modern rice cultivars, N-fertilizer application is necessary in most soils. Nitrogen is the most deficient nutrient element in Bangladesh soils and almost every farmer has to apply the costly N-fertilizer to get a desirable yield of rice. Optimum dose of nitrogen fertilization plays a vital role in growth and development of rice plant. Rice growth is seriously hampered when lower dose of nitrogen is applied which drastically reduces yield. Nitrogen has a positive influence on the production of effective tillers per plant, yield and yield attributes. On the other hand, excessive nitrogen fertilization encourages excessive vegetative growth which makes the plant susceptible to insects, pests and diseases and ultimately reduces yield. Rice grain yield was recorded significantly highest between ranges of 90-250 kg $ha^{-1}$ nitrogen application (Marazi *et al*., 1993; Daniel and Wahab, 1994; Bali *et al*., 1995; Meena *et al*., 2003). A significant increase in tillering (Hussain *et al*., 1989; Meena *et al*., 2003) with increase in nitrogen supply was observed. By applying proper dose we can save money and can also keep our environment sound. A suitable combination of variety and rate of nitrogen is necessary for better yield.

The application of N chemical fertilizer in combination with green manure (GM) is an alternative approach to enhance crop production, N use efficiency (NUE) and soil fertility with less chemical inputs (Li *et al.,* 2015). GM is generally eco-friendly, economically viable and renewable for sustainable agriculture.

Very little information is available regarding duckweed as GM (the widespread floating aquatic plant), which includes 37 species in 5 genera (Spirodela, Lemna, Landoltia, Wolffia and Wolffiela) within the family Lemnaceae and with doubling times of 1.34–4.54 days and yield ranges between 8.8–117 t dry weight $ha^{-1}$ $year^{-1}$ (Cheng *et al*., 2002; Forni and Tommasi, 2016).

Over the last 40 years, research regarding duckweed mainly focused on phytoremediation and nutrient recovery from wastewater and for animal feedstock and the production of biofuels, due to its high growth rate, high biomass yield, excellent nutrient uptake ability, and tolerance to high nutrient levels (Cheng *et al*., 2002; Mohedano *et al*., 2012). It is worth noting that duckweed can grow well in paddy fields (Wu *et al*., 2012); however, the performance of duckweed in paddy rice agriculture has been rarely studied. So far, few studies have examined the influence of duckweed on $NH_3$ volatilization (Zimmo *et al.*, 2003; Li *et al*., 2009; Sun *et al*., 2015), and only Li *et al.* (2009) reported that duckweed cover combined with urea could effectively increase rice yield at 90 and 180 kg N $ha^{-1}$. Meanwhile, the current Chinese agriculture systems are highly fertilized, few studies have comprehensively accessed the agronomic and economic benefits and N balance of urea combined with duckweed in current intensive rice cropping systems.

Therefore, a field experiment was conducted with the aims to increasing N use efficiency with floating duckweed on crop yield rice fields with the following objectives:

1. To determine the effect of duckweeds on growth and yield of boro rice
2. To quantify the combined effects of N-fertilizer and duckweeds on yield of boro rice

# Chapter II
# Review of literature

# CHAPTER II

# REVIEW OF LITERATURE

## Introduction of Duckweed and its field application

The family Lemnacae consists of two sub-families (*Lemnoidea* and *Wolffioideae*), with four genera (*Spirodella*, *Lemna*, *Wolffia* and *Wolffina*), encompassing at least 34 species (Landolt, 1986). All plants are tiny (0.4 to 15 mm) and identification is therefore difficult (Leng, 1999).

Duckweeds are monocotyledonous, floating plants, and are the world's smallest and simplest flowering plants (Hillman and Culley, 1978). Each plant consists of little more than two, poorly differentiated fronds, a combination of leaf and stem. The tissue is composed principally of chlorenchymatous cells, separated by large intercellular spaces that provide buoyancy. The upper epidermis is cutinized and sheds water. In Lemna and Spirodella the roots are believed to be adventitious, are only a small proportion of overall plant weight and lack root hairs. The other two genera lack roots. An important feature of their structure is the almost total lack of woody tissue.

Members of the Lemnacae family are found almost worldwide, being absent only in the Polar Regions and deserts. Distribution of species is however, far from uniform with the Americas having over 60% of recorded species, and Australia and Europe each having less than 30% of the total. Species recorded in Australia comprise *Spirodella polyrrhiza*; *S. punctata*; *Lemna disperma*; *L. trisulca*; *L. aequinoctialis*; *Wolffia australiana*; *W. angusta* (Landolt, 1986).

The growth of lemnacae may be nearly exponential, if carbon dioxide, light and nutrient supplies are satisfactory. Discussion in this review is limited to the three major plant macronutrients (nitrogen, phosphorus, potassium). Calcium and sulphur are not generally considered to be limiting to growth (Landolt, 1986), whereas nitrogen and phosphorus influence growth strongly and have an interactive effect.

Lemnacae are able to absorb nitrogen as ammonium, nitrate, nitrite, urea and some amino acids, however the first two represent the main nitrogen source for most species. Minimum, optimal, and toxic levels of nitrogen vary greatly between species and geographic isolates and increasing light intensity is thought to elevate optimal nitrogen requirements for growth. Of the species studied, *L. miniscula* has the lowest (0.0016 mM/l) and an unclassified species of Lemna the highest (0.08 mM/l) minimum requirement for nitrogen (Landolt, 1986). Similarly, the maximum tolerated level of nitrogen varies from 30 mM/l (*L. miniscula*) to 450 mM/l for *L. aequinoctialis* (Landolt, 1986). The optimal recorded nitrogen requirement ranges from 0.01 mM/l for W. colombia, up to 30 mM/l for S. polyrrhiza (Landolt, 1986).

Duckweed's requirement for phosphorous, is variable (0.003-1.75 mM/l) between species as is seen for nitrogen requirement, but appears unrelated to it (Landolt, 1986). Duckweed is reputedly able to accumulate up to 1.5% of its weight as phosphorus in nutrient rich waters (Leng, 1999). Between species differences are also evident for potassium, with requirements also being influenced by light intensity.

As of this writing, no publications have examined duckweed's potential to support crop yields while limiting nutrient pollution when applied to agricultural fields. In order to supply plant-available N, organic amendments must have a low carbon-to-nitrogen (C:N) ratio. Amendments with a C:N ratio less than 20 will provide plant-available N, while ratios greater than 30 will cause microorganisms to scavenge plant-available N. Typical C:N ratios are 10 for soil, 9 - 12 for microorganisms, 17 - 19 for cow manure, 120 - 150 for straw and wheat, and 500 for fresh sawdust (De-Bertoldi *et al*. 1983). Duckweed's C:N ratio has been measured to be 7 when grown on raw wastewater, and 14 when grown on treated wastewater. In either case duckweed is expected to provide a net increase in plant-available N which will support crop yield. The N in duckweed must be “mineralized” before a plant can utilize it. Mineralization refers to the process of microorganisms breaking apart organic matter structures that contain N into ammonium ($NH_4^+$), which is an inorganic form of N. $NH_4^+$ may be subsequently converted into nitrate ($NO_3^{2-}$), both of which are “mineral” forms of N.

The mineralization process may be relied upon to reduce N losses. When organic materials (manure, compost, duckweed, etc.) are applied to a field they must undergo the mineralization process, which requires time. NH+ is held by the soil cation exchange capacity (CEC), but $NO_3^{2-}$ leaches rapidly. Therefore, it is desirable for N to be in the form of $NH^+_4$ which is likely to be retained in the soil until crops can use it.

The ability of duckweed to sequester nitrogen and phosphorus, and in so doing “cleanse” dirty water, has been widely discussed in the literature for nearly 30 years (Culley and Epps, 1973; Hillman and Culley, 1978; Oran *et al*., 1986; Landolt and Kandeler, 1987; Leng, 1999). Systems utilising various species of duckweed, either alone, or in combination with other plants, have been used to treat primary and secondary effluent in the U.S.A. (Zirschky and Reed, 1988), the Middle East (Oran *et al*., 1985) and the Indian subcontinent (Skillicorn *et al*., 1993; Van-der-Steen *et al*., 1998).

Not with standing this reputation, some species and isolates are apparently quite sensitive to high levels of nitrogen and/or phosphorous (Bergman *et al*., 2000), and effluent with a high biological oxygen demand (BOD), such as abattoir waste, may kill the plants. Although duckweed has a reputation for absorbing large amounts of dissolved nitrogen, the degree of absorption appears to vary with concentration of nitrogen, time, species, and (at least in temperate zones) the season. There is also strong evidence that there is a symbiotic, or at least a synergistic relationship between duckweed and bacteria, both in the fixation of nitrogen (Duong and Tiedje, 1985), and the removal of Chemical Oxygen Demand (COD) (Korner *et al*., 1998) from water.

Differences in methodology, scale, and the parameters, both recorded and measured, make direct comparisons between the many trials in published literature difficult. However most research indicates that duckweed removes 40 to 60% of nitrogen in solution over a 12 to 24 day period. Volatilization may account for a similar loss of nitrogen (Vermaat and Haniff, 1998), although recent work completed in Israel (Van-der-Steen *et al.,* 1998), has suggested that direct duckweed absorption may account for less than 20% of nitrogen loss, and volatilization/ denitrification may account for over 70%.

In a similar fashion, lemnacae are generally able to absorb 30 to 50% of dissolved phosphorous, although one researcher (Alaerts *et al*., 1996) has claimed over 90% removal in a working, full scale system. Phosphorous uptake (as measured by tissue phosphorous) and crude protein, increased linearly with increases in nutrient concentration, up to approximately 1.5 g P/l, and increased in absolute terms, up to 2.1 g P/l (Sutton and Ornes, 1975). This was recorded in conjunction with a proportional rise in nitrogen concentration, thus the association between nitrogen and phosphorous concentrations was unclear.

COD is a measure that quantifies water quality as determined by dissolved oxygen. All research in the use of duckweed for improving effluent quality has determined significant but variable decreases in COD (Alaerts *et al*., 1996; Karpiscak *et al*., 1996; Bonomo *et al*., 1997; Vermaat and Haniff, 1998; Van-der- Steen *et al*., 1999). However, a substantial decrease in COD would be expected in open ponds without the presence of duckweed (Al-Nozaily *et al.,* 2000), so this improvement may not be attributable to the actions of duckweed.

Simplistically, the duckweed’s environment is somewhat two-dimensional. In practice, this means that once the surface of a body of water is completely covered, the plant has limited further opportunities to grow. Thus, in situations where there are high nutrient levels, the clearance of dissolved nutrients is likely to be limited by harvesting rate. The work of Whitehead *et al*. (1987) confirms that at high average nutrient levels (short retention time), nitrogen and phosphorous removal is enhanced with increased cropping rate, whereas low nutrient concentrations favour low cropping rates. This latter state indicates that growth is limited by nutrient availability.

Degradation of bacterial pathogens is a complex process and a comprehensive discussion is beyond the scope of the current paper. However, two groups conducting specific investigations into this issue (Karpiscak *et al.*, 1996; Van-der- Steen *et al*., 1999) found that faecal coliforms decreased by 50 to 90% and that Giardia and Cryptosporidium fell by over 80% in eutrophic waters in which duckweed was grown.

Goopy and Murray (2003) carried out a study and found that the family of lemnacae colloquially known as duckweed contains the world's smallest species of flowering plants (macrophytes). Aquatic and free-floating, their most striking qualities are a capacity for explosive reproduction and an almost complete lack of fibrous material. They are widely used for reducing chemical loading in facultative sewage lagoons, but their greatest potential lies in their ability to produce large quantities of protein rich biomass, suitable for feeding to a wide range of animals, including fish, poultry and cattle. Despite these qualities there are numerous impediments to these plants being incorporated into western farming systems. Large genetically determined variations in growth in response to nutrients and climate, apparent anti-nutritional factors, concerns about sequestration of heavy metals and possible transference of pathogens raise questions about the safety and usefulness of these plants. A clear understanding of how to address and overcome these impediments needs to be developed before duckweed is widely accepted for nutrient reclamation and as a source of animal feed.

Increasing rice production to feed the world's growing population while protecting the environment requires more optimal use of fertilizers. In China, the current high input, high output and high reliance on synthetic nitrogen (N) fertilizer in agriculture has resulted in high N losses, especially ammonia ($NH_3$) emission. Urea combined with green manure (GM) might be a promising approach to improve N fertilizer management. However, few studies have evaluated duckweed in this manner. Duckweed does not require arable land for cultivation and thus avoids competition with food crops. Therefore, a field experiment was conducted for three years with five treatments (CK, no N-fertilizer; CT, conventional practice, urea alone at 300 kg N $ha^{-1}$; CTD, urea combined with duckweed at 300 kg N $ha^{-1}$; RN, urea alone at 225 kg N $ha^{-1}$; and RND, urea combined with duckweed at 225 kg N $ha^{-1}$) in an intensive rice cropping system by (Yao and Zhang, 2017). The results for two years showed that urea combined with duckweed cover reduced $NH_3$ loss by 36–52% over CT. This reduction was attributed primarily to the formation of a physical barrier and the uptake of $NH_4^+$ by duckweed. The 15N recovery for 15N balance conducted for one year was 38% higher and the 15N loss was 16% lower for CTD than that of CT. Furthermore, urea combined with duckweed increased N accumulation in the aboveground plants by 14–25% over CT for the 3 years. As a result, urea combined with duckweed achieved higher rice yield by 9–10%, and higher net economic benefit by 10–11% over CT for the 3 years; however, using the conventional rate of 300 kg N $ha^{-1}$ did not increase rice yield over using the reduced N rate of 225 kg N $ha^{-1}$, with or without duckweed. Thus, duckweed as GM combined with chemical fertilizer application provided an approach for increasing the rice yield without increasing inputs of N fertilizer and thereby provided a financially attractive option for farmers to achieve environmental integrity and ensure food security in rice production (Yao and Zhang, 2017).

## 2.2 Effect of nitrogen

Karim (2019) carried out an experiment to observe the effect of urea fertilizer on the yield of boro rice varieties in haor areas of Bangladesh. Two factors experiment viz. Varieties BRRI dhan29 and BRRI dhan58; and six urea fertilizer levels including: 340 (F1), 320 (F2), 300 (F3), 280 (F4), 260 (F5), and 165 kg ha$^{-1}$ (F6) [Farmer's practice (FP)] were used. In case of F1-F5, the MoP-TSP-$CaSO_4$-$ZnSO_4$ as 127-112-75-11 kg ha$^{-1}$ was used while Farmers' practice (FP) was done with only 82 kg ha$^{-1}$ TSP. The experiment was laid out in two factors randomized complete block design (RCBD) with three farmers' replications. Data were collected on growth, yield and yield contributing characters of boro rice. Plant height varied at harvest stage in relation to variety and fertilizer. The tillers production hill$^{-1}$ varied at harvest in case of variety and urea application. Higher plant height was found in BRRI dhan58 (93.9 cm) in comparison to BRRI dhan29 (90.3 cm). Plant height was also influenced due to urea fertilizers application. The higher tillers hill$^{-1}$ (15.9), effective tillers hill$^{-1}$ (12.3) and longer panicle length (21.1 cm) were produced by BRRI dhan58 at harvest compared to BRRI dhan29. The longest panicle (21.4 cm) was produced in the treatment F3 (300 kg urea ha$^{-1}$). Higher number of sterile spikelets panicle$^{-1}$ (58.5) and 1000-grain weight (23.2 g) was produced by BRRI dhan58. Higher number of grains panicle$^{-1}$ (137.5) was produced by BRRI dhan29. The highest grain yield (6.7 t ha$^{-1}$) and straw yield (7.91 t ha$^{-1}$) were obtained in the treatment F3 (300 kg urea ha$^{-1}$). The experimental soil analyses showed that the nutrient contents in post-harvest soils were higher compared to initial soil due to balanced fertilizer application. It is concluded that 300 kg urea ha$^{-1}$ promoted highest grain yield.

Gewaily and Adel (2018) conducted a field experiments during 2016 and 2017 growing seasons to evaluate the efficiency of varying nitrogen fertilizer rates on growth and yield parameters, along with nitrogen use efficiency of some newly released rice varieties (Sakha 108) and some promising lines GZ9399-4-1-1-3-2-2, GZ10101- 5-1-1-1 and GZ10154-3-1-1-1. Five nitrogen levels (i.e. 0, 55, 110, 165 and 220 kg N ha$^{-1}$) were used. The results from both growing seasons indicated that, Sakha 108 recorded the highest grain yield while GZ10154 and GZ10101 recorded the lowest grain yields. A linear increase in grain yield was observed with continuous rate increase of nitrogen from 0 to 220 kg ha$^{-1}$, while 220 kg N ha$^{-1}$ treatment showed maximum grain yield followed by 165 kg N ha$^{-1}$, with control as minimum. Agronomic nitrogen use efficiency (AE) for studied rice genotypes varied significantly, and ranged from 3.63 to 32.9 and from 2.72 to 34.12 kg grain yield produced per kg of nitrogen applied in 2016 and 2017 respectively. Across N levels, GZ9399 recorded the highest values of AE for the nitrogen fertilizer rate of 165 kg N ha$^{-1}$ in both seasons.

Chaturvedi (2018) carried out a field trial to determine the effect of different nitrogenous (N) fertilizers on growth, yield and quality of hybrid rice variety ‘Proagro 6207’, comprising of 10 different treatments using randomized complete block design with three replications was conducted at Agricultural Research Station, Bilaspur Chhattisgarh, India. The two years data during 2002 and 2003 revealed that all the growth characters, yield parameters and grain nitrogen (N) increased significantly with an application of sulphur-containing nitrogen fertilizer- Super Net. These results were statistically at par with that of treatment T4, where ammonium sulphate nitrate was applied. In this series of experiment, non-sulphur-containing nitrogen fertilizer, urea gave lowest yield and grain nitrogen (N) content and these reductions were significant in all of the experiments.

Adhikari (2018) conducted a research work to study the effect of nitrogen fertilizer and weed management on the growth and yield of transplant aman rice cv. BRRI dhan46. The experiment consisted of four fertilizer treatments viz. 0 kg N ha$^{-1}$ (N0), 40 kg N ha$^{-1}$ (N1), 80 kg N ha$^{-1}$ (N2) and 120 kg N ha$^{-1}$ (N3) and four weeding treatments viz. one hand weeding at 20 DAT (W1), two hand weedings at 20 and 35 DAT (W2), three hand weedings at 20, 35 and 50 DAT (W3), weeding by Japanese rice weeder twice at 20 and 35 DAT (W4) and unweeded control (W5). The experiment was laid out in randomized complete block design with three replications. The highest plant height (113.00

cm), number of total tillers hill$^{-1}$ (8.74), number of effective tillers hill$^{-1}$ (6.18), panicle length (21.98 cm), number of grains panicle$^{-1}$ (114.20), grain yield (4.00 t ha$^{-1}$), straw yield (5.25 t ha$^{-1}$) and biological yield (9.25 t ha$^{-1}$) were recorded in N2 (80 kg N ha$^{-1}$) treatment. The lowest plant height (106.00 cm), number of total tillers hill$^{-1}$ (7.20), number of effective tillers hill$^{-1}$ (5.00), panicle length (20.70 cm), number of grains panicle$^{-1}$ (97.60), grain yield (3.52 t ha$^{-1}$), straw yield (4.46 t ha$^{-1}$) and biological yield (7.97 t ha$^{-1}$) were recorded from N0 (No nitrogen fertilizer control) treatment. On the other hand, the highest grain yield 4.23 t ha$^{-1}$ was observed in three weedings condition because of the highest number of effective tillers hill$^{-1}$ (6.81), number of grains panicle$^{-1}$ (111.10). The highest straw yield (5.51 t ha$^{-1}$) was also found in three weeding condition. The lowest grain yield (3.40 t ha$^{-1}$) was recorded in W5 (unweeded control) treatment. The lowest straw yield (4.31 t ha$^{-1}$) was also observed in W5 (unweeded control) treatment because of the smallest plant (106.97 cm) and lower number of total tillers hill$^{-1}$ (7.20). Therefore, 80 kg N ha$^{-1}$ along with three hand weedings at 20, 35 and 50 DAT may be used for obtaining the highest grain and straw yields of BRRI dhan46.

Chamely and Islam (2015) conducted an experiment to study the effect of variety and rate of nitrogen on the performance of Boro rice. The experiment comprised three varieties viz., BRRI dhan28 (V1), BRRI dhan29 (V2) and BRRI dhan45 (V3); and five rates of nitrogen viz., control (N0), 50 kg (N1), 100 kg (N2), 150 kg (N3) and 200 kg (N4) N ha$^{-1}$. The experiment was laid out in a randomized complete block design with four replications. The growth analysis results indicate that the tallest plant (80.88 cm) and the highest number of total tillers hill$^{-1}$ (13.80) were observed in BRRI dhan29 at 70 DATs and the highest total dry matter (66.41 g m$^{-2}$) was observed in BRRI dhan45. The shortest plant (78.15 cm) and the lowest number of tillers hill$^{-1}$ (12.41) were recorded from BRRI dhan45 and the lowest dry matter (61.24 g) was observed in BRRI dhan29. The tallest plants (84.01 cm), highest number of tillers hill$^{-1}$ (14.06) and the highest dry matter (69.58 g m$^{-2}$) were obtained from 200 kg N ha$^{-1}$. The tallest plants (86.48 cm) and maximum dry matter (72.30 g m$^{-2}$) were recorded from BRRI dhan28 with 200 kg N ha$^{-1}$ and BRRI dhan45 with 200 kg N ha$^{-1}$, respectively. The highest number of tillers hill$^{-1}$ (15.14) was obtained from BRRI dhan29 with 50 kg N ha$^{-1}$. The harvest data reveal that variety had significant effect on total tillers hill$^{-1}$, effective tillers hill$^{-1}$, non-effective tillers hill$^{-1}$, panicle length, grain yield, straw yield and harvest index. The highest grain yield (4.84 t ha$^{-1}$) was recorded from BRRI dhan29. The results of the experiment also indicate that total tillers hill$^{-1}$, effective tillers, grains panicle$^{-1}$, sterile spikelets panicle$^{-1}$, grain yield, straw yield and harvest index were significantly affected by levels of nitrogen, while plant height, panicle length, 1000-grain weight were not significantly affected by levels of nitrogen. The highest grain yield (5.58 t ha$^{-1}$) was obtained from 200 kg N ha$^{-1}$. Interaction effect of variety × 200 kg N ha$^{-1}$ produced the highest grain yield (5.82 t ha$^{-1}$). From the results of the study it may be concluded that BRRI dhan29 rice may be cultivated with 200 kg N ha$^{-1}$ for obtaining higher yield in AEZ 9 of Bangladesh.

Khatun *et al*., (2014) conducted an experiment during Boro season (November-April) in 2009-10 to evaluate the effect of N fertilizer on seed yield and its quality. The experiment included BRRI dhan28 and BRRI dhan29 and 0, 50, 100, 150, 200 and 250 kg ha$^{-1}$ N rates. Seed yield increased significantly in a quadratic fashion with the increase of N rate both in BRRI dhan28 and BRRI dhan29. Application of N fertilizer increased seed yield by about 3-4 t ha$^{-1}$ compared to control. The highest yield of 5.15 and 6.34 t ha$^{-1}$ was obtained with 150 kg N ha$^{-1}$ in BRRI dhan28 and BRRI dhan29 respectively. However, the predicted economic optimum doses of N appeared as 156 and 158 kg ha$^{-1}$ for BRRI dhan28 and BRRI dhan29 respectively. Nitrogen application to rice seed crop did not impair seed quality in terms of germination, viability, vigour and seed color. The seed N concentration ranged from 0.94 to 1.31% in BRRI dhan28 and 0.85 to 1.07% in BRRI dhan29 among different N rates. The seed phosphorus concentration varied from 0.30 to 0.41% in BRRI dhan28 and 0.28

to 0.36% in BRRI dhan29 among different N rates. The seed K varied from 0.23 to 0.27% and 0.20 to 0.23% in BRRI dhan28 and BRRI dhan29 respectively, among different N rates. The average seed protein of BRRI dhan28 (6.59%) was significantly higher than that of BRRI dhan29 (5.68%). Seed N and protein content slightly increased with the increase of N rate. Nitrogen application did not influence phosphorus and magnesium content in rice seed. However, seed potassium slightly decreased with the N application.

Singh *et al.* (2008) conducted field experiments in Patna, Bihar. India, from 2001 - 02 to 2003-04, to study the effect of irrigation and nitrogen (N) fertilizers on yield, water use efficiency and nutrient balance in a rice-based cropping system. Application of optimum levels of irrigation and N fertilizer increased the rice- equivalent yield by 8.40, 6.38 and 6.90% over the sub-optimum level in the both cropping systems.

Wen Ge *et al.* (2008) reported the effects of nitrogen application and planting density on yield and its components of middle-season indicia hybrid rice Wandao 153. The N application increased yield significantly, with the highest yield at 225 kg N $ha^{-1}$ followed by 300 kg N $ha^{-1}$.

Prudente *et al.* (2008) conducted a field experiment to determine the effect of different levels of N on N uptake, yield components and dry matter yield of japonica (Hatsuboshi) and indica (IR-13) rice varieties. The results showed an increasing trend in N uptake, rice yield, panicle number, tiller number and dry matter production, with increasing the amount of applied N fertilizer. There was a 30 kg $ha^{-1}$ increase in the yield of brown rice and about 1.4% increase in the total N uptake for every additional kilogram of applied N $ha^{-1}$. The increase in yield could be attributed to the increase in N uptake with increasing N application.

Xiao Fei *et al.* (2008) studied the effects of N rate on N metabolism in rice (cv. Liangyoupeijiu. The N rate had significant effects on nitrate reductase activity. Glutamine synthetase activity increased in leaves with the increase in the N rate. The activities of glutamate pyruvate transaminase (GPT) and glutamate oxaloacetate transaminase (GOT) in leaves increased with increasing N levels. The chlorophyll concentration in leaves, and protein and free amino acid concentrations in leaves and roots increased with the increase in N rate.

Malik and Kaleem (2007) conducted a field study in Allahabad. Uttar Pradesh. India to evaluate the effect of N rates (100, 150 and 200 kg $ha^{-1}$) and application date on the performance of hybrid rice. The N application increased grain yield, straw yield, harvest index, test weight up to 200 kg $ha^{-1}$. Split application of N produced higher values of yield components in both cultivars PAC-832 and PAC- 801; when N was applied as basal, maximum tillering and panicle initiation.

Hui Zhe *et al.* (2007) evaluated the effect of N application at 0, 45, 90, 135 and 180 kg $ha^{-1}$, supplied during spikelet initiation, on the growth and photosynthetic rate of canopy leaves of rice super hybrids Guodao 6 and Liangyoupeijiu. Nitrogen addition showed a higher effect on flag leaves and second leaves from the top than other leaves (such as the third leaf). The length, width and area of the flag leaf and the second leaves from the top increased with increasing N rates. Nitrogen had higher effects on leaf length than width. Droopy index increased due to overlong leaf which resulted in poor light penetration and air movement in the canopy after flowering. The photosynthetic rate of the flag leaf was increased by increasing the N rate. SPAD value was positively correlated with the photosynthetic rate of the flag leaf after full heading stage.

Oo *et al.* (2007) conducted a field experiment during the rainy season of 2003 at the research farm of the Indian Agricultural Research Institute, New Delhi to study the effect of N and S levels on the productivity and nutrient uptake of aromatic rice. Treatments comprised 4 N levels (0, 50, 100 and 150 kg $ha^{-1}$). The growth and yield attributes, grain, straw and biological yields increased significantly with increasing N levels. The increase in grain yield due to application of 100 and 150 kg N $ha^{-1}$ over the control was 1.99 and 1.95 t/ha (or 49.5 and 48.5%), respectively. Various N levels had a significant effect on grain, straw and total N, P, K and S uptake. Based on the total N uptake (grain + straw) there was 49.9. 63.9 and 70.4% increase in the N uptake over the control with 50, 100 and 150 kg N $ha^{-1}$, respectively.

Poshtmasari *et al.* (2007) from the Rice Research Institute of Iran-Deputy of Mazandaran (Amol) reported that nitrogen fertilizer rates and split application had significant effect on dry matter remobilization in shoot, stem and leaves (except flag leaf). This amount was obtained at the 100 kg $ha^{-1}$ nitrogen fertilizer and the first split application treatment. The highest rate of dry matter remobilization in leaves (except flag leaf) was obtained in 200 kg ha $^{1}$ nitrogen fertilizer level. Also, flag leaf had the highest dry matter remobilization, although it was not affected by nitrogen fertilizer rates and split application.

Rahman *et al.* (2007) conducted an experiment in Agricultural University, Mymensingh during T. Aman season of 2002 to study the effect of different levels of nitrogen on growth and yield of transplant aman rice. The experiment included four treatments viz. 0, 60, 80 and 100 kg N $ha^{-1}$. Nitrogen level significantly influenced growth and yield components. The highest number of effective tillers $hill^{1}$, maximum grains panicle $^{1}$ and highest grain yield and the highest harvest index i.e. maximum yield were obtained with 80 kg N ha

Tari *et al.* (2007) carried out a field experiment in Iran to study the effects of transplanting date (2, 12 and 22 May), planting space (16x30. 20x20 and 25x25cm) and N application rates (92, 115 and 135 kg $ha^{1}$) on morphological characters of a promising rice line (IR6874-2). Die N levels had significant effect on panicle length, 1000-grain weight and grain yield of rice. The 1000-grain weight, harvest index and filled grain percentage had the highest correlation with grain yield.

Singh *et al.* (2006) from a field experiment in Ludhiana. Punjab, India, during kharif 2003 reported that N application significantly increased plant height, number of grains panicle[1], 1000-grain weight and LAI but it did not influence the number of effective tillers plant'[1], panicle length and branches panicle'[1]. A progressive and significant increase in grain and straw yield was observed with each increment of nitrogen up to 40 kg ha$^{-1}$. Overall acceptability score with respect to aroma, colour, flavour, tenderness and cohesiveness was increased with early transplanting, less plant population and application of different levels of nitrogen compared to the control.

Sharma and Agarwal (2006) conducted a field experiment in the Taraj region, near Bareilly, Uttar Pradesh, India, to evaluate the effects of different levels of N (0, 60, 90. 120 and 150 kg ha$^{-1}$) on the grain yield, harvest index and chlorophyll content of rice cultivars Pant-4 and Manhar. All parameters increased with increasing levels of N up to 120 kg ha$^{-1}$. Pant-4 produced higher yield than Manhar.

Masud (2006) reported that application of nitrogen exerted positive effect on all crop characteristics. The rice genotypes differ significantly in yield contributing characters and grain yield. Manzoor *et al.* (2006) conducted a study during kharif season of three successive years from 2001 to 2003 at Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan. Nine nitrogen levels (0, 50, 75, 100, 125, 150, 175, 200 and 225 kg ha[1]) were studied to see their effect on paddy yield. According to the results plant height, number of productive tillers per hill, panicle length, number of grains per panicle. 1000 grain weight and paddy yield showed increasing trend from up to 175 kg N per hectare. The yield parameters including paddy yield, number of grains per panicle and 1000-grain weight started declining at 200 kg N per hectare level and above. The maximum paddy yield (5.34 t ha$^{-1}$) was obtained from 175 kg N application which also produced higher number of grains per panicle (142.27) along with maximum 1000-grain weight (24% g). The plant height (145.56 cm), productive tillers per hill (19.67) and panicle length (36.62 cm) were the maximum at 225 kg N level.

Roul and Sarawgi (2005) found that the grain yield was significantly higher under 100% recommended dose of N blended with farm yard manure (FYM) and 100% recommended dose of N+5 ton FYM than the other treatments.

Rahman *et al.* (2005) reported that the highest grain yield (4.80 t $ha^{1}$) was obtained from treatment 100% recommended dose of nitrogen which was at par with 75% recommended dose of nitrogen producing 4.79 t grain $ha^{-1}$.

Mazumder *et al.* (2005) reported that different levels of nitrogen influenced grain yield straw yield and biological yield with the application of 100% RD of N (99.82 kg N $ha^{-1}$) which was statistically followed by other treatments in descending order. The highest grain yield (4.86 t $ha^{1}$) was obtained with 100% recomended dose of N and the lowest one (3.80 t $ha^{-1}$) from no application of nitrogen.

The effects of N fertilizer rate (0, 11 or 22 kg/10 a) on the elongation of epidermal cell and guard cell in rice cultivars Seoanbyeo and Dasanbyeo were studied by Sung *et al.* (2004). Nitrogen was applied to seedlings after transplanting in pots. Leaf elongation in both cultivars was generally stimulated with increasing N levels. Leaf elongation rates were 1.6, 2.5 and 3.0 cm per day in Seoanbyeo. and 2.0, 3.5 and 4.0 cm per day with 0, 11 and 22 kg N $ha^{-1}$, respectively. Leaf growth increased rapidly within 7 to 8 days after the leaf had protruded above the collar of the previous leaf, gradually slowed down for 2 to 3 days, then stopped. Averaged between cultivars and N levels, the initial cell length was approximately 17 micro m. whereas the final cell length was approximately 130 micro m.

Wang (2004) conducted a field experiment in Taiwan to investigate the effect of deep placement of fertilizer and nitrogen top dressing on rice and to develop a simple method for diagnosing the level of nitrogen (N) top-dressing during panicle initiation stage. The deep placement of N fertilizer promoted N uptake, grain nitrogen and nitrogen harvest index, resulted in a higher dry matter production, harvest index and a higher grain yield rice plant compared with conventional nitrogen application. Similarly, top-dressing of nitrogen at panicle initiation stage also increased nitrogen uptake, dry production, nitrogen harvest index, harvest index and grain yield of rice plants.

Pariyani and Naik (2004) showed that increasing levels of nitrogen (90. 120 and 150 kg/ha) significantly increased tillers $hill^{-1}$, leaf area index (LAI), panicle length and grain yield up to 150 kg N $ha^{-1}$ in hybrid rice (Pro agro-6201, PHB-71 and PAC-801) at Jabalpur. Madhya Pradesh, India during the kharif season of 1999. Planting one or two seedlings hill'$^{1}$ did not show significant variations in yield attributes and yield. PHB-71 gave 20.6 and 10.3% higher grain yield over Proagro- 6201 and PAC-801.respectively. Proagro-6201 responded up to 150 kg N $ha^{-1}$.

Duan *et al.* (2006) stated that Different responses to N form have been found among rice cultivars. The three rice cultivars in this research responded differently to $NO3^{-}$ nutrition. Compared to rice cultivar 4007, Nanguang and Yunjing 38 showed the best response to $NO_3^-$, $NH^+_4$ which played a more important role on the growth of Yunjing 38 at the reproductive stage rather than that at the vegetative stage, while it improved the growth of rice cultivar 4007 only at the seedling stage.

Xingkai-Xu *et al.* (2005) found that the fresh weight of the aboveground biomass of rice plants was significantly higher ($P<0.05$) in the U (urea) + DCD (dicyandiamide) and U + HQ (hydroquinone) + DCD treatments than in the other three treatments. However, there were no significant differences between U + DCD and U + HQ + DCD. On 20 and 40 days after fertilization, the number of tillers in the U + DCD and U + HQ + DCD treatments was much higher than in the U and U + HQ treatments whereas on day 60, there were no significant differences among all four treatments containing urea. hybrid rice (‘Proagro 6207') production. Ammonium sulfate nitrate, produced maximum number of grains $panicle^{-1}$. And significantly lowest grain weight $panicle^{-1}$ (1.24 g) was recorded for urea treatment.

Indira chaturvedi (2005) found that urea gave significant reductions in growth and yields in most of the experiments. It gave the lowest grain N content in experiments. Thus in this series of experiments, urea had little effect on the quality of the grain. It may be concluded that nitrogen fertilizers, Super Net and ammonium sulphate nitrate were found to be optimum for

Kenzo (2004) stated that higher yields can be attained in single basal applications of fertilizer consisting of 50% to 70% of coated urea nitrogen than in split applications of ammonium sulfate. No significant difference was found also in yield components and in nitrogen content of grain among the methods of fertilization. The rice yield increased in both ammonium sulfate plots and in coated urea plots with the increase in nitrogen application. The percent yield increase was greater in the ammonium sulfate plots than in the coated urea plots on account of lower absorption efficiency of ammonium nitrogen. Yield in the coated urea plots was 10% to 13% greater than the ammonium sulfate plots. Rice in the coated urea plots had 17% greater nitrogen absorption than in the ammonium sulfate plots.

Sarkar *et al.* (2003) found that application of inorganic fertilizers produced 10 - 17% higher grain yield of rice, compared to sole application of organic sources or combined organic and inorganic sources. Annual application of wheat straw and farmyard manure gave higher grain yield of rice.

Paromita and Kashyap (2003) studied that The $NH^{+}_{4}$ - N/NO3" - N ratio was always greater than in the mineral - N pool indicating efficient nitrate uptake by the rice plants. Fertilization enhanced the grain yield by 16.2% over control in Sarju-52, 2.1% in Malviya-36, and in Pant Dhan-4 the grain yield increased by 23.8% over control. Also urea fertilization increased the nitrifier population significantly.

Vanaja and Raju (2002) showed that application of entire nitrogen through urea resulted in 85.2, 99.2 and 85.9% of dry matter yield at flowering, respectively over control. The relationship between total dry matter production at maturity and total uptake of nutrients (N, P and K) was highly significant. Grain and straw yield were improved.

Shamima *et al*. (2002) in Bangladesh, reported that the grain and straw yield of BRRI Dhan29 was influenced significantly by the combined use of Azolla and urea-N. The highest grain yield (6.02 t $ha^{-1}$) was obtained with $T_{10}$ (0.2 kg $m^{-2}$ inoculation plus 70% urea-N applied in 3 splits [15, 45 and 60 days after transplanting]). Urea combined with duckweed cover treatments effectively enhanced rice yield over urea alone treatments. There is limited information on the effects of duckweed in rice production. The duckweed cover could increase grain yield by 9.8 and9.4% at 90 and 180 kg Nha−1 over urea alone (Li *et al.*, 2009). The higher rice yields in the duckweed cover treatments were mainly attributed to the reduced N loss and enhanced crop N accumulation (Yao and Zhang, 2017). Urea combined with duckweed cover effectively reduced $^{15N}$ loss and $NH_3$ loss and thereby, more N was available for rice plants under duckweed cover (Yao, and Zhang, 2017). Moreover, the $NH^+_4$, N uptake by duckweed and its release was also responsible for the enhanced crop N accumulation under duckweed cover treatments. Duckweed can act as an excellent “nutrient sink” for harvesting nutrients over a short period of time when a large amount of $NH^+_4$ N is available. The reduction of $NH_3$ volatilization under duckweed cover treatments was mainly attributed to the formation of a physical barrier and the uptake of $NH^+_4$ by duckweed. Urea combined with duckweed cover effectively reduced the $NH_3$ loss the surface water was fully covered by duckweed and thus, duckweed formed a densely physical barrier, which could inhibit the $NH_3$ escaping. Duckweed cover remarkably promoted the development of rice roots in the soil surface layer and increased tiller numbers by 18–21% compared to those of urea alone (Yao, and Zhang, 2017). The total N content of duckweed declined during the mid-rice season due to the large amount of duckweed death caused by the mid-season aeration event. This indicated that the duckweed had a rapid decomposition rate and that a considerable amount of the N accumulated by duckweed was released into field water or soil; thus, more N is available for rice plant in the duckweed cover treatments.

# Chapter III

# Materials and Methods

# CHAPTER III

# MATERIALS AND METHODS

The experiment was carried out at Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2018 to June 2019. The details of the materials and methods have been presented below:

## 3.1 Description of the experimental site

### 3.1.1 Location

The geographical location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

### 3.1.2 Soil

The soil belongs to “The Modhupur Tract”, AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.1 and has 0.45% organic carbon. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details are presented in Appendix III.

### 3.1.3 Climate

The experimental site lies under the subtropical climate, characterized by 3 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 on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Bangladesh Meteorological Department, Sher-e-Bangla Nagar, presented in Appendix II.

### 3.2 Experimental details

#### 3.2.1 Treatments

The experiment comprised of two factors shown under factor A and factor B below:

**Factor A: Duckweed at four levels**

1. $D_0$ = Control (0 g duckweeds $m^{-2}$)
2. $D_1$ = 200 g duckweeds $m^{-2}$
3. $D_2$ = 400 g duckweeds $m^{-2}$
4. $D_3$ = 600 g duckweeds $m^{-2}$

**Factor B: Nitrogen at three levels**

1. $N_1$ = 45 kg N $ha^{-1}$
2. $N_2$ = 90 kg N $ha^{-1}$
1. $N_3$ = 180 kg N $ha^{-1}$

#### 3.2.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the duckweed and nitrogen in different plots as complete randomization. There were 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 3 m × 1.8 m. The distance between blocks and plots were 1 m and 0.5 m respectively. The layout of the experiment field is shown in Appendix IV.

### 3.3 Crop Management

#### 3.3.1 Seed Collection

Healthy seeds of BRRI dhan28 were collected from the Breeding Division, BRRI, Joydebpur, Gazipur.

### 3.3.2 Sprouting of seed

The seeds were soaked in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and became suitable for sowing after 72 hours.

### 3.3.3 Raising of seedlings

Seedlings were raised on a high land in the south-east side of the research farm of SAU. Seeds were sown in the seedbed on November 07, 2018 for raising seedlings. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. Proper care was taken to raise seedlings in the nursery bed. The beds were kept weed free throughout the period of seedling raised.

## 3.4 Preparation of experimental land

The experimental field was first ploughed on December 10, 2018 with the help of a tractor drawn rotary plough, later on December 12, 2018 the land was irrigated and prepared by three successive ploughing and cross ploughing with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on December 15, 2018 according to experimental specification.

## 3.5 Fertilizer application

Triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate was applied at the rate of 148-178-100-15 kg ha$^{-1}$ (Adhunik Dhaner Chas, 2017). Full dose of TSP, MoP, gypsum and zinc sulphate were applied as basal dose at final land preparation of individual plots. Urea as of treatment was applied to the plot in three equal splits at 15, 30 and 55 days after transplanting (DAT).

### 3.6 Transplanting of seedlings

Seedlings were transplanted on December 17, 2018 (40 days old seedling) in the well-puddled experimental plots. Spacings were given 25 cm × 15 cm. Soil of the plots was kept moist without allowing standing water at the time of transplanting. Two seedlings of BRRI dhan28 was hill$^{-1}$ transplanted.

### 3.7 Inter-cultural operations

#### 3.7.1 Gap filling

After one week of transplanting gap filling were done to maintain the constant population. After transplanting the gap filling was done whenever it was necessary using the seedling from the nursery bed.

#### 3.7.2 Weeding

Weed infestation was a severe problem during the early stage of crop establishment. The experimental plots were infested with some common weeds. To minimize weed infestation, manual weeding through hand pulling was done three times during entire growing season.

#### 3.7.3 Irrigation and drainage

Irrigation was done by alternate wetting and drying from transplanting to maximum tillering stage. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Water was removed from the plots during ripening stage.

#### 3.7.4 Plant protection measures

Plants were started to infestation with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by applying Diazinon @ 10 ml/10 liter of water and by Furadan 5G @ 10 kg/ha. Crop was protected from birds during the grain filling period. For controlling the birds watching was done properly, especially during morning and afternoon. No remarkable disease infestation was noticed in the field. So no control measure was needed against diseases.

### 3.8 Harvesting and post harvest processing

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting of BRRI dhan28 was done on April 18, 2019. Hills from the central $1m^2$ area of each plot were harvested for collecting data on crop yield. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The crops were threshed by pedal thresher and then grains were cleaned. The grain and straw weights for each plot were recorded after proper sun drying and then converted into ton $hectare^{-1}$. The grain yield was adjusted at 14% moisture level. Moisture percentage was measured by moisture meter.

### 3.9 Collection of Plant Samples

Five hills were randomly selected from each plot at maturity to record the yield contributing characters.

### 3.10 Introduction and maintenance of duckweed in research plots

After collection of duckweeds from sources those were kept in a cistern in research field for purification and refreshing. When field was ready then measured in several packets previously determined weight after water removal. Duckweeds were introduced in the target plots after two days of planting seedlings. When duckweeds applied to the plots they were spontaneously spread in plots. To maintain the exact thickness in plots with duckweeds nets were placed in every plots drainage openings. Duckweeds were reserved for in emergency case. But in sometimes a little bit duckweeds observed in control plots and without delay those were removed carefully. Water level of plots maintained in below plots ridges to control duckweeds in desired plots.

### 3.11 Recording of data

Data were collected on the following parameters

**Growth parameter**

1. Plant height (cm)
2. Number of tillers hill$^{-1}$

**Yield contributing parameters**

1. Non-effective tillers hill$^{-1}$
2. Effective tillers hill$^{-1}$
3. Grains panicle$^{-1}$
4. Filled grains panicle$^{-1}$
5. Unfilled grains panicle$^{-1}$
6. Panicle length (cm)
7. 1000 grain weight (g)

**Yield parameters**

1. Seed yield (t ha$^{-1}$)
2. Straw yield (t ha$^{-1}$)
3. Biological yield (t ha$^{-1}$)
4. Harvest index (%)

### 3.12 Procedure of recording data

A brief outline on data recording procedure followed during the study is given below:

#### 3.12.1 Growth characters

**Plant height (cm)**

The first plant height was measured at 25 DAT and continued up to harvest with 20 days interval. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of the flag leaf after heading. From each plot, plants of 5 hills were measured and averaged.

**Tillers per hill (no.)**

Number of tillers hill$^{-1}$ was counted at 20 days interval starting from 25 DAT. Only those tillers having three or more leaves were used for counting

### 3.12.2 Yield contributing parameters

The sample plants of 5 hills were harvested randomly from each plot and tagged them separately. Data on yield components were collected from the sample plants of each plot.

**Non-effective tillers hill$^{-1}$ (no.)**

The panicle which had no grain was recorded as non-effective tillers.

**Effective tillers hill$^{-1}$ (no.)**

Tillers having panicles which had at least one grain were considered as effective tillers.

**Filled grains panicle$^{-1}$ (no.)**

Presence of any kernel in the spikelet was considered as grain and total number of filled grain on each panicle was counted.

**Unfilled grains panicle$^{-1}$ (no.)**

Spikelet having no food material inside was considered as unfilled spikelet i.e. sterile spikelet and the number of such spikelet present in each panicle was recorded.

**Panicle length**

The measurement of panicle length was taken from basal node of the rachis to apex of each panicle and expressed in centimeter (cm). Each observation was an average of 5 hills

**Weight of 1000 grains**

One thousand clean dried grains from the seed stock of each plot were counted separately and weighed by using a digital electric balance at the stage the grain retained 14% level moisture by moisture meter after 3 days sun drying and the mean weight were expressed in gram.

**3.12.3 Yield parameters**

**Seed yield (t ha$^{-1}$)**

Grains obtained from the central 1 m$^2$ areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 14% moisture level by moisture meter. Dry weight of grams of each plot was converted into t ha$^{-1}$

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

Straw obtained from the central 1 m$^2$ area of each plot were sun dried, cleaned, weighed separately and finally converted into t ha$^{-1}$.

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

Biological yield (t ha$^{-1}$) = Grain yield (t ha$^{-1}$) + Straw yield (t ha$^{-1}$)

**Harvest index (%)**

It is the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

### 3.13 Statistical analysis of the data

The analysis of variance for different crop characters of the treatments were made and the significant differences were judged at 5% level of probability by using Least Significant Difference (LSD) with a computer operated program named MSTAT-C.

# Chapter IV

# Results and Discussion

# CHAPTER IV

# RESULTS AND DISCUSSION

Result obtained from the study of nitrogen use efficiency on growth and yield of boro rice grown with floating duckweed have been presented and discussed in this chapter. Treatments effect of duckweed and nitrogen on all the studied parameters have been presented in various tables and figures and discussed below under the following sub-headings.

## 4.1 Growth of rice plants

### 4.1.1 Plant height

**Effect of duckweed**

Significant difference was found among the treatment on plant height of rice at all growth stages due to application of duckweed at different rates (Table 1). Results revealed that the highest plant height (23.19, 61.41 and 97.49 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically same with $D_1$ (200 g duckweeds $m^{-2}$) at 60 DAT but at harvest it was significantly different from other treatments. The lowest plant height (20.28, 52.82 and cm at 30, 60 DAT and at harvest, respectively) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

**Effect of nitrogen**

Different doses of nitrogen showed significant variation on plant height of rice at all growth stages (Table 1). Results showed that the highest plant height (23.06, 60.69 and 97.28 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment $N_3$ (180 kg N $ha^{-1}$) which was statistically similar with $N_2$ (90 kg N $ha^{-1}$) whereas the lowest plant height (20.21, 54.68 and 89.14 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment $N_1$ (45 kg N $ha^{-1}$). The result obtained from the present study was followed the findings of Adhikari (2018) and Chamely and Islam (2015).

Table 1. Plant height of rice as influenced by duckweed and nitrogen and also their combination

| Treatment | Plant height (cm) | | |
|---|---|---|---|
| | 30 DAT | 60 DAT | At harvest |
| Effect of duckweed | | | |
| $D_0$ | 20.28 b | 52.82 d | 88.35 c |
| $D_1$ | 22.12 ab | 59.78 a | 94.29 b |
| $D_2$ | 23.19 a | 61.41 a | 97.49 a |
| $D_3$ | 21.16 ab | 56.78 c | 92.86 b |
| $LSD_{(0.05)}$ | 2.41 | 2.30 | 1.87 |
| CV (%) | 11.35 | 11.16 | 10.03 |
| Effect of nitrogen (N) | | | |
| $N_1$ | 20.21 b | 54.68 b | 89.14 b |
| $N_2$ | 21.80 ab | 57.72 ab | 93.32 ab |
| $N_3$ | 23.06 a | 60.69 a | 97.28 a |
| $LSD_{(0.05)}$ | 2.08 | 5.45 | 7.92 |
| CV (%) | 11.35 | 11.16 | 10.03 |
| Combined effect of duckweed and nitrogen | | | |
| $D_0N_1$ | 21.77 a-c | 55.59 a-c | 92.73 ab |
| $D_0N_2$ | 19.94 bc | 52.80 bc | 88.30 ab |
| $D_0N_3$ | 19.14 c | 50.08 c | 84.03 b |
| $D_1N_1$ | 22.18 a-c | 60.67 a-c | 94.77 ab |
| $D_1N_2$ | 23.21 a-c | 62.43 ab | 98.11 ab |
| $D_1N_3$ | 20.96 a-c | 56.23 a-c | 89.98 ab |
| $D_2N_1$ | 23.63 ab | 61.46 ab | 96.59 ab |
| $D_2N_2$ | 21.49 a-c | 58.79 a-c | 94.93 ab |
| $D_2N_3$ | 24.43 a | 63.99 a | 100.9 a |
| $D_3N_1$ | 21.43 a-c | 55.97 a-c | 93.62 ab |
| $D_3N_2$ | 22.81 a-c | 60.73 a-c | 97.33 ab |
| $D_3N_3$ | 19.24 c | 53.63 a-c | 87.63 ab |
| $LSD_{(0.05)}$ | 4.17 | 10.90 | 15.83 |
| CV (%) | 11.35 | 11.16 | 10.03 |

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

$D_0$ = Control (0 g duckweeds $m^{-2}$), $D_1$ = 200 g duckweeds $m^{-2}$, $D_2$ = 400 g duckweeds $m^{-2}$, $D_3$ = 600 g duckweeds $m^{-2}$

$N_1$ = 45 kg N $ha^{-1}$, $N_2$ = 90 kg N $ha^{-1}$, $N_3$ = 180 kg N $ha^{-1}$

### Combined effect of duckweed and nitrogen

Treatment combination of duckweed and nitrogen at different doses showed significant variation on plant height of rice at different growth stages (Table 1). It was observed that the highest plant height (24.43, 63.99 and 100.90 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of $D_2N_3$ whereas the lowest plant height (21.77, 55.59 and 92.73 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of $D_0N_1$.

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

### Effect of duckweed

Significant effect was found on number of tillers hill$^{-1}$ of rice among the treatment at all growth stages due to application of duckweed at different rates (Table 2). Results revealed that the highest number of tillers hill$^{-1}$ (9.29, 14.16 and 14.76 at 30, 60 DAT and at harvest, respectively) was found from the treatment $D_2$ (400 g duckweeds m$^{-2}$) which was statistically similar with $D_1$ (200 g duckweeds m$^{-2}$) at 60 DAT and at harvest whereas the lowest number of tillers hill$^{-1}$ (6.26, 10.03 and 10.81 at 30, 60 DAT and at harvest, respectively) was found from control treatment $D_0$ (0 g duckweeds m$^{-2}$).

### Effect of nitrogen

Different doses of nitrogen showed significant influence on number of tillers hill$^{-1}$ of rice at all growth stages (Table 2). Results showed that the highest number of tillers hill$^{-1}$ (7.88, 13.60 and 14.89 at 30, 60 DAT and at harvest, respectively) was found from the treatment $N_2$ (90 kg N ha$^{-1}$) which was significantly different from other treatments. The lowest number of tillers hill$^{-1}$ (7.39, 10.66 and 11.85 at 30, 60 DAT and at harvest, respectively) was found from the treatment $N_3$ (180 kg N ha$^{-1}$) which was statistically identical with $N_1$ (45 kg N ha$^{-1}$). More or less Similar result was also observed by Karim (2019), Adhikari (2018) and Chamely and Islam (2015) who found that N had significant effect on number of tillers hill$^{-1}$ which supported the present study.

Table 2. Number of tillers hill$^{-1}$ of rice as influenced by duckweed and nitrogen and also their combination

| Treatment | Number of tillers hill$^{-1}$ | | |
|---|---|---|---|
| | 30 DAT | 60 DAT | At harvest |
| Effect of duckweed | | | |
| $D_0$ | 6.256 c | 10.03 b | 10.81 c |
| $D_1$ | 7.333 b | 13.09 a | 14.44 ab |
| $D_2$ | 9.289 a | 14.16 a | 14.76 a |
| $D_3$ | 6.978 bc | 10.95 b | 13.06 b |
| $LSD_{(0.05)}$ | 0.92 | 1.40 | 1.50 |
| CV (%) | 12.67 | 11.90 | 11.53 |
| Effect of nitrogen (N) | | | |
| $N_1$ | 7.125 | 11.91 b | 13.06 b |
| $N_2$ | 7.875 | 13.60 a | 14.89 a |
| $N_3$ | 7.392 | 10.66 c | 11.85 b |
| $LSD_{(0.05)}$ | NS | 1.22 | 1.30 |
| CV (%) | 12.67 | 11.90 | 11.53 |
| Combined effect of duckweed and nitrogen | | | |
| $D_0N_1$ | 6.00 e | 9.913 e-g | 10.22 de |
| $D_0N_2$ | 6.87 de | 10.93 d-g | 12.41 b-d |
| $D_0N_3$ | 5.90 e | 9.253 g | 9.800 e |
| $D_1N_1$ | 6.20 de | 13.07 b-d | 14.27 ab |
| $D_1N_2$ | 6.60 de | 14.40 ab | 15.99 a |
| $D_1N_3$ | 9.20 bc | 11.80 c-f | 13.07 bc |
| $D_2N_1$ | 9.77 b | 14.19 a-c | 14.54 ab |
| $D_2N_2$ | 11.43 a | 16.17 a | 16.40 a |
| $D_2N_3$ | 6.67 de | 12.13 b-e | 13.33 bc |
| $D_3N_1$ | 6.53 de | 10.47 e-g | 13.20 bc |
| $D_3N_2$ | 6.60 de | 12.91 b-d | 14.76 ab |
| $D_3N_3$ | 7.80 cd | 9.46 fg | 11.21 c-e |
| $LSD_{(0.05)}$ | 1.60 | 2.43 | 2.59 |
| CV (%) | 12.67 | 11.90 | 11.53 |

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

$D_0$ = Control (0 g duckweeds m$^{-2}$), $D_1$ = 200 g duckweeds m$^{-2}$, $D_2$ = 400 g duckweeds m$^{-2}$, $D_3$ = 600 g duckweeds m$^{-2}$

$N_1$ = 45 kg N ha$^{-1}$, $N_2$ = 90 kg N ha$^{-1}$, $N_3$ = 180 kg N ha$^{-1}$

**Combined effect of duckweed and nitrogen**

Number of tillers hill$^{-1}$ of rice at all growth stages showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 2). Results indicated that the highest number of tillers hill$^{-1}$ (11.43, 16.17 and 16.40 at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_1$, $D_1N_2$, $D_2N_1$ and $D_3N_2$. The lowest number of tillers hill$^{-1}$ (5.90, 9.25 and 9.80 at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$ and $D_3N_3$.

**4.2 Yield contributing parameters**

**4.2.1 Number of non-effective tillers hill$^{-1}$**

**Effect of duckweed**

Significant effect was found on number of non-effective tillers hill$^{-1}$ of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the lowest number of non-effective tillers hill$^{-1}$ (1.76) was found from the treatment $D_2$ (400 g duckweeds m$^{-2}$) which was significantly different from other treatments followed by $D_3$ (600 g duckweeds m$^{-2}$). The highest number of non-effective tillers hill$^{-1}$ (4.25) was found from control treatment $D_0$ (0 g duckweeds m$^{-2}$) which was significantly different from other treatments.

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on number of non-effective tillers hill$^{-1}$ of rice (Table 3). Results showed that the lowest number of non-effective tillers hill$^{-1}$ (2.26) was found from the treatment $N_2$ (90 kg N ha$^{-1}$) which was significantly different from other treatments followed by $N_1$ (45 kg N ha$^{-1}$) whereas the highest number of non-effective tillers hill$^{-1}$ (3.45) was found from the treatment $N_3$ (180 kg N ha$^{-1}$). The result obtained from the present study was followed with the findings of Karim (2019) and Adhikari (2018).

### Combined effect of duckweed and nitrogen

Number of non-effective tillers hill$^{-1}$ of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). The lowest number of non-effective tillers hill$^{-1}$ (1.40) was found from the treatment combination of $D_2N_2$ which was statistically similar with $D_1N_2$ and $D_2N_1$. The highest number of non-effective tillers hill$^{-1}$ (4.80) was found from the treatment combination of $D_0N_3$ which was statistically identical with the treatment combination of $D_0N_3$.

### 4.2.2 Effective tillers hill$^{-1}$

### Effect of duckweed

Significant effect was found on number of effective tillers hill$^{-1}$ of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the highest number of effective tillers hill$^{-1}$ (13.02) was found from the treatment $D_2$ (400 g duckweeds m$^{-2}$) followed by $D_1$ (200 g duckweeds m$^{-2}$) whereas the lowest number of effective tillers hill$^{-1}$ (7.41) was found from control treatment $D_0$ (0 g duckweeds m$^{-2}$).

### Effect of nitrogen

Different doses of nitrogen showed significant influence on number of effective tillers hill$^{-1}$ of rice (Table 3). Results showed that the highest number of effective tillers hill$^{-1}$ (11.67) was found from the treatment $N_2$ (90 kg N ha$^{-1}$) followed by $N_1$ (45 kg N ha$^{-1}$) whereas the lowest number of effective tillers hill$^{-1}$ (8.97) was found from the treatment $N_3$ (180 kg N ha$^{-1}$). Karim (2019) and Chamely and Islam (2015) also found significant effect of N on number of effective tillers hill$^{-1}$ of rice which supported the present study.

**Combined effect of duckweed and nitrogen**

Number of effective tillers $hill^{-1}$ of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). The highest number of effective tillers $hill^{-1}$ (14.73) was found from the treatment combination of $D_2N_2$ which was statistically similar with $D_1N_2$ whereas the lowest number of effective tillers $hill^{-1}$ (6.40) was found from the treatment combination of $D_0N_3$ which was statistically similar with $D_0N_1$ and $D_3N_3$.

### 4.2.3 Number of grains $panicle^{-1}$

**Effect of duckweed**

Significant effect was found on number of grains $panicle^{-1}$ of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the highest number of grains $panicle^{-1}$ (179.40) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically identical with $D_1$ (200 g duckweeds $m^{-2}$) whereas the lowest number of grains $panicle^{-1}$ (132.60) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on number of grains $panicle^{-1}$ of rice (Table 3). Results showed that the highest number of grains $panicle^{-1}$ (169.70) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) which was statistically similar with $N_1$ (45 kg N $ha^{-1}$) whereas the lowest number of grains $panicle^{-1}$ (149.80) was found from the treatment $N_3$ (180 kg N $ha^{-1}$). The result obtained from the present study was good relation with the findings of Karim (2019), Adhikari (2018) and Chamely and Islam (2015).

**Combined effect of duckweed and nitrogen**

Number of grains $panicle^{-1}$ of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). Results indicated that the highest number of grains $panicle^{-1}$ (189.50) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_1$, $D_1N_2$, $D_2N_1$, $D_2N_3$ and $D_3N_2$. The lowest number of grains panicle$^{-1}$ (121.50) was found from the treatment combination of $D_0N_3$ which was statistically similar with $D_0N_1$, $D_0N_2$ and $D_3N_3$.

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

**Effect of duckweed**

Significant effect was found on number of filled grains panicle$^{-1}$ of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the highest number of filled grains panicle$^{-1}$ (170.00) was found from the treatment $D_2$ (400 g duckweeds m$^{-2}$) which was statistically identical with $D_1$ (200 g duckweeds m$^{-2}$) whereas the lowest number of filled grains panicle$^{-1}$ (110.10) was found from control treatment $D_0$ (0 g duckweeds m$^{-2}$).

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on number of filled grains panicle$^{-1}$ of rice (Table 3). Results showed that the highest number of filled grains panicle$^{-1}$ (156.60) was found from the treatment $N_2$ (90 kg N ha$^{-1}$) whereas the lowest number of filled grains panicle$^{-1}$ (129.30) was found from the treatment $N_3$ (180 kg N ha$^{-1}$) which was statistically identical with $N_1$ (45 kg N ha$^{-1}$). Similar result was also observed by Chamely and Islam (2015) and Adhikari (2018).

**Combined effect of duckweed and nitrogen**

Number of filled grains panicle$^{-1}$ of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). The highest number of filled grains panicle$^{-1}$ (183.90) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_2$, $D_2N_1$ and $D_2N_3$. The lowest number of filled grains panicle$^{-1}$ (93.18) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$.

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

**Effect of duckweed**

Significant effect was found on number of unfilled grains panicle$^{-1}$ of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the lowest number of unfilled grains panicle$^{-1}$ (9.35) was found from the treatment $D_2$ (400 g duckweeds m$^{-2}$) which was significantly different from other treatments. The highest number of unfilled grains panicle$^{-1}$ (22.53) was found from control treatment $D_0$ (0 g duckweeds m$^{-2}$) which was significantly different from other treatments followed by $D_1$ (200 g duckweeds m$^{-2}$). Chamely and Islam (2015) also found similar result with the present study.

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on number of unfilled grains panicle$^{-1}$ of rice (Table 3). Results showed that the lowest number of unfilled grains panicle$^{-1}$ (13.08) was found from the treatment $N_2$ (90 kg N ha$^{-1}$) whereas the highest number of unfilled grains panicle$^{-1}$ (20.51) was found from the treatment $N_3$ (180 kg N ha$^{-1}$) followed by $N_1$ (45 kg N ha$^{-1}$).

**Combined effect of duckweed and nitrogen**

Number of unfilled grains panicle$^{-1}$ of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). Results indicated that the lowest number of unfilled grains panicle$^{-1}$ (5.62) was found from the treatment combination of $D_2N_2$ which was significantly different from other treatment combinations whereas the highest number of unfilled grains panicle$^{-1}$ (28.29) was found from the treatment combination of $D_0N_3$ followed by $D_0N_1$ and $D_3N_3$.

Table 3. Yield contributing parameters of rice as influenced by duckweed and nitrogen and also their combination

| Treatments | Yield contributing parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | No. of non-effective tillers hill$^{-1}$ | No. of effective tillers hill$^{-1}$ | No. of grains panicle$^{-1}$ | No. of filled grains panicle$^{-1}$ | No. of unfilled grains panicle$^{-1}$ | Panicle length (cm) | 1000 grain weight (g) |
| Effect of duckweed | | | | | | | |
| $D_0$ | 4.25 a | 7.41 d | 132.6 c | 110.1 c | 22.53 a | 18.89 c | 20.94 b |
| $D_1$ | 2.40 c | 11.87 b | 171.6 a | 155.7 a | 15.81c | 23.48 a | 23.05 ab |
| $D_2$ | 1.76 d | 13.02 a | 179.4 a | 170.0 a | 9.35 d | 24.58 a | 24.49 a |
| $D_3$ | 3.11 b | 8.58 c | 152.8 b | 133.5 b | 19.30 b | 21.29 b | 22.31 b |
| $LSD_{(0.05)}$ | 0.31 | 1.05 | 16.89 | 15.34 | 1.73 | 2.07 | 2.13 |
| CV (%) | 11.13 | 10.49 | 10.86 | 11.02 | 10.53 | 9.62 | 9.59 |
| Effect of nitrogen (N) | | | | | | | |
| $N_1$ | 2.93 b | 10.02 b | 157.7 ab | 141.1 b | 16.65 b | 22.01 ab | 22.88 ab |
| $N_2$ | 2.26 c | 11.67 a | 169.7 a | 156.6 a | 13.08 c | 23.29 a | 23.82 a |
| $N_3$ | 3.45 a | 8.972 c | 149.8 b | 129.3 b | 20.51 a | 20.88 b | 21.40 b |
| $LSD_{(0.05)}$ | 0.27 | 0.91 | 14.62 | 13.28 | 1.49 | 1.80 | 1.84 |
| CV (%) | 11.13 | 10.49 | 10.86 | 11.02 | 10.53 | 9.62 | 9.59 |
| Combined effect of duckweed and nitrogen | | | | | | | |
| $D_0N_1$ | 4.53 a | 7.57 fg | 131.1 de | 108.8 ef | 22.26 b | 18.90 ef | 21.40 b-d |
| $D_0N_2$ | 3.43 bc | 8.25 ef | 145.3 c-e | 128.3 de | 17.03 cd | 20.61 c-f | 22.07 a-d |
| $D_0N_3$ | 4.80 a | 6.40 g | 121.5 e | 93.18 f | 28.29 a | 17.17 f | 19.37 d |
| $D_1N_1$ | 2.47 e | 11.30 cd | 170.7 a-c | 155.0 bc | 15.69 de | 23.73 a-d | 23.03 a-d |
| $D_1N_2$ | 1.53 g | 13.80 ab | 180.2 ab | 167.4 ab | 12.79 e | 24.55 ab | 24.45 a-c |
| $D_1N_3$ | 3.20 b-d | 10.52 d | 163.7 a-c | 144.8 b-d | 18.96 c | 22.15 b-e | 21.67 a-d |
| $D_2N_1$ | 1.67 fg | 12.80 bc | 178.1 ab | 168.4 ab | 9.723 f | 24.15 a-c | 24.67 ab |
| $D_2N_2$ | 1.40 g | 14.73 a | 189.5 a | 183.9 a | 5.623 g | 25.83 a | 25.13 a |
| $D_2N_3$ | 2.20 ef | 11.53 cd | 170.4 a-c | 157.7 a-c | 12.71 e | 23.75 a-d | 23.67 a-c |
| $D_3N_1$ | 3.03 cd | 8.42 ef | 151.0 b-d | 132.1 c-e | 18.94 c | 21.27 b-e | 22.40 a-d |
| $D_3N_2$ | 2.67 de | 9.89 de | 163.7 a-c | 146.8 b-d | 16.86 cd | 22.17 b-e | 23.63 a-c |
| $D_3N_3$ | 3.62 b | 7.44 fg | 143.7 c-e | 121.6 de | 22.09 b | 20.43 d-f | 20.91 cd |
| $LSD_{(0.05)}$ | 0.54 | 1.82 | 29.25 | 26.57 | 2.99 | 3.59 | 3.69 |
| CV (%) | 11.13 | 10.49 | 10.86 | 11.02 | 10.53 | 9.62 | 9.59 |

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

$D_0$ = Control (0 g duckweeds m$^{-2}$), $D_1$ = 200 g duckweeds m$^{-2}$, $D_2$ = 400 g duckweeds m$^{-2}$, $D_3$ = 600 g duckweeds m$^{-2}$

$N_1$ = 45 kg N ha$^{-1}$, $N_2$ = 90 kg N ha$^{-1}$, $N_3$ = 180 kg N ha$^{-1}$

### 4.2.6 Panicle length

**Effect of duckweed**

Significant effect was found on panicle length of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the highest panicle length (24.58 cm) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically identical with $D_1$ (200 g duckweeds $m^{-2}$) whereas the lowest panicle length (18.89 cm) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on panicle length of rice (Table 3). Results showed that the highest panicle length (23.29 cm) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) which was statistically similar with $N_1$ (45 kg N $ha^{-1}$) whereas the lowest panicle length (20.88 cm) was found from the treatment $N_3$ (180 kg N $ha^{-1}$). Similar result was also observed by Chamely and Islam (2015) and Adhikari (2018) who found significant effect of N on panicle length of rice.

**Combined effect of duckweed and nitrogen**

Panicle length of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). Results indicated that the highest panicle length (25.83 cm) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_1$, $D_1N_2$, $D_2N_1$ and $D_2N_3$. The lowest panicle length (17.17 cm) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$, $D_0N_2$ and $D_3N_3$.

### 4.2.7 Weight of 1000 grain

**Effect of duckweed**

Significant effect was found on 1000 grain weight of rice among the treatment due to application of duckweed at different rates (Table 3). Results revealed that the highest 1000 grain weight (24.49 g) was found from the treatment $D_2$ (400 g duckweeds per $m^2$) which was statistically similar with $D_1$ (200 g duckweeds per $m^2$) whereas the lowest 1000 grain weight (20.94 g) was found from control treatment $D_0$ (0 g duckweeds per $m^2$) which was statistically identical with $D_3$ (600 g duckweeds per $m^2$).

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on 1000 grain weight of rice (Table 3). Results showed that the highest 1000 grain weight (23.82 g) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) which was statistically similar with $N_1$ (45 kg N $ha^{-1}$) whereas the lowest 1000 grain weight (21.40 g) was found from the treatment $N_3$ (180 kg N $ha^{-1}$). The result obtained from the present study was following with the findings of Chamely and Islam (2015).

**Combined effect of duckweed and nitrogen**

Weight of 1000 grains of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 3). Results indicated that the highest 1000 grain weight (25.13 g) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_0N_2$, $D_1N_1$, $D_1N_2$, $D_1N_3$, $D_2N_1$, $D_2N_3$, $D_3N_1$ and $D_3N_2$. The lowest 1000 grain weight (19.34 g) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$ and $D_3N_3$.

## 4.3 Yield parameters

### 4.3.1 Seed yield

#### Effect of duckweed

Significant effect was found on seed yield of rice among the treatment due to application of duckweed at different rates (Table 4). Results revealed that the highest seed yield (6.24 t $ha^{-1}$) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically identical with $D_1$ (200 g duckweeds $m^{-2}$) whereas the lowest seed yield (3.87 t $ha^{-1}$) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

#### Effect of nitrogen

Different doses of nitrogen showed significant influence on seed yield of rice (Table 4). Results showed that the highest seed yield (6.08 t $ha^{-1}$) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) which was significantly different from other treatments followed by $N_1$ (45 kg N $ha^{-1}$). The lowest seed yield (4.39 t $ha^{-1}$) was found from the treatment $N_3$ (180 kg N $ha^{-1}$) which was significantly different from other treatments. Similar result was also observed by Karim (2019), Adhikari (2018), Gewaily and Adel (2018) and Chamely and Islam (2015). Gewaily and Adel (2018) found a linear increase in grain yield with continuous rate increase of nitrogen from 0 to 220 kg $ha^{-1}$.

#### Combined effect of duckweed and nitrogen

Seed yield of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 4). Results indicated that the highest seed yield (7.24 t $ha^{-1}$) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_2$. the lowest seed yield (3.40 t $ha^{-1}$) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$, $D_3N_1$ and $D_3N_3$. The result obtained on seed yield of rice was conformity with the findings of Yao and Zhang (2017) who found increased N use efficiency with duckweed and also found that rice cultivation using urea combined with duckweed achieved higher rice yield by 9–10%.

### 4.3.2 Straw yield

**Effect of duckweed**

Significant effect was found on straw yield of rice among the treatment due to application of duckweed at different rates (Table 4). Results revealed that the highest straw yield (7.71 t $ha^{-1}$) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically similar with $D_1$ (200 g duckweeds $m^{-2}$) whereas the lowest straw yield (06.600 t $ha^{-1}$) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

**Effect of nitrogen**

Different doses of nitrogen showed significant influence on straw yield of rice (Table 4). Results showed that the highest straw yield (7.77 t $ha^{-1}$) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) which was significantly different from other treatments. The lowest straw yield (6.57 t $ha^{-1}$) was found from the treatment $N_3$ (180 kg N $ha^{-1}$) which was statistically identical with $N_1$ (45 kg N $ha^{-1}$). Similar result was also observed by Chamely and Islam (2015).

**Combined effect of duckweed and nitrogen**

Straw yield of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 4). The highest straw yield (8.47 t $ha^{-1}$) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_2$, $D_2N_1$ and $D_3N_2$. The lowest straw yield (6.10 t $ha^{-1}$) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$, $D_1N_3$, $D_3N_1$ and $D_3N_3$.

Table 4. Yield parameters of rice as influenced by duckweed and nitrogen and also their combination

| Treatments | Yield parameters | | | |
|---|---|---|---|---|
| | Seed yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest index (%) |
| Effect of duckweed | | | | |
| $D_0$ | 3.87 c | 6.60 b | 10.47 b | 36.90 b |
| $D_1$ | 5.89 a | 7.27 ab | 13.05 a | 44.54 a |
| $D_2$ | 6.24 a | 7.71 a | 13.94 a | 44.61 a |
| $D_3$ | 4.64 b | 6.85 b | 11.50 b | 40.16 ab |
| $LSD_{(0.05)}$ | 0.61 | 0.69 | 1.30 | 4.46 |
| CV (%) | 12.09 | 9.93 | 10.87 | 10.98 |
| Effect of nitrogen (N) | | | | |
| $N_1$ | 5.01 b | 6.99 b | 11.92 b | 41.34 |
| $N_2$ | 6.08 a | 7.77 a | 13.84 a | 43.52 |
| $N_3$ | 4.39 c | 6.57 b | 10.96 b | 39.80 |
| $LSD_{(0.05)}$ | 0.53 | 0.60 | 1.13 | NS |
| CV (%) | 12.09 | 9.93 | 10.87 | 10.98 |
| Combined effect of duckweed and nitrogen | | | | |
| $D_0N_1$ | 3.75 gh | 6.46 cd | 10.21 fg | 36.76 c |
| $D_0N_2$ | 4.46 efg | 7.24 b-d | 11.70 c-g | 38.09 bc |
| $D_0N_3$ | 3.40 h | 6.10 d | 9.51 g | 35.84 c |
| $D_1N_1$ | 5.84 cd | 7.17 b-d | 12.68 c-e | 44.83 ab |
| $D_1N_2$ | 6.95 ab | 8.02 ab | 14.97 ab | 46.39 a |
| $D_1N_3$ | 4.87 d-f | 6.63 cd | 11.51 c-g | 42.41 a-c |
| $D_2N_1$ | 6.16 bc | 7.55 a-c | 13.71 a-c | 44.94 ab |
| $D_2N_2$ | 7.24 a | 8.47 a | 15.71 a | 46.09 a |
| $D_2N_3$ | 5.31 c-e | 7.10 b-d | 12.41 c-f | 42.82 a-c |
| $D_3N_1$ | 4.30 e-h | 6.76 cd | 11.07 d-g | 38.83 a-c |
| $D_3N_2$ | 5.65 cd | 7.34 a-c | 13.00 b-d | 43.52 a-c |
| $D_3N_3$ | 3.98 f-h | 6.45 cd | 10.43 e-g | 38.12 bc |
| $LSD_{(0.05)}$ | 1.06 | 1.20 | 2.25 | 7.72 |
| CV (%) | 12.09 | 9.93 | 10.87 | 10.98 |

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

$D_0$ = Control (0 g duckweeds $m^{-2}$), $D_1$ = 200 g duckweeds $m^{-2}$, $D_2$ = 400 g duckweeds $m^{-2}$, $D_3$ = 600 g duckweeds $m^{-2}$

$N_1$ = 45 kg N $ha^{-1}$, $N_2$ = 90 kg N $ha^{-1}$, $N_3$ = 180 kg N $ha^{-1}$

### 4.3.3 Biological yield

**Effect of duckweed**

Significant effect was found on biological yield of rice among the treatment due to application of duckweed at different rates (Table 4). Results revealed that the highest biological yield (13.64 t $ha^{-1}$) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically identical with $D_1$ (200 g duckweeds $m^{-2}$). The lowest biological yield (10.47 t $ha^{-1}$) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$) which was statistically identical with $D_3$ (600 g duckweeds $m^{-2}$).

**Effect of nitrogen source**

Different doses of nitrogen showed significant influence on biological yield of rice (Table 4). Results showed that the highest biological yield (13.84 t $ha^{-1}$) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) which was significantly different from other treatments whereas the lowest biological yield (11.92 t $ha^{-1}$) was found from the treatment $N_3$ (180 kg N $ha^{-1}$) which was statistically identical with $N_1$ (45 kg N $ha^{-1}$). Chamely and Islam (2015) and Karim (2019) also found similar result with the present study.

**Combined effect of duckweed and nitrogen**

Biological yield of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 4). The highest biological yield (15.71 t $ha^{-1}$) was found from the treatment combination of $D_2N_2$ which was statistically similar with the treatment combination of $D_1N_2$ and $D_2N_1$. The lowest biological yield (9.51 t $ha^{-1}$) was found from the treatment combination of $D_0N_3$ which was statistically similar with the treatment combination of $D_0N_1$.

### 4.3.4 Harvest index

**Effect of duckweed**

Significant effect was found on harvest index of rice among the treatment due to application of duckweed at different rates (Table 4). Results revealed that the highest harvest index (44.61%) was found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) which was statistically similar with $D_1$ (200 g duckweeds $m^{-2}$) and $D_2$ (400 g duckweeds $m^{-2}$) whereas the lowest harvest index (36.90%) was found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

**Effect of nitrogen**

Different doses of nitrogen showed non-significant influence on harvest index of rice (Table 4). However, the highest harvest index (43.52%) was found from the treatment $N_2$ (90 kg N $ha^{-1}$) whereas the lowest harvest index (39.80%) was found from the treatment $N_3$ (180 kg N $ha^{-1}$). Karim (2019) and Chamely and Islam (2015) also found similar result which supported the present study.

**Combined effect of duckweed and nitrogen**

Harvest index of rice showed significant variation due to combined effect of duckweed and nitrogen at different doses (Table 4). Results indicated that the highest harvest index (46.09%) was found from the treatment combination of $D_2N_2$ which was statistically identical with the treatment combination of $D_1N_2$. Treatment combinations, $D_1N_1$ and $D_2N_1$ were similar with $D_2N_2$. The lowest harvest index (35.84%) was found from the treatment combination of $D_0N_3$ which was statistically identical with $D_0N_1$.

# Chapter V

# Summary and Conclusion

# CHAPTER V

# SUMMARY AND CONCLUSION

An experiment was conducted to study on nitrogen requirement of boro rice grown with floating duckweed at the Agronomy Research Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2018 to June 2019. The experiment consisted of two factors; Factor A: $D_0$ = Control (0 g duckweeds $m^{-2}$), $D_1$ = 200 g duckweeds $m^{-2}$, $D_2$ = 400 g duckweeds $m^{-2}$ and $D_3$ = 600 g duckweeds $m^{-2}$ and factor B: $N_1$ = 45 kg N $ha^{-1}$, $N_2$ = 90 kg N $ha^{-1}$ and $N_3$ = 180 kg N $ha^{-1}$. The experiment was laid out in randomized complete block design with three replications where duckweed treatment (Factor A) and nitrogen treatment (Factor B). There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 6 $m^2$ (3 m × 1.8 m). Data on different growth and yield parameters were recorded and analysis was done using MSTAT software. Recorded data on different growth and yield parameters were affected significantly due to duckweed and nitrogen treatments and also their combination.

Consideration of duckweed effect on growth parameters of rice, the highest plant height (23.19, 61.41 and 97.49 cm at 30, 60 DAT and at harvest, respectively), number of tillers $hill^{-1}$ (9.29, 14.16 and 14.76 at 30, 60 DAT and at harvest, respectively) and dry weight $hill^{-1}$ (15.75, 47.04 and 44.86 g at 30, 60 DAT and at harvest, respectively) were found from the treatment $D_2$ (400 g duckweeds $m^{-2}$) whereas the lowest plant height (20.28, 52.82 and cm at 30, 60 DAT and at harvest, respectively), number of tillers $hill^{-1}$ (6.26, 10.03 and 10.81 at 30, 60 DAT and at harvest, respectively) and dry weight $hill^{-1}$ (8.47, 30.23 and 27.99 g at 30, 60 DAT and at harvest, respectively) were found from control treatment $D_0$ (0 g duckweeds $m^{-2}$).

Regarding yield and yield contributing parameters affected by duckweed treatments, the lowest number of non-effective tillers hill$^{-1}$ (1.76) and number of unfilled grains panicle$^{-1}$ (9.35) were found from the treatment $D_2$ (400 g duckweeds m$^{-2}$) whereas the highest number of non-effective tillers hill$^{-1}$ (4.25) and number of unfilled grains panicle$^{-1}$ (22.53) were found from control treatment $D_0$ (0 g duckweeds m$^{-2}$). Similarly, the highest number of effective tillers hill$^{-1}$ (13.02), number of grains panicle$^{-1}$ (179.40), number of filled grains panicle$^{-1}$ (170.00), panicle length (24.58 cm), 1000 grain weight (24.49 g), seed yield (6.24 t ha$^{-1}$), straw yield (7.71 t ha$^{-1}$), biological yield (13.64 t ha$^{-1}$) and harvest index (44.61%) were found from the treatment $D_2$ (400 g duckweeds m$^{-2}$). On the other hand, the lowest number of effective tillers hill$^{-1}$ (7.41), number of grains panicle$^{-1}$ (132.60), number of filled grains panicle$^{-1}$ (110.10), panicle length (18.89 cm), 1000 grain weight (20.94 g), seed yield (3.87 t ha$^{-1}$), straw yield (06.600 t ha$^{-1}$), biological yield (10.47 t ha$^{-1}$) and harvest index (36.90%) were found from control treatment $D_0$ (0 g duckweeds m$^{-2}$).

Consideration of nitrogen effect on growth parameters of rice, the maximum plant height (23.06, 60.69 and 97.28 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment $N_3$ (180 kg N ha$^{-1}$) whereas the minimum plant height (20.21, 54.68 and 89.14 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment $N_1$ (45 kg N ha$^{-1}$). But the highest number of tillers hill$^{-1}$ (7.88, 13.60 and 14.89 at 30, 60 DAT and at harvest, respectively) and dry weight hill$^{-1}$ (13.95, 43.64 and 41.69 g at 30, 60 DAT and at harvest, respectively) were found from $N_2$ (90 kg N ha$^{-1}$) whereas lowest number of tillers hill$^{-1}$ (7.39, 10.66 and 11.85 at 30, 60 DAT and at harvest, respectively) and dry weight hill$^{-1}$ (10.77, 35.92 and 33.43 g at 30, 60 DAT and at harvest, respectively) were found from $N_3$ (180 kg N ha$^{-1}$).

Regarding yield and yield contributing parameters affected by nitrogen treatments, the lowest number of non-effective tillers hill$^{-1}$ (2.26) and number of unfilled grains panicle$^{-1}$ (13.08) were found from the treatment $N_2$ (90 kg N ha$^{-1}$) whereas the highest number of non-effective tillers hill$^{-1}$ (3.45) and number of unfilled grains panicle$^{-1}$ (20.51) were found from the treatment $N_3$ (180 kg N ha$^{-1}$). Similarly, the highest number of effective tillers hill$^{-1}$ (11.67), number of grains panicle$^{-1}$ (169.70), number of filled grains panicle$^{-1}$ (156.60), panicle length (23.29 cm), 1000 grain weight (23.82 g), seed yield (6.08 t ha$^{-1}$), straw yield (7.77 t ha$^{-1}$), biological yield (13.84 t ha$^{-1}$) and harvest index (43.52%) were found from $N_2$ (90 kg N ha$^{-1}$) whereas the lowest number of effective tillers hill$^{-1}$ (8.97), number of grains panicle$^{-1}$ (149.80), number of filled grains panicle$^{-1}$ (129.30), panicle length (20.88 cm), 1000 grain weight (21.40 g), seed yield (4.39 t ha$^{-1}$), straw yield (6.57 t ha$^{-1}$), biological yield (11.92 t ha$^{-1}$) and harvest index (39.80%) were found from $N_3$ (180 kg N ha$^{-1}$).

In case of combined effect of duckweed and nitrogen on growth parameters of rice, the tallest plant (24.43, 63.99 and 100.90 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of $D_2N_3$ whereas the shortest plant (21.77, 55.59 and 92.73 cm at 30, 60 DAT and at harvest, respectively) was found from the treatment combination of $D_0N_1$. But the highest number of tillers hill$^{-1}$ (11.43, 16.17 and 16.40 at 30, 60 DAT and at harvest, respectively) and dry weight hill$^{-1}$ (17.41, 51.10, 48.97 g at 30, 60 DAT and at harvest, respectively) were found from the treatment combination of $D_2N_2$ whereas the lowest number of tillers hill$^{-1}$ (5.90, 9.25 and 9.80 at 30, 60 DAT and at harvest, respectively) and dry weight hill$^{-1}$ (7.27, 27.63 and25.14 g at 30, 60 DAT and at harvest, respectively) were found from the treatment combination of $D_0N_3$.

In terms of yield and yield contributing parameters affected by duckweed and nitrogen treatment combination, the lowest number of non-effective tillers hill$^{-1}$ (1.40) and number of unfilled grains panicle$^{-1}$ (5.62) were found from $D_2N_2$ whereas the highest number of non-effective tillers hill$^{-1}$ (4.80) and number of unfilled grains panicle$^{-1}$ (28.29) were found from the treatment combination of $D_0N_3$. Again, the highest number of effective tillers hill$^{-1}$ (14.73), number of grains panicle$^{-1}$ (189.50), number of filled grains panicle$^{-1}$ (183.90), panicle length (25.83 cm), 1000 grain weight (25.13 g), seed yield (7.24 t ha$^{-1}$), straw yield (8.47 t ha$^{-1}$), biological yield (15.71 t ha$^{-1}$) and harvest index (46.09%) were found from the treatment combination of $D_2N_2$. Conversely, the lowest number of effective tillers hill$^{-1}$ (6.40), number of grains panicle$^{-1}$ (121.50), number of filled grains panicle$^{-1}$ (93.18), panicle length (17.17 cm), 1000 grain weight (19.34 g), seed yield (3.40 t ha$^{-1}$), straw yield (6.10 t ha$^{-1}$), biological yield (9.51 t ha$^{-1}$) and harvest index (35.84%) were found from the treatment combination of $D_0N_3$.

On the basis of the study, it might be concluded that

1. $D_2$ (400 g duckweeds m$^{-2}$) application showed the superiority over other treatments to produce higher grain yield of rice.
2. $N_2$ (90 kg N ha$^{-1}$) nitrogen application showed best rice yield over other nitrogen treatments.
3. Interaction treatment of $D_2$ (400 g duckweeds m$^{-2}$) and $N_2$ (90 kg N ha$^{-1}$) performed the best.

This is a single year and single location trial also Randomized Complete Block Design. Further design of this relevant research will be Split plot design. More over dissolve nitrogen in each plot will be measured for precise result. So more research is needed in different agro–ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.

# References

## REFERENCES


Adhikari, J. (2018). Effect of nitrogen fertilizer and weed management on the yield of transplant aman rice. *J. Bangladesh Agril. Univ*., **16**(1): 12–16.

Alaerts, G. J., Mahbubar, M. D. R. and Kelderman. (1996). Performance Analysis of a Full-Scale Duckweed-Covered Lagoon *Wat. Res*. **30**(4): 843-52.

Al-Nozaily, F., Alaerts, G. and Veenstra, S. (2000). Performance of Duckweed-Covered Lagoons-II. Nitrogen and Phosphorous Balance and Plant Productivity. *Wat. Res*. **34**(10):2734-41.

Adhunik Dhaner Chash. (2017). Bangladesh Rice Research Institute (BRRI). . $18^{th}$ Edition, 8-10.

BADC, Bangladesh Agricultural Development Corporation (2016). Minor irrigation survey report 2007–08. Ministry of Agriculture, Dhaka, Bangladesh.

Bali, A.S., Siddique, M., Ganai, B.A., Khan, H.V. and Singh, K.N. (1995). Response of rice (Oryza sativa) genotypes to nitrogen levels under transplanted conditions in Kashmir valley. *Indian J. Agron*. **40**(1): 35-37.

BBS (Bangladesh Bureau of Statistics). (2016). Statistical Year Book of Bangladesh. Stat. Div. Min. Planning. Dhaka; 2016.

BBS (Bangladesh Bureau of Statistics). (2018). Statistical Year Book of Bangladesh. Stat. Div. Min. Planning. Dhaka.

Bergman, B. A., Cheng, J., Classen, J. and Stomp, A. M. (2000). In vitro selection of Duckweed Geographic Isolates for Potential Use in Swine Lagoon Effluent Renovation. *Bioresource Technol*. **73**:13-20.

Bonomo, L., Pastorelli, G. and Zambon, N. (1997). Advantages and Limitations of Duckweed-Based Wastewater Treatment Systems. *Wat. Sci. Technol.* **35**(5):239-46.

Chamely, S.G. and Islam, N. (2015). Effect of variety and nitrogen rate on the yield performance of boro rice. *Progress. Agric*. **26** (1): 6-14.

Chaturvedi, I. (2018). Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (*Oryza sativa*). *J. Central European Agric*. **6** (4): 611-618.

Chen, X., Cui, Z., Fan, M., Yan, X., An, N., Zhang, W. and Zhang, F., (2014). Producing more grain with lower environmental costs. *Nature*. **514**: 486-489.

Cheng, J., Bergmann, B.A., Classen, J.J., Stomp, A.M., Howard, J.W., (2002). Nutrient recovery from swine lagoon water by Spirodela punctata. Bioresour. *Technol*. **81**:81-85.

Culley, D. D. and Epps, E. A., (1973). Use of Duckweeds for waste Treatment and Animal Feed *J. Water Pol. Cont. Fed.* **45**:337-47.

Daniel, K.V. and Wahab, K. (1994). Levels and time of nitrogen in semi dry rice. *Madras Agric. J.* **81**(6): 357-358.

De-Bertoldi, M., Vallini, G. and Pera, A. (1983). The Biology of Composting: a Review. *Waste Manag. Res.,* **1:** 157-176.

Duan-Ying-Hua, Zhang-Ya-Li, Shen-Qi-Rong and Wang-Song-Wei. (2006). Nitrate Effect on Rice Growth and Nitrogen Absorption and Assimilation at Different Growth Stages. Soil Sci. Society of China **16**(6): 707 - 717.

Duong, T. P. and Tiedje, J. M. (1985). Nitrogen Fixation by Naturally Occurring Duckweed-Cyanobacterial Associations Can. *J. Microbiol*. **31**:327-30.

Forni, C., Tommasi, F., (2016). Duckweed: a tool for ecotoxicology and a candidate for phytoremediation. *Curr. Biotechnol*. **5**: 2-10.

Gewaily, E.E. and Adel, M.G. (2018). Effects of nitrogen levels on growth, yield and nitrogen use efficiency of some newly released Egyptian rice genotypes. Open Agriculture. **3**: 310–318.

Goopy, J.P. and Murray, P. J. (2003). A Review on the Role of Duckweed in Nutrient Reclamation and as a Source of Animal Feed. *Asian-Aust. J. Anim. Sci*. **16**(2): 297-305.

Hillman, W. S. and Culley, D. D. (1978). The Uses of Duckweed Amer. Scien. **66**: 442-51.

Hui-Zhe, C., De-Feng. Z., Xian-Qing, L., Yu-Ping, Z. and Wei-Xing, Z. (2007). Effect of nitrogen application for spikelet promotion on growth and photosynthetic rate of canopy leaves in super hybrid rice. *J. Hunan Agril. Uni*. **33**(5): 617-621.

Hussain, T., Jilani, G. and Ghaffar, A. (1989). Influence of rate and time of nitrogen application on growth and yield of rice in Pakistan. *Int. Rice. Res. Newsl*. **14**(6): 18.

Indira-Chaturvedi (2005). Effect of nitrogen fertilizers on growth, yield and quality of hybrid rice (*Oryza sativa*). *J. Central European Agric*. **6**(4): 611-618.

Karim, M. (2019). Effect of Different Doses of Urea on the Yield of Boro Rice Varieties in Haor Areas of Bangladesh. *Asian Pl. Res. J.* **3**(2): 1-9.

Karpiscak, M. M., Gerba, C. P. Watt, P. M. Foster, K. E. and Falabi, J. A. (1996). Multi-Species Systems for Wastewater Quality Improvements and Habitat Enhancement. *Wat. Sci. Technol*. **33**(10-11):231-36.

Kenzo-wakimoto. (2004). Utilization Advantages of Controlled Release Nitrogen Fertilizer on Paddy Rice Cultivation. *JARQ***. 38** (1):15-20.

Khatun, A., Bhuiya, M.S.U. and Saleque, M.A. (2014). Response of Nitrogen on Yield and Seed Quality of Boro Rice. *Bangladesh Rice J*. **18**(1&2): 24-32.

Korner, S., Lyatuu, G. B. and Vermaat, J. E. (1998). The Influence of L. Gibba on the Degradation of Organic Material in Duckweed-Covered. *Domestic Wastewater Res*. **32** (10):3092-98.

Landolt, E. (1986). The Family of Lemnacae - A Monographic Study vol 1. Part of the series: Biosystematic Investigations in the family of duckweeds (Lemnacae), Vol 2 of 4. Veroffentlichungen Des Geobotanischen (pub.)

Landolt, E. and R. Kandeler eds. (1987). The Family of Lemnacae - A Monographic Study.. Vol 2. Part of the series: Biosystematic Investigations in the family of duckweeds (Lemnacae), vol 3 of 4. Veroffentlichungen Des Geobotanischen (pub.)

Leng, R. A. (1999). Duckweed, a tiny aquatic plant with enormous potential for agriculture and environment FAO. Tran Phu Printing Co.

Li, F., Wang, Z., Dai, J., Li, Q., Wang, X., Xue, C., Liu, H., He, G., ( 2015). Fate of nitrogen from green manure, straw, and fertilizer applied to wheat under different summer fallow management strategies in dry land. *Biol. Fert. Soils.* **51**:769-780.

Li, H., Liang, X., Lian, Y., Xu, L., Chen, Y., (2009). Reduction of ammonia volatilization from urea by a floating duckweed in flooded rice fields. *Soil Sci. Soc. Am. J.* **73**:1890-1895.

Malik. T.H. and Kaleem, M. (2007). Response of hybrid rice to levels and time of nitrogen application. *Environ. Ecol*. **25**(4): 927-928.

Manzoor. Z., Awan, T.H., Safdar, M.E., Ali. R.I., Ashraf. M.M. and Ahmad. M. (2006). Effect of nitrogen levels on yield and yield components of Basmati (2000). *Lahore J. Agril. Res*. **44**(2): 115-120.

Marazi, A.R., Khan, G.M., Singh, K.H., Bali, A.S. (1993). Response of rice (*Oryza sativa*) to different N levels and water regimes in Kashmir Valley. *Indian J. Agric. Sci.* **63**(11): 726- 727.

Masud, M.A.A. (2006). Yield performance and nitrogen use efficiency of five advanced lines of rice in boro season. M.S. Thesis. Dept, of Soil Science, *Bangladesh Agril. Uni.*. Mymensingh.

Mazumder. M. R., Bhuiya, M.S.U. and Hossain. S.M.A. (2005). Effect of nitrogen level and split application of *Sesbania rostrata* as green manure on the performance of transplanted aman rice cv. BRRI dhan31. *Bangladesh J. Agril. Sci.* **31**(2): 183-188.

Meena, S.L., Surendra, S., Shivay, Y.S., Singh, S. (2003). Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay loam soils. *Indian J. Agric. Sci*. **73**(1): 8-11.

Mohedano, R.A., Costa, R.H.R., Tavares, F.A., Belli-Filho, P. (2012). Highnutrient removal rate from swine wastes and protein biomass production by full-scale duckweed ponds. *Bioresour. Technol.* **112**: 98-104.

Sun, H.J., Zhang, H.L., Min, J., Feng, Y.F., Shi, W.M., (2015). Controlled-release fertilizer, floating duckweed, and biochar affect ammonia volatilization and nitrous oxide emission from rice paddy fields irrigated with nitrogen-rich wastewater. *Paddy Wat. Environ*. **14**:105-111.

Oo, N.M.L., Shivay, Y.S. and Kumar, D. (2007). Effect of nitrogen and sulphur fertilization on yield attributes, productivity and nutrient uptake of aromatic rice (*Oryza sativa*). *Indian J. Agril. Sci.* **77**(11): 772-775.

Oran, G., Porath, D. and Wildschut, L. R. (1986). Wastewater Treatment & Renovation by Different Duckweed Species. *J. Envirom. Enginrer*. **112**(2):247-262.

Pariyani, A.K. and Naik. K.R. (2004). Effect of nitrogen level and seedling number on yield attributes and yield of rice hybrids. *J. Soils Crops*. **14**(2): 234-236.

Paromita-Ghosh and Kashyap, A.K. (2003). Effect of rice cultivars on rate of N-mineralization, nitrification and nitrifier population size in an irrigated rice ecosystem. *Appl. Soil Ecol*. **24**: 27- 41.

Poshtmasan, H. K., Pirdashti, H., Nasiri, M. and Bahmanyar. M. A. (2007). Study on the effect of nitrogen fertilizer management on dry matter remobilization of three cultivars of rice *(Oryza sativa* L.). *Pakistan J. Biol. Sci.* **10**(19): 3425- 3429.

Rahman, M.M., Sanker, M.N.H, Aktar. F.M.F and Masud. M.M. (2005). Comparative yield performance of two high yielding rice varieties to different nitrogen levels. *Bangladesh J. Crop Sci*. **16**(1): 73-78.

Rahman. M.H., Ali. M.H.. Ali. M.M. and Khatun, M.M. (2007). Effect of different level of nitrogen on growth and yield of transplant aman rice cv BRRI dhan32. *Int. J. Sustainable Crop Prod*. **2**(1): 28-34.

Roul, P.K. and Sarawgi, S.K. (2005). Effect of integrated nitrogen nutrition techniques on yield, N content uptake and use efficiency of rice *(Oryza sativa* L.). *Indian J. Agron*. **50**(2): 129-131.

Sarkar, S., Singh, S.R. and Singh, R.P. (2003). The effect of organic and inorganic fertilizers on soil physical condition and the productivity of a rice - lentil cropping sequence in India. *J. Agril. Sci,* **140**(4): 419 - 425

Shamima, A., Mian, M.H. Kader, M.A. and Begum, S.A. (2002). Combination of Azolla and Urea Nitrogen for Satisfactory Production of Irrigated Boro Rice (BRRI Dhan29). *Pakistan J. Agron*. **1**(4): 127 - 130.

Sharma, P., and Agarwal, A. (2006). Effect of different levels of nitrogen fertilizer application on yield, yield attributes and chlorophyll in two rice *(Oryza sativa)* varieties. *Vegetos*. **19**(1/2): 101-106.

Singh, G.R.. Parihar, S.S. and Chaure, N.K. (2004). Effect of poultry manure and its combination with nitrogen in rice wheat cropping system. *Indian Agriculturalist*. **45**(3-4): 235-240.

Singh, T., Singh. T.P. and Sharma, S. (2006). Effect of date of transplanting, plant population and nitrogen level on yield and quality of Basmati rice *(Oryza sativa). Crop Res*. **7**(3): 643-646.

Singh. R.D., Sikka, A.K. and Rajan. K. (2008). Effect of irrigation and nitrogen on yield, water use efficiency and nutrient balance in rice *(Oryza sativa*) based cropping system. *Indian J. Agril. Sci.* **78**(1): 21-26.

Skillicorn, P., Spira, W. and Journey, W. (1993). Duckweed Aquaculture-a New Aquatic Farming System for Developing Countries. The World Bank Washington DC.

Sutton, D. L. and Ornes, W. H. (1975). Phosphorus removal from Static Sewage Effluent using Duckweed. *J. Environ. Qual.*

Tari, D.B., Pridashti. H., Nasiri, M., Gazanchian. A. and Hoseini. S.S.(2007). Determination of morphological characteristics affected by different agronomical treatments in rice (IR68 74-3-2). *Asian J. Plant Sci.* **6**(1): 61-65.

Van-der-Steen, P., Brenner, A. and Oron, G. (1998). An Integrated Duckweed and Algae Pond System for Nitrogen Removal and Renovation. *Wat. Sci. Technol*. **38**(1):335-343.

Van-der-Steen, P., Brenner, A. Van, J. and Oron, G. (1999). Post-Treatment of USAB Reactor Effluent in an Integrated Duckweed and Stabilization Pond System. *Wat. Res*. **33**(3): 615-620.

Vanaja, M. and Raju, A.S. (2002). Integrated nutrient management performance in rice crop. *Ann. agric. Res*., **23**(1): 51 - 56.

Vermaat, J. E. and Haniff, M. K. (1998). Performance of Common Duckweed Species (Lemnacae) and the water Ferm Azolla Filiculoides on Different Types of Waste Water. *Wat. Res.* **32**(9):2569-2576.

Wang, C.H.( 2004). Response of rice yield to deep placement of fertilizer and nitrogen top-dressing during panicle initiation stage and its diagnosis of fertilizer application. *Taiwanese J. Agril C'hem. Food Sci*. **12**(5): 383-395.

Wen-Ge, W., Lian-Song, Y., Jue Jian, Z., Gen Sheng, H. Wen Jie. F., Yi Song. B,, Si Hai. Z. and Yu Hai, Z. (2008). Effects of amount of nitrogen applied and planting density on yield and its components of middle-season indica hybrid rice. *J. Anhui Agril. Uni.* **35**(1): 49-55.

Whitehead, A. J., Lo, K. V. and Bulley, N. R. (1987). The Effect of Hydraulic Retention Time and Duckweed Cropping Rate on Nutrient Removal from Dairy Barn Wastewater. In: Aquatic Plants for Water Treatment and Resource Recovery (Ed. K. R. Reddy and W. H. Smith). Magnolia Publishing Inc.

Xiao-Fei, C., Shu-Ju, N., Zhi, W. and Hong Ping, Z. (2008). Effect of nitrogen level on nitrogen metabolism in rice seedling. Zhongguo Shengtai Nongye Xuebao/Chinese *J. Eco. Agric.* **16**(3): 571-575.

Xingkai-Xu, Pascal, B., Cleemput, O.V. and Kazuyuki, I. (2004). Mineral nitrogen in a rhizosphere soil and in standing water during rice *(Oryza sativa* L.) growth: effect of hydroquinone and dicyandiamide. *Agric. Ecos. Environ*. **109**: 107-117.

Yao, Y. and Zhang, M. (2017). Duckweed (*Spirodela polyrhiza*) as green manure for increasing yield and reducing nitrogen loss in rice production. *Field Crops Res*. **214**: 273–282.

Zhang, X., Davidson, E.A., Mauzerall, D.L., Searchinger, T.D., Dumas, P., Shen, Y., (2015). Managing nitrogen for sustainable development. *Nature*. **528**: 51-59.

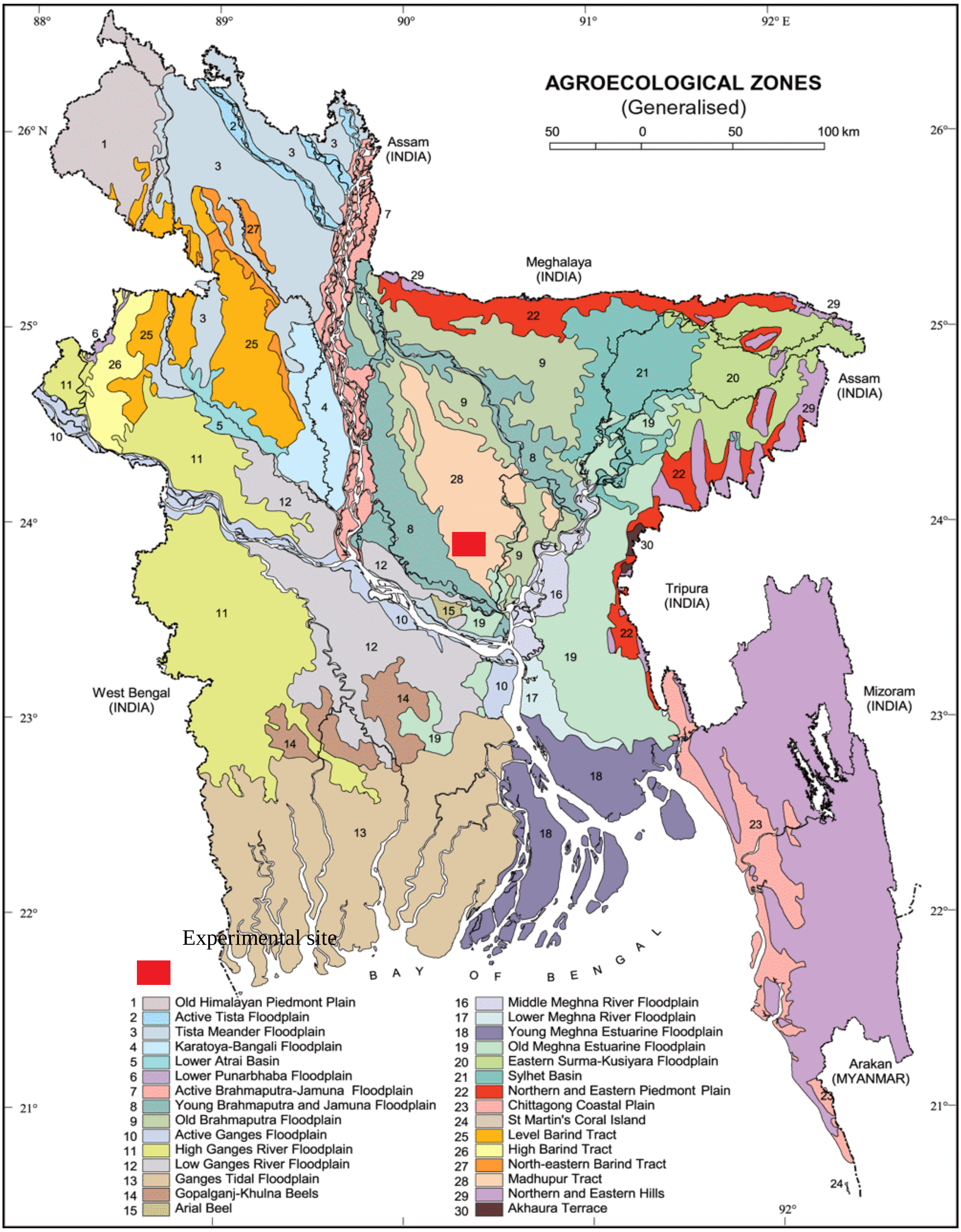
Zimmo, O.R., Van-der-Steen, N.P., Gijzen, H.J., (2003). Comparison of ammonia volatilisation rates in algae and duckweed-based waste stabilisation ponds treating domestic wastewater. *Water Res*. **37**: 4587-4594.

Zirschky, J and Reed, S. C. (1988). The Use of Duckweed for Wastewater Treatment. *J. Water Poll. Cont. Fed* **60**(7):1253-57.

# Appendices

# APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2018 to April 2019.

| Year | Month | Air temperature (°C) | | | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|---|
| | | *Max* | *Min* | *Mean* | | |
| 2018 | November | 28.60 | 8.52 | 18.56 | 56.75 | 14.40 |
| 2018 | December | 25.50 | 6.70 | 16.10 | 54.80 | 0.0 |
| 2019 | January | 23.80 | 11.70 | 17.75 | 46.20 | 0.0 |
| 2019 | February | 22.75 | 14.26 | 18.51 | 37.90 | 0.0 |
| 2019 | March | 35.20 | 21.00 | 28.10 | 52.44 | 20.4 |
| 2019 | April | 34.70 | 24.60 | 29.65 | 65.40 | 165.0 |

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

| **Morphological features** | **Characteristics** |
|---|---|
| Location | Agronomy Farm, SAU, Dhaka |
| *AEZ* | Modhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |
| Flood level | Above flood level |
| Drainage | Well drained |
| Cropping pattern | Not Applicable |

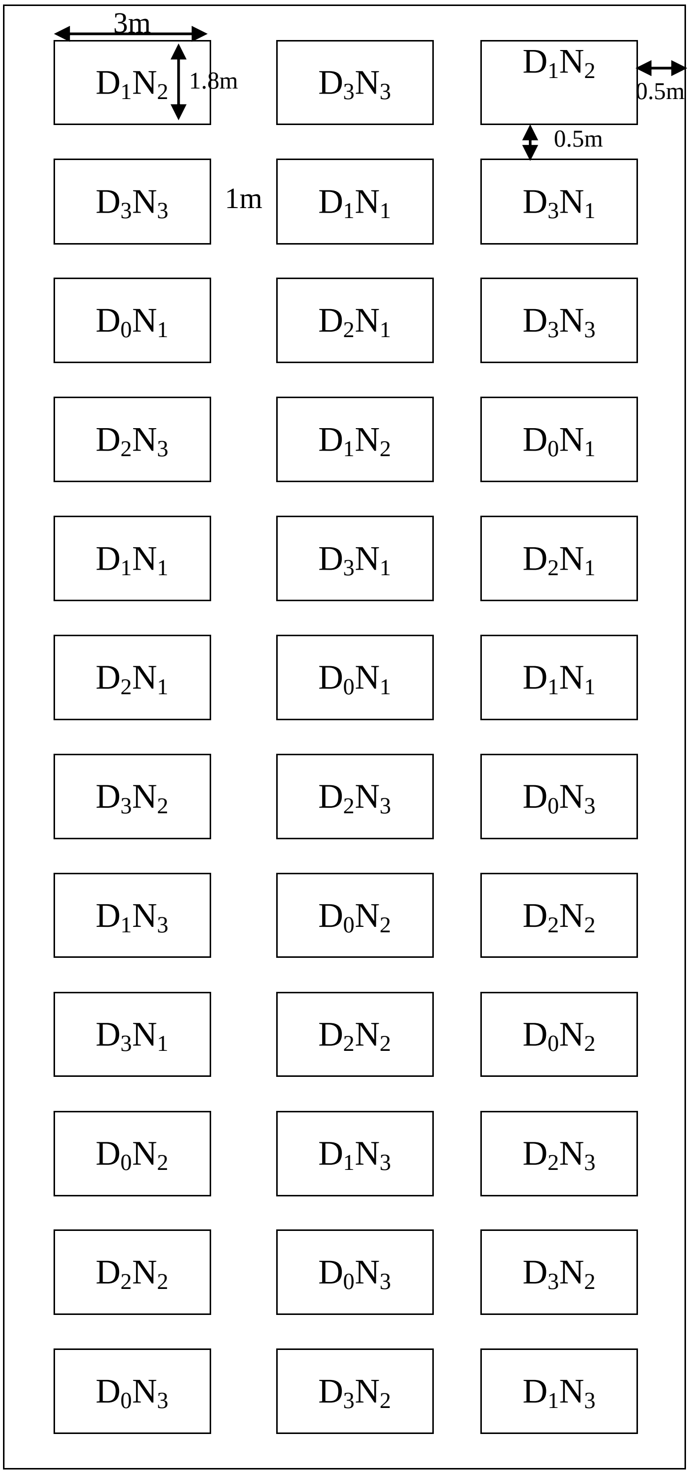
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

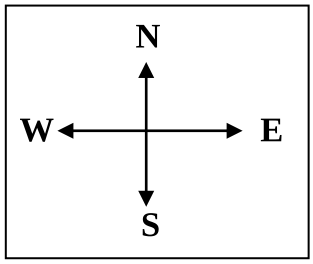
| **Characteristics** | **Value** |
|---|---|
| Partical size analysis % Sand | 27 |
| %Silt | 43 |
| % Clay | 30 |
| Textural class | Silty Clay Loam (ISSS) |
| pH | 5.6 |
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.78 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20 |
| Exchangeable K ( me/100 g soil) | 0.1 |
| Available S (ppm) | 45 |

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field and design




**Legend**




**Treatments**

**Factor A: Duckweed at four levels**

1. $D_0$ = Control (0 g duckweeds $m^{-2}$)
2. $D_1$ = 200 g duckweeds $m^{-2}$
3. $D_2$ = 400 g duckweeds $m^{-2}$
4. $D_3$ = 600 g duckweeds $m^{-2}$

**Factor B: Nitrogen at three levels**

1. $N_1$ = 45 kg N $ha^{-1}$
2. $N_2$ = 90 kg N $ha^{-1}$
3. $N_3$ = 180 kg N $ha^{-1}$

Appendix V. Plant height of rice as influenced by duckweed and nitrogen and also their combination

| Sources of variation | Degrees of freedom | Plant height (cm) | | |
|---|---|---|---|---|
| | | 30 DAT | 60 DAT | At harvest |
| Replication | 2 | 1.425 | 4.855 | 71.132 |
| Factor A | 3 | 14.04* | 128.22* | 129.49* |
| Factor B | 2 | 24.43* | 108.12* | 198.54* |
| AB | 6 | 0.494** | 1.624** | 3.003** |
| Error | 22 | 6.058 | 41.471 | 87.425 |

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Number of tillers hill$^{-1}$ of rice as influenced by duckweed and nitrogen and also their combination

| Sources of variation | Degrees of freedom | Number of tillers hill$^{-1}$ | | |
|---|---|---|---|---|
| | | 30 DAT | 60 DAT | At harvest |
| Replication | 2 | 1.085 | 0.397 | 0.783 |
| Factor A | 3 | 15.13* | 32.46* | 29.07* |
| Factor B | 2 | NS | 26.14* | 28.04* |
| AB | 6 | 8.717 | 0.908** | 0.318** |
| Error | 22 | 0.894 | 2.058 | 2.341 |

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Dry weight hill$^{-1}$ of rice as influenced by duckweed and nitrogen and also their combination

| Sources of variation | Degrees of freedom | Dry weight hill$^{-1}$ | | |
|---|---|---|---|---|
| | | 30 DAT | 60 DAT | At harvest |
| Replication | 2 | 0.156 | 0.477 | 27.924 |
| Factor A | 3 | 93.72* | 539.99* | 535.06* |
| Factor B | 2 | 31.11* | 179.16* | 206.46* |
| AB | 6 | 0.318** | 3.011** | 3.548** |
| Error | 22 | 1.715 | 20.579 | 12.543 |

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Yield contributing parameters of rice as influenced by duckweed and nitrogen and also their combination

| Sources of variation | Degrees of freedom | Yield contributing parameters | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | No. of non-effective tillers hill$^{-1}$ | No. of effective tillers hill$^{-1}$ | No. of grains panicle$^{-1}$ | No. of filled grains panicle$^{-1}$ | No. of unfilled grains panicle$^{-1}$ | Panicle length (cm) | 1000 grain weight (g) |
| Replication | 2 | 0.203 | 1.294 | 166.848 | 179.12 | 3.119 | 1.363 | 3.595 |
| Factor A | 3 | 10.30* | 63.56* | 3919.4* | 6188.8* | 286.28* | 56.88* | 19.68* |
| Factor B | 2 | 4.315* | 22.13* | 1200.3* | 2250.4* | 165.99* | 17.50** | 17.85* |
| AB | 6 | 0.182** | 0.547** | 7.419** | 22.424* | 5.523* | 0.581** | 0.397** |
| Error | 22 | 0.103 | 1.149 | 298.334 | 246.14 | 3.112 | 4.500 | 4.744 |

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Yield contributing parameters of rice as influenced by duckweed and nitrogen and also their combination

| Sources of variation | Degrees of freedom | Yield contributing parameters | | | |
|---|---|---|---|---|---|
| | | Seed yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
| Replication | 2 | 0.135 | 0.424 | 2.808 | 12.49 |
| Factor A | 3 | 10.83* | 2.125** | 21.69* | 125.8* |
| Factor B | 2 | 8.710* | 4.426* | 25.84* | 42.05* |
| AB | 6 | 0.191** | 0.043** | 0.290** | 2.658** |
| Error | 22 | 0.389 | 0.498 | 1.771 | 20.802 |

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Plate 1. Collected sample Duckweed

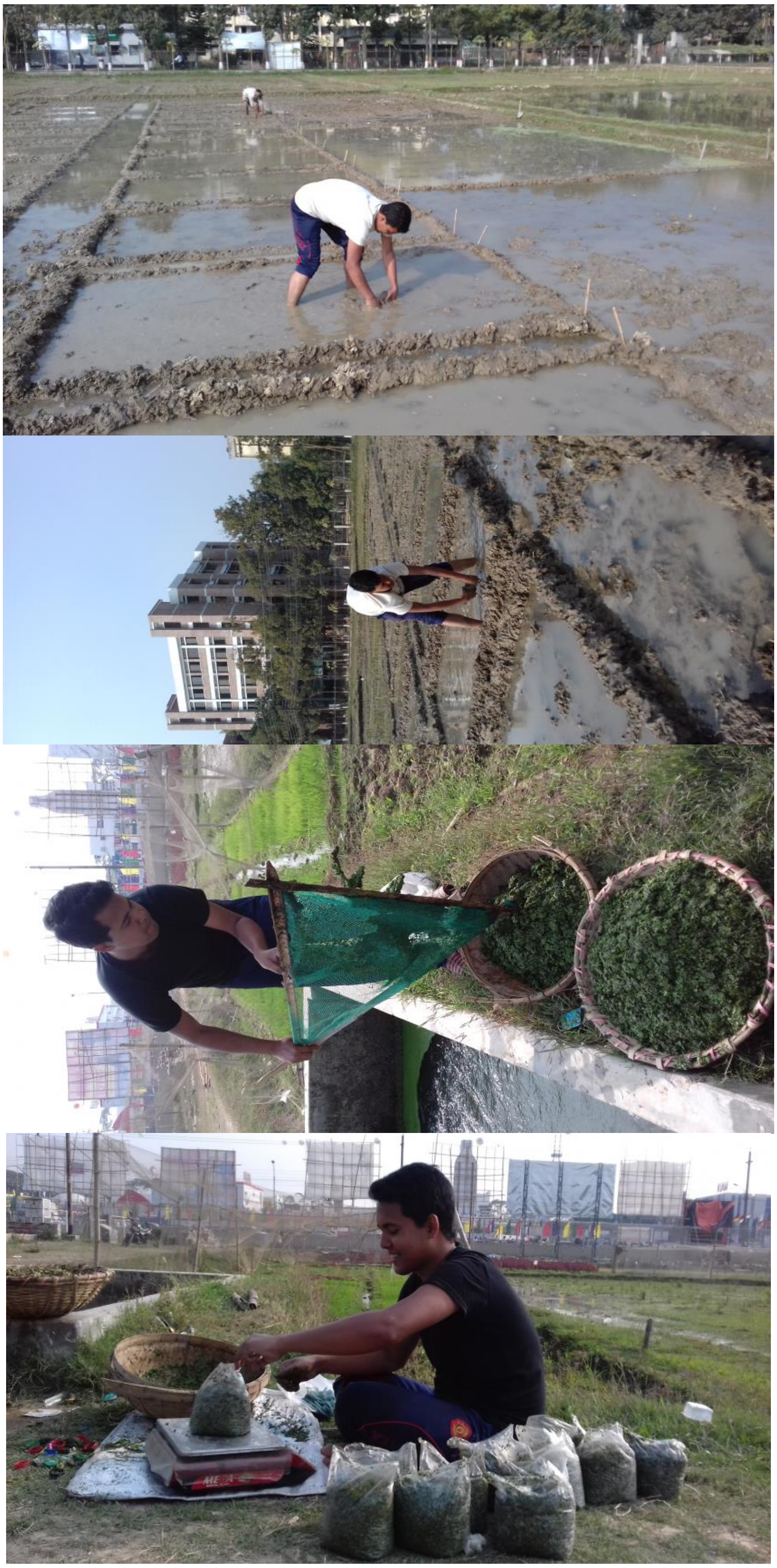


Plate 2. Land preparation and preparation of Duckweed doses

Plate 3. Duckweed application in Transplanted rice plot

Plate 4. Field condition after duckweed application at 10 DAT

Plate.5 Plant growth sample using duckweed as well as control plot

Plate 6. Reproductive stage of rice using duckweed