GROWTH AND YIELD OF BORO RICE AS AFFECTED BY APPLICATION METHOD AND SOURCE OF NITROGEN FERTILIZER

AFIFA OWAHIDA

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

AFIFA OWAHIDA

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Approved by:

Prof. Dr. Parimal Kanti Biswas **Supervisor**	**(Prof. H. M. M. Tariq Hossain)** **Co-Supervisor**

(Prof. Dr. Tuhin Suvra Roy)
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, "**GROWTH AND YIELD OF BORO RICE AS AFFECTED BY APPLICATION METHOD AND SOURCE OF NITROGEN FERTILIZE"** 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,** embodies the results of a piece of bona-fide research work carried out by **Afifa Owahida**, Registration No. **14-05824** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

Prof. Dr. Parimal Kanti Biswas

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

AND

ALL THE FARMERS

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ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2019 to May, 2020 to study the influence of *Azolla pinnata* as supplementary nitrogen source of boro rice. The trial comprised of two methods of fertilizer application viz. Basal (M_1) and top dressing (M_2) and five fertilizer sources viz. fresh *Azolla pinnata* (S_1), dry *Azolla pinnata* (S_2), 100% Urea (S_3), 50% *Azolla pinnata* + 50% Urea (S_4), control (no urea and no *Azolla pinnata*) (S_5). The experiment was laid out in split-plot design with three replications by assigning in fertilizer application methods in the main plot and fertilizer sources in the sub plot. Results revealed that different fertilizer application methods did not significantly influenced most of the growth and yield parameters except plant height at 25 and 45 DAT, panicle length, filled grains, total grain, dry straw weight hill^{-1}, fresh and dry grain yield, grain-straw ratio, biological yield, pH and total N content in post-harvest soil. The maximum dry grain yield (6.46 t ha^{-1}) was recorded from top dressing and the minimum dry grain yield (5.76 t ha^{-1}) was recorded from basal application. Significant variation was recorded for fertilizer sources in case of most of the growth and yield parameters except days to maturity, number of ineffective tillers hill^{-1} and available P content in post-harvest soil. The maximum filled grains and total grains panicle^{-1} (180.43 and 166.16, respectively) was recorded from 100 % urea application which was statistically similar with 50% urea + 50% *Azolla pinnata* application. The minimum filled grains and total grains panicle^{-1} (136.07 and 162.17, respectively) was recorded from 100 % urea application. The maximum weight of 1000–grain (23.56 g) was obtained from 100 % urea application while the minimum weight of 1000-grains (20.17 g) was obtained from 100% dry *Azolla pinnata* application. The maximum dry grain yield (8.15 t ha^{-1}) was recorded from 100% urea application and the minimum dry grain yield (4.62 t ha^{-1}) was recorded from fresh *Azolla pinnata* application. The interaction of fertilizer application methods and fertilizer sources had no significant effect on days to flowering and maturity, effect on number of ineffective tillers hill^{-1}, P and K in post-harvest soil that showed the positive indication of replacing chemical fertilizer by *Azolla pinnata* application.

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LIST OF ACRONYMS

AEZ	Agro ecological
BNF	Biological Nitrogen Fixation
cm	Centimeter
CV	Coefficient of Variation
DAT	Days After Transplanting
DO	Dis-solved Oxygen
et al.	And others (*et alibi*)
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
HI	Harvest Index
kg	Kilogram
LAI	Leaf Area Index
LSD	Least Significant Difference
m^2	Square Meter
MP	Muriate of potash
meq %	milliequivalent
N	Nitrogen
No.	Number
NPK	Nitrogen phosphorus potassium
NS	Non Significant
%	Percent
pH	Hydrogen ion concentration
$panicle^{-1}$	per panicle
PU	Prilled Urea
t ha^{-1}	Ton (s) per hectare
TSP	Triple super phosphate
USG	Urea Super Granule

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Rice is the most important human food, eaten by more than half of the world's population every day. In Asia, where 90% of rice is consumed, ensuring there is enough affordable rice for everyone, or rice security, is equivalent to food security (IRRI, 2019). It is the grain with the second-highest worldwide production, after corn. Bangladesh is the third highest rice (*Oryza sativa* L.) producing country in the world (FAO, 2019). Bangladesh will have to produce 36 million metric tons of rice of which boro rice production may increase 4.5 lakh metric tons from the target production of 204.36 lakh metric tons this year (USDA, 2019).

Almost all soils of Bangladesh are very deficient in nitrogen. The situation has arisen mainly due to low level of organic matter caused by rapid decomposition due to warm climate, continuous intensive cropping, and rare addition of organic manure (Portch and Islam, 1984). Soil organic matter is an important factor to be considered in improving crop productivity. Because of the tropical climate, organic matter decomposition in Bangladesh soil is high. Moreover, the rural population has little chance to add organic residues to soil through farmyard manure, composts and organic residues as the major portion of these materials are being used as fuel. About 70% of the net cultivable area in high and medium-high lands of Bangladesh has a soil organic matter content of less than 2%. So, the proper soil organic matter management needs due attention in view of the low organic matter status of soil (Zaman *et al*., 2004).

Azolla pinnata is a free-floating freshwater fern of the tropics and sub-tropics having unique capacity to fix atmospheric nitrogen through its endophyte *Anabaena-Azolla*. *Azolla pinnata* is natural inhabitant of fresh waters of canals, ponds, bills, rivers, and water-logged rice field of Bangladesh. *Azolla pinnata* plants form dense mats on water bodies throughout the warm, temperate and tropical regions of the world. Each leaf lobe has a cavity containing the blue-green nitrogen-fixing alga *Anabaena-Azolla*. *Azolla pinata* has long been used as both a green manure for rice and as a fodder for poultry and livestock in China and Vietnam. Production potential as a source of fertilizer nitrogen, the *Azolla-Anabaena* symbiosis can fix 100-170kg N/ha/year. Under field conditions selected species can fix about 1.2kg N/day and in excess of 40kg N in 35 days. The *Azolla-Anabaena* symbiosis has already become a potential bio-fertilizer for rice production due to its high N_2-fixing ability, rapid growth and easily decomposable characteristics (Khan, 1988 and Mian, 2000). Therefore, *Azolla pinnata* has a bright future as a source of both nitrogen and organic matter for lowland rice and the soils that are irrigated for rice cultivation in Bangladesh (Mian, 1997 and Mian, 2000). Due to this symbiotic partnership, *Azolla pinnata* multiply very fast and incorporating high nitrogen, thus making it as desirable organic fertilizer either as fresh, dried or composted (Lumpkin and Plucknett, 1980; Lumpkin, 1987; Khan, 1983; Wagner, 1997; Kannaiyan, 2002).

In Asia, *Azolla* pinnata is the most used as green manure for rice crop, due to its high growth rate, nitrogen-fixing capacity and ability to scavenge nutrients from soil and water. The fern doubles its biomass in 2–5 days under ideal environmental conditions (Watanabe *et al.*, 1989). *Azolla pinnata* can supply more than half of the required nitrogen to the rice crop and besides providing nitrogen it is beneficial in wetland rice fields for bringing number of changes which include preventing rise in pH, reducing water temperature, curbing NH_3 volatilization, suppressing weeds and mosquito proliferation (Pabby *et al.*, 2004). *Azolla pinnata* has been used for several decades as green manure in rice fields, suitable and effective bio-fertilizer for maintaining soil productivity and rice yield (Sheeno and Sahu, 2006).

Additionally, bio-fertilizers are low price, renewable sources of plant nutrients which supplement chemical fertilizers. Use of bio-fertilizer is of great importance because they are components of integrated nutrient management, and they are also cost effective and renewable source of energy for plants and to help in reducing the use of chemical fertilizers for sustainable agriculture. Biological nitrogen fixation not only improves plant growth but also helps to minimize the use of chemical nitrogen fertilizers, so that the cost of production and environmental risks are reduced (Rana and Kapoor, 2013).

The yield of rice plants is strongly influenced by N fertilizer. Nitrogen in rice plants has roles in vegetative growth, tiller formation and increasing yield through rice protein formation. *Azolla pinnata* can be added to the rice field as organic fertilizer in form of fresh biomass or composted. During decomposition, organic nitrogen is mineralized rapidly during the first two weeks and then at a more gradual rate (Watanabe, 1984). Nitrogen is released mainly in the form of ammonium. Ammonium-nitrogen released was found to stabilize at about 1 mg ammonium-N g^{-1} of dry *Azolla pinnata*, which was 26-28% of the total nitrogen content of *Azolla pinnata* (Tung and Shen, 1985).

Because of A*zolla pinnata* decomposes rapidly, its nitrogen, phosphorus and other nutrients are rapidly released into the water and made available for uptake by rice during grain development. *Azolla pinnata* has a greater ability than rice to accumulate potassium in its tissues in low-potassium environments, providing rice with potassium after *Azolla pinnata*'s decomposition. In contrast with chemical nitrogenous fertilizers, *Azolla pinnata* has various positive long-term effects, including the improvement of soil fertility by increasing total nitrogen, organic carbon, plus phosphorus, potassium, other nutrients and organic matter. If chemical nitrogenous fertilizers are applied, the presence of an *Azolla pinnata* mat reduces ammonia volatilization that would normally occur. When grown in a rice field, *Azolla pinnata* reduces the ammonia volatilization that occurs following the application of inorganic nitrogen fertilizers by 20% to 50%. This is due to the fact that the *Azolla pinnata* cover reduces light penetration into the floodwater, thus hindering the rise of pH which normally stimulates ammonia volatilization in an *Azolla pinnata* free rice field (Watanabe and Liu, 1992).

Chemical fertilizers and *Azolla pinnata* in crop production can play a vital role in improving soil environment and sustainable agriculture. In Bangladesh, few studies have been conducted on the effect of *Azolla pinnata* and urea on rice. Therefore, the present study was undertaken to examine the feasibility of using *Azolla pinnata* as nutritional alternative for rice crop. *Azolla pinnata* bio-fertilizer may be a promising approach to achieve better N use efficiency (NUE) in rice fields due to its great potential for biological N fixation (BNF). This experiment was conducted with the following objectives:

- To find out the effect of *Azolla pinnata* on growth and yield of boro rice.
- To study the possibility of reducing chemical fertilizer use in boro rice through *Azolla pinnata*
- To assess yield of boro rice by different application methods and source of fertilizer.

Chapter 2

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Rice is the major food crop for the people of Bangladesh. Many research works have been carried out extensively in many countries including Bangladesh and other countries for improving fertilizer management and increase production of rice. Nitrogen fertilizer plays an important role on growth and yield of boro rice. *Azolla pinnata* is a good source of nitrogen for rice production. The influence of *Azolla pinnata* and urea on rice (*Oryza sativa*) has been reviewed below in this chapter.

2.1 Effect of fertilizer application methods

The field experiment was conducted by Joseph *et al.* (2017) at the University of Ghana's Soil and Irrigation Research Centre-Kpong during 2014 and 2015 cropping seasons to evaluate the influence of N fertilizer rates and timing of application on rice yield. A 3×2 factorial experiment was laid out in a randomized complete block design and replicated three times. Fertilizer rate and time of nitrogen application were the factors involved. The levels of fertilizer rate were: 0, 75, 90 and 120 kg N ha^{-1}, while time of the nitrogen application included; conventional practice (2 times, basal and top dress) and multi-split (weekly application till booting stage). High N fertilization rates increased growth and yield components, grain yield. However, better grain yield was obtained when N was multi-split for topdressing (eg. 90 kg N; 5.0 t ha^{-1}) than the conventional method (90 kg N; 4.6 t ha^{-1}). The study revealed that, the generally followed blanket nitrogen application rate and two-split traditional practice, was not adequate to obtain higher yields. Rice response to fertilizer was better at 120 kg N ha^{-1} than the other lower N rates. However, 120 kg N ha^{-1} applied at seven splits performed better (5.4 t ha^{-1}) than 120 kg ha^{-1} applied at the conventional (5.0 t ha^{-1}) application of basal and top-dress at panicle initiation stage.

Kamruzzaman *et al.* (2014) carried out a field experiment to study the effect of different levels and split application of nitrogen (N) fertilizer on yield and yield attributes of transplanted boro rice. The experiment was laid out in a split-plot design with four split levels of N : T_1 [N at basal + N at 25 days after transplanting (DAT) + N at 50 DAT] T_2 [½ N at 25 DAT + ½ N at 50 DAT], T_3 [N at 15 DAT + N at 30 DAT + N at 45 DAT], T_4 [¼ at N 15 DAT + ½ N at 30 DAT + ¼ N at 45 DAT] in the main plot and four levels of N in the sub-plot: control (0 kg N ha^{-1}), N_1 (40 kg N ha^{-1}), N_2 (80 kg N ha^{-1}), and N_3 (120 kg N ha^{-1}). Data collected were total tillers $hill^{-1}$, effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, grain yield (t ha^{-1}), biological yield (t ha^{-1}) as well as some other morphological characters. Among the N splits, treatment T_3 produced highest total tillers $hill^{-1}$ (16.45), effective tillers $hill^{-1}$ (12.73), panicle length (24.97 cm), grains $panicle^{-1}$ (127.92), grain yield (5.53 t ha^{-1}), biological yield (12.87 t ha^{-1}), and harvest index (42.79%). Among the N levels treatment N_3

produced highest total tillers hill^{-1} (16.50), effective tillers hill^{-1} (12.69), grains/panicle (130.36), grain yield (5.40 t ha^{-1}), and biological yield (12.66 t ha^{-1}). Conversely, the treatment combination of N_3 and T_3 produced the highest value for most of the traits evaluated, namely total tillers hill^{-1} (18.03), effective tillers hill^{-1} (14.97), grains/panicle (137.48), grain yield (5.77 t ha^{-1}), biological yield (13.08 t ha^{-1}), and harvest index (44.10%). Hence, the treatment combination of N_3 and T_3 is suggested to bring higher economic benefit from transplanted Boro rice in the study area.

Ahmed *et al*. (2018) conducted an experiment with a view to find out the performance of Boro rice in response to different application methods of urea fertilizer during 2012/2013 and2013/2014 growing seasons. The experiment was arranged in split-plot design with three replications having two genotypes viz. (i) V_1 = GSR I Sal Y 1242 and (ii) V_2 = BRRI dhan28 placed in main plot and four urea application methods viz. (i) T_1 = 220 kg ha^{-1} PU at three equal splits (ii) T_2= 2% foliar spray @ 80 kg ha^{-1} (iii) T_3= 75 kg N ha^{-1} USG (2.7 g) and (iv) T_4= LCC based urea @ 67.5 kg ha^{-1} placed in sub plot. Results showed that genotypes had non-significant influence for most of the growth parameters and yield components, whereas urea fertilizer application methods had significant effect on all growth parameters, yield and yield attributes except plant height at 40 DAT and 50% flowering stage. With different methods of urea application, T_4 achieved significantly the highest value of all growth parameters, yield and yield components with total N content hill^{-1} (3.859%) and harvest index (50.70%) except filled grain panicle^{-1} (82.98) at harvest. Among the interactive treatments, the highest number of tillers m^{-2} (351.66), dry weight hill^{-1} (88.13 g), panicle number m^{-2} (340.83), panicle length (23.33 cm) and grain yield (7.32 t ha^{-1}) was obtained at V_1T_4. So, in aspect of yield and other parameters, V_1T_4 was the best treatment under the present study.

Nath *et al.* (2018) conducted an experiment to observe the effect of fertilizer and agronomic management on growth, yield and yield contributes of boro rice. The experimental site was located under the Agro-ecological Region Sylhet Basin (AEZ-21) having moderately acidic soils. The experiment was designed with seven treatments including T_1: Farmers’ practiced based fertilizer (180-42-42 kg ha$^{–1}$ of urea-TSP-MOP), T_2: BARC recommended dose based fertilizer (300-112-127-75-11 kg ha$^{–1}$ of urea-TSP-MoP-CaSO4-ZnSO4), T_3: T_2+Wet Irrigation, T_4: T_2+Wet and dry irrigation, T_5: T_2+Proper seedling age, T_6: T_2+PSA (proper seedling age), T_7: IPNS (integrated plant nutrient system)+proper seedling age+ IPM. The test crop was BRRI dhan58. The experiment was laid out in a randomized complete block design (RCBD) with five farmers’ replications. Data were taken on growth, yield and yield contributing characters of BRRI dhan58 and analysed with the help of MSTAT-C program. The plant height varied significantly and found the longest plants due to T_7. Tillering followed the similar pattern of plant height where the highest number of tillers hill$^{–1}$were recorded in T_7 IPNS (integrated plant nutrient system) + proper seedling age and spacing + IPM. The yield and yield contributing characters of BRRI dhan58 varied significantly due to application of balanced fertilizers according to BARC recommendation guide with proper agronomic management. The highest grain yield (8.74 t ha^{-1}) and straw yield (11.77 t ha^{-1}) were recorded from IPNS (integrated plant nutrient system) + proper seedling age and spacing + IPM over farmers' practice based fertilizers (T_1). Post-harvest soils showed the higher nutrient content in comparison to initial soil due to application of balanced fertilizers. It was concluded that balanced fertilizer application with proper agronomic management may be recommended for higher yield of BRRI dhan58 in the hoar area.

Iqbal (2011) conducted a pot experiment in a silty-clay soil for two crop seasons. This study was conducted at the rice research institute of Iran, located in Rasht, Guilan province, where rice is the most cultivated crop. The study was a factorial based on a Randomized Complete Block Design (RCBD) with three replications. The amount of N fertilizers was accounted as a first factor i.e. 30, 60, 90, and 120 kg N ha^{-1} or 50, 125, 200 and 275 kg urea ha^{-1}, and the times of nitrogen application were the second factor i.e. basal application at transplanting, two splits application i.e. at transplanting and at the beginning of tillering, and finally three splits applications i.e. at transplanting, at the beginning of tillering and just before flowering. The dimensions of pot were 25×25×25 cm. The pots were filled with paddy field soil with a layer of coarse sand at the bottom. The water samples were taken by a hose which was at the side of pots inserted to the bottom of the pots. The effects of treatments on nitrogen leaching were determined by measuring total nitrogen in drained water of the pots every five days. The highest nitrogen leaching was with basal application, whereas the lowest nitrogen leaching was recorded in three splits treatment. In basal application whole urea applied together and produced nitrate in the surface layers of submerged soil moves easily by diffusion and percolate into lower layers. This result is in agreement that nitrogen leaching from paddy field under different fertilization rates in China.

Li *et al.* (2018) demonstrated the effects of controlled release N fertilizer in enhancing rice yield and NUE. Moreover, the advantage of controlled-release urea (CRU) is that it can be applied as a single basal dose, making it convenient for farmers to implement. Theoretically, the cumulative N release of CRU follows a "S" shape curve over time, which could provide better synchronization with rice N demands than traditional fertilizers. Particularly, certain CRUs could provide a sustained N supply to rice crops through prolonged N release, which is crucial for increasing N uptake at late growth stages of rice and thus, grain yield. However, it is worth noting that there is substantial variability in the reported benefits of CRU in increasing crop yield and NUE. Differences in coating materials as well as in the environmental conditions of given regions may lead to variations in N release characteristics and the synchronization with crops' demands. However, previous studies evaluating CRU effects over multiple site-years are rare, despite their importance and necessity. Although CRU has been recommended as an effective means to increase rice yield, the underlying agronomical and physiological mechanisms are not well documented. Rice yield is determined by yield components, including effective panicle number (PN), number of spikelets per panicle (SPP), spikelet number (SN) per m^2, grain weight (GW), and grain filling (GF) percentage. Crop management based on multi-split topdressing is known to influence rice yield through regulation of yield components such as PN and SN, with SN being considered as the main factor determining yield. In contrast, the grain weight of rice is a very stable varietal character, as spikelet size is rigidly controlled by hull size under most conditions. Despite the advances in our understanding of N influence on rice yield components, the CRU effect still needs to be better understood.

A field experiment was conducted by Zhaoming *et al.* (2018) to assess the effects of two CRUs (resin-coated urea (RCU) and polyurethane-coated urea (PCU)) on rice yields, NUE and soil fertility at two sites (Lincheng town (LC) and Xintang town (XT)). Four treatments were established at each site: (1) control with no N application (CK), (2) split application of conventional urea (U, 270 kg N ha^{-1}), (3) single basal application of RCU (RCU, 216 kg N ha^{-1}), and (4) single basal application of PCU (PCU, 216 kg N ha^{-1}). The N application rate in the CRU treatment compared to the U treatment was reduced by 20%. However, the results showed that, compared to split application of urea, single basal application of CRU led to similar rice grain yields and aboveground biomass at both sites. No significant difference in the N uptake by rice plant was observed between the U and CRU treatments at either site. There were no significant differences in the N apparent recovery efficiency (NARE) among the U, RCU and PCU treatments, with the exception of that in XT in 2015. Compared to application of U, application of CRU increased the N agronomic efficiency (NAE) and N partial factor productivity (NPFP) by 17.4–52.6% and 23.4–29.8% at the LC site, and 15.0–84.1% and 23.2–33.4% at the XT site, respectively, during 2015–2017. Yield component analysis revealed that greater rice grain yield in response to N fertilizer was attributed mainly to the number of panicles per m^2, which increased in the fertilized treatments compared to the CK treatment. The application of CRU did not affect the soil fertility after rice harvest in 2016. Overall, these results suggest that single basal application of CRU constitutes a promising alternative N management practice for reducing N application rates, time- and labor-consuming in rice production in southeast China.

The experiment was carried out by Karim *et al.* (2019) at Sunamganj district observed that 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 (F_1), 320 (F_2), 300 (F_3), 280 (F_4), 260 (F_5), and 165 kg ha^{-1} (F_6) [Farmer's practice (FP)] were used. In case of F_1-F_5, the MoP-TSP-$CaS0_4$-$ZnS0_4$ 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 F_3 (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 F_3 (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.

A field experiment was carried out by Rahman *et al*. (2015) at the field laboratory of Department of Agronomy, Patuakhali Science and Technology University, Dumki, to compare the advantages of using Urea Super Granule (USG) and NPK briquette over normal urea and also predict the better performing transplanted boro rice in the tidal ecosystem. The effect of different levels of fertilizer was studied on growth, yield and yield attributing character of transplanted boro rice. Five fertilizer treatments (N_1 = Recommended doses of all fertilizers, N_2 = Urea super granule at 112.5 kg/during 10 DAT at available tide free time, N_3 = NPK briquette at 150 kg ha^{-1} during 14 DAT at available tide free time, N_4 = Nitrogen control, N_5 = Absolute control) with four HYV boro rice varieties (V_1 = BRRI dhan28, V_2 = BRRI dhan47, V_3 = BRRI dhan55 and V_4 = BRRI dhan64). The experiment was laid out in a split plot design with 3 replications. The analysis revealed that different fertilizer management practices with a few exceptions significantly influenced the growth, yield and yield attributes of the transplanted boro rice varieties. Plant height, number of effective tillers hill^{-1}, panicle length (cm), number of grains panicle^{-1}, nitrogen use efficiency (%), straw yield (t ha^{-1}) and grain yield (t ha^{-1}) were found highest when USG was applied with BRRI dhan47 and all the characters showed lowest value when absolute control with BRRI dhan55. The highest number of effective tillers hill^{-1} (11.15) and grain yield (3.33 t ha^{-1}) was obtained from USG and BRRIdhan47 and where lowest number of effective tillers hill^{-1} (9.21) and grain yield (2.28 t ha^{-1}) in absolute control with BRRIdhan55. The NPK briquettes showed higher agronomic efficiency than Prilled Urea (PU) and Urea Super Granule (USG). The USG (1.8 g) and NPK briquettes (2.4 g) could save 11.3 and 19.55 kg N ha^{-1} compared to recommended PU. There was no residual effect of USG on soil chemical properties. The USG with BRRI dhan48 were found beneficial to the farmers in tidal ecosystem. Urea Super Granule and NPK briquette on growth and yield of different varieties of boro Rice in tidal ecosystem.

2. 2 **Effect of *Azolla pinnata* on N fixation**

Rathaur *et al.* (2012) reported that the *Azolla pinnata*-*Anabaena* association is important agronomical owing to its capacity to fix atmospheric nitrogen at cheaper and faster rates and making it available to crop plants. *Azolla pinnata* seems to help sustain the soil nitrogen supply by returning nitrogen to quantities roughly equal to those extracted from the soil by the rice plant.

Abraham *et al.* (2014) reported that the nitrogen fixing aquatic pteridophyte *Azolla pinnata* has the ability to fix atmospheric nitrogen at cheaper and faster rates due to the presence of a symbiotically cyanobacteria *Anabaena*-*Azolla*. Because of this property it has been exploited widely as bio-fertilizer for rice plants. In addition to this it has several other uses such as food, feed, biogas producer and hyper accumulator of heavy metals etc. Because of the multifaceted uses the promotion and use of *Azolla*-*Anabaena* system would be ideal and environment friendly in sustainable agriculture.

This was confirmed by Chung-Chu *et al.* (1984), who determined that only 3 to 4% of the total nitrogen fixed to the soil in rice field by *Azolla pinnata* was excreted into the water medium during its growth.

Ramesh and Chandrasekaran (2004) observed that *Azolla pinnata* can fix 1.1 kg N ha^{-1} day^{-1} when used as a green manure and in 30 days, under favorable environmental condition, about 30 kg N ha^{-1} would have been fixed. Apart from *Azolla pinnata* being used as a green manure for rice and other such crops, it significantly improves the soil organic carbon content, thus sequestering carbon in soil.

Wagner (1997) reported that in Asia, *Azolla pinnata* has been long used as green manure for crop production and a supplement to diets for pig and poultry. Some strains of *Azolla pinnata* can fix as much as 2-3 kg of nitrogen ha^{-1} day^{-1}. *Azolla pinnata* doubles its biomass in 3-10 days, depending on conditions, and easily reaches a standing crop of 8-10 t ha^{-1} fresh weight in Asian rice fields, 37.8 t ha^{-1} fresh weights (2.78 t ha^{-1} dry weight) has been reported for *Azolla pinnata* in India.

2.3 **Effect of fertilizer sources**

Shamima *et al.* (2002) were investigated a suitable combination of *Azolla pinnata* and urea-N for cultivation of rice (cv. BRRI dhan29). For this purpose an attempt was made to apply 30, 40, 50, 60 and 70% of the recommended doses of urea in 2 or 3 splits along with incorporation of one layer of *Azolla pinnata* grown from 0.2 kg m^{-2} inoculum. Two separate treatments of applying 100% of the recommended dose of urea in 3-splits (without *Azolla pinnata*) and no application of N at all from either urea or *Azolla* were included. *Azolla* *pinnata* covered the surface area in 13 days after inoculation at 7 DAT and reached the maximum growth in 19 days producing 14.0 to 18.3 t ha^{-1} fresh biomass containing 20.7 to 26.4 kg N ha^{-1}. Incorporation of one layer of *Azolla pinnata* at 30 DAT plus application of 50, 60 and 70 kg N ha^{-1} in 3 splits constituted the application of 72.7, 81.6 and 91.1 kg N ha^{-1} that produced 5.58, 6.00 and 6.02 t ha^{-1} grain yields which were statistically similar to each other but the latter two were statistically superior to the grain yield of 5.40 t ha^{-1} produced by conventional recommended practice. Total uptake of N, P and S by the rice plants (grain + straw) were increased significantly due to incorporation of *Azolla pinnata*. Incorporation of one layer of *Azolla pinnata* plus application of 60% of urea-N appeared as the best combination in this study.

Bhuvaneshwari and Singh (2012) was carried out an experiment consisted of four treatments: the conventional rice cultivation without N fertilizer, the conventional rice cultivation with common N fertilizer (200 kg N ha^{-1}), the rice + *Azolla pinnata* without N fertilizer, and the rice + *Azolla pinnata* with moderate N fertilizer (100 kg N ha^{-1}). The common N fertilizer application at a typical rate of 200 kg N ha^{-1} per season was in line with the local application rate. The treatments were arranged in a completely randomized block design with three replications. Twelve plots of 30 m^2 (5 × 6 m) per individual plot were used. N fertilizer (urea) was applied in two split doses: 70% as basal fertilizer and 30% as topdressing approximately 25 days after rice seedling transplanting. A total of 85 kg P_2O_5 ha^{-1} (calcium super-phosphate) was applied in two split doses for all plots: 75 kg ha^{-1} as basal fertilizer and 10 kg ha^{-1} as topdressing 1 day after *Azolla pinnata* inoculation. A total of 100 kg K_2O ha^{-1} (potassium chloride) was used as basal fertilizer. Basic fertilizers were applied 1 day before rice transplanting. In accordance with the local water regime, flooding was initiated 3–4 days prior to rice seedling transplanting and maintained for approximately 30 days until midseason drainage to aerate the paddy soils.

A pot experiment was conducted at Institute of Agricultural Sciences, BHU (2012) under net house condition. There were three pots per treatment and the control experiment was inclusive. Six seedlings of Mahsoori rice variety were transplanted in each pot. *Azolla pinnata* was used as green manure (basal) and dual (associated), at the rate of 0.012 kg pot^{-1} (2 ton ha^{-1}) and in basal treatments it was incorporated in soil before transplanting. Equal shares of *Azolla pinnata* and *Azolla filiculoides* were mixed for achieving a more stable plant growth.

Rennie and Kemp (1984) found that the response of rice to *Azolla pinnata* was similar to that obtained by applying 60 kg N ha^{-1} as urea in three split applications. The different *Azolla pinnata* isolates differed in their growth, N_2-fixation and response to rice crops and soil fertility. All these characteristics were better in the isolates from Bangkok and Vietnam than in those from

Bangladesh and India. *Azolla pinnata* growth and N_2-fixation were better with short rice varieties (IR-36, Ratna and Kalinga-II) than with Mahsuri, a tall rice variety, but Mahsuri, having a longer growing season, showed a better response to *Azolla pinnata*.

Cisse and Vlek (2003) reported that *Azolla pinnata* helps to sustain soil nitrogen supply by returning N to the soil in quantities roughly equal to those extracted from soil by the rice plants.

Bhuvaneshwari and Kumar (2013) conducted an experiment at Banaras Hindu University, Varanasi and found beneficial effects of *Azolla pinnata* in the cultivation of rice. They observed that application of dry *Azolla pinnata* significantly improved the physical and chemical properties of the soil especially nitrogen, organic matter and other cations such as magnesium, calcium and sodium released into the soil.

Chen *et al.* (1997) reported that the benefits of the rice + *Azolla pinnata* cropping system with respect to decreasing N fertilizer application and mitigating CH_4 emissions are unknown in double rice cropping systems. The current experiment will provide unique insights regarding the rice + *Azolla pinnata* farming system in double rice cropping systems in southern China. The objectives of the study were to estimate the effect of a dual cropping of *Azolla pinnata* along with double rice on CH_4 emissions from double rice cropped fields in southern China and to clarify the mechanism underlying the impacts of *Azolla pinnata* on CH_4 emission.

A 3-year field experiment was conducted by Dommergues *et al.* (1982) with five treatments: CK (control without urea), FN (farmers' N practice), FNA (the farmers' N combined with *Azolla pinnata* bio-fertilizer), RN (reducing farmers' N by 25%) and RNA (substituting *Azolla pinnata* bio-fertilizer for 25% farmers' N). The NUE, ammonia (NH_3) volatilization, rice yield and net economic benefit (the difference between the value of the harvest grain and the costs of fertilizer and *Azolla pinnata* inputs) were assessed. The results showed that in the RNA and FNA treatments, *Azolla pinnata* bio-fertilizer produced higher recovery efficiency of fertilizer N by 69% and 59%, provided higher agronomic N use efficiency by 52% and 31% and achieved higher partial factor productivity of applied N by 43% and 13% than FN for the 3 years, respectively. In addition, the RNA and FNA treatments achieved crop N recovery that was 64% and 49% higher than the FN treatment, respectively. The improved NUE under the *Azolla pinnata* bio-fertilizer treatments were attributed to reduced N loss and enhanced N uptake by rice plants. The RNA and FNA treatments significantly reduced N loss by 48% and 26%, as well as lowered NH_3 loss by 42% and 12% over FN, respectively. In addition, *Azolla pinnata* could fix 52 and 44 kg N ha^{-1} $crop^{-1}$ in the RNA and FNA treatments, and thereby, *Azolla pinnata* bio-fertilizer resulted in higher N uptake that was 17% and 33% higher in the RNA and FNA groups than in FN, respectively. As a result, the RNA and FNA treatments achieved higher rice yield by 8% and 14% over FN, respectively, but they attained similar and higher net economic benefit over FN for the 3 years. Therefore, substituting *Azolla pinnata* bio-fertilizer for 25% of urea-N provides a financially attractive option for farmers to substantially improve NUE and yield and effectively reduce N loss in intensive rice cropping systems. *Azolla pinnata* bio-fertilizer substantially improved NUE and yield for rice crop. *Azolla pinnata* bio-fertilizer increased crop ^{15}N recovery by 49–64% and reduced ^{15}N loss by 26–48% (42–77 kg N ha^{-1}). *Azolla pinnata* mat on floodwater reduced NH_3 volatilization by 12–42% (5–17 kg N ha^{-1}). *Azolla pinnata* fixed 44 kg N ha^{-1} $crop^{-1}$ at farmer's N rate, and 52 kg N ha^{-1} $crop^{-1}$ at reduced N rate. *Azolla pinnata* bio-fertilizer resulted in higher rice yield by 8–14%.

Manna and Singh (1989) found that application of 0, 30, 60, 90 and 120 kg N ha^{-1} of urea in split doses with and without *Azolla pinnata* and rice. It was studied for three consecutive seasons under planted field condition. Fresh weight, acetylene reduction activity and N yield of *Azolla pinnata* were found to be maximum 14 days after inoculation. Among the different treatments, maximum *Azolla pinnata* growth was recorded in no N control. The fresh weight, acetylene reduction activity and N yield of *Azolla pinnata* were inhibited increasingly with the increase in N levels. Irrespective of season, FW and N yield of *Azolla pinnata* were inhibited only a small extent with 90 kg N ha^{-1} urea, beyond which the inhibition was pronounced. Acetylene reduction activity was inhibited only slightly up to 60 kg nitrogen ha^{-1} of urea. Grain yield and crop nitrogen uptake of rice increased significantly up to 90 kg N ha^{-1} of urea (alone or in combination with *Azolla pinnata*) in the dry seasons (variety IR 36) and up to 60 kg N ha^{-1} urea in the wet season (variety CR 1018). Rice yields as influenced by *Azolla pinnata* N_2 fixation and urea N-fertilization.

Lumpkin and Plucknett (1982) conducted a field experiment which first planted organic rice. The randomized block design was used, repeated three times with the treatment: cow manure 100% and the combination of *Azolla pinnata* + manure 25%, 50%, and 75% up to 100%. The results showed that *Azolla pinnata*50% + cow manure 50% could increase plant height and tillers number, but the organic C content, total N, and C/N of soil was not different than the application of 100% cow manure. Although the yield of all treatments showed similarly, it could increase the dry grain rice weight as much as 19.17% compared with the 100% manure treatment. The *Azolla pinnata* 50% + cow manure 50% treatment could increase the soil organic C content ranging from 1.3% to 1.7% which indicates the restoration of sick soil leads to healthy soil.
Singh *et al.* (1992) reported that increase in yield due to application of *Azolla pinnata* was demonstrated by several studies conducted in the past at several locations in the country. Similar results have been obtained with *Azolla pinnata* along with the application of chemical nitrogenous fertilizers.

Singh and Riso (1977) compared the effect of the use of fresh *Azolla pinnata* and compost powder of *Azolla pinnata* on some soil and plant chemical properties and rice yield. The treatments applied were fresh *Azolla pinnata* at the dose of 0, 10 and 20 ton ha^{-1} and *Azolla pinnata* compost powder at 12.5 and 25 kg ha^{-1}. The results showed that incorporation of fresh *Azolla pinnata* at 20 tons ha^{-1} and its compost powder at 25 kg ha^{-1} increased the available P of soil, plant P content and tiller number, but did not affect the content of organic-C, total soil N, plant N content and rice yield. This study suggested the benefits of *Azolla pinnata* compost powder technology in organic fertilization of soil to increase the nutrient content of soil and rice plants.

Singh (2000) reported that highest grain yield in rice plants is observed when a comparison of *Azolla pinnata* application is made with other bio-fertilizers. Suppression of weeds and reduction in the volatilization of ammonia in rice fields due to the formation of a thick mat in rice fields by *Azolla pinnata* is observed.

Weiguo *et al.* (2015) reported that the effects of *Azolla pinnata* R. Br. on weed emergence were evaluated in terms of plot area coverage by an *Azolla pinnata* mat, its biomass production and the amount of weed emergence, using fresh and dry weights, in a rice paddy field experiment. The experiment was conducted following a randomized block design with five combinations of fertilizers and *Azolla pinnata* treatments (control, *Azolla pinnata* upper phosphate, *Azolla pinnata* + urea, *Azolla pinnata* + compound fertilizer, *Azolla pinnata* + cow manure). The results revealed that after 18 days of inoculation, all superphosphate (T_1) and cow manure (T_4) - treated plots were fully covered by the *Azolla pinnata* mat. However, coverage of the urea (T_2) and compound fertilizer (T_3) - treated plots were only 80% and 70%, respectively. The full plot area coverage by the *Azolla pinnata* mat and the highest biomass production with superphosphate and cow manure-treated plots were able to completely inhibit two weed species (*Scirpus juncoides* var. *hotarui* and *Monochoria vaginalis* f. *Presl* var. *plantaginea*) and significantly suppressed four other weeds (*Cyperus serotinus*, *Echinochloa oryzicola* and *Eclipta prostrata*). In all the treatments, the fresh weight of weeds significantly reduced to 13, 29, 34, and 9%, respectively, for treatments T_1, T_2, T_3, and T_4. The dry weights also were significantly reduced to 10, 16, 22, and 7.26%, respectively, for treatments T_1, T_2, T_3, and T_4 over the control. The results revealed that there was a significant correlation among plot area coverage by the *Azolla pinnata* mat, its biomass production and weed emergence in a rice paddy field over the control. *Azolla pinnata* did not have any detrimental effect on the growth of rice plants.

Ying *et al.* (2000) reported that a dual cropping of *Azolla Pinnata* greatly increases CH_4 emissions from rice fields. It was found a significant decrease in Dis-solved Oxygen (DO) concentration in surface water and an increase in NH_4^+-N content in rice field soil due to the presence of *Azolla pinnata*, which enhanced CH_4 production and inhibited CH_4 oxidation, thereby leading to an increase in CH_4 emissions. Otherwise, the exudation of *Azolla pinnata* root and the decomposition of dead *Azolla pinnata* could offer abundant substrates for methanogens and hence CH_4 production. In addition, reported that *Azolla pinnata* mediates CH_4 transport from the floodwater of a rice soil into the atmosphere just as rice plants did.

Pabby *et al.* (2004) showed that the influence of associated and incorporated *Azolla pinnata* on phosphorus and potassium contents in rice plants, combining both ways of using *Azolla pinnata* surpassed the remaining treatments, followed by the variants where *Azolla pinnata* was associated to rice crop, and where it was incorporated. This could be due to the influence of supplying these elements where fern is decomposed, as well as the effect on pH provoked by the associated *Azolla pinnata,* which increases the solubility of such elements. It was also reported that *Azolla pinnata* increased fertilizer efficiency, when applied in both ways.

An experiment was conducted by Peters and Meeks (1978) reported that *Azolla pinnata* increased rice yields by 112% over unfertilized controls when applied as a mono-crop during the fallow season, by just 23% when applied as an intercrop with rice. However, the amount increased by 216% when *Azolla pinnata* was applied both as a mono-crop and an intercrop.

Singh (1990) carried out a field experiment with four isolates of *Azolla pinnata* from Bangkok, Bangladesh, Vietnam and India were grown in paddy fields before and after transplanting. Two ton of fresh *Azolla pinnata* inoculated 20 days before transplanting in a fallow rice field, and 10 and 30 days after transplanting in a transplanted rice field produced mats on the water surface 5 DAT, 25 DAT, and 45 DAT, resp. The Bangkok and Vietnam isolates showed more biomass and N_2-fixation than those of the Bangladesh and Indian isolates. Growth and N_2-fixation by *Azolla pinnata* isolates were greater in fallow fields than in planted fields. In planted fields, growth and N_2 fixation were greater with the first *Azolla pinnata* crop at 25 DAT than with the second *Azolla pinnata* crop at 45 DAT. Growing three crops of *Azolla pinnata* once before transplanting and twice after transplanting produced 40.0 to 47.3, 36.7 to 46.3, 38.7 to 50.7, and 31.0 to 42.7 t/ha fresh biomass in the Bangkok, Bangladesh, Vietnam and Indian isolates resp., which fixed 68.4 to 84.2, 61.0 to 73.7, 64.4 to 86.5 and 41.7 to 68.3 kg N/ha, respectively, depending upon the rice varieties used.

Watanabe *et al*. (1977) said that the aquatic *Azolla pinnata* is an excellent bio-fertilizer and green manure having global distribution. Ability of *Azolla* -*Anabaena* system to fix atmospheric nitrogen at faster rates makes it an outstanding agronomic choice for the cultivation of rice under tropical conditions. Nitrogen fixation potential of the *Azolla*-*Anabaena* system has been estimated to be 1.1 kg N ha^{-1} day^{-1} and one crop of *Azolla pinnata* provided 20-40 kg N ha^{-1} to the rice crop in about 20- 25 days.

Pramanik *et al.* (2014) reported that *Azolla pinnata* is very responsive to phosphorus and requires a continuous supply for rapid growth. Trials have shown that each kilogramme of phosphorus resulted in more than 5kg of additional nitrogen in the *Azolla pinnata* biomass after 35 days' growth. Most research on *Azolla pinnata* in the tropics has been carried out in Asia, but trials were conducted simultaneously by the West African Rice Development Association (WARDA) at the Richard Toll Forage Station (Senegal) under semi-arid conditions and at Rokupr (Sierra Leone), which has a wet humid climate. These have indicated its potential but also its limitations in the semi-arid Sahelian zone and in the humid tropic zone of Africa. In northern Senegal, where farmers apply nitrogen at high rates (120kg N ha^{-1}) it was demonstrated that up to 50% of the mineral N can be supplied by *Azolla pinnata*. In the mangrove swamps of Sierra Leone *Azolla pinnata* nitrogen can completely replace mineral N at the recommended rate of 40kg N/ha. *Azolla pinnata* can also control weeds in irrigated rice. Constraints *Azolla pinnata* growth depends on a constant and sufficient depth of water in rice fields. In Asia, where rice is transplanted into flooded paddies, inoculation with *Azolla pinnata* is followed by a very rapid proliferation, a suppression of weeds and a generous production of nitrogen.

Joy and Havangagi (1985) reported that dual culture of *Azolla pinnata* applied at the rate of 3 t ha^{-1}With rice in presence of 0. 50 and 100 kg N ha^{-1} as urea improved rice growth. Grain yield was adversely affected at higher N level due to reduced panicle weight and grain weight per panicle. The highest grain yield (5.8 t ha^{-1}) was obtained with dual *Azolla pinnata* without N fertilizer, followed by that obtained with 50 kg N ha^{-1}.

Sisworo *et al*. (1995) described *Azolla pinnata* growing standing rice crop buffered soil nitrogen availability, absorbing available excess N in early rice growth stage and releases N at later stage which is helpful to increase N use efficiency.

Kern *et al.* (2007) was found that *Azolla pinnata* used as a cover on the floodwater surface of rice can indeed control the volatilization losses through its influence on floodwater pH, the most important factor influencing NH_3 volatilization. A full *Azolla pinnata* cover on the floodwater surface at the time of the first urea application effectively prevented the rapid increase in floodwater pH associated with urea hydrolysis and the algal photosynthetic activities. Ammonia volatilization and the gaseous emission of NH_3 to the atmosphere are the major cause of low N fertilizer efficiency and important mechanisms for N losses in lowland rice fields. And such gaseous losses are responsible for substantial economic loss to farmers and create negative impacts on the atmosphere and water quality. Therefore, use of *Azolla pinnata* to improve the N fertilizer efficiency has created a more concern.

De Macale and Vlek (2004) reported that application of *Azolla pinnata* enhances the soil nutrients availability by their biological activity in particular and helps build up the micro flora. The decomposed organic matter from *Azolla pinnata* biomass plays an active role in the development of microbial population irrespective of the time taken for mineralization. Its continuous application increased the organic nitrogen content of the soil significantly.

Yadav *et al.* (2014) stated that there were increased cellulolytic and urea hydrolyzing activities in addition to significant increase in the population of heterotrophic bacteria due to *Azolla pinnata* application. *Azolla pinnata* incorporation also increased the soil urease and phosphatase activity. Therefore, besides sustaining rice yields, it also enhances the soil biological health and optimizes use of organic, inorganic and biological inputs in an integrated manner taking into consideration the ecological and soil conditions to sustain crop productivity.

Krishnakumar *et al.* (2005) reported that maximum population of bacteria, fungi and actinomycetes and high urease and dehydrogenase activities due to organic farming using *Azolla pinnata* as one of the components.

An experiment conducted by Galal (1997) showed that the proportion of N uptake by rice plant derived from urea and *Azolla pinnata* was identical for the treatments which received the same N rate from both the source. Incorporation of N labeled *Azolla pinnata* into the soil gave a N recovery by rice (shoot and roots) of 40% and 24% for the sterilized and normal soil, respectively. Nitrogen derived from *Azolla pinnata* ranged from 29% to 43% when urea and unlabeled *Azolla pinnata* were applied.

Sampaio *et al.* (1914) observed that incorporation of *Azolla pinnata* increase leaf dry matter concern, root dry weight and total P content. The percent of rice P derived from apiece P as *Azolla pinnata* varied from 36.6% to 65.5% in leaves and 24 to 45.5% in roots, while only 8.1 and 7.2% respectively was derived from P fertilizer when this was the only source applied to the soil.

An experiment was conducted by Rahman *et al.* (1994) found that the grain yield of BR3 rice in boro season was 3.44 t ha^{-1} for using 100 kg N ha^{-1} as urea compared to 3.37 t ha^{-1} due to incorporation of two layers of *Azolla pinnata* along with 4 kg N ha^{-1} as urea which, not significantly different and they further reported 10.3,2. and 0.55 kg more N, P and S uptake due to two incorporation of *Azolla pinnata* along with 40 kg ha^{-1} , respectively, over using 100 kg N ha^{-1} as urea.

Mian (2014) showed that the highest amount of N uptake (73.98 kg ha-1) occurred due to urea + *Azolla pinnata* treatment and 71 kg ha-^{1} total N uptake occurred due to *Azolla pinnata* treatment only. The N uptake was increased by

65 and 59% over control due urea + *Azolla pinnata* treatment respectively, whereas in urea treatment it was 50% the control. About 33% N from *Azolla pinnata* was available to the BR3 rice.

Latha *et al.* (2018) reported that N uptake in grain was the highest when N and *Azolla pinnata* were applied. When N rate increased from 0 to 120 kg ha^{-1}, increased the rice yields from 1.5 to 2.64 t ha^{-1} in tall rice cv. Nagpur 22 and increased N, P and K uptake and their contents in grain and straw.

Mian and Stewart (1984) found that about 36% of the *Azolla pinnata* N added to the soil was released in 60 days and of that about 71% was assimilated by the rice plant 2% regained in soil as NH_4 (-N) and NO_3 (-N) and 27% was lost to the atmosphere as gas.

2.4 **Effect of fresh *Azolla pinnata***

Tung and Shen (1985) found that fresh *Azolla pinnata* grown with rice appeared to suppress the growth of rice in the early stages, probably due to competition. However, at maturity, although rice grown with *Azolla pinnata* did not have greater height or tiller number, straw and grain yield were higher, particularly grain yield which was 42-55% lower than the controls where no *Azolla pinnata* was applied.

Kumarasinghe and Eskew (1986) indicated that one of the major problems in comparing the yield response of rice to N added as an *Azolla pinnata* green manure is that it is difficult to apply an exact amount of N as fresh *Azolla pinnata*. This is due to the fact that the % dry weight and % N of the fresh *Azolla pinnata* biomass tends to vary from day to day and with the method of draining excess water. An exact amount of N as *Azolla pinnata* can be applied if the material is first air or oven-dried. However, the result of drying reduces the N availability from *Azolla pinnata* by 30%.

Connor *et al.* (2015) reported that maintaining the *Azolla pinnata* inoculate between cropping seasons is a major constraint to its vegetative would be eliminated if mass quantities of spores could be obtained. Unfortunately, technologies to induce mass sporulation have not been developed, although some research has been carried out to address this problem. The selection of superior germ-plasma, development of improved *Azolla pinnata* hybrids, and an understanding of the mechanism for inducing sporulation may help in developing *Azolla pinnata* as an adoptable technology.

Setiawati *et al.* (2018) conducted a research to compare the effect of the use of fresh *Azolla pinnata* and compost powder of *Azolla pinnata* on some soil and plant chemical properties and rice yield. The treatments applied were fresh *A. pinnata* at the dose of 0, 10 and 20 ton ha^{-1} and *Azolla pinnata* compost powder at 12.5 and 25 kg ha^{-1}. The results showed that incorporation of fresh *Azolla pinnata* at 20 tons ha^{-1} and its compost powder at 25 kg ha^{-1} increased the available P of soil, plant P content and tiller number, organic-C, total soil N, plant N content and rice yield. This study suggested the benefits of *Azolla pinnata* compost powder technology in organic fertilization of soil to increase the nutrient content of soil and rice plants than the fresh *Azolla pinnata* application.

Ram *et al.* (1994) found that incorporation of 6,12,18 and 24 t ha^{-1} of fresh *Azolla pinnata* into the soil significantly decreased water holding capacity, organic carbon, ammonium nitrogen, nitrate-nitrogen and its available phosphorus, potassium, calcium and magnesium, while it decreased pH and bulk density, such incorporation significantly decreased the yield of rice than the dry *Azolla pinnata* incorporation.

Ito and Watanabe (1983) conducted a pot experiment in the experimental field of the University of Ghana, Legon to examine the effectiveness of dry *Azolla pinnat*a as N source in flooded rice field. The treatments included incorporating fresh *Azolla pinnata* (FA at 90 kg N/ha), dry *Azolla pinnata* (DA at 90 kg N/ha), dry *Azolla pinnata* + Ammonium sulphate (DA at 45 kg N/ha + AS at 45 kg N/ha), fresh *Azolla pinnata* + dry *Azolla pinnata* (FA at 45 kg N/ha + DA at 45 kg N/ha), ammonium sulphate (AS at 90 kg N/ha) and a control (C at 0 kg N/ha). The treatments were applied 8 days after transplanting rice. Results showed that the DA + AS treatment, that is, the treatment where dry *Azolla pinnata* + ammonium sulphate were used to fertilize the rice had the highest dry weight and total N yield followed by the treatment AS. Total N for the DA + AS treatment was 36.67% over the control whilst that for the AS was 25% over the control. Dry *Azolla pinnata* has the potential for supplementing for the nitrogen requirement for irrigated rice.

Studies conducted by Li *et al.* (1982) showed that the lignin content of dry *Azolla pinnata* was 21%, and this was higher than fresh *Azolla pinnata* lignin of 18%, making the mineralization of dried *Azolla pinnata* more difficult.

Chapter 3

Materials & Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the Boro season of November, 2019 to May, 2020 to study the influence of *Azolla pinnata* and urea on fertilizer application methods and fertilizer sources of boro rice. The materials used and methodology followed in the investigation have been presented details in this chapter.

Description of the experimental site

3.1.1 Geographical location

The experimental area was situated at $23^0$77'N latitude and $90^0$33'E longitude at an altitude of 9 meter above the sea level.

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

Soil

The soil of the experimental site belongs to the general soil type, shallow red brown terrace soils under Tejgaon Series. Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.2 and organic matter 1.14%.

3.1.4 **Climate**

The area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March).

3.1.5 Experimental treatments

There were two sets of factors included in the experiment; the first set comprised of fertilizer application methods and the second set consisted of five treatments of fertilizer sources. Two sets of treatments were as follows:

A. Main plot (fertilizer application methods): 2

1. Basal application (M_1)
2. Top dressing (M_2)

B. Sub-plot (fertilizer sources): 5

1. 100% fresh *Azolla pinnata* (S_1)
2. 100% dry *Azolla pinnata* (S_2)
3. 100% urea (S_3)
4. 50% urea + 50% dry *Azolla pinnata* (S_4)
5. Control (S_5)-no urea and *Azolla pinnata*

3.1.6 Experimental design and layout

The experiment was laid out into Split-plot design with three replications having fertilizer application methods in the main plot and fertilizer sources in the sub-plot. Each replication had ten unit plots to which the treatment combinations were assigned as per design. The total numbers of unit plots were thirty. The size of unit plot was 4.4m^2 (2.2 m x 2.0 m). The distance between replication to replication and plot to plot was 0.75 m. The layout of the experiment has been shown in Appendix II.

3.1.7 Collection of *Azolla pinnata*

The fresh *Azolla pinnata* were collected in the ponds of Turag area in Dhaka. The dry *Azolla pinnata* used in the study was previously collected from an experimental boro rice field of Sher-e-Bangla Agricultural University then spread in the threshing floor and sun dried and preserved. Finally, the dried *Azolla pinnata* were used in the experiment. The *Azolla pinnata* need in the experiment was 0.8 kg m^{-2} and 0.4 kg m^{-2} for fresh and dry materials, respectively.

3.2 Growing of crop

3.2.1 Planting material

BRRI dhan89, a high yielding variety of boro rice was used as a test crop. The variety was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The pedigree line (BR9786-BC2-59-1-2) of the variety was derived from a cross BRRI dhan29/IRGC103404). BRRI released the variety in 2018 for cultivation in Boro season. The characterized of this rice variety is 106 cm in height, life cycle lasts for 154-158 days, average yield 8t ha^{-1} and health thousand grains weight 24.4 gram.

3.2.2 Seed collection and seed sprouting

Seeds of the BRRI dhan89 were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. Healthy seeds were selected following standard method. Seeds were immersed in a bucket for 24 hours. Then these were taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.2.3 Raising of seedling

Seedlings were raised in seedbed. The nursery bed prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation provided to the bed when needed. No fertilizer was applied to the nursery bed.

3.2.4 Collection and preparation of initial soil sample

Initial soil sample were collected before land preparation from a 0-15 cm soil depth. Samples were collected through an auger from different location covering the whole experimental plot. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air dried and sieved by a 10-mesh sieve and stored in a clean plastic packet for physical and chemical analysis. The physical and chemical analysis result shown in Appendices III.

3.2.5 Preparation of experimental land

The plot selected for the experiment was opened on December 28, 2019 with a power tiller, and was exposed to the sun for a week, later on January 05, 2020 the land was irrigated and prepared by harrow, plough and cross-plough several times followed by laddering to obtain a good puddled field. Weeds and stubble were removed from the field. After the final land preparation, the field layout was made on January 07, 2020 according to experimental plan. Individual plots were cleaned and finally leveled with the help of wooden plank so that water pocket would remain in the field.

3.2.6 Fertilizers and manure application

The recommended fertilizer uses for the experiment was 180 kg ha^{-1}, 80 kg ha^{-1}, 120 kg ha^{-1}, 24 kg ha^{-1}, 3 kg ha^{-1} and 2 kg ha^{-1} of N, P_2O_5, K_2O, S, Zn and B in the form of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MOP), Gypsum, Zinc sulphate and Boric acid respectively as per treatment. The entire amount of TSP, MOP, Gypsum, Zinc sulphate and Boric acid were applied during the final preparation of land. Urea was applied as per treatment following the standard procedure. Fresh and dry *Azolla pinnata* was applied during final land preparation (basal) and 10 DAT (top dressing) as per treatment.

3.2.7 Seedling Transplanting

Land was prepared for transplanting of seedlings. Forty days old seedlings were transplanted in the line following the spacing of 20 cm × 20 cm having two seedlings hill^{-1} in the lines. The seedlings were transplanted on January 09, 2020.

3.3 Intercultural operations

3.3.1 Top dressing

The urea fertilizer was top-dressed in 3 equal installments in selected plots as per treatment.

3.3.2 Gap filling

First gap filling was done on January 20, 2020 and second gap filling was done one week after first gap filling on January 27, 2020.

3.3.3 Weeding

During plant growth period two hand weedings were done, first weeding was done at 25 DAT (days after transplanting) followed by second weeding at 40 DAT.

3.3.4 Application of irrigation water

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other two irrigations were given 2-3 days before weeding. Supplemented irrigation water was also added to each plot during reproductive and ripening phase as and when necessary.

3.3.5 Drainage

Drainage channels were properly prepared to easy and quick drained out of excess water.

3.3.6 Plant protection measures

Rice plans were infested with rice stem borer and leaf hopper which were successfully controlled by applying Aktara on 03 March, Diazinone on 19 March and Ripcord on 7 April, 2020 by following recommended produces.

3.4 General observation of the experimental field

The experimental field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, infests and diseases so that the considerable losses by pest should be minimize. Attack of rice stem borer, green leaf hopper, leaf roller was observed and controlled properly. But no bacterial and fungal disease was observed.

3.5 Harvesting and post-harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. Growth, yield and other crop data were recorded from 5 randomly selected hills of each plot. Five mid lines from each plot was separately harvested, bundled, properly tagged and brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12 %. Straw was also sun dried properly. Finally grain and straw yield were recorded and converted to ton ha^{-1}.

3.6 Recording of data

The following data were collected during the study period:

A. Crop growth characters

i. Plant height (cm) from 25 DAT to harvest with 20 days interval
ii. Number of tillers hill^{-1} from 25 DAT to harvest with 20 days interval
iii. Number of leaves hill^{-1} from 25 DAT to harvest with 20 days interval
iv. Leaf area index (LAI) from 25 DAT to harvest with 20 days interval
v. Dry matter hill^{-1} from 30 DAT to harvest with 30 days interval
vi. SPAD value at 45 and 75 DAT
vii. Time of flowering
viii. Time of maturity

B. Yield contributing characters

i. Number of effective tillers hill^{-1}
ii. Number of in-effective tillers hill^{-1}
iii. Number of total tillers hill^{-1}
iv. Length of flag leaf
v. Number of rachis branches panicle^{-1}
vi. Length of panicle
vii. Filled grains panicle^{-1}
viii. Unfilled grains panicle^{-1}
ix. Total grains panicle^{-1}
x. Weight of 1000 grains
xi. Fresh grain weight hill^{-1}
xii. Dry grain weight hill^{-1}
xiii. Fresh straw weight hill^{-1}
xiv. Dry straw weight hill^{-1}
xv. Fresh grain yield
xvi. Dry grain yield
xvii. Fresh straw yield
xviii. Dry straw yield
xix. Biological yield
xx. Harvest index

C. Soil characters

i. Organic matter
ii. pH
iii. Total nitrogen
iv. Available phosphorus
v. Exchangeable potassium
vi Available sulphur

3.7 Detailed procedures of recording data

3.7.1 Crop growth characters

3.7.1.1 Plant height

The height of plant was recorded in centimeter (cm) at 25, 45, 65, 85 DAT (days after transplanting) and at harvest. Data were recorded and averaged from 5 plants pre- selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.7.1.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 25, 45, 65, 85 DAT (days after transplanting) and at harvest by counting total tillers and averaged from 5 hills pre-selected at random from the inner rows of each plot. Tillers having at least leaves were considered for counting.

3.7.1.3 Number of leaves hill^{-1}

The number of leaves hill^{-1} was recorded at 25, 45, 65, 85 DAT (days after transplanting) and at harvest by counting total number of leaves and averaged from 5 hills pre- selected at random from the inner rows of each plot.

3.7.1.4 Leaf area index (LAI)

Leaf area index were estimated at 25, 45, 65, 85 DAT (days after transplanting) and at harvest manually by the total number of leaves plant^{-1} and measuring the length and average width of leaf and multiplying by a factor of 0.75.

3.7.1.5 Dry matter hill^{-1} (g)

Total dry matter hill^{-1} was recorded at 30, 60, 90 DAT and at harvest by oven drying plant sample. Data were recorded and averaged from 2 sample hills plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.7.1.6 SPAD value

The SPAD value of three leaves from five plants of each plot were measured with the help of a chlorophyll meter (SPAD 502 plus) and the mean values were determined.

3.7.1.7 Time of flowering

Time of flowering was measured when about 50% panicles of the plants within a plot emerged. The number of days for flowers was recorded.

Yield and other crop characters

3.7.2.1 Number of Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted from the number of panicle bearing tillers hill^{-1}. Data on effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.7.2.2 Number of in-effective tillers hill^{-1}

The total number of in-effective tillers hill^{-1} was counted from the number of non-panicle bearing tillers hill^{-1}. Data on in-effective tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.7.2.3 Total tillers hill^{-1}

The total tillers hill^{-1} was calculated by adding effective and in-effective tillers hill^{-1} and average value was recorded.

3.7.2.4 Length of flag leaf

The length of flag leaf was measured with a meter scale from 10 randomly selected panicles and the average value was recorded in cm.

3.7.2.5 Number of rachis branches panicle^{-1}

The number of rachis branches panicle^{-1} was calculated by counting rachis branches from 10 randomly selected panicles and the average value was recorded.

3.7.2.6 Length of panicle

The length of panicle was measured with a meter scale from 10 randomly selected panicles and the average value was recorded in cm.

3.7.2.7 Filled grains panicle^{-1}

The total number of filled grains was collected from randomly selected 10 panicles of a plot and then average number of filled grains panicle^{-1} was recorded.

3.7.2.8 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected from randomly selected 10 panicles of a plot and then average number of unfilled grains panicle^{-1} was recorded.

3.7.2.9 Total grains panicle^{-1}

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

3.7.2.10 Weight of 1000 grains

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

3.7.2.11 Grain yield

Grains obtained from the central 5 lines from each plot were harvested, threshed and weighed carefully. Then grains were sun-dried and weighted again. The fresh and dry weight of grains (14% moisture) converted to t ha^{-1} basis.

3.7.2.12 Straw yield

Straws obtained of the central 5 lines from each plot were harvested, threshed and weighed carefully. Then grains were sun-dried and weighted again. Finally the fresh and dry weight of straws converted to t ha^{-1} basis.

3.7.2.13 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

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

3.7.2.14 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.8 Statistical Analysis

The data collected on different characters were statistically analyzed to obtain the level of significance using the CropStat computer package program. The mean different among the treatment were compared by least significance difference test at 5% level of significance.

Chapter 4

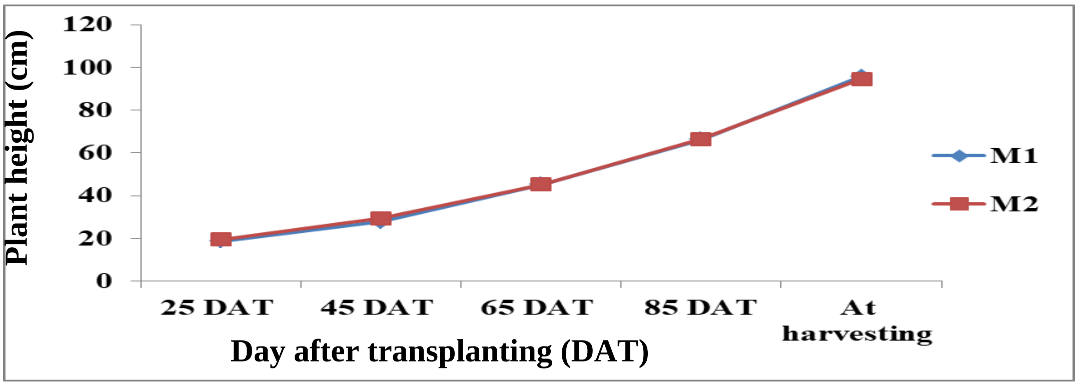
Results& Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to study the effect of fertilizer application methods and fertilizer sources on boro rice. Data on different growth and yield contributing characters were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix IV-XIII. The results have been presented with the help of Tables and Graphs and possible interpretations given under the following headings:

4.1 Crop growth characters
4.1.1 Plant height
4.1.1.1 Effect of fertilizer application methods

The plant height of boro rice was significantly influenced by fertilizer application methods at 25 and 45 days after transplanting (DAT) but at 65, 85 DAT and at harvesting had no significant variations (Appendix IV and Figure 1). The result revealed that at 25 DAT, the higher plant height (19.53 cm) was obtained from top dressing (M_2) and the lower (18.72 cm) from basal application (M_1). The higher plant height (29.53 cm) was recorded at 45 DAT from top dressing followed by basal application (24.93 cm). But plant heights at 65, 85 DAT and at harvest were statistically similar. The results were similar with the findings of Nath *et al*. (2018) who observed that plant height increased by maintaining the recommended dose of urea.



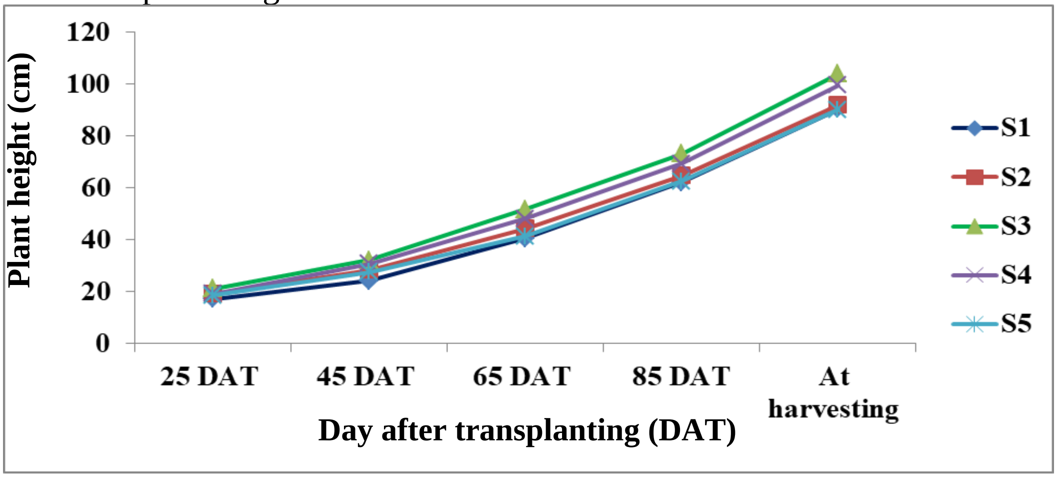
Note: M_1 = Basal application, M_2 = Top dressing

Figure 1. Plant height of boro rice as influenced by fertilizer application methods ($LSD_{(0.05)}$= 0.99, 1.33, NS, NS and NS at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.1.2 Effect of fertilizer sources

Fertilizer sources had significant effect on plant height at 25, 45, 65, 85 DAT and at harvest (Appendix IV and Figure 2). At 25 DAT, the highest plant height (21.23 cm) was obtained from 100% urea (S_3 treatment) and the lowest plant height (17.19 cm) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment) which was statistically similar with the height (18.70 cm) of control (S_5

treatment). At 45 DAT, the highest plant height (32.31 cm) was obtained from 100% urea (S_3 treatment) and the lowest plant height (24.23 cm) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment). At 65 and 85 DAT, the highest plant height (51.71 and 73.14 cm, respectively) was obtained from 100% urea (S_3 treatment). The lowest plant height (40.52 and 62.23 cm) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment) at 65 and 85 DAT, respectively. At harvest, the highest plant height (103.91 cm) was obtained from 100% urea (S_3 treatment). The lowest plant height (90.15 cm) at harvesting was obtained from control (S_5 treatment) which was statistically similar with 100% fresh *Azolla pinnata* (S_1 treatment) and 50% urea and 50% dry *Azolla pinnata* (S_2 treatment). Andrade and Amorim (1996) observed that increasing level of N increased plant height.



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 2. Plant height of boro rice as influenced by fertilizer sources ($LSD_{(0.05)}$ at 25, 45, 65, 85 and at harvest = 1.57, 2.11, 2.72, 2.74 and 3.17, respectively).

4.1.1.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on plant height observed at 25, 45, 65, 85 DAT and at harvest (Appendix IV and Table 1). At 25 DAS, the highest plant height was (21.27cm observed in M_1S_3 treatment (basal application by 100% urea) and lowest plant height observed in M_1S_1 (basal application by 100% fresh *Azolla pinnata*). At 45 DAT, the highest plant height was observed (33.10 cm) in M_1S_3 treatment (top dressing by 100% urea) and lowest plant height was (16.29 cm) observed in M_1S_1 treatment. But at 65 and 85 DAT, plant height (53.29 and 74.71 cm, respectively) was highest in M_1S_3 treatment (basal application by 100% urea). At harvest, the highest plant height was found in M_1S_3 treatment (basal application by 100% urea) and lowest plant height (90.07cm) was found in M_2S_5 treatment (control by top dressing).

Table 1. Interaction effect of fertilizer application methods and fertilizer sources on plant height of boro rice

Treatments	Plant height (cm) at different DAT				
	25 DAT	45 DAT	65 DAT	85 DAT	At harvest
M_1S_1	16.29 f	22.39 i	39.65 f	62.00 e	91.99 e
M_1S_2	18.97 bd	28.13 d-g	45.15 d	64.30 e	90.85 e
M_1S_3	21.27 a	31.69 ab	53.29 a	74.71 a	105.53 a
M_1S_4	18.72 c-e	30.48 a-d	47.17 b-d	68.77 b-d	99.81 bc
M_1S_5	18.34 c-f	26.74 e-h	41.17 ef	61.81 e	90.23 e
M_2S_1	18.09 c-f	26.06 e-h	41.40 ef	62.47 e	88.81 e
M_2S_2	19.58 a-c	28.81 c-e	43.57 de	65.29 de	92.79 e
M_2S_3	21.18 ab	33.10 a	50.13 ab	71.57 ab	102.29 a
M_2S_4	19.72 a-c	31.23 a-c	49.13 bc	69.87 bc	99.03 b-d
M_2S_5	19.07 ab	28.44 d-f	41.61 ef	63.20 e	90.07 e
$LSD_{(0.05)}$	2.21	2.98	3.84	3.88	4.48
CV (%)	6.09	6.00	4.90	3.05	4.19

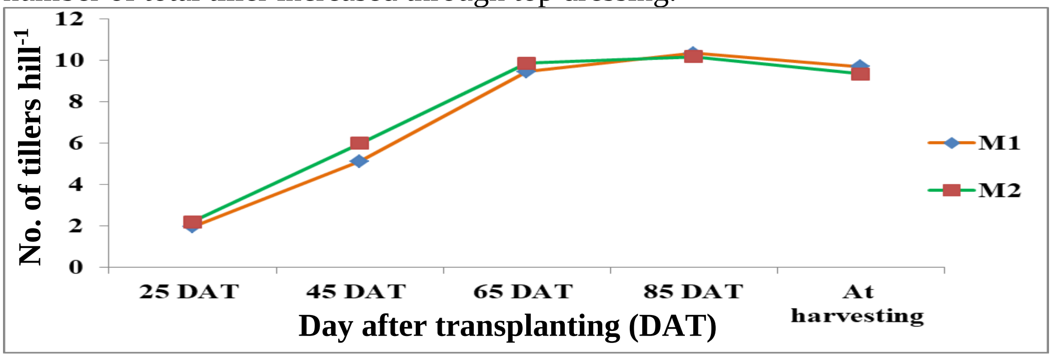
In a column, the means having the same letter (s) do not differ significantly. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.2 Number of tillers hill^{-1}

4.1.2.1 Effect of fertilizer application methods

Fertilizer application methods had non-significant on number of tillers hill^{-1} at 25, 45, 65, 85 DAT and at harvest (Appendix V and Figure 3). The result revealed that at 25, 45, 65 DAT, the higher number of tillers hill^{-1} (2.19, 5.99 and 9.87 respectively) was obtained from top dressing (M_2) of urea. The higher number of tillers hill^{-1} (10.35 and 9.71) was recorded at 85 and at harvest from basal application of urea. Kamruzzaman *et al.* (2014) reported that number of total tiller increased through top dressing.

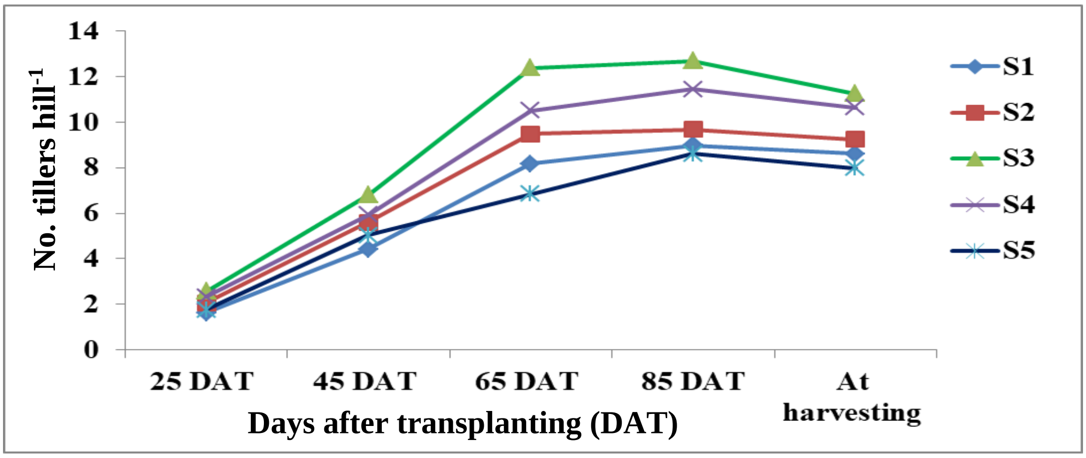


Note: M_1 = Basal application, M_2 = Top dressing

Figure 3. Number of tillers hill^{-1} of boro rice as influenced by fertilizer application methods ($LSD_{(0.05)}$= NS, NS, NS, NS and NS at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.2.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of tiller at 45, 65, 85 DAT and at harvesting (Appendix V and Figure 4). At 25 DAT, the maximum tiller number hill^{-1} (2.57) was obtained from 100% urea (S_3 treatment) while the minimum tiller number hill^{-1} (1.63) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment). At 45 DAT, the maximum tiller number hill^{-1} (5.93) was obtained from 100% urea (S_3) treatment while the minimum tiller number hill^{-1} at 45 DAT was (4.43) obtained from 100% fresh *Azolla pinnata* (S_1 treatment). At 65 DAT, the maximum tiller number hill^{-1} (10.50) was obtained from 50% urea and 50% dry *Azolla pinnata* (S_4) treatment while the minimum tiller number at 65 DAT was (6.83) obtained from control (no urea and *Azolla pinnata)* (S_5) treatment. At 85 DAT and harvest, the maximum tiller number hill^{-1} (12.67 and 11.23) was obtained from (S_3 treatment) 100% urea treatment while the minimum tiller number hill^{-1} (8.60 and 7.97) at harvesting was obtained from control condition (S_5 treatment) which was statistically similar with 100% fresh *Azolla pinnata* (S_1 treatment). Setiawati *et al.* (2018) reported that tiller number hill^{-1} reduced by application of fresh *Azolla pinnata* in the rice field.



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea , S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 4. Number of tillers hill^{-1} of boro rice as influenced by fertilizer sources (LSD$_{(0.05)}$= NS, 0.52, 1.77, 1.32 and 0.75 at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.2.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on tiller number observed at 25, 45, 65, 85 DAT and at harvest (Appendix V and Table 2). At 25 DAS, the maximum tiller number was (2.67) observed in M_2S_3 treatment (top dressing by 100% urea) and the minimum tiller number was (1.47) observed in M_1S_1 treatment (basal application by 100% urea). At 45 DAT, the maximum tiller number hill^{-1} was observed (7.60) in M_2S_3 treatment (top dressing by 100% urea) which was statically different from other treatments and the minimum tiller number hill^{-1} (4.87) was obtained from 100% fresh *Azolla pinnata* (M_1S_5 treatment). But at 65, the maximum tiller number (13.80) in M_1S_3 treatment (basal application by 100% urea) while the minimum tiller number was (7.60) observed in M_2S_5 treatment (top dressing by 100% control). At 85 DAT and harvest, the maximum tiller number hill^{-1} (12.80 and 11.53) had found in M_1S_3 treatment (basal application by 100% urea) respectively and the minimum tiller number hill^{-1} (8.53 and 7.93) had found in M_1S_5 treatment (basal application by control) and M_2S_5 treatment (top dressing by control), respectively.

Table 2. Interaction effect of fertilizer application method and fertilizer source on number of tiller hill^{-1} of boro rice

Treatments	Number of tiller hill^{-1} of boro rice at different DAT				
	25 DAT	45 DAT	65 DAT	85 DAT	At harvest
M_1S_1	1.47 d	3.67 i	7.87 f	9.00 e	8.80 de
M_1S_2	2.07 a-d	5.33 b-f	8.87 c-f	9.80 b-e	9.00 de
M_1S_3	2.47 ab	6.00 bc	13.80 a	12.80 a	11.53 a
M_1S_4	2.20 a-c	5.80 b-e	10.73 c	11.60 a-c	11.20 ab
M_1S_5	1.60 cd	4.87 f-h	6.07 f	8.53 e	8.00 e
M_2S_1	1.80 cd	5.20 d-g	8.47 d-f	8.93 e	8.40 de
M_2S_2	2.10 a-d	5.87 b-d	10.07 c-e	9.53 bd	9.47 d
M_2S_3	2.67 a	7.60 a	12.93 ab	12.53 ab	10.93 a-c
M_2S_4	2.47 ab	6.07 b	10.27 cd	11.27 a-d	10.07 c
M_2S_5	1.93 cd	5.20 d-g	7.60 f	8.67 e	7.93 e
$LSD_{(0.05)}$	0.64	0.74	1.96	1.81	1.07
CV (%)	2.47	7.63	7.19	10.49	6.47

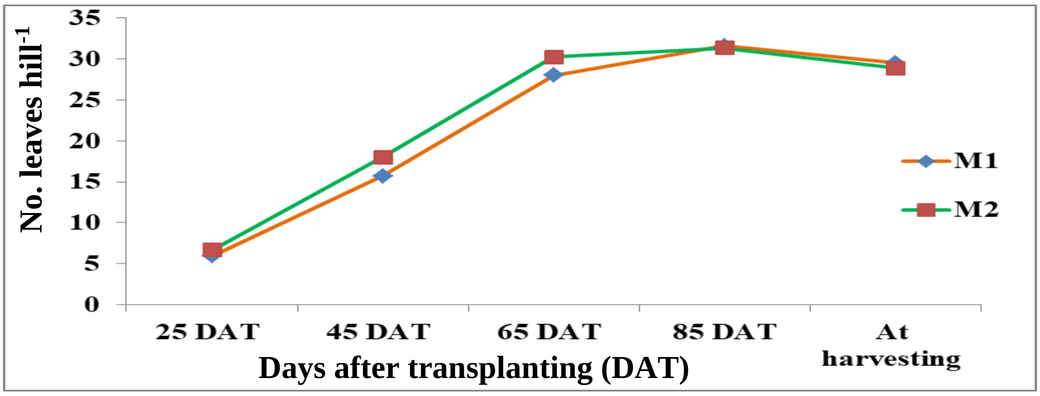
In a column, the means having the same letter (s) do not differ significantly. NS= Non-significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.3 Number of leaves hill^{-1}

4.1.3.1 Effect of fertilizer application methods

The number of leaves of boro rice was non-significantly influenced by fertilizer application methods at 25, 45, 65, 85 DAT and harvest after transplanting (Appendix VI and Figure 5). The result revealed that at 25 DAT, the maximum number of leaves hill^{-1} (6.66) was obtained from top dressing (M_2) but the result was statistically similar with other treatment. The maximum leaves number (18.01 and 30.28) was also recorded at 45 and 65 DAT from top dressing followed by basal application (15.73 and 28.04). But number of leaves at 85 DAT and at harvesting, the maximum result (31.63 and 29.51) shown in basal application followed by top dressing (31.35 and 28.91). The results were statistically similar in each case.

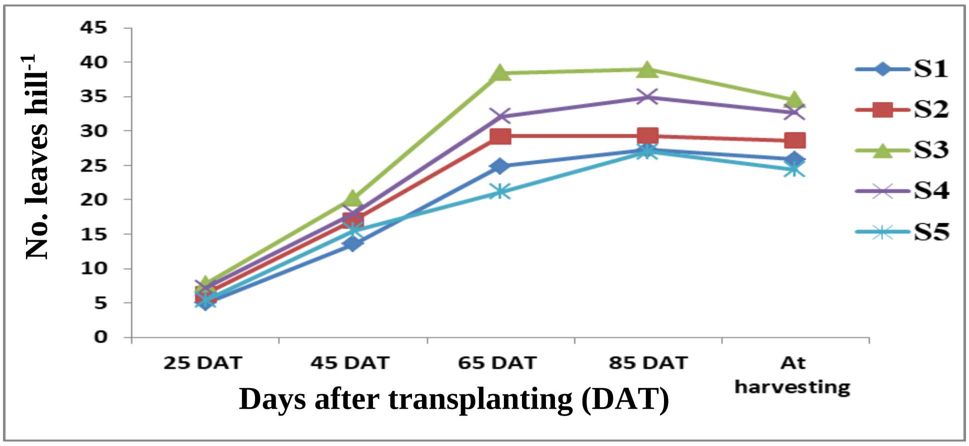


Note: M_1 = Basal application, M_2 = Top dressing

Figure 5. Number of leaves hill^{-1} of boro rice as influenced by fertilizer application methods (LSD$_{(0.05)}$= NS, NS, NS, NS and NS at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.3.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of leaves at 25, 45, 65, 85 DAT and harvest (Appendix VI and Figure 6). At 25 DAT, the maximum number of leaves (7.73) was obtained from 100% urea (S_3 treatment) which was statistically similar with the number of leave from (S_4 treatment) 50% urea + 50% *Azolla pinnata*. The minimum leaves number hill^{-1} (4.97) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment) which was statistically similar with the number of leaves hill^{-1} (5.38) from control (S_5 treatment). At 45 DAT, the maximum leaves number hill^{-1} (20.23) was obtained from 100% urea (S_3 treatment) which was statistically different from other treatments. The minimum leaves number (13.55) at 45 DAT was obtained from100% fresh *Azolla pinnata* (S_1 treatment). At 65 and 85 DAT, the maximum leaves number (38.47 and 38.93) was obtained 100% urea (S_3 treatment) while the minimum leaves number (21.23 and 27) was obtained from control (S_5 treatment) which was similar with the number of leaves hill^{-1} (24.87 and 27.27) from 100% fresh *Azolla pinnata* (S_1 treatment) *and* 100% dry *Azolla pinnata* (S_4 treatment). At harvesting, the maximum leaves number hill^{-1} was obtained from 100% urea (S_3 treatment) which was statistically similar with (32.67) from 50% urea + 50% *Azolla pinnata* (S_4 treatment) and the minimum leaves number hill^{-1} (24.37) was obtain from control (S_5 treatment) which was at per with 100% fresh *Azolla pinnata* (S_1 treatment).



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 6. Number of leaves hill^{-1} (cm) of boro rice as influenced by fertilizer sources ($LSD_{(0.05)}$= 0.99, 1.53, 4.60, 3.74 and 2.48 at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.3.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of leaves hill^{-1} at 25, 45, 65, 85 DAT and at harvest (Appendix VI and Table 3). At 25 DAS, the maximum number of leaves hill^{-1} was (8.03) observed in M_2S_3 treatment (top dressing by 100% urea) while the minimum number of leaves was (4.47) observed in M_1S_1 treatment (basal application by 100% fresh *Azolla pinnata*). At 45 DAT, the maximum number of leaves hill^{-1} was also observed (21.93) in M_2S_3 treatment (top dressing by 100% urea) while the lowest number of leaves was observed (11.30) in M_1S_1 treatment (top dressing by 100% fresh *Azolla pinnata*). At 65 DAT, the maximum number of leaves (39.67) was observed in M_1S_3 treatment (basal application by 100% urea) which was statistically similar with other treatments. At 85 and at harvesting, the maximum number of leaves hill^{-1} (39.53 and 35.00) was observed in M_1S_3 treatment (basal application by 100% urea) while the minimum number of leaves hill^{-1} (27.07 and 24.27) was observed in M_1S_3 treatment (basal application by 100% urea) and M_2S_5 treatment (top dressing by control), respectively.

Table 3. Interaction effect of fertilizer application methods and fertilizer sources on number of leaves hill^{-1} of boro rice

Treatments	Number of leaves hill^{-1} of boro rice at different DAT				
	25 DAT	45 DAT	65 DAT	85 DAT	At harvest
M_1S_1	4.47 f	11.30 k	23.93 gh	27.07 f	26.20 f-h
M_1S_2	6.30 bc	16.27 c-f	27.73 ef	29.07 f	28.20 fg
M_1S_3	7.43 ab	18.53 b	37.27 ab	39.53 a	35.00 a
M_1S_4	6.70 a-c	17.67 b-e	32.60 c	35.67 bc	33.67 a-c
M_1S_5	4.90 ef	14.90 f-j	18.67 j	26.80 f	24.47 h
M_2S_1	5.47 c-f	15.80 d-i	25.80 fg	27.47 f	25.53 f
M_2S_2	6.33 b-d	17.73 b-d	30.73 c-e	29.60 f	29.07 df
M_2S_3	8.03 a	21.93 a	39.67 a	38.33 ab	34.00 ab
M_2S_4	7.60 ab	18.40 bc	31.60 cd	34.13 cd	31.67 a-d
M_2S_5	5.87 c-e	16.20 d-g	23.60 g-i	27.20 f	24.27 h
$LSD_{(0.05)}$	1.39	2.17	3.05	3.17	3.51
CV (%)	2.78	4.43	6.49	9.71	6.94

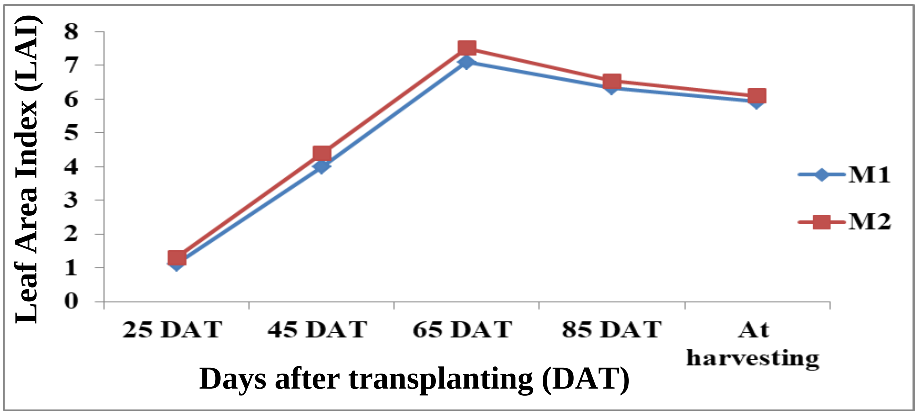
In a column, the means having the same letter (s) do not differ significantly. NS= Non-significant, CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.4 Leaf area index (LAI)

4.1.4.1 Effect of fertilizer application methods

Fertilizer application methods had non-significant on leaf area index (LAI) at 25, 45, 65, 85 DAT and harvest after transplanting (Appendix VII and Figure 7). The result revealed that at 25 DAT, the higher leaf area index (1.30) was obtained from top dressing (M_2). The higher leaf area index (4.39, 7.51, 6.54 and 6.10 respectively) was also recorded at 45, 65 DAT, 58 DAT, and at harvest from top dressing followed by basal application (3.99, 7.10, 6.33 and 5.92, respectively). The results were statistically similar in each case.

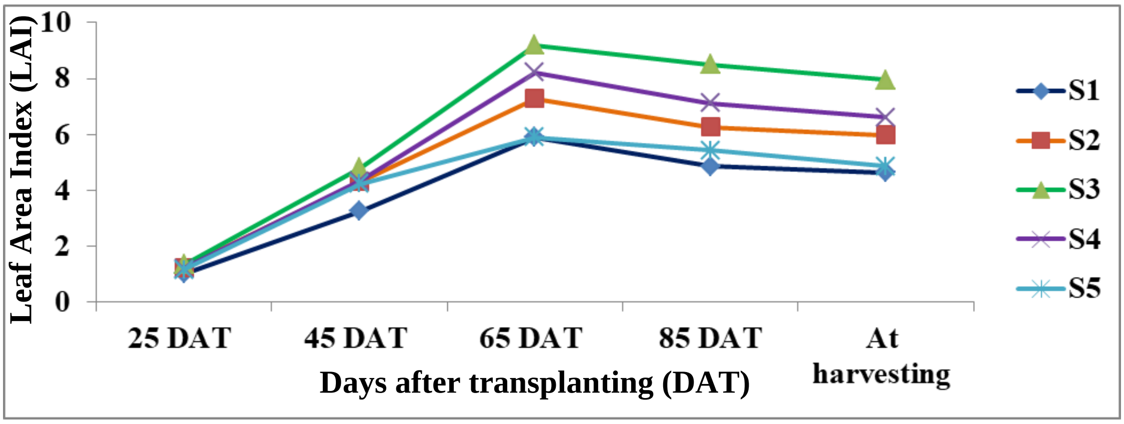


Note: M_1 = Basal application, M_2 = Top dressing

Figure 7. Number of Leaf Area Index (LAI) of boro rice as influenced by fertilizer application methods ($LSD_{(0.05)}$= NS, NS, NS, NS and NS at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.4.2 Effect of fertilizer sources

Fertilizer sources had significant effect on leaf area index (LAI) at 25, 45, 65, 85 DAT and harvest (Appendix VII and Figure 8). At 25 DAT, the highest leaf area index (1.35) was obtained from 100% urea (S_3 treatment) while the lowest leaf area index (1.02) was obtained from (S_1 treatment) 100% fresh *Azolla pinnata*. At 45 DAT, the highest leaf area index (4.81) was obtained from 100% urea (S_3 treatment) while the lowest leaf area index (3.26) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment). The higher leaf area index (9.20, 8.50 and 7.96) was also recorded at 65, 85 DAT and harvest, respectively from 100% urea (S_3 treatment). The lowest leaf area index (5.90, 4.86 and 4.63) was also recorded at 65, 85 DAT and harvest, respectively from 100% fresh *Azolla pinnata* (S_1 treatment).



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 8. Number of Leaf Area Index (LAI) of boro rice as influenced by fertilizer sources ($LSD_{(0.05)}$= 0.34, 0.68, 0.66, 0.48 and 0.52 at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.4.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on leaf area index (LAI) observed at 25, 45, 6, 85 DAT and at harvest (Appendix VII and Table 4). At 25 and 45 DAT, the maximum leaf area index was (1.41 and 4.91) observed from 100% urea by top dressing (M_2S_3 treatment) while the minimum leaf area index was (0.90 and 2.93) obtained from 100% fresh *Azolla pinnata* by basal application (M_1S_1 treatment). But at 65 and 85 DAT the maximum leaf area index was also observed (9.30 and 8.52) from 100% urea by basal application (M_1S_3 treatment) while the minimum leaf area index was (5.67 and 4.67) obtained from 100% *Azolla pinnata* by basal application (M_1S_1 treatment). At harvesting, the maximum leaf area index was (8.15) obtained from 100% urea by top dressing (M_2S_3 treatment) which was statistically similar with 100% urea by basal application (M_1S_3 treatment) and the minimum leaf area index was (3.58) obtained from 100% *Azolla pinnata* by basal application (M_1S_1 treatment).

Table 4. Interaction effect of fertilizer application methods and fertilizer sources on Leaf Area Index (LAI) of boro rice at different growth stages

Treatments	Leaf Area Index (LAI) of boro rice at different DAT				
	25 DAT	45 DAT	65 DAT	85 DAT	At harvest
M_1S_1	0.90 f	2.93 h	5.67 ef	4.67 h	3.58 g
M_1S_2	1.03 f	4.17 a-e	6.80 e	6.01 e	5.77 de
M_1S_3	1.29 cd	4.70 ab	9.30 ab	8.52 a	7.77 ab
M_1S_4	1.35 cd	4.02 a-g	8.20 bc	7.28 c	6.77 c
M_1S_5	1.04 f	4.13 a-f	5.43 f	5.16 g	4.72 f
M_2S_1	1.13 f	3.59 d-h	6.14 ef	5.06 g	4.68 f
M_2S_2	1.44 a	4.47 ab	7.77 cd	6.51d	6.21 c-e
M_2S_3	1.41 ab	4.91 a	9.10 a	8.48 ab	8.15 a
M_2S_4	1.24 ef	4.66 a-c	8.15 c	6.97 cd	6.47 cd
M_2S_5	1.28 c-e	4.37 a-d	6.38 e	5.70 f	5.00 f
$LSD_{(0.05)}$	0.04	0.97	0.94	0.34	0.74
CV (%)	3.14	2.91	2.43	2.78	2.76

In a column, the means having the same letter (s) do not differ significantly.

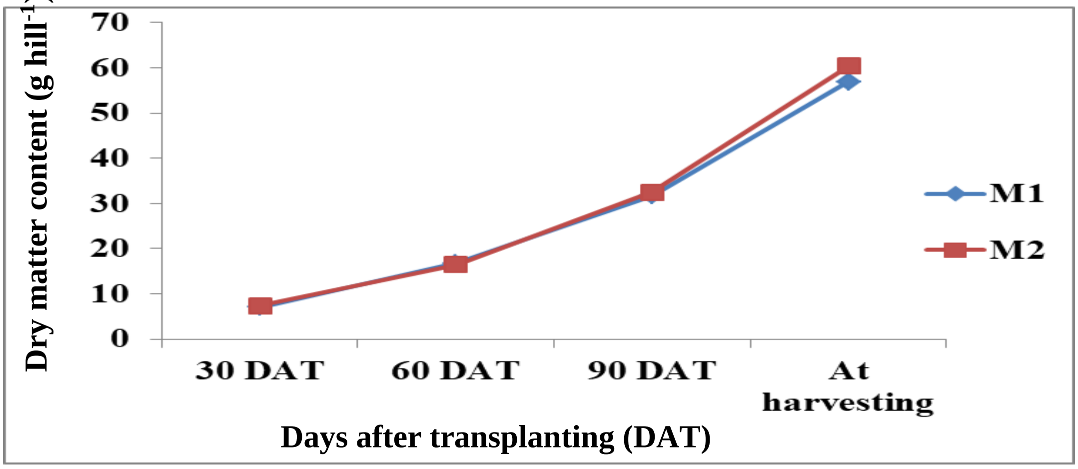
CV= Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1= 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.5 Dry matter (Above ground) hill^{-1}

4.1.5.1 Effect of fertilizer application methods

Fertilizer application methods had non-significantly influenced on at 30, 60, 90 DAT and at harvesting (Appendix VII and Figure 9). The result revealed that at 30 DAT, the maximum dry matter hill^{-1} (above ground) (7.33 g) was obtained from top dressing (M_2) but the result was statistically similar with other treatment. At 60 DAT, the maximum dry matter hill^{-1} (16.79 g) was also recorded from basal application (M_1) followed by top dressing (16.46 g). But at 90DAT, the maximum dry matter hill^{-1} was (31.76 g) shown in top dressing (M_2) followed by basal application (M_1). At harvesting, the maximum dry matter hill^{-1} (60.45 g) was obtained from top dressing (M_2). The results were statistically similar in each case. So effect of fertilizer application methods was not significant in respect of dry matter hill^{-1} of boro rice. Ahmed *et al.* (2018) also found that dry matter hill^{-1} was increasing through top dressing of urea fertilizer application.

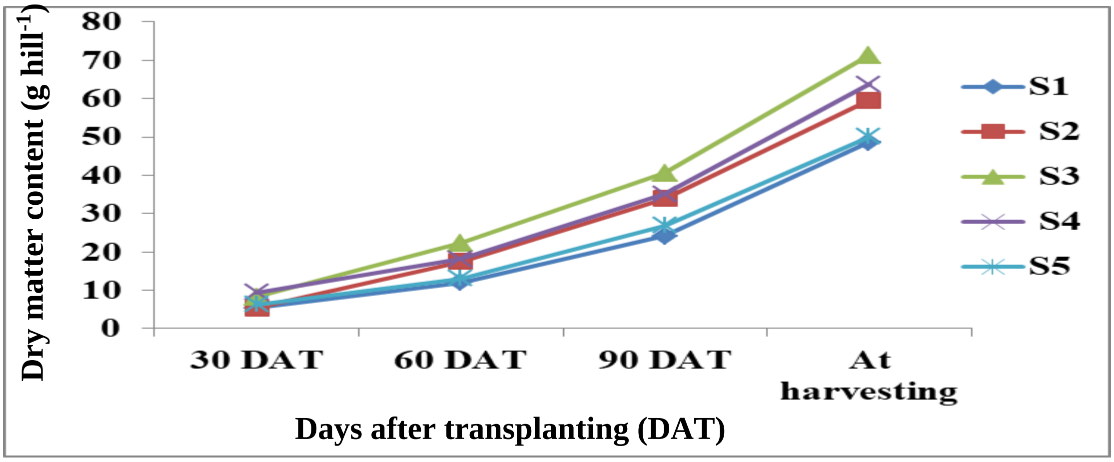


Note: M_1 = Basal application, M_2 = Top dressing

Figure 9. Dry matter hill^{-1} (above ground) of boro rice as influenced by fertilizer application methods (LSD$_{(0.05)}$= NS, NS, NS, NS and NS at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.5.2 Effect of fertilizer sources

Fertilizer sources had significant effect on dry matter content hill^{-1} (above ground) had significant effect at 30, 60, 90 DAT and at harvest (Appendix VIII and Figure 10). At 30 DAT, the maximum dry matter hill^{-1} (9.45 g) was obtained from 50 % urea + 50% *Azolla pinnata* (S_4 treatment) which was statistically similar to 100 % urea (S_3 treatment). The minimum dry matter hill^{-1} (5.38 g) at 30 DAT was obtained from (S_1 treatment) 100% fresh *Azolla pinnata* which was statistically similar with the control (S_5 treatment). At 60 DAT, the maximum dry matter hill^{-1} (22.37 g) was obtained from 100% urea (S_3 treatment) which was statistically (S_2 treatment) and 50 % urea + 50% *Azolla pinnata* (S_4 treatment. The minimum dry matter hill^{-1} (above ground) (12.06 g) at 60 DAT was obtained from (S_1 treatment) 100% fresh *Azolla pinnata*. At 90 DAT and harvest, the maximum dry matter hill^{-1} was (24.16 and 48.66 g) obtained from 100% urea (S_3 treatment) which is statistically different from other treatments. At 90 DAT and harvest, the minimum dry matter content hill^{-1} was (24.16 and 48.66 g) obtained from 100% fresh *Azolla pinnata* (S_1 treatment).



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 10. Dry matter hill^{-1} (above ground) of boro rice as influenced by fertilizer sources ($LSD_{(0.05)}$= 2.49, 5.07, 5.51 and 6.39 at 25, 45, 65, 85 DAT and at harvest, respectively).

4.1.5.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect at 30, 60, 90 DAT and at harvest (Appendix VII and Table 5). At 30 DAS, the maximum dry matter content hill^{-1} was (8.78 g) observed in M_2S_3 treatment (top dressing by 100% urea) while the minimum dry matter hill^{-1} was (5.01 g) observed in top dressing by 100% fresh *Azolla pinnata* (M_2S_1 treatment). At 60 DAT, the maximum dry matter hill^{-1} was observed (23.39 g) in M_1S_3 treatment (basal application by 100% urea) while the minimum dry matter hill^{-1} was (11.29 g) observed in top dressing by 100% fresh *Azolla pinnata* (M_2S_1 treatment). At 90 DAT, dry matter hill^{-1} was (40.61 g) obtained in M_2S_3 treatment (top dressing by 100% urea) while the minimum dry matter hill^{-1} was (25.97 g) observed in basal application by control (M_1S_5 treatment). At harvest, the maximum dry matter hill^{-1} was (73.51 g) found in M_1S_3 treatment (basal application by 100% urea) which is different from other treatments and the minimum dry matter content hill^{-1} was (52 g) obtained from M_1S_1 which was statistically similar with 100% dry *Azolla pinnata*, control and 100% fresh *Azolla pinnata* (M_1S_2, M_1S_5 and M_2S_1 treatments), respectively.

Table 5. Interaction effect of fertilizer application methods and fertilizer sources on dry matter hill^{-1} (above ground) of boro rice at different growth stages

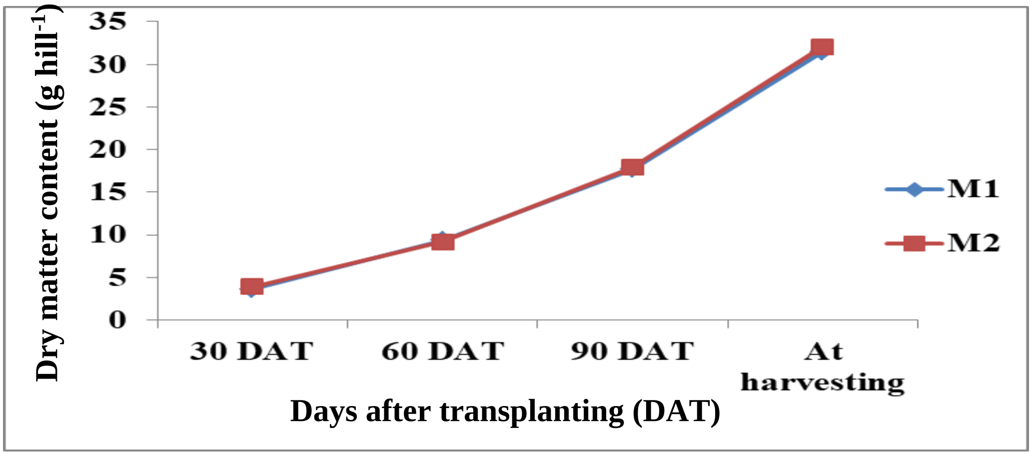
Treatments	Dry matter content (g hill^{-1})			
	30 DAT	60 DAT	90 DAT	At harvest
M_1S_1	5.66 d-f	12.72 c-e	27.38 d-f	52.00f g
M_1S_2	5.24 d-f	15.35 b-e	30.00 de	53.32 e-g
M_1S_3	7.84 a-d	23.39 a	40.51 ab	73.51 a
M_1S_4	9.56 a	19.92 a-c	34.91 a-d	61.70 b-e
M_1S_5	6.74 b-f	12.55 de	25.97 ef	44.35 g
M_2S_1	5.01 f	11.39 e	20.93 f	45.32 g
M_2S_2	5.61 d-f	19.66 a-d	37.93 a-c	65.91 a-c
M_2S_3	8.78 a-c	21.35 ab	40.61 a	69.25 ab
M_2S_4	9.34 ab	16.37 a-d	35.29 bc	65.80 a-d
M_2S_5	7.80 a-e	13.53 c-e	27.69 d-f	55.89 ef
$LSD_{(0.05)}$	2.73	7.17	7.79	9.03
CV (%)	3.63	2.49	3.91	8.89

In a column, the means having the same letter (s) do not differ significantly.
CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.6 Dry matter (Root) hill^{-1}

4.1.6.1 Effect of fertilizer application methods

Fertilizer application methods had non-significantly influenced on dry matter content hill^{-1} (root) at 30, 60, 90 DAT and at harvest after transplanting (Appendix IX and Figure 11). The result revealed that at 30 DAT, the maximum dry matter content hill^{-1} (root) (7.33 g) was obtained from top dressing (M_2) followed by basal application. At 60 DAT, the maximum dry matter content hill^{-1} (root) (16.79 g) was also recorded from basal application (M_1) followed by top dressing (16.46 g). But at 90 DAT, the maximum dry matter hill^{-1} (root) was (31.76) shown in top dressing (M_2) followed by basal application (M_1). At harvest, the maximum dry matter content hill^{-1} (root) (60.45 g) was obtained from top dressing (M_2). The results were statistically similar in each case.

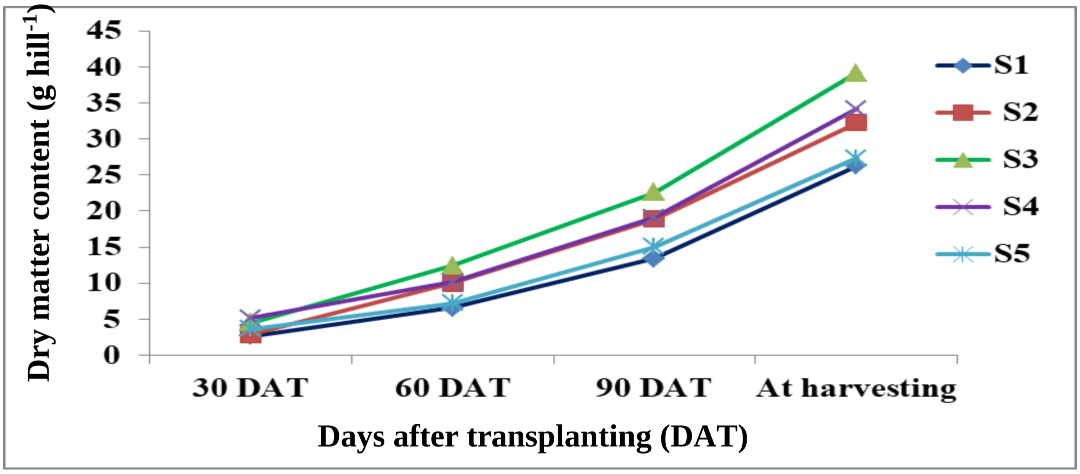


Note: M_1 = Basal application, M_2 = Top dressing

Figure 11. Dry matter hill^{-1} (Root) of boro rice as influenced by fertilizer application methods (LSD$_{(0.05)}$= NS, NS, NS and NS at 30, 60, 90 DAT and at harvest, respectively).

4.1.6.2Effect of fertilizer sources

Fertilizer sources had significant effect on dry matter hill^{-1} (root) had significant effect at 30, 60, 90 DAT and at harvest (Appendix IX and Figure 12). At 30 DAT, the maximum dry matter content hill^{-1} (root) (5.12 g) was obtained from 50 % urea + 50% *Azolla pinnata* (S_4 treatment) while the minimum dry matter hill^{-1} (root) (2.65 g) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment). At 60 DAT, the maximum dry matter hill^{-1} (root) (12.41 g) was obtained from 100% urea (S_3 treatment) while the minimum dry matter hill^{-1} (root) (6.55 g) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment). At 90 DAT and harvest, the maximum dry matter hill^{-1} (root) was (22.60 and 39.13 g) from 100% urea (S_3 treatment) and the minimum dry matter hill^{-1} (root) was (26.29 g) obtained from 100% fresh *Azolla pinnata* (S_1 treatment).



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 12. Dry matter hill^{-1} (root) of boro rice as influenced by fertilizer sources ($LSD_{(0.05)=}$ 1.44, 2.71, 3.23 and 3.44 at 30, 60, 90 DAT and at harvest, respectively).

4.1.6.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on dry matter hill^{-1} (root) observed at 30, 60, 90 DAT and at harvest (Appendix IX and Table 6). At 30 DAS, the maximum dry matter content hill^{-1} (root) was (4.84 g) observed in top dressing by 100% urea (M_2S_3 treatment) and the minimum dry matter content hill^{-1} (root) was (2.52 g) observed in top dressing by 100% fresh *Azolla pinnata* (M_2S_1 treatment). At 60 DAT, the maximum dry matter hill^{-1} (root) was observed (12.97) in basal application by 100% urea (M_1S_3 treatment) while the minimum dry matter content hill^{-1} (root) was (6.80 g) observed in top dressing by 100% fresh *Azolla pinnata* (M_2S_1 treatment). At 90 dry matters content hill^{-1} (root) was (22.74) maximum in basal application by 100% urea (M_1S_3 treatment) the minimum dry matter content hill^{-1} (root) was (11.54 g) observed in top dressing by 100% fresh *Azolla pinnata* (M_2S_1 treatment). At harvest, dry matter hill^{-1} (above ground) was (40.42) found in basal application by 100% urea (M_1S_3 treatment) which was different from other treatments.

Table 6. Interaction effect of fertilizer application method and sources on dry matter content hill^{-1} (root) of boro rice at different growth stages

Treatments	Dry matter content of root (g hill^{-1})			
	30 DAT	60 DAT	90 DAT	At harvest
M_1S_1	2.78 de	7.02 e	15.21 d-g	28.49 e-g
M_1S_2	2.69 de	8.62 b-e	16.53 b-f	29.04 ef
M_1S_3	4.11 a-d	12.97 a	22.74 a	40.42 a
M_1S_4	5.07 ab	11.02 a-d	19.28 a-d	34.52 b
M_1S_5	3.51 b-e	7.19 c-e	14.64 ef	25.11 ef
M_2S_1	2.52 de	6.08 e	11.54 g	24.09 g
M_2S_2	3.01 c-e	11.30 a-c	21.29 a-c	35.41 bc
M_2S_3	4.84 a-c	11.85 ab	22.47 ab	37.84 ab
M_2S_4	5.18 a	9.29 a-e	18.85 a-e	34.07 b-d
M_2S_5	3.83 a-e	7.30 c-e	15.31 d-g	29.57 de
$LSD_{(0.05)}$	2.04	3.83	4.57	4.87
CV (%)	3.33	2.88	4.85	8.83

In a column, the means having the same letter (s) do not differ significantly.

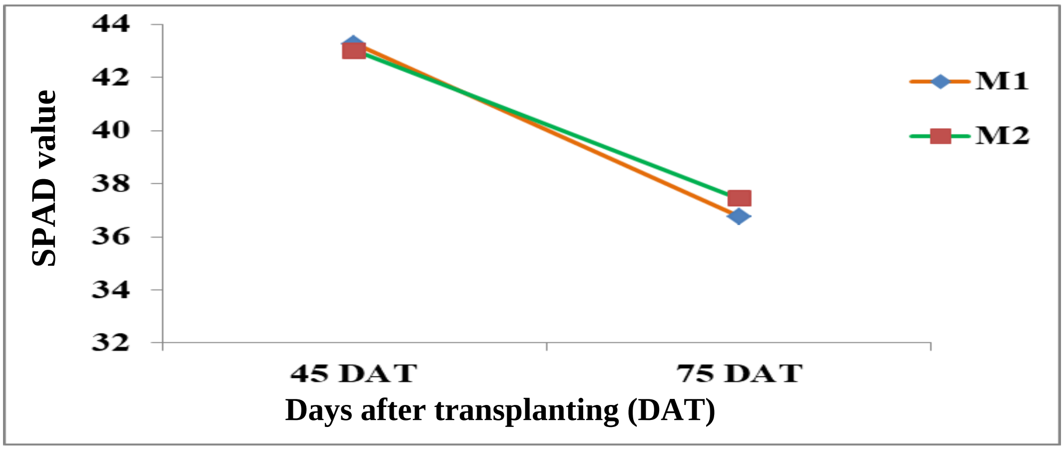
CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.7 SPAD value

4.1.7.1 Effect of fertilizer application methods

Fertilizer application methods had non-significantly influenced on SPAD value at 45 and 75 DAT after transplanting (Appendix X and Figure 13). The result revealed that at 45 DAT, the maximum SPAD value (43.27) was obtained from basal application (M_1) but the result was statistically similar with other treatments. At 75 DAT, the maximum SPAD value (37.45) was also recorded from top dressing (M_2) followed by basal application (M_1 treatment). The results were statistically similar in each case.

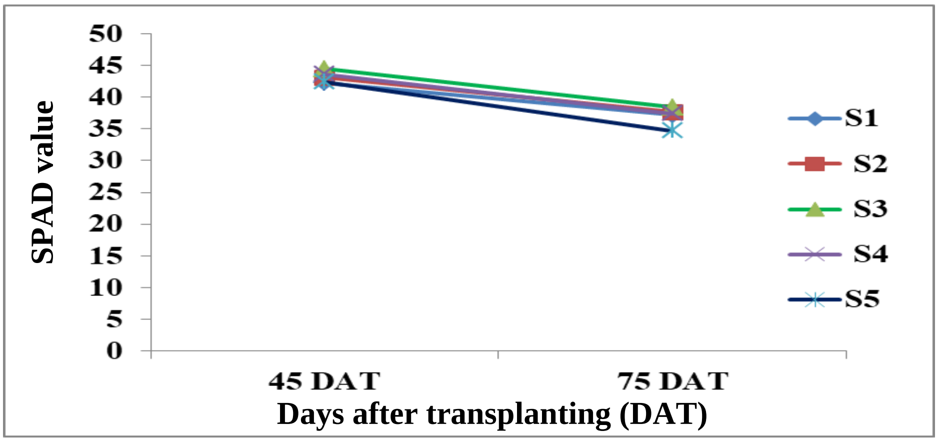


Note: M_1 = Basal application, M_2 = Top dressing

Figure 13. SPAD value of boro rice as influenced by fertilizer application methods ($LSD_{(0.05)}$= NS and NS at 45 and 75 DAT, respectively).

4.1.7.2 Effect of fertilizer sources

Fertilizer sources had significant effect on SPAD value at 45 and 75 DAT (Appendix (X and Figure 14). At 45 DAT, the maximum SPAD value (44.43) was obtained from 100% urea (S_3 treatment) which was different from other treatments and the minimum SPAD value (42.27) was obtained from 100% fresh *Azolla pinnata* (S_1 treatment). At 75 DAT, the maximum SPAD value (38.44) was obtained from 100% urea (S_3 treatment) which was statistically similar with 100% dry *Azolla pinnata* (S_2 treatment), 50% urea + 50% dry *Azolla pinnata* (S_4 treatment) *and* 100% *Azolla pinnata* (S_1 treatment). The minimum SPAD value (34.72) was obtained from control (S_5 treatment).



Note: S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 14. SPAD value of boro rice as influenced by fertilizer sources ($LSD_{(0.05)}$= 0.99 and 2.29 at 45 and 75 DAT, respectively).

4.1.7.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on SPAD value observed at 45 and 75 DAT (Appendix X and Table 7). At 45 DAT, the maximum SPAD value was (45.08) observed in basal application by 100% urea (M_1S_3 treatment) and the minimum SPAD value was (42.17) obtained in basal application by 100% *Azolla pinnata* (M_1S_1 treatment). At 75 DAT, the maximum SPAD value was observed (38.61) in M_2S_3 treatment (top dressing by 100% urea) and the minimum SPAD value was (34.71) obtained in top dressing by 100% *Azolla pinnata* (M_2S_5 treatment).

Table 7. Interaction effect of fertilizer application methods and sources on SPAD value of boro rice at different growth stages

Treatments	SPAD value at	
	45 DAT	75 DAT
M_1S_1	42.17 c	36.87 a-f
M_1S_2	43.57 bc	36.92 a-f
M_1S_3	45.08 a	38.27 a-c
M_1S_4	43.13 bc	37.02 a-e
M_1S_5	42.42 c	34.73 d-f
M_2S_1	42.37 c	37.59 a-e
M_2S_2	42.61c	38.45 ab
M_2S_3	43.79 a	38.61 a
M_2S_4	44.15 ab	37.88 a-d
M_2S_5	42.58 c	34.71 d-f
$LSD_{(0.05)}$	1.40	3.24
CV (%)	1.88	5.04

In a column, the means having the same letter (s) do not differ significantly.
CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.8 Time of flowering and maturity

4.1.8.1 Effect of fertilizer application methods

Fertilizer application methods had not significantly influenced on flowering and maturity duration (Appendix XI and Table 8). The result revealed that the maximum duration required for flowering was (128.93 days) observed in top dressing (M_2) which was statistically similar with (128.40 days) basal application (M_1). The maximum maturity duration (159 days) was observed in top dressing (M_2) and minimum maturity (158.53 days) was observed in basal application (M_1) which was statistically similar.

4.1.8.2 Effect of fertilizer sources

Fertilizer sources had significant effect on flowering and maturity duration (Appendix XI and Table 8). The maximum duration of flowering (130.67 days) was obtained from control method (S_5 treatment) while the minimum duration of flowering (127.33 days) was obtained from 100% dry *Azolla pinnata* (S_2 treatment). The maximum duration of maturity (159.17 days) was obtained from control (S_5 treatment).The result shown that the effect of fertilizer sources on flowering and maturity duration was non-significant and statistically similar.

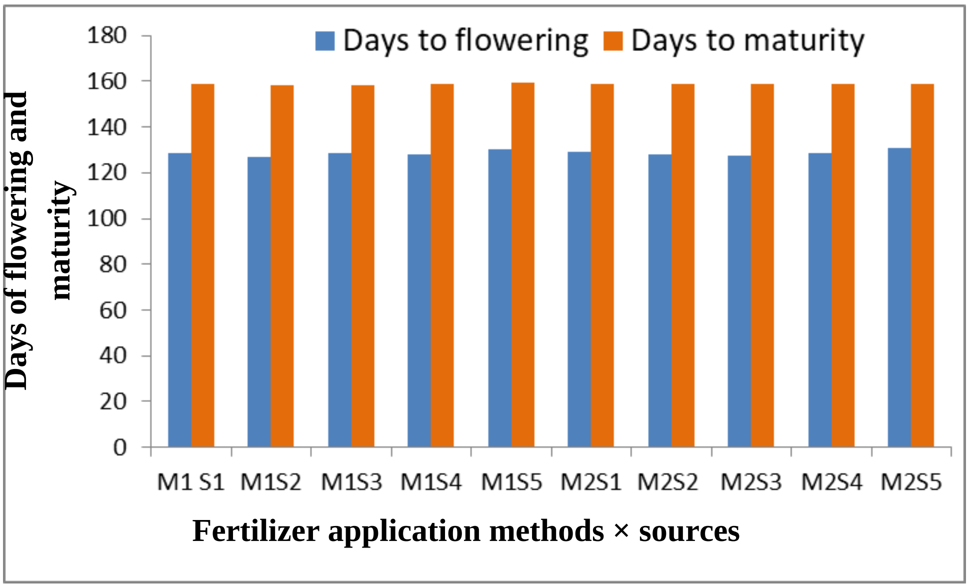
Table 8. Effect of fertilizer application methods and sources on flowering and maturity of boro rice

Treatments	Days to flowering	Days to maturity
Fertilizer application methods		
M_1	128.40	158.53
M_2	128.93	159
$LSD_{(0.05)}$	NS	NS
CV (%)	0.57	0.80
Fertilizer sources		
S_1	129.00ab	158.83
S_2	127.33b	158.50
S_3	128.00b	158.50
S_4	128.33b	158.83
S_5	130.67a	159.17
$LSD_{(0.05)}$	1.88	NS
CV (%)	1.19	0.43

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.1.8.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect was observed on flowering and maturity duration (Appendix XI and Figure 15). The maximum flowering duration (130.33 days) was observed in basal application by control (M_1S_5 treatment) but the result was statistically similar with other treatments. The maximum maturity duration (159.33 days) was observed in basal application by control (M_1S_5 treatment) which was statistically similar with other treatments.



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 15. Duration of flowering and maturity influenced by interaction effect of fertilizer application methods and fertilizer sources ($LSD_{(0.05)}$= NS and NS at days of flowering and maturity respectively).

4.2 Yield contributing characters

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of fertilizer application methods

Fertilizer application methods had non-significant effect on number of effective tillers hill^{-1} at harvest (Appendix XII and Table 9). The maximum number of effective tillers hill^{-1} (9.61) was recorded from basal application (M_1 treatment) but the result was statistically similar with other treatment.

4.2.1.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of effective tillers hill^{-1} at harvest (Appendix XII and Table 9). The highest number of effective tillers hill^{-1} (11.03) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 50% urea + 50% *Azolla pinnata* (S_4 treatment). Whereas the lowest number of effective tiller hill^{-1} (7.97) from control (no Urea and no *Azolla pinnata*) (S_5 treatment) which was statistically similar with 100% from *Azolla pinnata* (S_1 treatment). Rahman *et al*. (2015) stated that effective tillers hill^{-1} was increased by apply urea fertilizer at recommended.

Table 9. Effect of fertilizer application methods and fertilizer sources on no. of effective tillers, ineffective tillers and total tillers hill^{-1} of boro rice

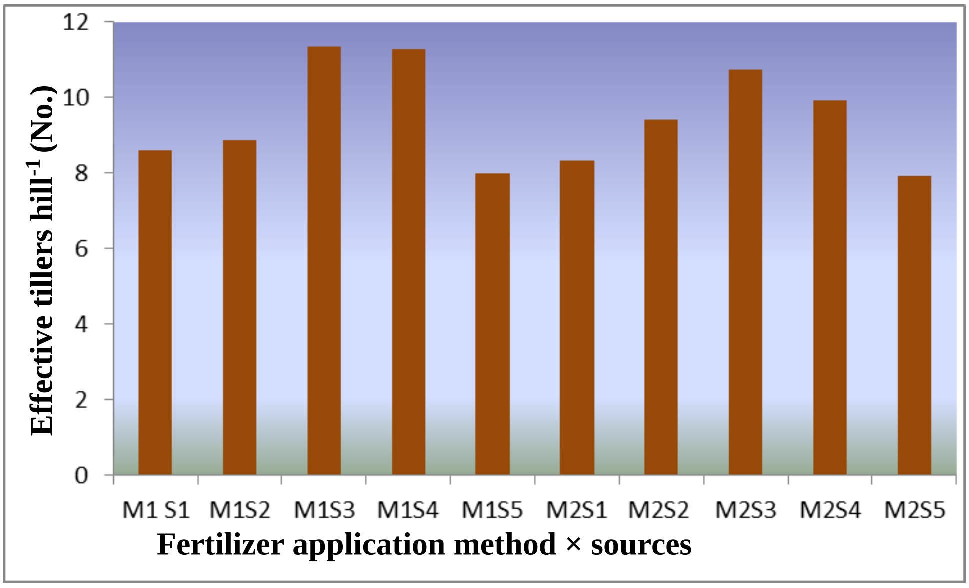
Treatments	No. of effective tillers hill^{-1}	No. of ineffective tillers hill^{-1}	No of total tillers hill^{-1}
Fertilizer application methods			
M_1	9.61	0.13	9.75
M_2	9.27	0.80	9.35
$LSD_{(0.05)}$	NS	NS	NS
CV (%)	6.48	8.73	12.27
Fertilizer sources			
S_1	8.47 cd	0.10	8.57 cd
S_2	9.13 c	0.10	9.23 c
S_3	11.03 a	0.20	11.23 a
S_4	10.60 ab	0.13	10.73 ab
S_5	7.97 d	0	7.97 d
$LSD_{(0.05)}$	0.74	NS	0.76
CV (%)	6.36	4.52	9.56

In a column, the means having the same letter (s) do not differ significantly. NS= Non-significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.2.1.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of effective tiller hill^{-1} at harvest (Appendix XII and Figure 16). The maximum number of effective tiller hill^{-1} (11.33) was observed in basal application by 100% urea (M_1S_3 treatment) which was statistically similar with M_1S_4 treatment. The minimum number of effective tillers hill^{-1} (7.93) was observed in top dressing by control condition (M_2S_5 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 16. Interaction effect of fertilizer application methods and sources on number of effective tillers hill^{-1} of boro rice ($LSD_{(0.05)}$= 1.04).

4.2.2 Number of in-effective tillers hill^{-1}

4.2.2.1 Effect of fertilizer application methods

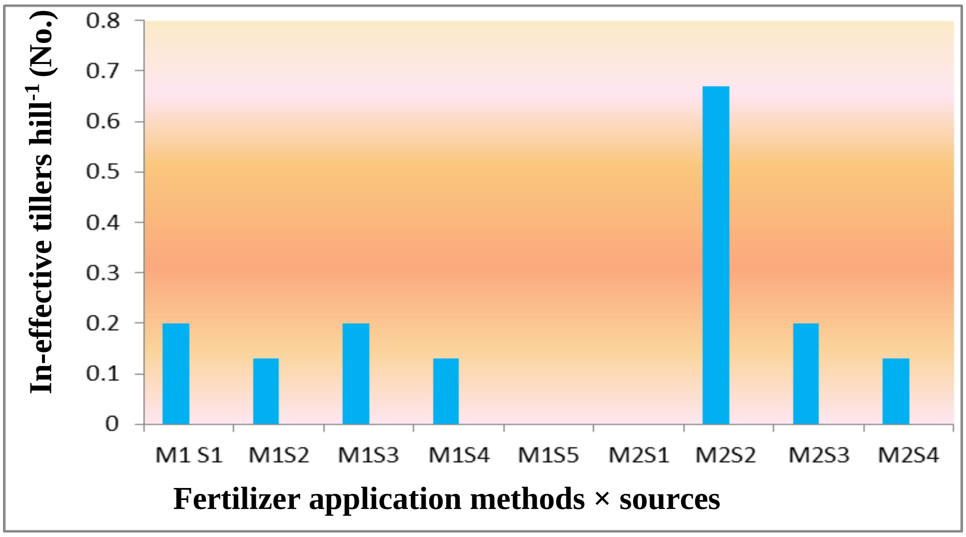
Fertilizer application methods had no significant effect on number of in-effective tillers hill^{-1} at harvest (Appendix XII and Table 9). The maximum number of in-effective tillers hill^{-1} (0.80) was recorded from top dressing (M_2 treatment) which was statically similar with other treatment. So number of in-effective tillers hill^{-1} at harvest of boro rice was not affected by fertilizer application methods.

4.2.2.2 Effect of fertilizer sources

Fertilizer sources had no significant effect on number of in-effective tillers hill^{-1} at harvest (Appendix XII and Table 9). The maximum number of non-effective tillers hill^{-1} (0.20) was recorded from 100% urea (S_3 treatment) which was similar with other treatment. So, the effect of fertilizer sources showed non-significant effect on number of in-effective tillers hill^{-1}.

4.2.2.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect on number of in-effective tillers hill^{-1} was observed at harvesting (Appendix XII and Figure 17). The maximum number of in-effective tiller hill^{-1} (0.67) was observed in 100% urea top dressing (M_2S_2 treatment) which was statistically similar result showed with other treatments. So, interaction effect of fertilizer application methods and fertilizer sources on number of in-effective tillers hill^{-1} was non-significant and statistically similar.



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 17. Interaction effect of fertilizer application methods and sources on number of in-effective tillers hill^{-1} of boro rice

4.2.3.1 Number of total tillers hill^{-1}

4.2.3.1 Effect of fertilizer application methods

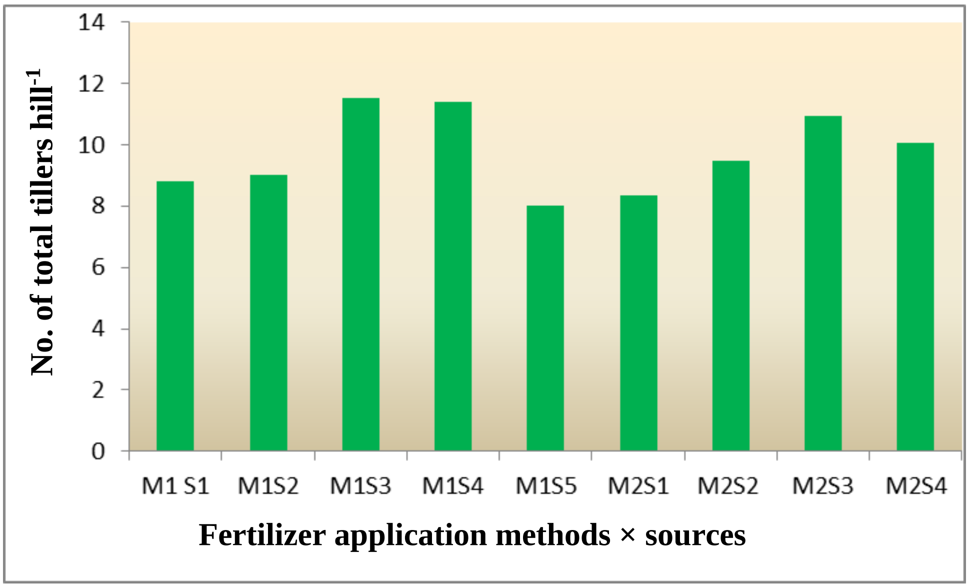
Fertilizer application methods had not significantly effect on number of total tillers hill^{-1} at harvest (Appendix XII and Table 9). The maximum number of total tillers hill^{-1} (9.75) was recorded from basal application (M_1 treatment) which was statically similar with top dressing (M_2 treatment).

4.2.3.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of total tillers hill^{-1} at harvest (Appendix XII and Table 9). The maximum number of total tillers hill^{-1} (11.23) was recorded from 100% urea (S_3 treatment) which was statistically similar with 50% urea and 50% dry *Azolla pinnata* (S_4 treatment). The minimum number of total tillers hill^{-1} (7.97) was recorded from control (S_5 treatment) which was statistically similar with 100% fresh *Azolla pinnata* (S_1 treatment).

4.2.3.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of total tiller hill^{-1} was observed at harvesting (Appendix XII and Figure 18). The maximum number of total tiller hill^{-1} (11.53) was observed in basal application by 100% urea (M_1S_3 treatment) which was statistically similar with basal application by 50% urea + 50% dry *Azolla pinnata* (M_1S_4 treatment) and the minimum number of total tiller hill^{-1} (7.93) was observe in top dressing by control (M_2S_5 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 18. Interaction effect of fertilizer application methods and sources on number of total tillers hill^{-1} of boro rice ($LSD_{(0.05)}$= 1.36).

4.2.4 Length of flag leaf

4.2.4.1 Effect of fertilizer application methods

Fertilizer application methods had no significant effect on length of flag leaf was observed (Appendix XIII and Table 10). The maximum length of flag leaf (19.56 cm) was recorded from basal application (M_1 treatment) which was similar with other treatment.

4.2.4.2 Effect of fertilizer sources

Fertilizer sources significantly effect on length of flag leaf observed (Appendix XIII and Table 10). The highest flag leaf length (20.33 cm) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 100% fresh *Azolla pinnata* (S_1 treatment) and 50% urea + 50% *Azolla pinnata* (S_4 treatment) whereas the lowest length of flag leaf (17.82 cm) recorded from 100% fresh *Azolla pinnata* (S_1 treatment) which was statistically similar to control (S_5 treatment).

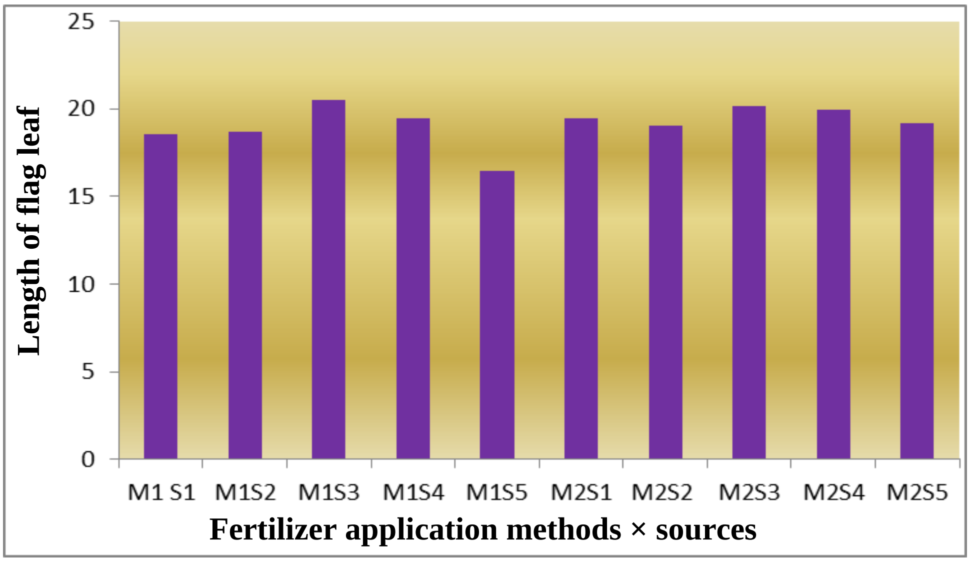
Table 10. Effect of fertilizer application methods and fertilizer sources on flag leaf length, number of rachis branches panicle^{-1} and panicle length of boro rice

Treatments	Flag leaf length (cm)	Rachis branches panicle^{-1} (no.)	Panicle length (cm)
Fertilizer application methods			
M_1	18.73	9.48	25.70 a
M_2	19.56	9.47	24.95 b
$LSD_{(0.05)}$	NS	NS	0.87
CV (%)	6.35	7.53	3.23
Fertilizer sources			
S_1	19.00 a-c	8.67 d	24.05 c
S_2	18.88 bc	9.25 c	24.93 c
S_3	20.33 a	10.53 a	26.91 a
S_4	19.71 ab	10.08 ab	26.83 ab
S_5	17.82 c	8.85 cd	23.90 c
$LSD_{(0.05)}$	1.62	0.56	1.37
CV (%)	6.89	4.83	4.43

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.2.4.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on length of flag leaf was observed (Appendix XII and Figure 19). The maximum flag leaf length (20.53 cm) was observed in basal application by 100% urea (M_1S_3 treatment). The minimum flag leaf length (18.53 cm) was observed in 100% fresh *Azolla pinnata* (M_1S_1 treatment). So, the interaction effect of fertilizer application methods and fertilizer sources on flag leaf length was statistically significant.



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 19. Interaction effect of fertilizer application methods and fertilizer sources on flag leaf length of boro rice

4.2.5 Number of rachis branches panicle^{-1}

4.2.5.1 Effect of fertilizer application methods

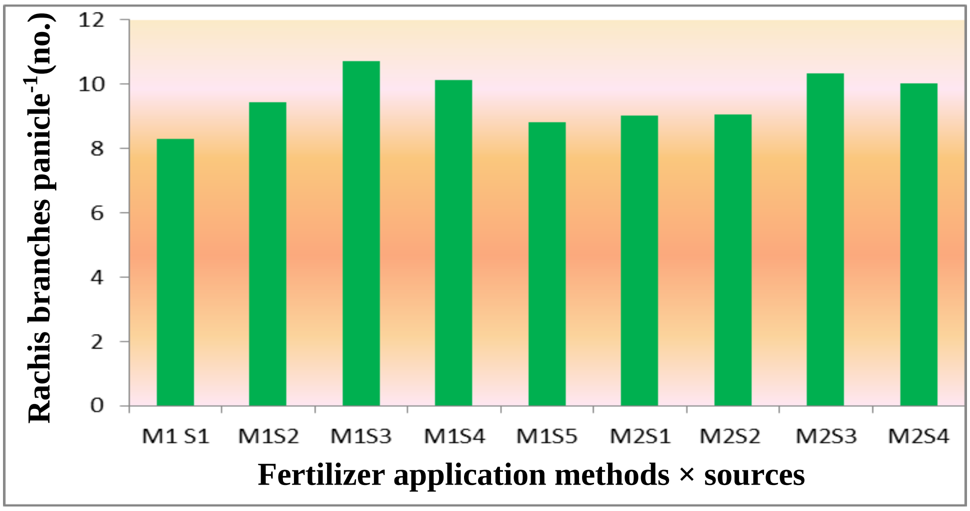
Fertilizer application methods had no significant effect on number of rachis branches panicle^{-1} (Appendix XIII and Table 10). The maximum number of rachis branches panicle^{-1} (9.48) was recorded from basal application (M_1 treatment) which was similar with other treatment.

4.2.5.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of rachis branches panicle^{-1} (Appendix XIII and Table 10). The maximum number of rachis branches panicle^{-1} (10.53) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 50% urea + 50% *Azolla pinnata* (S_4 treatment). Whereas the minimum number of rachis branches panicle^{-1} (8.67) from 100% *Azolla pinnata* (S_1 treatment) which was statistically 100 % fresh *Azolla pinnata* (S_1 treatment) and control (no Urea and no *Azolla pinnata*) (S_5 treatment).

4.2.5.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of rachis branches panicle^{-1} (Appendix XIII and Figure 20). The maximum number of rachis branches panicle^{-1} (10.73) was observed in basal application of 100% urea (M_1S_3 treatment) which was statistically similar with basal application of 50% urea + 50% dry *Azolla pinnata* (M_1S_4 treatment) and top dressing of 100% urea (M_2S_3 treatment). The minimum number of rachis branches panicle^{-1} (8.30) was observed in basal application of 100% fresh *Azolla pinnata* (M_1S_1 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 20. Interaction effect of fertilizer application methods and fertilizer source on number of rachis branches panicle^{-1} of boro rice ($LSD_{(0.05)}$= 0.79).

4.2.6 Length of panicle

4.2.6.1 Effect of fertilizer application methods

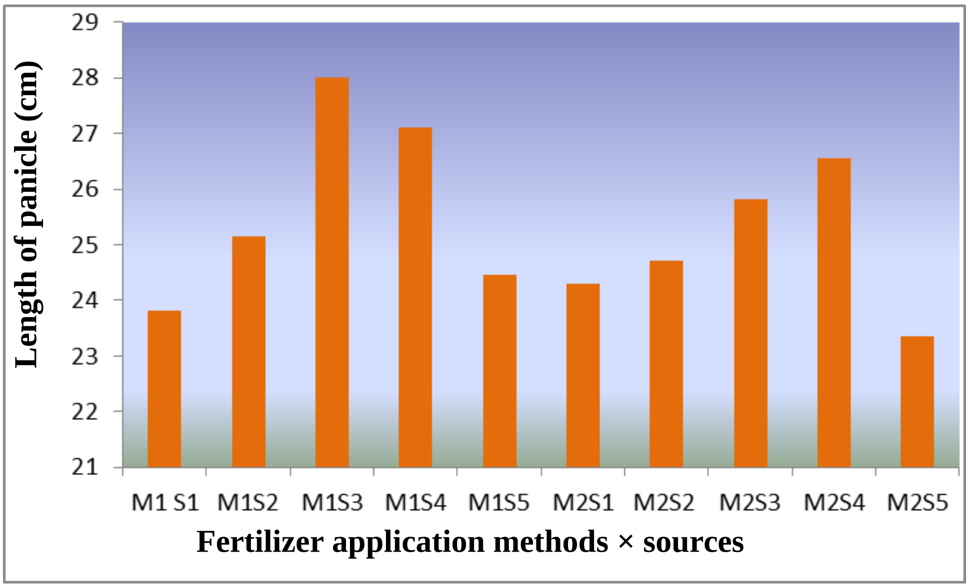
Fertilizer application methods had significant effect on length of panicle (Appendix XIII and Table 10). The maximum length of panicle (25.70 cm) was recorded from basal application (M_1 treatment) which was statistically different from other treatment. The minimum panicle length was (24.95 cm) observed from top dressing (M_2 treatment).

4.2.6.2 Effect of fertilizer sources

Fertilizer sources had significant effect on length of panicle (Appendix XIII and Table 10). The maximum length of panicle (26.91 cm) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 50% urea + 50% *Azolla pinnata* (S_4 treatment). Whereas the minimum (23.90 cm) from control (S_5 treatment) (no Urea and no *Azolla pinnata*) which was statistically similar to 100 % fresh *Azolla pinnata* (S_1 treatment). Karim *et al.* (2019) also reported that highest panicle length obtained from higher urea fertilizer application.

4.2.6.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on length of panicle (Appendix XII and Figure 21). The maximum length of panicle (28.01 cm) was observed in basal application by 100% urea (M_1S_3 treatment) which was statistically similar with basal application by 50% urea + 50% dry *Azolla pinnata* (M_1S_4 treatment). The minimum length of panicle (23.35 cm) was observed in basal application by control (M_2S_5 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 21. Interaction effect of fertilizer application methods and fertilizer source length on panicle of boro rice ($LSD_{(0.05)}$= 1.94).

4.2.7 Filled grains panicle^{-1}

4.2.7.1 Effect of fertilizer application methods

Fertilizer application methods had significant effect on filled grains panicle^{-1} (Appendix XIV and Table 11). The maximum number of filled grains panicle^{-1} (166.16) was recorded from M_2 treatment (top dressing) whereas the minimum number of filled grains panicle^{-1} (158.07) from basal application (M_1 treatment). Kamruzzaman *et al.* (2014) also suggest that highest filled grain obtain from top dressing.

4.2.7.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of filled grains panicle^{-1} (Appendix XIV and Table 11). The maximum filled grains panicle^{-1} (180.43) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 50% urea + 50% *Azolla pinnata* (S_4 treatment). Whereas the minimum number of filled grains panicle^{-1} (136.07) obtained from 100 % fresh *Azolla pinnata* (S_1 treatment).

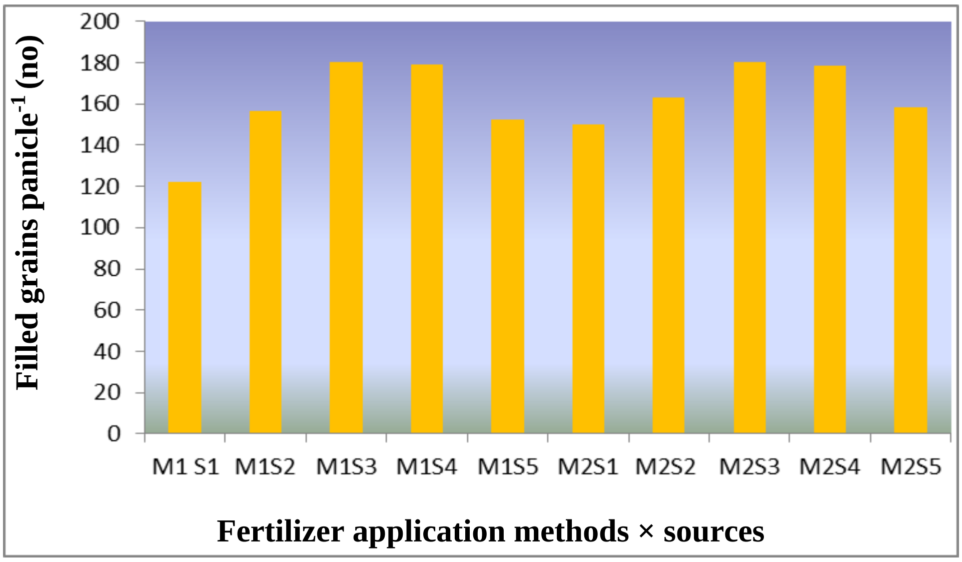
Table 11. Effect of fertilizer application methods and fertilizer sources on number of filled grains unfilled grains, total grains per panicle and 1000 grains weight of boro rice

Treatments	No. of filled grains $panicle^{-1}$	No. of unfilled grains $panicle^{-1}$	No. of total grains $panicle^{-1}$	1000 grains weight (g)
Fertilizer application methods				
M_1	158.07 b	18.75	176.83 b	22.63
M_2	166.16 a	18.37	184.53 a	21.46
$LSD_{(0.05)}$	7.61	NS	8.34	NS
CV (%)	5.56	9.89	5.87	12.92
Fertilizer sources				
S_1	136.07 e	26.10 a	162.17 d	21.67 a-c
S_2	159.83 c	15.90 c	175.73 c	20.17 c
S_3	180.43 a	13.18 c	193.62 a	23.56 a
S_4	178.83 ab	14.22 c	193.05 ab	21.83 a-c
S_5	155.42 cd	23.42 ab	178.83 c	22.99 ab
$LSD_{(0.05)}$	12.02	3.02	13.20	2.48
CV (%)	6.06	13.21	5.97	9.23

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

4.2.7.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of filled grains $panicle^{-1}$ (Appendix XIV and Figure 22). The maximum number of filled grains $panicle^{-1}$ (180.50) was observed in top dressing by 100% urea (M_2S_3 treatment) and the minimum number of filled grains $panicle^{-1}$ (121.97) was observed in basal application 100% fresh *Azolla pinnata* (M_1S_1 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 21. Interaction effect of fertilizer application methods and fertilizer sources on number of filled grain panicle^{-1} of boro rice ($LSD_{(0.05)}$= 5.67).

4.2.8 Unfilled grains panicle^{-1}

4.2.8.1 Effect of fertilizer application methods

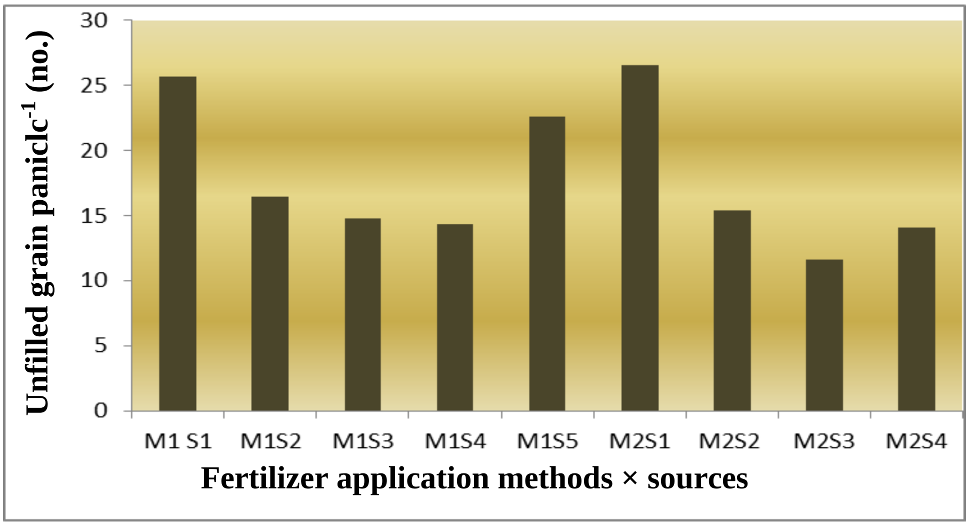
Fertilizer application methods had no significant effect on number of unfilled grains panicle^{-1} (Appendix XIV and Table 11). The maximum number of unfilled grains panicle^{-1} (18.75) was recorded from basal application (M_1 treatment which was similar with other treatment.

4.2.8.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of unfilled grains panicle^{-1} (Appendix XIV and Table 11). The maximum number of unfilled grains panicle^{-1} (26.10) was recorded from S_1 treatment (100 % fresh *Azolla pinnata*) which was statistically similar (.42) with control (no Urea and no *Azolla pinnata*). (S_5 treatment) Whereas the minimum number of unfilled grains panicle^{-1} (13.18) from 100 % urea (S_1 treatment) which was statistically similar with 50% urea + 50 % fresh *Azolla pinnata* (S_4 treatment) and 100 % dry *Azolla pinnata* (S_2 treatment).

4.2.8.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of unfilled grains panicle^{-1} (Appendix XIV and Figure 23). The numerically maximum number of unfilled grains panicle^{-1} (26.57) was observed in top dressing by 100% *Azolla pinnata* (M_2S_1 treatment). The minimum number of unfilled grains panicle^{-1} (11.63) was observed in top dressing by 100% urea (M_2S_3 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 22. Interaction effect of fertilizer application methods and fertilizer sources on length of panicle of boro rice

4.2.9 Total grains panicle^{-1}

4.2.9.1 Effect of fertilizer application methods

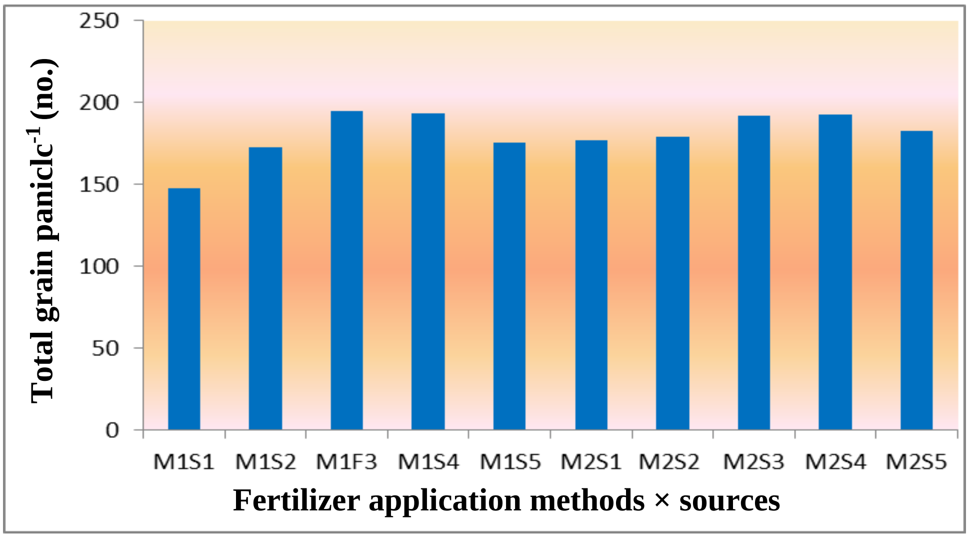
Fertilizer application methods had significant effect on total grains panicle^{-1} (Appendix XIV and Table 11). The maximum number of total grains panicle^{-1} (166.16) was recorded from top dressing (M_2 treatment) whereas the minimum number of total grains panicle^{-1} was (158.07) from basal application (S_1 treatment).

4.2.9.2 Effect of fertilizer sources

Fertilizer sources had significant effect on number of total grains panicle^{-1} (Appendix XIV and Table 11). The maximum total grains panicle^{-1} (180.43) was recorded from 100 % urea (S_3 treatment) which (178.83) was statistically similar with S_4 treatment (50% urea + 50% *Azolla pinnata*). Whereas the minimum number of total grains panicle^{-1} (162.17) obtained from 100 % fresh *Azolla pinnata* (S_1 treatment).

4.2.9.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of total grains panicle^{-1} (Appendix XIV and Figure 24). The maximum number of filled grains panicle^{-1} (180.50) was observed top dressing by 100% urea (M_2S_3 treatment). The minimum number of filled grains panicle^{-1} (121.97) was observed in basal application by 100% fresh *Azolla pinnata* (M_1S_1 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 23. Interaction effect of fertilizer application methods and fertilizer sources on total grain panicle^{-1} of boro rice (LSD$_{(0.05)}$= 6.22).

4.2.10 Weight of 1000 grains

4.2.10.1 Effect of fertilizer application methods

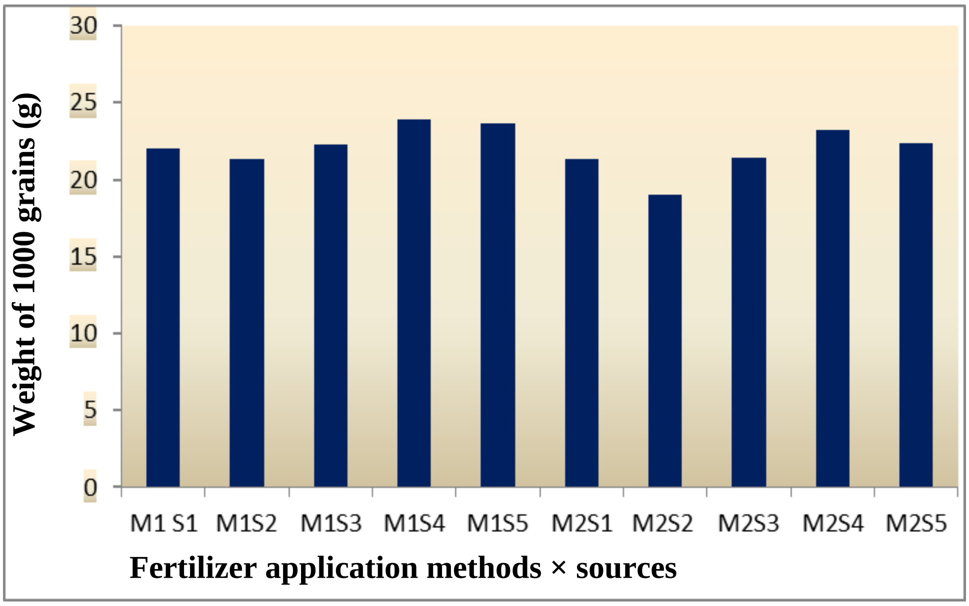
Fertilizer application methods had no significant effect on weight of 1000 grains of boro rice (Appendix XIV and Table 11). The maximum weight of 1000 grain (22.63 g) was recorded from basal application (M_1 treatment) which was different from other treatment. The result shown the effect of fertilizer application methods on weight of 1000 grains was non-significant and similar.

4.2.10.2 Effect of fertilizer sources

Fertilizer source had significant effect on weight of 1000 grains of boro rice (Appendix XIII and Table 11). The maximum weight of 1000 grains (23.56 g) was recorded from 100 % urea (S_3 treatment) whereas the minimum weight of 1000 grains was (20.17 g) from 100 % dry *Azolla pinnata* (S_2 treatment). Karim *et al.* (2019) reported that urea applied at recommendation dose increased 1000 grains weight.

4.2.10.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on weight of 1000-grains (Appendix XIV and Figure 26). The maximum weight of 1000 grain (23.93 g) was observed in basal application by 50% urea + 50 % *Azolla pinnata* (M_1S_4 treatment) whereas the minimum weight of 1000 grains (19 g) was observed in top dressing 100% dry *Azolla pinnata* (M_2S_2 treatment).



M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata)*

Figure 24. Interaction effect of fertilizer application methods and fertilizer sources on 1000-grain weight of boro rice ($LSD_{(0.05)}$= 3.52).

4.2.11 Fresh grain weight hill^{-1}

4.2.11.1 Effect of fertilizer application methods

Fertilizer application methods had no significant effect on fresh grain weight hill^{-1} (g) of boro rice (Appendix XV and Table 12). The maximum fresh grain weight hill^{-1} (30.49 g) was recorded from top dressing (M_2 treatment) which was similar with other treatment.

4.2.11.2 Effect of fertilizer sources

Fertilizer sources had significant effect on fresh grain weight hill^{-1} of boro rice (Appendix XIV and Table 12). The maximum fresh grain weight hill^{-1} (35.63 g) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 50% urea + 50% dry *Azolla pinnata* (S_4 treatment) whereas the minimum fresh grain weight hill^{-1} was (23.70 g) from control (S_5 treatment) which was statistically similar with 100% fresh *Azolla pinnata* (S_1 treatment) . The result shown the effect of fertilizer sources on fresh grain weight hill^{-1} was statistically significant.

Table 12. Effect of fertilizer application methods and fertilizer source on grain and straw weight hill^{-1} of boro rice

Treatments	Fresh grain weight hill^{-1}(g)	Dry grain weight hill^{-1}(g)	Fresh straw weight hill^{-1}(g)	Dry straw Weight hill^{-1} (g)
Fertilizer application methods				
M_1	28.13	25.51	43.15	31.46 b
M_2	30.49	27.47	42.83	34.97 a
$LSD_{(0.05)}$	NS	NS	NS	3.14
CV (%)	10.71	9.64	6.83	7.45
Fertilizer sources				
S_1	25.33 cd	23.00 cd	35.50 cd	29.27 cd
S_2	29.03 bc	26.48 bc	41.87 bc	34.28 b
S_3	35.63 a	31.73 a	57.07 a	41.40 a
S_4	32.87 ab	29.47 ab	46.90 b	33.87 bc
S_5	23.70 d	21.77 d	33.65 d	27.27 d
$LSD_{(0.05)}$	4.43	3.74	6.70	4.97
CV (%)	11.24	6.98	11.93	6.58

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.2.11.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on fresh grain weight hill^{-1} of boro rice (Appendix XIII and Table 13). The maximum fresh grain weight hill^{-1} (37.80 g) was observed in basal application by 100% urea (M_1S_3 treatment) while the minimum fresh grain weight hill^{-1} (21.33 g) was observed in controlled basal application by control (M_1S_5 treatment).

Table 13. Interaction effect of fertilizer application methods and fertilizer sources on grain and straw weight hill^{-1} of boro rice

Treatments	Fresh grain weight hill^{-1}(g)	Dry grain weight hill^{-1}(g)	Fresh straw weight hill^{-1}(g)	Dry straw weight hill^{-1} (g)
M_1S_1	25.80 de	23.27 ef	37.20 d-g	29.67 d-g
M_1S_2	25.47 de	23.17 ef	40.00 cd	30.77 c-e
M_1S_3	37.80 a	33.80 a	61.47 a	40.47 ab
M_1S_4	30.27 b-d	27.27 b-e	49.40 bc	34.13 b-d
M_1S_5	21.33 e	20.07 f	27.67 h	22.27 h
M_2S_1	24.87 de	22.73 ef	33.80 f-h	28.87 e-h
M_2S_2	32.60 a-d	29.80 a-c	43.63 b-e	37.80 a-c
M_2S_3	33.47 a-c	29.67 a-d	52.67 ab	42.33 a
M_2S_4	35.47 ab	31.67 ab	44.40 bd	33.60 b-e
M_2S_5	26.07 de	23.47 ef	39.63 d-f	32.27 c-f
$LSD_{(0.05)}$	6.27	5.29	9.48	7.03
CV (%)	11.24	6.98	11.93	6.58

In a column, the means having the same letter (s) do not differ significantly. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.2.12 Dry grain weight hill^{-1} (g)

4.2.12.1 Effect of fertilizer application methods

Fertilizer application methods had no significant effect on dry grain weight hill^{-1} of boro rice (Appendix XV and Table 12). The maximum dry grain weight hill^{-1} (27.47 g) was recorded from top dressing (M_2 treatment) which was similar with other treatment.

4.2.12.2 Effect of fertilizer sources

Fertilizer source had significant effect on dry grain weight hill^{-1} (Appendix XV and Table 12). The maximum dry grain weight hill^{-1} (31.73 g) was recorded from 100 % urea (S_3 treatment) which was statistically similar with 50% urea + 50% dry *Azolla pinnata* (S_4 treatment) whereas the minimum was (21.77g) from control application (S_5 treatment) which was statistically similar with 100 % fresh *Azolla pinnata* (S_1 treatment). The result shown the effect of fertilizer sources on dry grain weight hill^{-1} was statistically significant.

4.2.12.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect on fresh grain weight hill^{-1} of boro rice (Appendix XV and Table 13). The maximum dry grain weight hill^{-1} (33.80 g) was observed in basal application by 100% urea (M_1S_3 treatment) which was similar with other treatments.

4.2.13 Fresh straw weight hill^{-1}

4.2.13.1 Effect of fertilizer application methods

Fertilizer application methods had no significant effect on fresh straw weight hill^{-1} of boro rice (Appendix XV and Table 12). The maximum fresh straw weight hill^{-1} (43.15 g) was recorded from basal application (M_1 treatment) whereas the minimum fresh straw weight hill^{-1} was (42.83 g) from top dressing (M_1 treatment).

4.2.13.2 Effect of fertilizer sources

Fertilizer source had significant effect on fresh straw weight hill^{-1} of boro rice (Appendix XV and Table 12). The maximum fresh straw weight hill^{-1} (41.40 g) was recorded from 100 % urea (S_3 treatment) which was statistically different from other treatments. Whereas the lower was (33.65 g) from control (S_5 treatment) which was statistically similar with100 % fresh *Azolla pinnata* (S_1 treatment).

4.2.13.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on fresh straw weight hill^{-1} (g) was observed (Appendix XV and Table 13). The maximum fresh straw weight hill^{-1} (61.47 g) was observed in basal application by 100% urea (M_1S_3 treatment). The minimum fresh straw weight hill^{-1} (27.67 g) was observed in top dressing by 100% fresh *Azolla pinnata* (M_1S_1 treatment).

4.2.14 Dry straw weight hill^{-1}

4.2.14.1 Effect of fertilizer application methods

Fertilizer application methods had significant effect on dry straw weight hill^{-1} of boro rice (Appendix XIV and Table 12). The maximum dry straw weight hill^{-1} (34.97 g) was recorded from top dressing (M_2 treatment) which was statistically different from other treatments and the minimum fresh straw weight hill^{-1} was (31.46 g) from basal application (M_1 treatment).

4.2.14.2 Effect of fertilizer sources

Fertilizer sources had significant effect on dry straw weight hill^{-1} of boro rice (Appendix XIV and Table 12). The maximum dry straw weight hill^{-1} (41.40 g) was recorded from 100 % urea (S_3 treatment) which was statistically different from other treatments. Whereas the minimum dry straw weight hill^{-1} (27.27 g) was from control (S_5 treatment) which was statistically similar with 100 % fresh *Azolla pinnata* (S_1 treatment).

4.2.14.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on dry straw weight hill^{-1} of boro rice (Appendix XIII and Table 13). The maximum dry straw weight hill^{-1} (40.47 g) was observed in basal application by 100% urea (M_1S_3 treatment). The minimum fresh straw weight hill^{-1} (22.27 g) was observed in top dressing by 100% fresh *Azolla pinnata* (M_1S_5 treatment).

4.2.15 Fresh grain yield

2.2.15.1 Effect of fertilizer application methods

Fertilizer application methods had significant effect on fresh grain yield (t ha^{-1}) of boro rice (Appendix XV and Table 14). The maximum fresh grain yield (7.37 t ha^{-1}) was recorded from top dressing (M_2 treatment) whereas the minimum fresh grain yield (6.86 t ha^{-1}) was from basal application (M_1 treatment).

4.2.15.2 Effect of fertilizer sources

Fertilizer source had significant effect on fresh grain yield (t ha^{-1}) of boro rice (Appendix XV and Table 14). The maximum fresh grain yield (9.18t ha^{-1}) was recorded from 100 % urea (S_3 treatment) which was statistically different from other treatments. Whereas the minimum fresh grain yield (5.35t ha^{-1}) was from 100 % fresh *Azolla pinnata* (S_1 treatment) which was statistically similar with control (S_5 treatment).

Table 14. Effect of fertilizer application methods and fertilizer sources on grain and straw yield (t ha^{-1}) of boro rice

Treatments	Fresh grain yield (t ha^{-1})	Dry grain yield (t ha^{-1})	Fresh straw yield (t ha^{-1})	Dry straw yield (t ha^{-1})
Fertilizer application methods				
M_1	6.86 b	5.76 b	10.64	7.85
M_2	7.37 a	6.46 a	11.17	8.04
$LSD_{(0.05)}$	0.45	0.47	NS	NS
CV (%)	10.61	8.96	10.85	6.73
Fertilizer sources				
S_1	5.35 d	4.62 d	8.11 c	6.01 d
S_2	7.53 bc	6.37 bc	9.64 c	7.51 c
S_3	9.18 a	8.15 a	15.41 a	11.10 a
S_4	7.81 b	6.70 b	12.87 b	8.85 b
S_5	5.61 d	4.73 d	8.41 c	6.27 d
$LSD_{(0.05)}$	0.71	0.74	1.69	1.16
CV (%)	8.08	9.96	8.50	11.87

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.2.15.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on fresh grain yield (t ha^{-1}) of boro rice (Appendix XV and Table 15). The maximum fresh grain yield (9.34 t ha^{-1}) was observed in top dressing by 100 % urea (M_2S_3 treatment) which was statistically similar with basal application by 100 % urea (M_1S_3 treatment). The minimum fresh grain yield (5.18 t ha^{-1}) was observed in basal application by 100% fresh *Azolla pinnata* (M_1S_1 treatment).

Table 15. Interaction effect of fertilizer application methods and fertilizer source on grain and straw yield (t ha^{-1}) of boro rice

Treatments	Fresh grain yield (t ha^{-1})	Dry grain yield (t ha^{-1})	Fresh straw yield (t ha^{-1})	Dry straw yield (t ha^{-1})
M_1S_1	5.18 h	4.49 f	8.28 e	6.08 f
M_1S_2	7.13 d-g	5.86 de	10.07 de	7.91 c-e
M_1S_3	9.03 ab	7.78 ab	14.76 ab	10.47 ab
M_1S_4	7.77 c-f	6.32 c	11.64 d	8.28 cd
M_1S_5	5.19 h	4.37 f	8.45 e	6.52 ef
M_2S_1	5.51 h	4.75 f	7.94 e	5.95 f
M_2S_2	7.90 c-e	6.88 b-d	9.21 e	7.10 d
M_2S_3	9.34 a	8.52 a	16.24 a	11.73 a
M_2S_4	8.03 cd	7.08 bc	14.10 a-c	9.42 bc
M_2S_5	6.04 h	5.08 ef	8.37 e	6.02 f
$LSD_{(0.05)}$	0.91	1.04	2.39	1.63
CV (%)	8.08 c	9.96	8.50	11.87

In a column, the means having the same letter (s) do not differ significantly.

CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting

M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.2.16 Dry grain yield

4.2.16.1 Effect of fertilizer application methods

Fertilizer application methods had significant effect on dry grain yield (t ha^{-1}) of boro rice (Appendix XVI and Table 14). The higher dry grain yield (6.46 t ha^{-1}) was recorded from top dressing (M_2 treatment). Whereas the lower dry grain yield (5.76t ha^{-1}) was from basal application (M_1 treatment). The result shown the effect of fertilizer application methods on dry grain yield was statistically significant. Joseph *et al.* (2017) reported that grain yield increased in top dressing method than the basal application.

4.2.16.2 Effect of fertilizer sources

Fertilizer source had significant effect on dry grain yield (t ha^{-1}) was observed (Appendix XVI and Table 14). The maximum dry grain yield (8.15t ha^{-1}) was recorded from 100 % urea (S_3 treatment) which was statistically different from other treatments. Whereas the minimum dry grains yield (4.62t ha^{-1}) was from 100 % fresh *Azolla pinnata* (S_1 treatment) which was statistically similar with control (S_5 treatment).

4.2.16.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on dry grain yield (t ha^{-1}) of boro rice (Appendix XV and Table 15). The maximum dry grain yield (8.52 t ha^{-1}) was observed in top dressing by 100% urea (M_2S_3 treatment). The minimum dry grain yield (4.37t ha^{-1}) was observed in basal application by control (M_1S_5 treatment).

4.2.17 Fresh Straw yield

4.2.17.1 Effect of fertilizer application methods

Fertilizer application methods had no significant effect on fresh straw yield (t ha^{-1} of boro rice (Appendix XV and Table 14). The maximum fresh straw yield (11.17 t ha^{-1}) was recorded from top dressing (M_2 treatment). Whereas the minimum fresh straws yield (10.64t ha^{-1}) was from basal application (M_1 treatment).

4.2.17.2 Effect of fertilizer sources

Fertilizer source had significant effect on fresh straw yield (t ha^{-1}) of boro rice (Appendix XV and Table 14). The maximum fresh straw yield (15.41 t ha^{-1}) was recorded from S_3 treatment (100 % urea) which was statistically different from other treatments. Whereas the minimum fresh straws yield (4.62t ha^{-1}) was from S_1 treatment (100 % fresh *Azolla pinnata*) which was statistically similar with S_5 treatment (control).

4.2.17.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on fresh straw yield (t ha^{-1}) of boro rice (Appendix XV and Table 15). The maximum fresh straw yield (14.76 t ha^{-1}) was observed in basal application by 100% urea (M_1S_3 treatment). The minimum fresh straw yield (8.28t ha^{-1}) was observed in basal application by 100% fresh *Azolla pinnata* (M_1S_1 treatment).

4.2.18 Dry Straw yield

4.2.18.1 Effect of fertilizer application methods

Fertilizer application methods had non-significant effect on dry straw yield (t ha^{-1}) of boro rice (Appendix XV and Table 14). The maximum dry straw yield (8.04t ha^{-1}) was recorded from top dressing (M_2 treatment). Whereas the minimum dry straws yield (7.85t ha^{-1}) was from basal application (M_1 treatment).

4.2.18.2 Effect of fertilizer sources

Fertilizer source had significant effect on dry straw yield (t ha^{-1}) of boro rice (Appendix XIV and Table 14). The maximum dry straw yield (11.10 t ha^{-1}) was recorded from 100 % urea (S_3 treatment) which was statistically different from other treatments. Whereas the minimum fresh straws yield (6.01t ha^{-1}) was from 100 % fresh *Azolla pinnata* (S_1 treatment) which was statistically similar with S_5 treatment (control).

4.2.18.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on dry straw yield (t ha^{-1}) of boro rice (Appendix XV and Table 15). The maximum dry straw yield (11.73 t ha^{-1}) was observed in top dressing by 100% urea (M_2S_3 treatment). The minimum dry straw yield (5.95t ha^{-1}) was observed in top dressing by 100% fresh *Azolla pinnata* (M_2S_1 treatment).

4.2.19 Grain-straw ratio

4.2.19.1 Effect of fertilizer application methods

Fertilizer application methods had significant effect on grain-straw ratio of boro rice (Appendix XVII and Table 16). The maximum grain-straw ratio (0.82) was recorded from M_2 treatment (top dressing) whereas the minimum grain-straw ratio was (0.73) from M_1 treatment (basal application).

4.2.19.2 Effect of fertilizer sources

Fertilizer source had significant effect on grain-straw ratio of boro rice (Appendix XVII and Table 16). The maximum grain-straw ratio (0.87) was recorded from 100 % dry *Azolla pinnata* (S_2 treatment) whereas the minimum grain-straw ratio (0.72) was from 100 % urea application (S_3 treatment).

Table 16. Effect of fertilizer application methods and fertilizer sources on grain-straw ratio, biological yield and harvest index of boro rice

Treatments	Grain-straw ratio	Biological yield (t ha^{-1})	Harvest index (%)
Fertilizer application methods			
M_1	0.73 b	13.61 b	42.95
M_2	0.84 a	14.51 a	44.89
$LSD_{(0.05)}$	0.10	0.80	NS
CV (%)	5.34	10.62	7.54
Fertilizer sources			
S_1	0.78 ab	10.63 d	44.26 b
S_2	0.87 a	13.88 c	46.14 a
S_3	0.72 b	19.25 a	42.43 d
S_4	0.75 b	15.55 b	44.17 bc
S_5	0.77 a	10.99 d	42.60 d
$LSD_{(0.05)}$	0.10	1.27	1.21
CV (%)	5.51	7.43	10.13

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.2.19.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on number of grain-straw ratio was observed (Appendix XVII and Table 17). The maximum number of grain-straw ratio was observed in top dressing by 100% dry *Azolla pinnata* (M_2S_2). The minimum grain-straw ratio (0.69) was observed in basal application by control (M_1S_5 treatment).

Table 17. Interaction effect of fertilizer application methods and sources on grain and straw yield (t ha^{-1}) of boro rice

Treatments	Grain straw Ratio	Biological yield (t ha-^{1})	Harvest Index (%)
M_1S_1	0.74 d-f	10.56 f	42.49 b-f
M_1S_2	0.75 de	13.77 e	44.03 b-e
M_1S_3	0.75 de	18.25 b	42.64 b-f
M_1S_4	0.74 d	14.51 d	45.07 bc
M_1S_5	0.69 f	10.89 f	40.51 f
M_2S_1	0.82 bc	10.70 f	46.04 ab
M_2S_2	0.90 a	13.98 d	48.24 a
M_2S_3	0.70 f	20.25 a	42.21 b-f
M_2S_4	0.76 d	16.50 c	43.27 b-f
M_2S_5	0.84 b	11.10 f	44.69 b-d
$LSD_{(0.05)}$	0.05	1.70	2.86
CV (%)	5.51	7.43	10.13

In a column, the means having the same letter (s) do not differ significantly.
CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.2.20 Biological yield

4.2.20.1 Effect of fertilizer application methods

Fertilizer application methods had significant on biological yield (t ha^{-1}) of boro rice (Appendix XVII and Table 16). The maximum biological yield (14.51 t ha^{-1}) was recorded from top dressing (M_2 treatment). Whereas the minimum biological yield (13.61t ha^{-1}) was from basal application (M_1 treatment).

4.2.20.2 Effect of fertilizer sources

Fertilizer sources had significant effect on biological yield (t ha^{-1}) was observed (Appendix XVII and Table 16). The maximum biological yield (19.25t ha^{-1}) was recorded from 100 % urea (S_3 treatment) which was statistically different from other treatments. Whereas the minimum biological yield (10.63t ha^{-1}) was from 100 % fresh *Azolla pinnata* (S_1 treatment) which was statistically similar with control (S_5 treatment).

4.2.20.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect on biological yield (t ha^{-1}) was observed (Appendix XVII and Table 17). The maximum biological yield (20.25 t ha^{-1}) was observed in top dressing by 100% urea application (M_2S_3 treatment). The minimum biological yield (10.56 t ha^{-1}) was observed in basal application by 100% fresh *Azolla pinnata* (M_1S_1 treatment).

4.2.21 Harvest index

4.2.21.1 Effect of fertilizer application methods

Fertilizer application methods had no significant effect on harvest index (%) was observed (Appendix XVII and Table 16). The maximum harvest index (44.89 %) was recorded from top dressing (M_2 treatment) whereas the minimum harvest index (42.95 %) from basal application (M_1 treatment).

4.2.21.2 Effect of fertilizer sources

Fertilizer sources had significant effect on harvest index (%) was observed (Appendix XVII and Table 16). The maximum harvest index (46.14 %) was recorded from 100 % dry *Azolla pinnata* (S_2 treatment) whereas the minimum harvest index (42.43 %) was from 100 % urea application (S_3 treatment).

4.2.21.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on harvest index (%) of boro rice (Appendix XVI and Table 17). The maximum harvest index (46.04 %) was observed in top dressing by 100 % fresh *Azolla pinnata* (M_2S_1 treatment). The minimum harvest index (42.21 %) was observed in top dressing by 100% urea application (M_2S_3 treatment).

4.3 Organic matter, pH, total N, available P, exchangeable K and available S in post-harvest soil

4.3.1 Organic matter

4.3.1.1 Effect of fertilizer application methods

Non-significant effect of fertilizer application methods was found on organic matter content in post-harvest soil (Appendix XVIII and Table 18). The maximum organic matter (1.33%) was recorded from basal application (M_1 treatment) whereas the minimum organic matter content (1.32%) from top dressing (M_2 treatment).

Table 18. Effect of fertilizer application methods and fertilizer sources on organic matter, pH, total N, available P, exchangeable K and available S of post-harvest soil.

Treatments	Organic matter (%)	pH	Total N (%)	Available P (ppm)	Exchangeable K (meq /100g soil)	Available S (ppm)
Fertilizer Application Methods						
M_1	1.33	6.31 b	0.49 a	31.16	0.16	22.07
M_2	1.32	6.41 a	0.47 b	31.69	0.16	22.07
$LSD_{(0.05)}$	NS	0.04	0.01	NS	NS	NS
CV (%)	4.55	5.21	1.25	4.54	5.96	2.35
Fertilizer source						
S_1	1.30 a	6.37 a-c	0.47 c	28.91	0.15 c	21.61 d
S_2	1.33 b	6.31 c	0.49 b	32.29	0.15 c	21.92 c
S_3	1.36 a	6.45 a	0.54 a	34.41	0.17 a	22.79 a
S_4	1.33 a	6.42 ab	0.49 b	33.24	0.16 b	22.47 b
S_5	1.28 b	6.37 a-c	0.42 d	28.29	0.15 c	21.47 d
$LSD_{(0.05)}$	0.07	0.08	0.01	NS	0.01	0.21
CV (%)	4.21	9.74	6.32	1.63	4.06	4.51

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.3.1.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on organic matter of boro rice (Appendix XVIII and Table 19). The maximum organic matter content (1.36%) was observed in top dressing by 100% urea (M_2S_3 treatment). The minimum organic matter content (1.21%) was observed in basal application by 100% *Azolla pinnata* (M_1S_1 treatment). Ram *et al.* (1994) also found that fresh *Azolla pinnata* had non-significant effect on soil organic carbon, pH, nitrogen, phosphorous and other nutrients.

Table 19. Interaction effect of fertilizer application method on organic matter, pH, total N, available P, exchangeable K and available S of post-harvest soil

Treatments	Organic matter (%)	pH	Total N (%)	Available P (ppm)	Exchangeable K (meq /100 g soil)	Available S (ppm)
M_1S_1	1.21 h	6.37 b	0.49 c	29.48	0.15	21.68 cd
M_1 S_2	1.34 bc	6.39 ab	0.52 b	32.79	0.15	21.64 cd
M_1F_3	1.35 ab	6.45 ab	0.55 a	34.20	0.17	22.89 a
M_1S_4	1.34 bc	6.42 ab	0.48 cd	33.42	0.17	22.61 ab
M_1S_5	1.29 f	6.36 b	0.42 g	25.91	0.15	21.54 e
M_2S_1	1.30 f	6.38 a	0.45 f	28.33	0.15	21.71 c-e
M_2S_2	1.32 e	6.48 a	0.47 de	31.78	0.15	22.21 a-c
M_2S_3	1.36 a	6.46 ab	0.53 b	34.62	0.16	22.69 ab
M_2S_4	1.33 cd	6.42 a	0.48 cd	33.06	0.16	22.33 a-c
M_2S_5	1.27 g	6.37 b	0.41 g	30.67	0.15	21.39 e
$LSD_{(0.05)}$	0.01	0.10	0.01	NS	NS	0.72
CV (%)	4.21	9.74	6.32	1.63	4.06	4.51

In a column, the means having the same letter (s) do not differ significantly.
NS= Non- significant. CV = Coefficient of variation, $LSD_{(0.05)}$= Least significant difference at 5% level, DAT = Days after transplanting
M_1= basal application, M_2= top dressing, S_1 = 100 % fresh *Azolla pinnata*, S_2 = 100 % dry *Azolla pinnata*, S_3 = 100 % urea, S_4 = 50 % urea + 50 % *Azolla pinnata*, S_5 = control (no urea and no *Azolla pinnata*

4.3.2 pH

4.3.2.1 Effect of fertilizer application method

Significant effect of fertilizer application methods was found on pH value in post-harvest soil (Appendix XVIII and Table 18). The higher pH value (6.41) was recorded from top dressing (M_2 treatment) whereas the lower pH value (6.31) from basal application (M_1 treatment).

4.3.2.2 Effect of fertilizer sources

Significant effect of fertilizer sources was found on pH value in post-harvest soil (Appendix XVIII and Table 18). The maximum pH value (6.45) was recorded from 100 % urea application (S_3 treatment). Whereas the minimum pH value (6.37) was from 100 % fresh *Azolla pinnata* (S_1 treatment) and control condition (S_5 treatment).

4.3.2.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on pH of boor rice (Appendix XVI and Table 19). The maximum pH value (6.48) was observed in top dressing by 100% dry *Azolla pinnata* (M_2S_2 treatment) and the minimum pH value (6.36) was observed in basal application by control (M_1S_5 treatment).

4.3.3 Total N

4.3.3.1 Effect of fertilizer application method

Significant effect of fertilizer application methods had observed on total N in post-harvest soil (Appendix XVIII and Table 18). The maximum total N (0.49%) was recorded from basal application (M_1 treatment) whereas the minimum total N (0.47%) from top dressing (M_2 treatment).

4.3.3.2 Effect of fertilizer sources

Significant effect of fertilizer sources was found on total N in post-harvest soil (Appendix XVIII and Table 18). The maximum total N (0.54) was recorded from 100 % urea application (S_3 treatment) whereas the minimum total N (0.42) was from control method (S_5 treatment).

4.3.3.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect on total N was observed (Appendix XVI and Table 19). The maximum total N (0.55 %) was observed in basal application by 100% urea (M_1S_3 treatment). The minimum total N (0.41 %) was observed in top dressing by control method (M_2S_5 treatment).

4.3.4 Available P

4.3.4.1 Effect of fertilizer application methods

Non-significant effect of fertilizer application methods was observed on available P in post-harvest soil (Appendix XVIII and Table 18). The maximum available P (31.69 ppm) was recorded from basal application (M_1 treatment) whereas the minimum available P (31.16 ppm) from top dressing (M_2 treatment).

4.3.4.2 Effect of fertilizer sources

Non-significant effect of fertilizer sources was found on available P in post-harvest soil (Appendix XVIII and Table 18). The maximum available P (34.41 ppm) was recorded from 100 % urea application (S_3 treatment) whereas the minimum available (28.29 ppm) was from control (S_5 treatment).

4.3.4.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect on available P was observed (Appendix XVIII and Table 19). The maximum available P (34.62 ppm) was observed in top dressing by 100% urea application (M_2S_3 treatment). The minimum available P (25.91 ppm) was observed in basal application by control method (M_1S_5 treatment).

4.3.5 Exchangeable K

4.3.5.1 Effect of fertilizer application methods

Non-significant effect of fertilizer application methods was observed on exchangeable K in post-harvest soil (Appendix XVIII and Table 18). The maximum exchangeable K (0.16 meq/100 g soil) was recorded from basal application (M_1 treatment) which was similar with top dressing (M_2 treatment).

4.3.5.2 Effect of fertilizer sources

Significant effect of fertilizer sources was found on exchangeable K in post-harvest soil (Appendix XVIII and Table 18). The maximum exchangeable K (0.17 meq/100 g soil) was recorded from 100 % urea application (S_3 treatment) whereas the minimum exchangeable K (0.15 meq/100 g soil) was from fresh 100% *Azolla pinnata* (S_1 treatment) which was similar with 100% dry *Azolla pinnata* (S_2 treatment) and control method (S_5 treatment).

4.3.5.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had no significant effect on available P was observed (Appendix XVIII and Table 19). The maximum exchangeable K (0.17 meq/100 g soil) was observed in basal application by 100% urea application (M_1S_3 treatment) similar to 50% urea + 50% dry *Azolla pinnata*.

4.3.6 Available S

4.3.6.1 Effect of fertilizer application methods

Non-significant effect of fertilizer application methods was observed on available S in post-harvest soil (Appendix XVIII and Table 18). The maximum available S (22.07 ppm) was recorded from basal application (M_1 treatment) which was similar to top dressing (M_2 treatment).

4.3.6.2 Effect of fertilizer sources

Significant effect of fertilizer sources was found on available S in post-harvest soil (Appendix XVIII and Table 18). The maximum available S (22.79 ppm) was recorded from 100 % urea application (S_3 treatment) whereas the minimum available (21.47 ppm) was from control method (S_5 treatment).

4.3.6.3 Interaction effect of fertilizer application methods and fertilizer sources

Interaction between fertilizer application methods and fertilizer sources had significant effect on available S (Appendix XVIII and Table 19). The maximum available S (22.89 ppm) was observed in basal application by 100% urea application (M_1S_3 treatment). The minimum available S (ppm) was observed in top dressing by control method (M_2S_5 treatment).

Chapter 5

Summary & Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2019 to May, 2020 to study the influence of nitrogen supplement of boro rice under the Modhupur Tract (AEZ-28) as affected by fertilizer application methods and fertilizer sources. The experiment comprised as two factors A) Factor A: Fertilizer Sources: 2 levels- i) basal application (M_1) and ii) top dressing (M_2); B) Factor B: Fertilizer application methods: 5 levels- i) fresh *Azolla pinnata* (S_1), ii) Dry *Azolla pinnata* (S_2), iii) 100% Urea (S_3), iv) 50% *Azolla pinnata* + 50% Urea (S_4), v) control (no urea & no *Azolla pinnata*) (S_5). The experiment was laid out in Split plot design with three replications having fertilizer application methods in the main plot and fertilizer sources in sub-plots. The data on crop growth characters (plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf area index, days to flowering and maturity) were recorded from five plants which were randomly selected from each unit plot for taking observations with 20 days interval at 25, 45, 65, 85 days after transplanting and at harvest and yield as well as yield contributing characters (number of effective, ineffective tillers hill^{-1}, number of tiller hill^{-1}, flag leaf length, panicle length, number of rachis branches panicle^{-1}, number of total grains panicle^{-1}, number of filled and unfilled grains panicle^{-1}, 1000 grains weight, weight of grain and straw hill^{-1}, yield of grain and straw, biological yield and harvest index) were recorded after harvest and analyzed using the Cropstat package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Fertilizer application methods showed no significant influence on most of the growth and yield parameters except plant height at 25 and 45 DAT, panicle length, filled grains, total grain panicle^{-1}, dry straw weight hill^{-1}, fresh grain yield, dry grain yield, grain-straw ratio, biological yield, pH and total N contain in post-harvest soil. The higher plant height (19.53 cm and 29.53 cm) was obtained from top dressing (M_2) at 25 DAT and 45 DAT respectively, and the lower plant height (18.72 cm and 24.93 cm, respectively) at basal application (M_1). The maximum number of tillers hill^{-1} at 25, 45 and 65 DAT (2.19, 5.99, 9.87, respectively) was obtained from top dressing (M_2) of urea and the minimum (1.96, 5.13, 9.47, respectively) from basal application (M_1) of urea. The maximum duration required for flowering (128.93 days) observed from top dressing (M_2) which was statistically similar with (128.40 days) basal application (M_1). The higher panicle length (25.70 cm) was found from basal application (M_1) and lower panicle length (23.35 cm) was found from top dressing (M_2). The higher number of filled grains panicle^{-1} (166.16) was recorded from top dressing (M_2) whereas the lower number of filled grains panicle^{-1} (158.07) was from basal application. The higher dry grain yield (6.46 t ha^{-1}) was recorded from top dressing (M_2) whereas the lower dry grain yield (5.76 t ha^{-1}) was from basal application (M_1). The maximum total N content (0.49%) was recorded from basal application (M_1 treatment) whereas the minimum total N content (0.47%) from top dressing (M_2 treatment) in post-harvest soil.

Significant variation was recorded for fertilizer sources on most of the growth and yield parameters except days of maturity, number of ineffective tillers hill^{-1} and available P content in post-harvest soil. The maximum plant height (21.23 cm, 32.31 cm, 51.71 cm, 73.14 cm and 103.91cm, respectively) at 25, 45, 65, 85 DAT and at harvesting, respectively was obtained from 100% urea (S_3). The minimum plant height (17.19 cm, 24.23 cm, 40.52 cm and 62.23 cm, respectively) at 25, 45, 65 and 85 DAT respectively was obtained from (S_1) 100% fresh *Azolla pinnata.* At harvest, the lowest plant height (90.15 cm) was obtained from control method (S_5 treatment). The maximum number of tiller hill^{-1} (2.57, 5.93) at 25, 45, 85 DAT and at harvesting, respectively was obtained from 100% urea (M_3) but at 65 DAT, the maximum tiller number (10.50) was obtained from 50% urea and 50% dry *Azolla pinnata* (S_4). The minimum tiller number hill^{-1} (1.63, 4.43 and 7.97) was at 25, 45 DAT and harvesting, respectively obtained from 100% fresh *Azolla pinnat*a (S_1). But at 65 and 85 DAT, the minimum tiller number hill^{-1} (6.83 and 8.60) from control method (S_5) which was statistically similar with 100% fresh *Azolla pinnata* (S_4).The maximum leaf area index (1.35, 4.81, 9.20, 8.50 and 7.96, respectively) at 25, 45, 65, 85 DAT and at harvest respectively obtained from 100% urea (S_3 treatment) and the minimum leaf area index (1.02, 3.26, 5.90, 4.86 and 4.6, respectively) from 100% fresh *Azolla pinnata.* At 90 DAT and harvesting, the maximum dry matter content hill^{-1} (above ground) obtained (24.16 g and 48.66 g) from 100% urea (S_3) and the minimum dry matter content hill^{-1} (above ground) was (48.66 g) obtained from 100% fresh *Azolla pinnata* (S_1). The highest duration of flowering (130.67 days) obtained from control method (S_5 treatment) which was statistically similar to (129.00 days) 100 % fresh *Azolla pinnata.* The lowest duration of flowering (127.33 days) was obtained from (S_2) 100% dry *Azolla pinnata*. The highest number of effective tillers hill^{-1} (11.03) was recorded from 100 % urea (S_3) which was statistically similar with 50% urea + 50% *Azolla pinnata*. (S_4). Whereas the lowest number of effective tillers hill^{-1} (7.97) from control (no Urea and no *Azolla pinnata*) (S_5) which was statistically similar with 100% *Azolla pinnata* *(*S_1). The maximum number of filled grains panicle^{-1} (180.43) was recorded from 100 % urea (S_3) which (178.83) was statistically similar with 50% urea + 50% *Azolla pinnata* (S_4) whereas the minimum number of filled grains panicle^{-1} (136.07) from 100 % fresh *Azolla pinnata (*S_1). The highest weight of 1000 grains (23.56) was recorded from 50 % urea + 50 % dry *Azolla pinnata* (S_4) whereas the minimum weight of 1000 grains was (20.17 g) from 100 % dry *Azolla pinnata* (S_2). The maximum grain weight hill^{-1} (31.73 g) was recorded from 100 % urea (S_3) which was statistically similar with 50% urea + 50% dry *Azolla pinnata* (S_4 treatment) whereas the minimum was (21.77g) from control (S_5) which was statistically similar with 100 % fresh *Azolla pinnata* (S_1). The maximum weight of 1000–grain (23.56 g) was obtained from 100 % urea application while the minimum weight of 1000-grains (20.17 g) was obtained from 100% dry *Azolla pinnata* application. The maximum grain yield (8.15 t ha^{-1}) was recorded from 100% urea application (S_3) and minimum grain yield (4.62t ha^{-1}) was recorded from fresh *Azolla pinnata* application (S_1).

The interaction of fertilizer application methods and fertilizer sources had significant effect on all growth and yield contributing characters except number of ineffective tillers $hill^{-1}$, harvesting index, P and K content in soil. At 25, 65, 85 DAT and at harvest, the highest plant height (21.27cm, 53.29 cm, 74.71cm and 105.53 cm, respectively) was obtained from basal application by 100% urea (M_1S_3). The lowest plant height (16.29 cm, 22.39 cm, 39.65 cm and 62.00 cm) at 25, 45, 65 and 85 DAT, respectively was obtained from (M_1S_1) basal application by 100% fresh *Azolla pinnata.* The highest number of tiller $hill^{-1}$ (2.67, 6.60) at 25 and 45 DAT was obtained from top dressing by 100% urea (M_2S_3) but at 65 DAT, the highest tiller number (13.80) was obtained from basal application by 100% urea (M_1S_4). The lowest tiller number $hill^{-1}$ (1.47, and 3.67) was at 25 and 45 DAT obtained from basal application by 100% fresh *Azolla pinnat*a (M_1S_1). At harvest, dry matter $hill^{-1}$ (above ground) was (73.51) found in S_1S_3 treatment (basal application by 100% urea) and the lowest dry matter $hill^{-1}$ (above ground) was (52 g) obtained from S_1 F_1 which was statistically similar with 100% dry *Azolla pinnata*, control and 100% fresh *Azolla pinnata.* The highest number of effective tillers $hill^{-1}$ (11.33) was recorded from basal application by 100 % urea (M_1S_3) which was statistically similar with basal application by 50% urea + 50% *Azolla pinnata* (M_1S_4). The highest 1000 grains weight (23.93 g) recorded from basal application by 100 % urea (M_1S_3) and lowest 1000 grains weight 21.33 g) recorded from top dressing by 100% fresh *Azolla pinnata* (M_2S_1). The highest dry grain yield (8.52 t ha^{-1}) was recorded from top dressing by 100% urea (M_2S_3) followed by basal application by 100% urea (M_1S_3 treatment) and top dressing by 50% urea and 50% *Azolla pinnata* application *(*M_2S_4 treatment) whereas the lowest dry grain yield (4.37t ha^{-1}) was from basal application by control (M_1S_5) which was statistically similar with basal application by 100% *Azolla pinnata* application (M_1S_1 treatment) and top dressing by 100% *Azolla pinnata* application (M_2S_1 treatment).

Considering the facts of the present experiment, the following conclusions may be drawn-

- The higher dry grain yield (6.46 t ha^{-1}) was recoded from top dressing (M_2 treatment) whereas the lower dry grain yield (5.76 t ha^{-1}) was recorded from basal application (M_1 treatment). Most of the growth and yield characters were not affected by fertilizer application methods.

- The chemical fertilizer (urea) cannot be replaced by *Azolla pinnata* (fresh or dry). But sacrificing around 18% grain yield of boro rice, 50% chemical fertilizer can be replaced by adding 50% dry *Azolla pinnata* @ 0.4 kg m^{-2} along with 50% urea.

- Interaction of fertilizer application methods and fertilizer sources had significant effect on most of the growth and yield characters of boro rice. Top dressing of 100% urea (M_2S_3 treatment) resulted the highest yield (8.5 t ha^{-1}) that followed by basal application of 100% urea (M_1S_3 treatment) and topdressing of 50% urea + 50% dry *Azolla pinnata* (M_2S_4 treatment).

However, to reach a specific conclusion and recommendation, more research work of bio-fertilizer *Azolla pinnata* on other crops should be done over different Agro- ecological zones in Bangladesh.

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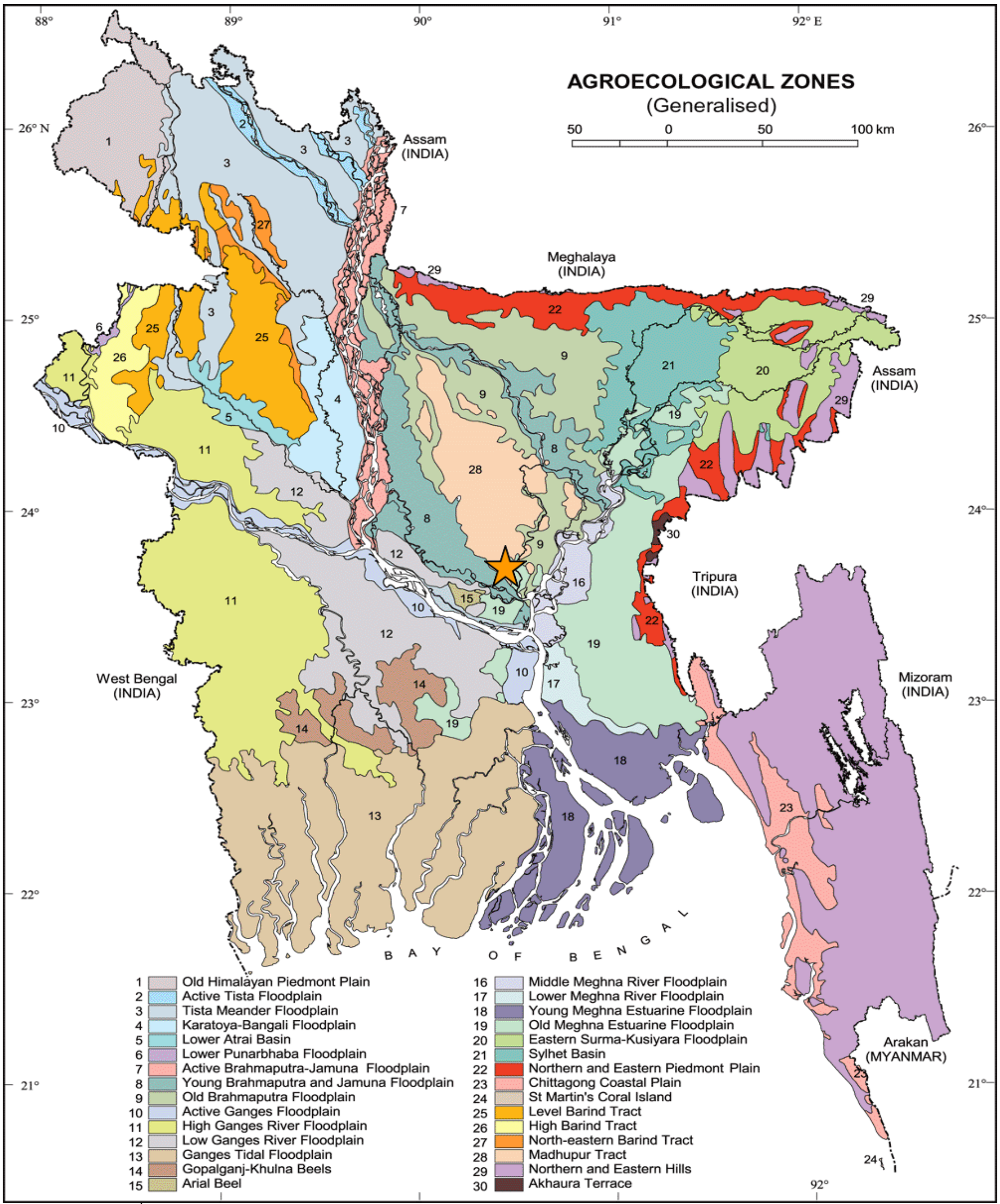
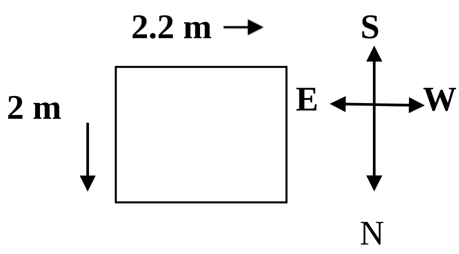
APPENDICES

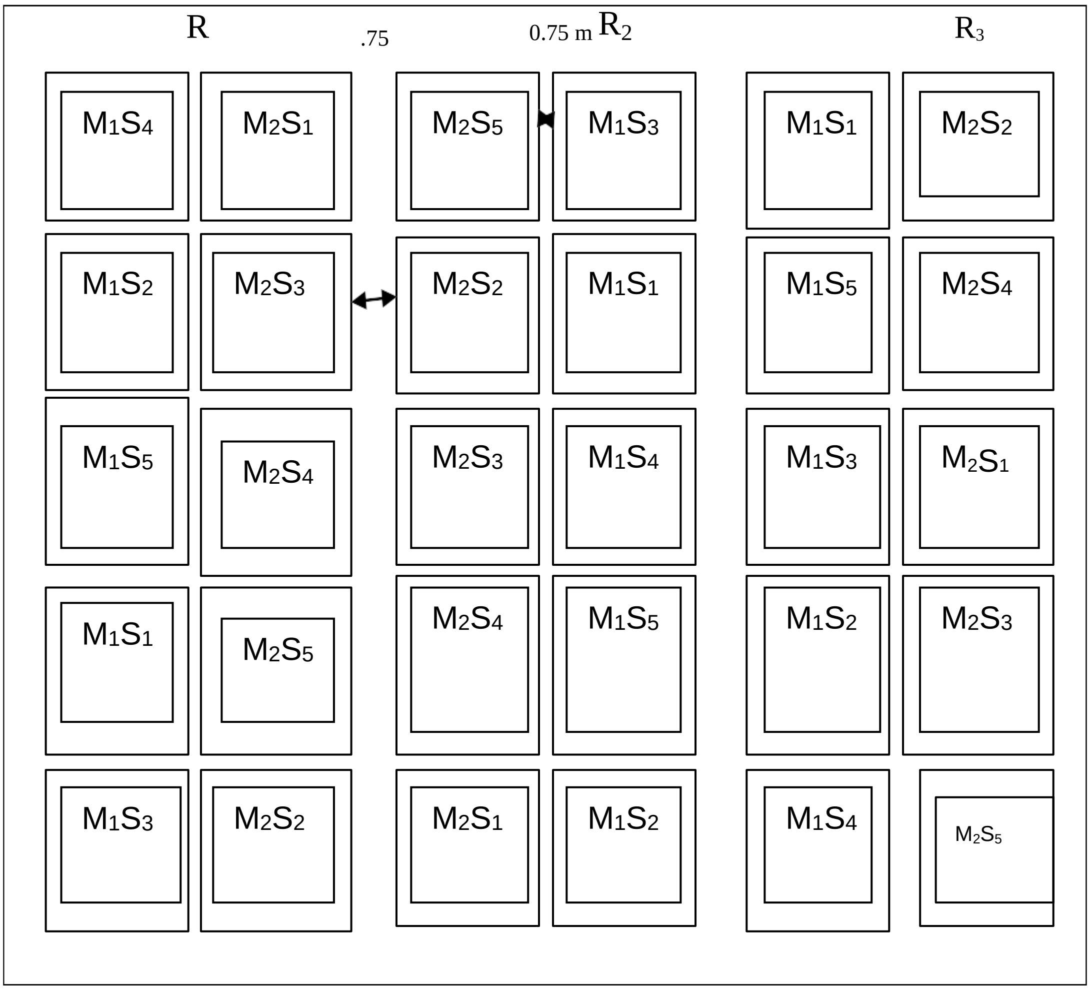
Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

Appendix II. Layout of the experiment





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

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Field laboratory, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of initial soil in the study area.

Characteristics	Value
Sand (%)	26
Silt (%)	44
Clay (%)	30
Texture class	Silty-clay
pH	6.2
Organic matter (%)	1.14
Total N (%)	0.03
Available P (ppm)	28
Exchangeable K (meq /100 g soil)	0.14
Available S (ppm)	17

Appendix IV. Means square values for plant height of boro rice at different days after transplanting

Source of variation	Degrees of freedom	Mean square values at				
		25 DAT	45 DAT	65 DAT	85 DAT	At harvest
Replication	2	0.39	7.49	19.82	2.27	6.70
Fertilizer application methods (FAM)	1	4.93*	20.21**	0.09	0.11	8.73
Error(I)	2	1.04	4.32	4.95	1.43	10.56
Fertilizer Sources (FS)	4	12.58 **	59.31**	132.31**	133.66**	230.48 **
FAM × FS	4	7.0**	22.0**	73.2**	52.8**	71.7**
Error(II)	16	1.64	2.97	4.92	5.02	15.91

**Significant at 1% level
* Significant at 5% level

Appendix V. Means square values for number of tiller hill^{-1} of boro rice at different days after transplanting

Source of variation	Degrees of freedom	Mean square values at				
		25 DAT	45 DAT	65 DAT	85 DAT	At harvest
Replication	2	0.43	0.71	4.63	3.46	0.23
Fertilizer application methods (FAM)	1	0.43	5.47	1.20	0.19	0.90
Error(I)	2	0.11	12.58	2.08	3.25	1.32
Fertilizer Sources (FS)	4	8.10**	4.84**	37.05**	17.92**	11.27**
FAM × FS	4	2.38*	6.5**	6.2*	5.5**	5.4**
Error(II)	16	0.75	0.18	2.09	1.16	0.38

**Significant at 1% level
* Significant at 5% level

Appendix VI. Means square values for number of leaves hill^{-1} of boro rice at different days after transplanting

Source of variation	Degrees of freedom	Mean square values at				
		25 DAT	45 DAT	65 DAT	85 DAT	At Harvest
Replication	2	3.19	4.69	13.31	29.06	5.53
Fertilizer application methods (FAM)	1	3.68	8.99	3.76	5.9	27.0
Error(I)	2	1.04	8.34	2.33	3.75	10.19
Fertilizer Sources (FS)	4	8.09**	38.17**	267.19**	164.52**	112.35**
FAM × FS	4	3.5**	6.2**	29.4*	5.50*	16.6**
Error(II)	16	0.65	1.57	14.15	1.34	4.11

**Significant at 1% level
* Significant at 5% level

Appendix VII. Means square values for leaves area index (LAI) of boro rice at different days after transplanting

Source of variation	Degrees of freedom	Mean square values at				
		25 DAT	45 DAT	65 DAT	85 DAT	At Harvest
Replication	2	0.20	0.66	0.35	0.93	1.64
Fertilizer application methods (FAM)	1	0.24	1.22	1.23	0.35	0.26
Error(I)	2	0.10	1.92	0.11	0.24	0.19
Fertilizer Sources (FS)	4	29.0**	10.1**	12.55**	12.37**	11.07**
FAM × FS	4	5.4**	7.7**	4.8**	4.1**	13.0**
Error(II)	16	0.66	0.31	0.29	0.16	0.18

**Significant at 1% level

Appendix VIII. Means square values for number of Dry weight hill^{-1} (above ground) of boro rice at different days after transplanting

Source of variation	Degrees Of freedom	Mean square values at			
		30 DAT	60 DAT	90 DAT	At Harvest
Replication	2	0.95	129.39	411.03	61.45
Fertilizer application methods (FAM)	1	0.76	0.78	4.23	90.62
Error(I)	2	0.63	8.07	101.91	57.73
Fertilizer Sources (FS)	4	19.15**	104.75**	263.49**	542.42**
FAM × FS	4	17.5**	140.5**	139.33**	117.38**
Error(II)	16	4.16	17.17	20.21	27.24

**Significant at 1% level

Appendix IX. Means square values for Dry hill hill^{-1} (Root) of boro rice at different days different growth stages

Source of variation	Degrees of freedom	Mean square values at			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	0.72	38.39	144.63	18.51
Fertilizer application methods (FAM)	1	0.52	0.30	0.39	3.44
Error(I)	2	0.75	4.36	27.63	12.21
Fertilizer Sources (FS)	4	6.55**	33.89**	79.77**	165.57**
FAM × FS	4	4.20*	14.56**	18.75*	31.62*
Error(II)	16	1.38	4.89	6.98	7.91

**Significant at 1% level
* Significant at 5% level

Appendix X. Means square values for SPAD value of boro rice at different growth stages

Source of variation	Degrees of freedom	Mean square values at	
		45 DAT	75 DAT
Replication	2	6.06	21.31
Fertilizer application methods (FAM)	1	0.24	3.56**
Error(I)	2	5.58	0.64
Fertilizer Sources (FS)	4	4.63*	11.92**
FAM × FS	4	13.2**	15.1**
Error(II)	16	0.66	3.50

**Significant at 1% level
* Significant at 5% level

Appendix XI. Means square values for flowering and maturity duration of boro rice

Source of variation	Degrees of freedom	Mean square values	
		Days of flowering	Days of maturity
Replication	2	0.93	1.63
Fertilizer application methods (FAM)	1	2.13	1.63
Error(I)	2	0.53	1.63
Fertilizer Sources (FS)	4	9.67*	0.47
FAM × FS	4	4.0	4.7
Error(II)	16	2.36	2.7

* Significant at 5% level

Appendix XII. Means square values for effective tiller numbers hill^{-1} of boro rice

Source of variation	Degrees of freedom	Mean square values		
		No. of effective tillers hill^{-1}	No. of ineffective tillers hill^{-1}	No of total tillers hill^{-1}
Replication	2	0.30	0.97	0.21
Fertilizer application methods (FAM)	1	0.90	0.21	1.20
Error(I)	2	1.62	0.17	1.37
Fertilizer Sources (FS)	4	10.65**	0.31	11.71**
FAM × FS	4	7.1**	11	6.7**
Error(II)	16	0.36	0.37	0.39

**Significant at 1% level

Appendix XIII. Means square values for length of flag leaf, number of rachis branches panicle^{-1} and panicle length of boro rice at harvest

Source of variation	Degrees of freedom	Mean square values		
		Flag leaf length	No. of rachis branches panicle^{-1}	Panicle length
Replication	2	2.41	0.30	1.21
Fertilizer application methods (FAM)	1	5.16	0.33	4.29**
Error(I)	2	2.19	0.51	0.67
Fertilizer Sources (FS)	4	5.35*	3.88**	12.92**
FAM × FS	4	20.6**	3.2**	14.4**
Error(II)	16	1.74	0.21	1.26

**Significant at 1% level
* Significant at 5% level

Appendix XIV. Means square values for filled grain, unfilled grain, total grains panicle^{-1} and 1000 grains weight of boro rice

Source of variation	Degrees of freedom	Mean square values			
		No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	No. of Total grains panicle^{-1}	1000-grains weight
Replication	2	492.71	23.78	640.39	1.04
Fertilizer application methods (FAM)	1	490.46**	1.08	445.45*	10.28
Error(I)	2	81.36	3.37	112.64	8.11
Fertilizer Sources (FS)	4	2015.48**	202.93**	103.50**	103.3**
FAM × FS	4	206.30*	50.3**	243.49**	26.0**
Error(II)	16	96.49	6.09	16.32	4.14

**Significant at 1% level
* Significant at 5% level

Appendix XV. Means square values for grain and straw weight hill^{-1} of boro rice

Source of variation	Degrees of freedom	Mean square values			
		Fresh grain weight hill^{-1}	Dry grain weight hill^{-1}	Fresh straw weight hill^{-1}	Dry straw weight hill^{-1}
Replication	2	7.43	3.91	67.44	91.87
Fertilizer application methods (FAM)	1	41.77	28.62	0.77	92.58**
Error(I)	2	36.21	28.63	35.67	6.88
Fertilizer Sources (FS)	4	149.91**	106.26**	537.23**	179.21**
FAM × FS	4	134.50**	37.46*	101.21**	64.56**
Error(II)	16	13.12	9.35	29.91	16.50

**Significant at 1% level
* Significant at 5% level

Appendix XVI. Means square values for grain and straw yield of boro rice

Source of variation	Degrees of freedom	Mean square values			
		Fresh grain yield	Dry grain yield	Fresh straw yield	Dry straw yield
Replication	2	0.68	0.32	7.96	2.26
Fertilizer application methods (FAM)	1	19.5**	3.67**	2.13	0.28
Error(I)	2	0.58	0.30	1.40	1.77
Fertilizer Sources (FS)	4	15.67**	13.05**	60.91**	26.29**
FAM × FS	4	12.00**	11.00**	28.8**	13.5**
Error(II)	16	0.33	0.37	1.91	0.89

**Significant at 1% level

Appendix XVII. Analysis of variance of the data on grain-straw ratio, biological yield and harvesting index of boro rice

Source of variation	Degrees of freedom	Mean square values		
		Grain straw ratio	Biological yield	Harvest Index
Replication	2	0.18	3.85	17.04
Fertilizer application methods (FAM)	1	5.90**	6.98*	28.34
Error(I)	2	0.20	2.23	10.99
Fertilizer Sources (FS)	4	1.9*	75.41**	13.61**
FAM × FS	4	2.0*	14.1**	12.10**
Error(II)	16	0.21	1.09	1.78

**Significant at 1% level
* Significant at 5% level

Appendix XVIII. Analysis of variance of the data on Organic matter, pH, total N, available P, exchangeable K and available S of post-harvest soil

Source of variation	Degrees of freedom	Mean square values					
		Organic matter	pH	Total N	Available P	Exchangeable K	Available S
Replication	2	0.18	0.74	0.28	0.22	0.65	0.87
Fertilizer application methods (FAM)	1	0.40	1.1*	3.4**	2.10	0.91	0.27
Error(I)	2	0.40	0.11	0.36	2.10	0.91	0.27
Fertilizer Sources (FS)	4	5.8**	7.7**	2.1*	4.36	2.9**	3.80*
FAM × FS	4	4.0**	4.7**	6.3**	4.96	0.18	4.70*
Error(II)	16	0.31	0.39	0.60	2.32	0.15	0.99

**Significant at 1% level
* Significant at 5% level

PLATES

Fresh *Azolla pinnata* Dry *Azolla pinnata*

Plate 1. Fresh and dry *Azolla pinnata*

Plate 2. Fresh *Azolla pinnata* application into the field

50 % Dry *Azolla pinnata* 100% Dry *Azolla pinnata*

Plate 3. Dry *Azolla pinnata* application into the field before transplanting

Plate 4. Experimental field under study at 25 days after transplanting

Plate 5. Experimental field under study at 45 days after transplanting

Plate 6. Experimental field under study at flowering stage

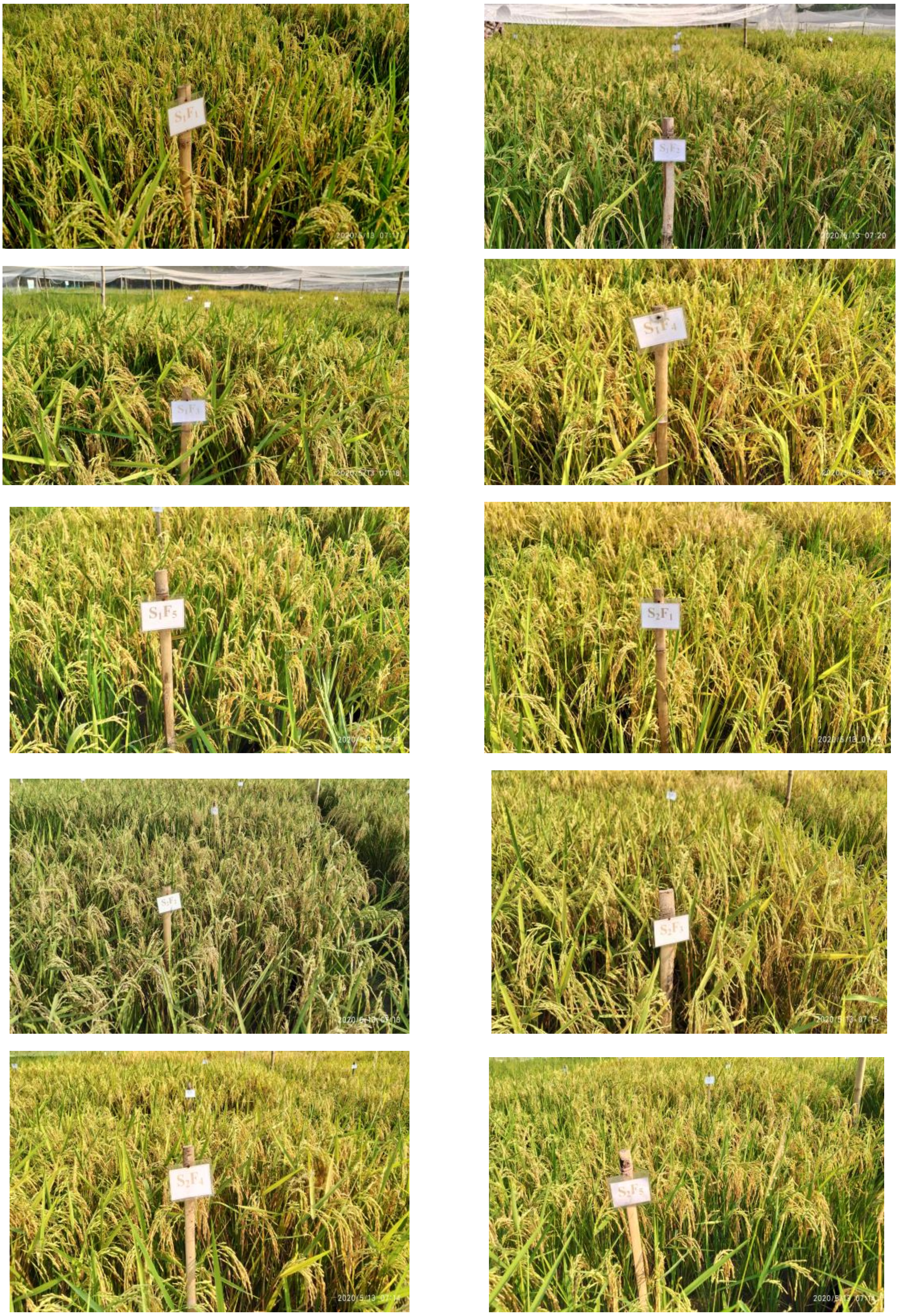


Plate 7. Experimental field under study at harvesting