# GROWTH AND YIELD OF T. AMAN RICE VARIETIES AS AFFECTED BY SEEDLING NUMBER HILL$^{-1}$ AND UREA SUPERGRANULES


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# *CERTIFICATE*

This is to certify that the thesis entitled, **"GROWTH AND YIELD OF T. AMAN RICE VARIETIES AS AFFECTED BY SEEDLING NUMBER HILL$^{-1}$ AND UREA SUPERGRANULES"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by **SHEIKH MUHAMMAD MASUM,** Registration No. **27475/00801** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.



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

**Dated:** 26/6/08

**Place: Dhaka, Bangladesh**

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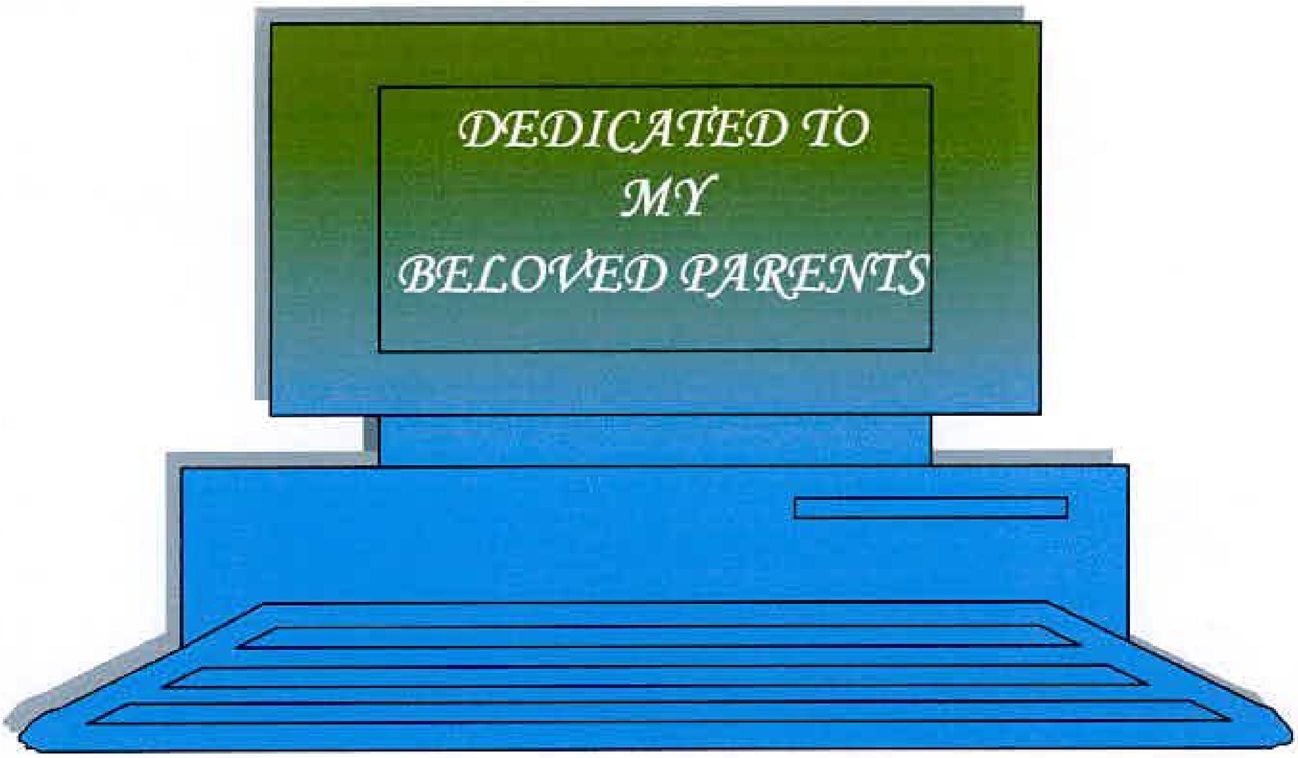
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# ABSTRACT

A field experiment was conducted at the experimental field of Sher-e-Bangla agricultural university during July to December 2007 to find out the effect of four levels of seedling hill$^{-1}$ *viz.*; 1, 2, 3 and 4 and two forms of nitrogen fertilizer-prilled urea (PU) and urea supergranules (USG) on growth, yield and yield components of modern (BRRI Dhan 44) and traditional (Nizershail) transplant *aman* rice. The experiment was laid out in a split-split-plot design with three replications. Urea was top dressed @ 58 kg N ha$^{-1}$ in three equal splits at 10, 30 and 50 DAT. The USG (1.8 g) was placed at 5-10 cm soil depth at 10 DAT in the center of four hills in alternate rows @ 1 granule in one spot to supply 58 kg N ha$^{-1}$. Results showed that rice varieties differed significantly in all growth characters and BRRI Dhan 44 produced higher grain yield (4.85 t ha$^{-1}$). Two seedlings hill$^{-1}$ gave the highest grain yield (3.96 t ha$^{-1}$) while four seedlings hill$^{-1}$ had the highest numbers of total tiller hill$^{-1}$, leaf area index and total dry matter. USG performed well in growth and gave higher grain yield (12.2%) over PU. Interaction results showed that significantly higher grain yields were given by transplanting one seedling of BRRI Dhan 44 (5.38 t ha$^{-1}$), application of USG in BRRI Dhan 44 (5.08 t ha$^{-1}$) and transplanting one seedling hill$^{-1}$ with application USG (4.18 t ha$^{-1}$) and finally placement of USG by transplanting one seedling hill$^{-1}$ of BRRI Dhan 44 (5.77 t ha$^{-1}$). The higher grain yield was attributed mainly to the number of effective tillers hill$^{-1}$, filled grains panicle$^{-1}$ and 1000-grain weight.

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## LIST OF ACRONYMS

| | | |
|---|---|---|
| AEZ | = | Agro- Ecological Zone |
| BARC | = | Bangladesh Agricultural Research Council |
| BBS | = | Bangladesh Bureau of Statistics |
| BINA | = | Bangladesh Institute of Nuclear Agriculture |
| BRRI | = | Bangladesh Rice Research Institute |
| cm | = | Centi-meter |
| cv. | = | Cultivar |
| DAT | = | Days after transplanting |
| $^{0}$C | = | Degree Centigrade |
| DF | = | Degree of freedom |
| EC | = | Emulsifiable Concentrate |
| *et al.* | = | and others |
| etc. | = | Etcetera |
| FAO | = | Food and Agriculture Organization |
| g | = | Gram |
| HI | = | Harvest Index |
| HYV | = | High yielding variety |
| hr | = | hour |
| IRRI | = | International Rice Research Institute |
| Kg | = | kilogram |
| LV | = | Local variety |
| LYV | = | Low yielding varieties |
| LSD | = | Least significant difference |
| m | = | Meter |
| $m^2$ | = | meter squares |
| MPCU | = | Mussorie phos-coated urea |
| MV | = | Modern variety |
| mm | = | Millimeter |
| *viz.* | = | namely |
| N | = | Nitrogen |
| ns | = | Non significant |
| % | = | Percent |
| CV % | = | Percentage of Coefficient of Variance |
| P | = | Phosphorus |
| K | = | Potassium |
| ppm | = | Parts per million |
| PU | = | Prilled urea |
| SAU | = | Sher-e- Bangla Agricultural University |
| S | = | Sulphur |
| SCU | = | Sulphur coated urea |
| t $ha^{-1}$ | = | Tons per hectare |
| UNDP | = | United Nations Development Program |
| USG | = | Urea supergranules |
| Zn | = | Zinc |

# Chapter 1
# Introduction

# INTRODUCTION

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Rice (*Oryza sativa* L.) is a semi aquatic cereal among the oldest and most important food crops of the world (Mikkelsen *et al*., 1995). Rice cultivation is favoured by the hot, humid climate and the large number of deltas across Asia's vast tropical and subtropical areas. As a main source of nourishment for more than two billion people in Asia and many millions in Africa and Latin America, it is by far one of the most important commercial food crops. Rice is a nutritious food, providing about 90 percent of calories from carbohydrates and as much as 13 percent calories from protein (Anon., 2005).

Rice is the staple food of about 140.6 million people of Bangladesh (BBS, 2006) and contributes 14.6% to the national GDP (BBS, 2004a) and supplies 71% of the total calories and 51% of the protein in a typical Bangladeshi diet (BBS, 1998). Bangladesh with its flat topography, abundant water and humid tropical climate constitutes an excellent habitat for the rice plant (BRRI, 1997a). In Bangladesh, 8.65 million hectare of arable land of which 75% is devoted to rice cultivation (BBS, 2004b). Rice is grown in the country under diverse ecosystem like irrigated, rainfed and deep water conditions in three distinct overlapping seasons namely *aus*, *aman* and *boro*. Among these three seasons, the monsoon rice, transplanted *aman* covers the largest area (50.58% of total rice area) and average yield of *aman* rice is 3.33 t $ha^{-1}$ (BBS, 2005). The population of Bangladesh is still growing by two million every year and may increase by another 30 millions over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million hectares. Rice (clean) yield therefore, needs to be increased from the present 2.44 to 3.74 t $ha^{-1}$ (BRRI, 2006).

Horizontal expansion of rice area is not possible in Bangladesh due to limited land resources and high population density. So the only avenue left is to increase production of rice by vertical means i.e.; management practices. The potential for increased rice production strongly depends on the ability to integrate a better crop management for the different varieties into the existing cultivation systems (Mikkelsen *et al.,* 1995). Variety itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop. Yield components are directly related to the variety and neighboring environments in which it grows. Earlier literatures indicated that there were marked differences in yield and ancillary characteristics among rice varieties (Chowdhury and Bhuian, 1991 and Miah *et al.*, 1989). In the year 2005 among the *aman* rice varieties modern varieties covered 67.99% and yield was 2.3 t $ha^{-1}$ on the other hand local varieties covered 31.91% and yield was 1.37 t $ha^{-1}$ (BBS, 2005). It was the farmers who have gradually replaced the local indigenous low yielding rice varieties by HYV and MV of rice developed by BRRI only because of getting 20% to 30 % more yield $unit^{-1}$ land area (Shahjahan, 2007). In Bangladesh as well as in the world rice research is predominantly conducted to develop modern high yielding varieties. After the introduction of high yielding varieties research interest shifted from local varieties to modern varieties of rice and thus the local varieties, the indigenous resources remained neglected. Bangladesh has a large reserve of local rice cultivars (Amin *et al.*, 2006). Although the yield potential of local varieties is less than that of modern varieties the farmers widely use local varieties because of their suitability for particular environmental conditions to which modern varieties are not adaptable (BRRI, 1980). Mustafi *et al.* (1993) justified the cultivation of traditional *aman* varieties by the poor farmers. They reported that major reasons for growing traditional *aman* varieties were low production cost, palatability of rice and lack of irrigation water. Talukdar (1998), Ichikawa *et al.* (1996) and Chowdhury (1995) indicated that some traditional wet season varieties could bring comparable grain yields to the modern varieties. However, more studies on their morphological, phenological and physiological characteristics are essential.

Planting density as a management practice in transplanted rice culture constitutes the number of seedling hill$^{-1}$ or per hills unit area. Grain yield was negatively correlated with increasing seedling hill$^{-1}$ (Nakano and Mizushima, 1994). Seedlings hill$^{-1}$ had no effect on panicles hill$^{-1}$, grains panicle$^{-1}$ and grain yield (Shah *et al.*, 1991). Wen and Yang (1991) found that effective panicles, the number of grains panicle$^{-1}$ and the 1000-grain weight were also higher with only 1 seedling hill$^{-1}$. Obulamma *et al.* (2002) recorded the highest grain yield, crop growth rate and net assimilation rate from one seedling hill$^{-1}$. Panda *et al.* (1999) found that grain yield was the highest with 4 seedlings hill$^{-1}$. Biswas and Salokhe (2001) revealed similar yield of rice by planting 2-4 vegetative tillers hill$^{-1}$. Excess or less number of seedlings hill$^{-1}$ may badly affect the normal physiological activities (Miah *et al.*, 2004).

Urea is the principal source of N, which is the essential element in determining the yield potential of rice (Mae, 1997). Generally urea is broadcast in three equal splits-one as basal dose at the time of final land preparation, one at maximum tillering stage and the remaining one before panicle initiation stage. However, under this practices high floodwater, pH, high ammonium N concentration in floodwater, high temperature and high wind speed are the factors, which have been identified to enhance ammonium-N loss. Numerous experiments have shown that the efficiency at which N is utilized by wetland rice is only about 30% of the applied fertilizer N and in many cases even less (Prasad and De Datta, 1979). So, any method of fertilizer N application that reduce the concentration of floodwater N(urea + $NH_4$) in the rice field will be subject to less loss of N through $NH_3$ volatization, algal assimilation, denitrification and surface runoff. Modifying urea materials is an important aspect of nitrogen management in rice from the view points of its efficient utilization. These losses of N may be reduced by the deep placement of urea supergranules (USG) instead of broadcasting prilled urea (PU). Point placement of USG can increase the efficiency of N utilization by rice in wet season (Roy, 1985). According to Crasswell and De datta (1980) broadcast application of urea on the surface soil causes losses upto 50% but point placement of USG in 10 cm depth results negligible loss. They also stated that USG placement provides a bonus of nitrogen to the soil. This technology improves N-use efficiency by keeping most of the urea N in the soil close to plant roots and out of the floodwater, where it is more susceptible to loss as gaseous compounds or runoff (Mohanty *et al.*, 1999; Savant and Stangel, 1990). Moreover, in conventional urea fertilization, it is often difficult to determine when to apply fertilizer to achieve optimal results.

Keeping all the points in mind mentioned above, the present piece of research work was under taken with the following objectives.

I. Compare the performance of modern and traditional variety of T. *aman* rice.

II. Identify optimum seedling(s) hill$^{-1}$ for optimum use of resources.

III. Study the effect of point placement of urea supergranules on T. *aman* rice

IV. Find out interaction effect of cultivars, seedling(s) hill$^{-1}$ and urea supergranules on the growth, yield and yield contributing characters of T. *aman* rice.

# Chapter 2
# Review of literature

# REVIEW OF LITERATURE

Number of seedlings hill$^{-1}$ is an important factor as it influences the plant population unit area$^{-1}$, availability of sunlight, nutrient competition, photosynthesis, respiration etc. which ultimately influence the growth and development of the crops. In agronomic point of view nitrogen management for modern rice cultivation has become an important issue. To minimize the N losses from soil-plant water system and to increase the N use efficiency, suitable techniques are essential for N application in soil. Since 1975 deep placement of urea supergranules (USG) has been practiced pertaining to improve N efficiency. Considering the above points, available literature was reviewed under seedling numbers hill$^{-1}$ and application of USG for rice varieties

**2.1 Effect of variety**

Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. Some available information and literature related to the effect of variety on the yield of rice are discussed below.

**2.1.1 Effect on growth characters**

**2.1.1.1 Plant height**

Om *et al.* (1998) in an experiment with hybrid rice cultivars ORI 161 and PMS 2A x IR 31802 found taller plants, more productive tillers, in ORI 161 than in PMS 2A x IR 31802.

BINA (1993) evaluated the performance of four rice varieties- IRATOM 24, BR14, BINA13 and BINA19. It was found that varieties differed significantly in respect of plant height.

BRRI (1991) conducted that plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in *boro* season. Hosain and Alam (1991) found that the plant height in modern rice varieties in *boro* season BR3, BR11, BR14 and pajam were 90.4, 94.5, 81.3 and 100.7 cm respectively.

Miah *et al.* (1990) conducted an experiment where rice cv. Nizershail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizershail.

Shamsuddin *et al.* (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among varieties.

Sawant *et al.* (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

**2.1.1.2 Tillering pattern**

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2(KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded IR20. In IR20, the tiller number was higher than that of KRH2.

Islam (1995) in an experiment with four rice cultivars viz.; BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill$^{-1}$ was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

Hossain and Alam (1991) also found that the growth characters like total tillers hill$^{-1}$ differed significantly among BR3, BR11, Pajam and Jaguli varieties in *boro* season.

Idris and Matin (1990) stated that number of total tillers hill$^{-1}$ was identical among the six varieties studied.

#### 2.1.1.3 Leaf area index

Swain *et al.* (2006) evaluated in a field experiment the performance of rice hybrids NRH1, NRH3, NRH4, NRH5, PA6111, PA6201, DRRH1, IR64, CR749-20-2 and Lalat conducted in Orissa, India during 1999-2000. Among the hybrids tested, PA 6201 recorded the highest leaf area index.

Roy (1999) reported that in Nizershail, leaf area index peaked around panicle initiation stage and in BRRI Dhan 31, although maximum leaf area index was attained at or just before heading stage, the increase of leaf area index from panicle initiation stage to heading stage was only small.

#### 2.1.1.4 Total dry matter production

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (viz.; Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (viz.; KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Son *et al.* (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, were evaluated at plant densities of 10 to 300 plants $m^{-2}$ and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo regardless of plant density.

### 2.1.2 Effect on yield contributing characters

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

Devaraju *et al.* (1998) also reported that the increased yield of KRH2 was mainly attributed due to the higher number of productive tillers plant$^{-1}$.

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Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e.; number of productive tillers $hill^{-1}$.

### 2.1.2.2 Panicle length, filled grains $panicle^{-1}$, unfilled grains $panicle^{-1}$, filled grain percentage, 1000-grain weight

Wang *et al.* (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling $hill^{-1}$, equal row spacing and 3 seedlings $hill^{-1}$, wide-narrow row spacing and one seedling $hill^{-1}$, and wide-narrow row spacing and 3 seedlings $hill^{-1}$) on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Guilani *et al.* (2003) studied on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran, during 1997. Grain number $panicle^{-1}$ was not significantly different among cultivars. The highest grain number $panicle^{-1}$ was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

Ahmed *et al.* (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved variety, Nizershail. The fertilizer dose was 60-60-40 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$, respectively for all the varieties and found that percent filled grain was the highest in Nizershail followed by BR25 and the lowest in BR11 and BR23.

BRRI (1994) studied the performance of BR14, BR5, Pajam, and Tulsimala and reported that Tulsimala produced the highest number of filled grains $panicle^{-1}$ and BR14 produced the lowest number of filled grains $penicle^{-1}$.

BINA (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle length and sterile spikelets panicle$^{-1}$. It was also reported that varieties BINA13 and BINA19 each had better morphological characters like more grains panicle$^{-1}$ compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

BRRI (1991) also reported that the filled grains penicle$^{-1}$ of different modern varieties were 95-100 in BR3, 125 in BR4, 120-130 in BR22 and 110-120 in BR23 when they were cultivated in transplant *aman* season.

Idris and Matin (1990) also observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties.

Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-1009, IET-5656 and IET-6314 and reported that grain number panicle$^{-1}$, 1000 grain weight were higher for C-14-8 than those of any other three varieties. Rafey *et al.* (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grains differed among the cultivars studied.

Shamsuddin *et al.* (1988) also observed that panicle number hill$^{-1}$ and 1000-grain weight differed significantly among the varieties. Kamal *et al.* (1988) evaluated BR3, IR20, and Pajam2 and found that number of grain panicle$^{-1}$ were 107.6, 123.0 and 170.9 respectively, for the varieties.

Costa and Hoque (1986) studied during kharif-II season, 1985 at Tangail FSR site, Palima, Bangladesh with five different varieties of T. *aman* BR4, BR10, BR11, Nizershail and Indrasail. Significant differences were observed in panicle length and number of unfilled grains panicle$^{-1}$ among the tested varieties.

BRRI (1979) reported that weight of 1000 grains of Haloi, Tilocha-Chari, Nizershail and Latisail were 26.5, 27.7, 19.6 and 25.0 g respectively.

**2.1.3 Effect on grain yield and straw yield**

Swain *et al.* (2006) also reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t $ha^{-1}$ that was at par with hybrid PA6201.

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles $m^{-2}$, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Patel (2000) studied that the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

Julfiquar *et al.* (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *boro* season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Julfiquar *et al.* (1998) also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during the boro season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t $ha^{-1}$. Rajendra *et al.* (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR3 and observed that mean grain yields of Pusa 834 and Pusa HR3 were 3.3 t $ha^{-1}$ and 5.6 t $ha^{-1}$, respectively.

BRRI (1997b) reported that three modern upland rice varieties namely, BR 20, BR 21, BR 24 was suitable for high rainfall belts of Bangladesh. Under proper management,



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the grain yield was 3.5 ton for BR20, 3.0 ton for BR21 and 3.5 ton for BR24 $ha^{-1}$. Nematzadeh *et al.* (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, it gives an average grain yield of 8 t $ha^{-1}$, twice as much as local cultivars.

BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including to local checks Challish and Nizershail produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70 5 t $ha^{-1}$, respectively. Chowdhury *et al.* (1995) studied on seven varieties of rice, of which three were native (Maloti, Nizershail and Chandrashail) and four were improved (BR3, BR11, Pasam and Mala). Straw and grain yields were recorded and found that both the grain and straw yields were higher in the improved than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice II-You 92 and found an average yield of 7.5 t $ha^{-1}$ which was 10% higher than that of standard hybrid Shanyou 64.

In field experiments at Gazipur in 1989-1990 rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizershail (strongly photosensitive) were sown at various intervals from July to Sept. and transplanted from Aug. to Oct. Among the cv. BR22 gave the highest grain yield from most of the sowing dates in both years (Ali *et al.*, 1993). Chowdhury *et al.* (1993) also reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e.; grain yield and straw yield.

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and

IR62829A/IR54 which in turn out yielded way-seputih. Chandra *et al.* (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A IR58025Ax 1R35366-62-1-2-2-3R.

Hossain and Alam (1991) also studied farmers production technology in haor area and found that the grain yield of modern varieties of *boro* rice were 2.12, 2.18, 3.17, 2.27 and 3.05 t $ha^{-1}$, with BR14, BR11, BR9, IR8 and BR3, respectively.

In evaluation of performance of four HYV and local varieties-BR4, BR16, Rajasail and Kajalsail in *aman* season, BR4 and BR16 were found to produce more grain yield among four varieties (BRRI, 1985).

BRRI (1979) also reported that Haloi gave the highest yield (2.64 t $ha^{-1}$) which was not different from Nizershail (2.64 t $ha^{-1}$) and Latisail (2.74 t $ha^{-1}$).

## 2.2 Effect of seedling numbers $hill^{-1}$

### 2.2.1 Effect on growth character

#### 2.2.1.1 Plant height

Hushine (2004) reported that number of seedling $hill^{-1}$ significantly influenced all the growth parameters except plant height. Miah *et al.* (2004) carried out an experiment to determine the effects of planting rate of 1, 2, 3 or 4 seedlings $hill^{-1}$ on the yield and yield components of transplanted rice cv. BINA dhan 4. Plant height was highest with planting of 1 and 2 seedlings $hill^{-1}$, respectively.

Faruque (1996) reported that plant height increased with the increased number of seedling(s) $hill^{-1}$.

Shah *et al.* (1991) reported that plant height increased with decrease in seedling number $hill^{-1}$.

#### 2.2.1.2 Tillering pattern

Inaba and Kitano (2005) reported on tiller production of rice plants (cv. Kinuhikari) transplanted at different seedling numbers hill$^{-1}$ (1, 3, 5, 7 and 9 seedlings hill$^{-1}$) in Japan. Tillering duration decreased with increasing number of seedlings hill$^{-1}$ (density), and that in the 9-seedling hills was two weeks shorter than that in the 1-seedling hills. The higher the seedling density, the earlier was the time of tillering. In 1 to 5-seedling hills, the tiller production rate increased with increasing seedling density, but the rate decreased in the hills with higher seedling densities.

Shrirame *et al.* (2000) carried out a field experiment during the kharif 1996 in Nagpur, Maharashtra, India on rice cv. TNRH10, TNRH13 and TNRH18 were grown at 1, 2 or 3 seedlings hill$^{-1}$ and found that two seedlings hill$^{-1}$ gave significantly higher number of tillers hill$^{-1}$ than three seedlings hill$^{-1}$.

Hossain and Haque (1990) reported that the number of basal tillers plot$^{-1}$ increased with increasing seedling number.

Hussain *et al.* (1989) carried out an experiment with rice cv. Baspati and observed that the number of tillers increased upto 16.4 hill$^{-1}$ with increasing number of seedlings hill$^{-1}$.

Patniswamy and Gomez (1976) reported that number of total tillers hill$^{-1}$ increased with increasing number of seedlings hill$^{-1}$.

#### 2.2.1.3 Leaf area index and total dry matter production

Miah *et al.* (2004) reported that leaf area index and total dry matter were highest with the planting of 4 seedlings hill$^{-1}$.

Obulamma *et al.* (2002) carried out an experiment with hybrid rice DPRH-1 and APHR-2. The treatments were 4 spacings (15 x 10, 20 x 20, 15 x 15 and 20 x 15 cm$^2$) and 3 seedlings hill$^{-1}$ (1, 2 and 3 seedlings hill$^{-1}$). One seedling hill$^{-1}$ recorded the highest grain yield, while 3 seedlings hill$^{-1}$ had the highest leaf area index and dry matter production.

### 2.2.2 Effect on yield contributing character

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

Baloch *et al.* (2006) initiated studies for two consecutive years to find out the effect of time of transplanting and seedlings hill$^{-1}$ (1, 2, 3 or 4) on the productivity of rice in Dera Ismail Khan district of North West Frontier Province (NWFP), Pakistan. They reported that the maximum productive tillers (548.3 m$^{-2}$) were recorded with 4 seedlings hill$^{-1}$ followed by 533.3 productive tillers m$^{-2}$ with 3 seedlings hill$^{-1}$ on the same date.

Park *et al.* (1998) stated that increasing plant density hill$^{-1}$ increased total tiller numbers but decreased the proportion of effective tillers.

Research results at BINA revealed that the number of seedlings hill$^{-1}$ of four rice varieties of aus rice viz.; Iratom24, Iratom38, BR3 and Pajam with use the number of seedling hill$^{-1}$ were 1, 2, 3 and 4. It was found that the number of effective tillers hill$^{-1}$ increased progressively from 1 seedling hill$^{-1}$, seedlings number 2, 3 and 4 seedlings gave statistically same effective tillers hill$^{-1}$ (BINA, 1987).

Islam (1980) conducted an experiment to determine the suitable number of seedling hill$^{-1}$ for transplanting aman rice cv. Nizershail, Tilackchari and Badshabog. The results revealed that 2-3 seedlings hill$^{-1}$ were as good as 3-4 seedlings hill$^{-1}$ with respect to effective tillers hill$^{-1}$ production.

#### 2.2.2.2 Panicle length, filled grains panicle$^{-1}$, unfilled grains panicle$^{-1}$, filled grain percentage, 1000-grain weight

Wang *et al.* (2006) reported that planting of one seedling hill$^{-1}$ was suitable for hybrids, whereas planting of 3 seedlings hill$^{-1}$ was suitable for conventional cultivars.

Pariyani and Naik (2004) reported that planting one or two seedlings $hill^{-1}$ did not show significant variations in yield attributes like panicle length, filled grains, sterile spikelets, 1000-grains weight of rice.

Karmakar *et al.* (2002) showed that number of effective tillers $hill^{-1}$ and straw yield were the highest with 6 seedlings $hill^{-1}$ while panicle length grains $panicle^{-1}$ were the highest with 2 seedlings $hill^{-1}$ in case of late transplant *aman* rice.

Bisht *et al.* (1999) conducted a field experiment on hybrid variety PRH1 transplanting with 1, 2 and 3 seedlings $hill^{-1}$ and reported that number of panicles and total spikelets increased with 2 or 3 seedlings $hill^{-1}$. Rajarathinam and Balasubramaniyan (1999) found that the planting one seedling $hill^{-1}$ gave similar results to planting 2 seedlings $hill^{-1}$ in respects of yield parameters (panicles $m^{-2}$, panicle weight and length, grains $panicle^{-1}$, filled grains $panicle^{-1}$, filled grain percentage and 1000-grain weight of hybrid rice cv. CORH-2.

Nakano and Mizushima (1994) elucidated the effect of the number of seedling $hill^{-1}$ on yield components and yield, rice plants cv. Nipponbare and Hourei, which were transplanted at three levels (1, 4, and 7) and two levels (4 and 7) of the seedling number $hill^{-1}$ in 1984 and 1985, respectively. In the higher seedling number $hill^{-1}$ the number of filled grains $panicle^{-1}$ and the percentage of filled grain were smaller. The 1000-grains-weight was not affected by the seedling number $hill^{-1}$.

Wen and Yang (1991) reported that late rice yields in a double cropping system were higher with 1 seedling $hill^{-1}$ than with 4 seedlings $hill^{-1}$. The proportion of effective panicle, the number of grains $panicle^{-1}$ and 1000 grain weight were also higher with only 1 seedlings $hill^{-1}$.

Singh (1990) observed that panicle $hill^{-1}$ and grain $panicle^{-1}$ increased with increase seedlings $hill^{-1}$, but panicle length, filled spikelets $panicle^{-1}$ and seed size decreased.

Rameswamy *et al.* (1987) reported that increasing number of seedlings $hill^{-1}$ had an adverse effect on yield parameters of rice. All yield parameters were reduced with more than two seedlings $hill^{-1}$. Singh *et al.* (1987) conducted an experiment with seed rate in nursery and seedlings $hill^{-1}$ on yield of transplanted rice. They found that grains $panicle^{-1}$ and number of seedlings $hill^{-1}$ had no significant effect.

Akita (1978) conducted an experiment with (a) 4, (b) 16, (c) 25 or (d) 49 tillers $m^{-2}$. Results of number of panicles, glumous spikelets and grain and paddy weight $hill^{-1}$ decreased in the order of (a)> (b)> (c)> (d). Maximum values of this parameters $m^{-2}$ were obtained in (c). Numbers of glumous spikelets $panicle^{-1}$ decreased in the order of (a)> (d)> (c)> (b). Percentage of ripened grains was 90, 92, 90 and 78 % in (a), (b), (c) and (d) respectively.

**2.2.3 Effect on grain yield and Straw yield**

Baloch *et al.* (2006) also reported that among seedlings $hill^{-1}$ highest paddy yield and net return with 1 seedling $hill^{-1}$. It explains that the use of more seedlings $hill^{-1}$ not only adds to cost but is also a mere wastage of natural resources. Nayak *et al.* (2006) studied on the effect of planting varying number of seedlings $hill^{-1}$ (1, 2 and 3 seedlings $hill^{-1}$) on yield components as well as yield of 3 hybrid cultivars (Pro-Agro6201, CNHR-3 and PAC-801) and one high-yielding cultivar (Khitish) of rice. The hybrid cultivars exhibited better performance in terms of yield components and yield at 2 seedlings $hill^{-1}$ than at one seedling $hill^{-1}$ but there was no yield advantage by planting 3 seedlings $hill^{-1}$ over 2 seedlings $hill^{-1}$. Khitish performed better at 3 seedlings $hill^{-1}$ than at 1 or 2 seedlings $hill^{-1}$.

Zhang *et al.* (2004) conducted a field experiment with III You 98 (sown on 11 May 2002) in Hefei, Anhui, China. The effects were investigated of different transplanting densities and number of seedlings $hill^{-1}$ (1 and 2) on some agronomic traits and grain yield-related indices. Although differences in plant height, panicle length and 1000-grain weight were insignificant but extremely significant differences in grain yield were noted. Crop management including reasonably close planting and 2 seedlings $hill^{-1}$ resulted in relatively high grain yield. For yields of more than 10.0 t $ha^{-1}$, the transplanting density should be 281300 hills $ha^{-1}$ at 2 seedlings $hill^{-1}$ or 365800 hills $ha^{-1}$ at 1 seedling $hill^{-1}$.

Rajesh and Thanunathan (2003) conducted an experiment on traditional Kambanchamba rice variety in Tamil Nadu, India, during the 2000/01 samba season. The seedling age (30, 40 and 50 days), number of seedlings (2 and 4 seedlings $hill^{-1}$) and spacing (20x15, 20x10 and 15x15 cm) were tested. Planting of 2 seedlings $hill^{-1}$ recorded the maximum grain yield of 2.85 and 2.65 t $ha^{-1}$ in experiments I and II, respectively.

Dongarwar *et al.* (2002) carried out an experiment with hybrid rice KJTRH-1 with 3 spacing (20 x 20, 20 x 15 and 20 x 20 $cm^2$) and 2 levels of seedlings (1 and 2 seedlings $hill^{-1}$) were tested. Irrespective of spacing treatments planting of one seedling $hill^{-1}$ was on at par with planting of two seedlings $hill^{-1}$ in respect of grain yield. Islam *et al.* (2002) conducted an experiment with fine rice cv. Kalizira including three hill densities viz.; 25 cm x 20 cm, 25 cm x 15 cm, 25 cm x 10 cm and two levels of seedlings $hill^{-1}$ viz.; 2 seedlings $hill^{-1}$ and 4 seedlings $hill^{-1}$. The highest grain yield was recorded form 25 cm x 20 cm spacing and 2 seedlings $hill^{-1}$.

Kabir (2002) carried out an experiment to find out the effect of variety and number of seedlings $hill^{-1}$ on yield and yield contributing characters of *boro* rice. The experiment comprised of three varieties viz.; Sonar Bangla 1, BINA dhan 5 and BINA dhan 6 and four different numbers of seedlings $hill^{-1}$ viz.; 1, 2, 3 and 4 seedlings $hill^{-1}$. Number of seedlings differed significantly in respect of growth characters and yield attributes.

The highest grain yield (5.37 t ha$^{-1}$) was obtained from 2 seedlings hill$^{-1}$ and lowest grain yield (4.58 t ha$^{-1}$) was obtained from single seedling hill$^{-1}$ which was statistically similar to 3 seedlings hill$^{-1}$ (4.77 t ha$^{-1}$) and 4 seedlings hill$^{-1}$ (4.35 t ha$^{-1}$). The highest straw yield (6.52 t ha$^{-1}$) was obtained from 2 seedlings hill$^{-1}$ and the lowest one (5.11 t ha$^{-1}$) was obtained from 4 seedlings hill$^{-1}$.

Molla (2001) reported that seedlings hill$^{-1}$ significantly influenced the number of tillers, mature panicles m$^{-2}$ and rice yield. Two seedlings hill$^{-1}$ had significantly higher yield than one seedling, including other parameters, in hybrids. For HYV, no significant response was obtained by increasing the number of seedlings from 3 to 6.

Shrirame *et al.* (2000) reported that one seedling hill$^{-1}$ gave significantly higher harvest index (HI) but grain yield were not affected by seedlings number hill$^{-1}$. Srivastava and Tripathi (2000) carried out an experiment where rice cv. Hybrid 6201 and R 320-300 were grown at 20 cm x 15 cm or 15 cm x 10 cm spacing at 1, 2 and 3 seedlings hill$^{-1}$ and observed that cv. R 320-300 were grown at the 15 cm x 10 cm spacing at 2 seedlings hill$^{-1}$ produced the highest grain yield of 7.59 t ha$^{-1}$.

Experiment was conducted at BRRI to find out the effect of seedling number on the panicle production and yields of a local variety Kumragoin transplanting at 1, 3, 6 and 9 seedlings hill$^{-1}$. The results revealed that panicle and grain yield did not differ significantly due to seedling number hill$^{-1}$ (BRRI, 1999). Srinivasulu *et al.* (1999) conducted an experiment on rice hybrids APHR-1 and APHR-2 and the conventional variety Chaitanya, planted with 1 or 2 seedlings hill$^{-1}$ and found that planting of two seedlings hill$^{-1}$ of Chaitanya recorded significantly higher grain yield than one seedling hill$^{-1}$ but in case of hybrids both the treatments were at par.

Asif *et al.* (1997) conducted an experiment with rice cv. Basmati 385 grown at 1, 2 or 3 seedlings hill$^{-1}$ and observed that grain yield was highest at 2 seedlings hill$^{-1}$. Banik *et al.* (1997) conducted a field experiment in 1993-95 in Bihar with 30-, 40-, 50-, or 60-day old rice cv. Pankaj and Patnation seedlings were transplanted at 2, 4, 6 and 8 seedlings $hill^{-1}$. They reported that yield was the highest with 4 seedlings $hill^{-1}$ (4.22 t $ha^{-1}$).

Paraye and Kandalkar (1994) conducted an experiment with 3 rice cultivars and showed that similar grain yields were obtained from planting 3 or 6 seedlings $hill^{-1}$.

Experiment was conducted at BINA with the number of seedlings $hill^{-1}$ of three rice varieties in *boro* season viz.; Iratom 24, BR14 and BR3 and three number of seedlings $hill^{-1}$ viz.; 1, 2 and 3 seedlings $hill^{-1}$. It was found that number of seedlings $hill^{-1}$ produced significant effect on filled grains $panicle^{-1}$ and significant higher yield by planting 4-5 seedlings $hill^{-1}$ compared to 2-3 seedlings $hill^{-1}$ (BINA, 1993). Chowdhury *et al.* (1993) conducted an experiment with 2, 4 and 6 seedlings $hill^{-1}$ to study their effect on the yield components of rice cv. BR23 and Pajam during the *aman* season. They reported that 6 seedlings $hill^{-1}$ gave the highest grain and straw yields. Rao and Reddy (1993) conducted a field experiment with rice cv. Rasi in the Kharif (Monsoon) season at 33, 44, 50, 67 and 200 hills $m^{-2}$ with 1, 2, 4, 6 and 8 $hill^{-1}$. They reported that grain yield increased with decreasing spacing from 33-200 hills $m^{-2}$ with 1 seedling $hill^{-1}$, when 10 seedlings $hill^{-1}$ were planted yield decreased at the widest spacing.

An experiment was conducted at BRRI with a local variety Kumaragoir at 25 cm x 15 cm and 25 cm x 45 cm spacing and 1, 3, 6 and 9 seedlings $hill^{-1}$. The results showed that with any spacing, seedling mortality decreased markedly with an increase in the number of seedlings $hill^{-1}$, but spacing appraised to have no marked effect on seedling mortality. The number of panicles $m^{-2}$ was generally greater with a closer spacing and fewer seedlings $hill^{-1}$. As regards yield, it was interesting about the same for all the spacing number combinations (BRRI, 1992). Prasad *et al.* (1992) conducted an experiment with 2, 3, 4 and 5 seedlings $hill^{-1}$ to study their effect on yield and yield components of rice cv. Sarjoo-52 and found that for all factors 4 seedlings $hill^{-1}$ were better for grain yield. Singh and Singh (1992) conducted an experiment with 2, 4 and 6 seedlings $hill^{-1}$ to study their effect on the yield and yield components of rice cv. Madhukar and found that for all factors 4 seedlings $hill^{-1}$ were better for grain yield.

BRRI (1991) was conducted another study to find out the effect of seedling number (2, 3, 4 and 5 seedlings $hill^{-1}$) on the grain yield and yield components of BR3, BR9 and BR14. The results showed that there was no significant effect of seedling number on the yield of BR3 and BR14. Planting of 4-5 seedlings $hill^{-1}$ gave significantly higher yield in BR9 than 2-3 seedlings $hill^{-1}$ although such differences were not apparent in yield components.

BRRI (1990) was conducted an experiment to find out the optimum plant population required for a satisfactory grain yield of rice both at Joydebpur and Habiganj at the combination of different plant spacing with 2-3 and 5-6 seedlings $hill^{-1}$ but significantly produced the highest grain yield was obtained by using 5-6 seedling $hill^{-1}$ in both the places . Increase in seedlings number from 2-3 to 5-6 seedling $hill^{-1}$ produced grain yield in most cases. Zhang and Huang (1990) studied the effects of seedlings $hill^{-1}$ of medium duration rice variety, transplanted at 1-5 seedlings $hill^{-1}$ and found that 2 or 3 seedlings $hill^{-1}$ gave best yield with increasing grain yield but harvest index were unaffected by the different number of seedlings $hill^{-1}$.

On the other hand Budhar *et al.* (1989) observed paddy yield, yields in early maturing rice cv. CR666-18 grown with 2 or 4 seedlings $hill^{-1}$ though the yield difference was not significant.

In an experiment of Karim *et al.* (1987), Nizershail was planted with 1, 2, 3, 4 and 5 seedlings hill$^{-1}$ and observed that highest grain yield of Nizershail was obtained with 4 followed by 3 seedlings hiil$^{-1}$ while 1 seedling hill$^{-1}$ yielded the lowest.

Sarma *et al.* (1979) observed that increased grain yield when seedling(s) hill$^{-1}$ was increased from 2 to 4 seedlings hill$^{-1}$.

Kang and Choi (1978) reported that in rice cultivar Tongil when grown with 1, 3, 5 and 7 seedlings hill$^{-1}$, shortened the growth duration and increased the ripened grain ratio with increasing number of seedlings hill$^{-1}$. But the effect was not joint significant in the early season. Increasing the number of seedlings hill$^{-1}$ increased grain yields in Tongil, especially in late-season crops but not in cv. Milyang 15. For early, 3-5 seedlings hill$^{-1}$ and for late 5-6 seedlings hill$^{-1}$ produced maximum yield.

Shahi and Gill (1976) observed that there was no significant difference in paddy yields of dwarf rice cultivar Jaya grown at a spacing of 20 cm X 20 cm or 15 cm X 15 cm with 1-4 seedlings hill$^{-1}$.Yield tended to be the highest at 20 cm X 20 cm and with 2 seedlings hill$^{1}$.

**2.3 Effect of urea supergranules (USG)**

Deep placement of urea supergranules (USG) has been proven to improve N fertilizer efficiency. In terms of N recovery, agronomical and physiological efficiency, rice varieties utilized N more efficiently when applied as urea (Miah and Ahmed, 2002).

**2.3.1 Effect on growth character**

**2.3.1.1 Plant height**

Mishra *et al.* (2000) conducted a field experiment in 1994-95 in Bhubaneswar, Orissa, India, and reported that rice cv. Lalate was given 76 kg N ha$^{-1}$ as USG at 0, 7, 14 for 21 days after transplanting (DAT), and these treated control and reported that USG application increased plant height.

Vijaya and Subbaiah (1997) showed that plant height of rice increased with the application of USG and were greater with the deep placement method of application both N and P compared with broadcasting.

On the other hand Rekhi *et al.* (1989) conducted an experiment on a sandy loamy soil with rice cv. PR106 providing 0, 37.5 or 75 or 112.5 kg N $ha^{-1}$ as 15 N-labeled PU or USG. They noted that application of PU produced the highest plant height.

Singh and Singh (1986) worked with different levels of nitrogen as USG, sulphur coated and PU @ 27, 54 and 87 kg $ha^{-1}$. They reported that deep placement of USG resulted in the highest plant height than PU.

Rajagopalan and Palanisamy (1985) found that 75 kg $ha^{-1}$ N as USG gave the tallest plant (83 cm).

**2.3.1.2 Tillering pattern**

Mirzeo and Reddy (1989) worked with different modified urea material and levels of N @30, 60 and 90 kg $ha^{-1}$. They reported that root zone placement of USG produced the highest number of tillers at 30 or 60 days after transplanting.

Singh and Singh (1986) also reported that the number of tillers $m^{-2}$ was significantly greater in USG than PU in all levels of nitrogen.

**2.3.1.3 Leaf area index and total dry matter production**

Miah *et al.* (2004) found that LAI was significantly higher in USG receiving plots than urea at heading and the total dry matter production was affected significantly by the forms of N fertilizer. USG applied plots gave higher TDM compared to urea irrespective of number of seedling transplanted $hill^{-1}$. At the same time it also noticed that the difference between treatments for TDM was narrower at early growth stages but became larger in later stages.

Das (1989) reported that the dry matter yield of rice were higher with application of USG.

Of various forms and methods of application of N fertilizers to rice grown under flooded conditions, placement of N as USG (1 and 2 g size) in the root zone at transplanting was the most effective in increasing dry matter production and were the lowest with urea applied as a basal drilling (Rambabu *et al.* 1983).

### 2.3.2 Effect on yield contributing character

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

Jee and Mahapatra (1989) observed that number of effective tillers m$^{-2}$ were significantly higher with 90 kg N ha$^{-1}$as deep placed USG than split application of urea. Rama *et al.* (1989) mentioned that the number of panicles m$^{-2}$ increased significantly when nitrogen level increased from 40 to 120 kg N ha$^{-1}$ as different modified urea materials and USG produced significantly higher number of panicles m$^{-2}$ than split application of PU.

Nayak *et al.* (1986) carried out an experiment under rainfed low land conditions with the amount of 58 kg N ha$^{-1}$as USG placed in root zone. They showed that USG was significantly superior to as sulphur coated urea (SCU) or applying in split dressing, increasing panicle production unit$^{-1}$ area.

#### 2.3.2.2 Panicle length, filled grains panicle$^{-1}$, unfilled grains panicle$^{-1}$, filled grain percentage, 1000 grain weight

Hasan *et al.* (2002) determined the response of hybrid (Sonar Bangla-1 and Alok 6201) and inbred (BRRI Dhan 34) rice varieties to the application methods of urea supergranules (USG) and prilled urea (PU) and reported that the effect of application method of USG and PU was not significant in respect of panicle length, number of unfilled grains panicle$^{-1}$ and 1000-grains weight.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea supergranules (USG) and broadcasting prilled urea (PU) as sources of N in T. *aman* rice. USG and PU were applied @ 40, 80, 120 or 160 Kg N $ha^{-1}$. A control treatment was also included in the experiment. They reported that USG was more efficient than PU at all respective levels of nitrogen in producing panicle length, filled grains $panicle^{-1}$ and 1000-grain weight.

Patel and Mishra (1994) carried out an experiment with rice cv. IR36 and were given 0, 30, 60 or 90 kg N $ha^{-1}$ as Muossorie rock phosphate-coated urea, *neem* cake-coated urea and gypsum coated urea, USG or PU. The coated materials as incorporated before transplanting and USG as placed 5-10 cm deep a week after transplanting and urea as applied in 3 split doses. They showed that N management practices had no significant effect on panicle length and percent sterility.

Roy *et al.* (1991) compared deep placement of urea supergranules (USG) by hand and machine and prilled urea (PU) by 2 to 3 split applications in rainfed rice during 1986 and 1987. They reported that USG performed better than PU in all the parameters tested. Filled grains $panicle^{-1}$ was significantly identical with USG and PU three split treated plots with the highest from PU three split treated plots. Significant difference was observed in 1000-grain weight and highest grain weight was obtained from USG (by hand) treated plots. Thakur (1991a) observed that yield attributes differed significantly due to levels and sources of' nitrogen at 60 kg N $ha^{-1}$ through USG produced the highest panicle weight, number of grains $panicle^{-1}$, 1000- grain weight.

Sen and Pandey (1990) carried out a field trial to study the effects of placement of USG (5, 10 or 15 cm deep) or broadcast PU @ 38.32 kg N $ha^{-1}$ on rice of tall long duration Mashuri and dwarf, short duration Mashuri. They revealed that all depths of

USG placement resulted in higher yield characters than broadcast PU; however, differences except for panicle lengths were not significant.

In a field trial, Sarder *et al.* (1988) found that, 94.8 kg N $ha^{-1}$ as basal application of USG gave longer panicle and total number of filled grains penicle$^{-1}$ than the other N sources.

**2.3.3 Effect on grain yield and straw yield**

Nitrogen fertilizer when applied as USG was reported to have increased grain yield by around 18% and saved around 32% N in wetland rice over prilled urea and appeared to be a good alternative N fertilizer management for rice production (Annon., 2004).

Ahmed *et al.* (2000) also revealed that USG was more efficient than PU at all respective levels of nitrogen in producing all yield components and in turn, grain and straw yields. Placement of USG @ 160 Kg N $ha^{-1}$produced the highest grain yield (4.32 t $ha^{-1}$) which was statistically identical to that obtained from 120 kg N $ha^{-1}$ as USG and significantly superior to that obtained from any other level and source of N.

Balaswamy (1999) found that in an experiment deep placement of nitrogen as urea supergranules reduced the dry weight of weeds resulting in more panicles and filled grains and increased the grain yield of rice over the split application of prilled urea by 0.43 and 0.3 t $ha^{-1}$ and basal application of large granular urea by 0.73 and 0.64 t $ha^{-1}$ in 1985 and 1986, respectively.

Detailed results of the experiments conducted at BRRI during the period from 1975-1985 on USG were presented in a technical session on fertilizer nitrogen deep placement for rice. The recommendation made in that technical session showed that deep placement of urea for rice was superior to split broadcast application during the dry season and the economics of use appeared favorable. But inconsistent results during wet seasons indicate further research is needed. The economic benefit of USG relative to PU was very high during the *boro* season than the transplant *aman* season. However, the benefit was higher in a lower rate of USG application in both seasons (Bhuiyan *et al.*, 1998). Department of Agricultural Extension conducted 432 demonstrations in 72 Upazilla as of 31 districts in Bangladesh during the 1996-97-winter season of' *boro* rice. It was .reported that USG plots, on an average, produced nearly 5 percent higher yields than the PU treated plots while applying 30-40% less urea in the form of USG (Islam and Black, 1998)

Singh and Singh (1997) conducted a field experiment in 1987 in Uttar Pradesh, India, dwarf rice cv. Jaya was given 90 or 120 kg N $ha^{-1}$ as urea super granules, large granular urea or neem cake coated urea. N was applied basally, or in 2 equal splits (basally and panicle initiation). They found that grain yield was highest with 120 kg N (4.65 t $ha^{-1}$), was not affected by N source and was higher with split application.

Kumar *et al.* (1996) reported that application of USG in the sub soil gave 22% higher grain yield than control. Pandey and Tiwari (1996) conducted a field trial in 1990-91 at Rewa, Madhya Pradesh , rice was given 87 kg N $ha^{-1}$ as a basal application of urea super granules (USG), prilled urea (PU), Mussoorie rock phosphate urea (MRPU), large granular urea (LGU) or nimin [neem seed extract]-coated urea (NCU) or PU, MRPU, LGU and NCU as 66% basal incorporation + 33% top dressing at panicle initiation and found that grain yield was highest with N applied as a basal application of USG or MRPU applied in 2 split applications. Rashid *et al.* (1996) conducted field experiments in two locations of Gazipur district during *boro* season (Jan-May) of 1989 to determine the nitrogen use efficiency of urea supergranules (USG) and prilled urea (PU) irrigated rice cultivation. It was observed that 87 kg N $ha^{-1}$ from USG produced the highest grain yield. However, 58 kg N $ha^{-1}$ from USG and 87 kg N $ha^{-1}$ from PU produced statistically similar grain yield to that of 87 kg $ha^{-1}$ from USG.

Bastia and Sarker (1995) conducted a field trial in Kharif seasons with rice cv. Jagnnath was given lac-coated urea and observed that grain yield and N content were 4.07 t $ha^{-1}$ and 1.43% respectively with USG and the lowest 2.66 t $ha^{-1}$ and 1.31% with PU. Dweivedi and Bajpai (1995) observed through using 0 to 90 kg N $ha^{-1}$ as urea, USG + urea or urea spray and they found that grain yield and net returns increased with the increased rate of N application and were highest with USG and lowest with urea spray. Harun *et al.* (1995) studied in the farmer's fields at the BRRI project area, Gazipur during the *boro* seasons of 1988-89 and 1989-90 to compare of urea supergranules (USG) and prilled urea (PU) application in irrigated rice. Nitrogenous fertilizers were applied at the rate of 29, 58 and 87 kg $ha^{-1}$, separately, from USG and PU. The performance of USG was found better than that of PU in relation to grain yield. Surendra *et al.* (1995) conducted an experiment during rainy season with nitrogen level @ 0, 40, 80, 120 kg $ha^{-1}$ and sources of nitrogen, USG and urea dicyandiamide @ 80 ka $ha^{-1}$. They showed that USG and urea dicyandiamide produced significantly more panicles grains $panicle^{-1}$, panicle weight and grain yield than PU @ 80 kg N $ha^{-1}$. Swain *et al.* (1995) evaluated the performance of USG application methods in low land transplanted rice. He reported that USG gave higher grain and straw yield.

Das and Singh (1994) pointed out the grain yield of rice cv. RTH-2 during Kharif season was greater for deep placed USG than USG for broadcast and incorporated or three split applications of PU. Mishra *et al.* (1994) conducted a field trial with rice cv. Sita giving 0 or 80kg N $ha^{-1}$ as urea, urea supergranules, *neem* coated urea. They reported that the highest grain yield was obtained by urea in three split applications (3.39 t $ha^{-1}$). Quayum and Prasad (1994) conducted field trials during Kharif season with 5 rates of N (0, 37.5, 75, 112.5 and 150 kg $ha^{-1}$) and six different sources of nitrogen with rice cv. Sita and found that application of up to 112.5 kg N $ha^{-1}$ increased grain (4.37 t $ha^{-1}$) and straw yields (5.49 t $ha^{-1}$). They also reported that N applied as USG gave the best yield and concluded that slow release fertilizers were effective for rainfed lowland rice.

Bhale and Salunke (1993) conducted a field trial to study the response of upland irrigated rice to nitrogen applied through urea and USG. They found that grain yield increased with up to 120 kg urea and 100 kg USG. Bhardwaj and Singh (1993) observed that placement of 84 kg N as USG produced a grain yield t $ha^{-1}$ which was similar to placing 112 kg USG and significantly greater than nitrogen sources and rates. Budhar and Palaniappan (1993) compared the performance of 30 or 60 kg N $ha^{-1}$ as PU, lac-coated urea or USG applied as basal, split or deep placement in Jalmagna rice. They reported that grain yield and N uptake increased with the rate of N application and was highest with deep placement USG. They also reported that N use efficiency was highest with 30 kg N $ha^{-1}$ as deep placement of USG. Harun *et al.* (1993) compared the benefits of USG application over PU and they found that USG produced at least 25% higher yield than PU and the marginal rate of return highest for USG at 58 kg N $ha^{-1}$. Singh *et al.* (1993) pointed out that application of 30 or 60 kg N $ha^{-1}$ as PU or USG gave the highest grain yield and N uptake increase with the rate of N application and were highest with deep placed USG. N use efficiency was the highest with 30 kg N $ha^{-1}$ from deep placed USG. Zaman *et al.* (1993) conducted two experiments on a coastal saline soil at the Bangladesh Rice Research Institute (BRRI), Regional station, Sonagazi in 1988 and 1989 *aus* seasons to compare the efficiencies of prilled urea (PU) and urea supergranules (USG) as sources of N for upland rice. The N doses used as treatments were 29 kg $ha^{-1}$ and 58 Kg $ha^{-1}$ for both PU and USG.

The test variety was BR20. They found that USG consistently produced significantly higher grain yield and straw yield than PU.

Bhagat *et al.* (1992) conducted a field experiment with rice cv. IR 36 and was given 56 kg N $ha^{-1}$ as prilled urea, large granule urea or urea supergranules or 84 kg N as prilled urea produced mean grain yields of 2.15, 2.18, 2.25, 2.58 and 2.72 t $ha^{-1}$, respectively, compared with the control (given no N) yield of 1.48 t $ha^{-1}$. They reported that the relative N use efficiency was the highest from the application of 84 kg N as prilled urea. Johnkutty and Mathew (1992) conducted an experiment with different forms of nitrogen on rice cv. Jyothy during rainy season and reported that 84 kg N $ha^{-1}$ USG gave higher yield than PU.

Sahu *et al.* (1991) worked on the method of application of USG in low land rice soil and showed that USG gave higher yields than PU when USG was placed at midway between at every alternate 4 hills. Satrusajong *et al.* (1991) conducted a field experiment to study the effect of N and S fertilizers on yields of rainfed low land rice. They found that rice yield was statistically greater for deep placement of urea as USG than all other N fertilizer treatments that included PU, urea amended with increase inhibitor and ammonium phosphate sulfate (16% N, 8.6% P). Thakur (1991b) carried out an experiment in 1986 on silty loam soil. The effect of N @ 0, 30 or 60 kg $ha^{-1}$ as PU, USG or urea briquettes were evaluated on yield and N use efficiency of rice cv. IET 7599, IET 7300, IET 6903 and Pankaj, he reported that USG gave highest grain yield and N use efficiency of 19.0 kg $grains^{-1}$ kg N. Singh *et al.* (1991) studied the effect of sources and level of N on the yield, yield attributes and N uptake of rice and reported that yield was affected significantly due to sources and levels of N. Deep placement of USG showed the highest grain yield (2.59 t $ha^{-1}$) followed by 2.43, 2.32

and 2.15 t $ha^{-1}$ with sulphur coated urea, Mussoorie rock phosphate-coated urea and PU, respectively.

The USG @ 75 kg N $ha^{-1}$ gave grain yield of 5.22 t $ha^{-1}$ whereas prilled urea gave only 4.29 t $ha^{-1}$ with the same rate. Uptake and use efficiency of N were also higher with USG compared to prilled urea (Chakraborti *et al*., 1989). Chauhan and Mishra (1989) found that application of N@ 20, 80, 120 kg $ha^{-1}$ as USG gave grain yield 4.08, 4.86 and 5.17 t $ha^{-1}$ and as PU gave 3.95, 3.72 and 4.33 t $ha^{-1}$respectively. Deep placement of USG proved superior to PU. Mirzeo and Reddy (1989) also reported that deep placement of USG gave 10.3% more grain yield than PU or *neem* coated urea. The straw yields also the highest with USG. Mohanty *et al.* (1989) observed that placement of USG in rice gave significantly higher grain and straw yields of 36 and 39% in dry and 17 and 18% in wet season, respectively than split application of PU. Sahu and Mitra (1989) reported that higher grain yields were obtained with large granular urea @ 60 or 90 kg N $ha^{-1}$ applied in two splits (7 days after transplanting and panicle initiation stage) than with PU. USG gave higher yields than large granular urea or PU.

Lal *et al.* (1988) reported that placement of N as USG and broadcast incorporation of SCU were superior to PU (applied in three split surface dressings) at 29, 58 and 87 kg N $ha^{-1}$ but not at 116 kg N $ha^{-1}$. SCU gave the highest grain yield followed by USG and both maintained superiority over PU up to 87 kg N $ha^{-1}$. On other hand Zia *et al.* (1988) reported that urea in three split applications produced the maximum rice yield followed by SCU, USG, UNS.

Raju *et al.* (1987) conducted an experiment with different sources of N fertilizers @ 0, 37.5, 75, 112.5 and 150 kg N $ha^{-1}$. They reported that among all the sources of N, USG recorded highest grain yield (5.4 t $ha^{-1}$) and proved significantly superior to rest of the sources. The increase in yield due to USG over urea application was to the turn of 14.7%. The rest of N sources failed to exert any differential effect on yield. Setty *et al.* (1987) evaluated different levels of modified urea on rice as USG and sulphur coated urea. They observed that grain yield increased significantly with increase N rate up to 87 kg ha$^{-1}$. Sulphur coated urea and USG gave similar yields, which were significantly higher than urea in 2-3 split application. N use efficiency was greater with sulphur coated and USG than urea. Tomar (1987) investigated that split applications of PU, sulphur coated urea (SCU), Mussoric phos-coated urea (MPCU) and USG @ 58, 87 or 116 kg N ha$^{-1}$ of rice in Kharif season gave higher grain yield from USG and sulphur coated urea @ 87 kg N ha$^{-1}$ than other two forms of urea.

Patel and Chandrawansi (1986) conducted an experiment with rice cv. Sumridhi (R-23.84) giving without N, or with 40 kg N ha$^{-1}$ as urea broadcast and incorporated as a basal dose before sowing USG applied in furrows and seeds drilled in alternate rows, urea or USG and seed drilled in the same furrow. They reported that the treatments did not significantly affect the number of panicles m$^{-2}$ but yield was highest (2.4 t ha$^{-1}$) in the last of the above treatments. Reddy *et al.* (1986) reported that N as USG placed in the root zone in soil gave significantly higher yields than N as *neem* cake coated urea, Dicyandiamide incorporated urea mixed with moist soil or urea.

Ali (1985) carried out a field trial with rice cv. BR3 growing on gray flood plain and red brown terrace soils applying N as PU, USG or SCU, immediately before or after transplanting or in 2-3 splits. It was reported that deep point placement of USG was superior to 2 or 3 applications of PU on both soils. The superiority of USG was more pronounced in *boro* than in *aus* season or T. *aman* season. USG was superior at all N rates; 62 kg N ha$^{-1}$ regardless of management. SCU produced the lowest yield at both sites. Manickam and Ramaswami (1985) stated that the highest grain yield varying from 3.4 to 4.6 t $ha^{-1}$, were obtained with USG and followed by PPDU and PU. Roy (1985) concluded that point placement of urea in mud balls or as USG could increase efficiency of N utilization by rice and increase yield in wet season. Sen *et al.* (1985) reported that the average increase in yield from USG placement compared with urea alone in three splits dressing was about 46% (in 1982 and 20% (in 1983). All yield components were positively correlated with yield.

Apparao (1983) pointed out that deep placement of 50 kg N $ha^{-1}$ as USG gave significantly higher paddy yields compared with urea applied basally or 3 applications. Lal *et al.* (1983) conducted an experiment to study effects of deep placement of USG or PU on yields of cv. Jaya and Govind and revealed that with random transplanting, deep placement of USG increased yield of cv. Jaya and Govinid by 0.4 and 1.1 $ha^{-1}$, respectively over yields with broadcast application of PU. Savant *et al.* (1983) found that deep application of USG was 11101-c effective in terms of yield than broadcast application of urea for wetland rice.

In trials in several countries, rice was given 0-176 kg N $ha^{-1}$ at each of three growth stages as urea, or USG applied broadcast, incorporated or deep placement. Recovery of N was generally higher with USG than with urea and less USG than was needed to give the same grain yield (Yamada *et al.*, 1981).

Evaluation of rice program during 1975 to 78 showed that deep placement of USG is an effective means of increasing rice yields compared with traditional split application of PU (Craswell and De Datta, 1980).

From the reviews cited and discussed above, it can be concluded that variety, seedling number $hill^{-1}$ and urea supergranules play a remarkable role for the growth, yield and yield components of transplant *aman* rice.

# Chapter 3

# Materials and Methods

# MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

### 3.1 Experimental period

The experiment was conducted during the period from July to December, 2007 in T. *aman* season.

### 3.2 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding about the experimental site is shown in the Map of AEZ of Bangladesh in Appendix I.

### 3.3 Climate

The experimental area under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix II.

### 3.4 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done at Soil Resource and Development

Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

### 3.5 Crop / planting material

Rice variety BRRI dhan 44 and Nizershail were used as the test crop.

#### 3.5.1 Description of rice cultivars

**BRRI Dhan 44**

The variety was developed through hybridization between BRRI Dhan 30 and BRRI Dhan 31 and grown in transplanted *aman* season. The variety is recommended for cultivation in medium high lands and medium low lands where the maximum tidal depths not exceed to 50 cm. This cultivar matures at 145-150 days of planting. It attains a plant height 125-130 cm. The cultivar gives an average yield of 6.5 t $ha^{-1}$.

**Nizershail**

A well established local improved variety of rice. It is highly photosensitive in nature. Nizershail is only adopted in transplanted *aman* season. This cultivar matures at 150-160 days of planting. It attains a plant height of 155-160 cm. The cultivar gives an average yield of 2.4- 3.3 t $ha^{-1}$.

#### 3.5.2 Description of the sources of nitrogen

Ordinary or PU and USG were used as the sources of nitrogen fertilizer.

**Prilled Urea (PU)**

Ordinary or prilled urea is the most common form of urea available in the market. It contains 46% N. The mean diameter of PU is 1.5 mm.

**Urea supergranules (USG)**

Urea supergranules fertilizer was manufactured from a physical modification of ordinary urea fertilizer. The International Fertilizer Development Centre (IFDC), Muscle Shoals, Alabama 35660, USA, has developed it. Its nature and properties are similar to that of urea. But its granule size is bigger and condensed with some conditions for slow hydrolysis. USG is spherical in shape containing 46% N which is similar to that of PU average diameter of the granule is 11.5mm. It is not a slow release fertilizer but can be considered as a slowly available N fertilizer. The supergranules are made by compressing prilled or granular urea in small machines with indented pocket rollers that, depending on the size of the pocket, produce individual briquettes varying in weight from 0.9 to 2.7 g. Within a week after transplanting rice, the supergranules are inserted into the puddled soil by hand, being placed to a depth of 7–10 cm in the middle of alternating squares of four hills of rice. Often refer to as urea deep placement (UDP).

### 3.6 Seed collection and sprouting

Seeds of BRRI Dhan 44 and Nizershail were collected from BRRI, Joydebpur, Gazipur. Healthy seeds were selected following standard method. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

### 3.7 Raising of seedlings

A common procedure was followed in raising of seedlings in the seedbed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

### 3.8 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

**3.9 Preparation of experimental land**

The experimental field was first opened on 16 July, 2007 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 26 July, 2007 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

**3.10 Fertilizer management**

At the time of first ploughing cowdung at the rate of 10 t $ha^{-1}$ was applied. The experimental plots were fertilized with @ 100, 50, 62.5, 10 kg $ha^{-1}$ in the form of triple superphosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate, respectively (BARC, 1989) one day before transplanting. Urea was top dressed @ 58 kg N $ha^{-1}$ in three equal splits at 10, 30 and 50 DAT. The entire amounts of triple superphosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate were applied at final land preparation as basal dose. The USG weighing 1.8 g each were placed at 5-10 cm soil depth at 10 DAT in the center of four hills in alternate rows @ 1 granule in one spot to supply 58kg N $ha^{-1.}$

### 3.11 Experimental treatments

Three sets of treatments included in the experiment were as follows:

A. Variety (2)

1. $V_1$= BRRI Dhan 44 (MV)
2. $V_2$= Nizershail (LV)

B. Seedling(s) No. $Hill^{-1}$ (4)

1. $S_1$= 1 seedling
2. $S_2$= 2 Seedlings
3. $S_3$= 3 Seedlings and
4. $S_4$= 4 Seedlings

C. Form of nitrogen fertilizer (2)

1. $N_1$= Prilled Urea
2. $N_2$= Urea Supergranules

### 3.12 Experimental design

The experiment was laid out in a split-split plot design with three replications having urea application in the main plots, variety in the sub-plots and seedling number(s) $hill^{-1}$ in the sub-split plots. There were 16 treatments combinations. The total numbers of unit plots were 48. The size of unit plot was 5 m x 3 m = 15 $m^2$. The distances between sub-split plot to sub-split plot, sub-plot to sub-plot, main plot to main plot and replication to replication were, 0.5, 0.75, 1.0 and 1.5 m respectively.

### 3.13 Uprooting and Transplanting of seedlings

Thirty days old seedlings were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted as per experimental treatment with 25 cm spacing between lines and 15 cm spacing between hills on the well puddled plots on 27 July 2007. In each plot, there were 12 rows, each row containing 33 hills of rice seedlings. There were in total 396 hills in each plot.

**3.14 Intercultural operations**

**3.14.1 Gap filling**

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

**3.14.2 Weeding**

During plant growth period two hand weeding were done, first weeding was done at 23 DAT (Days after transplanting) followed by second weeding at 38 DAT.

**3.14.3 Application of irrigation water**

Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

**3.14.4 Method of water application**

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed in each plot which were used to measure depth of irrigation water.

**3.14.5 Plant protection measures**

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of Diazinone 60 EC on 20 August and 3 September, 2007. Crop was protected from birds during the grain filling period.

**3.15 General observation of the experimental field**

The field was investigated time to time to detect visual difference among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage. However, no bacterial or fungal disease was observed. The flowering was not uniform. Lodging occurred in local variety plots during the heading stage due to heavy rainfall with gusty winds and in entire experimental plots on 15 November due to sidr at maturity stage.

**3.16 Harvesting and post harvest operation**

Harvesting was done on different dates as and when different varieties become ready for harvest (BRRI Dhan 44 on $28^{th}$ November and Nizershail on $5^{th}$ December). Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting was done on ten pre-selected hills from which data were collected and 6 mid lines from each plot was separately harvested, bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t $ha^{-1}$.

**3.17 Recording of data**

**A. Crop growth characters**

Plant height (cm) at 15 days interval

Number of tillers $hill^{-1}$ at 15 days interval

Leaf area index at 15 days interval

Dry matter weight of plant at 30 days interval

**B. Yield contributing characters**

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

Number of ineffective tillers $hill^{-1}$

Number of fertile spikelets (filled grains) $panicle^{-1}$

Number of sterile spikelets (unfilled grains) panicle$^{-1}$

Weight of 1000- grain (g)

**C. Yield**

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

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

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

Harvest index (%)

**3.18 Experimental measurements**

Experimental data collection began at 15 days after transplanting, and continued till harvest. The necessary data on agronomic characters were collected from ten selected hills from each plot in field at 15 days interval and at harvest.

**Plant height**

Plant height was measured at 15 days interval and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of panicle after heading.

**Number of tillers hill$^{-1}$**

Number of tillers hill$^{-1}$ were counted at 15 days interval up to harvest from pre selected hills and finally averaged as their number hill$^{-1}$. Only those tillers having three or more leaves were considered for counting.

**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).

**Dry matter weight of plant**

The sub-samples of 5 hills plot$^{-1}$ uprooting from $2^{nd}$ line were oven dried until a constant level from which the weight of above ground dry matter were recorded at 30 days interval up to harvest.

**Panicle length**

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

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

The panicles which had at least one grain was considered as effective tiller.

**Number of ineffective tillers hill$^{-1}$**

The tiller having no panicle was regarded as ineffective tiller.

**Number of fertile spikelets (filled grains) panicle$^{-1}$**

Spikelet was considered to be fertile if any kernel was present there in. The number of total fertile spikelets present on each panicle was recorded.

**Number of sterile spikelets (unfilled grains) panicle$^{-1}$**

Sterile spikelet means the absence of any kernel inside in and such spikelets present on each panicle were counted.

**Number of total spikelets panicle$^{-1}$**

The number of fertile spikelets panicle$^{-1}$ plus the number of sterile spikelets panicle$^{-1}$ gave the total number of spikelets panicle$^{-1}$.

**Weight of 1000-grain**

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

**Grain yield**

Grain yield was determined from the central 5 m length of all 6 inner rows of the plot and expressed as t $ha^{-1}$ on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

**Straw yield**

Straw yield was determined from the central 5 m length of all 6 inner rows of each plot. After threshing, the sub-sample was oven dried to a constant weight and finally converted to t $ha^{-1}$.

**Biological yield**

The biological yield was calculated with the following formula-

Biological yield= Grain yield + Straw yield

**Harvest index (%)**

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

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

**3.19 Analysis of data**

The data collected on different parameters were statistically analyzed to obtain the level of significance using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

# Chapter 4
# Results and Discussion

# RESULTS AND DISCUSSION

The experiment was conducted to compare the performance of modern and traditional T. *aman* rice variety with seedlings hill$^{-1}$ and urea supergranules. BRRI Dhan 44 and Nizershail were considered as modern and traditional variety, respectively and 4 seedling numbers i.e.; 1, 2, 3 and 4 seedlings with two forms of N-fertilizer *viz.*; prilled urea and urea supergranules were treated to find out the results.

## 4.1 Crop growth characters

### 4.1.1 Plant height

#### 4.1.1.1 Effect of variety

Plant height of the cultivars were measured at 15, 30, 45, 60, 75 DAT and at maturity. It was observed from Figure 1 and Appendix IV that the height of the plant was significantly influenced by variety at all the sampling dates. Figure 1 shows that irrespective of varieties, the height of rice plants increased rapidly at the early stages of growth and rate of progression in height was slow at the later stages. At harvest Nizershail produced the taller plant (157.79 cm) and BRRI Dhan 44 produced shorter (130.17 cm). Probably the genetic make up of varieties was responsible for the variation in plant height. This confirms the reports of BINA (1992), BRRI (1991) and Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.

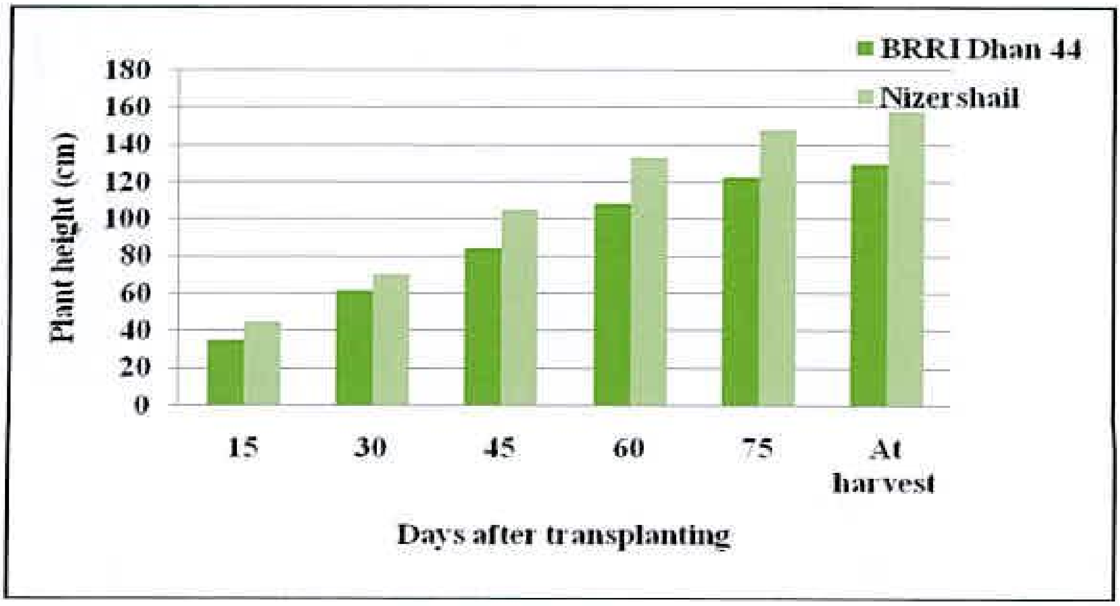


**Figure 1. Effect of variety on plant height (cm) of T. *aman* rice at different days after transplanting**

#### 4.1.1.2 Effect of seedling numbers hill$^{-1}$

Number of seedlings hill$^{-1}$ had no significant effect on plant height (Figure 2 and Appendix IV). Plant height was also unaffected by the different number of seedlings hill$^{-1}$ at 15, 30, 45, 60 and 75 DAT and even at harvest. At harvest, numerically the tallest plant (148.08 cm) was obtained from 1 seedlings hill$^{-1}$ and the shortest plant (140.08 cm) was obtained from 4 seedling hill$^{-1}$. The results are similar to the findings of Hushine (2004), Shrirame *et al.* (2000) and Zhang and Huang (1990), who reported that plant height was not significantly affected by seedlings hill$^{-1}$. The results are conflict with that of Miah *et al.* (2004) and Shah *et al.* (1991) who stated that plant height increased with decrease in seedling number hill$^{-1}$ where as Faruque (1996) and Singh (1990) showed that plant height increased with increased the seedling number hill$^{-1}$.

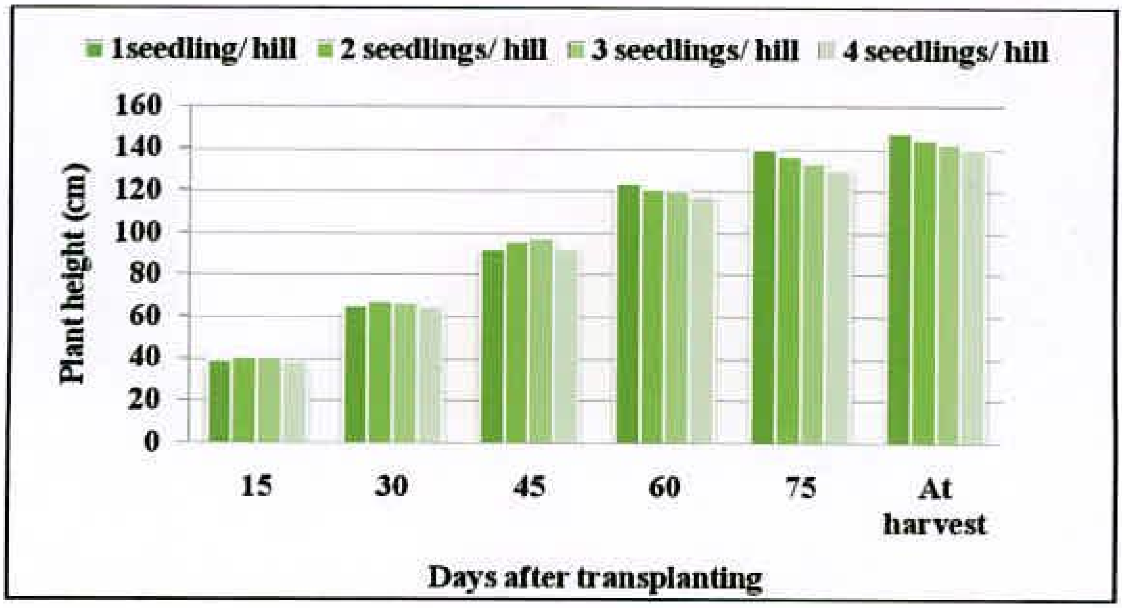


**Figure 2. Effect of seedling numbers hill$^{-1}$ on plant height (cm) of T. *aman* rice at different days after transplanting**

#### 4.1.1.3 Effect of form of nitrogen fertilizer

Although there was no significant effect at 15 and 30 DAT of sampling but the results revealed that there was a significant effect at 45, 60, 75 DAT and also at harvest on plant height due to the form of nitrogen fertilizer (Figure 3 and Appendix IV). Figure 3 shows that the plants those received N in the form of USG had always maintained higher plant length compared to urea. It might be due to continuous availability of N from the deep placed USG that released N slowly and it enhanced growth to crop more than urea. The results are in agreement with those of Singh and Singh (1986) who reported that USG produced taller plants than prilled urea when applied @ 27 to 87 kg N ha$^{-1}$.

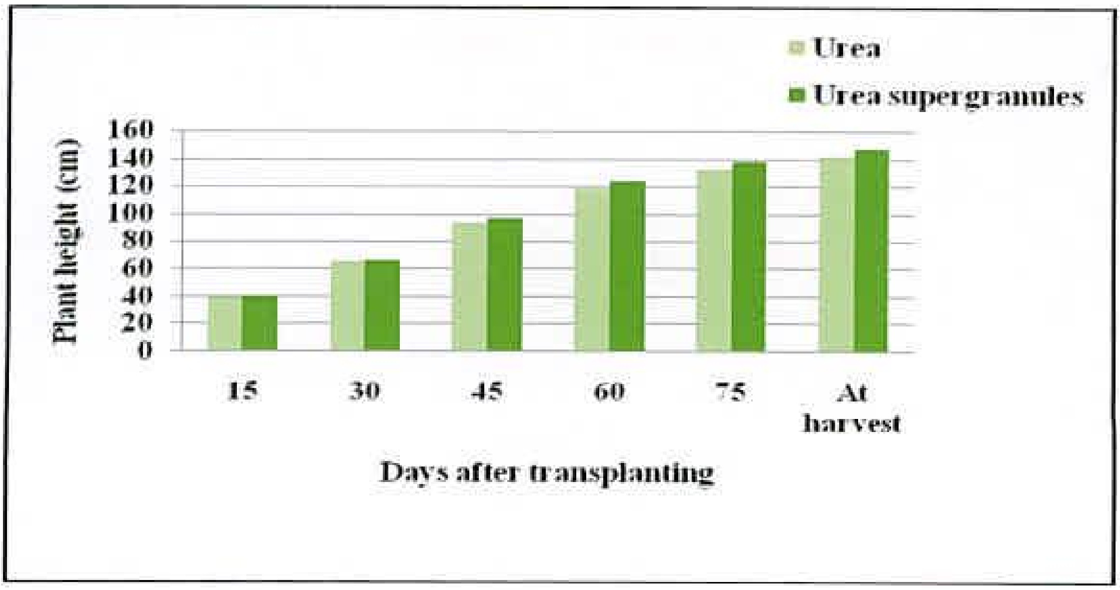


**Figure 3. Effect of form of nitrogen fertilizer on plant height (cm) of T. *aman* rice at different days after transplanting**

#### 4.1.1.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Interaction effect of variety and seedling numbers hill$^{-1}$ on plant height was found significant at different date of sampling except at 30 DAT (Table 1). At harvest the tallest plant (162.00 cm) found from the Nizershail with 1 seedling hill$^{-1}$ which was statistically similar with the combination of same variety with rest other seedlings hill$^{-1}$ and the shortest plant (127.33 cm) was found from the combination of BRRI Dhan 44 with 4 seedlings which was statistically similar with the combination of same variety with rest other seedlings hill$^{-1}$.

#### 4.1.1.5 Interaction effect of variety and form of nitrogen fertilizer

Plant height at different date of sampling was significantly affected by the interaction between variety and forms of urea (Table 1). At harvest the tallest plant (161.83 cm) was found from Nizershail with USG application and the shortest plant (128.92 cm) from BRRI Dhan 44 which was statistically similar to irrespective of USG and PU application.

#### 4.1.1.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

From the Appendix IV it was revealed that at different date of sampling interaction of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on plant height did not show significant variation among treatment combination but at harvest numerically single seedling hill$^{-1}$ with USG produced the tallest plant (150.50 cm) than higher number of seedlings hill$^{-1}$ (data were not shown).

#### 4.1.1.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

From the interaction data of variety, seedling numbers hill$^{-1}$ and form of N fertilizer at different date of sampling (Table 1), it was found that although plant height was non significant at 15, 30, 45, 75 DAT but significant at 60 DAT and at harvest. Such type of discontinuity in increasing plant height might have been caused by the variation between varieties in response to nitrogen or might be due to differences in crop growth pattern. At harvest tallest plant (165.67cm) obtained from Nizershail x 1 seedling x USG which was statistically similar with same varietal combination irrespective of seedlings hill$^{-1}$ and source of N. The shortest (126.00 cm) plant was observed from BRRI Dhan 44 x 4 seedlings x PU which was also statistically similar with same varietal combination irrespective of seedlings hill$^{-1}$ and source of N.

**Table 1. Interaction effect of variety and seedling numbers $hill^{-1}$, variety and form of nitrogen fertilizer, variety x seedling numbers $hill^{-1}$ x form of nitrogen fertilizer on plant height (cm) of T. *aman* rice at different days after transplanting**

| Treatment | Days after transplanting | | | | | |
|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 75 | At Harvest |
| **Variety and seedling numbers $hill^{-1}$** | | | | | | |
| $V_1S_1$ | 34.67 | 62.35 | 84.32 | 112.50 | 129.50 | 134.17 |
| $V_1S_2$ | 37.10 | 64.63 | 87.93 | 108.50 | 123.50 | 130.50 |
| $V_1S_3$ | 35.60 | 62.80 | 88.33 | 109.50 | 120.00 | 128.67 |
| $V_1S_4$ | 34.05 | 59.47 | 78.37 | 104.67 | 118.00 | 127.33 |
| $V_2S_1$ | 44.50 | 68.97 | 101.12 | 135.83 | 151.17 | 162.00 |
| $V_2S_2$ | 45.50 | 70.37 | 105.47 | 133.83 | 150.33 | 159.33 |
| $V_2S_3$ | 46.10 | 72.02 | 107.68 | 131.83 | 147.50 | 157.00 |
| $V_2S_4$ | 44.10 | 70.45 | 107.20 | 131.17 | 143.25 | 152.83 |
| LSD (5%) | 4.92 | ns | 7.40 | 7.41 | 6.16 | 5.08 |
| CV % | 10.26 | 8.07 | 6.53 | 5.14 | 3.82 | 2.96 |
| **Variety and form of nitrogen fertilizer** | | | | | | |
| $N_1V_1$ | 35.23 | 61.86 | 83.01 | 106.50 | 120.67 | 128.92 |
| $N_1V_2$ | 45.05 | 70.15 | 103.18 | 130.42 | 144.54 | 153.75 |
| $N_2V_1$ | 35.48 | 62.76 | 86.47 | 111.08 | 124.83 | 131.42 |
| $N_2V_2$ | 45.05 | 70.75 | 107.55 | 135.92 | 151.58 | 161.83 |
| LSD (5%) | 3.48 | 4.51 | 5.23 | 5.24 | 4.36 | 3.59 |
| CV % | 8.77 | 9.02 | 12.92 | 8.34 | 8.84 | 4.68 |
| **Variety x Seedling numbers $hill^{-1}$ x Form of nitrogen fertilizer** | | | | | | |
| $N_1V_1S_1$ | 34.33 | 60.70 | 80.60 | 112.00 | 127.33 | 133.00 |
| $N_1V_1S_2$ | 37.20 | 63.60 | 85.90 | 106.67 | 121.67 | 129.33 |
| $N_1V_1S_3$ | 35.40 | 65.80 | 89.07 | 107.00 | 118.33 | 127.33 |
| $N_1V_1S_4$ | 34.00 | 57.33 | 76.47 | 100.33 | 115.33 | 126.00 |
| $N_1V_2S_1$ | 44.00 | 68.60 | 95.57 | 133.67 | 146.67 | 158.33 |
| $N_1V_2S_2$ | 45.80 | 69.47 | 102.60 | 131.33 | 146.67 | 156.00 |
| $N_1V_2S_3$ | 46.20 | 72.70 | 107.40 | 127.67 | 144.67 | 150.00 |
| $N_1V_2S_4$ | 44.20 | 69.83 | 107.17 | 129.00 | 140.17 | 150.67 |
| $N_2V_1S_1$ | 35.00 | 64.00 | 88.03 | 113.00 | 131.67 | 135.33 |
| $N_2V_1S_2$ | 37.00 | 65.67 | 89.97 | 110.33 | 125.33 | 131.67 |
| $N_2V_1S_3$ | 35.80 | 59.80 | 87.60 | 112.00 | 121.67 | 130.00 |
| $N_2V_1S_4$ | 34.10 | 61.60 | 80.27 | 109.00 | 120.67 | 128.67 |
| $N_2V_2S_1$ | 45.00 | 69.33 | 106.67 | 138.00 | 155.67 | 165.67 |
| $N_2V_2S_2$ | 45.20 | 71.27 | 108.33 | 136.33 | 154.00 | 162.67 |
| $N_2V_2S_3$ | 46.00 | 71.33 | 107.97 | 136.00 | 150.33 | 164.00 |
| $N_2V_2S_4$ | 44.00 | 71.07 | 107.23 | 133.33 | 146.33 | 155.00 |
| LSD (0.05) | ns | ns | ns | 10.48 | ns | 7.19 |
| CV % | 10.26 | 8.07 | 6.53 | 5.14 | 3.82 | 2.96 |

**Note: $N_1$= Prilled urea, $N_2$= Urea supergranules, $V_1$= BRRI Dhan 44, $V_2$= Nizershail, $S_1$= 1 seedling, $S_2$= 2seedlings, $S_3$= 3 seedlings, $S_4$= 4 seedlings**

### 4.1.2 Number of total tiller hill$^{-1}$

#### 4.1.2.1 Effect of variety

The number of total tillers hill$^{-1}$ was significantly influenced by variety at all stages of crop growth (Figure 4 and Appendix V). Varietal effects on the formation of total number of tillers are shown in Figure 4. Maximum (25.63) number of tillers were produced by Nizershail at 45 DAT, then with advancement to age it declined up to maturity, where as in the case of BRRI Dhan 44 maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT and also then with advancement to age it declined up to maturity. The value decreased because some of the last emerged tillers died due to their failure in competing for light and nutrients as observed by Ishhizuka and Tanaka (1963). This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992). Variable effect of variety on number of total tillers hill$^{-1}$ was also reported by Hussain *et al.* (1989) who noticed that number of total tillers hill$^{-1}$ differed among the varieties.

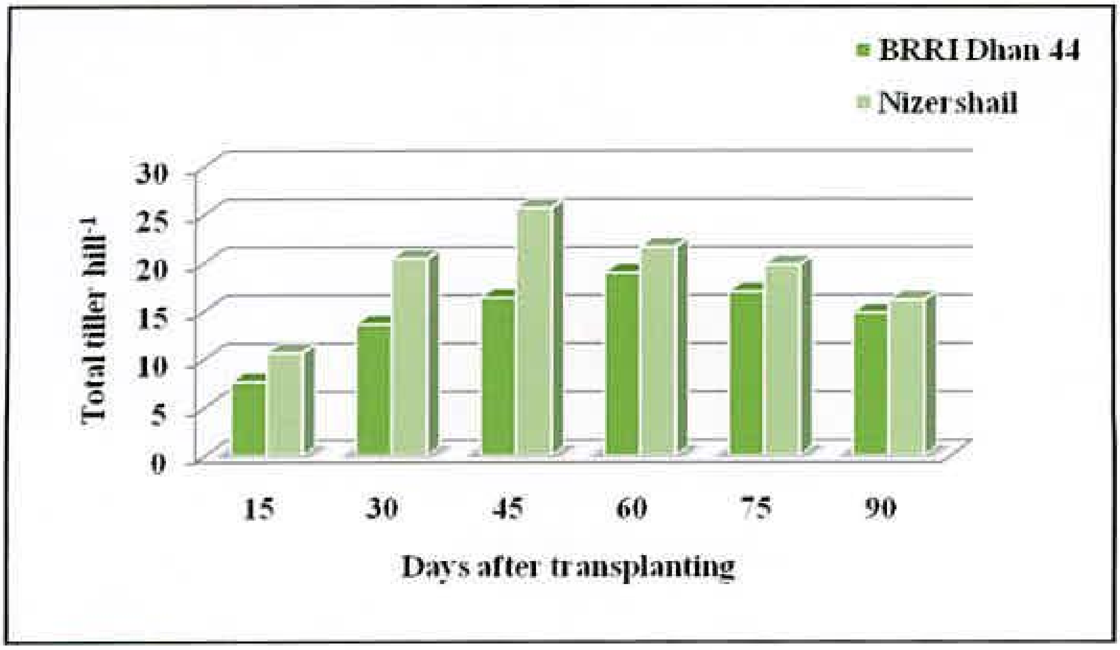


**Figure 4. Effect of variety on total tiller hill$^{-1}$ of T. *aman* rice at different days after transplanting**

#### 4.1.2.2 Effect of seedling numbers hill$^{-1}$

Grist (1986) indicated that tiller production is a varietal characteristic, but is also influenced by cultural practice. Except at 15 and 30 DAT, total tiller numbers hill$^{-1}$ was significantly influenced by the different number of seedlings hill$^{-1}$ at 45, 60, 75 and 90 DAT (Figure 5 and Appendix V). At 15 DAT, maximum (11.42) number of tillers hill$^{-1}$ was counted with transplanting 4 seedlings hill$^{-1}$ and it was followed by transplanting 3 and 2 seedlings hill$^{-1}$ and minimum (6.75) number of tillers hill$^{-1}$ was counted with transplanting 1 seedling hill$^{-1}$. At 30 DAT, maximum (20.25) number of tillers hill$^{-1}$ was counted with transplanting 4 seedlings hill$^{-1}$ and it was followed by transplanting 3 and 2 seedlings hill$^{-1}$ and minimum (13.92) number of tillers hill$^{-1}$ was counted with transplanting 1 seedling hill$^{-1}$. At 45 DAT, maximum (25.17) number of tillers hill$^{-1}$ was obtained with transplanting 4 seedlings hill$^{-1}$ and it was followed by transplanting 3 and 2 seedlings hill$^{-1}$ and the minimum (16.5) number of tillers hill$^{-1}$

was obtained at 1 seedling hill$^{-1}$. The similar trend of tiller production was also observed at 60, 75 and 90 DAT. These results are in agreement with the findings of Miah *et al.* (2004), Pataniswamy and Gomez (1976) who found that number of total tillers hill$^{-1}$ increased with increasing number of seedling hill$^{-1}$.

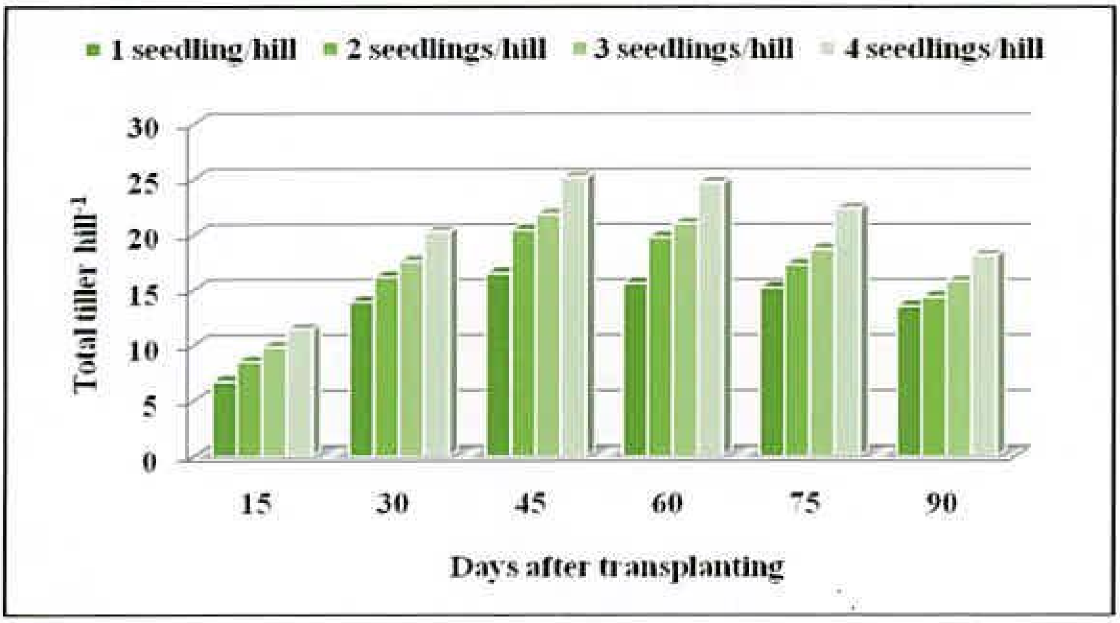


**Figure 5. Effect of seedling numbers hill$^{-1}$ on total tiller hill$^{-1}$ of T. *aman* rice at different days after transplanting**

#### 4.1.2.3 Effect of form of nitrogen fertilizer

Except at 15 and 30 DAT forms of N fertilizer affected tiller production significantly at all observations of crop growth (Figure 6 and Appendix V). Figure 6 shows that irrespective of variety and numbers of seedling hill$^{-1}$ the USG applied plants always produced higher number of total tiller hill$^{-1}$. Increased number of tillers in USG than PU might be due to uniform N supply through USG. Maximum (22.21) tillers hill$^{-1}$ was observed in USG at 45 DAT. Mirzeo and Reddy (1989) and Singh and Singh (1986), also reported similar results. On the other hand Peng *et al.* (1996) and Schnier *et al.* (1990) reported that N supply controlled the tiller production of rice plant unless other factors such as spacing or light became limiting.

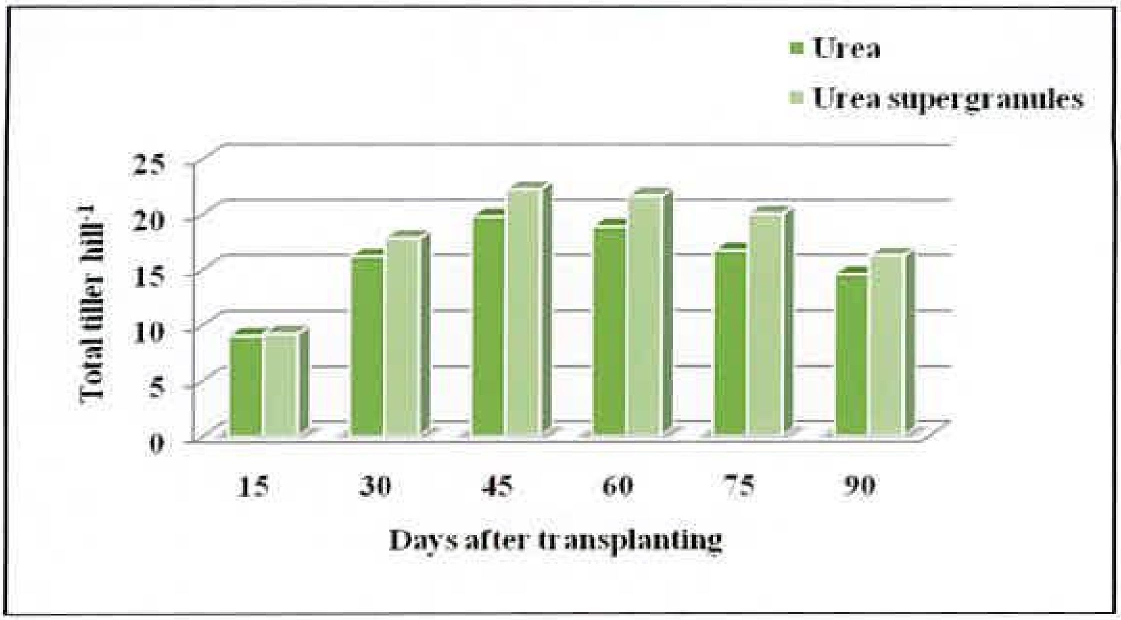


**Figure 6. Effect of form of nitrogen fertilizer on total tiller hill$^{-1}$ of T. *aman* rice at different days after transplanting**

#### 4.1.2.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Interaction effect of variety and seedling hill$^{-1}$ was observed to be insignificant at 15, 30 and 45 DAT but significant at 60, 75 and 90 DAT (Table 2). At 15 DAT numerically maximum (13.0) tillers hill$^{-1}$ was found from the combination of Nizershail with 4 seedlings and minimum (5.5) was found from BRRI Dhan 44 with 1 seedling. Similar trend was also observed at 30 and 45 DAT. Significantly maximum (26.0) tillers hill$^{-1}$ was found from the combination of Nizershail with 4 seedlings and minimum (14.0) was found from BRRI Dhan 44 with 1 seedling. Similar trend was also observed at 75 and 90 DAT. In the case of BRRI Dhan 44 maximum (23.33) tillers hill$^{-1}$ was counted from the combination with 4 seedlings at 60 DAT and in the case of Nizershail maximum (30.0) was counted from the combination with 4 seedlings at 45 DAT.

### 4.1.2.5 Interaction effect of variety and form of nitrogen fertilizer

The effect of variety and application of USG and PU were statistically significant at 15, 30, 45, 60, 75, even at 90 DAT (Table 2). But at all sampling dates in the case of both variety combination with either PU or USG gave statistically similar tillers hill$^{-1}$. Apparently, the maximum number of total tillers hill$^{-1}$ was obtained from Nizershail with USG application at all sampling dates. By the interaction of variety and form of nitrogen fertilizer maximum (26.83) tillers hill$^{-1}$ was counted at 45 DAT.

### 4.1.2.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on tillers hill$^{-1}$ of the crop was found non significant at 15, 30, 45 and 60 DAT but significant results were observed at 75 and 90 DAT (table 2). At the same time in all sampling dates, it was observed that total tillers hill$^{-1}$ with USG were higher than those of urea and number of tillers hill$^{-1}$ increased with increasing number of seedlings hill$^{-1}$. Maximum (26.5) tillers hill$^{-1}$ was observed from the combination of 4 seedlings with USG at 45 DAT.

**Table 2. Interaction effect of variety and seedling numbers $hill^{-1}$, variety and form of nitrogen fertilizer, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer, variety x seedling numbers $hill^{-1}$ x form of nitrogen fertilizer on total tiller production $hill^{-1}$ of T. *aman* rice at different days after transplanting**

| Treatment | Days after transplanting | | | | | |
|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 75 | 90 |
| **Variety and seedling numbers $hill^{-1}$** | | | | | | |
| $V_1S_1$ | 5.50 | 11.00 | 11.83 | 14.00 | 14.17 | 13.17 |
| $V_1S_2$ | 7.00 | 12.50 | 16.17 | 18.50 | 15.83 | 14.17 |
| $V_1S_3$ | 8.17 | 14.00 | 17.00 | 19.83 | 17.00 | 14.83 |
| $V_1S_4$ | 9.83 | 16.83 | 20.33 | 23.33 | 20.83 | 16.83 |
| $V_2S_1$ | 8.00 | 16.83 | 21.17 | 17.17 | 16.17 | 13.83 |
| $V_2S_2$ | 10.00 | 19.83 | 24.67 | 21.00 | 18.67 | 14.50 |
| $V_2S_3$ | 11.50 | 21.17 | 26.67 | 22.17 | 20.33 | 16.67 |
| $V_2S_4$ | 13.00 | 23.67 | 30.00 | 26.00 | 23.83 | 19.33 |
| LSD (5%) | ns | ns | ns | 2.97 | 2.28 | 1.49 |
| CV % | 23.62 | 20.16 | 17.68 | 12.31 | 10.44 | 8.10 |
| **Variety and form of nitrogen fertilizer** | | | | | | |
| $N_1V_1$ | 7.67 | 12.92 | 15.08 | 17.83 | 15.58 | 13.83 |
| $N_1V_2$ | 10.42 | 19.42 | 24.42 | 19.92 | 17.83 | 15.33 |
| $N_2V_1$ | 7.58 | 14.25 | 17.58 | 20.00 | 18.33 | 15.67 |
| $N_2V_2$ | 10.83 | 21.33 | 26.83 | 23.25 | 21.67 | 16.83 |
| LSD (5%) | 1.82 | 2.88 | 3.13 | 2.10 | 1.62 | 1.05 |
| CV % | 14.50 | 13.28 | 28.01 | 10.57 | 16.65 | 4.68 |
| **Seedling numbers $hill^{-1}$ and form of nitrogen fertilizer** | | | | | | |
| $N_1S_1$ | 6.50 | 13.33 | 15.67 | 14.33 | 14.00 | 13.17 |
| $N_1S_2$ | 8.33 | 14.50 | 19.00 | 17.67 | 15.17 | 13.33 |
| $N_1S_3$ | 9.83 | 16.50 | 20.50 | 20.00 | 17.17 | 14.83 |
| $N_1S_4$ | 11.50 | 20.33 | 23.83 | 23.50 | 20.50 | 17.00 |
| $N_2S_1$ | 7.00 | 14.50 | 17.33 | 16.83 | 16.33 | 13.83 |
| $N_2S_2$ | 8.67 | 17.83 | 21.83 | 21.83 | 19.33 | 15.33 |
| $N_2S_3$ | 9.83 | 18.67 | 23.17 | 22.00 | 20.17 | 16.67 |
| $N_2S_4$ | 11.33 | 20.17 | 26.50 | 25.83 | 24.17 | 19.17 |
| LSD (5%) | ns | ns | ns | ns | 2.28 | 1.49 |
| CV % | 23.62 | 20.16 | 17.68 | 12.31 | 10.44 | 8.10 |

**Table 2 (cont'd).**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Variety x Seedling numbers hill$^{-1}$ x Form of nitrogen fertilizer** | | | | | | |
| **$N_1V_1S_1$** | 5.33 | 10.67 | 11.33 | 13.33 | 13.33 | 12.67 |
| **$N_1V_1S_2$** | 7.00 | 10.67 | 14.00 | 16.00 | 14.33 | 13.00 |
| **$N_1V_1S_3$** | 8.33 | 13.00 | 16.00 | 19.00 | 15.67 | 13.67 |
| **$N_1V_1S_4$** | 10.00 | 17.33 | 19.00 | 23.00 | 19.00 | 16.00 |
| **$N_1V_2S_1$** | 7.67 | 16.00 | 20.00 | 15.33 | 14.67 | 13.67 |
| **$N_1V_2S_2$** | 9.67 | 18.33 | 24.00 | 19.33 | 16.00 | 13.67 |
| **$N_1V_2S_3$** | 11.33 | 20.00 | 25.00 | 21.00 | 18.67 | 16.00 |
| **$N_1V_2S_4$** | 13.00 | 23.33 | 28.67 | 24.00 | 22.00 | 18.00 |
| **$N_2V_1S_1$** | 5.67 | 11.33 | 12.33 | 14.67 | 15.00 | 13.67 |
| **$N_2V_1S_2$** | 7.00 | 14.33 | 18.33 | 21.00 | 17.33 | 15.33 |
| **$N_2V_1S_3$** | 8.00 | 15.00 | 18.00 | 20.67 | 18.33 | 16.00 |
| **$N_2V_1S_4$** | 9.67 | 16.33 | 21.67 | 23.67 | 22.67 | 17.67 |
| **$N_2V_2S_1$** | 8.33 | 17.67 | 22.33 | 19.00 | 17.67 | 14.00 |
| **$N_2V_2S_2$** | 10.33 | 21.33 | 25.33 | 22.67 | 21.33 | 15.33 |
| **$N_2V_2S_3$** | 11.67 | 22.33 | 28.33 | 23.33 | 22.00 | 17.33 |
| **$N_2V_2S_4$** | 13.00 | 24.00 | 31.33 | 28.00 | 25.67 | 20.67 |
| **LSD (0.05)** | ns | ns | ns | ns | 3.22 | 2.11 |
| **CV %** | 23.62 | 20.16 | 17.68 | 12.31 | 10.44 | 8.10 |

**Note: $N_1$= Prilled urea, $N_2$= Urea supergranules, $V_1$= BRRI Dhan 44, $V_2$= Nizershail, $S_1$= 1 seedling, $S_2$= 2seedlings, $S_3$= 3 seedlings, $S_4$= 4 seedlings**

#### 4.1.2.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Tiller production at 15, 30, 45 and 60 DAT was unaffected but at 75 and 90 DAT it was affected significantly due to the interaction of variety, seedling numbers hill$^{-1}$ and urea source (Table 2). At 15 DAT, it was observed that total tillers hill$^{-1}$ numerically maximum (13.0) comes from the combination of Nizershail x 4 seedlings x USG and minimum (5.33) was observed from the combination of BRRI Dhan 44 x 1 seedling x PU. Similar trend was also observed at 30, 45 and 60 DAT. At 75 DAT significantly maximum (25.67) tillers hill$^{-1}$ was observed from the combination of Nizershail x 4 seedlings x USG and minimum (13.33) was observed from the combination of BRRI Dhan 44 x 1 seedling x PU which was statistically similar with 2 and 3 seedlings of same variety and same form of nitrogen fertilizer. Similar trend was also observed at 90 DAT.

### 4. 1.3 Leaf Area Index (LAI)

#### 4.1.3.1 Effect of variety

Leaf area index (LAI) or the surface area of green leaves produced by rice plants unit area$^{-1}$ of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. LAI was significantly affected by variety at all the sampling dates (Figure 7 and Appendix VI). Figure 7 shows that irrespective of varieties, LAI increased sharply after transplanting attaining a peak at around 60 DAT. Initially the LAI of BRRI Dhan 44 was slightly higher than that of Nizershail and at 60 DAT, BRRI Dhan 44 showed much higher LAI of 6.83, which was about 50.44% higher than that of Nizershail. Nizershail intercepted the least amount of light at all growth stages. This was attributed to lower LAI (Ahmed *et al.*, 1996 and Turner *et al.*, 1986). The LAI as a normal phenomenon increased with the advancement of plant age and declined after attaining its maximum value with time. The decline was comparatively faster in the BRRI Dhan 44 than Nizershail. Finally at 90 DAT the LAI of BRRI Dhan 44 was slightly lower than Nizershail, it was due to early leaf senescence.

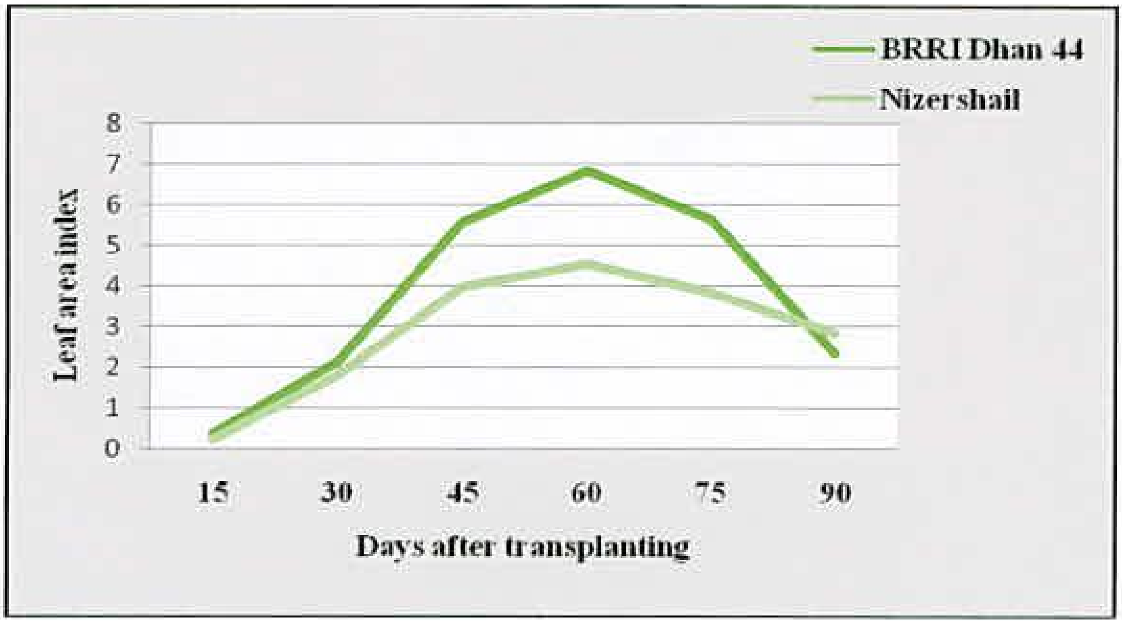


**Figure 7. Changes in leaf area index of T. *aman* rice due to the effect of variety at different days after transplanting**

### 4.1.3.2 Effect of seedling numbers hill$^{-1}$

Number of seedlings hill$^{-1}$ had remarkable influence on leaf area index (LAI). There were significant variations among different seedling hill$^{-1}$ treatments observed at 15, 30, 45, 60 and 75 DAT but insignificant at 90 DAT (Figure 8 and Appendix VI). At 15 DAT, maximum leaf area index (0.41) was obtained from 4 seedlings hill$^{-1}$ followed by 3 seedlings hill$^{-1}$ (0.37) that followed by 2 seedlings hill$^{-1}$ (0.27). Minimum leaf area index (0.18) was counted at single seedling hill$^{-1}$. The similar trend was also continued up to 75 DAT where single seedling showed significantly the lowest LAI. The maximum LAI (6.5) was recorded from 4 seedlings followed by 3 seedlings (6.04) then 2 seedlings (5.42) and after then 1 seedling (4.7) at 60 DAT. The findings are in agreement with Miah *et al.* (2004) and Obulamma *et al.* (2002) who stated the highest LAI at 4 and 3 seedlings hill$^{-1}$ respectively whereas, Shrirame *et al.* (2000) recorded no significant difference of LAI among 1, 2, and 3 seedlings hill$^{-1}$.

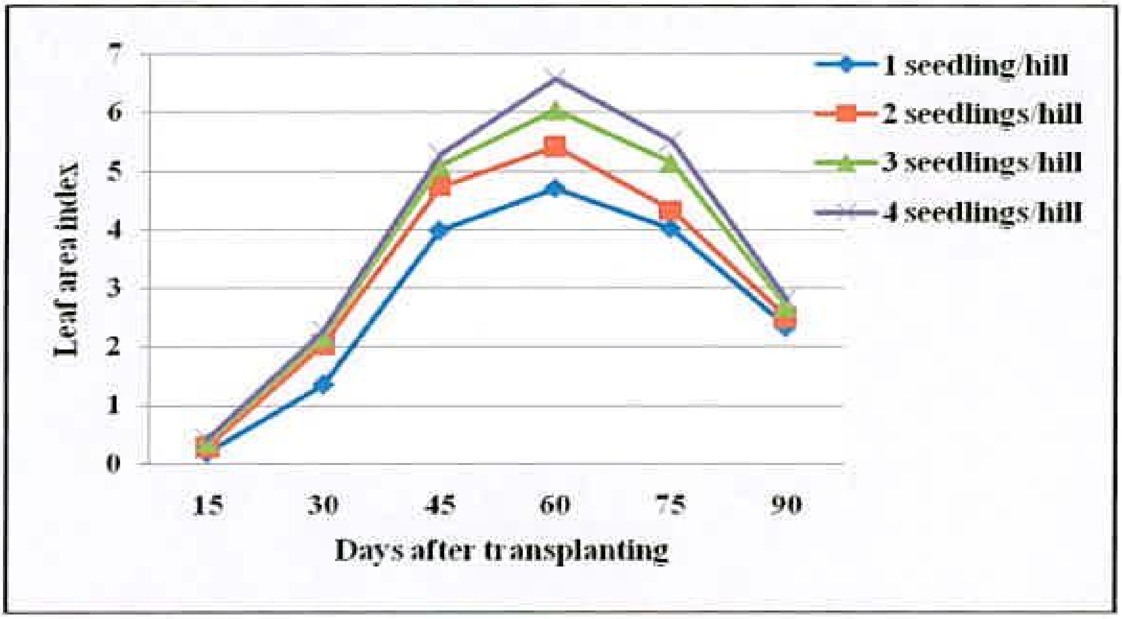


**Figure 8. Changes in leaf area index of T. *aman* rice due to the effect of seedling numbers hill$^{-1}$ at different days after transplanting**

#### 4.1.3.3 Effect of form of nitrogen fertilizer

There was no statistical difference in the values of LAI observed at 15 and 30 DAT due to forms of N fertilizer but LAI was significantly higher in USG receiving plants than urea in other sampling dates (Figure 9 and Appendix VI). Maximum (6.11) LAI was found at 60 DAT due to the effect of USG. However, after 60 DAT, LAI declined due to senescence of leaves with the progress to maturity in both the forms of N fertilizer but LAI of USG receiving plants remained always higher than urea at all stages of sampling. The higher LAI obviously caused by higher number of tillers as well as growth enhancement of leaves by a steady supply of N from USG. Ali (2005) and Miah *et al.* (2004) also reported that LAI was significantly higher in USG receiving plants than urea.

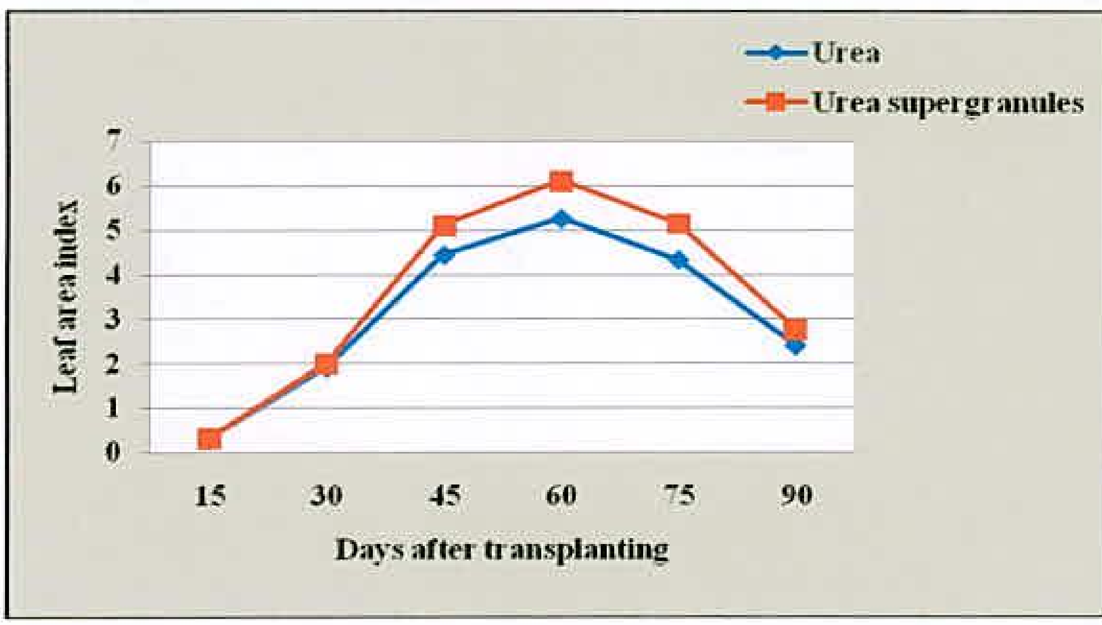


**Figure 9. Changes in leaf area index of T. *aman* rice due to the effect of form of nitrogen fertilizer at different days after transplanting**

#### 4.1.3.4 Interaction effect of variety and seedling numbers hill$^{-1}$

It was observed from Table 3 that except at 15 and 75 DAT LAI was not significantly affected by the interaction of variety and seedling numbers hill$^{-1}$ at rest sampling dates. AT 15 DAT maximum LAI (0.48) was observed from BRRI Dhan 44 combination with 4 seedlings hill$^{-1}$ and significantly minimum (0.12) from Nizershail combination with 1 seedling $hill^{-1}$. At 30 DAT numerically maximum (2.38) LAI was found from BRRI Dhan 44 combination with 4 seedlings $hill^{-1}$ and minimum (1.13) from Nizershail combination with 1 seedling $hill^{-1}$. The similar trend was also continued up to 60 DAT. At 75 DAT maximum (6.40) LAI observed from BRRI Dhan 44 combination with 4 seedlings $hill^{-1}$ which was statistically similar with same variety combination with 3 seedlings $hill^{-1}$ and minimum (3.12) from Nizershail combination with 1 seedling $hill^{-1}$ which was statistically similar with same variety combination with 2 seedlings $hill^{-1}$. At 90 DAT numerically maximum (3.05) LAI observed from Nizershail combination with 4 seedlings $hill^{-1}$ and minimum (2.08) from BRRI Dhan 44 combination with 1 seedling $hill^{-1}$.

#### 4.1.3.5 Interaction effect of variety and form of nitrogen fertilizer

There was no statistical difference in the value of LAI as was observed at 30 DAT but significant at other sampling date due to the interaction of variety and source of N (Table 3). From the Table 3 it is also observed that at 15 DAT, LAI differed due to varietal difference. At 45 DAT maximum (5.97) LAI was observed from BRRI Dhan 44 with USG and minimum (3.69) from Nizershail with PU. The similar trend also continued up to 90 DAT.

#### 4.1.3.6 Interaction effect of seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

From the Table 3 it is observed that LAI was affected due to interaction of seedling numbers $hill^{-1}$ and urea forms at 75 DAT but it was remained unaffected at rest other sampling dates. Maximum LAI was observed at 60 DAT, where numerically the highest (7.15) was observed from USG with 4 seedlings $hill^{-1}$ and the lowest (4.43) from PU with 1 seedling $hill^{-1}$. Significantly maximum (6.02) LAI was observed from USG with 4 seedlings $hill^{-1}$ at 75 DAT.

**Table 3. Interaction effect of variety and seedling numbers hill$^{-1}$, variety and form of nitrogen fertilizer, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on leaf area index of T. *aman* rice at different days after transplanting**

| Treatment | Days after transplanting | | | | | |
|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 75 | 90 |
| **Variety and seedling numbers hill$^{-1}$** | | | | | | |
| $V_1S_1$ | 0.24 | 1.57 | 4.72 | 5.82 | 4.90 | 2.08 |
| $V_1S_2$ | 0.34 | 2.18 | 5.58 | 6.63 | 5.25 | 2.22 |
| $V_1S_3$ | 0.44 | 2.33 | 5.90 | 7.22 | 5.97 | 2.42 |
| $V_1S_4$ | 0.48 | 2.38 | 6.12 | 7.65 | 6.40 | 2.57 |
| $V_2S_1$ | 0.12 | 1.13 | 3.25 | 3.58 | 3.12 | 2.58 |
| $V_2S_2$ | 0.21 | 1.88 | 3.88 | 4.20 | 3.38 | 2.77 |
| $V_2S_3$ | 0.29 | 2.0 | 4.27 | 4.87 | 4.28 | 2.95 |
| $V_2S_4$ | 0.35 | 2.15 | 4.45 | 5.5 | 4.62 | 3.05 |
| LSD (5%) | 0.08 | ns | ns | ns | 0.55 | ns |
| CV% | 23.03 | 21.76 | 16.39 | 12.57 | 9.90 | 9.49 |
| **Variety and form of nitrogen fertilizer** | | | | | | |
| $N_1V_1$ | 0.37 | 2.05 | 5.19 | 6.39 | 5.18 | 2.10 |
| $N_1V_2$ | 0.24 | 1.77 | 3.69 | 4.13 | 3.48 | 2.70 |
| $N_2V_1$ | 0.37 | 2.18 | 5.97 | 7.27 | 6.08 | 2.54 |
| $N_2V_2$ | 0.24 | 1.82 | 4.23 | 4.95 | 4.23 | 2.98 |
| LSD (5%) | 0.06 | ns | 0.66 | 0.60 | 0.39 | 0.21 |
| CV% | 32.61 | 13.57 | 21.28 | 19.13 | 15.50 | 2.12 |
| **Seedling numbers hill$^{-1}$ and form of nitrogen fertilizer** | | | | | | |
| $N_1S_1$ | 0.18 | 1.32 | 3.55 | 4.43 | 3.57 | 2.13 |
| $N_1S_2$ | 0.29 | 1.98 | 4.37 | 5.02 | 3.88 | 2.33 |
| $N_1S_3$ | 0.35 | 2.13 | 4.93 | 5.58 | 4.85 | 2.52 |
| $N_1S_4$ | 0.41 | 2.20 | 4.92 | 6.00 | 5.00 | 2.62 |
| $N_2S_1$ | 0.18 | 1.38 | 4.42 | 4.97 | 4.45 | 2.53 |
| $N_2S_2$ | 0.26 | 2.08 | 5.10 | 5.82 | 4.75 | 2.65 |
| $N_2S_3$ | 0.38 | 2.20 | 5.23 | 6.50 | 5.40 | 2.85 |
| $N_2S_4$ | 0.41 | 2.33 | 5.65 | 7.15 | 6.02 | 3.00 |
| LSD (5%) | ns | ns | ns | ns | 0.55 | ns |
| CV% | 23.03 | 21.76 | 16.39 | 12.57 | 9.90 | 9.49 |

Note: $N_1$= Prilled urea, $N_2$= Urea supergranules, $V_1$= BRRI Dhan 44, $V_2$= Nizershail, $S_1$= 1 seedling, $S_2$= 2seedlings, $S_3$= 3 seedlings, $S_4$= 4 seedlings

#### 4.1.3.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Non significant response was observed at all sampling date due to the interaction of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer (Appendix VI). From 15 to 75 DAT numerically maximum LAI was observed from BRRI Dhan 44 x 4 seedlings x USG and minimum from Nizershail x 1 seedling x PU. But at 90 DAT numerically maximum LAI was observed from Nizershail x 4 seedlings x USG and minimum from BRRI Dhan 44 x 1 seedling x PU. Irrespective of treatments maximum leaf area index was observed at 60 DAT and numerically maximum (8.20) LAI was observed from combination of BRRI Dhan 44 x 4 seedlings x USG and minimum (3.37) from x 1 seedling x PU (data were not shown). After 60 DAT, all treatments showed decreasing trend which was due to leaf senescence and decreasing rate of leaf growth and tiller production.

### 4.1.4 Total dry matter production

#### 4.1.4.1 Effect of variety

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. TDM of roots, leaves, leaf sheath + stem and or panicles of used varieties data were measured at 30, 60 and at harvest. It was evident from Figure 10 and Appendix VII that irrespective of treatments TDM of BRRI Dhan 44 and Nizershail significantly varied at all sampling dates. Figure 10 shows that at 30 DAT Nizershail had significant higher amount of dry matter of 6.38 g hill$^{-1}$ (35.46% higher than BRRI Dhan 44) and at 60 DAT also Nizershail had significant higher amount of dry matter of 32.31 g hill$^{-1}$ (18.01% higher than BRRI Dhan 44) but at harvest BRRI Dhan 44 had significantly higher amount of dry matter of 39.85 g hill$^{-1}$ (18.42% higher than Nizershail). Lower amount of dry matter production at harvest in Nizershail might be due to lodging in heading stage. This confirms the reports of Amin *et al.* (2006) and Son *et al.* (1998) that total dry matter production differed due to varietal variation.

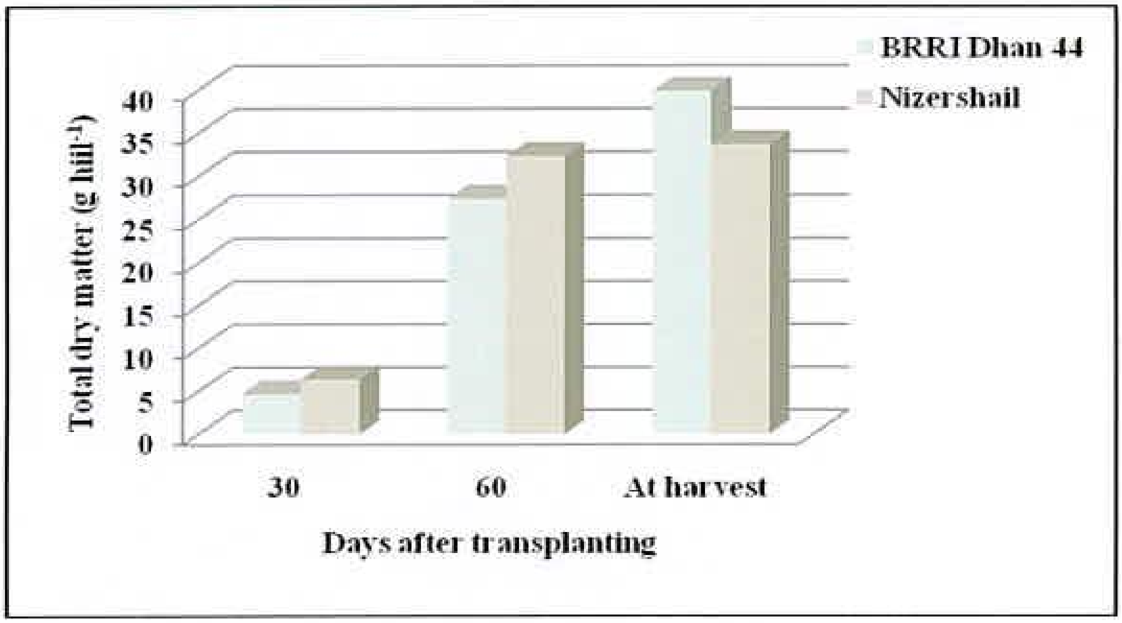


**Figure 10. Effect of variety on total dry matter production (g hill$^{-1}$) of T. *aman* rice at different days after transplanting**

#### 4.1.4.2 Effect of seedling numbers hill$^{-1}$

Dry matter production was significantly influenced by different seedling number hill$^{-1}$ at 30, 60 DAT and even at harvest (Figure 11 and Appendix VII). From Figure 11 it was observed that total dry matter produced at different dates showed the trend of 1 seedling<2 seedlings<3 seedlings<4 seedlings hill$^{-1}$. The maximum TDM was 42.59 g hill$^{-1}$ recorded at maturity with 4 seedlings hill$^{-1}$. This higher TDM with 4 seedlings hill$^{-1}$ might be the outcome of higher number of total tillers produced by this treatment. The result was conformity with Miah *et al.* (2004), Obulamma *et al.* (2002) who observed significant increased in dry matter production with the increased seedlings number hill$^{-1}$.

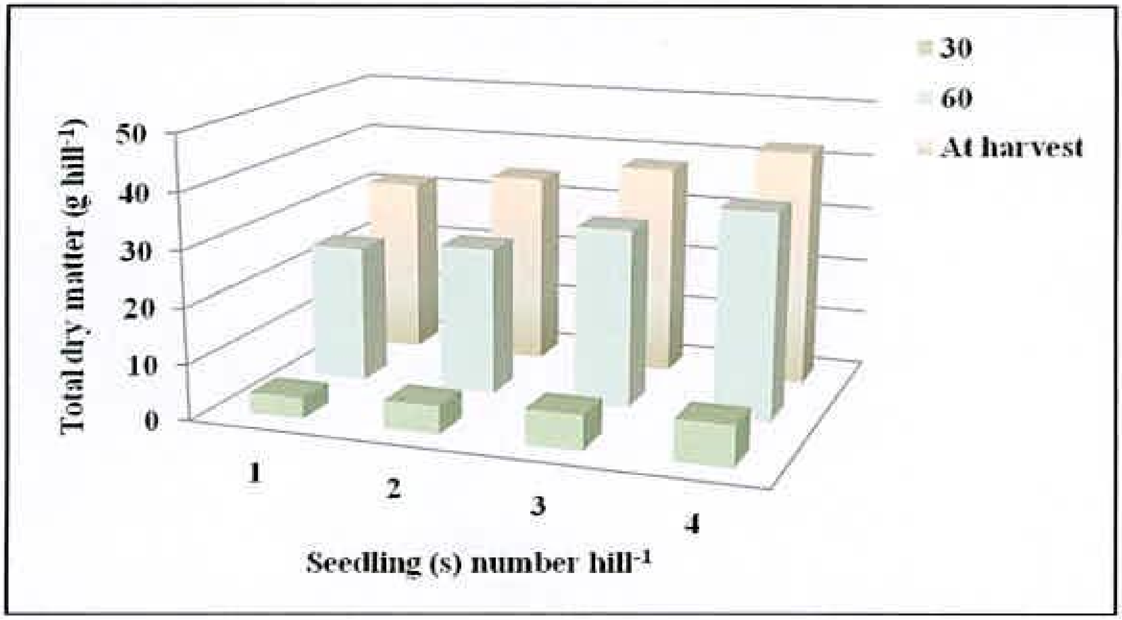


**Figure 11. Effect of seedling numbers hill$^{-1}$ on total dry matter production (g hill$^{-1}$) of T. *aman* rice at different days after transplanting**

#### 4.1.4.3 Effect of form of nitrogen fertilizer

The TDM production was unaffected at 30 DAT but affected significantly at 60 DAT and at harvest by the forms of N fertilizer (Figure 12 and Appendix VII). It could be observed from the Figure 12 that at each sampling, USG applied plants gave higher TDM compared to urea irrespective of variety and numbers of seedling transplanted hill$^{-1}$. Maximum (38.55 g hill$^{-1}$) TDM found from the USG application at harvest. At the same time it could also be noticed that the difference between treatments for TDM was narrower at early growth stages but became larger in later stages. This might be due to the fact that USG receiving plants got continuous supply of N and plants could better utilize it and growth parameters were positively responded to it. Rambabu *et al.* (1983) and Rao *et al.* (1986) from their study concluded that USG was the most effective in increasing TDM than split application of urea.

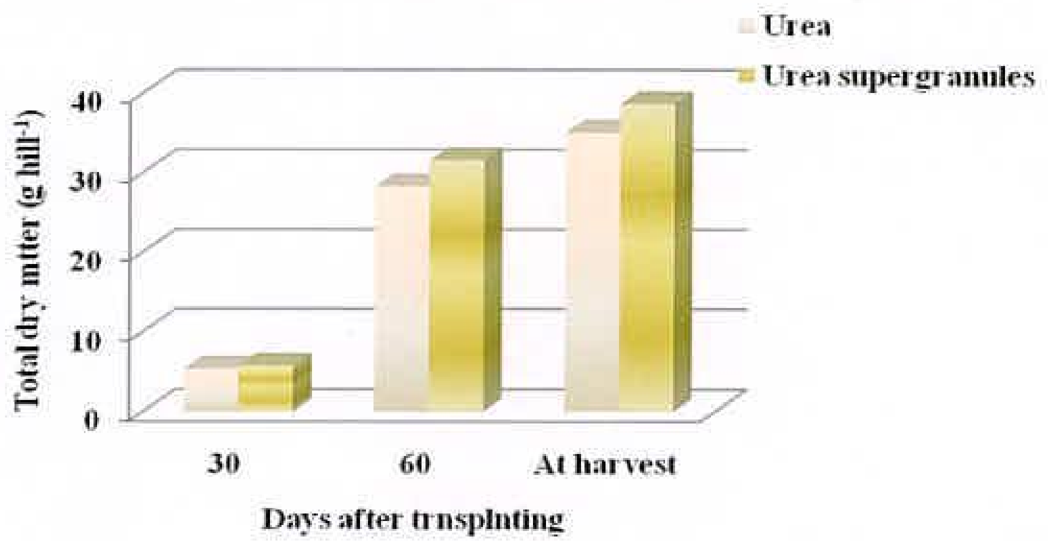


**Figure 12. Effect of form of nitrogen fertilizer on total dry matter production (g hill$^{-1}$) of T. *aman* rice at different days after transplanting**

#### 4.1.4.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Total dry matter production was significantly affected due to the interaction of variety and seedling hill$^{-1}$ at 30 DAT but unaffected at 60 DAT and at harvest (Table 4). At 30 DAT maximum (8.21 g hill$^{-1}$) TDM was found from the combination of Nizershail with 4 seedlings which was statistically similar with other combinations except the combination BRRI Dhan 44 with 1 seedling which was significantly minimum (2.34 g hill$^{-1}$). At 60 DAT numerically maximum (40.12 g hill$^{-1}$) TDM was found from the combination of Nizershail with 4 seedlings and minimum (22.25 g hill$^{-1}$) was found from BRRI Dhan 44 with 1 seedling. At harvest numerically maximum (46.58 g hill$^{-1}$) TDM was found from the combination of BRRI Dhan 44 with 4 seedlings and minimum (30.07 g hill$^{-1}$) was found from Nizershail with 1 seedling.

#### 4.1.4.5 Interaction effect of variety and form of nitrogen fertilizer

The table 4 revealed that interaction of variety and urea source on TDM production significantly affected only at 30 DAT. At 30 DAT significantly maximum (6.55 g hill$^{-1}$) TDM found from the combination of Nizershail with USG and minimum (4.49 g hill$^{-1}$) from the combination of BRRI Dhan 44 with PU and it was also observed that either USG or PU combination with same variety was statistically similar. At harvest numerically maximum (41.68 g hill$^{-1}$) TDM was found from BRRI Dhan 44 with USG and minimum (31.90 g hill$^{-1}$) was observed from Nizershail with PU.

#### 4.1.4.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

It was observed from the Appendix VII that interaction effect of seedling numbers hill$^{-1}$ and urea forms showed insignificant in TDM production at all sampling dates. At 30 DAT maximum (7.55 g hill$^{-1}$) TDM was found from the combination of 4 seedlings with USG and minimum (3.42 g hill$^{-1}$) from the 1 seedling with PU. Similar trend for TDM production due to the interaction also observed at 60 DAT and at harvest (data were not shown).

**Table 4. Total dry matter production (g $hill^{-1}$) of T. *aman* rice as influenced by the interaction of variety and seedling numbers $hill^{-1}$, variety and form of nitrogen fertilizer at different days after transplanting**

| Treatment | Days after transplanting | | |
|---|---|---|---|
| | 30 | 60 | At harvest |
| **Variety and seedling numbers $hill^{-1}$** | | | |
| $V_1S_1$ | 2.34 | 22.25 | 33.60 |
| $V_1S_2$ | 4.53 | 25.03 | 37.60 |
| $V_1S_3$ | 5.60 | 28.80 | 41.63 |
| $V_1S_4$ | 6.38 | 23.45 | 46.58 |
| $V_2S_1$ | 5.10 | 26.47 | 30.07 |
| $V_2S_2$ | 5.44 | 27.87 | 31.62 |
| $V_2S_3$ | 6.78 | 34.75 | 34.33 |
| $V_2S_4$ | 8.21 | 40.12 | 38.60 |
| LSD (5%) | 1.78 | ns | ns |
| CV % | 26.97 | 18.39 | 14.4 |
| **Variety and form of nitrogen fertilizer** | | | |
| $N_1V_1$ | 4.49 | 25.97 | 38.03 |
| $N_1V_2$ | 6.21 | 30.44 | 31.90 |
| $N_2V_1$ | 4.93 | 28.80 | 41.68 |
| $N_2V_2$ | 6.55 | 34.18 | 35.41 |
| LSD (5%) | 1.26 | ns | ns |
| CV % | 29.83 | 9.79 | 6.18 |

Note: $N_1$= Prilled urea, $N_2$= Urea supergranules, $V_1$= BRRI Dhan 44, $V_2$= Nizershail, $S_1$= 1 seedling, $S_2$= 2seedlings, $S_3$= 3 seedlings, $S_4$= 4 seedlings

### 4.1.4.7 Interaction effect of variety, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

From the Appendix VII it was observed that the interaction of variety, seedling $hill^{-1}$ and form of N fertilizer on TDM production had non significant effect at 30, 60 DAT and even at harvest. At 30 DAT numerically maximum (8.41 g $hill^{-1}$) TDM found from the combination of Nizershail x 4 seedlings x USG and minimum (2.04 g $hill^{-1}$) from the combination of BRRI Dhan 44 x 1 seedling x PU. Similar trend was also observed at 60 DAT. But at harvest numerically maximum (48.37 g $hill^{-1}$) TDM was found from the combination of BRRI Dhan 44 x 4 seedlings x USG and minimum (28.00 g $hill^{-1}$) from the combination of Nizershail x 1 seedling x PU (data were not shown).

## 4.2 Yield contributing characters

### 4.2.5 Effective tiller $hill^{-1}$

### 4.2.5.1 Effect of variety

Total tillers determine the amount of dry matter production unit $area^{-1}$ while productive tillers unit $area^{-1}$ determined the final yield of rice. This is why it is said that higher the effective tillers, higher the yield. It was observed from Table 5 that variety had significant effect on numbers of effective tiller. BRRI Dhan 44 produced higher number (11.30) and Nizershail produced lower number (7.50) of productive tiller. This confirms the report of Sawant *et al.* (1986), who reported that variable effect of variety on the number of effective tillers $hill^{-1}$. Although Nizershail produced higher number of tiller but a high tiller number also increased tiller abortion rate as was observed in this study. The same result was reported by Peng *et al.* (1996) and

Schnier *et al.* (1990). They found a negative correlation between maximum tiller number and percentage of productive tillers.

#### 4.2.5.2 Effect of seedling numbers hill$^{-1}$

Number of effective tillers hill$^{-1}$ was not significantly influenced by seedlings number hill$^{-1}$ (Table 5). The highest numbers of effective tiller hill$^{-1}$ (10.06) was counted at 4 seedlings hill$^{-1}$ that was followed by other treatments. The findings are in agreement with those of stated by BRRI (1999), Shah *et al.* (1991), Singh *et al.* (1987), BINA (1987), Islam (1980), Shahi and Gill (1976) who reported that effective tillers were significantly unaffected by the variation of seedling numbers hill$^{-1}$. But Ashraf *et al.* (1999) stated that transplanting of 2 and 3 seedlings hill$^{-1}$ gave more promising results in terms of more productive tillers unit area$^{-1}$. While Zhong *et al.* (2001) found that the productive tiller percentage was significantly and negatively correlated with maximum tiller number unit$^{-1}$ area.

#### 4.2.5.3 Effect of form of nitrogen fertilizer

Nitrogen in the form of USG produced significantly higher (9.94) productive tillers hill$^{-1}$ compared to urea split application (Table 5). It is in agreement with Rama *et al.* (1989), who reported that USG produced higher numbers of panicle m$^{-2}$ than splits application of urea. Adequacy of nitrogen and uniform supply through USG probably favoured the cellular activities during panicle formation and development which added to increase number of effective tillers hill$^{-1}$. Thakur (1991b) and Gosh *et al.* (1991) also agreed to this view.

#### 4.2.5.4 Interaction effect of variety and seedling numbers $hill^{-1}$

Interaction effect of variety and seedling numbers $hill^{-1}$ significantly affected the effective tiller $hill^{-1}$ (Table 5). The highest (11.92) productive tiller was found in BRRI Dhan 44 combination with 4 seedlings which was statistically similar with the combinations of rest other seedlings number $hill^{-1}$ of same variety and the lowest (6.62) was observed in Nizershail combination with 1 seedling which was also statistically similar with the combinations of rest other seedlings number $hill^{-1}$ of the same variety.

#### 4.2.5.5 Interaction effect of variety and form of nitrogen fertilizer

The effect of interaction between variety and source of N was found to be significant in respect of number of productive tillers $hill^{-1}$. Combination of BRRI Dhan 44 with USG produced highest (11.85) number of productive tillers $hill^{-1}$ which was statistically similar to same variety with PU (Table 5). It was also observed that in case of both varieties USG receiving plants produced higher productive tillers $hill^{-1}$ than split urea receiving plants.

#### 4.2.5.6 Interaction effect of seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

There was no significant effect of interaction of seedling numbers $hill^{-1}$ and form of N fertilizer on numbers of effective tiller $hill^{-1}$ (Table 5). Numerically highest (10.42) numbers of effective tiller $hill^{-1}$ was found from the treatment combination of 4 seedlings $hill^{-1}$ with USG.

#### 4.2.5.7 Interaction effect of variety, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

From Table 5 it was observed that there was no remarkable effect on effective tiller $hill^{-1}$ with the combination of variety, seedling numbers $hill^{-1}$ and form of N fertilizer.

Numerically the highest (12.43) effective tillers hill$^{-1}$ was found from the combination of BRRI Dhan 44 x 4 seedlings x USG and the lowest (5.63) was observed from the combination of Nizershail x 1 seedling x PU (Table 5).

#### 4.2.6 Panicle length

#### 4.2.6.1 Effect of variety

The panicle length varied significantly due to variety shown in Table 5. It was observed that BRRI Dhan 44 produced longer (28.65 cm) panicle than Nizershail (24.52 cm). This confirms the report of Ahmed *et al.* (1997) and Idris and Matin (1990) that panicle length was differed due to variety.

#### 4.2.6.2 Effect of seedling numbers hill$^{-1}$

The longest (26.94 cm) and the shortest (26.18 cm) panicle length was observed in 1 and 4 seedlings hill$^{-1}$, respectively though the value did not differ significantly (Table 5). The results are in conformity with Hushine (2004), BRRI (1999), Zhang and Huang (1990) who stated that panicle length was unaffected by the number of seedlings hill$^{-1}$.

#### 4.2.6.3 Effect of form of nitrogen fertilizer

Panicle length was statistically unaffected by forms of urea (Table 5). Longer (26.69 cm) panicle was produced due to application of USG which was statistically similar (26.48 cm) due to application of PU. A similar finding was reported by Hasan *et al.* (2002). Sen and Pandey (1990) also found similar panicle length by applying 38.32 kg N ha$^{-1}$ either in the form of USG or prilled urea.

#### 4.2.6.4 Interaction effect of variety and seedling numbers $hill^{-1}$

Panicle length was significantly affected by the interaction of variety and seedling numbers $hill^{-1}$ (Table 5). Longer (29.0 cm) panicle length was observed from the combination BRRI Dhan 44 and 1 seedling $hill^{-1}$ which was statistically similar with same variety with rest other seedling numbers $hill^{-1}$ and lowest (24.13 cm) was found from the combination Nizershail with 4 seedlings which was also statistically similar with same variety with rest other seedling numbers $hill^{-1}$.

#### 4.2.6.5 Interaction effect of variety and form of nitrogen fertilizer

Panicle length was statistically influenced by the interaction of variety and forms of urea (Table 5). But statistically similar panicle length observed from the combination of same variety with either USG or PU but USG receiving plants produced always higher length of panicle. It was ranged from 24.48 cm to 28.83 cm.

#### 4.2.6.6 Interaction effect of seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

Interaction of number of seedling $hill^{-1}$ and the forms of N fertilizer exerted statistically non significant influence on panicle length (Table 5). However, in the present experiment numerically the longest panicle (27.03 cm) was obtained in the treatment combination of 1 seedling $hill^{-1}$ with USG and the shortest in 4 seedlings $hill^{-1}$ with PU (26.07 cm).

#### 4.2.6.7 Interaction effect of variety, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

From the Table 5 it was observed that interaction effect of variety, seedling numbers $hill^{-1}$ and urea source had significant effect on panicle length. The highest (29.13 cm) panicle length was observed from the combination of BRRI Dhan 44 x 1 seedling x USG which was statistically similar with different combination of the same variety and the lowest (24.1 cm) from Nizershail x 4 seedlings x PU which was also statistically similar with different combination of the same variety. It might be due to inherent characters of the variety that might not be much changed by cultural treatment although there were numerical variations.

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

#### 4.2.7.1 Effect of variety

Table 5 shows that cultivars affected significantly in number of filled grains panicle$^{-1}$ i.e.; grains panicle$^{-1}$. From the Table 5 it was revealed that BRRI Dhan 44 gave significantly higher number (119.29) grains panicle$^{-1}$ than Nizershail (86.35). BRRI (1994) found that number of filled grains panicle$^{-1}$ significantly differed due to variety.

#### 4.2.7.2 Effect of seedling numbers hill$^{-1}$

Number of filled grains panicle$^{-1}$ was not significantly influenced by the number of seedlings hill$^{-1}$ (Table 5). The highest (109.43) and lowest (95.77) of filled grains panicle$^{-1}$ were obtained with 1 and 4 seedlings hill$^{-1}$, respectively. The result is in agreement with Shah *et al.* (1991) and Singh *et al.* (1987) who stated that filled grains panicle$^{-1}$ was unaffected by the number of seedlings hill$^{-1}$ and number of filled grains panicle$^{-1}$ increased with the decrease in seedling number hill$^{-1}$.

#### 4.2.7.3 Effect of form of nitrogen fertilizer

From the table 5 it was observed that there was a statistical variation in number of filled grains panicle$^{-1}$ due to form of N fertilizer. Results showed that higher number of filled grains panicle$^{-1}$ was obtained with USG (105.91) than urea (99.73). Rama *et al.* (1989) found significantly higher filled grains panicle$^{-1}$ with 40, 80 or 120 kg N ha$^{-1}$ applied as USG over split application of urea. The present results supported those results.

### 4.2.7.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Results presented in Table 5 shows that interaction effect of variety and seedling numbers hill$^{-1}$ was significant on filled grains paicle$^{-1}$. The highest (127.17) filled grains panicle$^{-1}$ was found from the combination of BRRI Dhan 44 with 1 seedling which was statistically similar with the other seedlings combinations of same variety and the lowest (80.43) was found from Nizershail with 4 seedlings which was also statistically similar with the other seedlings combinations of same variety.

### 4.2.7.5 Interaction effect of variety and form of nitrogen fertilizer

Interaction effect of variety and form of N fertilizer was found significant on filled grains panicle$^{-1}$ (Table 5). From the results of Table 5 it was observed that the highest (121.47) filled grains panicle$^{-1}$ was found from the combination of BRRI Dhan 44 with USG which was statistically similar with the combination of BRRI Dhan 44 with PU and the lowest (82.35) in Nizershail with PU which was statistically similar with the combination of Nizershail with USG. It indicated that BRRI Dhan 44 was the best performer with USG in terms of filled grains panicle$^{-1}$.

### 4.2.7.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Interaction effect of seedling numbers hill$^{-1}$ and urea form showed a non significant response on filled grains panicle$^{-1}$ (Table 5). However, irrespective of variety, combination of 1 seedling with USG numerically produced the highest (112.63) filled grains panicle$^{-1}$. The lowest (92.20) filled grains panicle$^{-1}$ was found from the combination of 4 seedlings with PU.

### 4.2.7.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Many factors affect the grains panicle$^{-1}$ such as genotype, cultural practices used (planting date, seeding rate and soil fertility) and growing conditions (air and soil temperature, etc.). Results presented in Table 5 shows that interaction of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer was non significant on filled grains panicle$^{-1}$. The highest (130.2) filled grains panicle$^{-1}$ was found from the combination of BRRI Dhan 44 x 1 seedling x USG and the lowest (75.0) filled grains panicle$^{-1}$ was found from the combination of Nizershail x 4 seedlings x PU.

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

### 4.2.8.1 Effect of variety

Among the traits made, number of unfilled grains panicle$^{-1}$ plays a vital role in yield reduction. Results showed that variety had significant effect in respect of the number of unfilled grains panicle$^{-1}$ (Table 5). Nizershail produced minimum number (11.22) of unfilled grains panicle$^{-1}$ and BRRI Dhan 44 produced maximum number (16.97) of unfilled grains panicle$^{-1}$ and this variation might be due to genetic characteristics. BINA (1993) and Chowdury *et al*. (1993) also reported differences in number of unfilled grains panicle$^{-1}$ due to varietal differences.

### 4.2.8.2 Effect of seedling numbers hill$^{-1}$

Number of unfilled grains panicle$^{-1}$ was not statistically influenced by the number of seedlings hill$^{-1}$ (Table 5). The minimum number (11.71) of unfilled grains panicle$^{-1}$ was counted at single seedling hill$^{-1}$ and the maximum number (16.58) was found at 4 seedlings hill$^{-1}$. Hushine (2004) also observed that sterile spikelets panicle$^{-1}$ was unaffected by seedlings number hill$^{-1}$.

#### 4.2.8.3 Effect of form of nitrogen fertilizer

Number of unfilled grains panicle$^{-1}$ was not statistically influenced from the N source (Table 5). However, numerical variation was noticed. Numerically minimum (13.50) unfilled grains panicle$^{-1}$ was obtained from the application of USG. Hasan *et al.* (2002) also observed that unfilled grains panicle$^{-1}$ was unaffected by the application of USG and PU.

#### 4.2.8.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Interaction of variety and seedling numbers hill$^{-1}$ had no significant effect on unfilled grains panicle$^{-1}$ (Table 5). Numerically minimum (8.60) unfilled grains panicle$^{-1}$ was obtained from Nizershail with 1 seedling and maximum (19.17) unfilled grains panicle$^{-1}$ was obtained from BRRI Dhan 44 with 4 seedlings.

#### 4.2.8.5 Interaction effect of variety and form of nitrogen fertilizer

Interaction of variety and urea source showed significant response on unfilled grains panicle$^{-1}$ (Table 5). From the table it was observed that minimum (10.57) unfilled grains panicle$^{-1}$ was observed from Nizershail with USG which was statistically similar to same variety with PU and maximum (17.52) unfilled grains panicle$^{-1}$ from BRRI Dhan 44 with PU which was statistically similar to same variety with USG.

#### 4.2.8.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Interaction of seedling numbers hill$^{-1}$ and form of N fertilizer showed a non significant response on unfilled grains panicle$^{-1}$ (Table 5). Numerically minimum (11.00) unfilled grains panicle$^{-1}$ was found from the combination of 1 seedling with USG and maximum (17.07) unfilled grains panicle$^{-1}$ was found from the combination of 4 seedlings with PU.

#### 4.2.8.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on unfilled grains panicle$^{-1}$ showed non significant response, in all respect of combination and it was ranged from 8.0 to 19.53 unfilled grains panicle$^{-1}$ (Table 5). Minimum (8.00) from Nizershail x 1 seedling x USG combination and maximum (19.53) unfilled grains panicle$^{-1}$ was found from BRRI Dhan 44 x 4 seedlings x PU combination.

### 4.2.9 Filled Grain %

#### 4.2.9.1 Effect of variety

Although the varietal effect on filled grain percentage was found insignificant but numerically the higher (88.31%) filled grain percentage was obtained in Nizershail and the lower (87.42%) filled grain percentage was obtained in BRRI Dhan 44 (Table 5). Ahmed *et al.* (1997) reported that Nizershail produced the highest filled grain percentage among the variety studied.

#### 4.2.9.2 Effect of seedling numbers hill$^{-1}$

Percentage of filled grain did not show statistically significant variation due to seedlings transplanted hill$^{-1}$ (Table 5). But numerically filled grain percentage was the highest at 1 seedling hill$^{-1}$ (90.48%) and the lowest percentage of filled gains (85.14%) was observed at 4 seedlings hill$^{-1}$. This confirms the report of Miah *et al.* (2004), who reported that percentage of filled grain did not show statistically significant variation due to seedlings transplanted hill$^{-1}$.

#### 4.2.9.3 Effect of form of nitrogen fertilizer

The filled grain percentage was not significantly affected by the source of N (Table 5). However, application with USG treated plants produced higher (88.75%) filled grain percentage than PU (87.04%). Miah *et al.* (2004) also reported that percentage of filled grain did not show statistically significant variation by the forms of N fertilizer.

#### 4.2.9.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Interaction of variety and seedling numbers hill$^{-1}$ was affected insignificantly in terms of filled grain percentage (Table 5). Numerically the highest (91.40%) filled grain percentage was obtained from the interaction effect of Nizershail with 1 seedling and the lowest (85.03%) was obtained from the interaction effect of BRRI Dhan 44 with 4 seedlings.

#### 4.2.9.5 Interaction effect of variety and form of nitrogen fertilizer

Insignificant effect was observed in filled grain percentage from the interaction of variety and source of N (Table 5). The numeric maximum (89.48%) filled grain percentage was obtained by the interaction of Nizershail with USG and the minimum (86.92%) filled grain percentage was found in BRRI Dhan 44 with PU.

#### 4.2.9.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Percentage of filled grains panicle$^{-1}$ did not show statistically significant variation due to seedlings transplanted hill$^{-1}$ with forms of N fertilizer (Table 5). However, it ranged from maximum 91.31% in 1 seedlings hill$^{-1}$ with USG to minimum 84.20% in 4 seedlings hill$^{-1}$ with PU.

Table 5. Effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer and their interaction effect on yield contributing characters of T. *aman* rice

| Treatment | Effective tillers hill$^{-1}$ (No.) | Panicle length (cm) | Filled grains panicle$^{-1}$ (No.) | Unfilled grains panicle$^{-1}$ (No.) | Total grains panicle$^{-1}$ (No.) | Filled grains panicle$^{-1}$ (%) | 1000-grain weight (g) |
|---|---|---|---|---|---|---|---|
| **Variety** | | | | | | | |
| $V_1$ | 11.30 | 28.65 | 119.29 | 16.97 | 136.27 | 87.47 | 29.34 |
| $V_2$ | 7.50 | 24.51 | 86.35 | 11.22 | 97.57 | 88.31 | 19.30 |
| LSD (5%) | 1.00 | 0.58 | 5.67 | 1.57 | 5.64 | ns | 0.79 |
| CV (%) | 11.91 | 2.71 | 2.45 | 15.54 | 2.31 | 2.22 | 7.15 |
| **Seedling numbers hill$^{-1}$** | | | | | | | |
| $S_1$ | 8.66 | 26.94 | 109.43 | 11.71 | 121.13 | 90.48 | 25.63 |
| $S_2$ | 9.23 | 26.78 | 105.74 | 13.22 | 118.97 | 88.90 | 25.11 |
| $S_3$ | 9.68 | 26.43 | 100.35 | 14.88 | 115.23 | 87.05 | 23.46 |
| $S_4$ | 10.06 | 26.18 | 95.77 | 16.58 | 112.35 | 85.14 | 23.08 |
| LSD (5%) | ns | ns | ns | ns | ns | ns | 1.12 |
| CV (%) | 17.75 | 3.67 | 9.26 | 18.69 | 8.09 | 2.82 | 5.47 |
| **Form of nitrogen fertilizer** | | | | | | | |
| $N_1$ | 8.87 | 26.48 | 99.73 | 14.70 | 114.43 | 87.04 | 24.01 |
| $N_2$ | 9.94 | 26.69 | 105.91 | 13.50 | 119.40 | 88.75 | 24.63 |
| LSD (5%) | 1.00 | ns | 5.67 | ns | ns | ns | ns |
| CV (%) | 23.88 | 4.81 | 13.12 | 14.81 | 11.77 | 2.0 | 4.17 |
| **Interaction of variety and seedling numbers hill$^{-1}$** | | | | | | | |
| $V_1S_1$ | 10.70 | 29.00 | 127.17 | 14.82 | 141.98 | 89.56 | 30.59 |
| $V_1S_2$ | 11.10 | 28.92 | 121.83 | 15.97 | 137.80 | 88.36 | 29.92 |
| $V_1S_3$ | 11.50 | 28.47 | 117.07 | 17.95 | 135.02 | 86.73 | 28.66 |
| $V_1S_4$ | 11.92 | 28.23 | 111.10 | 19.17 | 130.27 | 85.25 | 28.19 |
| $V_2S_1$ | 6.62 | 24.88 | 91.68 | 8.60 | 100.28 | 91.40 | 20.67 |
| $V_2S_2$ | 7.35 | 24.63 | 89.65 | 10.48 | 100.13 | 89.43 | 20.30 |
| $V_2S_3$ | 7.85 | 24.40 | 83.63 | 11.80 | 95.43 | 87.38 | 18.26 |
| $V_2S_4$ | 8.20 | 24.13 | 80.43 | 14.00 | 94.43 | 85.03 | 17.98 |
| LSD(5%) | 2.00 | 1.16 | 11.34 | ns | 11.27 | ns | 1.58 |
| CV (%) | 17.75 | 3.67 | 9.26 | 18.69 | 8.09 | 2.82 | 5.47 |

Table 5 (cont'd)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Interaction of variety and form of nitrogen fertilizer** | | | | | | | |
| **$N_1V_1$** | 10.75 | 28.48 | 117.12 | 17.52 | 134.64 | 86.92 | 29.08 |
| **$N_1V_2$** | 6.98 | 24.48 | 82.35 | 11.88 | 94.23 | 87.15 | 18.95 |
| **$N_2V_1$** | 11.85 | 28.83 | 121.47 | 16.43 | 137.89 | 88.02 | 29.60 |
| **$N_2V_2$** | 8.03 | 24.54 | 90.35 | 10.57 | 100.92 | 89.48 | 19.65 |
| **LSD (5%)** | 1.41 | 0.82 | 8.02 | 2.22 | 7.97 | ns | 1.12 |
| **CV (%)** | 11.91 | 2.71 | 2.45 | 15.54 | 2.31 | 2.22 | 7.15 |
| **Interaction of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer** | | | | | | | |
| **$N_1S_1$** | 7.92 | 26.85 | 106.22 | 12.42 | 118.63 | 89.66 | 25.22 |
| **$N_1S_2$** | 8.60 | 26.68 | 102.82 | 14.02 | 116.83 | 87.98 | 24.48 |
| **$N_1S_3$** | 9.25 | 26.32 | 97.70 | 15.30 | 113.00 | 86.31 | 23.32 |
| **$N_1S_4$** | 9.70 | 26.07 | 92.20 | 17.07 | 109.27 | 84.20 | 23.03 |
| **$N_2S_1$** | 9.4 | 27.03 | 112.63 | 11.00 | 123.63 | 91.31 | 26.04 |
| **$N_2S_2$** | 9.85 | 26.87 | 108.67 | 12.43 | 121.10 | 89.81 | 25.74 |
| **$N_2S_3$** | 10.10 | 26.55 | 103.00 | 14.45 | 117.45 | 87.80 | 23.60 |
| **$N_2S_4$** | 10.42 | 26.30 | 99.33 | 16.10 | 115.43 | 86.08 | 23.13 |
| **LSD (5%)** | ns | ns | ns | ns | ns | ns | ns |
| **CV (%)** | 17.75 | 3.67 | 9.26 | 18.69 | 8.09 | 2.82 | 5.47 |
| **Interaction of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer** | | | | | | | |
| **$N_1V_1S_1$** | 10.20 | 28.87 | 124.13 | 15.63 | 139.78 | 88.81 | 29.81 |
| **$N_1V_1S_2$** | 10.40 | 28.77 | 119.33 | 16.73 | 136.06 | 87.65 | 29.65 |
| **$N_1V_1S_3$** | 11.00 | 28.23 | 115.60 | 18.20 | 133.80 | 86.44 | 28.55 |
| **$N_1V_1S_4$** | 11.40 | 28.03 | 109.40 | 19.53 | 128.93 | 84.79 | 28.29 |
| **$N_1V_2S_1$** | 5.63 | 24.83 | 88.30 | 9.20 | 97.50 | 90.50 | 20.63 |
| **$N_1V_2S_2$** | 6.80 | 24.60 | 86.30 | 11.30 | 97.60 | 88.32 | 19.31 |
| **$N_1V_2S_3$** | 7.50 | 24.40 | 79.8 | 12.40 | 92.20 | 86.18 | 18.09 |
| **$N_1V_2S_4$** | 8.00 | 24.10 | 75.00 | 14.60 | 89.60 | 83.60 | 17.77 |
| **$N_2V_1S_1$** | 11.20 | 29.13 | 130.20 | 14.00 | 144.20 | 90.31 | 31.37 |
| **$N_2V_1S_2$** | 11.80 | 29.07 | 124.33 | 15.20 | 139.53 | 89.06 | 30.19 |
| **$N_2V_1S_3$** | 12.00 | 28.70 | 118.53 | 17.70 | 136.23 | 87.02 | 28.77 |
| **$N_2V_1S_4$** | 12.43 | 28.43 | 112.80 | 18.80 | 131.60 | 85.71 | 28.08 |
| **$N_2V_2S_1$** | 7.60 | 24.93 | 95.07 | 8.00 | 103.07 | 92.31 | 20.71 |
| **$N_2V_2S_2$** | 7.90 | 24.67 | 93.00 | 9.67 | 102.67 | 90.56 | 21.28 |
| **$N_2V_2S_3$** | 8.20 | 24.40 | 87.47 | 11.20 | 98.67 | 88.58 | 18.44 |
| **$N_2V_2S_4$** | 8.40 | 24.17 | 85.87 | 13.40 | 99.27 | 86.45 | 18.18 |
| **LSD (0.05)** | ns | 1.64 | ns | ns | 15.94 | ns | 2.24 |
| **CV (%)** | 17.75 | 3.67 | 9.26 | 18.69 | 8.09 | 2.82 | 5.47 |

**Note: $N_1$= Prilled urea, $N_2$= Urea supergranules, $V_1$= BRRI Dhan 44, $V_2$= Nizershail, $S_1$= 1seedling, $S_2$=2seedlings, $S_3$= 3 seedlings, $S_4$= 4 seedlings**

### 4.2.9.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Percentage of filled grain was not significantly varied due to the interaction of variety, seedling transplanted hill$^{-1}$ with forms of N fertilizer (Table 5). However, it ranged from maximum 92.31% in Nizershail x 1 seedling hill$^{-1}$ x USG to minimum 83.60% in Nizershail x 4 seedlings hill$^{-1}$ x PU.

### 4.2.10 1000-grain weight

### 4.2.10.1 Effect of variety

Variety had significant effect on 1000-grain weight (Table 5). From the Table 5, it was revealed that 1000-grain weight of BRRI Dhan 44 was much heavier (29.34 g) than that of Nizershail (19.30 g), which is attributed to bold and larger grain size of this variety. This result is in agreement with the findings of Rafey *et al.* (1989) who stated that weight of 1000-grain differed due to the varietal differences.

### 4.2.10.2 Effect of seedling numbers hill$^{-1}$

Weight of 1000 grain was significantly influenced by the number of seedlings hill$^{-1}$ (Table 5). The heaviest (25.63 g) 1000-grain weight was found under the transplanting 1 seedling hill$^{-1}$ which was statistically similar with 2 seedlings hill$^{-1}$ and the lowest (23.08 g) 1000-grain weight was found at 4 seedlings hill$^{-1}$ which was statistically similar with 3 seedlings hill$^{-1}$. The results showed that 1000 grain weight was declined with increasing seedling numbers hill$^{-1}$ (Table 5). Karim *et al.* (1992) reported that 1000-grain weight slightly decreased with increasing plant density. This findings also accord with those of Wen and Yang (1991) who reported higher 1000-grain weight by using 1 seedling hill$^{-1}$ than with 4 seedlings hill$^{-1}$.

#### 4.2.10.3 Effect of form of nitrogen fertilizer

There was no significant variation in 1000-seed weight due to different forms of N (Table 5). The weight of 1000-seed was 24.63g and 24.01g for USG and PU, respectively. The 1000-grain weight of rice is more or less a stable genetic character (Yoshida, 1981) and N management strategy could not increase the grain weight in this case. Hasan *et al.* (2002) also reported that the effect of application method of USG and PU was not significant in respect of 1000-grain weight.

#### 4.2.10.4 Interaction effect of variety and seedling numbers hill$^{-1}$

Interaction effect of variety and seedling numbers hill$^{-1}$ on 1000-grain weight was observed significant (Table 5) and with the statistical similarity of 1 to 4 seedlings hill$^{-1}$, the heaviest (30.59 g) 1000-grain weight was found in the combination of BRRI Dhan 44 with 1 seedling hill$^{-1}$.

#### 4.2.10.5 Interaction effect of variety and form of nitrogen fertilizer

Interaction of variety and different forms of N was showed significant on 1000-grain (Table 5). It was ranged between 29.60 to 18.95 g. The heaviest (29.60 g) 1000-grain weight was obtained from BRRI Dhan 44 with USG and the lowest (18.95 g) was obtained from Nizershail with PU.

#### 4.2.10.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Seedling numbers hill$^{-1}$ and source of N fertilizer had insignificant interaction effect on 1000-grain weight (Table 5). Numerically the highest (26.04 g) 1000 grain weight obtained from 1 seedling hill$^{-1}$ with USG and the lowest (23.03 g) was from 4 seedling hill$^{-1}$ with PU.

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#### 4.2.10.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

Interaction of variety, seedling numbers hill$^{-1}$ and form of N fertilizer had significant effect on 1000 grain weight (Table 5). The highest (31.37 g) 1000-grain weight obtained from BRRI Dhan 44 x 1 seedling hill$^{-1}$ x USG which was statistically similar in all combination with BRRI Dhan 44 and the lowest (17.77 g) 1000-grain weight obtained from Nizershail x 4 seedlings hill$^{-1}$ x PU which was statistically similar in all combination with Nizershail.

### 4.3 Yield

#### 4.3.1 Grain yield

#### 4.3.1.1 Effect of variety

Grain yield is a function of interplay of various yield components such as number of productive tillers, grains panicle$^{-1}$ and 1000-grain weight (Hassan *et al.*, 2003). In present experiment variety had significant effect on grain yield (Table 6). It was observed from Table 6 that BRRI Dhan 44 produced higher (4.85 t ha$^{-1}$) grain yield which was contributed from higher number of effective tiller hill$^{-1}$, higher number of grains panicle$^{-1}$ and more weight of 1000-grain than Nizershail (2.46 t ha$^{-1}$). Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1988) and IRRI (1978) who recorded variable grain yield among tested varieties. The probable reason for variation in yield due to the heredity of the variety.

#### 4.3.1.2 Effect of seedling numbers hill$^{-1}$

Grain yield was significantly influenced by the number of seedlings hill$^{-1}$ (Table 6). The highest (3.96 t ha$^{-1}$) grain yield was found with 2 seedlings hill$^{-1}$ which was statistically similar to 1 seedling hill$^{-1}$ (3.83 t ha$^{-1}$) and the lowest (3.26 t ha$^{-1}$) grain yield was found with 4 seedlings hill$^{-1}$ (Table 6). The result is in conformity with the findings of Islam *et al.* (2002), Kabir (2002), Rajarathinam and Balasubramanuyan (1999) , Asif *et al.* (1997) and Hossain and Haque (1990) who observed the highest grain yield with 2 seedlings $hill^{-1}$. Likewise, Srinivasulu *et al.* (1999) noted that planting 1 seedling $hill^{-1}$ of rice gave grain yield comparable to that of 2 seedlings $hill^{-1}$. Whereas, Shrirame *et al.* (2000) found similar grain yield under 1, 2 and 3 seedlings $hill^{-1}$.

#### 4.3.1.3 Effect of form of nitrogen fertilizer

Grain yield affected significantly due to the forms of N-fertilizer (Table 6). Higher (3.87 t $ha^{-1}$) grain yield by urea supergranules indicated its superiority over split application of urea (3.45 t $ha^{-1}$). Placement of nitrogen fertilizer in the form of USG @ 58 kg N $ha^{-1}$ in the present experiment produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave higher grain yield than split application of urea. This result is in agreement with those of BRRI (2000) that USG gave 18% yield increase over the recommended prilled urea. In the present experiment it 12.2% higher grain yield was found in USG over urea. Similar results were reported by Mishra *et al.* (2000) and Raju *et al.* (1987) who observed that among all the forms of N, urea supergranules recorded the highest grain yield and proved significantly superior to other sources.

#### 4.3.1.4 Interaction effect of variety and seedling numbers $hill^{-1}$

Grain yield was significantly influenced by the interaction of variety and seedlings $hill^{-1}$ (Figure 13 and Appendix VIII). From Figure 13 the highest (5.38 t $ha^{-1}$) grain yield was observed from the combination of BRRI Dhan 44 with 1 seedling which was statistically similar with the combination of the same variety with 2 seedlings (5.25 t $ha^{-1}$) and the lowest (2.28 t $ha^{-1}$) was found from the combination of Nizershail with 1 seedling which was statistically similar (2.3 t $ha^{-1}$) with the combination of the same variety with 4 seedlings.

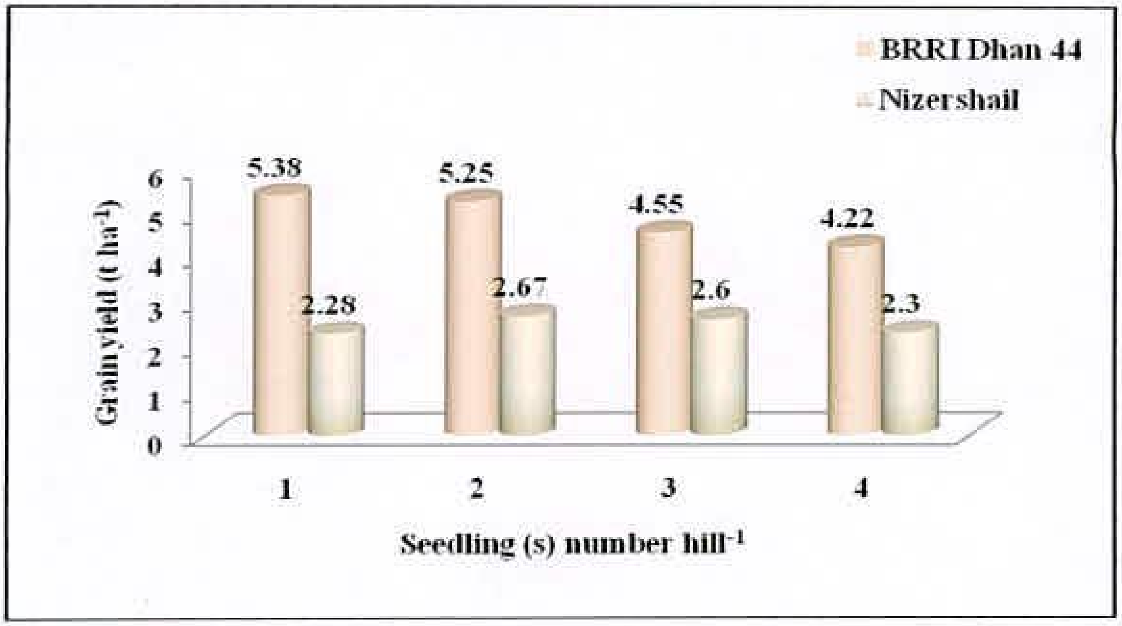


**Figure 13. Interaction effect of variety and seedling numbers $hill^{-1}$ on grain yield (t $ha^{-1}$) of T. *aman* rice**

#### 4.3.1.5 Interaction effect of variety and form of nitrogen fertilizer

From the Figure 14 and Appendix VIII it was evident that interaction of variety and form of urea significantly affected the grain yield. In the case of both varieties superior grain yield was found by the application of USG. Significantly the highest (5.08 t $ha^{-1}$) grain yield was found from the combination of BRRI Dhan 44 with USG and the lowest (2.27 t $ha^{-1}$) from Nizershail with PU. Due to application of USG 9.72% in BRRI Dhan 44 and 17.18% in Nizershail, higher yield was found over urea.

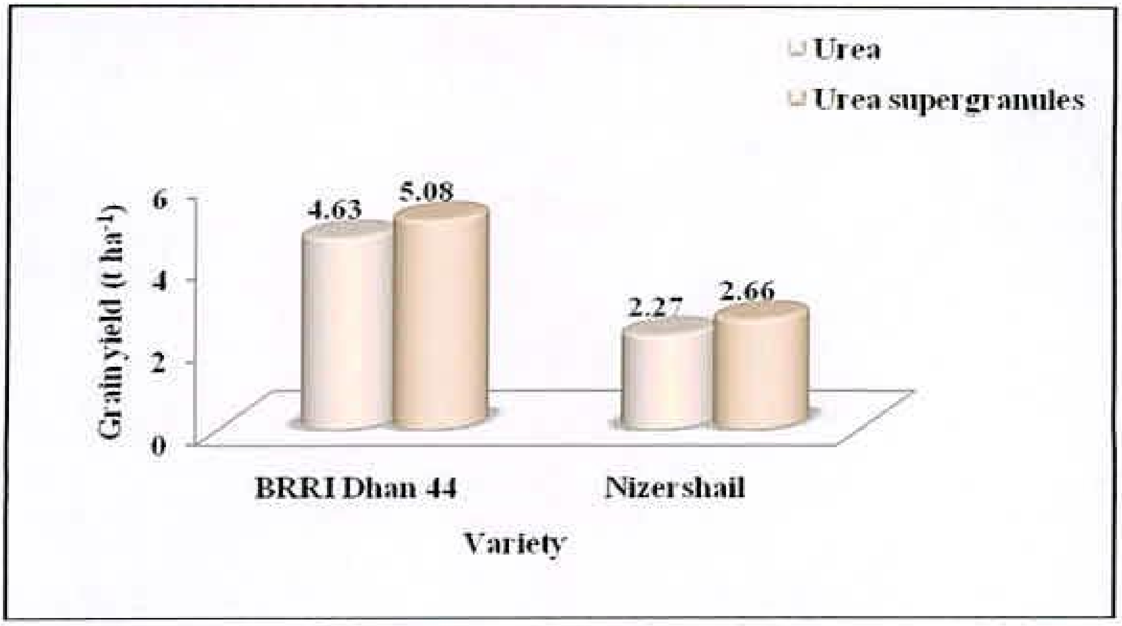


**Figure 14. Interaction effect of variety and form of nitrogen fertilizer on grain yield (t ha$^{-1}$) of T. *aman* rice**

#### 4.3.1.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

The interaction between number of seedling hill$^{-1}$ and forms of N-fertilizer produced significant variation on yield (Figure 15 and Appendix VIII). Apparently the highest (4.18 t ha$^{-1}$) grain yield was recorded by the treatment combination of 1 seedling hill $^{-1}$ with USG which was statistically similar (4.13 t ha$^{-1}$) with the combination of 2 seedlings hill$^{-1}$ with same urea form. It was also observed that grain yield decreased when more than 2 seedlings hill$^{-1}$ was transplanted but the yield of USG receiving plants were yet produced higher than those with urea applied plants.

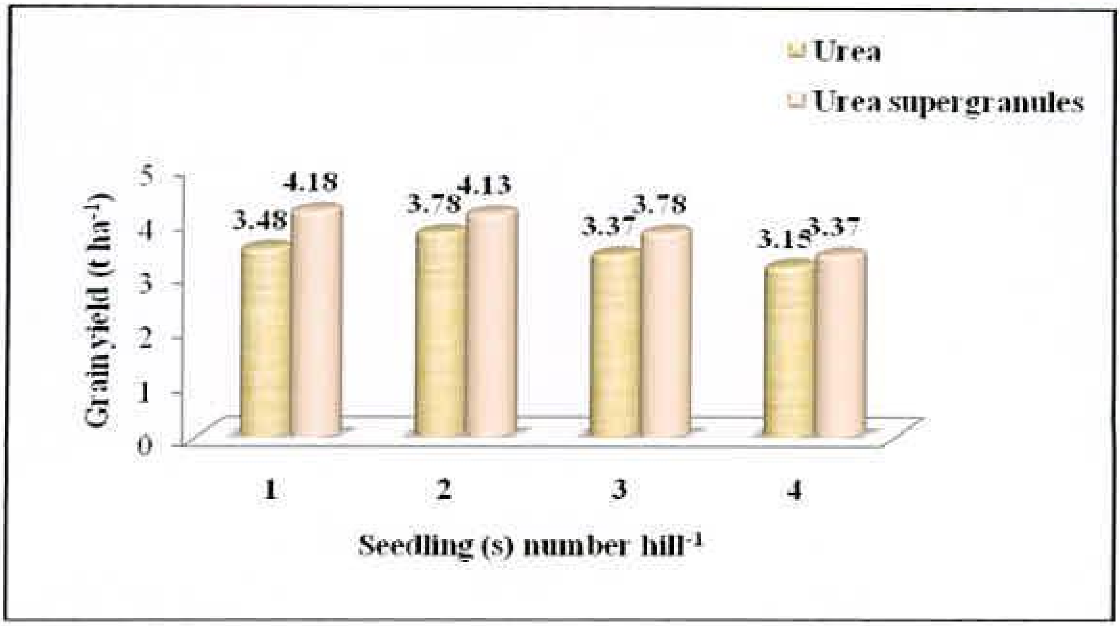


**Figure 15. Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on grain yield (t ha$^{-1}$) of T. *aman* rice**

### 4.3.1.7 Interaction effect variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

It was revealed that the interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer had significant effect on grain yield (Table 6). Maximum (5.77 t ha$^{-1}$) grain yield was obtained from the combination of BRRI Dhan 44 x 1 seedling x USG and lowest (1.97 t ha$^{-1}$) grain yield was obtained from the combination of Nizershail x 1 seedling x PU which was statistically similar with many other combinations.

### 4.3.2 Straw yield

#### 4.3.2.1 Effect of variety

The yield of straw was observed to differ significantly due to varieties (Table 6). It is evident from the experimental results Nizershail produced higher (7. 22 t ha$^{-1}$) straw yield compared to BRRI Dhan 44 (6.34 t ha$^{-1}$). The variety Nizershail was tall variety which produced higher straw yield compared to dwarf variety BRRI Dhan 44. The result is in agreement with the findings of Panda and Leeuwrik (1971) who reported that the straw yield could be assigned to plant height.

#### 4.3.2.2 Effect of seedling numbers hill$^{-1}$

Straw yield was not significantly influenced by the different level of seedling numbers hill$^{-1}$ (Table 6). Numerically the maximum (7.13 t ha$^{-1}$) straw yield was found with 4 seedlings hill$^{-1}$ and the minimum (6.29 t ha$^{-1}$) straw yield was from 1 seedling hill$^{-1}$ (Table 6). The higher straw yield with four seedlings hill$^{-1}$ was mainly due to higher number of total tillers hill$^{-1}$. The other possible reasons were that they could produce more biomass but mutual shading hampered translocation of enough food materials from body to growing panicles and thus favor the production of more straw instead of grain. On the contrary, 1 seedling hill$^{-1}$ though produced lower number of total tillers hill$^{-1}$ compared to 4 seedlings hill$^{-1}$ but produced more effective tillers which bear panicles and growing panicles received more stored matter from stems and as a result straw yield was lower. These results are in agreement with the findings of Mian and Gaffer (1970) who reported that straw yield increased with the increasing number of seedling hill$^{-1}$ from 1 to 4. Karim *et al.* (1987) also reported that 4 seedlings hill$^{-1}$ produced higher straw than 1 seedling hill$^{-1}$. Rajarathinam and Balasubramanuyan (1999) also revealed no significant difference of straw yield due to different levels of seedlings hill$^{-1}$.

#### 4.3.2.3 Effect of form of nitrogen fertilizer

From the Table 6, it was found that straw yield was significantly affected due to the forms of N fertilizer. The mean straw yield due to form of N fertilizer revealed that straw yield was the higher (7.04 t ha$^{-1}$) in urea supergranules. Mirzeo and Reddy

(1989) also observed that urea supergranules in rice gave higher straw yield than split application of prilled urea. On the other hand Patrick and Reddy (1976) reported that split application of N produced lower straw yield.

#### 4.3.2.4 Interaction effect of variety and seedling numbers hill$^{-1}$

It was observed from the Figure 16 and Appendix VIII that interaction of variety and seedling numbers hill$^{-1}$ had no significant effect on straw yield. Numerically the highest (7.57 t ha$^{-1}$) straw yield was found from the combination of Nizershail with 4 seedling numbers hill$^{-1}$ and the lowest (5.9 t ha$^{-1}$) from the combination BRRI Dhan 44 with 1 seedling number hill$^{-1}$.

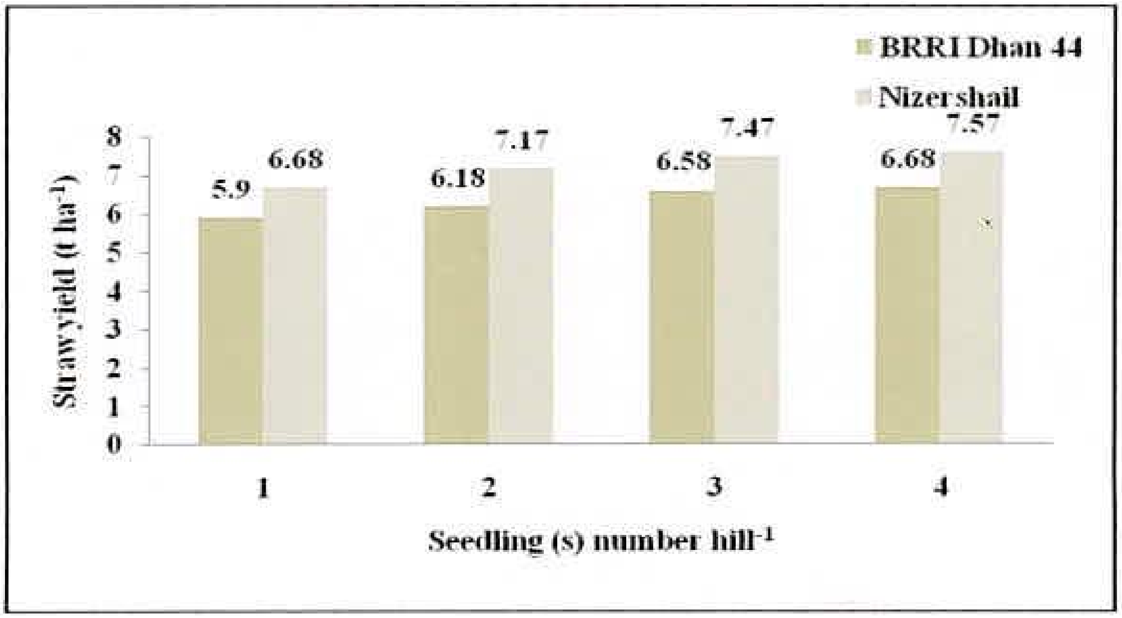


**Figure 16. Interaction effect of variety and seedling numbers hill$^{-1}$ on straw yield (t ha$^{-1}$) of T. *aman* rice**

#### 4.3.2.5 Interaction effect of variety and form of nitrogen fertilizer

Interaction effect of variety and form of N fertilizer was observed significant on straw yield (Figure 17 and Appendix VIII). The highest (7.48 t $ha^{-1}$) straw yield was found from the combination of Nizershail with USG and the lowest (6.07 t $ha^{-1}$) from the combination of BRRI Dhan 44 with PU.

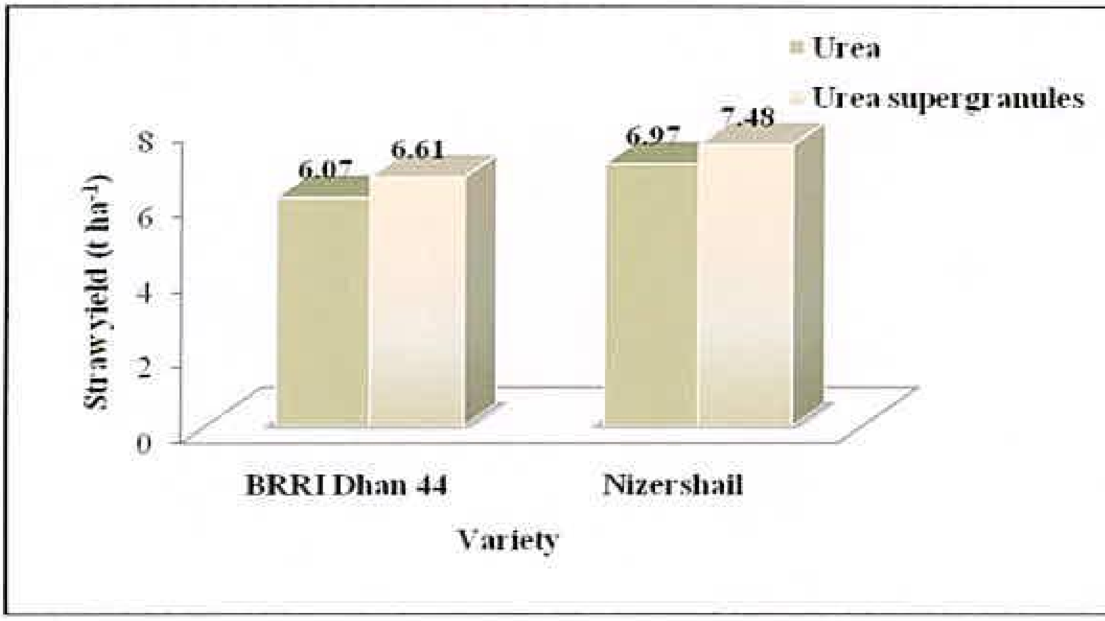


**Figure 17. Interaction effect of variety and form of nitrogen fertilizer on straw yield (t $ha^{-1}$) of T. *aman* rice**

#### 4.3.2.6 Interaction effect of seedling numbers $hill^{-1}$ and form of nitrogen fertilizer

Straw yield differed significantly due to interaction of numbers of seedling $hill^{-1}$ and forms of nitrogen fertilizer, apparently, the highest (7.48 t $ha^{-1}$) straw yield was obtained from the treatment combination of 4 seedlings $hill^{-1}$ with USG and the lowest one (6.05 t $ha^{-1}$) was from the treatment combination of 1 seedling $hill^{-1}$ with PU (results were shown from Figure 18 and Appendix VIII).

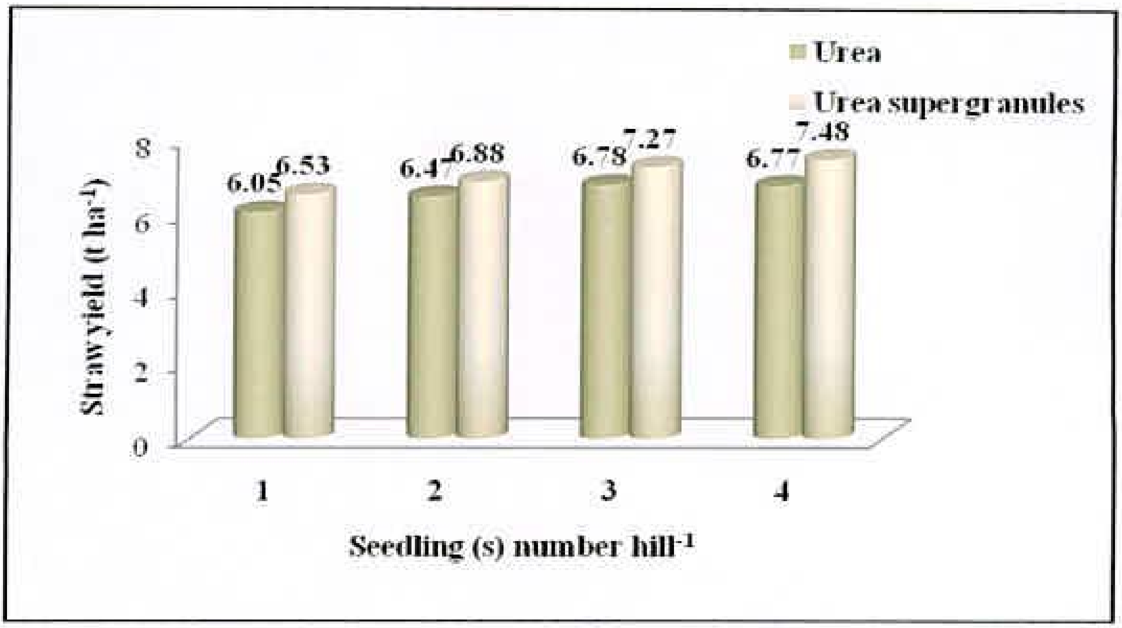


**Figure 18. Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on straw yield (t ha$^{-1}$) of T. *aman* rice**

### 4.3.2.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

It was observed from the Table 6 that interaction of variety, seedling numbers hill$^{-1}$ and form of N fertilizer had no significant effect on straw yield. The highest (8.0 t ha$^{-1}$) straw yield was found from the combination of Nizershail x 4 seedlings x USG and the lowest (5.63 t ha$^{-1}$) from the combination of BRRI Dhan 44 x 1 seedling x PU.

Table 6. Grain yield, straw yield, biological yield and harvest index of T. *aman* rice as influenced by variety, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer and by the interaction of variety x seedling numbers $hill^{-1}$ x form of nitrogen fertilizer

| Treatment | Grain yield ($t\ ha^{-1}$) | Straw yield ($t\ ha^{-1}$) | Biological yield ($t\ ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| **Variety** | | | | |
| $V_1$ | 4.85 | 6.34 | 11.19 | 43.32 |
| $V_2$ | 2.46 | 7.22 | 9.68 | 25.42 |
| LSD (5%) | 0.14 | 0.30 | 0.34 | 1.33 |
| CV (%) | 3.86 | 8.21 | 5.33 | 6.77 |
| **Seedling numbers $hill^{-1}$** | | | | |
| $S_1$ | 3.83 | 6.29 | 10.13 | 36.52 |
| $S_2$ | 3.96 | 6.68 | 10.63 | 36.50 |
| $S_3$ | 3.58 | 7.03 | 10.60 | 33.40 |
| $S_4$ | 3.26 | 7.13 | 10.38 | 31.07 |
| LSD (5%) | 0.20 | ns | ns | 1.89 |
| CV (%) | 6.58 | 7.52 | 5.42 | 6.51 |
| **Form of nitrogen fertilizer** | | | | |
| $N_1$ | 3.45 | 6.52 | 9.96 | 33.87 |
| $N_2$ | 3.87 | 7.04 | 10.91 | 34.86 |
| LSD (5%) | 0.14 | 0.30 | 0.34 | ns |
| CV (%) | 9.85 | 17.26 | 12.38 | 11.63 |
| **Variety x Seedling numbers $hill^{-1}$ x Form of Nitrogen fertilizer** | | | | |
| $N_1V_1S_1$ | 5.00 | 5.63 | 10.63 | 47.01 |
| $N_1V_1S_2$ | 5.20 | 5.97 | 11.17 | 46.62 |
| $N_1V_1S_3$ | 4.20 | 6.27 | 10.47 | 40.19 |
| $N_1V_1S_4$ | 4.10 | 6.40 | 10.50 | 39.04 |
| $N_1V_2S_1$ | 1.97 | 6.47 | 8.43 | 23.34 |
| $N_1V_2S_2$ | 2.37 | 6.97 | 9.33 | 25.33 |
| $N_1V_2S_3$ | 2.53 | 7.30 | 9.83 | 25.75 |
| $N_2V_2S_4$ | 2.20 | 7.13 | 9.33 | 23.70 |
| $N_2V_1S_1$ | 5.77 | 6.17 | 11.93 | 48.37 |
| $N_2V_1S_2$ | 5.30 | 6.40 | 11.70 | 45.36 |
| $N_2V_1S_3$ | 4.90 | 6.90 | 11.80 | 41.56 |
| $N_2V_1S_4$ | 4.33 | 6.97 | 11.30 | 38.38 |
| $N_2V_2S_1$ | 2.60 | 6.90 | 9.50 | 27.34 |
| $N_2V_2S_2$ | 2.97 | 7.37 | 10.33 | 28.68 |
| $N_2V_2S_3$ | 2.67 | 7.63 | 10.30 | 26.09 |
| $N_2V_2S_4$ | 2.40 | 8.00 | 10.40 | 23.15 |
| LSD (0.05) | 0.41 | ns | ns | 3.77 |
| CV (%) | 6.58 | 7.52 | 5.42 | 6.51 |

Note: $N_1$= Prilled urea, $N_2$= Urea supergranules, $V_1$= BRRI Dhan 44, $V_2$= Nizershail, $S_1$= 1 seedling, $S_2$= 2 seedlings, $S_3$= 3 seedlings, $S_4$= 4 seedlings

### 4.3.3 Biological yield

#### 4.3.3.1 Effect of variety

Varieties differed significantly between themselves regarding biological yield (Table 6). It was found that BRRI Dhan 44 produced the higher (11.19 t $ha^{-1}$) biological yield than Nizershail (9.68 t $ha^{-1}$). Higher grain yield attributed to the higher biological yield. This view was supported by Singh and Ganger (1989).

#### 4.3.3.2 Effect of seedling numbers $hill^{-1}$

Biological yield was not influenced by seedling numbers $hill^{-1}$ (Table 6). Maximum (10.63 t $ha^{-1}$) biological yield was observed with 2 seedlings $hill^{-1}$ whereas, minimum (10.13 t $ha^{-1}$) biological yield was found with planting 4 seedlings $hill^{-1}$.

#### 4.3.3.3 Effect of form of nitrogen fertilizer

It was observed from the results (Table 6) that biological yield was significantly affected by the forms of N fertilizer. Maximum (10.91 t $ha^{-1}$) biological yield was observed from the USG treated plots than PU treated plots (9.96 t $ha^{-1}$).

#### 4.3.3.4 Interaction effect of variety and seedling numbers $hill^{-1}$

Interaction effect of variety and seedling numbers $hill^{-1}$ had significant effect on biological yield (Figure 19 and Appendix VIII). Maximum (11.43 t $ha^{-1}$) biological yield was found from the combination of BRRI Dhan 44 with 2 seedlings which was statistically identical with the combination of the same variety with other seedlings number and minimum (8.97 t $ha^{-1}$) was obtained from the combination of Nizershail with 1 seedling. From the results it was evident that interaction effect of variety and seedling numbers $hill^{-1}$ showed significant due to varietal difference.

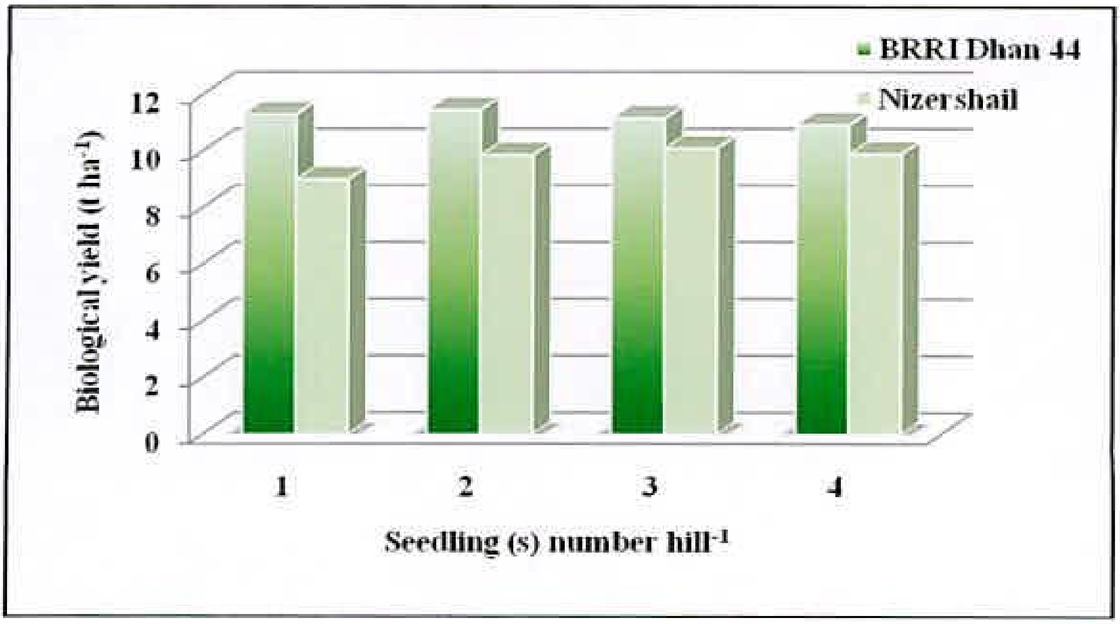


**Figure 19. Interaction effect of variety and seedling numbers hill$^{-1}$ on biological yield (t ha$^{-1}$) of T. *aman* rice**

### 4.3.3.5 Interaction effect of variety and form of nitrogen fertilizer

It was found that biological yield was affected significantly due to the interaction of variety and form of nitrogen fertilizer (Figure 20 and Appendix VIII). Maximum (11.68 t ha$^{-1}$) biological yield was obtained from the combination of BRRI Dhan 44 with USG and minimum (9.23 t ha$^{-1}$) from Nizershail with PU.

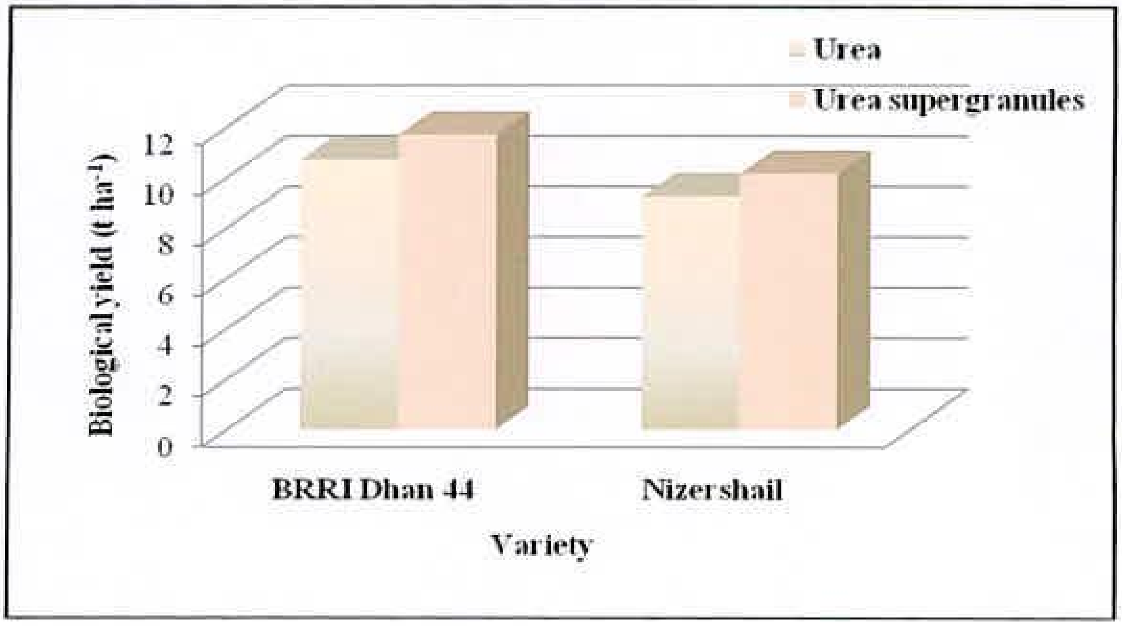


**Figure 20. Interaction effect of variety and form of nitrogen fertilizer on biological yield (t ha$^{-1}$) of T. *aman* rice**

### 4.3.3.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

The effect of interaction between seedling numbers hill$^{-1}$ and forms of urea has been shown in Figure 21 and Appendix VIII. It was revealed that there was significant effect on biological yield due to the interaction. Maximum biological yield was obtained from the combination of 2 seedlings hill$^{-1}$ with USG (11.02 t ha$^{-1}$) which was statistically similar with 3 and 4 seedlings hill$^{-1}$ with USG and minimum (9.53 t ha$^{-1}$) was found from 1 seedling with PU.

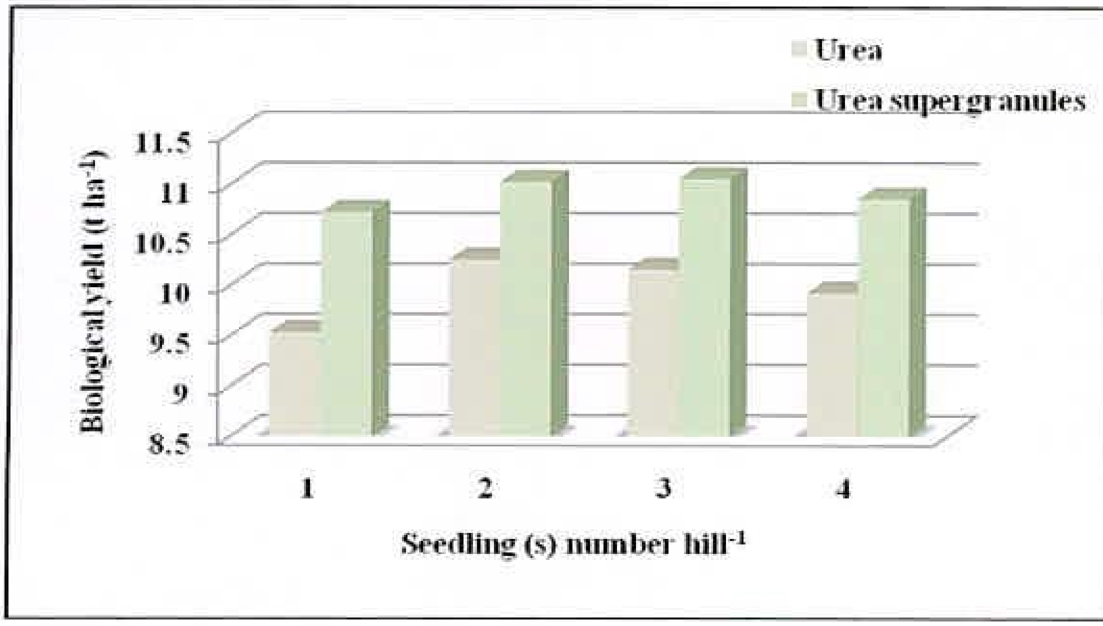


**Figure 21. Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on biological yield (t ha$^{-1}$) of T. *aman* rice**

### 4.3.3.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

From Table 6 it was revealed that there was no significant effect due to the interaction of variety, seedling numbers hill$^{-1}$ and form of N fertilizer on biological yield. Numerically maximum (11.93 t ha$^{-1}$) biological yield was found from the combination of BRRI Dhan 44 x 1 seedling x USG and minimum (8.43t ha$^{-1}$) was found from the combination of Nizershail x 1 seedling x PU.

## 4.4 Harvest Index

### 4.4.1 Effect of variety

It was found from Table 6 that variety had significant effect on harvest index. From the results it is evident that BRRI Dhan 44 produced the higher (43.32%) harvest index than Nizershail (25.42%). Low HI in Nizershail was caused by poor grain yield.

On the other hand harvest index had been reported to decrease with the increase in plant height and Nizershail was of the highest in plant height.

### 4.4.2 Effect of seedling numbers hill$^{-1}$

Seedling numbers variation had very little significant effect on harvest index (Table 6). However, 1 seedling hill$^{-1}$ produced the maximum (36.52%) harvest index which was statistically similar to 2 seedlings hill$^{-1}$. On the other hand, the minimum (31.07%) harvest index was obtained from 4 seedlings hill$^{-1}$. One seedling produced higher grain yield compared to straw. The increase of harvest index was more prominent in less seedling number hill$^{-1}$ and it was decreased with increasing planting density. The result is in agreement with the findings of Shrirame *et al.* (2000) who reported that harvest index significantly affected by seedlings number hill$^{-1}$ but Shah *et al.* (1991) and Zhang and Huang (1990) reported that harvest index was unaffected by the number of seedlings hill$^{-1}$.

### 4.4.3 Effect of form of nitrogen fertilizer

Forms of nitrogen fertilizer had no exerted significant variation on harvest index (Table 6) and it was 34.86% in urea supergranules and 33.87% in prilled urea. Ali (2005) was reported that N management strategy did not influence HI. On the other hand Miah *et al.* (2004) also reported that forms of nitrogen fertilizer had exerted very little variation on harvest index.

### 4.4.4 Interaction effect of variety and seedling numbers hill$^{-1}$

The effect of interaction of variety and seedling numbers hill$^{-1}$ was found significant (Figure 22 and Appendix VIII). Maximum (47.69%) harvest index was found from the combination of BRRI Dhan 44 with 1 seedling which was statistically identical with combination of the same variety with 2 seedlings and minimum (23.43%) was found from the combination of Nizershail with 4 seedlings which was statistically similar with the combination of Nizershail with 1 and 3 seedlings.

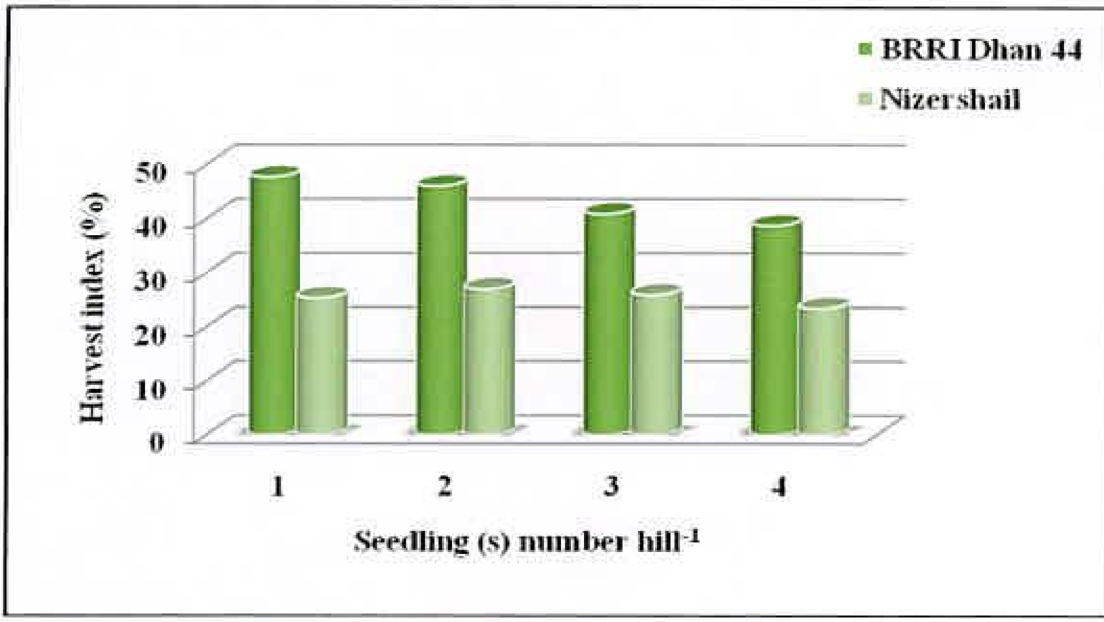


**Figure 22. Interaction effect of variety and seedling numbers hill$^{-1}$ on harvest index (%) of T. *aman* rice**

### 4.4.5 Interaction effect of variety and form of nitrogen fertilizer

There was significant effect on harvest index by the interaction of variety and urea source (Figure 23 and Appendix VIII). Maximum (43.42%) harvest index was found from the combination of BRRI Dhan 44 with USG which was statistically similar of same variety with PU and minimum (24.53%) was found from the combination of Nizershail with PU which was also statistically similar to same variety with USG.

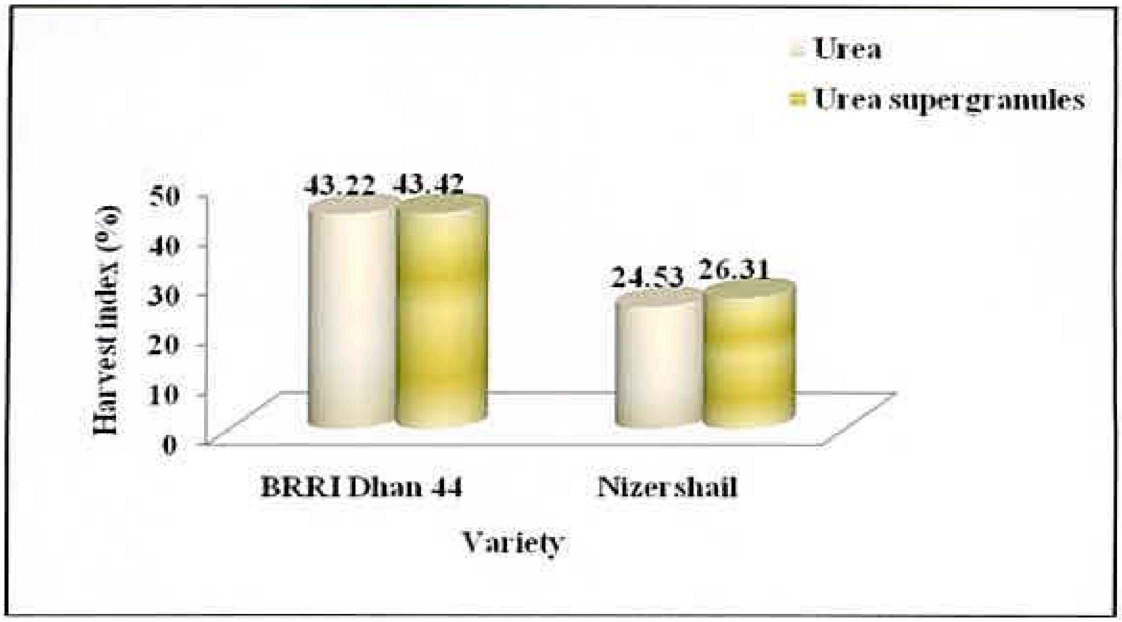


**Figure 23. Interaction effect of variety and form of nitrogen fertilizer on harvest index (%) of T. *aman* rice**

### 4.4.6 Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

It was evident from Figure 24 and Appendix VIII that interaction of seedling numbers hill$^{-1}$ and form of urea had no significant effect on harvest index. Numerically maximum (37.86%) harvest index was found from the combination of 1 seedling with USG.

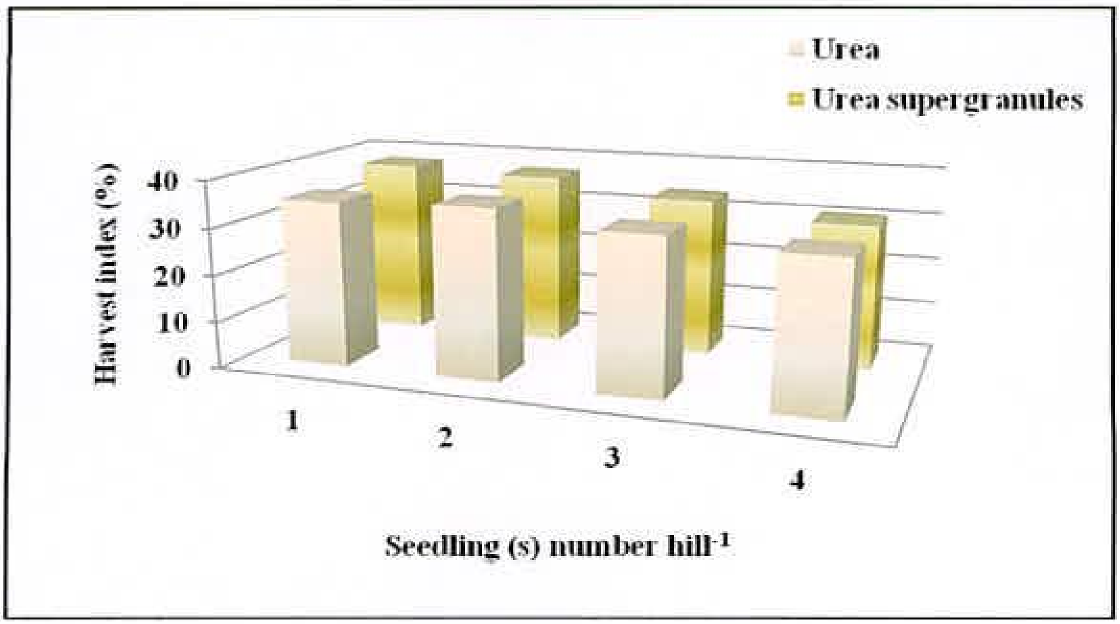


**Figure 24. Interaction effect of seedling numbers hill$^{-1}$ and form of nitrogen fertilizer on harvest index (%) of T. *aman* rice**

### 4.4.7 Interaction effect of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer

It was evident from the results (Table 6) that effect of interaction of variety, seedling numbers hill$^{-1}$ and form of nitrogen fertilizer had significant effect on harvest index. Combination of BRRI Dhan 44 x 1 seedling x USG produced the highest (48.37%) harvest index and lowest (23.15%) was found from the combination of Nizershail x 4 seedlings x USG which was statistically similar with other combination of same variety.

# Chapter 5

# Summary and conclusion

# SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University (SAU), during July to December, 2007 with a view to finding out the modern and traditional varietal performance of *aman* rice as affected by seedling numbers hill$^{-1}$ and urea supergranules. The experimental treatments included two T. *aman* rice varieties *viz.*; BRRI Dhan 44 as modern variety and Nizershail as traditional variety, four levels seedling hill$^{-1}$ (1, 2, 3 and 4) and two forms of urea *viz.*; prilled urea (PU) and urea supergranules (USG). The experiment was laid out in a split-split plot design with three replications having urea application in the main plots, variety, in the sub-plots and seedling number(s) hill$^{-1}$ in the sub-split plots. There were 16 treatments combinations. The total numbers of unit plots were 48. The size of unit plot was 5 m x 3 m = 15 m$^2$.

PU was applied in three equal splits at 10, 30 and 50 DAT at 58 kg N ha$^{-1}$. On the other hand, USG (1.8 g) was placed manually at 5-10 cm depth of soil in the middle of four consecutive hills of two adjacent rows. The 30 days-old seedlings were transplanted with 25 cm spacing between lines and 15 cm spacing between hills on 27 July, 2007. Cultural operations were done as and when necessary.

The data on crop growth characters like plant height, number of tillers hill$^{-1}$ and leaf area index were recorded at 15, 30, 45, 60, 75 and 90 DAT and dry mater were recorded at 30 DAT, 60 DAT and at harvest in the field at 15 days interval and yield as well as yield contributing characters like number of effective tillers hill$^{-1}$, panicle length, number of grains panicle$^{-1}$, percent filled and unfilled grains, 1000-grain weight, grain and straw yield were recorded after harvest. Finally grain and straw

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yields plot$^{-1}$ were recorded and converted to t ha$^{-1}$ and analyzed the data using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference (LSD) test at 5 % level of significance.

Results of the experiment showed that variety had significant difference for all the characters studied except filled grain (%). BRRI Dhan 44 gave maximum total dry matter (39.85 g hill$^{-1}$) at harvest, higher effective tiller hill$^{-1}$ (11.3), longer panicle length (28.65 cm), the highest number of filled grains panicle$^{-1}$ (119.29) and maximum 1000-grain weight (29.34 g). As a result BRRI Dhan 44 contributed to higher grain yield variety (4.85 t ha$^{-1}$). Biological yield (11.19 t ha$^{-1}$) and harvest index (43.32%) also higher in BRRI Dhan 44. On the other hand traditional variety of T. *aman* rice-Nizershail gave taller plant (157.79 cm), the highest number tiller hill$^{-1}$ (25.63), minimum number of unfilled grain (11.22) and maximum straw yield (7.22 t ha$^{-1}$) but lower total dry matter (33.65 g hill$^{-1}$) at harvest, lower effective tiller hill$^{-1}$ (7.5), lower number of filled grains panicle$^{-1}$ (86.35) and lower 1000-grain weight (19.30 g). As a result Nizershail contributed to lower grain yield variety (2.46 t ha$^{-1}$) and also gave lower biological yield (9.68 t ha$^{-1}$) and lower harvest index (25.42%).

The total tiller production hill$^{-1}$ was significantly maximum with transplanting 4 seedlings hill$^{-1}$ and it was followed by transplanting 3 and 2 seedlings hill$^{-1}$ in which single seedling hill$^{-1}$ showed the lowest performance from 45 to 90 DAT. Leaf area index differed significantly from 15 to 75 DAT, whereas 2 to 4 seedlings hill$^{-1}$ showed significantly the highest value compared to single seedling hill$^{-1}$. Total dry matter produced at different dates showed the trend of 1 seedling<2 seedlings<3 seedlings<4 seedlings hill$^{-1}$. Among the yield component 1000-grain weight significantly decreased with increasing seedling number hill$^{-1}$. Grain yield was influenced significantly by seedling number hill$^{-1}$ but straw yield as well as biological yield was unaffected. The highest grain yield (3.96 t ha$^{-1}$) was found with 2 seedlings hill$^{-1}$ which was similar to 1 seedling hill$^{-1}$ (3.83 t ha$^{-1}$) and the lowest grain yield (3.26 t ha$^{-1}$) was at 4 seedlings hill$^{-1}$.

Form of nitrogen fertilizer significantly differed at all growth characters. However, at 15 and 30 DAT plant height, 15 and 30 DAT leaf area index and 30 DAT total dry matter production remained unaffected. Among the yield contributing parameters effective tillers hill$^{-1}$ and filled grains panicle$^{-1}$ affected significantly. Grain yield, straw yield as well as biological yield significantly increased but harvest index remained unaffected. It was 12.2% higher grain yield found in USG over PU.

Grain yield, biological yield and harvest index influenced due to the interaction effect of variety and seedling numbers hill$^{-1}$. BRRI Dhan 44 with 1 seedling hill$^{-1}$ gave highest (5.38 t ha$^{-1}$) grain yield which was similar to same variety combination with 2 seedlings hill$^{-1}$ (5.25 t ha$^{-1}$).

Interaction effect of variety and form of nitrogen fertilizer significantly influenced grain yield, straw yield, biological yield and harvest index. The highest (5.08 t ha$^{-1}$) grain yield recorded from BRRI Dhan 44 with urea supergranules and the lowest (2.27 t ha$^{-1}$) from Nizershail with prilled urea. Due to application of USG increased grain yield 9.72% in BRRI Dhan 44 and 17.18% in Nizershail over PU.

With the interaction of seedling numbers hill$^{-1}$ and source of nitrogen fertilizer increased grain yield, straw yield as well as biological yield significantly. The highest

($4.18\ t\ ha^{-1}$) grain yield was produced with USG from 1 seedling $hill^{-1}$, which was similar to 2 seedlings $hill^{-1}$ ($4.13\ t\ ha^{-1}$).

Grain yield and harvest index increased significantly with the interaction effect of variety, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer. Combination of BRRI Dhan 44 x 1seedling x USG gave maximum grain yield ($5.77\ t\ ha^{-1}$).

Based on the results of the present study it can be concluded that BRRI Dhan 44 was found to be a promising rice variety for higher grain yield, two seedlings $hill^{-1}$ and nitrogen fertilizer in the form of urea supergranules (USG) appeared as the promising practice to maximize yield in transplant *aman* under the agro-ecological conditions of present study. Therefore, it could be suggested that transplanting 1 or 2 seedlings $hill^{-1}$ for modern variety of transplant *aman* cv. BRRI Dhan 44 and 2 or 3 seedlings $hill^{-1}$ for traditional variety of Nizershail coupled with urea supergranules will be a promising practice for good yield. But suitable level of urea supergranules particularly for modern and traditional variety and its laborious application should be mind under consideration. However, to reach a specific conclusion and recommendation, more research work on modern and traditional variety, seedling numbers $hill^{-1}$ and form of nitrogen fertilizer should be done over different Agro-ecological zones.

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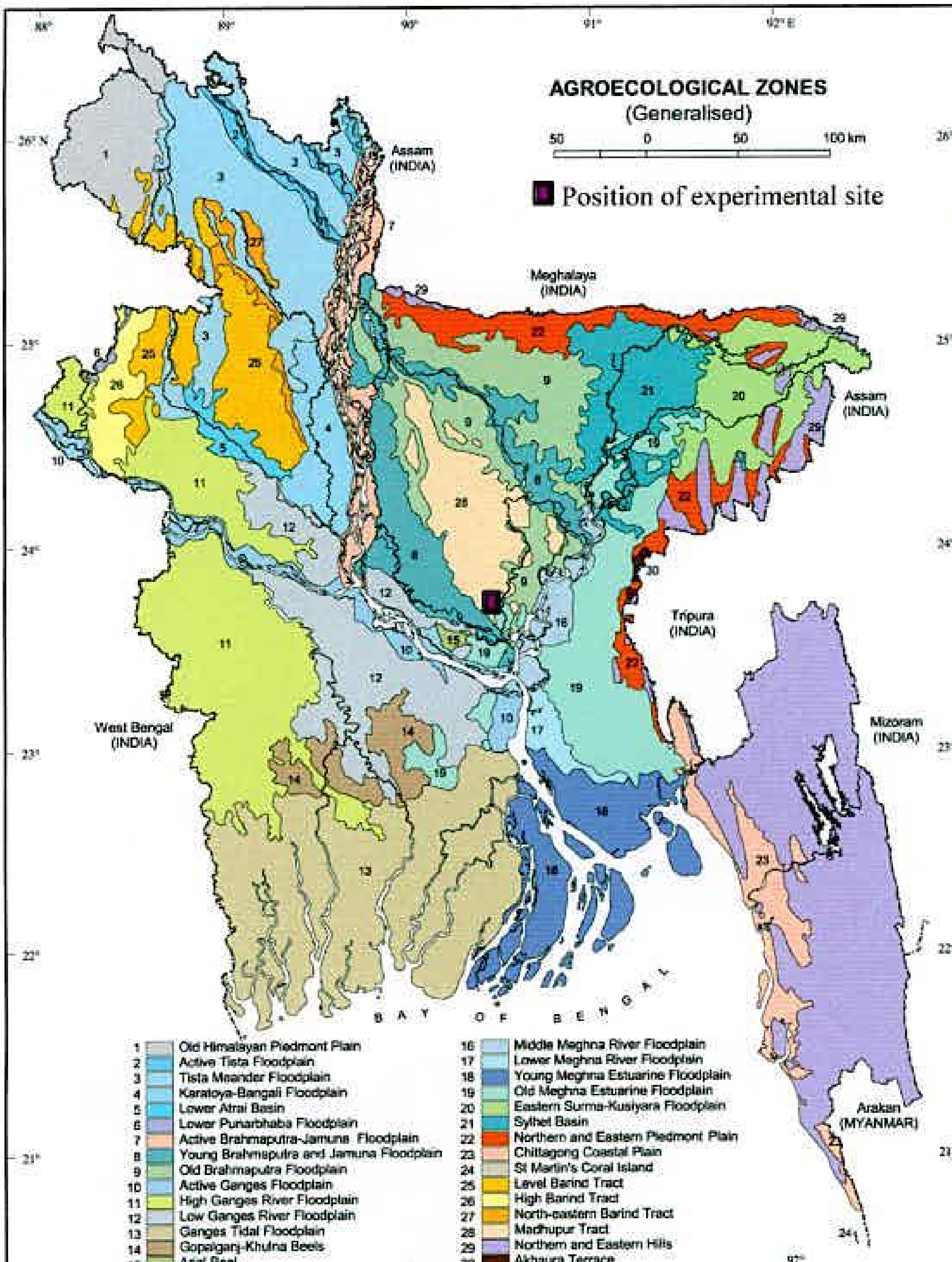
# Appendices

# APPENDICES

## Appendix I. Map showing the experimental site under study



**Appendix II. Weather data, 2007, Dhaka**

| Month | Average RH (%) | Average Temperature (°C) | | Total Rainfall (mm) | Average Sunshine hours |
|---|---|---|---|---|---|
| | | Min. | Max. | | |
| June | 81 | 25.5 | 32.4 | 628 | 4.7 |
| July | 84 | 25.7 | 31.4 | 753 | 3.3 |
| August | 80 | 26.4 | 32.5 | 505 | 4.9 |
| September | 80 | 26.4 | 32.0 | 179 | 3.0 |
| October | 78 | 23.8 | 31.4 | 320 | 5.2 |
| November | 77 | 19.9 | 29.0 | 111 | 5.7 |
| December | 69 | 15.0 | 25.8 | 0 | 5.5 |

**Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.**

**Appendix III. Physiochemical properties of the initial soil**

| Characteristics | Value |
|---|---|
| Partical size analysis. | |
| % Sand | 26 |
| % Silt | 45 |
| % Clay | 29 |
| Textural class | silty-clay |
| pH | 5.6 |
| Organic carbon (%) | 0.45 |
| Organic matter (%) | 0.78 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20.00 |
| Exchangeable K (me/100 g soil) | 0.10 |
| Available S (ppm) | 45 |

**Source: Soil Resources Development Institute (SRDI), Dhaka-1207**

**Appendix IV. Means square values for plant height (cm) of T. *aman* rice at different days after transplanting**

| Sources of variation | DF | Means square values at different days after transplanting | | | | | |
|---|---|---|---|---|---|---|---|
| | | 15 | 30 | 45 | 60 | 75 | At harvest |
| **Replication** | 2 | 11.40 | 26.69 | 55.04 | 67.52 | 5.64 | 13.40 |
| **Form of N fertilizer (N)** | 1 | 0.18 | 6.83 | 183.69* | 305.02** | 376.88** | 336.02** |
| **Error (a)** | 2 | 3.43 | 26.61 | 9.07 | 21.40 | 36.85 | 0.40 |
| **Variety (V)** | 1 | 1128.11** | 794.63** | 5106.75** | 7129.69** | 7688.67** | 9157.68** |
| **N x V** | 1 | 0.18* | 0.29* | 2.48* | 2.52* | 24.80* | 93.53* |
| **Error (b)** | 4 | 12.44 | 35.82 | 150.73 | 101.79 | 143.14 | 45.48 |
| **Seedling(s) hill$^{-1}$ (S)** | 3 | 13.11 | 19.42 | 88.23 | 78.69 | 208.64 | 136.85 |
| **N x S** | 3 | 0.81 | 26.66 | 52.59 | 10.91 | 2.38 | 13.30 |
| **V x S** | 3 | 2.47* | 17.36 | 93.19* | 10.69* | 20.39* | 6.52* |
| **N x V x S** | 3 | 0.12 | 9.24 | 7.75 | 9.85* | 2.08 | 12.58* |
| **Error (c)** | 24 | 17.01 | 28.69 | 38.54 | 38.68 | 26.75 | 18.19 |

*Significant at 5% level

**Significant at 1% level

**Appendix V. Means square values for total tiller number of T. *aman* rice at different days after transplanting**

| Sources of variation | DF | Means square values at different days after transplanting | | | | | |
|---|---|---|---|---|---|---|---|
| | | 15 | 30 | 45 | 60 | 75 | 90 |
| **Replication** | 2 | 15.06 | 0.02 | 24.15 | 7.75 | 0.58 | 2.77 |
| **Form of N fertilizer (N)** | 1 | 0.33 | 31.69 | 72.52* | 90.75** | 130..02** | 33.33** |
| **Error (a)** | 2 | 14.02 | 0.81 | 11.65 | 12.25 | 2.33 | 9.77 |
| **Variety (V)** | 1 | 108.00** | 553.21** | 1036.02** | 85.33** | 93.52** | 21.33** |
| **N x V** | 1 | 0.75* | 1.02* | 0.21* | 4.08* | 3.52* | 0.33* |
| **Error (b)** | 4 | 1.75 | 5.08 | 34.52 | 4.58 | 9.33 | 0.52 |
| **Seedling(s) hill$^{-1}$ (S)** | 3 | 47.14 | 84.41 | 154.58** | 168.39** | 109.24** | 48.28** |
| **N x S** | 3 | 0.28 | 6.63 | 0.86 | 2.81 | 1.91* | 1.39* |
| **V x S** | 3 | 0.39 | 1.35 | 0.91 | 0.39* | 0.97* | 3.06* |
| **N x V x S** | 3 | 0.03 | 0.74 | 3.13 | 3.58 | 0.74* | 0.61* |
| **Error (c)** | 24 | 4.65 | 11.72 | 13.76 | 6.21 | 3.67 | 1.56 |

*Significant at 5% level

**Significant at 1% level

Appendix VI. Means square values for LAI of T. *aman* rice at different days after transplanting

| Sources of variation | DF | Means square values at different days after transplanting | | | | | |
|---|---|---|---|---|---|---|---|
| | | 15 | 30 | 45 | 60 | 75 | 90 |
| Replication | 2 | 0.01 | 0.18 | 0.03 | 0.07 | 0.38 | 0.09 |
| Form of N fertilizer (N) | 1 | 0.00003 | 0.10 | 5.20** | 8.67** | 8.25** | 1.54** |
| Error (a) | 2 | 0.03 | 0.07 | 0.23 | 0.35 | 0.13 | 0.009 |
| Variety (V) | 1 | 0.21** | 1.27* | 31.36** | 63.02** | 37.99** | 3.20** |
| N x V | 1 | 0.0001* | 0.02 | 0.16* | 0.008* | 0.08* | 0.08* |
| Error (b) | 4 | 0.01 | 0.07 | 1.03 | 1.18 | 0.54 | 0.003 |
| Seedling(s) $hill^{-1}$ (S) | 3 | 0.13** | 2.06** | 3.93** | 7.85** | 5.81** | 0.53 |
| N x S | 3 | 0.002 | 0.003 | 0.18 | 0.20 | 0.12* | 0.005 |
| V x S | 3 | 0.0006* | 0.02 | 0.03 | 0.47 | 0.17* | 0.002 |
| N x V x S | 3 | 0.0007 | 0.003 | 0.49 | .013 | 0.26 | 0.01 |
| Error (c) | 24 | 0.005 | 0.18 | 0.61 | 0.51 | 0.22 | 0.06 |

*Significant at 5% level

**Significant at 1% level

**Appendix VII. Means square values for total dry matter weight (g $hill^{-1}$) of T. *aman* rice at different days after transplanting**

| Sources of variation | DF | Means square values at different days after transplanting | | |
|---|---|---|---|---|
| | | 30 | 60 | At harvest |
| Replication | 2 | 0.96 | 7.13 | 2.49 |
| Form of N fertilizer (N) | 1 | 1.88 | 129.69* | 154.08* |
| Error (a) | 2 | 1.90 | 10.66 | 38.04 |
| Variety (V) | 1 | 33.40** | 291.56** | 461.28** |
| N x V | 1 | 0.03* | 2.48 | .07 |
| Error (b) | 4 | 2.74 | 8.54 | 5.16 |
| Seedling(s) $hill^{-1}$ (S) | 3 | 28.53** | 375.37** | 257.63** |
| N x S | 3 | 0.11 | 17.44 | 0.60 |
| V x S | 3 | 2.03* | 9.14 | 11.55 |
| N x V x S | 3 | 0.16 | 4.16 | 0.71 |
| Error (c) | 24 | 2.24 | 30.14 | 28.00 |

*Significant at 5% level

**Significant at 1% level

**Appendix VIII. Means square values for grain yield, straw yield, biological yield and harvest index of T. *aman* rice**

| Sources of variation | DF | Means square values | | | |
|---|---|---|---|---|---|
| | | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest index (%) |
| **Replication** | 2 | 0.04 | 0.09 | 0.01 | 3.42 |
| **Form of N fertilizer (N)** | 1 | 2.13** | 3.31** | 10.74** | 11.80 |
| **Error (a)** | 2 | 0.13 | 1.37 | 1.67 | 15.98 |
| **Variety (V)** | 1 | 68.40** | 9.36** | 27.15** | 3842.22* |
| **N x V** | 1 | 0.01* | 0.003* | 0.03* | 7.49* |
| **Error (b)** | 4 | 0.02 | 0.31 | 0.31 | 5.41 |
| **Seedling(s) $hill^{-1}$ (S)** | 3 | 1.15** | 1.71** | 0.66 | 83.87** |
| **N x S** | 3 | 0.12* | 0.05* | 0.09* | 5.43 |
| **V x S** | 3 | 0.96* | 0.02 | 1.08* | 36.58* |
| **N x V x S** | 3 | 0.14* | 0.05 | 0.27 | 4.80* |
| **Error (c)** | 24 | 0.06 | 0.26 | 0.32 | 5.01 |

*Significant at 5% level

**Significant at 1% level

# LIST OF PLATES

**Plate 1. Field view after transplanting**

**Plate 2. Field view of BRRI Dhan 44 at 15 DAT**

**Plate 3. Field view of Nizershail at 15 DAT**


**Plate 4. Field view at maximum tillering stage**


**Plate 5. Field view of BRRI Dhan 44 at milking stage and Nizershail at panicle initiation stage**

**Plate 6. Lodging in Nizershail at heading stage**

**Plate 7. Lodging in the entire field due to sidr on 15 Novemer, 2007**

**Plate 8. Maturity stage of BRRI Dhan 44**

**Plate 9. Maturity stage of Nizershail**