STUDY ON PLANTING METHODS AND NITROGEN SPLITTINGS IN CULTIVATING BORO RICE

ZAHIR RAYHAN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2015

STUDY ON PLANTING METHODS AND NITROGEN SPLITTINGS IN CULTIVATING BORO RICE

By

ZAHIR RAYHAN

REGISTRATION NO. 14-06327

A Thesis

Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JULY-DECEMBER, 2015

Approved by:

(Prof. Dr. Parimal Kanti Biswas) **Supervisor**	**(Prof. Dr. Md. Fazlul Karim)** **Co-supervisor**

(Prof. Dr. Md. Fazlul Karim)
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Phone: 9134789

CERTIFICATE

This is to certify that the thesis entitled **"EFFECTIVENESS OF MECHANIZED PLANTING AND NITROGEN ECONOMY OF RICE CULTIVATION IN BORO SEASON"** submitted to the Faculty of Agriculture**,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **ZAHIR RAYHAN,** Registration. No. **14-06327** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

ACKNOWLEDGEMENTS

First of all, the author is grateful to "Almighty Allah" to complete the research work.

The author would like to express his heartfelt gratitude to his research supervisor, Dr. Parimal Kanti Biswas, Dean, Post Graduate Studies and Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for his constant supervision, valuable suggestions, scholastic guidance, continuous inspiration, constructive comments, extending generous help and encouragement during his research work and guidance in preparation of the thesis.

The author sincerely express his heartiest respect, deepest sence of gratitude and profound appreciation to his co-supervisor Dr. Md. Fazlul Karim, Professor and Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for constant encouragement, affable suggestions, helpful criticisms and valuable advice during the research period and preparing the thesis.

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for the valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and suggestions and encouragement to research work. The author would like to express his cordial thanks to the departmental and field staffs for their active help during the experimental period.

The author expresses his unplumbed tributes, sincere gratitude and heartfelt indebtedness from his core of heart to his father M. A. Mannan Molla, mother Nurjahan, whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of his higher study, and also pleasant to his brothers and sisters.

The Author

STUDY ON PLANTING METHODS AND NITROGEN SPLITTINGS IN CULTIVATING BORO RICE

ABSTRACT

A field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from December 2014 to July 2015 to study the growth and yield of BRRI dhan29 in *boro season* as affected by three planting methods and seven levels of N-splitting in *boro* season under the Modhupur Tract (AEZ-28). The experiment was comprised of two sets of treatments viz. Factor-A. (Planting method): conventional transplanting (M_1), drum seeder (M_2) and rice transplanter (M_3) and Factor-B. (N-splitting): 100% Urea of the recommended dose (RD) applied as 3 top dressing (T_1), 100% Urea of RD applied as 1 top dressing and 2 foliar spray (T_2), 100% Urea of RD applied as 3 foliar spray (T_3), 75% Urea of RD applied as 1 top dressing and 2 foliar spray (T_4), 75% Urea of RD applied as 3 foliar spray (T_5), 50% Urea of RD applied as 1 top dressing and 2 foliar spray (T_6) and 50% Urea of RD applied as 3 foliar spray (T_7). The experiment was laid out in a split-plot design replicated thrice assigning planting method in main plot and nitrogen splitting in the sub-plot. The maximum number of rachis branch^{-1}, filled grain and total grains panicle^{-1} and 1000-grains weight (10.15, 158.20, 175.57 and 23.43g respectively) were found in drum seeder while the minimum (9.81, 149.43, 165.57 were 22.33 respectively) were recorded from rice transplanter. The highest grain yield (8.09 t ha^{-1}), straw yield (6.88 t ha^{-1}) and biological yield (14.97 t ha^{-1}) were recorded from drum seeder whereas the lowest (7.33, 6.43 and 13.76 t ha^{-1} respectively) were found from rice transplanter. Grain yield and biological yield were significantly influenced by N-splitting where the highest grain yield (8.26 t ha^{-1}) and biological yield (15.02 t ha^{-1}) were observed in T_1 but the highest straw yield (7.03 t ha^{-1}) in T_3. The highest grain yield (8.68 t ha^{-1}) was observed in combined effect of drum seeder and 75% Urea of RD applied as 1 top dressing and 2 foliar spray that was similar (8.60 t ha^{-1}) with the same planting method having recommended dose of nitrogenous fertilizer applied as three top dress (M_2T_1).

LIST OF CONTENTS

LIST OF CONTENTS (Contd.)

LIST OF CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

%	Percentage
^0C	Degree Celsius
AEZ	Agro- Ecological Zone
Anon.	Anonymous
BRRI	Bangladesh Rice Research Institute
CV	Coefficient of Variance
Cv.	Cultivar
DAS	Days After Sowing
DAT	Days after transplanting
et al.	And others
FA	Foliar application
FAO	Food and Agriculture Organization
GDP	Gross domestic production
HI	Harvest index
IRRI	International Rice Research Institute
K	Potassium
K_2O	Potassium Oxide
LAI	Leaf area Index
LSD	Least Significant Difference
m	Meter
m^2	Meter squares
mm	Millimeter
MoP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P	Phosphorus
RD	Recommended dose
S	Sulphur
SA	Soil application
SAU	Sher-e- Bangla Agricultural University
SPAD	Soil plant analysis development
t ha^{-1}	Ton per hectare
T.	Transplanted
TSP	Triple Super Phosphate
USG	Urea Super Granule
Wt.	Weight

CHAPTER I

INTRODUCTION

Now-a-days half of the world's population subsists wholly or partially on rice. Ninety percent of the world rice is grown and consumed in Asia (FAO, 2009). Rice is the most important cereal crop and staple food in Bangladesh. About 75% of the total cropped area and more than 80% of the total irrigated area is planted to rice (Hossain and Deb, 2003). Almost all of the 13 million farm families grow rice as the climatic and edaphic conditions of Bangladesh are favorable for rice cultivation throughout the year. It provides nearly 40% of national employment (48% of rural employment), about 70-76% of total calorie supply and 66% of protein intakes of an average person in the country (Anon., 2004; Hossain and Deb, 2003). Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh (Hossain, 2002). Bangladesh is a densely populated country. As the population is increasing, so the demand of rice is also increasing. Yet, yields of the crop are levelling out. How the current level of annual rice production of around 545 million tons can be increased to about 700 million tons to feed an additional 650 million rice eaters by 2025 using less fertilizers and less land is indeed the great challenge in Asia (Dawe, 2003). So, it can be undoubtedly said that, rice plays a vital role in the livelihood of the people of Bangladesh. Among the rice growing countries, Bangladesh occupies third position in rice area and fourth position in rice production (BRRI, 2012). But the average yield is quite low compared to that in other leading rice growing countries. In Bangladesh total cultivable land is 10 million hectare and near about 70 per cent of this land is occupied by rice cultivation in which *boro* covers the largest part of about 4.70 million hectares with the production of 18.06 million metric tons. Food scarcity has been and will remain as a major concern for Bangladesh. Although the soil and climatic conditions of Bangladesh are favorable for rice cultivation throughout the year, the unit area yield is much below to those of other leading rice growing countries of the world.

Therefore, emphasis should be given to increase the yield and to decrease production cost of rice (specially *boro* rice) through reduction of labour along with other improved technology and management practices. Rice cultivation in Bangladesh is predominantly practiced in transplanting method is rather a resource and cost intensive method since, preparation of seedbed, raising of seedling and transplanting are labour and time intensive operations. Labor involvement for these operations consist nearly one third of the total cost of production in

Bangladesh. To avoid these difficulties several rice cultivation methods have been developed so far. Among those transplanter technique, drum seeder technique and using rice transplanter are gaining acceptance by the growers day by day than conventional transplanting.

In rice production, nitrogen plays a key role and is required in large amount. Rice plant cannot produce higher grain yield without addition of fertilizer in the crop field (BRRI, 2011a). Among the nutrients, nitrogen is the linchpin in rice farming for crop growth and development (Alam *et al*., 2010). Nitrogen is the most important limiting nutrient in rice production and has heavy system losses when applied as inorganic sources in puddle field (Fillery *et al.*, 1984). Nitrogen has a positive influence on the production of effective tiller per plant, yield and yield attributes (Jashim *et al.*, 1984, BRRI, 1990). It is necessary to find out the suitable rate of nitrogen fertilizer for efficient management and better yield of rice. Nitrogen is an essential constituent of chlorophyll and well-supplied nitrogen which enhanced crop growth vigorously (Dobermann and Fairhurst, 2000). In contrast, nitrogen deficiency results reduced tillering, grains panicle^{-1} and ultimately decreases grain yield of rice (Peng *et al.*, 2003). However, only optimum dose of N applied can play a vital role on the growth and development of rice plant (Hasanuzzaman *et al*., 2009). The absorption patterns of applied nitrogen vary with growth stages. About 52 to 60 % of total plant nitrogen in the high yielding plants has been absorbed by early panicle formation stage, and 70 to 80 % by heading stage; 20- 30 % nitrogen is absorbed during the ripening period (De Datta, 1981). Generally, the nitrogenous fertilizer (urea) is applied as basal and as top dressed at different growth stages for rice cultivation (BRRI, 2011b). Unfortunately, N use efficiency in the wetland rice culture is very low, rarely exceeding 30-40 % (Alam *et al*., 2000) and more than 50 % of the applied nitrogen is lost through denitrification, volatilization, leaching and runoff (Khan *et al*., 2009) and ultimately affect on cash loss of farmers and sometimes causes environmental as well as ground water pollution (De Datta, 1981; IRRI, 1997). High price of urea fertilizer and its availability at the right time endanger rice production occasionally. So, it is necessary to improve the efficiency of applied nitrogenous fertilizer utilization by rice plant (Miah and Panaullah, 1999). All the factors provide an indication of searching an effective alternate N application method for rice cultivation (BRRI, 2011b). However, foliar application can improve nutrient utilization and lower environment pollution through reducing amount of fertilizers added to soil (Abou-EI-Nour, 2002). In many cases aerial spray of nutrients is preferred and gives quicker and better results than the soil application which minimizes N losses to the environment without affecting rice yield (Millard and Robinson, 1990). Most plants absorb foliar applied urea rapidly and hydrolyze the urea in the

cytosol (Nicoulaud and Bloom, 1996). The NH_3 released may be transported into the chloroplast and be assimilated by the chloroplastidic Glutamine synthetase (Lam *et al*., 1996). Recently foliar application of nutrients has become an important practice in the production of crops while application of fertilizers to the soil remains the basic method of feeding the majority of the crop plants (Alam *et al.*, 2012b). Many factors determine the fertilizer use efficiency for rice crop during cultivation such as soil, cultivar, season, environment, planting time, water management, weed control, cropping pattern, source, form, rate, time of application and method of application (De Datta, 1978). Therefore, there is a crucial need to provide the required nutrients over and above the regular soil application through foliar application as well. Foliar application is well recognized and is being practiced in agriculturally advanced countries. In many cases aerial spray of nutrients is preferred and gives quicker and better results than the soil application (Jamal *et al*., 2006). Foliar feeding is an effective method for overcoming the flooded soil special condition. In case of foliar feeding, nutrients are absorbed directly where they are needed, the rate of the photosynthesis in the leaves is increased, and nutrient absorption by plant roots is stimulated and foliar nutrition applied at critical times. Other advantages are low application rates, uniform distribution of fertilizer, reduction in plant stress, plant's natural defense mechanisms to resist plant disease and insect infestations, improvement of plant health and yield (Finck, 1982). Nitrogen fertilizer is more urgent for security rice production. Liquid fertilization might reduce the use of chemical fertilizer specially the nitrogenous fertilizer in soil. Therefore, a suitable combination of variety and rate of nitrogen is necessary for better yield (BRRI, 1990). Selection of planting system in appropriate method and application of optimum amount of nutrient elements can play an important role in increasing yield and national income. That is why; the present study was carried out to meet up the following objectives:
The broad objective of the study was to determine the efficacy of planting method and nitrogenous fertilizer application method on growth and yield of boro rice.

The specific objectives were as follows:

- To compare the performance of BRRI dhan29 (inbred) in different mechanized planting methods.
- To find out the efficacy of several nitrogen doses in different ways.
- To predict the perfect planting method and N splitting ways for optimum growth and yield of boro rice.

CHAPTER II

REVIEW OF LITERATURE

Different technologies are available and received much attention to the researchers throughout Bangladesh to develop its apposite production technologies for rice areas. The attempt has been made in this chapter to review the relevant research information to rice cultivation in the different countries of the world especially in the context of Bangladesh. Literature on the influence of planting method and nitrogen splitting on growth and yield of boro rice is particularly less available. Sufficient information is not available from the research works of the different scientists of the world in regard to the nutrient contents with their relationship patterns in support of the present piece of research conducted in the university. It is therefore, apparent to find out real significant information on the two mentioned factors. Little information which is currently available relates mostly to the effect of planting method and nitrogen splitting on the agronomical characters and also total yield of crops have been reviewed in this chapter.

2.1 Effect of planting method

Murumkar *et al.* (2014) conducted a field trials at Krishi Vigyan Kendra, Bhandara (Sakoli) as well as on farmers field in 10 different villages during kharif 2011 with a view to reducing cost of transplanting operation of paddy crop. A self propelled four row paddy transplanter (MAHINDRA Model) was used for the transplanting purpose. The performance of the mechanical self propelled paddy transplanter was found quite satisfactory. The field capacity, field efficiency and fuel consumption of the four row self propelled paddy transplanter were 0.1 ha/h, 65% and 10 lit./ha, respectively. The cost of mechanical transplanting was found to be 1500 Rs/ha as compared to Rs 5000 Rs/ha as in case of traditional method of manual transplanting followed by farmers in the region. Crop yield in both manual and mechanical transplanting was found at per with average grain yield. The machine was found to be farmer friendly and feasible in terms of time, money and labour requirement as compared to manual method transplanting of paddy.

Chandrasekhararao *et al.* (2013) revealed that direct seeding reduced the cost of cultivation by Rs 9166/ha by avoiding nursery as well as transplanting cost. Crop duration is reduced by 8-10 days. Yields were increased to an extent of 8.3% in Kharif and 11% in Rabi. Results showed that area covered with five drum seeder will be 25% more than the four drum seeder in unit time and also reduced the labour cost (Rs 1500/ha).

Kumar and Kumar (2012) carried out a field study with a view to reducing the scarcity of labour and improper plant spacing due to manual transplantation, a manual 4-row rice transplanter was designed by CRRI, Cuttack and tested for its performance and adaptability in rice fields in Jharkhand. Manual 4-row rice transplanter was operated at BAU farm and in farmer's fields. The effective field capacity was 0.025 ha/hr at the operating speed of 0.47 km/hour. The cost of operation for transplantation by transplanter was Rs 2,429/ha whereas by traditional method this cost was Rs. 6,600/ha.

Pateriya and Datta (2012) conducted an experiment on design modifications of mat type rice transplanter, the observations indicated that all the modified components worked satisfactorily. From the results, it appears that the percentage of missing hill varied 8.06 to 9.75, plants per hill ranged 2 to 4, planting depth was 50 to 65 mm. The hill to hill spacing was 95 to 102.5 mm at low gear and 147.7 mm at high gear, the row to row spacing varied 230 to 235mm.

Hossain *et al.* (2012) tested walking type mechanical rice transplanter in different farmers field during *boro*/2012 season to evaluate the field performance. Yield performance of rice transplanting by mechanical rice transplanter were compared with hand transplanting method. In hand transplanting plot, farmer’s seedling of the same variety BRRI dhan28 and BRRI dhan29 was used. Average yield of the machine transplanting plot and hand transplanting plot were 6.42 t ha^{-1} and 6.28 t ha^{-1}.

Kaium (2010) reported an investigate the performance of mechanical rice transplanter at the Farm Power and Machinery department field laboratory in Bangladesh Agricultural University (BAU), Mymensingh, during Boro and Aman seasons, 2010. The study revealed that the mechanical rice transplanter was found suitable in terms of technical, agronomical and financial performance over manual transplanting of rice seedlings and recommended for the farmers of Bangladesh.

Manjunatha *et al.* (2009) carried out a study at Agricultural Research Station, Gangavathi, Karnataka state during 2002 to 2004 on the feasibility of mechanizing transplanting operations in paddy crop with a view to reduce the cost of cultivation. An eight row self-propelled paddy transplanter was used for the purpose. The field capacity, field efficiency and fuel consumption of the transplanter were 0.19 ha/hr, 78 per cent and 6.25 l/ha, respectively. Cost of mechanical transplanting was Rs.789/ha as compared to Rs.1625/ha in case of manual transplanting provided the machines are used for their maximum usage of 90 hectares in a year. As the usage of the machine in terms of number of hectares/year decreases, the cost of operation increases. To break even with the cost of manual operation, the mechanical transplanter should be used at least in an area of 28 hectares per year. Hence, the mechanical transplanting would be economical provided an area of 28 ha and above is covered every year. Grain yield in both manual and mechanical transplanting remained on par with mean grain yield of 53.77 and 54.01 q/ha, respectively.

Goel *et al. (*2008) conducted an experiment on three transplanters namely OUAT, CRRI and Yanji rice transplanter and evaluated the performance of these in sandy loam soil conditions with four levels of sedimentation period i.e. 24, 32, 48 and 56 hours. Transplanters were evaluated with respect to float sinkage, draft, depth of planting, floating hills, mechanical damage, buried hills, missing hills and hills mortality and the data were analyzed in accordance with split plot design of experiments. It was found that 32 hours of sedimentation period was suitable for operation of manual transplanter while the same was 56 hours for Yanji transplanter.

Das (2004) evaluated CRRI manual 4 row transplanter, 8 row VST (Yanji) self propelled rice transplanter as compared to conventional transplanting. The grain yields were 4.95 t ha^{-1} for 4 row manual transplanter, 4.62 t ha^{-1} for VST 8 row self propelled rice transplanter, 4.18 t ha^{-1} by conventional manual transplanting.

Tripathi *et al*. (2004) reported that due to rapid industrialization and migration to urban areas, the availability of labor became very scarce and with hike in the wages of labor, manual transplanting found costly leading to reduced profits to farmers. Under such circumstances a less expensive and laborsaving method of rice transplanting without yield loss is the urgent need of the hour.

Sivakumar *et al.* (2003) conducted a study on the performance of prototype direct-rice seeders with single and double ground wheels with and without furrow openers using dry and soaked seeds. It was found that the use of soaked seeds in the improved seeder with furrow opener resulted in a higher yield of grain and straw.

Subbaiah *et al.* (2002) conducted an experiment to evaluate the performance of drum seeder in farmers' fields. Crop established with a drum seeder resulted in higher mean grain yield (4.63 t ha^{-1}) then with transplanting (4.25 t ha^{-1}) and superior over broadcasting (3.34 t/ha). The drum seeder, providing the crop establishment equivalent to traditional transplanting method, also recorded not only the high yield, but also the highest net revenue of $ 304/ha with benefit cost ratio of 1.30. Proper leveling of land before sowing, use of effective herbicide 4 days after sowing of pre-germinated seed and mechanical weeding with rotary push hoe after first top dressing of nitrogen fertilizer (25 DAS) was a recommended package for drum seeding technology.

Umar *et al.* (2001) reported that the evaluation of diffusion possibilities of mechanical transplanting method revealed that on economic grounds, although this method is more expensive as compared with the conventional method, however, the yield benefits due to higher population stand makes it profitable to adopt.

Islam *et al*. (2001) conducted two experiments to observe the performance of Japanese power rice transplanter at BRRI Farm Gazipur. In T. *Aman* season a test with machine and hand transplanting methods were conducted with 14 and 32 days old seedlings respectively. The machine planting was 35 times faster and produced 15% less yield compared to hand planting method.

Nishimura *et al.* (2001) developed a precision direct seeder that controls seed depth. This investigation was focused on the influence of decreasing inappropriate germination (surface, floating, and lodging seedlings) on stable germination. The sowing performance of the developed machine and the rice growth process were analyzed in farmers' and experimental fields located in a total of 14 domestic areas in Japan, for two years (1997 and 1998). The results showed that the developed machine achieved high accuracy sowing depth control using a two-stage depth control with the new furrow opener, and a high rate of work. Therefore, the growth process was stable every year. The developed rice seeder was introduced in the market during the spring of 2000.

Islam *et al.* (2000) reported that about 400-450 man-hr/ha required for hand transplanting in rows and the work rate of random seeding (Broadcasting) by hand was nearly 100 times faster than hand transplanting. There was no yield difference between direct seeding and transplanting practices of rice production, if others production factors were applied effectively and identically. He also reported that rice transplanting was a highly labor intensive operation that required about 30% of the labor needed for rice production. Therefore, introducing direct seeding in wet bed rice cultivation would reduce the rice production cost.

Krishnaiah (1999) reported that the Directorate of Rice Research, Hyderabad, India, developed an 8-row modified seeder in 1997-98. The cost of seeder was about Rs.2000 and weight was only 12 kg. A single drum with 8-rows of holes was mounted on two wheels at the ends. The seed rate was adjustable to 50-75 kg/ha. Two workers were used for operating the machine in the field. The seeds were soaked for 24 hours and incubated for 24 hours before they were sown in the field.

Sawamura (1998) developed a new direct seeding rice culture system of surface broadcasting with pre-germinated paddy seed onto puddle field and seeding establishment in condition of no standing water. Labor requirements of this system were 45 man-hours/ha and the yield in brown rice is five t/ha almost same by transplanting system.

Garg *et al.* (1997) conducted a study on development and field evaluation of manually operated six row paddy transplanter. They reported that rice is grown either by direct seeding i.e. broadcasting, drilling, sowing, transplanting. In India, higher and more stable yield was obtained from transplanted rice than direct seeded rice. In most provinces of India, transplanted rice had 10 to 20 % higher yield than broadcasted rice.

Jinfu *et al.* (1997) developed a new direct paddy seeder at the Department of Agricultural Engineering, Huazhong Agricultural University. The seeder had many distinguishing construction features; (1) small power, (2) steel slide board, (3) wheel-driven feed roller, and (4) top delivery fluted feeder. The working width of seeder was 3000 mm and 14 rows. The performance test showed that the feed quantity could be adjusted from 30 to 150 kg/ha, the standard deviation of feed quantity was 2.95 g , the drilling rate was nil, the damage rate due to metering mechanism was 0.045 %, the field capacity was 0.67-0.8 ha/h, and the fuel consumption was 1.2-1.54 kg/ha. As compared with mechanical transplanting, manual broadcasting and manual transplanting the seeder raised yield of grain by 12.72-14.48 %, reduced production cost by 1.0-15.0%, saved manpower by 27.0-484.5 man-h/ha, and increased net income RMB Yen 429.60-740.55/ha.

Sahoo *et al.* (1994) developed a six-row power tiller operated pre-germinated paddy seeder. The effective field capacity of this seeder was 0.168 and 0.114 ha/h for 9.9cm and 25.3 cm hardpan depth, respectively. The row-to-row spacing was 20 cm and hill-to-hill spacing was 9.95 cm with 3-5 seeds per hill. The estimated cost of the seeder was Rs.2286 with an operating cost of Rs.173/ha. A net saving of Rs.327/ha and Rs.452/ha can be obtained by using the power tiller operated paddy seeder in lieu of the manual-hill dropping and transplanting methods.

Borlagdan (1994) developed four prototypes upland seeder; 1) semiautomatic seeder, 2) automatic seeder, 3) plow-attached seeder (convertible to a push type model), and 4) power tiller-attached multi-crop seeder. They could be used for sowing corn, soybean and mungbean. The prototypes were tested for maize (being the target priority crop) with a capacity of 0.03, 0.024, 0.136 and 0.183 ha/hr, respectively. A feasibility analysis showed a benefit cost ratio 2.45, 1.08, 1.24 and 1.00 with a corresponding break-even point of 0.30, 0.60, 0.53 and 2.63 ha, respectively.

Gupta and Totok (1992) designed and developed a direct paddy seeder to overcome high human stress and drudgery in transplanting operation. The seeder had a working width of 2 m and 8 rows. For each row, there was a seed hopper, 6 fluted seed metering roller and a double disc furrow opener. Two lugged driving wheels rotated the metering rollers mounted over a common shaft. Each flute in a metering roller can pick up 3 to 5 paddy seeds and place them in a furrow through seed guide at desired depth of 2 to 7 cm. The seeder was provided with a foot-operated clutch to disengage the metering mechanism and a canopy to protect the operator from direct sunlight. It had a field capacity of about 0.5 ha/hr at forward speed of 0.81 m/sec and field efficiency of 78 %. The seed rate was 15 to 20 kg/ha. Damage due to metering mechanism was nil for soaked seeds and 3 to 5percent for pre-germinated seeds.

Singh *et al.* (1985) conducted a study at field level at the International Rice Research Institute, IRRI, farm on a manual rice transplanter, developed at the IRRI, under the following conditions: three levels of land preparation (low, medium and high); three water depths: 0–30 mm, 30–60 mm and 60–100 mm; and three seedling ages of 14–17, 18–21 and 22–25 days. The studies were extended to two other types of soils in farmers' fields to assess the results for the combination of land preparation, water depth and seedling age found to give minimum defective hills among treatment groups at the IRRI farm. At this farm the transplanter performed well, with less than 5% defective hills when using seedlings 14–17 days old in up to 100 mm water depth at the medium level of land preparation, up to 60 mm water depth at the low level of land preparation and up to 30 mm water in over prepared (high level) land. The transplanter also worked satisfactorily using 18–21 day old seedlings at up to 60 mm water depth in medium level prepared fields and up to 30 mm water in low level tilled fields. In sticky soils, at Zaragoza, the planting depth was greater and there were more defective hills of all kinds than at the IRRI farm. In the loam soils of Florida-Blanca the planting depth was less, and only floating hills were significantly more than at the IRRI farm. The machine had an average work rate of 0·034 ha/hr.

Tiwari and Datta (1983) developed a wetland seeder, capable of sowing 6 seeds per hill at a hill-to-hill spacing of 16.0 cm. The average seed rate was 43.2 kg/ha for paddy at field capacity of 0.08 ha/hr. In agronomical consideration this two-row machine could be comfortably operated by one man.

Navacero (1969) designed and tested a paddy seeder with two-step metering mechanism. The first step was to meter a large quantity of seeds from the hopper and the second step was to distribute the metered seeds to the individual rows. One hectare required 4.9 man/hr with this 8 row seeder as compared to 199 man/hr for manual transplanting.

2.2 Effect of N-splitting

Alam *et al.* (2015) conducted a research to find out the effect of liquid fertilization (Magic Growth) on the performance of Kataribhog rice and to calculate how much urea can be saved without the reduction of grain yield. The research was accommodated with two levels of liquid fertilization viz., no liquid fertilization (Lo), Liquid fertilization with Magic Growth applied at 30, 45 and 60 DAT (L_1), and four levels of nitrogen fertilizer viz., no nitrogen fertilizer (N_0), 50% recommended nitrogen fertilizer (N_{50}), 75% recommended nitrogen fertilizer (N_{75}) and 100% recommended fertilizer (N_{100}). The liquid fertilizer and nitrogen fertilizer doses were assigned to the main plot and sub-plot respectively. Liquid fertilization (L_1) treatment provided greater grain yield compared to no liquid fertilization treatment (L_0) in all nitrogen levels. Additionally, with the increment of nitrogen level the grain yield was increased up to N_{100} compared to no liquid fertilization treatment (L_0), but in the application of liquid fertilization treatment (L_1), grain yield was increased up to N_{75} and thereafter decreased in N_{100} dose application. Moreover, Liquid fertilization with Magic Growth along with 75% of the recommended nitrogen fertilizer increased 10.5% grain yield with a saving of 25% of the recommended nitrogen fertilizer compared to recommended practice.

Shafiee *et al.* (2013) conducted an experiment to review the enhancing effect of SBAJATM (formerly known as BIPOMIXTM) on the growth and yields of rice (*Oryza sativa* L. var. MR 220). The clonal development of SBAJATM -treated rice crop based on plant height and tiller numbers plant^{-1}, even though temporal inconsistencies, did not register any significant difference from each other at $p<0.05$, save for those in the control plots at 45, 75 DAT, and at harvest with measurably lower tiller numbers plant^{-1}. The mean panicle length plant^{-1} and mean number of panicles m^{-2} were significantly ($p<0.05$) longer and higher, respectively in plots treated with SBAJATM *vis-à-vis* the control. While no significant differences were recorded in the 1000 grain weight, the percentage of filled grains panicle^{-1} and the number of grains panicle^{-1} were higher among rice plants in plots receiving the SBAJATM treatments. Perpetually, the Crop Cutting Tests (CCT) in plots subjected to foliar applications of SBAJATM registered measurable increase in rice yields from 15 to 29% *vis-à-vis* the equivalent foliar-applied fertilizer subsidy from the government, and the conventional NPK fertilizer applications of 100:30:20 (here served as the control), respectively. The SBAJATM treated plots registered a mean yield of 9.66 tons ha^{-1} compared with 7.49 tons ha^{-1} in the control plots. The parallel average yield from the equivalent foliar-applied fertilizer subsidy from the government was 8.38 tons ha^{-1}. In monetary terms, a yield increase of 1 ton ha^{-1} is translated as an extra net profit of RM 1,000 ha^{-1} season^{-1}.

Akhand *et al.* (2013) conducted an experiment at the Bangladesh Rice Research Institute Farm, Gazipur, during aman and boro seasons of 2009-2012. One observational and two replicated trials were conducted to find out the suitability of urea spraying of nitrogen management for rice cultivation. One observational trial, urea solution was sprayed at different concentration levels with or without addition of prilled urea. In this trial, 12 treatments were applied. Two replicated where applied treatments were; Urea at 266 kg ha^{-1} in boro and 175 kg ha^{-1} in aman, urea top dressed at 20, 30 DAT (date after transplanting) and at panicle initiation stage, 2/3rd of recommended N, top dressed at 20, 30 DAT along with 3.5% urea spraying at PI stage, 2/3rd of recommended N, top dressed at 20, 30 DAT along with 3.5% urea solution spraying at PI and booting stage, 2/3rd of recommended N along with 3.5% urea spraying at maximum tillering, PI and booting stage, and compared with without N. It was found that urea could be saved by 22% in aman and 27% in boro seasons without scarifying grain yield when 2/3rd of recommended N, top dressed at 20 and 30 DAT along with urea solution spraying with 3.5% concentration at tillering, panicle initiation and booting stages.

Parvin *et al.* (2013) conducted an experiment to investigate the effect of foliar application of urea on the yield and yield components of *Boro* rice *cv*. BRRI dhan29. The experiment included six methods of urea application viz. foliar spray @ 0, 60, 80,100 and120 kg ha^{-1} and soil application @ 220 kg ha^{-1} . Yield and yield contributing characters of *Boro* rice *cv*. BRRI dhan 29 were considerably influenced by foliar application of urea. The maximum grain yield was obtained from five times foliar urea spray @ 100 kg ha^{-1}. This maximum grain yield was the resultant effect of highest number of effective tillers hill^{-1} and grains panicle^{-1} in this treatment. The interaction of weeding and foliar application of urea also influenced grain yield of *Boro* rice *cv*. BRRI dhan29.

Alam *et al.* (2012b) conducted an experiment during Boro season with a view to examining the effect of soil and foliar application of urea on the yield and nutrient uptake of BRRI dhan29 and to evaluate whether urea foliar application (FA) could replace its soil application (SA) in the rice cultivation. The treatments were: T_1 (control), T_2 (282 kg urea ha^{-1} SA), T_3 (1% urea solution FA), T_4 (2% urea solution FA), T_5 (3% urea solution FA), T_6 (94 kg urea ha^{-1} SA + 1% urea solution FA), T_7 (94 kg urea ha^{-1} SA + 2% urea solution FA) and T_8 (94 kg urea ha^{-1} SA + 3% urea solution FA). The results showed that soil and foliar application of nitrogen significantly influenced the growth and yield of crop. The treatment T_2 (282 kg urea ha^{-1}) produced the highest grain yield (5.34 t ha^{-1}). The T_6 (94 kg urea ha^{-1} + 1% urea solution FA) produced the highest straw yield (6.58 t ha^{-1}) of the crop.

Bahmanyar and Mashaee (2010) conducted a research to investigate the effects of topdressing of different rates of nitrogen (N) and potassium (K) on grain yield and yield components of rice (*Oryza sativa cv. Tarrom*) and to observe N and K content of upper leaves analyzed at ten different times. Nitrogen was applied in the form of urea (46% N) at the rates of 0, 23 and 46 kg N/ha and potassium in the form of potassium chloride (60% K_2O) at the rates of 0, 30 and 60 kg/ha K_2O. Results indicated that panicle length, plant height, number of tiller, number of grain per panicle, hollow grain percentage, grain and biological yield were significantly affected by N and K fertilization. Highest grain yield (75.46 g/pot) occurred at 23 kg N/ha and 30 kg/ha K_2O. At flowering stage, K content of stems were higher than leaves, and N content in flag leaves was higher than other plant parts.

Islam *et al.* (2008a) conducted a field trial to establish the response and the most favorable rate of nutrients (NPK) for Chili- Fallow-T. *aman* cropping pattern. He found that grain yield influenced significantly due to application of different rates of nutrients and 60-19-36 kg/ha NPK maximized the yield of T. *aman* rice varieties in respect of yield and economics.

Islam *et al.* (2008b) conducted a field experiment to find out the effect of nitrogen levels and transplanting dates on the yield and yield components of aromatic rice cv. Kalizira. The experiment was laid out in a randomized complete block design with three replications using four (0, 50, 100, and 150 kg N/ha) levels of nitrogen and three transplanting dates (10 August, 22 August and 04 September, 2007) along with the basal doses of triple super phosphate (TSP), muriate of potash (M_OP) and gypsum. The study revealed that most of the yield and yield contributing characters with few exceptions were significantly influenced by nitrogen levels and transplanting dates. They had significant positive effect on tillers, grains/panicle and straw yield. The maximum grain yield (2.63 t/ha) was observed in 100 kg N/ha with 10 August transplanting treatment and straw yield (6.43 t/ha) was found highest in 150 kg N/ha with same date of transplanting and the lowest grain (1.83 t/ha) and straw yields (5.14 t/ha) were found in N control treatment with transplanting date of 04 September. The highest grain length (4.68 mm), grain breadth (2.49 mm) and imbibition ratio (6.93) were observed with 100 kg/ha N rate coupled with 10 August transplanting, and for length-breadth ratio, the same rate recorded the highest result, but with different transplanting date i.e. 22 August.

Ndaeyo *et al.* (2008) supervised a research in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600kg/ha). The results showed that 600kg/ha NPK (15:15:15) fertilizer rate significantly ($P < 0.05$) increased plant height, number of leaves and tillers per plant in two years. The 400kg/ha rate increased the number of panicles per plant, length of central panicle per plant and the overall grain yields, straw yield over other rates by 4-32% and 2-21% in 2005 and 2006, respectively.

Rahman *et al.* (2007) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during T. Aman season, 2002 to study the effect of different level of nitrogen on growth and yield of transplant Aman rice. The experiment included four treatments viz. 0, 60, 80 and 100 kg N/ha. Nitrogen level significantly influenced growth and yield components. The highest number of effective tillers/hill (9.20), maximum grains/panicle (100.80) and the maximum grain yield (5.34 t/ha) were obtained with 80 kg N/ha. The maximum straw yield (6.98 t/ha) was obtained at the maximum nitrogen level (100 kg N/ha). The maximum harvest index (44.50%) was observed at 80 kg N/ha. Consequences showed that 80 kg N/ha was optimum to produce maximum yield of transplant Aman rice cv. BRRI dhan32.

Ahmed *et al*. (2005) carried out a field experiment during aman season, 2003 at the experimental field of Agrotechnology Discipline, Khulna University, Khulna to study the effect of nitrogen on different characteristics of transplanted local aman rice variety, Jatai. The levels of nitrogen used in this study were 0, 20, 40, 60 and 80 kg ha^{-1}. Results of this study revealed that different agronomic characteristics varied significantly among the treatments. Higher N dose produced higher plant height. The highest effective tiller $hill^{-1}$, panicle length, filled grains $panicle^{-1}$, 1000-grain weight and grain yield was obtained with 40 kg N ha^{-1}. The highest and lowest biological yield was produced with 40 kg N $ha^{-1}$and 0-kg N ha^{-1} respectively.

Saha *et al.* (2004) conducted a field trial in 2002-2003 to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models were tested and compared with one check plot. Results show that the application of different packages estimated by different fertilizer models significantly influence panicle length, panicle numbers, spikelet number $panicle^{-1}$, total grains $panicle^{-1}$, number of filled grain and unfilled grain per panicle. The combination of NPK that gives the highest result was 120-13-70-20 kg/ha NPKS.

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. They found that increased fertilizer dose of NPK increase plant height.

Rasheed *et al.* (2003) reported that the effect of different NP levels i.e., 0-0, 25-0, 50-25, 75-50, 100-75 and 125-100 kg ha^{-1} on yield and yield attributes of rice Bas-385. Yield attributes (No. of effective tillers per hill, spikelet per panicle, normal kernels per panicle, 1000-grain weight) were improved linearly with increasing NP levels up to 100-75 kg/ha. The NP level of 100-75 kg/ha resulted in the highest grain yield of 4.53 t/ha with minimum kernel abnormalities (Sterility, abortive kernels and opaque kernels) as against the minimum of 2.356 t/ha in the control (0-0) followed by 25-0 kg NP/ha with maximum kernel abnormalities.

Singh *et al.* (2003) also reported that crop growth rate and relative growth rate such as total dry matter production was significantly influenced by NPK. The tiller number and total dry matter production are closely correlated with yield depending on the rice cultivar which can be greatly enhanced by applying proper nutrient.

Haq *et al.* (2002) conducted an experiment with twelve treatments mixture of N, P, K, S, Zn and Diazinon. They found that all the treatments significantly increase the grain and straw yield of BRRI dhan30 rice over control. 90 kg N + 50 kg P2O5 + 40 kg K2O + 10 kg S + 4 kg Zn ha-1 + diazinon gave the height grain and straw yield.

Asif *et al.* (2000) reported that NPK levels significantly increased the panicle length, number of primary and secondary branches panicle^{-1} when NPK fertilizers were applied at the dose of 180-90-90 kg ha^{-1}.This might be attributed due to the adequate supply of NPK.

Sarandon and Asborno (1996) conceded a field trial to study the effect of foliar urea spraying on biomass production, harvest index, grain yield and grain protein content on three rice cultivars. Nitrogen (30 kg/ha), was applied as foliar urea spraying at the end of tillering, heading or post-anthesis. Spraying N at heading augmented grain yield due to higher grain number/m^2 and a more efficient dry matter partition to the grain (harvest index), without changes in the biomass production. Both grain N content and grain protein percentage increased significantly with post-anthesis spraying in two of the three cultivars studied but it had no effect on the grain yield. The effectiveness of N fertilization for grain yield was higher when applied at heading. No apparent N recovery in the grain was recorded when urea spraying was done at tillering; but it rises to 70% when applied at heading and to 47% when applied at postanthesis. In all cultivars N spraying at heading increased grain protein production per ha due to an increase of both grain yield and grain protein percentage. It has been concluded that N spraying in rice, even at low doses, could be effective to increase grain yield and grain protein content depending on rice cultivars and time of application.

Mishra *et al.* (1994) carried out a field experiment with rice cv. Sita giving 0 or 80 kg N ha^{-1} as urea, USG and neem, lac, rock phosphate or karanj coated urea and showed that the highest grain yield was (3.39 t ha^{-1}) obtained by urea in three split applications.

2.3 Combination effect of planting method and N-splitting

Bhuyan *et al.* (2012) showed that foliar spray in bed planting method increased grain yield of transplanted aman rice up to 9.33% over conventional method. Foliar nitrogen fertilizer application in bed planting method increased the number of panicle m^{-2}, number of grains $panicle^{-1}$, and 1000-grain weight of rice than the conventional method. Sterility percentage and weed infestation were lower at foliar nitrogen fertilizer application in bed planting method than the conventional method. Thirty-nine percent of irrigation water and time for application could be saved through foliar nitrogen spray in bed planting than conventional method. Water use efficiency for grain and biomass production was higher by foliar nitrogen fertilizer application in bed planting than conventional method. Likewise, agronomic efficiency of foliar nitrogen fertilizer application in bed planting method was higher than the conventional method.

CHAPTER III
MATERIALS AND METHODS

The study was undertaken to compare the effects of different planting method and nitrogen splitting in BRRI dhan29. The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2014 to July 2015. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.1.2 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1988a). 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 (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The area prevails with sub tropical 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).

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranges from 5.4-5.6 and had organic carbon 0.82%. The experimental area was flat having available irrigation and drainage system and above flood level.

3.2 Details of the Experiment

3.2.1 Treatments

The experiment will be undertaken to study the effects of planting method (as main plot) and seven levels of nitrogen splitting (as sub plot).

A. Main plot (Planting Method-3):

1. M_1=Conventional transplanting,
2. M_2=Drum seeder
3. M_3=Rice transplanter

B. Sub-plot (Ways of N Application-7):

1. T_1=100% urea of RD in 3 top dress,
2. T_2=100% urea of RD in 1 top dress & 2 sprays,
3. T_3=100% urea of RD in 3 sprays,
4. T_4=75% urea of RD in 1 top dress & 2 sprays,
5. T_5=75% urea of RD in 3 sprays,
6. T_6=50% urea of RD in 1 top dress & 2 sprays and
7. T_7=50% urea of RD in 3 sprays.

3.2.2 Experimental design

The experiment was laid in a split-plot design with three replications having planting methods in the main plots and N-splitting in the sub-plots. There were 21 treatment combinations. The total numbers of unit plots were 63. The size of unit plot was 3.0 m by 2.5 m. The distances between plot to plot and replication to replication were 1 m. The layout of the experiment has been shown in Appendix II.

3.3 Description of materials

Two planting devices were used in this experiment.

3.3.1 Rice transplanter

The rice planter is a specialized transplanter fitted to transplant rice seedlings onto paddy field. Although rice is grown in areas other than Asia, rice transplanters are used mainly in East, Southeast, and South Asia. The machine can save considerable time and labor which makes it popular among the farmers. The rice planter is mainly comprised of three parts, the motor and the running gear and the transplanter device. The transplanter includes the seedling tray, the seeding tray shifter, plural pickup forks. The seeding tray is like a shed roof where mat type rice nursery is set. When the rice transplanter is brought in the field, the seedlings were fed on the seedling trays. Then the tray shifts seedlings like a carriage of typewriters as pickup forks get seedlings from the tray and put into the ground. The pickup forks act like human figures by taking seedlings from the tray and pushing them into the earth maintaining 30 cm in row to row distance.

3.3.2 Drum seeder

Balasubramaniam and Morales (1998) defined seeder as a device to drop the seeds in rows or all along the width of machine on the surface of seed bed from the seed hopper when it was operated. The drum seeder means the machine, which sows dry seeds at specified rates on seedbed. In this experiment, the drum seeder was used consisted of six drum maintaining 17 cm from row to row distance and 5cm from plant to plant distance.

3.4 Crop management

3.4.1 Raising of seedling

3.4.1.1 Seed collection

Seeds of BRRI dhan29 were collected from Genetic Resource and Seed Division, BRRI, Joydebpur, Gazipur, Bangladesh.

3.4.1.2 Seed sprouting

Healthy seeds were selected by following specific gravity method. Seeds were immersed into water in a bucket for 24 hours. These were then taken out of water and kept tightly in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.4.1.3 Preparation of seedling nursery

A common procedure was followed in raising of seedlings in the seedbed for conventional transplanting. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

A special tray, suited for specific rice transplanter, was used to raise seedling for transplanting of rice by rice transplanter. Loam soil and organic matter, each of which contain fifty percent, mixed well together and placed onto tray up to two-third of the tray and rest portion of the tray was filled with rice husk after sowing of germinating seed. Sprinkler irrigation was gently provided by water cane to the tray as and when needed. No fertilizer was used in the nursery bed.

In the case of direct seeding technique no seedling nursery was established as in this method direct seeding in main field was practiced with the help of drum seeder.

3.4.1.4 Seed sowing

Seeds were sown on the experimental plot, tray of rice transplanter and seed bed on December 15, 2014 for using different techniques.

3.4.2 Preparation of experimental land

The experimental field was first opened on December 08, 2014 with the help of a tractor drawn disc plough and then on December 13, 2014; January 08, 2015 and 18, 2015 for direct seeding, rice transplanter and conventional technique respectively. The land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor plough and subsequently leveled by laddering. All kinds of weeds and residues of previous crop were removed from the field. After the final land preparation the field layout was made on different date according to experimental plan. Individual plots were cleaned and finally leveled with the help of wooden plank so that no water pocket could remain in the puddled field.

3.4.3 Fertilizer application

The experimental plots were fertilized with recommended doses of 220, 80, 120, 100 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at final land preparation. Urea was applied as stated by the treatments in three equal installments. The first dose of urea was applied after seedling recovery, second during the vegetation stage and third at 7 days before panicle initiation (BRRI, 2010).

3.4.4 Uprooting and transplanting of seedlings

A little amount of water was applied on the trays for softening the soil which helped to get the seedling from mats easily. The mats were removed from trays by pulling the seedling and put on transplanter tray for transplanting.

The seedbeds were made wet by application of water in previous day before uprooting the seedlings for conventional method to minimize mechanical injury of roots. The 35 day old nursery seedlings were uprooted carefully on January 20, 2015 and were kept in soft mud in shade**.** The seedlings were then transplanted maintaining 25 cm × 15 cm spacing on the well-puddled plots.

3.4.5 Intercultural operations

3.4.5.1 Thinning and gap filling

A minor gap filling was done as and where necessary using the seedling or separated clonal tillers from the previous source as per treatment but gap filling operation was not conducted in drum seeder technique. No thinning was done for any treatment.

3.4.5.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for each treatment; first weeding was done at 20 days after conventional transplanting followed by second weeding at 15 days after first weeding.

3.4.5.3 Application of irrigation water

Irrigation water was added to each plot according to the need. All the plots were kept irrigated maintaining 3-5 cm stagnant water throughout the entire period up to 15 days before harvesting.

3.4.5.4 Plant protection measures

Crop was protected from birds during seedling establishment in main field, seed bed and tray and also during the grain filling period. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.5.5 General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. No incidence of insects was observed during experiment. There were also no bacterial and fungal disease was observed in the field.

3.4.5.6 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. Five pre-selected hills plot^{-1} from which different crop growth data were collected and 3 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by a pedal thresher. The grains were cleaned and oven dried to moisture content of about 12%. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}.

3.4.6 Recording of data

Experimental data were recorded from 50 days of growth duration and continued until harvest. Dry weights of plant were collected by harvesting respective number of hills at different dates from the inner rows leaving border rows and the area for harvesting grain yield grain. The following data were recorded during the experiment.

A. Crop growth characters

i. Plant height (cm) at 25 days interval from 50 DAS to harvest
ii. Number of tillers hill^{-1} at 25 days interval from 50 DAS to harvest
iii. Leaf area index at 25 days interval from 50 DAS to harvest
iv. Dry weight of plant at 25 days interval from 50 DAS to harvest

B. Yield and other crop characters

i. Number of effective tillers hill^{-1}
ii. Number of ineffective tillers hill^{-1}
iii. Length of panicle (cm)
iv. Number of rachis branches panicle^{-1}
v. Number of filled grains panicle^{-1}
vi. Number of unfilled grains panicle^{-1}
vii. Number of total grains panicle^{-1}
viii. Weight of 1000 grains (g)
ix. Grain yield (t ha^{-1})
x. Straw yield (t ha^{-1})
xi. Biological yield (t ha^{-1})
xii. Harvest index (%)

3.4.7 Detailed procedures of recording data

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

A. Crop growth characters

i. Plant height (cm)

In this experiment, plant height was measured at 50, 75, 100, 125 DAS and at harvest. The height of the randomly pre-selected 5 hills plot^{-1} was determined by measuring the distance from the soil surface to the tip of the leaf height before heading, and to the tip of panicle after heading. The collected data were finally averaged.

ii. Number of tillers hill^{-1}

Number of tillers hiil^{-1} were counted at 50, 75, 100, 125 DAS and at harvest from five randomly pre-selected hills and averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

iii. Leaf Area Index (LAI)

Leaf area index was estimated measuring the length and width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

iv. Dry weight of plant (g)

Two hills plot^{-1} was uprooted at 50, 75, 100, 125 DAS and at harvest from second line and oven dried (sub-sample) until a constant level from which the average weights of dry matter were recorded.

v. SPAD value

Measurement of SPAD value was taken from ten leaves of different plant with SPAD meter. Each observation was an average of 10 leaves.

B. Yield and other crop characters

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

The panicles which showed at least one grain was considered as effective tillers. The number of effective tillers of 5 hills was recorded and finally averaged for counting number of effective tillers hill^{-1}.

ii. Ineffective tillers hill^{-1} (no.)

The tiller having no panicle was regarded as ineffective tillers. The number of ineffective tillers of 5 hills was recorded and finally averaged for counting number of ineffective tillers hill^{-1}.

iii. Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was recorded from the average of 10 panicles.

iv. Rachis branches panicle^{-1} (no.)

Primary branches of panicle that contains a number of spikelet termed as rachis branches. The number of total rachis branches present on ten panicles were recorded and finally averaged.

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

Grain was considered to be filled if any kernel was present there in. The number of total filled grains present on ten panicles were recorded and finally averaged.

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

Unfilled grains means the absence of any kernel inside the spikelets and such spikelets present on each of ten panicles were counted and finally averaged.

vii. Total grains panicle^{-1} (no.)

The number of filled grains panicle^{-1} plus the number of unfilled grains panicle^{-1} were considered as the total number of grains panicle^{-1}.

viii. Weight of 1000 grains (g)

One thousand cleaned dried grains were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained about 12% moisture and the mean weight were expressed in gram.

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

Grain yield was determined from the central 3 m^2 area of each plot and expressed as t ha^{-1} after drying of grains at 12% moisture level. Grain moisture content was measured by using a digital moisture tester.

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

Straw yield was determined from the central 3 m^2 area of each plot. After separating of grains, the sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

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

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

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

xii. Harvest Index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Donald, 1963; Gardner *et al*., 1985).

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

3.4.8 Statistical Analyses

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using STATISTICS-10 computer package program and the mean differences were adjudged by least significant difference (LSD) test at 5 % level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

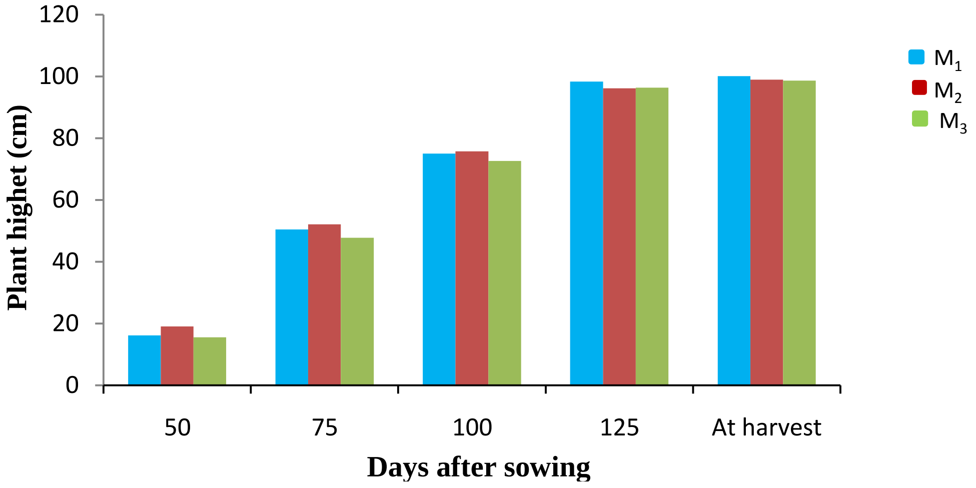
The results obtained from the study regarding the effects of planting methods of BRRI dhan29 and N-splitting and their interactions on the yield and yield components have been presented, discussed and compared in this chapter under the following headings:

4.1 Plant height at different days after sowing

4.1.1 Effect of planting methods

Significant variation of plant height was found due to different planting methods in growth duration from 50 DAS to 100 DAS but statistically similar at 125 DAS and harvest (Appendix III and Figure 01). The results revealed that, at 50 DAS, the tallest plant (19.09 cm) was obtained from the direct sowing by drum seeder followed by the conventional transplanting (16.17 cm) which was statistically similar with the shortest plant height (15.59 cm) obtained from transplanting by rice transplanter. The tallest plant height (52.13 cm) was recorded from the drum seeder technique at 75 DAS which was statistically similar with the plant height observed from conventional transplanting (50.45 cm) and the shortest plant height (47.75 cm) was obtained from transplanting by rice transplanter. Similar trend was also observed at 100 DAS. The tallest plant height (75.74 cm) was recorded from the drum seeder technique which was statistically similar with the plant height observed from conventional transplanting (74.98 cm) and the shortest plant height (72.62 cm) was obtained from transplanting by rice transplanter, statistically similar with conventional transplanting. At 125 DAS and harvest, plant height of different technique was statistically insignificant. At 125 DAS, the tallest plant (98.39 cm) was obtained from conventional transplanting followed by the transplanting by rice transplanter (96.38 cm) and the shortest plant height (96.17 cm) was obtained from direct sowing drum seeder. At harvest, the tallest plant (100.15 cm) was obtained from conventional transplanting followed by direct sowing drum seeder (99.00 cm) and the shortest plant height (98.65 cm) was obtained from transplanting by rice transplanter.

In the early stage of growth, the increase of plant height was very slow and the crop remained in vegetative phase. The rapid increase of plant height was observed from 50 to 100 DAS where tallest plant might be observed in drum seeder due to absence of recovery stage but shortest plant was observed in transplanting which was dissimilar to result of Munnaf *et al.* (2014) where mechanical transplanter produced taller plant compared to conventional methods. In maturity stage, the height of plant was statistically similar due to genetic similarity.



M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

Figure 01: Effect of planting methods on plant height ($LSD_{(0.05)}$ = 1.23, 1.66 and 2.16 at 50, 75 and 100 DAS respectively)

4.1.2 Effect of N-splitting

The plant height was found statistically similar due to nitrogen splitting at 50 and 75 DAS but significant at 100 DAS, 125 DAS and at harvest (Appendix III and Table 01). At 50 DAS, the maximum plant height (17.70 cm) was obtained from the T_6 and the shortest plant (16.37 cm) was obtained from the T_2 treatment which was statistically similar to all other treatments. At 75 DAS, the maximum plant height (51.60 cm) was recorded from T_5 followed by T_4 (51.24 cm), cm T_1 (50.10 cm), T_2 (49.92 cm), T_7 (49.70 cm), T_6 (49.32 cm) and the minimum plant height was obtained from T_3 (45.90 cm) all of which were statistically similar. At 100 DAS, the tallest plant (79.30 cm) was recorded from T_1 followed by T_5 (75.71 cm) and T_4 (75.42 cm), T_3 (74.66 cm) and T_2 (73.52 cm) plant height obtained from all these treatments were statistically similar and the shortest plant was obtained from T_7 (70.35 cm) which was statistically similar with T_6 (72.13 cm) and all other except T_1. The tallest plant (100.16 cm) was found from T_1 at 125 DAS followed by T_3 (97.01 cm), T_6 (96.96 cm), T_5 (96.92 cm) and T_2 (96.84 cm) which were statistically similar and the shortest plant was obtained from T_7 (94.55 cm) which was statistically similar with T_4 (96.42 cm) and all except T_1. These findings were in agreement with the findings of Das (2014) who reported that plant height increased with the increase of nitrogen level. Chopra and Chopra (2004) stated that nitrogen had significant effects on plant height.

Table 01. Effect of N-splitting on plant height at different days after sowing

Treatments	Plant height (cm) at different DAS				
	50	75	100	125	At harvest
T_1	16.82	50.10	79.30 a	100.16 a	101.91 a
T_2	16.93	49.92	73.52 ab	96. 84 ab	98.93 ab
T_3	16.83	45.90	74.66 ab	97.01 ab	99.94 ab
T_4	16.48	51.24	75.42 ab	96.42 ab	90.28 b
T_5	17.50	51.60	75.71 ab	96.92 ab	99.81 ab
T_6	17.70	49.32	72.13 b	96.96 ab	98.83 ab
T_7	16.37	49.70	70.35 b	94.55 b	97.18 b
$LSD_{(0.05)}$	NS	NS	5.83	3.43	3.28
CV (%)	13.40	7.97	8.18	3.70	3.46

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

4.1.3 Interaction effect of planting methods and N-splitting

Significant effect was found in interaction between the planting methods and N-splitting on plant height at different growth stages (Appendix III and Table 02). The results showed that at 50 DAS, the tallest plant (21.05 cm) was obtained from the M_2T_5 which was statistically significant except all treatments of drum seeder (M_2), M_1T_2 (17.58 cm) and M_1T_6 (17.78 cm) and the shortest plant (14.18 cm) was obtained from T_3 of rice transplanter (M_3). At 75 DAS and 100 DAS, the tallest plant (55.30 cm) and (82.85 cm) was obtained from the M_2T_5 but the shortest plant (44.64 cm) and (67.53 cm) was obtained from T_6 of rice transplanter (M_3). At 125 DAS, the tallest plant (104.23cm) was obtained from the M_1T_1 which was statistically similar with M_1T_6 (102.31 cm), M_2T_1 (98.23 cm), M_3T_2 (98.07 cm) and M_3T_1 (98.01 cm) and the shortest plant (92.93 cm) was obtained from T_7 of conventional transplanting (M_1) which was statistically similar with all combinations of treatment except M_1T_1 (104.23 cm), M_1T_6 (102.31 cm). At harvest, the tallest plant (105.60 cm) was obtained from the M_1T_1 which was statistically similar with M_1T_6 (103.68 cm), M_2T_3 (102.47 cm), M_3T_1 (100.90 cm), M_2T_5 (100.75 cm), M_1T_5 (100.68 cm) and M_3T_2 (100.30 cm) and the shortest plant (96.20 cm) was obtained from T_7 of conventional transplanting (M_1) which was statistically similar with all combinations of treatment except M_1T_1 (105.60 cm), M_1T_6 (103.68 cm) and M_2T_3 (102.47 cm).

4.2 Number of tillers hill^{-1} at different days after sowing

4. 2.1 Effect of planting method

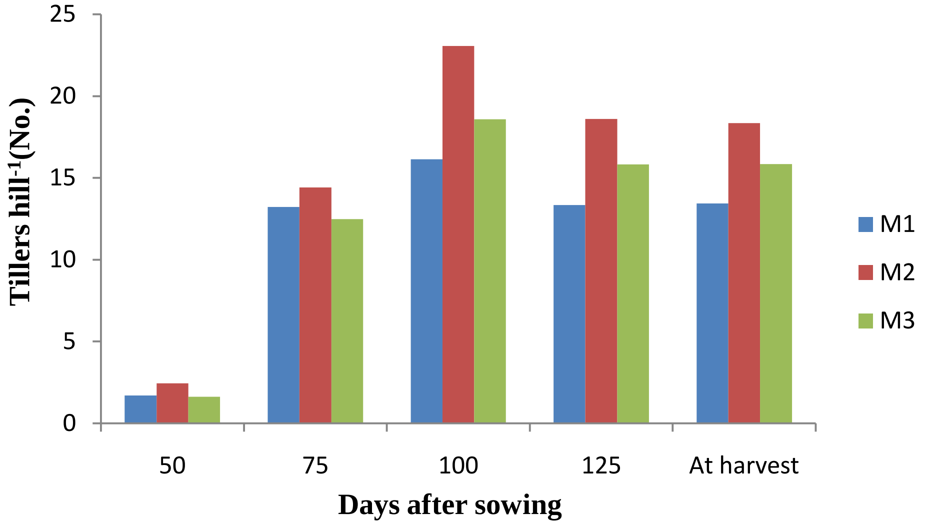
The production of total number of tillers hill^{-1} of BRRI dhan29 was statistically significant and influenced by different planting methods (Appendix IV and Figure 02). The higher number of tillers hill^{-1} (2.44), (14.41), (23.06), (18.60) and (18.35) was observed at 50, 75, 100, 125 DAS and at harvest respectively in the planting method of drum seeder shown statistically variation with other two methods except the number of tillers hill^{-1} (13.23) at 75 DAS of conventional method was dissimilar of founding non-significant effect of planting method on tillers hill^{-1}. The lower number of tillers hill^{-1} (1.62) and (12.48) was calculated from transplanter at 50 DAS and 75 DAS but lower number of tillers hill^{-1} was observed (16.14), (13.34) and (13.43) in conventional method at 100, 125 DAS and at harvest respectively which was statistically significant with other two method. This result supports founding of Maruf (2014) who observed higher number of tillers hill^{-1} in transplanter method than conventional.

Table 02. Interaction effect of planting method and N-splitting on plant height at different days after sowing

Treatments		Plant height (cm) at different DAS				
		50	75	100	125	At harvest
M_1	T_1	15.06 d-g	52.30 a-d	81.90 ab	104.23 a	105.60 a
	T_2	17.58 a-g	50.17 a-e	72.21 b-e	96.91 bc	98.22 b-d
	T_3	15.86 c-g	48.53 b-e	70.43 a-e	97.39 bc	98.36 b-d
	T_4	16.12 c-g	49.93 a-e	75.43 a-e	97.98 bc	98.33 b-d
	T_5	15.88 c-g	51.70 a-d	74.30 a-e	96.95 bc	100.68 a-d
	T_6	17.78 a-g	51.97 a-d	77.30 a-d	102.31 ab	103.68 ab
	T_7	14.91 e-g	48.85 a-e	68.10 de	92.93 c	96.20 d
M_2	T_1	19.50 a-c	52.47 a-c	77.80 a-c	98.23 a-c	99.23 b-d
	T_2	18.72 a-d	50.83 a-e	72.90 a-e	95.53 c	98.27 b-d
	T_3	20.41 ab	51.40 a-d	77.59 a-d	98.10 a-c	102.47 a-c
	T_4	17.38 a-g	53.40 ab	75.69 a-e	93.79 c	97.40 cd
	T_5	21.05 a	55.30 a	82.85 a	97.47 bc	100.75 a-d
	T_6	18.14 a-f	51.37 a-d	71.57 c-e	93.67 c	95.67 d
	T_7	18.35 a-e	50.41 a-e	71.79 c-e	96.40 bc	99.21 b-d
M_3	T_1	15.90 c-g	45.77 de	78.18 a-c	98.01 a-c	100.90 a-d
	T_2	14.50 fg	48.77 a-e	75.45 a-e	98.07 a-c	100.30 a-d
	T_3	14.18 g	46.72 c-e	70.96 c-e	95.55 c	98.98 b-d
	T_4	15.93 c-g	50.40 a-e	75.12 a-e	97.48 bc	99.11 b-d
	T_5	15.58 d-g	48.10 b-e	69.67 c-e	96.34 bc	97.99 b-ds
	T_6	17.17 b-g	44.64 e	67.53 e	94.91 c	97.15 cd
	T_7	15.86 c-g	49.83 a-e	71.15 c-e	94.32 c	96.13 d
$LSD_{(0.05)}$		3.76	6.61	10.09	5.93	5.69
CV (%)		13.40	7.97	8.18	3.70	3.46

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.



M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

Figure 02: Effect of planting methods on number of tillers hill^{-1} ($LSD_{(0.05)}$ = 0.09, 1.41, 2.16, 1.85 and 1.84 at 50, 75, 100 and 125 DAS and at harvest, respectively)

4.2.2 Effect of N-splitting

The total number of tillers hill^{-1} was significantly influenced by nitrogen splitting at 50, 75, 100, 125 DAS and at harvest (Appendix IV and Table 03). At 50 DAS the highest numbers of tillers hill^{-1} was detected in T_5 (2.29) and statistically different with all other treatments whereas the lowest number of tillers hill^{-1} was observed in T_4 (1.67) which was statistically similar with T_7 (1.70). At 75 DAS, the highest number of tillers hill^{-1} (14.65) was observed in T_1 which was statistically similar with all other treatments except T_6 (11.58) which produced the lowest numbers of tillers hill^{-1}. The highest number of tillers hill^{-1} (21.45) was observed in T_3 at 100 DAS which was statistically similar with all other treatments except T_6 (15.80) which produced the lowest numbers of tillers hill^{-1} and T_5 (16.89). At 125 DAS and at harvest the highest number of tillers hill^{-1} was calculated from T_1 (17.28 and 17.40 respectively) followed by T_4 (17.00 and 17.17 respectively), T_2 (16.82 and 16.78 respectively), T_3 (16.56 and 16.18 respectively), T_7 (16.33 and 16.31 respectively), T_5 (14.00 and 14.21 respectively) all of which were statistically similar and the lowest numbers of tillers hill^{-1} was attained from T_6 (13.45 and 13.05 respectively) Foliar application of urea provided higher tiller number than soil application. Bayan and Kandasamy (2002) reported that tillers hill^{-1} increased with the application of nitrogen fertilizer which supports the result of this study.

Table 03. Effect of N-splitting on number of tillers hill^{-1} at different days after sowing

Treatments	Number of tillers hill^{-1} at different DAS				
	50	**75**	**100**	**125**	**At harvest**
T_1	2.05 b	14.65 a	20.65 ab	17.28 a	17.40 a
T_2	1.90 b	13.40 ab	20.08 a-c	16.82 a	16.78 a
T_3	1.96 b	13.89 ab	21.45 a	16.56 ab	16.18 ab
T_4	1.67 d	13.8 ab	20.70 ab	17.00 a	17.17 a
T_5	2.29 a	13.07 ab	16.89 bc	14.00 ab	14.21 ab
T_6	1.89 bc	11.58 b	15.80 c	13.45 b	13.05 b
T_7	1.70 cd	13.20 ab	19.20 a-c	16.33 ab	16.31 ab
$LSD_{(0.05)}$	0.17	2.61	2.10	3.37	3.42
CV (%)	9.15	20.42	23.18	22.11	22.50

$\mathbf{T_1}$ = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, $\mathbf{T_2}$ = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, $\mathbf{T_3}$ = 100% Urea of RD was applied as 3 foliar spray, $\mathbf{T_4}$ = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, $\mathbf{T_5}$ = 75% Urea of RD was applied as 3 foliar spray, $\mathbf{T_6}$ = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, $\mathbf{T_7}$ = 50% Urea of RD was applied as 3 foliar spray.

4.2.3 Interaction effect of planting methods and N-splitting

Significant interaction effect between planting methods and N-splitting on number of tillers hill^{-1} was observed at 50, 75 and 100 DAS and at harvest (Appendix IV and Table 04). The results showed that at 50 DAS, the highest number of tillers hill^{-1} was observed in T_5 (3.50) of drum seeder (M_2) which was statistically dissimilar with all other treatments of all planting method and the lower tiller number was found in T_4 (1.2) of rice transplanter (M_3) that was statistically similar with T_1 (1.30) of rice transplanter (M_3) and T_7 (1.40), T_5 (1.45), T_2 (1.47) of conventional method (M_1). As like 50 DAS the highest numbers of tillers hill^{-1} was also observed in T_5 (16.07) of drum seeder (M_2) at 75 DAS which was statistically similar with all other treatment except T_5 (10.70) and T_6 (9.50), lowest tiller producing, of conventional (M_1) and rice transplanter (M_3) method respectively. At 100 DAS, the highest numbers of tillers hill^{-1} was observed in T_4 (26.73) of drum seeder (M_2) which was statistically similar with T_1 (21.93), T_2 (26.27), T_3 (25.27) of drum seeder (M_2); T_1 (21.53) and T_3 (19.67) of transplanter (M_3) and conventional method (M_1) but the lowest tiller number was counted in T_6 (13.00) of conventional method (M_1) that was statistically similar with all the treatments of conventional method (M_1) and transplanter (M_3) except T_1 (21.53) of rice transplanter (M_3) and T_1 (21.93), T_2 (26.27), T_3 (25.27), T_4 (26.73) and T_7 (23.50), of drum seeder (M_2). At 125 DAS and at harvest highest number of tillers hill^{-1} was calculated from T_4 (21.33 and 22.00 respectively) of drum seeder and the lowest numbers of tillers hill^{-1} was attained from T_5 (10.87 and 11.67 respectively) of conventional method which was statistically similar with all the treatments of conventional method (M_1). Different treatments of conventional method (M_1) produced lower number of tillers hill^{-1}. Higher N dose produced the highest effective tillers hill^{-1} which ultimately leads to achieve higher total tillers hill^{-1} (Ahmed *et al.*, 2005). Nitrogen is an essential plant nutrient and involves in enzymatic reactions, protein synthesis and is a major component of amino and nucleic acids but it is the most widely lost nutrients while applied in soil. Many studies showed that foliar urea application can reduce the nitrogen dose and increase the nutrient use efficiency.

4.3 Leaf area index at different days after sowing

4.3.1 Effect of planting method

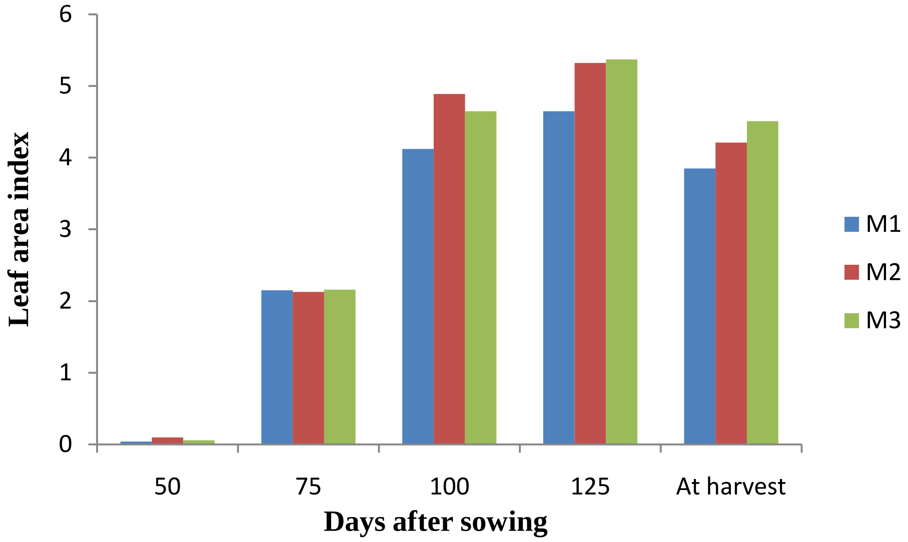
Leaf area index (LAI) was not significantly influenced by planting methods except 50 and 125 DAS (Appendix V and Figure 03). The result revealed that at 50 DAS, higher LAI (0.10) was produced by drum seeder followed by LAI (0.09) from rice transplanter and conventional transplanting produced lower LAI (0.06), all of them were statistically dissimilar. At 75 DAS, no significant variation was observed among planting method measuring higher LAI (2.16) from transplanter followed by conventional (2.15) and drum seeder (2.13). At 100 DAS, no significant variation was also observed among planting method measuring higher LAI (4.89) from drum seeder followed by transplanter (4.65) and conventional (4.12). Higher LAI (5.37) was recorded from transplanter which was statistically similar with drum seeder (5.32) at 125 DAS. The lowest LAI was documented from conventional method (4.65). At harvest, the effect of planting method on LAI was statistically similar calculated higher LAI (4.51) from rice transplanter. Maruf (2014) observed alternative higher and lower LAI in transplanter method and conventional. But in this study, the conventional method produced lowest leaf area index at almost all stages of growth than mechanization system.

Table 04. Interaction effect of planting method and N-splitting on number of tillers hill^{-1} at different days after sowing

Treatments		Number of tillers hill^{-1} at different DAS				
		50	75	100	125	At harvest
	T_1	2.00 d	15.40 a	18.47 c-f	15.10 b-e	15.13 b-e
	T_2	1.47 gh	13.20 a-c	15.80 ef	14.20 c-e	13.87 c-e
	T_3	1.87 e	14.87 ab	19.67 a-f	15.40 b-e	15.27 b-e
M_1	T_4	1.80 ef	12.67 a-c	16.67 d-f	13.40 c-e	13.23 c-e
	T_5	1.45 gh	10.70 bc	14.07 f	10.87 e	11.67 e
	T_6	2.00 d	13.00 a-c	13.00 f	11.80 e	12.07 e
	T_7	1.40 gh	12.70 a-c	15.33 ef	12.54 de	12.73 de
	T_1	2.8 b	14.70 ab	21.93 a-e	18.54 a-c	18.60 a-c
	T_2	2.27 cd	14.87 ab	26.27 ab	20.13 ab	20.27 ab
	T_3	2.47 c	13.80 a-c	25.27 a-c	18.00 a-d	17.40 a-e
M_2	T_4	1.90 e	15.30 a	26.73 a	21.33 a	22.00 a
	T_5	3.50 a	16.07 a	19.13 b-f	16.27 a-e	15.57 b-e
	T_6	1.80 ef	12.20 a-c	18.53 c-f	15.74 a-e	14.80 b-e
	T_7	2.27 cd	13.87 a-c	23.50 a-d	20.20 ab	19.80 ab
	T_1	1.30 gh	13.80 a-c	21.53 a-e	18.20 a-d	18.47 a-d
	T_2	2.00 de	12.13 a-c	18.13 c-f	16.13 a-e	16.20 b-e
	T_3	1.50 fg	13.00 a-c	19.40 b-f	16.27 a-e	15.87 b-e
M_3	T_4	1.20 h	13.40 a-c	18.80 c-f	16.27 a-e	16.27 a-e
	T_5	1.87 e	12.40 a-c	17.47 d-f	14.87 b-e	15.40 b-e
	T_6	1.87 e	9.50 c	15.94 ef	12.80 de	12.27 e
	T_7	1.50 fg	13.07 a-c	18.73 c-f	16.27 a-e	16.40 a-e
$LSD_{(0.05)}$		0.29	4.52	7.39	5.83	5.91
CV (%)		9.15	20.42	23.18	22.11	22.50

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.



M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

Figure 03: Effect of planting method on leaf area index (LSD$_{(0.05)}$ = 0.02, 0.43 and 0.71 at 50 DAS, 125 DAS and at harvest, respectively).

4.3.2 Effect of N-splitting

The LAI was significantly influenced by nitrogen splitting at 50, 75, 100, 125 DAS and at harvest (Appendix V and Table 05). At 50 DAS, the highest LAI (0.10) was recorded in T_5 which was statistically dissimilar with all the treatments and the lowest LAI (0.05) was recorded from T_2, T_4 and T_7. At 75 DAS the highest LAI (2.50) was recorded in T_1 which was statistically similar to all except the lower LAI (1.65) from T_6. At 100 DAS, the highest LAI (5.24) was recorded in T_1 which was statistically similar with T_2 (4.76), T_3 (5.00) and T_4 (4.77) and the lowest LAI (3.63) was recorded in T_6. At 125 DAS and at harvest, the highest LAI (6.64 and 5.51 respectively) was found in T_1 which was statistically dissimilar with all at where the lowest measurement of LAI (3.80 and 3.15 respectively) from plant treated with T_6 in both stages. Das (2014) recorded 1.21% higher LAI from foliar spray than basal dose at 75% of RD and calculated higher LAI from higher dose of nitrogen levels than lower doses which supports the findings of present study.

Table 05. Effect of N-splitting on leaf area index at different days after sowing

Treatments	Leaf area index at different DAS				
	50	75	100	125	At harvest
T_1	0.08 b	2.50 a	5.24 a	6.64 a	5.51 a
T_2	0.05 d	2.00 ab	4.76 ab	5.35 bc	4.23 bc
T_3	0.07 bc	2.21 ab	5.00 ab	5.56 b	4.59 b
T_4	0.05 cd	2.29 a	4.77 ab	5.03 cd	4.30 b
T_5	0.10 a	2.26 a	4.28 bc	4.71 d	3.88 cd
T_6	0.07 bc	1.65 b	3.63 c	3.80 e	3.15 e
T_7	0.05 cd	2.11 ab	4.17 bc	4.72 d	3.67 d
$LSD_{(0.05)}$	0.02	0.59	0.96	0.41	0.40
CV (%)	27.39	28.99	22.06	8.46	9.96

4.3.3 Interaction effect of planting methods and N-splitting

Significant interaction effect between the planting methods and N-splitting on LAI was observed at 50, 75, 100, 125 DAS and at harvest (Appendix V and Table 06). The results showed that at 50 DAS, the highest LAI was observed in T_5 (0.19) of drum seeder (M_2) and the lowest LAI was found in T_2 (0.02) of conventional (M_1). As like 50 DAS the highest LAI was also observed in T_5 (2.93) of drum seeder (M_2) at 75 DAS which was statistically similar with all other treatment except T_2 (1.81), T_5 (1.69) and T_7 (1.80) of conventional method; T_3 (1.76) and T_6 (1.59) of drum seeder and T_6 (1.22) of transplanter and lowest LAI (1.22) of rice transplanter (M_3). At 100 DAS, the highest LAI was observed in T_3 (5.63) of drum seeder (M_2) which was statistically similar with T_2 (3.89), T_6 (3.36) and T_7 (3.69) of conventional method (M_1); T_6 (3.83) of drum seeder (M_2) and T_6 (3.71) of transplanter (M_3) and the lowest LAI was calculated (3.36) from T_6 of conventional method (M_1). At 125 DAS, the highest LAI was calculated from T_1 (7.08) of conventional method and the lowest LAI was attained from T_6 (3.55) of drum seeder (M_2). At harvest, the highest LAI was calculated from T_1 (6.08) of rice transplanter and the lowest LAI was attained from T_6 (3.01) of conventional method (M_1).

Table 06. Interaction effect of planting method and N-splitting on leaf area index at different days after sowing

Treatments		Leaf area index at different DAS				
		50	**75**	**100**	**125**	At harvest
M_1	T_1	0.04 d-g	2.54 ab	5.32 a-c	7.08 a	5.75 ab
	T_2	0.02g	1.81 bc	3.89 b-e	4.48 e-g	3.72 h-i
	T_3	0.04 d-g	2.52 ab	4.69 a-e	4.61 ef	4.08 f-h
	T_4	0.04 d-g	2.54 ab	4.38 a-e	4.77 ef	4.17 e-h
	T_5	0.04 d-g	1.69 bc	3.55 de	3.74 h	3.29 ij
	T_6	0.05 c-f	2.14 a-c	3.36 e	3.79 gh	3.01 j
	T_7	0.03 fg	1.80 bc	3.69 de	4.10 f-h	2.92 j
M_2	T_1	0.14 b	2.44 ab	5.01 a-e	6.10 bc	4.71 c-f
	T_2	0.06 c-e	1.91 a-c	5.21 a-d	5.23 de	3.85 g-i
	T_3	0.12 b	1.76 bc	5.63 a	6.23 bc	4.91 cd
	T_4	0.07 c-e	2.18 a-c	4.91 a-e	5.12 de	4.05 f-h
	T_5	0.19 a	2.93 a	5.15 a-d	5.83 cd	4.53 c-g
	T_6	0.08 c	1.59 bc	3.83 b-e	3.55 h	3.15 ij
	T_7	0.06 c-e	2.12 a-c	4.49 a-e	5.16 de	4.29 d-h
M_3	T_1	0.05 c-f	2.52 ab	5.39 ab	6.73 ab	6.08 a
	T_2	0.06 c-e	2.27 ab	5.21 a-d	6.33 a-c	5.12 bc
	T_3	0.05 c-f	2.36 ab	4.71 a-e	5.84 cd	4.79 c-e
	T_4	0.04 d-g	2.14 a-c	5.01 a-e	5.19 de	4.68 c-f
	T_5	0.08 c	2.18 a-c	4.15 a-e	4.56 e-g	3.81 h-i
	T_6	0.07 cd	1.22 c	3.71 c-e	4.05 f-h	3.29 i-j
	T_7	0.07 c-e	2.42 ab	4.34 a-e	4.91 e	3.80 h-i
$LSD_{(0.05)}$		0.03	1.03	1.66	0.72	0.69
CV (%)		27.39	28.99	22.06	8.46	9.96

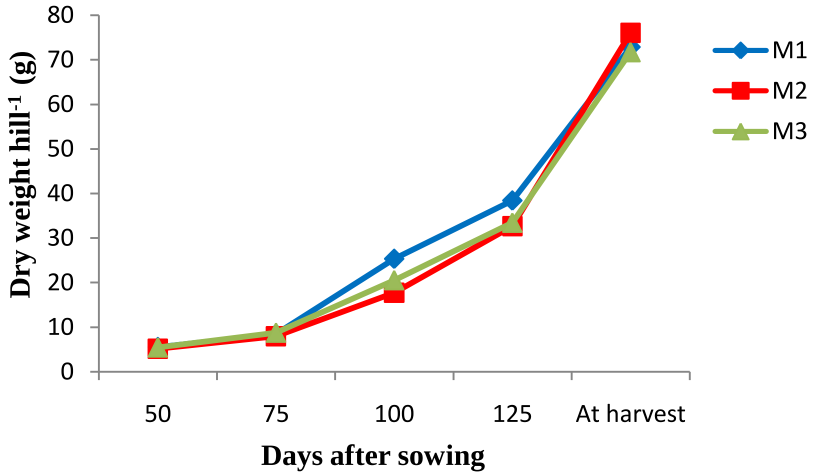
M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

4.4 Dry weight at different days after sowing

4.4.1 Effect of planting method

Efficacy of planting method significantly influenced dry weight at 100 and 125 DAS however; it was not significantly influenced at 50 DAS, 75 DAS and at harvest (Appendix VI and Figure 04). At 50 DAS, 75 DAS and at harvest the higher total dry weight (5.52 g, 8.76 g and 76.00 g hill^{-1} respectively) was found in the conventional (M_1), transplanter (M_3) and drum seeder (M_2) respectively and the lowest total dry weight was weighted from drum seeder (5.14 g hill^{-1}), drum seeder (7.95 g hill^{-1}) and transplanter (71.70 g hill^{-1}) respectively. At 100 DAS the conventional method (M_1) accumulated highest dry weight (25.33 g hill^{-1}) and was statistically dissimilar with other and this trend of accumulation also found at 100 DAS.



M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

Figure 04: Effect of planting methods on dry weight hill^{-1} (LSD$_{(0.05)}$ = 2.31 and 3.57 at 100 and 125 DAS respectively)

4.4.2 Effect of N-splitting

The total dry matter manufacture of plant was significantly influenced by nitrogen splitting at 50, 75, 100, 125 DAS and at harvest (Appendix VI and Table 07). At 50 DAS, the highest dry weight (5.67 g hill^{-1}) was recorded in T_5 and T_6 which was statistically similar with all the treatment except T_1 (4.67 g hill^{-1}) which produced lowest amount of dry matter. At 75 DAS the highest dry weight (9.67 g hill^{-1}) was recorded in T_2 which was followed by T_4 (9.00 g hill^{-1}), T_5 (8.78 g hill^{-1}), T_3 (8.67 g hill^{-1}) and T_1 (8.56 g hill^{-1}) all of which were statistically similar to each other where the lowest dry weight (7.00 g $hill^{-1}$) was found in T_6. At 100 DAS, the highest dry weight (24.22 g $hill^{-1}$) was recorded in T_1 which was statistically similar with T_2 (23.45 g $hill^{-1}$) and T_3 (23.61 g $hill^{-1}$) and the lowest dry weight (18.20 g $hill^{-1}$) was recorded in T_6 which was statistically similar with all treatments except T_1, T_2 and T_3. At 125 DAS and at harvest, the highest dry weight (37.56 g $hill^{-1}$) and (88.42 g $hill^{-1}$) was found in T_1 respectively which was statistically similar with all except T_7 (31.38 g $hill^{-1}$) and statistically similar with T_4 (83.99 g $hill^{-1}$) respectively where the lowest accumulation of dry matter (31.78 g $hill^{-1}$ and 64.43 g $hill^{-1}$) weighted from plant treated with T_7. Das (2014) weighted a similar trend at where highest dry matter (35.20 g $plant^{-1}$) at harvest with high level of nitrogen fertilizer.

Table 07. Effect of different N-splitting on dry weight at different days after Sowing

Treatments	**Dry weight (g) $hill^{-1}$ at different DAS**				
	50	**75**	**100**	**125**	At harvest
T_1	4.67 b	8.56 a	24.22 a	37.56 a	88.42 a
T_2	5.00 ab	9.67 a	23.45 ab	35.45 ab	69.13 cd
T_3	5.45 ab	8.67 a	23.61 ab	34.11 ab	76.36 bc
T_4	5.56 a	9.00 a	20.89 bc	34.67 ab	83.99 ab
T_5	5.67 a	8.78 a	18.67 c	35.67 ab	66.89 cd
T_6	5.67 a	7.00 b	18.20c	34.56 ab	65.47 d
T_7	5.56 a	7.11 b	19.20 c	31.78 b	64.43 d
$LSD_{(0.05)}$	0.79	1.42	2.85	4.37	10.70
CV (%)	15.46	17.69	14.06	13.12	15.23

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

4.4.3 Interaction effect of planting methods and N-splitting

Significant effect was found in interaction between the planting methods and N-splitting on dry matter at different growth stages such as 50, 75, 100, 125 DAS and at harvest (Appendix VI and Table 08). At 50 DAS, the highest (7.0 g hill^{-1}) total dry weight was recorded from M_1T_6 while the lowest (4.33 g hill^{-1}) total dry weight was recorded from M_1T_1, M_2T_2 and M_2-T_6 which was statistically similar with all the treatment except M_1T_6 (7.00 g hill^{-1}), M_2T_3 (6.00 g hill^{-1}), M_3T_4 (6.00 g hill^{-1}) and M_3T_7 (6.00 g hill^{-1}). At 75 DAS, the highest (10.67 g hill^{-1}) dry weight was recorded from M_2T_5 which was statistically similar with M_1T_1 (10.00 g hill^{-1}), M_1T_2 (9.67 g hill^{-1}), M_1T_3 (10.00 g hill^{-1}), M_1T_4 (8.33 g hill^{-1}), M_2T_2 (9.00 g hill^{-1}), M_2T_4 (10.00 g hill^{-1}), M_2T_5 (9.00 g hill^{-1}), M_3T_1 (10.00 g hill^{-1}), M_3T_2 (10.33 g hill^{-1}), M_3T_3 (8.33 g hill^{-1}), M_3T_4 (10.33 g hill^{-1}) and M_3T_5 (10.67 g hill^{-1}) whereas the lowest (6.00 g hill^{-1}) dry weight was recorded from M_2T_6. At 100 DAS, the highest (32.00 g hill^{-1}) total dry weight was observed from M_1T_1 which was statistically similar with M_1T_2 (30.33 g hill^{-1}), M_1T_3 (29.67 g hill^{-1}) and M_3T_4 (28.00 g hill^{-1}) whereas the lowest (12.33 g hill^{-1}) dry weight was recorded from M_1T_6 which was statistically similar with M_3T_7 (16.67 g hill^{-1}) and M_2T_4 (16.33 g hill^{-1}). At harvest, the highest (95.27 g hill^{-1}) dry weight was observed from M_3T_1 whereas the lowest (60.40 g hill^{-1}) total dry weight was recorded from M_1T_7. Bhuyan *et al.* (2012) showed that biomass production was higher by foliar nitrogen fertilizer application in bed planting than conventional method.

4.5 SPAD value of rice at 90 days after sowing

4.5.1 Effect of planting method

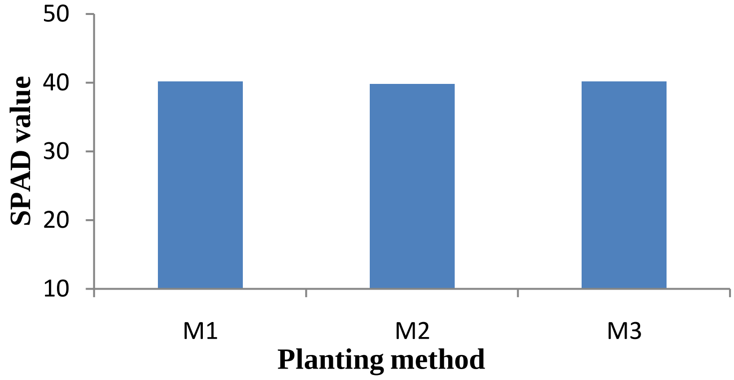
Effect of planting method was not significantly influenced on SPAD value at 90 DAS (Appendix VII and Figure 05). The SPAD value of plant cultivated in different methods were statistically similar with each other but numerically maximum SPAD value (40.19) was measured from conventional method (M_1) followed by transplanter (M_3) and drum seeder (M_2).

Table 08. Interaction effect of planting method and N-splitting on dry weight at different days after sowing

Treatments		Dry weight (g) hill^{-1} at different DAS				
		50	75	100	125	At harvest
M_1	T_1	4.33 c	10.00 a-c	32.00 a	39.67 ab	87.80 abc
	T_2	5.67 a-c	9.67 a-d	30.33 a	34.67 b-e	71.47 c-f
	T_3	5.33 bc	10.00 a-c	29.67 a	39.50 ab	80.93 a-e
	T_4	5.67 a-c	8.33 a-f	18.33 de	38.67 a-c	82.80 a-d
	T_5	5.67 a-c	6.67 ef	19.67 de	38.00 a-c	61.27 f
	T_6	7.00 a	8.00 b-f	24.67 bc	42.67 a	65.40 def
	T_7	5.00 bc	6.67 ef	22.67 cd	35.67 a-d	60.40 f
M_2	T_1	5.00 bc	7.00 ef	18.33 de	37.33 a-d	82.20 a-d
	T_2	4.33 c	9.00 a-e	19 de	36.33 a-d	65.00 def
	T_3	6.00 ab	7.67 c-f	21.17 c-e	29.83 d-f	77.73 a-f
	T_4	5.00 bc	9.67 a-d	16.33 ef	25.33 f	94.47 ab
	T_5	5.67 a-c	9.00 a-e	18.33 de	37.67 a-c	71.86 c-f
	T_6	4.33 c	6.00 f	12.33 f	27.67 ef	69.53 c-f
	T_7	5.67 a-c	7.33 d-f	18.33 de	34.33 b-e	71.30 c-f
M_3	T_1	4.67 bc	8.67 a-e	22.33 cd	35.67 a-d	95.27 a
	T_2	5.00 bc	10.33 ab	21.0 c-e	35.33 a-d	70.93 c-f
	T_3	5.00 bc	8.33 a-f	20.00 c-f	33.00 b-e	70.40 c-f
	T_4	6.00 ab	9.00 a-e	28.00 ab	40.00 ab	74.70 b-f
	T_5	5.67 a-c	10.67 a	18.00 de	31.33 c-f	67.53 def
	T_6	5.67 a-c	7.00 ef	17.67 de	33.33 b-e	61.47 ef
	T_7	6.00 ab	7.33 d-f	16.67 ef	25.33 f	61.60 ef
$LSD_{(0.05)}$		1.37	2.46	4.93	7.57	18.54
CV (%)		15.46	17.69	14.06	13.12	15.23

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray

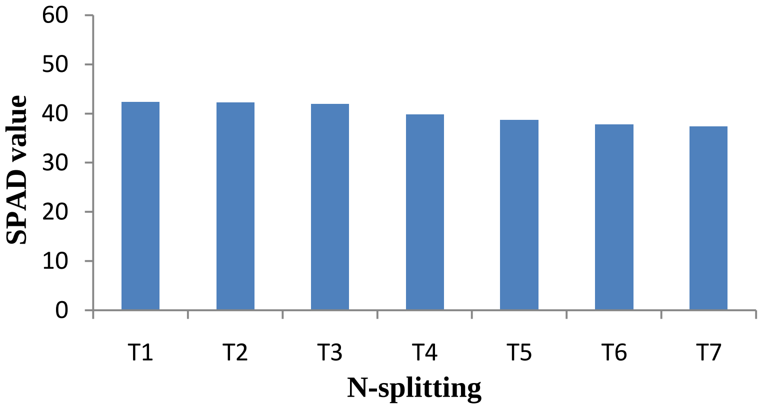


M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

Figure 05: Effect of planting methods on SPAD value of rice.

4.5.2 Effect of N-splitting

Efficacy of nitrogen splitting significantly influenced on SPAD value at 90 DAS (Appendix VII and Figure 06). The SPAD value of plant leaf treated with different N-splitting varied with each other and the highest value (42.41) was observed from T_1 followed by T_2 (42.25) and T_3 (42.03) that were statistically similar with each other and the lowest value (37.37) was observed from T_7 statistically similar with T_6 (37.83) and T_5 (38.73). The SPAD value of plant leaf was decreased with the shrinking dose of nitrogen.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 06: Effect of N-splitting on SPAD value of rice ($LSD_{(0.05)}$ = 2.02).

4.5.3 Interaction effect of planting methods and N-splitting

Significant effect was found in interaction between the planting methods and N-splitting on SPAD value at 90 DAS (Appendix VII and Table 09). At 90 DAS, the highest value (43.05) was observed from M_1T_2 which was followed by M_1T_1 (42.96), M_3T_1 (42.91), M_2T_2 (42.75), M_3T_3 (42.71), M_2T_3 (42.63), M_2T_1 (41.37), M_3T_2 (40.96), M_1T_3 (40.76), M_3T_4 (40.35), M_3T_4 (40.35) and all of these interactions were statistically similar to each other and the lowest (36.98) value was recorded from M_2T_6 that was statistically similar with T_4 to T_7 of all planting method.

Table 09: Interaction effect of planting methods and N-splitting on SPAD value of rice

Treatments	SPAD value		
	M_1	M_2	M_3
T_1	42.96 a	41.37 a-d	42.91 a
T_2	43.05 a	42.75 a	40.96 a-e
T_3	40.76 a-f	42.63 a-c	42.71 ab
T_4	39.87 a-g	39.21 b-g	40.35 a-g
T_5	39.14 c-g	38.71 d-g	38.33 d-g
T_6	37.84 d-g	36.98 g	38.67 d-g
T_7	37.75 e-g	36.99 g	37.35 fg
$LSD_{(0.05)}$	3.49	3.49	3.49
CV (%)	5.27	5.27	5.27

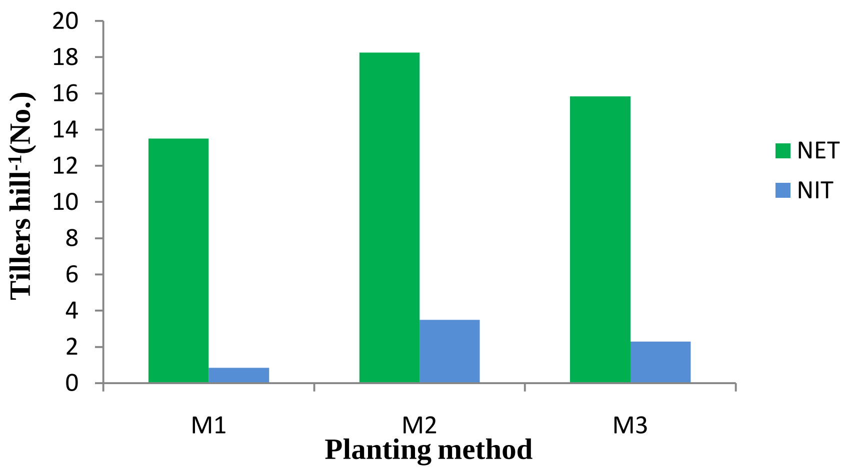
M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

4.6. Number of effective and ineffective tillers hill^{-1}

4.6.1 Effect of planting method

The number of effective tillers hill^{-1} was significantly influenced by different planting method (Appendix VII and Figure 07). The higher number of effective tillers hill^{-1} (18.26) was obtained from drum seeder method (M_2) and the lower number of effective tillers hill^{-1} (13.50) was observed in conventional method (M_1). Maruf (2014) obsereved 6.74% higher number of effective tillers hill^{-1} from rice transplanter than conventional. The number of ineffective tillers hill^{-1} was also significantly influenced by different planting methods (Appendix VII and Figure 07). The higher number of ineffective tillers hill^{-1} (3.50) was obtained from drum seeder method (M_2) and the lower number of ineffective tillers hill^{-1} (0.84) was observed in conventional method (M_1).



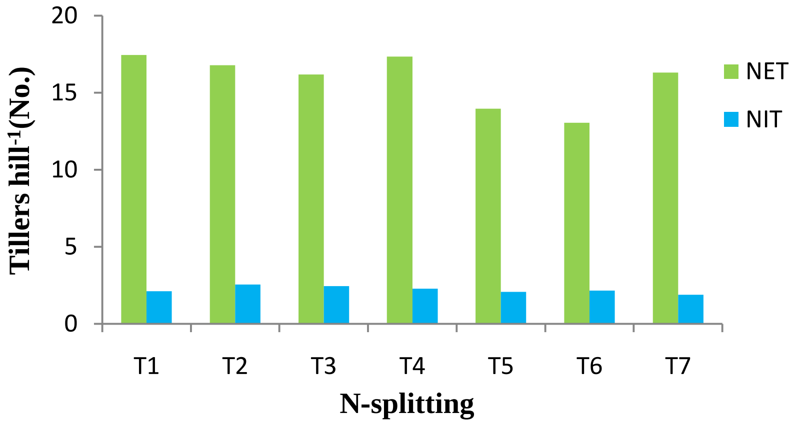
M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

NET- Number of effective tillers hill^{-1}, NIT- Number of ineffective tillers hill^{-1}

Figure 07: Effect of planting methods on number of effective and ineffective tillers hill^{-1} (LSD$_{(0.05)}$ = 1.86 and 0.34 for effective tillers and ineffective tillers hill^{-1} respectively)

4.6.2 Effect of N-splitting

Efficacy of nitrogen splitting influenced significantly the number of effective and ineffective tillers hill-1 (Appendix VII and Figure 08). In case of effective tillers hill-1, the highest (17.44) number of effective tillers hill-1 was observed from T1 that was statistically similar with T2 (16.78), T3 (16.18), T4 (17.34) and T7 (16.31) and the lowest (13.04) number of effective tillers hill-1 was observed in T6. Rasheed et al. (2003) reported that the number of effective tillers hill was increased when NP levels were increased. Chopra and Chopra (2004) reported that nitrogen had significant effects on effective tillers hill^{-1} with increasing levels of N up to 120 kg N ha^{-1} in rice. In case of ineffective tillers hill^{-1}, the highest (2.56) number of ineffective tillers hill^{-1} was observed from T_2 that was statistically similar with all the N-splitting except T_7 (0.52) which was the lowest number of ineffective tillers hill^{-1}.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 3 foliar spray, **T_3** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 3 foliar spray.

NET- Number of effective tiller hill^{-1}, NIT- Number of ineffective tiller hill^{-1}

Figure 08: Effect of N-splitting on number of effective and ineffective tillers hill^{-1} (LSD$_{(0.05)}$ = 3.41 and 0.52 for effective tillers and ineffective tillers hill^{-1} respectively)

4.6.3 Interaction effect of planting method and N-splitting

Significant effect was found in interaction between the planting methods and N-splitting on the number of effective and ineffective tillers hill^{-1} at harvest (Appendix VII and Table 10). The highest number of effective tillers hill^{-1} (22.00) was observed in T_4 of the drum seeder (M_2) which was statistically similar with T_1 (18.73), T_2 (20.27), T_3 (17.40) and T_7 (19.80) of drum seeder (M_2); T_1 (18.47), T_4 (16.27) and T_7 (16.40) of rice transplanter (M_3) and that was statistically similar with T_1 (1.30) of rice transplanter (M_3) and the lowest number of effective tillers hill^{-1} (11.67) was counted from T_5 of conventional (M_1) which was statistically similar with all interactions except T_1 (18.73), T_2 (20.27), T_4 (20.00) and T_7 (19.80) of drum seeder (M_2); T_1 (18.47) of transplanter (M_3). There was no significant effect observed on number of effective tillers hill^{-1} among different N-splitting in conventional method (M_1). The highest number of ineffective tillers hill^{-1} (4.27) was observed in T_2 of the drum seeder (M_2) which was statistically similar with T_3 (3.80), T_4 (4.00), T_6 (3.80) and T_7 (19.80) of drum seeder (M_2) and the lowest number of ineffective tillers hill^{-1} (0.67) was counted from T_4 and T_6 of conventional (M_1).

4.7 Panicle length

4.7.1 Effect of planting method

The length of panicle was not significantly influenced by planting method (Appendix VII and Table 11). Numerically the higher length of panicle (25.26 cm) was obtained from conventional planting method (M_1) and the lower length of panicle (24.54 cm) was observed in rice transplanter method (M_3). Maruf (2014) also found higher length of panicle (23.99 cm) in conventional planting method (M_1) than transplanter method (M_3) (23.86 cm).

Table 10. Interaction effect of N-splitting on number of effective and ineffective tillers hill^{-1} at harvesting

Treatments		No. of effective tillers hill^{-1}	No. of ineffective tillers hill^{-1}
M_1	T_1	15.13 b-e	0.80 h
	T_2	13.87 c-e	1.07 h
	T_3	15.27 b-e	1.13 gh
	T_4	13.77 c-e	0.67 h
	T_5	11.67 e	0.73 h
	T_6	12.07 e	0.67 h
	T_7	12.73 de	0.80 h
M_2	T_1	18.73 a-c	3.20 b-d
	T_2	20.27 ab	4.27 a
	T_3	17.40 a-e	3.80 a-c
	T_4	22.00 a	4.00 ab
	T_5	14.80 b-e	2.93 c-e
	T_6	14.80 b-e	3.80 a-c
	T_7	19.80 ab	2.53 d-f
M_3	T_1	18.47 a-d	2.33 d-f
	T_2	16.20 b-e	2.33 d-f
	T_3	15.87 b-e	2.40 d-f
	T_4	16.27 a-e	2.20 ef
	T_5	15.40 b-e	2.53 d-f
	T_6	12.27 e	2.00 fg
	T_7	16.40 a-e	2.33 d-f
$LSD_{(0.05)}$		5.91	0.90
CV (%)		22.48	24.41

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Table 11: Effect of planting method on yield and other crop characters at harvest

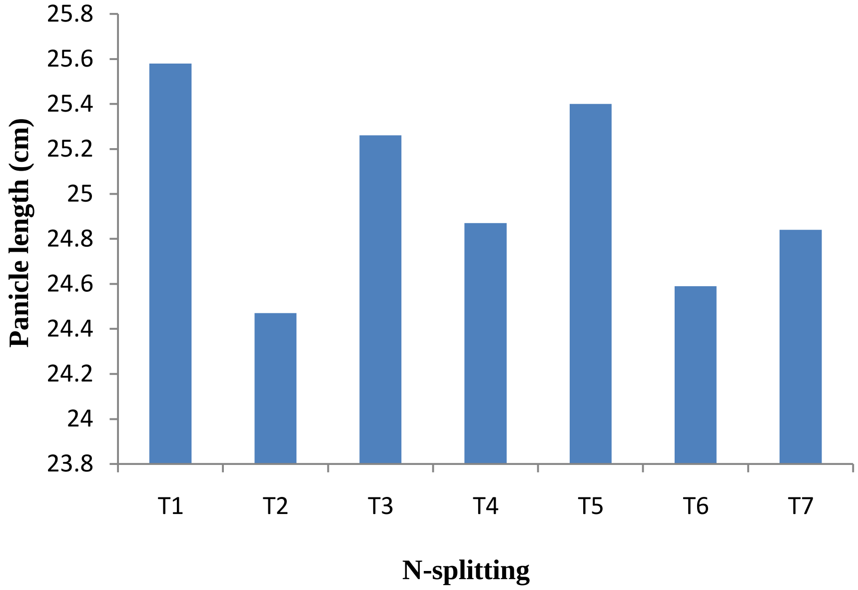
Treatments	Panicle length (cm)	No. of rachis branches panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	No. of total grains panicle^{-1}	1000-grains weight (g)
M_1	25.26	10.00	153.21	18.10	171.22	22.38
M_2	25.18	10.15	158.20	17.37	175.57	23.43
M_3	24.54	9.81	149.43	17.14	165.57	22.33
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS
CV (%)	10.58	14.27	21.33	28.25	21.36	7.92

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

NS-Non significant

4.7.2 Effect of N-splitting

There was no significant difference in panicle length observed due to N-splitting (Appendix VII and Figure 09). Numerically the maximum panicle length (25.58 cm) was recorded from T_1 and the lowest panicle length (24.47 cm) was obtained from T_2 which offence the experimental result of Shafiee *et al.* (2013) who conducted an experiment using liquid fertilizer SBAJATM (formerly known as BIPOMIXTM) and found the mean panicle lengths were significantly longer and higher, respectively in plots treated with SBAJATM *vis-à-vis* the control.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 09: Effect of N-splitting on panicle length of rice

4.7.3 Interaction effect of planting method and N-splitting

There was no significant effect by the interaction of planting methods and N-splitting on panicle length (Appendix VII and Table 12). Numerically the maximum panicle length (25.96 cm) was recorded from T_6 of conventional method (M_1) and the minimum panicle length (23.10 cm) was obtained from T_6 of transplanter method (M_3) but all interactions were statistically similar with each other. Ndaeyo *et al.* (2008) conducted an experiment in Nigeria and found that higher N doses increased length of central panicle per plant that was dissimilar from this study.

Table 12. Interaction effect of planting method and N-splitting on yield and other crop characters of rice

Treatments		Panicle length (cm)	No. of rachis branches $panicle^{-1}$	No. of filled grains $panicle^{-1}$	No. of unfilled grains $panicle^{-1}$	No. of total grains $panicle^{-1}$	1000-grains weight (g)
	T_1	25.32	10.50 a	155.03 b-g	17.20 a-d	172.23 d-f	22.67 a-c
	T_2	24.46	9.50 e	142.10 gh	16.43 a-d	158.53 gh	21.67 bc
	T_3	25.48	10.07 a-e	157.53 b-e	17.87 a-c	175.40 c-f	21.33 bc
M_1	T_4	24.96	10.10 a-e	161.53 a-d	20.37 a	181.90 a-d	23.67 a-c
	T_5	25.04	9.47 e	151.40 d-h	17.97 a-c	169.37 d-g	22.67 a-c
	T_6	25.96	10.23 a-d	154.73 b-g	18.97 a-c	173.70 c-f	22.33 a-c
	T_7	25.58	10.10 a-e	150.13 d-h	17.27 a-d	167.40 e-g	22.33 a-c
	T_1	25.69	10.37 ab	175.03 a	18.30 a-c	193.33 a	24.33 a
	T_2	24.68	10.30 a-c	152.61 c-h	16.67 a-d	169.28 d-g	22.67 a-c
	T_3	25.35	9.97 a-e	142.17 gh	14.13 cd	156.30 gh	24.00 ab
M_2	T_4	25.56	10.10 a-e	154.33 b-h	18.83 a-c	173.17 c-f	23.67 a-c
	T_5	25.90	10.27 a-d	165.87 a-c	19.70 ab	185.57 a-c	23.33 a-c
	T_6	24.70	10.07 a-e	161.27 a-d	16.20 a-d	177.47 b-e	23.00 a-c
	T_7	24.41	10.03 a-e	156.10 b-f	17.77 a-d	173.87 c-f	23.00 a-c
	T_1	25.73	10.07 a-e	166.80 ab	12.87 d	189.47 ab	22.67 a-c
	T_2	24.28	9.60 de	145.93 e-h	17.37 a-d	163.30 f-h	23.33 a-c
	T_3	24.93	9.73 b-e	145.97 e-h	17.97 a-c	163.93 f-h	22.67 a-c
M_3	T_4	24.10	9.63 c-e	143.93 f-h	12.87 d	156.80 gh	22.67 a-c
	T_5	25.27	9.90 a-e	152.43 d-h	16.17 a-d	168.60 d-g	21.00 c
	T_6	23.10	9.60 de	141.37 h	10.80 cd	152.17 h	22.67 a-c
	T_7	24.53	10.10 a-e	149.57 d-h	15.17 cd	164.73 e-h	21.67 bc
	$LSD_{(0.05)}$	NS	0.68	13.23	4.99	13.32	2.43
	CV (%)	4.81	4.11	5.20	10.91	4.71	6.46

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

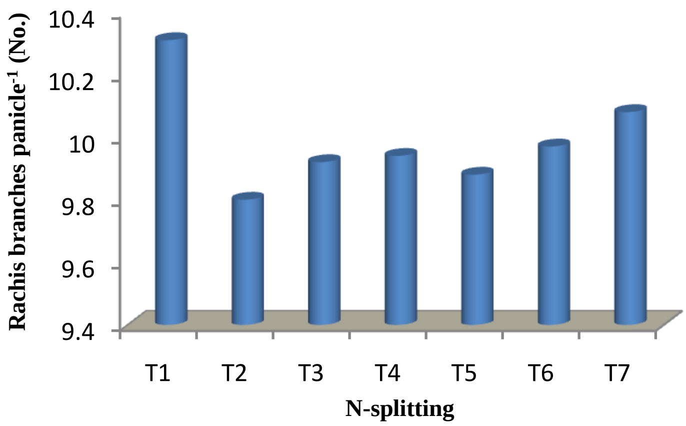
4.8 Number of rachis branches panicle^{-1}

4.8.1 Effect of planting method

The number of rachis branches panicle^{-1} was not significantly influenced by planting method (Appendix VII and Table 11). Numerically the higher number of rachis branches panicle^{-1} (10.15) was obtained from drum seeder (M_2) that followed conventional planting (10.00) and rice transplanter (9.81).

4.8.2 Effect of N-splitting

The number of rachis branches panicle^{-1} was significantly influenced by nitrogen splitting (Appendix VII and Figure 11). The highest number of rachis branches panicle^{-1} (10.31) was obtained from T_1 which was statistically similar with all treatments except T_2 (9.80) and T_5 (9.88) whereas the lowest number of rachis branches panicle^{-1} (9.80) was obtained from T_2 which was statistically similar with all treatment except T_1 (10.31)



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 10. Effect of N-splitting on the number of rachis branches panicle^{-1} ($LSD_{(0.05)}$ = 0.39).

4.8.3 Interaction effect of planting method and N-splitting

The number of rachis branches panicle^{-1} was significantly influenced by the interaction of planting methods and N-splitting (Appendix VII and Table 12). The highest number of rachis branches panicle^{-1} (10.50) was obtained from T_1 of conventional planting (M_1) which was statistically similar with T_3 (10.07), T_4 (10.10), T_6 (10.23) and T_7 (10.10) of the conventional planting (M_1); all treatments of drum seeder (M_2) and T_1 (10.07), T_5 (9.90) and T_7 (10.10) of rice transplanter (M_3).

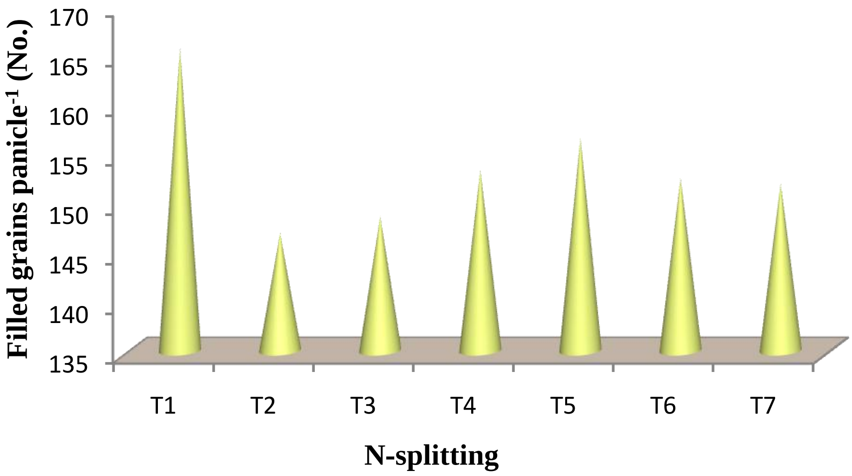
4.9 Number of filled grains panicle^{-1}

4.9.1 Effect of planting method

The number of filled grains panicle^{-1} was not significant for planting method (Appendix VII and Table 11). Numerically the higher number of filled grains panicle^{-1} (158.20) was found in drum seeder (M_2) and the lower number of filled grains panicle^{-1} (149.43) in rice transplanter (M_3) which was statistically similar.

4.9.2 Effect of N-splitting

The number of filled grains panicle^{-1} was not significantly influenced by nitrogen splitting (Appendix VII and Figure 11). Numerically the maximum number of filled grains panicle^{-1} (165.62) was observed in T_1 while the minimum number of filled grains panicle^{-1} (146.88) was obtained from T_2. Parvin *et al.* (2013) found that highest grains panicle^{-1} was obtained from five times foliar urea spray @ 100 kg ha^{-1} in BRRI dhan29.



$\mathbf{T_1}$ = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, $\mathbf{T_2}$ = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, $\mathbf{T_3}$ = 100% Urea of RD was applied as 3 foliar spray, $\mathbf{T_4}$ = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, $\mathbf{T_5}$ = 75% Urea of RD was applied as 3 foliar spray, $\mathbf{T_6}$ = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, $\mathbf{T_7}$ = 50% Urea of RD was applied as 3 foliar spray.

Figure 11. Effect of N-splitting on the number of filled grains panicle^{-1} (LSD$_{(0.05)}$ = 7.64)

4.9.3 Interaction effect of planting method and N-splitting

The number of filled grains panicle^{-1} was significantly influenced by the interaction of planting methods and N-splitting (Appendix VII and Table 12). The highest number of filled grains panicle^{-1} (175.03) was observed in T_1 of drum seeder (M_2) which was statistically similar with T_5 (165.87), T_6 (161.27) of the same method; T_4 (161.53) of the conventional method and T_1 (166.80) of the rice transplanter (M_3) but the lowest number of filled grains panicle^{-1} (141.37) was obtained from T_6 of the rice transplanter (M_3). Bhuyan *et al.* (2012) observed that bed planting with foliar nitrogen fertilizer produced higher number of grains panicle^{-1}. Filled grains panicle^{-1} is one of the most important yields contributing parameter in case of grain crops.

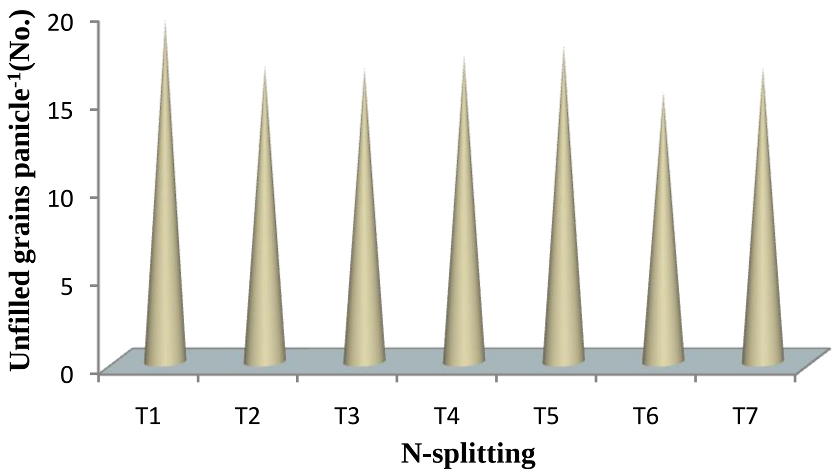
4.10 Number of unfilled grains panicle^{-1}

4.10.1 Effect of planting method

The number of unfilled grains panicle^{-1} was not significantly influenced by planting method (Appendix VI and Table 11). Numerically the higher number of unfilled grains panicle^{-1} (18.10) was obtained from the conventional planting and the lower number of unfilled grains panicle^{-1} (17.14) from rice transplanter method.

4.10.2 Effect of N-splitting

The number of unfilled grains panicle^{-1} was significantly influenced by nitrogen splitting (Appendix VII and Figure 12). The highest number of unfilled grains panicle^{-1} (19.39) was recorded in T_1 which was statistically similar with T_5 (17.94) whereas the lowest number of unfilled grains panicle^{-1} (15.32) was obtained from T_6.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 12. Effect of N-splitting on the number of unfilled grains panicle^{-1} ($LSD_{(0.05)}$ = 1.79)

4.10.3 Interaction effect of planting method and N-splitting

The number of unfilled grains panicle^{-1} was significantly influenced by the interaction of planting methods and N-splitting (Appendix VII and Table 12). The highest number of unfilled grains panicle^{-1} (20.37) was observed in T_4 of the conventional method (M_1) which was statistically similar with all treatment except T_3 (14.13) of drum seeder; T_1 (12.87), T_4 (12.87), T_6 (10.80) and T_7 (15.17) of the transplanter method (M_3) where the lowest unfilled grains panicle^{-1} T_6 (10.80) was counted from rice transplanter.

4.11 Number of total grains panicle^{-1}

4.11.1 Effect of planting method

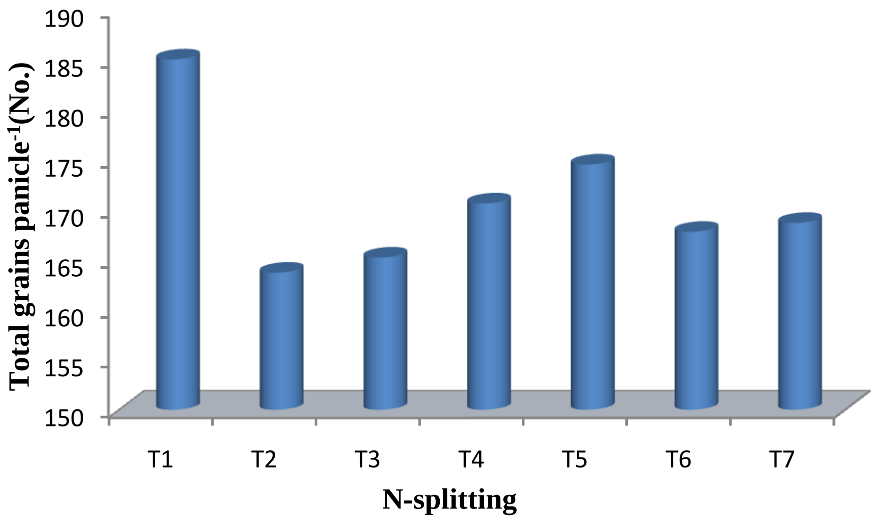
Insignificant effect of planting method on total grains panicle^{-1} was observed at harvesting (Appendix VII and Table 11). Numerically the higher number of total grains panicle^{-1} (175.57) was observed in drum seeder and the lower number of total grains panicle^{-1} (165.57) was obtained from rice transplanter.

4.11.2 Effect of N-splitting

The number of total grains panicle^{-1} was significantly influenced by N-splitting (Appendix VII and Figure 13). The highest number of total grains panicle^{-1} (185.01) was recorded in T_1 which was statistically dissimilar with all treatments and the lowest number of total grains panicle^{-1} (163.70) which was statistically similar with all treatments except T_1 (183.8) and T_5 (174.51). Bhuyan *et al.* (2012) observed that bed planting with foliar nitrogen fertilizer produced higher number of grains panicle^{-1}.

4.11.3 Interaction effect of planting method and N-splitting

The total number of grains panicle^{-1} was significantly influenced by the interaction of planting methods and N-splitting (Appendix VII and Table 12). The highest number of total grains panicle^{-1} (193.33) was observed in T_1 of the drum seeder (M_2) which was statistically similar with T_4 (181.90) of conventional (M_2); T_5 (185.57) of drum seeder (M_2) and T_1 (189.47) of transplanter. The lowest number of total grains panicle^{-1} (152.17) was obtained from T_6 of the rice transplanter. Rahman *et al.* (2007) conducted an experiment where the results showed that nitrogen level significantly influenced growth and yield components and maximum grains panicle^{-1} was found from 80 kg N/ha.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 13. Effect of N-splitting on the number of total grains panicle^{-1} (LSD$_{(0.05)}$ = 7.69)

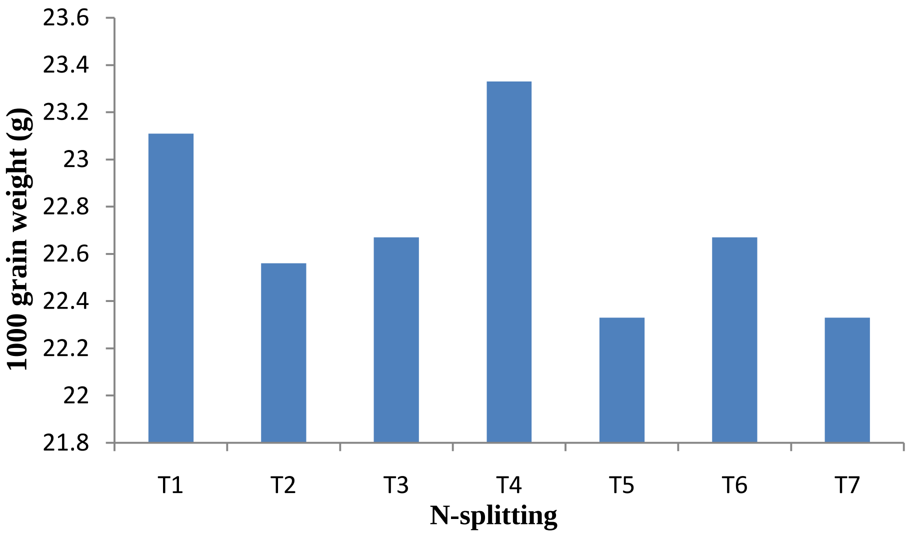
4.12 Weight of 1000-grains

4.12.1 Effect of planting method

The weight of 1000-grains was not significantly influenced by planting method (Appendix VII and Table 11). Numerically the maximum weight of 1000-grains (23.43 g) was obtained from the drum seeder followed by conventional transplanting and the minimum weight of 1000-grains (22.33 g) was observed in rice transplanter. Similar results were reported by Maruf (2014) weighted 1000-grains in conventional method which was 1.28% higher than rice transplanter.

4.12.2 Effect of N-splitting

The weight of 1000-grains (g) was not significantly influenced by N-splitting (Appendix VII and Figure 14). But numerically the maximum weight of 1000-grains (23.33g) was obtained from T_4 and the minimum weight of 1000-grains (22.33 g) was obtained from T_5 and T_7 treatment. These results were in agreed with Shafiee *et al.* (2013) who conducted an experiment using liquid fertilizer SBAJATM (formerly known as BIPOMIXTM) and found no significant differences in the 1000 grain weight.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 14. Effect of N-splitting on the weight of 1000 grains.

4.12.3 Interaction effect of planting method and N-splitting

Interaction effect of planting method and N-splitting significantly influenced the weight of 1000-grains (Appendix VI and Table 12). The highest weight of 1000-grains (24.33 g) was obtained from T_1 of the drum seeder (M_2) which was statistically similar with all interaction except T_2 (21.67 g) and T_3 (21.33 g) of conventional, T_5 (21.00 g) and T_7 (21.67 g) of rice transplanter which was the lowest weight of 1000 grains.

4.13 Grain yield

4.13.1 Effect of planting method

Grain yield was significantly influenced by the planting method (Appendix VII and Figure 15). The higher grain yield (8.09 t ha^{-1}) was obtained from the drum seeder (M_2). The lowest grain was produced (7.04 t ha^{-1}) by the rice transplanter which was statistically similar with the grain yield (7.39 t ha^{-1}) from conventional planting. A similar result was reported by Maruf (2014), who obtained 8.36% higher yield from conventional method than rice transplanter.

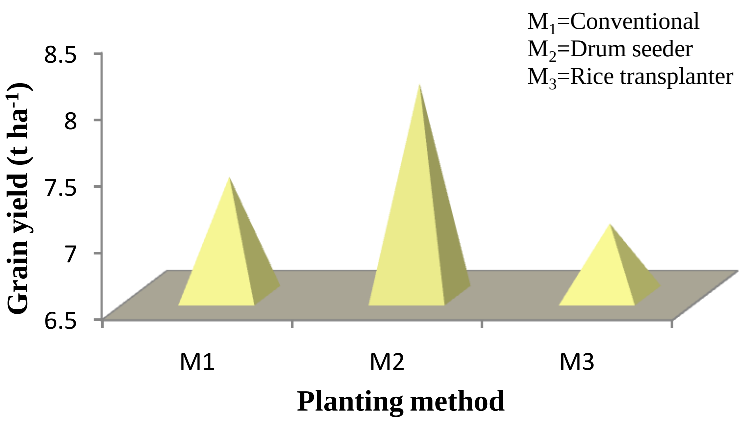
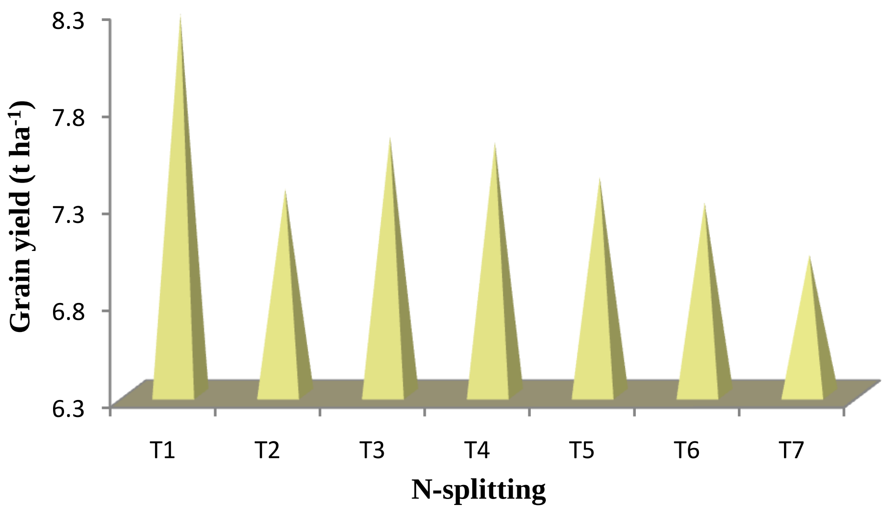


Figure 15: Effect of planting method on grain yield ($LSD_{(0.05)}$ = 0.47)

4.13.2 Effect of N-splitting

Grain yield was also significantly influenced by N-splitting (Appendix VII and Figure 16). The maximum grain yield (8.26 t ha^{-1}) was obtained from T_1 that is 100% recommended dose of urea (RD) applied as 3 top dressing which was statistically higher from all other treatments. The minimum grain yield (7.02 t ha^{-1}) was observed in T_7 that is 50% Urea of RD applied as 3 foliar spray statistically similar to all other treatments except T_1.

It has been reported that a small amount of nutrients (nitrogen, potash or phosphate) by foliar spraying increases yield of crops (Asenjo *et al.*, 2000). Alam *et al.* (2015) reported that with the increment of nitrogen level the grain yield was increased up to 100 kg N/ha compared to no liquid fertilization treatment, but in the application of liquid fertilization treatment, grain yield was increased up to 75 kg N/ha and also observed that, liquid fertilization with Magic Growth along with 75% of the recommended nitrogen fertilizer increased 10.5% grain yield with a saving of 25% of the recommended nitrogen fertilizer compared to recommended practice. Parvin *et al.* (2013) found that highest grain yield was obtained from five times foliar urea spray @ 100 kg ha^{-1} in BRRI dhan29.



T$_1$ = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T$_2$** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T$_3$** = 100% Urea of RD was applied as 3 foliar spray, **T$_4$** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T$_5$** = 75% Urea of RD was applied as 3 foliar spray, **T$_6$** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T$_7$** = 50% Urea of RD was applied as 3 foliar spray.

Figure 16: Effect of N-splitting on grain yield (LSD$_{(0.05)}$ = 0.37)

4.13.3 Interaction effect of planting method and N-splitting

Interaction between planting method and N-splitting played an important role for promoting the yield. Interaction effect of planting method and N-splitting had a significant effect on yield (Appendix VII and Table 13). Among the interaction, the highest grain yield (8.68 t ha^{-1}) was observed in T_4 of the drum seeder (M_2) which was statistically similar with T_1 (8.60 t ha^{-1}) of the same planting technique and the lowest grain yield (6.05 t ha^{-1}) was observed in T_2 of the rice transplanter (M_3). Alam *et al.* (2015) observed that, liquid fertilization with Magic Growth along with 75% of the recommended nitrogen fertilizer increased 10.5% grain yield with a saving of 25% of the recommended nitrogen fertilizer compared to recommended practice. Shafiee *et al.* (2013) conducted an experiment using liquid fertilizer SBAJATM (formerly known as BIPOMIXTM) and found the highest yield of grains (9.66 tons ha^{-1}) compared with (7.49 tons ha^{-1}) in the control plots. Islam *et al.* (2008a) observed that grain yield influenced significantly due to application of different rates of nutrients and 60-19-36 kg ha^{-1} NPK maximized the yield of T. *aman* rice varieties in respect of yield and economics.

4.14 Straw yield

4.14.1 Effect of planting method

Straw yield was not significantly influenced by planting method (Appendix VI and Figure 17). Numerically the maximum straw yield (6.88 t ha^{-1}) was observed in drum seeder and minimum straw yield (6.43 t ha^{-1}) was observed in rice transplanter. A dissimilar result was found by Islam (1995) and Toufiq (2003) who reported significant effect on planting method.

4.14.2 Effect of N-splitting

Straw yield was significantly influenced by N-splitting (Appendix VII and Figure 18). The highest straw yield (7.03 t ha^{-1}) was obtained from T_3 which was statistically similar with all treatments except T_6 (6.23 t ha^{-1}) and T_7 (6.40 t ha^{-1}) showed the lowest straw yield. Haq *et al.* (2002) conducted an experiment with twelve treatments combination of N, P, K, S, Zn and Diazinon and observed that all the treatments significantly increased the straw yield of BRRI dhan30 over control which supports the result of the experiment. Islam *et al.* (2008b) conducted a field experiment to find out the effect of nitrogen levels and transplanting dates on the yield and yield components of aromatic rice cv. Kalizira and found that straw yield was significantly influenced by nitrogen levels. This result was in an agreement with the findings of Dhane *et al.* (1989) who reported that straw yield increased with increasing nitrogen level.

4.14.3 Interaction effect of planting method and N-splitting

Straw yield was significantly influenced by the interaction effect of planting method and N-splitting (Appendix VII and Table 13). Among the treatments, the highest straw yield (7.85 t ha^{-1}) was observed in T_3 of the drum seeder which was statistically similar with T_1 and T_3 (7.34 t ha^{-1} and 7.11 t ha^{-1} respectively) of the conventional transplanting (M_1); T_1, T_4 and T_5 (6.97 t ha^{-1}, 7.02 t ha^{-1} and 6.95 t ha^{-1} respectively) of the drum seeder (M_2) and T_4 (7.25 t ha^{-1}) of the rice transplanter. The lowest straw yield (5.99 t ha^{-1}) was observed in T_1 of the rice transplanter.

Table 13. Interaction effect of planting method and N-splitting on yield and other crop Characters

Treatments		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
	T_1	7.71cd	7.34 ab	15.04 a-e	51.24 e-i
	T_2	7.56 d	6.46 b-f	14.02 d-i	53.94 b-f
	T_3	7.54 d	7.11 a-d	14.66 a-g	51.47 d-h
M_1	T_4	7.36 d-f	6.19 d-f	13.55 g-j	54.28 b-e
	T_5	7.31 d-f	6.86 b-f	14.18 c-h	51.58 d-h
	T_6	7.67 d	6.34 c-f	14.01 e-i	54.85 a-e
	T_7	6.57 gh	6.58 b-f	13.15 h-k	50.01 f-i
	T_1	8.60 a	6.97 a-e	15.56 ab	55.27 a-e
	T_2	8.44 ab	6.74 b-f	15.18 a-d	55.65 a-c
	T_3	7.50 d	7.85 a	15.34 a-c	49.10 g-i
M_2	T_4	8.68 a	7.02 a-e	15.69 a	55.36 a-d
	T_5	7.68 cd	6.95 a-e	14.63 a-g	52.69 b-g
	T_6	7.41 de	6.19 d-f	13.60 g-j	54.64 a-e
	T_7	8.33 a-c	6.45 b-f	14.79 a-f	56.36 ab
	T_1	8.47 ab	5.99 f	14.46 b-g	58.61 a
	T_2	6.05 h	6.78 b-f	12.83jk	47.20 i
	T_3	7.84 b-d	6.12 ef	13.96 e-j	56.22 a-c
M_3	T_4	6.75 fg	7.25 a-c	14.00 e-i	48.31 hi
	T_5	7.27 d-f	6.52 b-f	13.79 f-j	52.73 b-g
	T_6	6.77 e-g	6.16 d-f	12.93 i-k	52.26 c-h
	T_7	6.15 gh	6.18 d-f	12.33 k	49.92 f-i
$LSD_{(0.05)}$		0.65	0.95	1.16	4.09
CV (%)		5.19	8.63	4.95	4.67

M_1 - (Conventional method), M_2 – (Drum seeder) , M_3 – (Rice transplanter)

T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

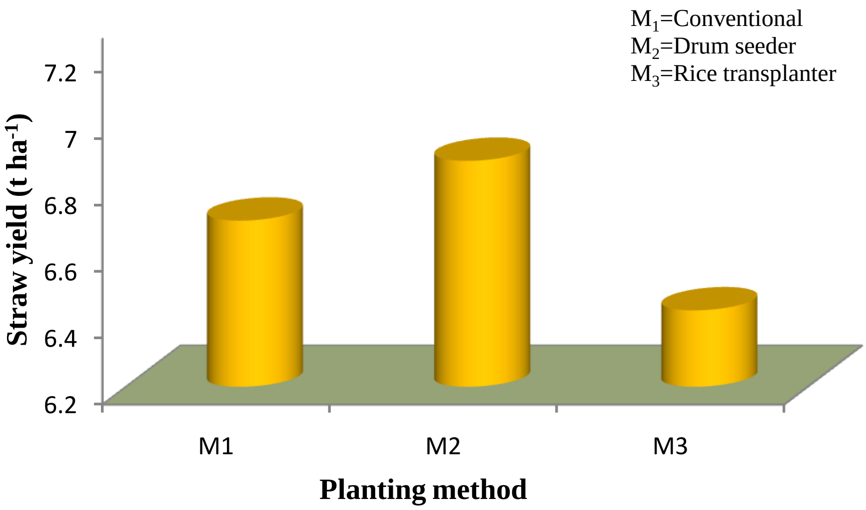
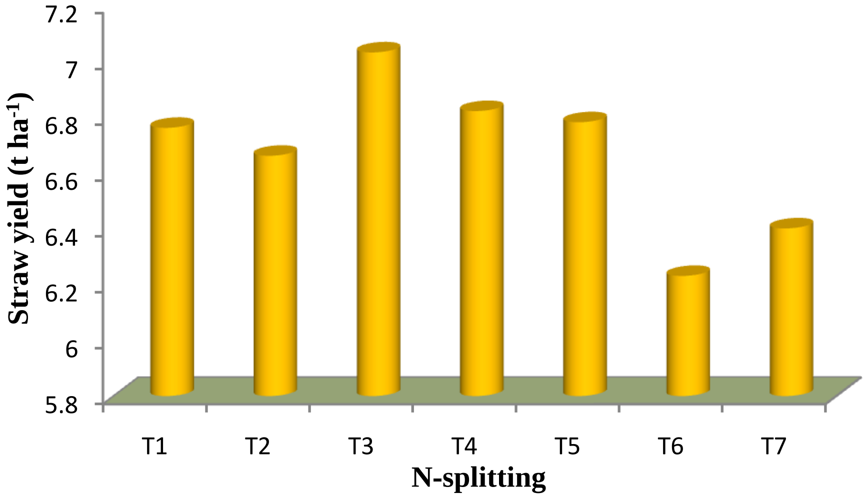


Figure 17: Effect of planting method on straw yield



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 18: Effect of N-splitting on straw yield ($LSD_{(0.05)}$ = 0.55)

4.15 Biological yield (t ha^{-1})

4.15.1 Effect of planting method

Biological yield was not significantly influenced by planting method (Appendix VII and Figure 19). The result exposed that higher biological yield (14.97 t ha^{-1}) obtained from the drum seeder method (M_2) and lower biological yield (13.47 t ha^{-1}) observed in rice transplanter (M_3).

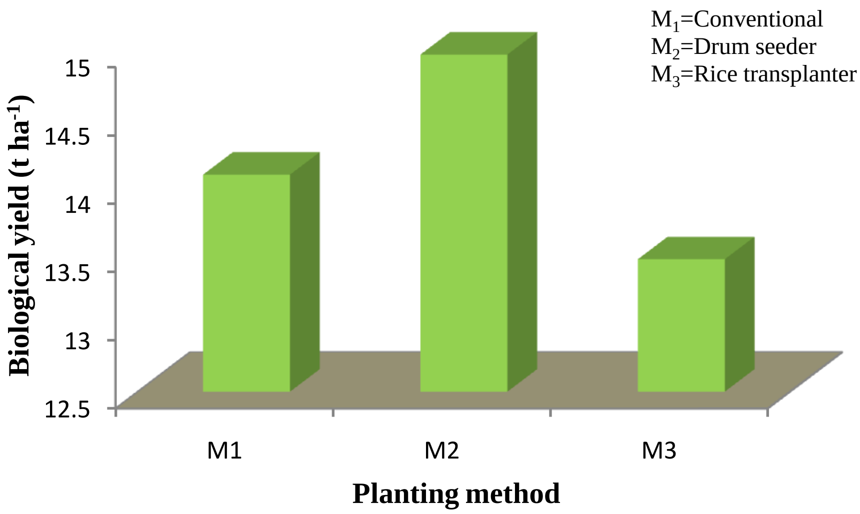
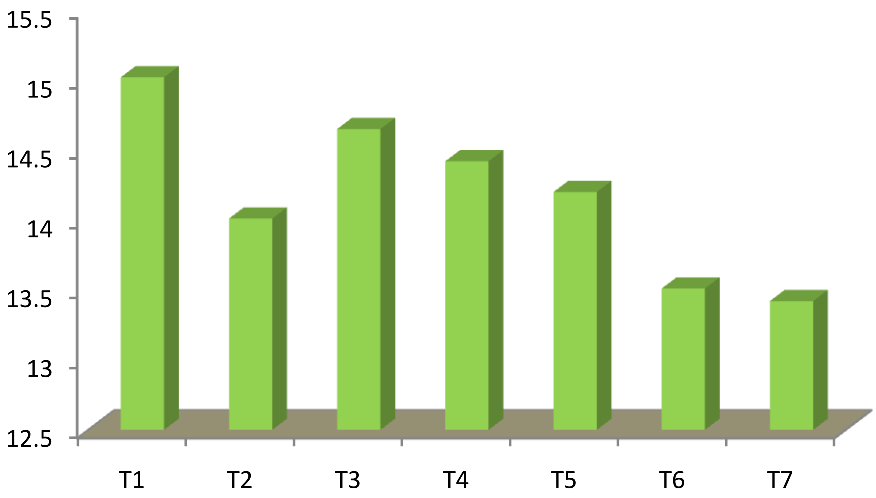


Figure 19: Effect of planting method on biological yield

4.15.2 Effect of N-splitting

Effects of N-splitting affected biological yield significantly (Appendix VII and Figure 20). The highest biological yield (15.02 t ha^{-1}) was obtained from the T_1 treatment (100% Urea of RD was applied as 3 top dressing). Treatment, T_1 produced the higher grain and straw yield that maximize biological yield. The lowest biological yield (13.42 t ha^{-1}) was found from T_7. This was due to the lower amount of grain and straw yield in T_7. Vegetative growth was higher due to the higher dose of urea and for the reason the grain and straw yield was also increased with the increased dose of nitrogenous fertilizer.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 20: Effect of N-splitting on biological yield ($LSD_{(0.05)}$ = 0.67)

4.15.3 Interaction effect of planting method and N-splitting

Interaction effect between planting method and N-splitting was significant in respect of biological yield (Appendix VII and Table 13). The highest biological yield (15.69 t ha^{-1}) was observed in T_4 of the drum seeder (M_2) which was statistically similar with T_1 (15.04 t ha^{-1}) and T_3 (14.66 t ha^{-1}) of the conventional transplanting method; T_1 (15.56 t ha^{-1}), T_2 (15.18 t ha^{-1}), T_3 (15.34 t ha^{-1}), T_5 (14.63 t ha^{-1}) and T_7 (14.79 t ha^{-1}) of the drum seeder (M_2). The lowest biological yield was observed in T_7 (12.33 t ha^{-1}) of the rice transplanter (M_3) which was statistically similar with T_2 (12.83 t ha^{-1}) and T_6 (12.93 t ha^{-1}) of same planting method and T_7 (13.15 t ha^{-1}) of conventional method.

4.16 Harvest index (%)

4.16.1 Effect of planting method

Harvest index was not significantly influenced by the planting method (Appendix VII and Figure 21). Numerically the highest harvest index (54.15 %) was obtained from the drum seeder technique and the lowest (52.18 %) from the rice transplanter all of which were statistically similar to each other.

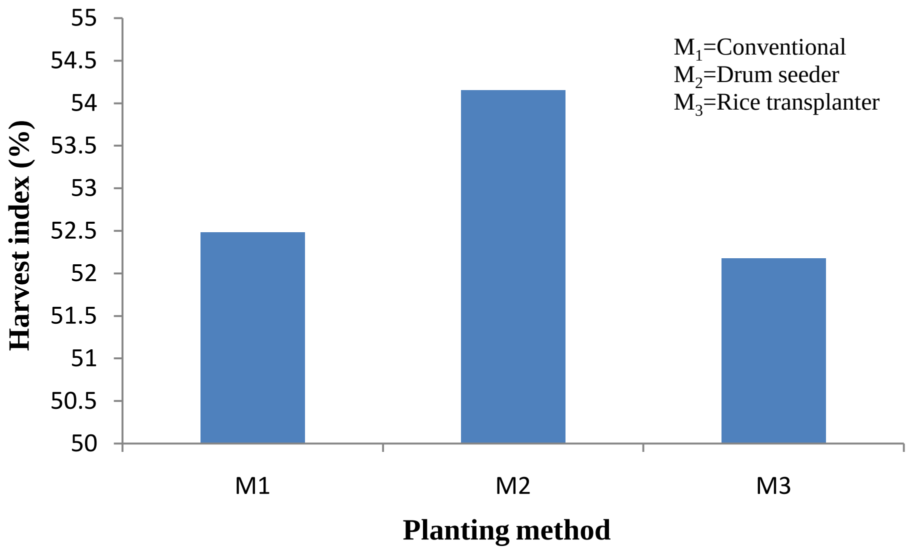
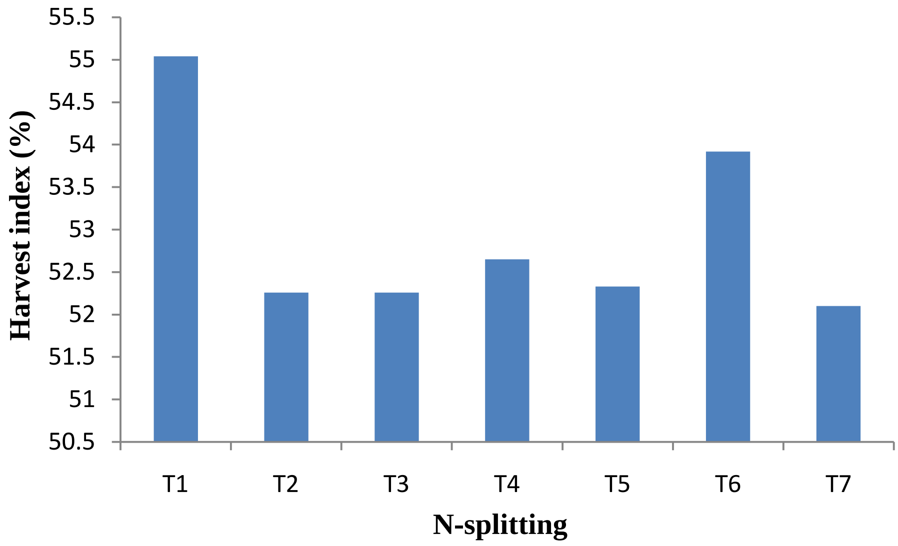


Figure 21: Effect of planting method on harvest index

4.16.2 Effect of N-splitting

Harvest index was significantly influenced by N-splitting (Appendix VII and Figure 22). The highest harvest index (55.04 %) was obtained from T_1 treatment whereas the lowest harvest index (52.10 %) was found from T_7 which was statistically similar with all treatments except T_1 (55.04 %). Awan *et al.* (2011) reported the highest harvest index with 156 kg N ha^{-1}.



T_1 = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Figure 22: Effect of N-splitting on harvest index ($LSD_{(0.05)}$ = 2.36)

4.16.3 Interaction effect of planting method and N-splitting

Interaction effect between planting method and N-splitting was significant in respect of harvest index (Appendix VII and Table 13). The highest harvest index (58.61 %) was observed in T_1 of the rice transplanter (M_3) which was statistically similar with T_3 (56.22 %) of the same planting method and T_6 (54.85 %) of conventional method and also similar to all treatments of drum seeder except T_3 (49.10 %) and T_5 (52.69 %) and the lowest harvest index (47.20 %) was observed in T_2 of the rice transplanter (M_3) which was statistically similar with T_1 (51.24 %) and T_7 (50.01 %) of conventional planting; T_3 (49.10 %) of drum seeder and T_4 and T_7 (48.31 % and 49.92 % respectively) of the rice transplanter.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from December 2014 to July 2015 to study the growth and yield of BRRI dhan29 in *boro season* as affected by three planting methods and seven levels of N-splitting under the Modhupur Tract (AEZ-28). The experiment was comprised of two sets of treatments viz. Factor-A. planting method: (conventional transplanting (M_1), drum seeder (M_2) and rice transplanter (M_3) and Factor-B. N-splitting: 100% Urea of the recommended dose (RD) was applied as 3 top dressing (T_1), 100% Urea of RD was applied as 1 top dressing 2 foliar spray (T_2), 100% Urea of RD was applied as 3 foliar spray (T_3), 75% Urea of RD was applied as 1 top dressing and 2 foliar spray (T_4), 75% Urea of RD was applied as 3 foliar spray (T_5), 50% Urea of RD was applied as 1 top dressing and 2 foliar spray (T_6) and 50% Urea of RD was applied as 3 foliar spray (T_7). The experiment was laid out in split-plot design with three replications scheming planting method in the main plots and nitrogen splitting in the sub-plots. The data on crop growth characters (plant height, number of tillers hill^{-1}, leaf area index (LAI) and dry weight) and yield as well as yield contributing characters (number of effective and ineffective tillers hill^{-1}, panicle length, rachis branches panicle^{-1}, number of filled grains panicle^{-1}, unfilled grains panicle^{-1} and number of total grains panicle^{-1}, 1000 grains weight, grain and straw yield, biological yield and harvest index) were documented after harvest and analyzed using the STATISTICS 10 package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

The planting method showed significant effect on all the agronomic parameters except SPAD value, panicle length, no. of rachis branches panicle^{-1}, no. of filled grains panicle^{-1}, no. of unfilled grains panicle^{-1}, no. of total grains panicle^{-1}, 1000-grains weight, straw yield and biological yield. It revealed that drum seeded plant showed significantly taller plant at 50 DAS and was continuing this trend upto 100 DAS. The higher number of tillers hill^{-1} was also counted in drum seeded plots from 50 DAS to harvest. The leaf area index (LAI) was not significantly influenced except 50 and 125 DAS. Total dry matter was balanced, insignificant except 100 DAS and 125 DAS where conventionally planted plots accumulated higher dry matter than other. Both the effective and ineffective tillers hill^{-1} was counted higher in drum seeded plots. The higher (25.26 cm) and lower (24.54 cm) panicle length were obtained from conventional method and rice transplanter respectively. The higher number of rachis branches panicle^{-1} (10.15) was observed in conventional method and the lower number of branches panicle^{-1} (9.81) was observed in rice transplanter. The higher number of filled grains and unfilled grains panicle^{-1} (158.20 and 18.10 respectively) were obtained from the drum seeder and conventional method respectively and the lower number of filled grains and unfilled grains panicle^{-1} (149.43 and 17.14) were obtained from the rice transplanter. The higher weight of 1000-grains (23.43 g) was obtained from the drum seeder and the lower weight of 1000-grains (22.33 g) was obtained from the rice transplanter. Drum seeded plots produced 8.65 % and 12.98 % higher grain yield than conventional and transplanter method respectively. Drum seeder performed better in case of straw yield, biological yield and harvest index than other.

Splitting of N-fertilizer also significantly influenced the growth and yield attributes except panicle length (cm) and 1000-grain weight. At 50 DAS, T_6 treatment produced tallest plant height (17.70 cm) and T_7 gave the shortest plant height (16.37 cm) but at 125 DAS and harvest T_1 produced the tallest plant significantly. Number of tillers hill^{-1} was found almost affected by N-level and T_1 produced higher tiller hill^{-1} (14.64, 17.28 and 17.4) at 75, 125 DAS and at harvest. Significantly the highest leaf area index (LAI) was observed at all record duration except 50 DAS (2.5, 5.24, 6.64 and 5.51 at 75, 100, 125 and harvest respectively) from T_1. Dry weight (g hill^{-1}) was significantly influenced by nitrogen splitting whereas T_5 and T_6 produced the highest dry weight (5.67 g hill^{-1}) at 50 DAS. At 75 DAS T_2 (9. 67 g hill^{-1}) and at 100, 125 and at harvest T_1 (24.22 g hill^{-1}, 37.56 g hill^{-1} and 88.42 g hill^{-1} respectively) produced higher dry matter. SPAD value was influenced by the doses of nitrogen and measured maximum from T_1 (42.41) and minimum from T_7 (37.37). The highest panicle length (25.58 cm) was observed in T_1 and the lowest panicle length (24.47 cm) in T_2. The highest number of rachis branches panicle^{-1} (10.31) was obtained from T_1 and the lowest number of rachis branches panicle^{-1} (9.80) was obtained from T_2. The maximum number of filled grains panicle^{-1} and 1000-grains weight (165.62 and 23.33 g respectively) was observed in T_1 and T_4 respectively and the lowest (146.88 and 22.33 g respectively) from T_2 and $T_{5.}$ Significantly the highest number of unfilled grains panicle^{-1} (19.39) and total grains panicle^{-1} (185.01) were observed in T_1 and the lowest number of unfilled grains panicle^{-1} (15.32) and total grains panicle^{-1} (163.70) were obtained from T_6 and T_2. The highest grain yield and straw yield (8.26 t ha^{-1} and 7.03 t ha^{-1} respectively) were obtained from T_1 and T_3 whereas the lowest grain yield and straw yield (7.02 t ha^{-1} and 6.23 t ha^{-1} respectively) were observed in T_7 and T_6 respectively.

Interaction effect of planting method and N-splitting also significantly influenced all the growth as well as yield and other crop characters. The results revealed that, at 50, 75 and 100 DAS the tallest plant (21.05 cm, 55.53 cm and 82.85 cm respectively) from M_2T_5 but at 125 DAS and at harvest the tallest plant (104.23 cm and 105.6 cm respectively) was obtained from the M_1T_1 and the shortest plant (92.93 cm and 95.67 cm) was obtained from the M_1T_7 and M_2T_6 respectively. The highest number of tillers $hill^{-1}$ was observed at 50 and 100 DAS in M_2T_5 (3.5 and 16.07 respectively) but at 100, 125 DAS and harvest in M_2T_4 (26.73, 21.33 and 22.00 respectively). At 50 and 75 DAS the lowest numbers of tillers $hill^{-1}$ was obtained from T_4 and T_6 (1.20 and 9.50 respectively) of M_3 but 125 DAS and at harvest it was (10.87 and 11.67 respectively) from M_1T_5. The highest leaf area index (LAI) at 50, 75, 100, 125 DAS and at harvest was observed in M_2T_5 (0.19), M_2T_5 (2.93), M_2T_3 (5.63), M_1T_1 (7.08) and M_3T_1 (6.08) respectively whereas the lowest LAI was observed in M_1T_2 (0.02), M_3T_5 (1.22), M_1T_6 (3.36), M_2T_6 (3.55) and M_1T_7 (2.92) respectively. At 50 and 125 DAS the highest dry weight was observed in M_1T_6 (7.0 g $hill^{-1}$ and 42.67 g $hill^{-1}$ respectively and the lowest in M_2T_6 (4.33 g $hill^{-1}$) and M_3T_7 (25.33 g $hill^{-1}$). At harvest the highest dry weight was obtained from M_3T_1 (95.27 g $hill^{-1}$) and the lowest from M_1T_7 (60.40 g $hill^{-1}$). The highest and the lowest SPAD values (43.05 and 36.98 respectively) were observed from M_1T_2 and M_2T_6 respectively. The highest number of effective tillers $hill^{-1}$ (22.00) was observed in M_2T_4 and the lowest number of effective tillers $hill^{-1}$ (11.67) was obtained from M_1T_5. The highest panicle length, number of filled grains $panicle^{-1}$, number of total grains $panicle^{-1}$ and 1000-grains weight were observed in M_2T_1 (25.69 cm, 175.03 and 193.33 and 24.33g respectively). The highest number of rachis branches $panicle^{-1}$ was observed in M_1T_1 (10.50) and that of the lowest from M_1T_5 (9.47). The highest grain yield (8.68 t ha^{-1}) was observed in M_2T_4 and the lowest grain yield was observed in M_3T_2 (6.05 t ha^{-1}). The maximum straw and biological yield were recorded from M_2T_3 (7.85 t ha^{-1}) and M_2T_4 (15.69 t ha^{-1}) respectively whereas the minimum straw and biological yields were recorded from M_3T_1 (5.99 t ha^{-1}) and M_3T_7 (12.33 t ha^{-1}) respectively. The highest harvest index (58.61 %) was obtained from M_3T_1 and the lowest harvest index (47.20 %) was obtained from M_3T_2.

Based on the results of the present study, the following conclusions may be drawn:

- Drum seeder performed better than conventional and transplanter technique.
- Among the N-splitting 100% urea of the recommended dose (RD) applied as three top dressing gave the better results. The urea dose can be reduced 25% by applying in 3 equal splits as sprays without any yield reduction.
- The conventional transplanting method can be substituted by drum seeder having 75% urea dose applied as one top dress and two foliar sprays and recommended dose of urea applied as three top dress.

REFERENCES

Abou El-Nour, E. A. A. (2002). Can supplemented potassium foliar feeding reduce the recommended soil potassium. *Pak. J. Biol. Sci.,* **5**(3): 259-262.

Ahmed, M., Islam, M. and Paul, S. K. (2005). Effect of nitrogen on yield and other plant characters of Local T. Aman Rice, Var. Jatai. *Res. J. Agric. Biol. Sci.,* **1**(2): 158-161.

Akhand, M. I. M., Roy, B. C., Biswas, J. C., Parvin, N. and Paul, S. (2013). Urea spraying as an effective alternate method of nitrogen management. *Eco-friendly Agril. J.,* **6**(09): 188- 192.

Alam, A. K. M. A., Rahman, M. M., Islam, M. M. and Anwar, M. N. (2000). Effect of azolla, farm yard manure (FYM) and fertilizer-N on yield and nutrient uptake of BR2 rice. *Bangladesh J., Life Sci.*, **12**(1&2): 91-98.

Alam, M. S., Baki, M. A., Sultana, M. S., Ali, K. J. and Islam, M. S. (2012b). Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant aman rice. *Intl. J. Agron. Agric. Res*. (IJAAR), **2**(12): 10-15.

Alam, M. Z., Sadekuzzaman, M., Sarker, S. and Hafiz, M. H. R. (2015). Reducing soil application of nitrogenous fertilizer as influenced by liquid fertilization on yield and yield traits of kataribhog rice. *Intl. J. Agron. Agric. Res. (IJAAR)*, **6**(1): 63-69.

Alam, S. S., Moslehuddin, A. Z. M., Islam, M. R. and Kamal, A. M. (2012a). Soil and foliar application of nitrogen for Boro rice (BRRI dhan29). *J. Bangladesh Agril. Univ.,* **8**(2): 199-202.

Amin, M., Khan, M. A., Khan, E. A. and Ramzan, M. (2004). Effect of increased plant density and fertilizer dose on the yield of rice variety IR-6. *J. Res. Sci*., **15**(1): 09-16.

Anon. (1988a). The Year Book of Production. FAO, Rome, Italy.

Anon. (1988b). Land resources appraisal of Bangladesh for agricultural development. Report no. 2. Agro Ecological Regions of Bangladesh, UNDP and FAO. pp. 472-496.

Anon. (2004). Annual Internal Review for 2000-2001. Effect of seedling throwing on the grain yield of wart land rice compared to other planting methods. Crop Soil Water Management Program, Agronomy Division, BRRI, Gazipur-1710.

Asenjo, M. C., Gonzalez, J. L. and Maldonado, J. M. (2000). Influence of humic extracts on germination and growth of rye grass. *Comm. Soil Sci. Pl. Anal.,* **31**: 101–114.

Asif, M., Aslam, M., Jabbar, A., Rafique, K., Babar, M. R. and Ehsanullah (2000). Panicle Structure, Kernel Quality and Yield of Fine Rice as Influenced by NPK Rates and Split Nitrogen application. *Intl. J. Agri. Biol.,* **2**(4): 306-308.

Awan, T. H., Ali, R. I., Manzoor, Z., Ahmed, M. and Akhtar, M. (2011). Effect of different nitrogen levels and row spacing on the performance of newly evolted medium grain rice variety, KSK-133. *J. Anim. and Pl. Sci.,* **21**(2): 231-234.

Bahmanyar, M. A. and Mashaee, S. S. (2010). Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice (*Oryza sativa*). *African J. Biotech*. **9**(18): 2648-2653.

Balasubramaniam, V. and Morales, A. C. (1998). An introduction to direct seeded rice system. Paper presented at the national workshop cum group meeting on CREMNET program in India, Directorate of Rice Research, Hyderabad, India, 7-9 January.

Bayan, H. C. and Kandasamy, O. S. (2002). Effect of weed control methods application of nitrogen on weed and crop in direct seeded puddle rice. *Res. Hisar.* **24** (2): 200-272.

Bhuyan, M. H. M., Ferdousi, M. R. and Iqbal, M. T. (2012). Foliar spray of nitrogen fertilizer on raised bed increases yield of transplanted aman rice over conventional method. *Intl. Schol. Res. Net.,* ID 184953.

Borlagdan, P. C. (1994). Multi-crop seeder development. *Agril. Mech. Asia Africa and Latin Am.* **25**(3):19-28.

BRRI (Bangladesh Rice Research Institute). (1990). Nitrogen response of promising variety. Annual Rep. Bangladesh Rice Res. Inst., Gazipur, p. 95.

BRRI (Bangladesh Rice Research Institute). (2010). Adhunik Dhaner Chash (In Bengali). 15th Edition. Bangladesh Rice Res. Inst., Gazipur, pp. 10-18.

BRRI (Bangladesh Rice Research Institute). (2011a). Adhunik Dhaner Chash (in bengali). Bangladesh Rice Res. Inst., Gazipur, p. 5.

BRRI (Bangladesh Rice Research Institute). (2011b). BRRI Annual Report 2008-2009. Publication no.187. pp.79-83.

BRRI (Bangladesh Rice Research Institute). (2012). Annual Report for 2012. Bangladesh Rice Res. Inst., Gazipur. pp. 9-13.

Chandrasekhararao C., Jitendranath S. and Murthy T. G. K. (2013). Resource optimisation in rice through direct seeding by drum seeder. *Intl. J. Agric. and Food Sci. Tech.*, **4**(3): 239-246.

Chopra, N. K. and Chopra, N. (2004). Seed yield and quality of "Pusa 44" rice (*Oryza sativa*) as influenced by nitrogen fertilizer and row spacing. *Indian. J. Agril. Sci.* **74**(3): 144-146.

Das, A. L. (2014). Growth and yield of boro rice as affected by different methods of urea application. M.S. Thesis. Dept. of Agronomy, Sher-e-Bangla Agril. Univ., Dhaka, Bangladesh.

Das, F. C. (2004). Improved farm implements for boro rice cultivation. Seminar on "Boro rice and strategies for enhancing rice production and productivity in the North East". Organised by Directorate of Rice Research, Hyderabad. pp. 116-120.

Dawe, D. (2003). New challenges and technological opportunities for rice-based production systems for food security and poverty alleviation in Asia and the Pacific. FAO Rice Conference, Rome, Italy, Feb. 12-13.

De Datta, S K. (1981). Principles and practices of rice production. IRRI, Los Banos, Philippines. pp. 9-535.

De Datta, S. K. (1978). Fertilizer management for efficient use in wetland rice soils. In F.N. Ponnamperuma, ed. Soil and Rice. IRRI, Los Banos, Philippines. pp. 671-670.

Dhane, S. S., Khadse, R. R., Patil, V. H. and Sauant, N. K. (1989). Effect of deep placed USG with limited green manure on transplanted rice yield. *Intl. Rice Res. Newsl.* **14**(4): 31.

Dobermann, A. and Fairhurst, T. (2000). Rice: Nutrient disorders and nutrient management and book series. pp. 41-157.

Donald, C. M. (1963). Competition among crops and pasture plants. *Adv. Agron.* **15**: 11-18.

FAO.(2009). Resource Stat-Fertilizer. Food and Agriculture Organization of the United Nations.

Fillery, I. R. P., Simpson, J. R. and De Datta, S. K. (1984). Influence of field environment and fertilizer management on ammonia loss from flooded rice. *J. Soil Sci. Soc. Am*. **48**: 914-920.

Finck, A. (1982). Fertilizers and Fertilization.Verlag Chimie GmbH, Weinheim, Germany.

Gardner, F. P., Pearce, R. B. and Mistechell, R. L. (1985). Physiology of crop plants. Iowa State Univ. Press, Powa. p. 66.

Garg, I. K. Sharma, V. K. and Mahal, J. S. (1997). Development and field evaluation of manually operated six row paddy transplanter. *Agril. Mech. Asia Africa and Latin Am.*, **28**(4): 21-28.

Goel A. K., Behera, D. and Swain, S. (2008). Effect of sedimentation period on performance of rice transplanter. *Intl. J. India Agril. Eng*. **10**: 07-35.

Gupta, C. P. and Totok, H. (1992). Design and development of a direct paddy seeder. *Agril. Mech. in Asia Africa and Latin Am.* **23**(1): 23-27.

Haq, M. T., Sattar, M. A., Hossain, M. M. and Hasan, M. M. (2002). Effects of fertilizers and pesticides on growth and yield of rice. *J. Biol. Sci.* **2**(2): 84-88.

Hasanuzzaman M., Nahar, K., Alam, M. M., Hossain, M. Z. and Islam, M. R. (2009). Response of transplanted rice to different application methods of urea fertilizer. *Intl. J. Sust. Agric.* **1**(1): 01-05.

Hossain, M. (2002). Rice research and poverty alleviation in Bangladesh. Center for Policy Dialogue.

Hossain, M. A., Huda, M. D. and Islam, M. S. (2012). Test and evaluation of mechanical rice transplanter during Aman season. BRRI Annual Research Review, 2011-12.

Hossain, M. and Deb, U. K. (2003). Liberalization of rice sector: Can Bangladesh withstand regional competition? Poster paper presented at PETRRA communication fair 2003 held at Hotel Sheraton, Dhaka on Aug. 10-11.

IRRI (1997). Rice Almanac, 2nd Ed.; IRRI in association with the West Africa Rice Development Association and the Centro Internacional de Agricultura Tropical: Manila, Philippines.

Islam, M. S. (1995). Effect of cultivar and weeding regime on growth and performance of boro rice. M. Sc. (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 40-43.

Islam, M. S., Baqui, M. A., Rahman, M. A. and Islam, A. K. M. S. (2001). Evaluation of power operated Japanese Rice Transplanter (AP-200) in Bangladesh. BRRI Annual Research Review 2000-01.

Islam, M. S., Hossain, M. A., Chowdhury, M. A. H. and Hannan, M. A. (2008b). Effect of nitrogen and transplanting date on yield and yield components of aromatic rice. *J. Bangladesh Agril. Univ.,* **6**(2):291-296.

Islam, M. S., Howlader, M. I. A., Rafiquzzaman, S., Bashar, H. M. K. and Al-Mamun, M. H. (2008a). Yield response of chili and T. aman rice to NPK fertilizers in Ganges Tidal Floodplain. *J. Soil. Nat*. **2**(1): 07-13.

Islam, S. M., Soom, A. M., Baqui M. A., Ahmad D., and Daud, B. M. (2000). A comparative study on the crop establishment technologies for paddy in Bangladesh: transplanting vs wet seeding. *Agril. Mech. in Asia Africa and Latin Am.* **31**(4): 41-46.

Jamal, Z., Hamayun, M., Ahmad, N. and Chaudhary, M. F. (2006).Effect of soil and foliar application of different concentrations of NPK and foliar application of $(NH4)_2SO_4$ on different parameters in wheat. *J. Agron*. **5**(2): 251-256.

Jashim, C., Ahmed, U. and Ahmed, K. U. (1984). Response of rice varieties to applied N in saline soils. *Intl. Rice Res. Newsl.* **9**(5): 22.

Jinfu, Gao and Ma T. (1997). Research and development of a new direct paddy seeder. *Agril. Mech. in Asia Africa and Latin Am.* **28**(3): 21-28.

Kaium, A. A. (2010). Performance of mechanical rice transplante at the farm power and machinery department field laboratory in Bangladesh Agricultural University (BAU), Mymensingh, during boro and aman seasons. MS. Thesis, Department of Farm Power and Machinery, Bangladesh Agril. Univ., Mymensingh.

Khan, P., Memon, M. Y, Imtiaz, M. and Aslam. M. (2009). Respone of wheat to foliar and soil application of urea at different growth stage. *Pak. J. Bot.* **41**(3): 1197-1204.

Krishnaiah, K. (1999). Row seeder for sowing rice in puddle soil. ICAR News, ICAR, Krishi Bhavan, New Delhi, India. p.12.

Kumar U. and Kumar A. (2012). Performance evaluation of manually operated four-row rice transplanter in Jharkhand (India). *SKUAST J. of Res.* **14**(1&2): 59-66.

Lam, H. M., Coschigano, K. T., Oliveira, I. C., Melo- Oliveira, R. and Coruzzi, G. M. (1996). The molecular-genetics of nitrogen assimilation into amino acids in higher plants. *J. Plant Physiol. Pl. Mol. Biol.* **47**: 569-593.

Manjunatha, M. V., Masthana, B. G., Reddy, Shashidhar, S. D. and Joshi, V. R. (2009). Studies on the performance of self-propelled rice transplanter and its effect on crop yield. *Karnataka J. Agric. Sci.*, **22**(2): 385-387.

Maruf, S. A. (2014). Influence of planting method and weeding on growth and yield of transplant aman rice. M.S. Thesis. Dept. of Agron., Sher-e-Bangla Agril. Univ., Dhaka, Bangladesh.

Miah, M. A. M. and Panaullah, G. M. (1999). Effect of water regimes and N-levels on soil available N, its uptake and use efficiency by transplanted rice. *Bangladesh J. Agril. Res.* **24**(2): 343-353.

Millard, P. and Robinson, D. (1990). Effect of the timing and rate of nitrogen-fertilization on the growth and recovery of fertilizer nitrogen within the potato (*Solanum tuberosum L*.). *Crop. Fert. Res.* **21**: 133-140.

Mishra, P. C., Sarker, A. K. and Mishra, B. (1994). Relative efficiency of different nitrogen sources in transplanted rice of Chotanagpur region. *J. Indian Soc. Soil Sci.* **42**(2): 333-335.

Munnaf, M. A., Hossain, M. M. and Ruma, F. Y. (2014). Techno-economic performance of imported kukje self-propelled rice transplanter. *J. Bangladesh Agril. Univ.* **12**(1): 161–166.

Murumkar, R. P., Dongarwar, U. R., Phad, D. S., Borkar, B. Y. and Pisalkar, P. S. (2014). Performance testing of four row self propelled paddy transplanter. *Intl. J. of Sci., Enviro. Tech.* **3**(6), 2015 – 2019.

Navacero, N. C. (1969). A row seeder for lowland rice soils. Saturday seminar (IRRI), IRRI, Los Banos, Manila, Philippines. September 6, 1969.

Ndaeyo, N. U., Iboko, K. U., Harry, G. I. and Edem, S. O. (2008). Growth and yield performances of some upland rice (*Oryza sativa L.*) cultivars as influenced by varied rates of NPK (15:15:15) fertilizer on an ultisol. *J. Trop. Agric. Food. Env. Ext.* **7**(3): 249 – 255.

Nicoulaud, B. A. L. and Bloom, A. J. (1996). Absorption and assimilation of foliarly applied urea in tomato. *J. Am. Soc. Hortic. Sci.* **121**: 1117.

Nishimura, Y., Hayashi, K., Gotoh, T., Horio, M., Ichikawa, T., Asano, S., Ueda, Y., Fukuma, H. and Nakao, T. (2001). Crop production machinery and system department, bio-oriented technology research advancement institution. *J. Japanese Soci. Agril. Mech.* **63**(6): 122-130.

Parvin, S., Uddin, S., Khanum, S. and Bhuiya, M. S. U. (2013). Effect of weeding and foliar urea spray on the yield and yield components of boro rice. *Am. Eur. J. Agric. & Env. Sci.* **13**(6): 866-871.

Pateriya, R. N. and Datta, R. K. (2012). Design modifications of mat type rice transplanter. *Intl. J. Adv. Tech. Eng. Res. (IJATER).* **2**(6): 87.

Peng, S., Buresh, R., Huang, J., Yang, J., Wang, G., Zhong, X. and Zou, Y. (2003). Principles and practices of real time nitrogen management: a case study on irrigated rice in China. IRRI, Los Banos, Philippines. p. 433.

Rahman, M. H., Khatun, M. M., Mamun, M. A. A., Islam, M. Z. and Islam, M. R. (2007). Effect of number of seedling hill^{-1} and nitrogen level on growth and yield of BRRI dhan32. *J. Soil Nat.* **1**(2): 01-07.

Rasheed, M., Asif, M. and Ghafoor, A. (2003). Yield and yield attributes of fine rice BAS-385 as affected by different NP levels on farmer's field. *Pak. J. Agric. Sci.* **40:** 1-2.

Saha, P. K., Saleque, M. A., Panaullah, G. M. and Miah, M. A. (2004). Comparison of the fertilizer recommendation Models for low land rice. *Bangladesh J. Soil Sci*. **30** (1&2): 31-37.

Sahoo, P. K., Pradhan, S. C. and Das, D. K. (1994). Development and testing of a power-operated pre-germinated cuban paddy seeder. *Agril. Mech. Asia Africa Latin Am.* **25** (1): 21-24.

Sarandon, S. J. and Asborno, M. D. (1996). Foliar urea spraying in rice (*Oryza sativa* L.). effects of time of application on grain yield and protein content. *Cereal Res. Comm.* **24** (4): 507-514.

Sawamura, N. (1998). Outline and research activities of Hokuriku National Agricultural Experiment Station. *Agril. Mech. in Asia Africa and Latin Am.* **29** (1): 74.

Shafiee, M. I., Boyce, A. N., Khandaker, M. M., Saad, J. M., Aziz, T. A., Mispan, M. S., Anuar, M. S. M. and Bakar, B. H. (2013). Pilot Studies on Rice. Yield enhancement with foliar application of SBAJA in Sungai Besar, Selangor, Malaysia. *J. Life Sci.* **10**(1): 329-335.

Singh, V. K., Dwivedi, B. S., Shukla, A. K. and Yadav, R. L. (2003). Effects of nitrogen and phosphorus fertilization on the growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) as influenced by the inclusion of forage cowpea (*Vigna unguiculata*) in rice-wheat system. *Indian J. Agril. Sci.* **73** (9): 482-489.

Singh, G., Sharma, T. R. and Bockhop, C. W. (1985). Field performance evaluation of a manual rice transplanter. *J. of Agric. Engin. Res.* **32**(3): 259-268.

Sivakumar, S. S., Manian, R. and Kathirvel, K. (2003). An improved direct-rice seeder. *Intl. Rice Res. Notes*. **28**(2): 53-54.

Subbaiah, S. V., Krishnaiah, K. and Balasubramanian, V. (2002). Evaluation of drum seeder in puddled rice fields. *Agril. Mech. Asia Africa Latin Am.* **33**(4): 23-26.

Tiwari, V. K. and Datta, R. K. (1983). Development of wetland seeder from mechanical and ergonomical consideration. *Agril. Mech. Asia Africa and Latin Am.* **14**(3): 21-27.

Toufiq, A. (2003). Integrated weed management in transplanted aman rice cv. BRRI dhan37. M.S. Thesis. Dept. Agron., Bangladesh Agril. Univ.,Mymensingh, Bangladesh.

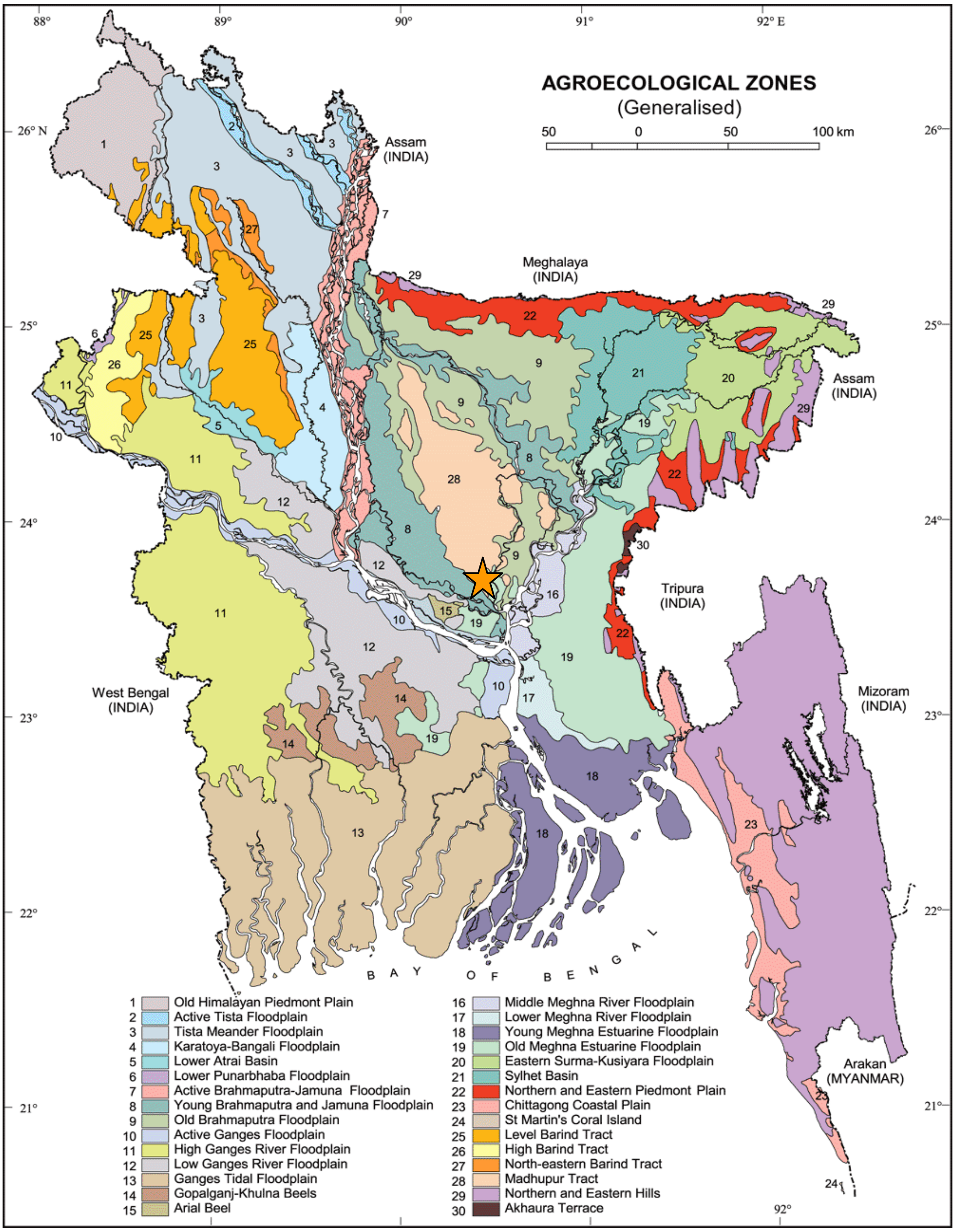
Tripathi, S. K., Jena, H. K. and Panda, P. K. (2004). Self-propelled rice transplanter for economizing labour. *Karnataka J. Agric. Sci.* **54**:23-25.

Umar F., Sheikh, A. D. Iqbal, M. Bashir, A. and Anwar, Z. (2001). The evaluation of diffusion possibilities of mechanical transplanting method. *Pak. Intl. J. Agric Biol.* **4**: 1560–1610.

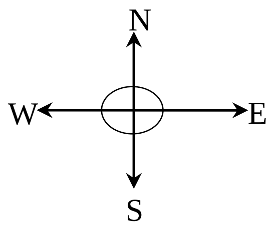
Yoshida, S. (1981). Fundamentals of Rice Crop Science, IRRI, Philippines.pp. 1-41.

APPENDICES

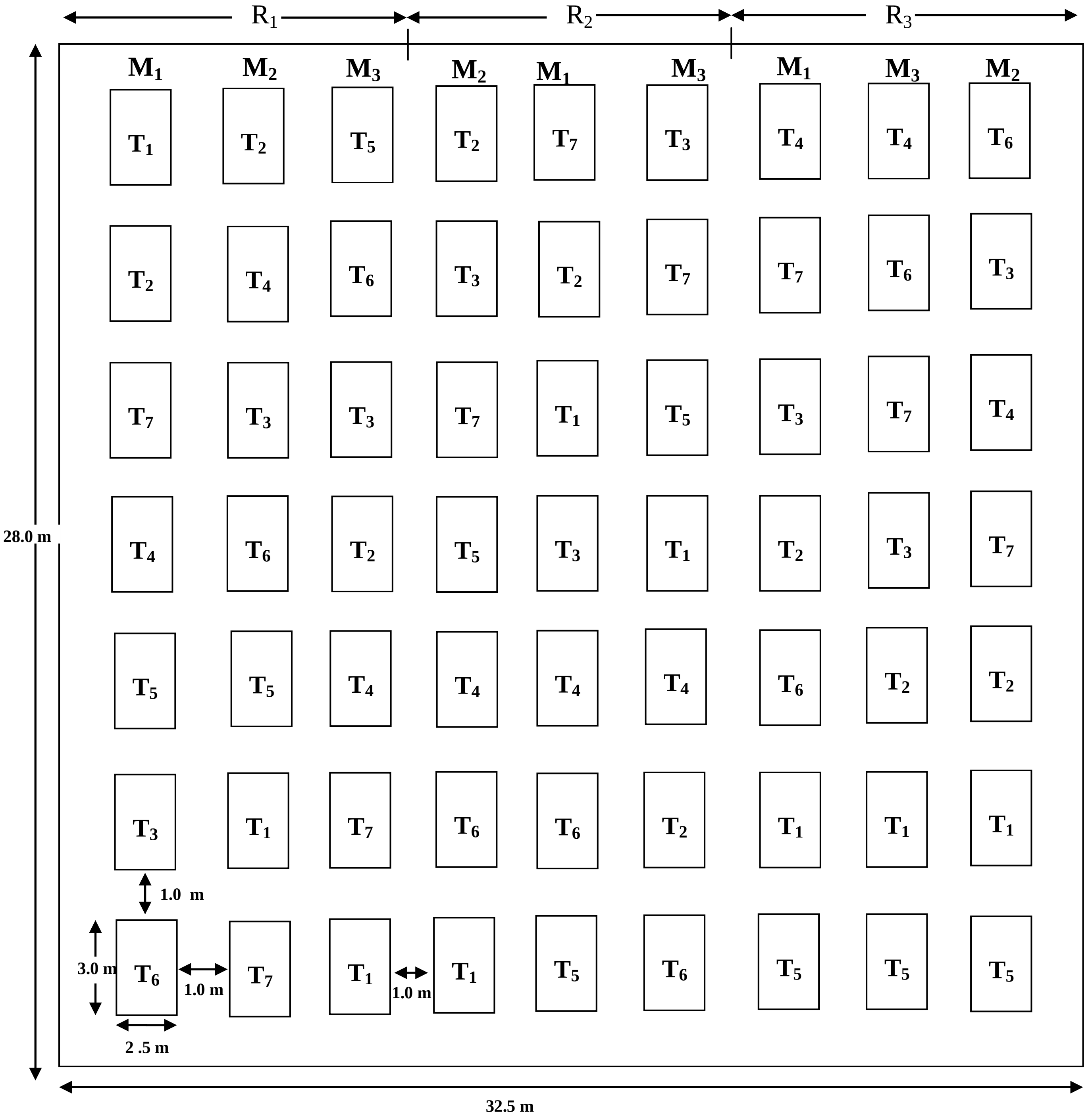
Appendix I. Map showing the experimental sites under study



☆ **The experimental site under study**



Appendix II. Layout of the experimental field



M_1 - (Conventional transplanting), **M_2** – (drum seeder), **M_3** - (Rice transplanter). **T_1** = 100% Urea of the recommended dose (RD) was applied as 3 top dressing, **T_2** = 100% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_3** = 100% Urea of RD was applied as 3 foliar spray, **T_4** = 75% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_5** = 75% Urea of RD was applied as 3 foliar spray, **T_6** = 50% Urea of RD was applied as 1 top dressing and 2 foliar spray, **T_7** = 50% Urea of RD was applied as 3 foliar spray.

Appendix III. Mean square values for plant height at different days after sowing

Sources of Variation	Degrees of freedom	Mean square values for plant height at different days after sowing				
		50	75	100	125	At harvest
Replication	2	3.65	30.40	215.97	6.12	9.02
A	2	73.72*	102.49*	55.28*	31.40NS	12.98NS
Error (a)	4	2.06	3.74	6.34	17.40	14.51
B	6	2.18NS	8.75NS	73.64*	24.51*	20.03*
A× B	12	4.90*	9.55*	36.07*	17.88*	18.67*
Error (b)	36	5.16	15.94	37.09	12.84	11.78

A=Planting method, B=N-splitting * Significant at 5% level NS= Non significant

Appendix IV. Mean square values for tiller numbers hill^{-1} at different days after sowing

Sources of Variation	Degrees of freedom	Mean square values for tiller numbers hill^{-1} at different days after sowing				
		50	75	100	125	At harvest
Replication	2	0.004	0.32	39.79	0.64	0.13
A	2	4.21*	19.94*	258.39*	146.01*	127.3*
Error (a)	4	0.01	2.71	6.33	4.66	4.66
B	6	0.39*	8.11*	40.43*	21.32*	23.81*
A×B	12	0.55*	4.87*	9.04*	4.35*	6.31*
Error (b)	36	0.03	7.46	19.92	12.4	12.75

A=Planting method, B=N-splitting * Significant at 5% level NS= Non significant

Appendix V. Mean square values for leaf area index at different days after sowing

Sources of Variation	Degrees of freedom	Mean square values for leaf area index at different days after sowing				
		50	75	100	125	At harvest
Replication	2	0.0006	0.31	1.46	0.31	1.47
A	2	0.02^{*}	0.004^{NS}	3.22^{NS}	3.37^{*}	2.31^{*}
Error (a)	4	0.003	0.14	1.4	0.25	0.69
B	6	0.003^{*}	0.05^{*}	2.76^{*}	6.94^{*}	5.05^{*}
A× B	12	0.002^{*}	0.49^{*}	0.43^{*}	1.11^{*}	0.77^{*}
Error (b)	36	0.0003	0.39	1.00	0.19	0.17

A=Planting method, B=N-splitting * Significant at 5% level NS= Non significant

Appendix VI. Mean square values for dry weight at different days after sowing

Sources of Variation	Degrees of freedom	Mean square values for dry weight at different days after sowing				
		50	75	100	125	At harvest
Replication	2	0.97	4.78	89.70	13.41	185.01
A	2	0.83^{NS}	3.54^{NS}	313.51^{*}	205.03^{*}	104.58^{NS}
Error (a)	4	0.83	1.76	7.24	17.40	143.85
B	6	1.32^{*}	8.74^{*}	58.92^{*}	27.66^{*}	825.53^{*}
A× B	12	1.42^{*}	4.30^{*}	48.43^{*}	64.77^{*}	114.65^{*}
Error (b)	36	0.69	2.20	8.87	20.89	125.33

A=Planting method, B=N-splitting * Significant at 5% level NS= Non significant

Appendix VII. Mean square values for crop growth characters, yield and other crop characters

Sources of Variation	Degrees of freedom	Mean square values												
		Chlorophyll content	Effective tillers hill^{-1}	Ineffective tillers hill^{-1}	Panicle length	Rachis branches panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Total grains panicle^{-1}	1000-grains weight	Grain yield	Straw yield	Biolo-gical yield	Harvest index
Replication	2	4.31	0.11	0.27	0.28	0.12	490.98	15.77	610.51	2.47	0.52	0.37	1.72	0.49
A	2	1.03*	118.82*	37.46*	3.04^{NS}	0.65^{NS}	406.21 ^{NS}	18.91 ^{NS}	527.65 ^{NS}	8.04 ^{NS}	5.96*	1.10^{NS}	11.91^{NS}	23.75^{NS}
Error (a)	4	3.17	4.69	0.16	6.99	2.03	1073.20	23.54	1330.65	3.23	0.30	1.87	2.90	18.62
B	6	42.47*	26.12*	0.48*	1.58^{NS}	0.25*	342.16*	14.32*	466.54*	1.29*	1.36*	0.65*	3.06^{*-}	11.15*
A× B	12	2.17*	6.38*	0.45*	1.18^{NS}	0.19*	158.71*	22.52*	267.14*	1.64*	1.16*	0.66*	0.75*	34.65*
Error (b)	36	4.47	12.72	0.29	1.49	0.17	63.80	3.51	64.73	2.15	0.15	0.33	0.49	6.11

A=Planting method, B=N-splitting * Significant at 5% level NS= Non significant