PERFORMANCE OF LOCAL AND MODERN T. AMAN VARIETIES UNDER DROUGHT STRESS CONDITION

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CERTIFICATE

This is to certify that the thesis entitled, **"PERFORMANCE OF LOCAL AND MODERN T. AMAN VARIETIES UNDER DROUGHT STRESS CONDITION"** 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 (MS.) IN AGRONOMY** embodies the result of a piece of bona fide research work carried out by **ISMAT JAHAN TUHIN,** Registration No. **09-03687** under my supervision and guidance. No part of the thesis has been submitted for any degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and style of thesis have been approved and recommended for submission.

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DEDICATED TO

MY BELOVED PARENTS

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PERFORMANCE OF LOCAL AND MODERN T. AMAN VARIETIES UNDER DROUGHT STRESS CONDITION

ABSTRACT

An experiment was conducted at the Sher-e-Bangla Agricultural University during the period from aman season (June-December 2014) with a view to study the performance of local and modern T. aman varieties under drought stress condition. The experiment comprised of 16 varieties, 12 local and 4 modern varieties viz. (i) Kartik Shail, (ii) Doodh Kalam, (iii) Nakhuchi Mota, (iv) Kartik Balam, (v) Lal Mota, (vi) Kalo Khaia, (vii) Changshai, (viii) Basmati Shakkar Khanna, (ix) Dholi Chikon, (x) Rani Salute, (xi) Ghashful Chikon, (xii) Moulata, (xiii) BRRI dhan34, (xiv) BRRI dhan33, (xv) BRRI dhan62 and (xvi) BU dhan1. The experiment was laid out in a RCBD design in field (non-stressed condition) and in pot (stressed condition), each with three replications. In stressed condition, at the time of harvest, the longest plant (139.50 cm) was found in Kartik Balam and Basmati Shakkar Khanna; highest number of total tillers hill^{-1} (20.33) and longest panicle (28.533 cm) were found in Lal Mota and Basmati Shakkar Khanna, respectively; highest number of total grains panicle^{-1} (163.33) and filled grains panicle^{-1} (135.33) were recorded in BRRI Dhan 34. However, the highest weight of 1000-grains (29.60 g), grain yield (4.92 t ha^{-1}), straw yield (20.98 t ha^{-1}) and biological yield (21.90t ha^{-1}) were found in Moulata. In non-stressed condition, at the time of harvest, the longest plant (184.83 cm) was found in Kalo Khaia; highest number of total tillers hill^{-1} (17.67) was found in BU Dhan 1. The longest panicle (31.50 cm), highest number of total grains panicle^{-1} (300.00) and filled grains panicle^{-1} (255.67) were recorded in Basmati Shakkar Khanna; highest weight of 1000-grains (32.07 g) was found in Rani Salute. The highest grain yield (12.35 t ha^{-1}) was recorded in BRRI dhan62; highest straw yield (20.98 t ha^{-1}) and biological yield (30.87 t ha^{-1}) were found in Moulata and Doodh Kalam, respectively. In the case of days to maturity, both in stressed and non-stressed condition, most of the local varieties mature at the same time or slightly late compared to the modern varieties. Local varieties especially Moulata could be recommended for further trials in multi locations for T. aman cultivation in stressed region.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CV%	Percentage Coefficient Variance
cv.	Cultivar (s)
cm	Centi-meter
DAT	Days After Transplanting
DOASL	Department of Agriculture Government of Sri Lanka
et al.	Et alii (And others)
etc.	Et cetra (And other similar things)
FAO	Food and Agriculture Organization
g	Gram
Ha	Hectare
HI	Harvest Index
i.e.	Id est (that is)
IRRI	International Rice Research Institute
Kg	Kilogram
L	Liter
L.	Linnaeus
LSD	Least Significant Differences
M	Meter
MoP	Muriate of Potash
RCBD	Randomized Completely Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
ssp.	Sub-species
TSP	Triple Super Phosphate
viz.	Namely

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in the world and it is the primary source of food and calories for about half of mankind (Kush, 2005). More than 75% of the annual rice supply comes from 79 million hectares of irrigated paddy land.The total world production is about 738.1 million tonnes in nearly 162.3 million hectares land (FAO, 2014).Rice is the staple food for nearly half of the world's population as well as for 144.043 million people of Bangladesh (AIS, 2016). To feed the rapidly enlarging global population, the world's annual rice production need to be increased to 760 million tons by the year 2020 (Kundu and Ladha, 1995).

Rice holds a strong position in our cropping systems in Bangladesh. Our cropping systems are mostly rice based throughout the country. There are three kinds of rice; aus, aman and boro. Rice grown in summer is called aus, while those planted in winter are boro. Rice planted in the rainy portion of summer and harvested in winter called aman (BRRI, 2013). Rice is grown both under irrigated and non-irrigated condition in Bangladesh. Non irrigated aus rice suffers from drought stress at the early part of crop growth when there is a shortfall of rain. Boro rice is grown under irrigated condition and this crops has been extensive especially after the onset of development of irrigation system in Bangladesh after eighties. Due to having good market price of rice coupled with inception of irrigation, boro cultivation extended even in the fields of pulses and oilseed crops in Bangladesh. Owing to the longer duration of the boro crops, area under aus rice production has reduced significantly. As a result we have to depend largely for food requirements on boro and aman.

To feed the ever increasing population of Bangladesh rice production must be increased either by increasing arable land or by increasing per hectare yield. However, increasing the arable lands in our densely populated country is quite difficult. For this reason our rice production must be increased by increasing per hectare productivity. The crop production or the yield productivity of a crop may be interrupted or reduced by lack of proper surrounding environment and natural calamities.

Bangladesh will require about 27.26 million tons of rice for the year 2020 (BRRI, 2011). During this time total rice area will also shrink to 10.28 million hectares. Rice yield therefore, needs to be increased from the present 2.74 to 3.74 t/ha (BNNC, 2008). The required paddy production of 52 million tons (34.7 million tons of rice) by 2020, which would require a production growth of 2.2% per year (BARC, 2006).

Bangladesh Rice Research Institute (BRRI) has developed 73 inbred and 4 hybrid rice varieties (AIS, 2016) adaptive for production in different agro-ecological zones of Bangladesh. Rice covers 11372.071 hectare of our land area which is 78.16% of total cropped area in Bangladesh (BBS, 2014). At present 5530.434 hectare of land is covered under aman cultivation which quantifies 48.63 % of total rice grown area. Out of this land area, modern or improved varieties of T. aman are grown in 4311.93 ha of land, while 1218.50 ha is under local or landraces amounting over 28% of the total T. aman grown area (BBS, 2014).

Both the local/landraces or improved varieties of aman rice are grown under flooded condition. In general, the duration of local varieties of rice is longer than the improved ones. Modern varieties are shorter with strong stem stature; erect leaves and suitable for growing on lands where shallow or water depth up to 30-45 cm remains at the pick rainy season (August-Septemper). Whereas, the local varieties are long (up to one meter) and can survive in deep water and as such are suitable to grow in the flooded lands where the modern varieties cannot be grown (Ullah, 2014).

The past years have seen a growing scarcity of water worldwide. The pressure to reduce water use in irrigated agriculture is mounting, especially in Asia where it accounts for 90% of total diverted fresh water. Rice is an obvious target for water conservation: it is grown on more than 30% of irrigated land and accounts for 50% of irrigation water (Barker *et al*., 1999).

Aman rice is generally cultivated under rain fed condition during June – December. It passes through vegetative stage during August to September when rainfall is sufficient. This crop suffers from moisture stress when the rainfall ceases by the first week of October. It passes through reproductive stages (panicle initiation, booting, flowering and grain filling) in October and November. The total rainfall in these two months is very irregular and often inadequate in Bangladesh which makes failure to meet the evapotranspiration demand of aman rice. Consequently water stress develops and affects translocation of assimilates and grain development in rice. Although, the aman rice are transplanted in rainy season and the tide water quite often floods the land during full moon and no moon, no irrigation is needed for the establishment and vegetative growth of this crop. But at the later part of growth stages especially at the reproductive phase, the occurrence of rainfall ceases as well as tide water also ceases on the onset of winter. As a result aman rice suffers from drought at the grain filling stage. This is also true for the local ones grown on the upper topography where soil dries off. This situation causes the crop to suffer from drought at the grain filling stage in the southern Bangladesh. This is also one of reasons of not enough expanding modern rice varieties in the tidal prone areas (Ullah, 2010).

The water shortage at the grain filling stage may cause drastically seed yield loss. The performance of rice varieties varies under water stress conditions at different growth stages have been evaluated by many workers. Islam *et al*. (1994 a) observed that yield losses resulting from water deficit are particularly severe when drought strikes at booting stage. Water stress at or before panicle initiation reduces potential spike number and decreases translocation of assimilates to the grains, which results low in gain weight and increases empty grains (Davatgara, 2009).

The rice growing areas of the southern districts are saucer shaped (Ullah, 2013; Ullah, 2014) where the central portion is deeper while the edges (near the river side) are of medium topography. Modern varieties are suitable along the river banks where the depth of water at high tides are within 45 cm and where on seedlings of modern rice varieties can be transplanted. But this crop suffers from drought at the post emergence stage where either rainfall seldom occurs or tide water does not flood the offshore. So, drought is a common phenomena both for the local land races as well as for modern aman rice. The effect of drought at the grain filling stage on the local aman rice yield has not so far been evaluated; and so it needs to be tried. Moreover, the performance of both the local and modern aman varieties under drought stress condition at the reproductive stage should be compared (Ullah, 2014).

So, it is essentially required to know the physiological potentiality of drought tolerance of different rice varieties so that tolerant varieties may be identified. To identify drought tolerant rice varieties the present study was undertaken to evaluate the effect of water stress at reproductive stage of different T aman rice varieties.

OBJECTIVES:

i) To evaluate the performance of the local and modern varieties of T.aman under drought stress condition at the reproductive stage.

ii) To identify suitable T. aman variety (s) to be grown on the lands where water deficit occurs at the grain filling stage of T aman rice in Bangladesh.

CHAPTER 2

REVIEW OF LITERATURE

Rice can be grown under irrigated (lowland) or rainfed (upland or lowland) conditions. Rainfed rice occupies about 45% of the global rice area and accounts for about 25% of the rice production. Drought has been identified as one of the main constraints for improving yield, which presently averages 2.3 t ha^{-1}. According to Garrity *et al*. (1986), 50% of rainfed lowland and all rainfed uplands are drought prone. Severe and mild droughts often occur in predominantly rainfed rice areas such as Northeast Thailand, Laos, Central Myanmar, East and Northeast India.

More than 75% of rice supply comes from 79 million ha of irrigated lowlands. Rice production in the sub-tropical regions of north and central China, Pakistan and northwest India mostly depends on wet season (summer) rainfall with supplementary irrigation (Tuong and Bouman,2016).

Dry season irrigated rice is concentrated in south China, south and east India and the whole of Southeast Asia (Tuong and Bouman, 2016).

It is speculated that wet season irrigated rice areas in north China (2.5 million ha), Pakistan (2.1 million ha) and north and central India (8.4 million ha) will experience "physical water scarcity" by 2025 (Tuong and Bouman, 2016).

Irrigated rice production is also increasingly facing competition from other sectors. The irrigated rice area in China was reduced by 4 million ha between the 1970s and the 1990s (Barker *et al*., 1999). Effect of drought may be reviewed in to following sub-sections:

2.1 Drought susceptibility of rice plants

Severe water stress may result in the arrest of photosynthesis, disturbance in metabolism and finally the death of plant (Jaleel, *et al*., 2008a). It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates and nutrient metabolism and growth promoters.

Farooq, *et al*., 2008, Jaleel, *et al*., 2008b and Razmjoo, *et al*., 2008 stated that water stress is a limiting factor in agriculture production by preventing a crop from reaching the genetically determined theoretical maximum yield (Begg and Turner, 1976). In plants, a better understanding of the morphological and physiological basis of changes in water stress resistance could be used to select or create new varieties of crops to obtain a better productivity under water stress conditions (Nam, *et al*., 2001 and Martinez, *et al*., 2007). The reactions of plants to water stress differ significantly at various organizational levels depending upon intensity, duration of stress, plant species and its growth stages (Chaves, *et al*., 2002; Jaleel, *et al*., 2008c).

Drought stress is characterized by reduction of water content diminished leaf water potential, turgor pressure, stomata activity and decreasement in cell enlargement and growth. Drought stress tolerance is seen in almost all plants but its extent varies from species to species, even within the species. Water deficit and salt stresses are global issues to ensure survival of agricultural crops and sustainable food production (Jaleel, *et al*., 2007). Conventional plant breeding attempts changed over to use physiological selection criteria since they are time consuming and rely on present genetic variability (Zhu, 2002).

Drought stress is considered to be a loss of water, which leads to stomatal closure and limitation of gas exchange. Drought stress in rice affects the crop in different ways. According to Tao *et al*. (2006) rice is the most unproductive crop in terms of water loss. On average, about 2,500 liters of water need to be supplied (by rainfall and/or irrigation) to a rice field to produce 1 kg of rough rice. These 2,500 liters account for all the outflows of water through evapotranspiration, seepage, and percolation (Bouman and Toung, 2001).

Drought stress is a major constraint for about 50% of the world production area of rice. Yield losses from drought in lowland rice can occur when soil water contents drop below saturation (Bouman and Toung, 2001). Rice crops are susceptible to drought, which causes large yield losses in many Asian countries (Bouman and Toung, 2002; Pantuwan *et al*., 2002), however, some genotypes are more drought resistance than others, out-yielding those exposed to the same degree of water stress. The development of drought resistant cultivars may be assisted if mechanisms of drought resistance are known.

Rice is a notoriously drought-susceptible crop due in part to its small root system, rapid stomatal closure and little circular wax during mild water stress (Hirasawa, 1999). Reduction of photosynthetic activity, accumulation of organic acids and osmolytes, and changes in carbohydrate metabolism, are typical physiological and biochemical responses to drought stress (Tabaeizadeh, 1998).

Water deficit also increases the formation of reactive oxygen species (ROS) resulting in lipid peroxidation, protein denaturation and nucleic acid damage with severe consequences on overall metabolism (Hansen *et al*., 2006).

It was reported that upland cultivar IRAT109 has higher values in the important traits of relative performance such as relative yield, relative spikelet fertility, relative biomass, relative grain weight, and relative harvest index than those of lowland cultivar Zhenshan97 under drought stress (Yue *et al*., 2006).

Effect of drought or water stress has been reviewed in details by Singh *et al*. (2010). Water stress is most severe limitation to the productivity of rice (Widawsky and O'Toole, 1990). Drought is a meteorological term and is commonly defined as the inadequacy of water availability including period without significant rainfall that affects the crop growth (Hanson, *et al*., 1995) and soil moisture storage capacity and it occurs when the available water in the soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation. Drought has been recognized as the primary constraint to rainfed rice production (Datta, *et al*., 1975).

Rice is very sensitive to water stress (Tuong and Bouman, 2016). Water scarcity is a severe environmental limitation to plant productivity. Drought induced loss in crop yield may exceeds loses from all other causes, since both the severity and duration of the stress are critical (Farooq *et al*., 2008). According to (DOASL, 2006), stress has been defined as “any environmental factor capable of inducing a potentially injurious strain in plants. Water is a major constituent of tissue, a reagent in chemical reaction, a solvent for and mode of translocation for metabolites and minerals within plant and is essential for cell enlargement through increasing turgor pressure. With the occurrence of water deficits many of the physiological processes associated with growth are affected and under severe deficits, death of plants may result.

Drought may delay the phenological development of the rice plant (Inthapan and Fukai, 1988) and affect physiological processes like transpiration, photosynthesis, respiration and translocation of assimilates to the grain (Turner, 1986). Plant processes that depend on cell volume enhancement are particularly sensitive to water deficit. Leaf expansion and leaf gas exchange rates are two such sensitive processes.

At the plant level, reduced leaf area is probably the obvious mechanism by which plants and crops restrict their water loss in response to drought (Sadras and Milory, 1996). Quantification of physiological and morphological responses of rice to water stress is essential to predict the impact of soil and weather conditions on rice production using process-based crop simulation models. Modeling plant responses to water deficit requires not only an understanding but also quantitative relationships for the effects of water deficits on leaf growth expansion and gas exchange rates (Sadras and Milory, 1996).

Leaf expansion during vegetative stage is very sensitive to water stress. Cell enlargement requires turgor to extend the cell wall and a gradient in water potential to bring water into the enlarging cell. Thus water stress decreases leaf area which reduces the intercepted solar radiation. Rice leaves in general have a very high transpiration rate thus under high radiation levels rice plant may suffer due to midday wilting. Rice plant can transpire its potential rate even when soil moisture was around field capacity. Water stress is one of the most limiting environmental factors to plant productivity worldwide and can be caused by both soil and atmospheric water deficits. Water stress is one of the most limiting factors for plant survival since it regulates growth and development and limits plant productivity. The effect of water stress varies with variety, degree and duration of stress and the growth of the plant (Adejare and Unebesse, 2008).

The effect of water stress on yield decrease of rice is very pronounced during certain period of growth, called the moisture sensitive periods. The most sensitive periods to water deficits are flowering and head development. In an experiment conducted in the Philippines (IRRI, 1973). It has been shown that moisture stress early in the growth of the rice reduced tillering, thereby reduced yield. When moisture stress was extended into reproductive phase, yield loss was significant.

Jana and Ghildyal, (1971) examined the effect of varying soil water regime during different growth phases on rice yield. They reported that the soil water stress applied at any of the growth phases reduced rice grain yield, compared to the continuous flooding irrigation. The ripening phase appeared to be most sensitive to compared to the other phases. Soil water stress during the earlier growth phases (vegetative) appeared the production of effective tillers resulting in the reduction of grain yield, while stress during the later growth phases (reproductive) appeared to affect the reproductive physiology by interfering with pollination, fertilization and grain filling in the reduction of grain yield. The objectives of this study are to examine the effects of water.

2.2 Effect of drought on rice varieties

The effect of water stress may vary with the variety, degree and duration of water stress and the growth stage of the rice crop. Water stress during vegetative stage reduces plant height, tiller number and leaf area. However, the effect during this stage varies with the severity of stress and age of the crop. Long duration varieties cause less yield damage than short duration varieties as long vegetative period could help the plant to recover when water stress is relieved.

Pramanik and Grupta (1989) subjected the varieties to moisture stress at different growth stages particularly during seeding stage. They identified some promising lines had tolerance to the water stress. Singh and Singh (1988) reported varietal differences among the cultivar for moisture stress.

Mahmod *et al*. (2014) carried out an experiment at MARDI Bertam, Seberang Perai, Malaysia to investigate the growth performances of different rice varieties; MRQ74, MR253 (adapted aerobic rice), MR232 (lowland rice). The objective was to assess the effects of different treatments on rice growth in aerobic ecosystem. Rice was cultivated with; soil covered by rice straw mulching (SC), plastic film (PC) and no soil cover (NC) with lowland rice as control. Significantly higher values were obtained for tiller number, panicle number, LAI, above ground biomass, grain weight density and grain yield recorded in SC and response for physiological traits i.e. photosynthesis rate, stomatal conductance and transpiration rate (A, gs, E) was found higher in control. The symptoms of water stress were observed in NC which impaired rice growth and reduced grain yield. Rice responds differently in morphological, physiological and yield component depending on rice varieties and treatments. Results indicated that MRQ74 has superior morphological and physiological characteristics in adaptations to aerobic condition.

Singh *et al*. (2010) stated that in upland adapted varieties (aerobic rice) have improved lodging resistance, as well as highest harvest index and input responsiveness. Aerobic rice can achieve yields of 4–6 tons per hectare and does not require flooded wetland (50 - 70% less water compared to lowland rice) (Qin *et al*., 2010). Generally, irrigated rice tends to become stressed when water is reduced. Thus aerobic rice is the strategy of water saving agriculture.

In a previous study, lowland rice and upland rice were characterized as drought avoidance and drought tolerance, respectively (Lian *et al*., 2004). So the comparison of upland rice and lowland rice appears to be a paradigm for studying the molecular mechanisms in drought resistance. The understanding of the biological function of the novel genes is a more difficult proposition than obtaining just the sequences. This challenge is because the amount of information on amino acid sequences of known proteins in the database does not match the wealth of information on nucleotide sequences being generated through genome projects. Hence, an understanding of gene expression on a global scale would lend considerable insight into the molecular mechanisms of plant development. During the last several years, the field of proteomics has evolved considerably, and has been employed to analyze protein changes in response to environmental changes. Comparative analysis of drought-responsive mechanisms between drought-tolerant and drought-sensitive rice cultivars will unravel novel regulatory mechanisms involved in stress tolerance. Zhenshan97B (Oryza sativa L. ssp. indica), considered to be drought susceptible, is a popular lowland rice variety in China, while IRAT109 (Oryza sativa L. ssp. japonica), considered to be drought tolerant, is an up-land japonica rice variety originally developed in the Ivory Coast and is often used as a drought resistant donor in the breeding program (Nemoto *et al*., 1998).

Rice is particularly susceptible to water deficit at the reproductive stage (Pirdashti *et al*., 2004; Fukai and Lilley, 1994; Zeigler, 1994) and drought causes the greatest reduction in grain yield when stress coincides with the irreversible reproductive process (Cruz and O' Toole, 1984).

2.3 Morphological attributes

2.3.1 Plant height

Rahman *et al*. (2002) reported that plant height was decreased with stress.

Sarvestani *et al*. (2008) conducted a field experiment during 2001-2003 to evaluate the effect of water stress on the yield and yield components of four rice cultivars commonly grown in Mazandaran province, Iran. In northern Iran irrigated lowland rice usually experiences water deficit during the growing season include of land preparation time, planting, tillering stage, flowering and grain filing period. Recently drought affected 20 of 28 provinces in Iran; with the southeastern, central and eastern parts of the country being most severely affected. The local and improved cultivars used were Tarom, Khazar, Fajr and N emat. The different water stress conditions were water stress during vegetative, flowering and grain filling stages and well-watered was the control. Water stress at vegetative stage significantly reduced plant height of all cultivars.

The result of a dry season pot experiment by Sokoto and Muhammad (2014) indicated that water stress had no significant ($P < 0.05$) effect on plant height at 3 Weeks after Planting (WAP). But at tillering resulted to significant ($P < 0.05$) reduction in plant height at 6, 9, 12 and 15 WAP. Control (unstress) was statistically ($P < 0.05$) similar with water stress at flowering and grain filling. The reduction in plant height was as a result of water stress imposed at tillering stage. This was because imposing water stress resulted in low leaf water potentials and reductions in photosynthesis; photosynthetic activity declines because of decreased stomatal opening and the inhibition of chloroplast activity; this reduced the length of the internodes at jointing stage which follows tillering stage. At the time when water stress was imposed at flowering and grain filling, the jointing stage had taken place and plants had reached their maximum height, thus the effect of water stress was ineffective. The significant differences among genotypes for plant height indicate appreciable amount of variability among the genotypes.

Bahattacharjee *et al*. (1973) and De Datta *et al*, (1973) found significant reductions in plant height and grain yield when water stress was imposed at tillering stage.

Water stress resulted to decreased in plant height, number of tillers per plant, total biomass and grain yield (Tantawi and Ghanem, 2001; Tuong *et al*., 2005).

Pramanik and Grupta (1989) subjected the varieties to moisture stress at different growth stages particularly during seeding stage. They identified some promising lines had tolerance to the water stress.

Zubaer *et al*. (2007) carried out a pot experiment with three transplanted aman rice genotypes (Basmoti, Binadhan 4 and RD 2585) at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during July to December 2006, putting them at three different soil water level (100%,70% and 40% FC) to evaluate the performance of the genotypes under varying drought stress. Results showed that at maturity stage, the highest plant was found at 100% FC (139.2 cm) followed by 70%FC and the shortest plant was found at 40% FC (117.1 cm) in all rice genotypes. The results indicate that plant height decreased with increasing soil moisture stress. It might be due to inhibition of cell division or cell enlargement under water stress. Variation in plant height among the genotypes also indicates that different genotypes had different water requirement.

2.3.2 Number of tillers

Rahman *et al.* (2002) reported that tiller number were decreased with stress.

An experiment by Mahmod *et al*. (2014) to investigate the growth performances of different rice varieties, significantly higher values were obtained for tiller number in aerobic ecosystem.

Zubaer *et al*. (2007) carried out a pot experiment to evaluate the performance of the genotypes under varying drought stress. Results showed that, at all growing stages (booting, flowering and maturity), the highest number tillers per hill were obtained from 100% FC and the lowest number of tillers from 40% FC. Number of tillers / hill varies due to different genotypes. Binadhan 4 produced the highest number of tillers per hill, Basmoti and RD 2585 produced the medium and the lowest number of tillers per hill, respectively. The number of tiller per hill was decreased with decreased soil moisture level. Reduced tiller production under lower soil moisture levels might be due to the fact that under water stress, plants were not able to produce enough assimilates for inhibited photosynthesis. Reduction in tiller number might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue (Murty, 1987; Castilo *et al.*, 1987; Cruz *et al.*, 1986; IRRI, 1974; Islam *et al*., 1994a).

The result of a pot experiment conducted by Sokoto and Muhammad (2014), indicated that water stress at tillering resulted in significantly ($P < 0.05$) fewer number of tillers than water stress at flowering or grain filling and control (no stress) which were statistically at par with each other. The fewer tillers recorded at tillering could be as a result of water stress imposed at tillering because non-availability of water at tillering stage resulted in reduction in the amount of intercepted photosynthetically active radiation (PAR). Similarly, during tillering plant produces leaves and due to reduced growth as a result of water stress, the leaf initiation gets decreased and thus, tends to reduce tillering. The effect of variety indicated that FARO 44 differed significantly ($P < 0.05$) with higher number of tillers per plant, while FARO15 and NERICA 2 did not differ significantly with fewer number of tillers plant. The significant differences among genotypes for number of tillers indicate appreciable amount of variability among the genotypes.

Bhattacharjee *et al.* (1973) and De Datta *et al*. (1973) reported that significant reductions in tillers and and grain yield were found when water stress was imposed at tillering stage. Pramanik and Grupta (1989) identified promising lines tolerance to water stress.

2.3.3 Number of leaves

Results a pot experiment Zubaer *et al*. (2007) showed that at booting (106.8), flowering (85) and maturity (58.11) stage, the highest number of leaves was found in 100% FC. The number decreased gradually with increasing soil moisture stress and 40%FC produced the lowest number of leaves per hill in all growing stages. Water stress might inhibit photosynthesis and produce less amount of assimilates which resulted in lower number of leaves (Hossain, 2001).

The result of a pot experiment by Sokoto and Muhammad (2014) indicated that water stress had no significant effect on number of leaves per plant at 3 Weeks after Planting (WAP). Water at tillering resulted to significant ($P < 0.05$) reduction in number of leaves per plant at 6, 9, 12 and 15 WAP. The decline in leaf number is due to death and abscission of leaves at faster rate as no new leaves were initiated during the reproductive stage. Significant reduction of number of leaves at tillering was as a result of water stress imposed at that stage, this was because law leaf water potential resulted in large reductions in photosynthesis, the reductions are caused both by decreases in the photosynthetic activity of a unit of leaf and in the production of new leaf surface.The effect of variety showed that FARO 44 differed significantly ($P < 0.05$) with higher number of leaves per plant, while FARO 15 and NERIC 2 did not differ significantly with fewer number of leaves per plant. The significant ($P < 0.05$) differences among genotypes for plant height indicate appreciable amount of variability among the genotypes.

Rice leaves in general have a very high transpiration rate, thus under high radiation levels rice plant may suffer due to midday wilting (Jongdee *et al*., 1998).

2.3.4 Days to panicle emergence

Most scientists indicated that days to panicle emergence has direct and indirect effect on yield, grains panicle^{-1} and also on plant height.

Iftekharuddaula *et al.* (2001) reported that days to panicle emergence, days to maturity, plant height and spikelets panicle^{-1} had positive and higher indirect effect on grain yield through grains panicle^{-1}.

Sathya *et al.* (1999) studied on eight quantitative traits in rice (*Oryza sativa*). Days to panicle emergence was the principal character responsible for grain yield plant^{-1} followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield.

Padmavathi *et al.* (1996) suggested that days to panicle emergence had higher positive direct effects on number of panicles plant^{-1} and panicle length. Days to 50% flowering, number of grains panicle^{-1} and plant height had positive direct effects on grain yield.

Roy *et al.* (1989) observed that generally the plants which needed more days for panicle emergence gave more yield.

2.3.5 Days to maturity

Patnaik and Mohanty (2006) showed that there was a wider variation in the maturity duration of varieties. The flowering duration was the longest in CR 874-23 (153 days) followed by CR 758-16 (151 days). The earliest variety found to be Swarna (110 days).

Sikuku *et al.* (2010) stated that water deficit affects the days to maturity and grain yield by decreasing tiller number, panicle length and field grain percentage of rice varieties.

2.4 Yield contributing characters and yield

2.4.1 Number of panicles

Mahmod *et al*. (2014) carried out an experiment to assess the effects of different treatments on rice growth in aerobic ecosystem. Significantly higher values were obtained for panicle number in aerobic ecosystem.

Lee *et al.* (1992) showed that the number of spikelet panicle^{-1}, panicle length and grain yield panicle^{-1} were higher in the main tiller and decreased with increasing tiller order with delaying panicle emergence in rice.

Rahman *et al.* (2002) reported that panicle number and yield were decreased with stress.

Bahattacharjee *et al*., (1973) and De Datta, (1973) found significant reductions in panicles numbers as well as grain yield when water stress was imposed at tillering stage.

2.4.2 Panicle length

Rahman *et al.* (2002) reported that panicle length and yield were decreased with stress.

In order to understand rice strategies in response to drought condition in the field, the drought-responsive mechanisms at the physiological and molecular levels were studied by Ji *et al*. (2012) in two rice genotypes with contrasting susceptibility to drought stress at reproductive stage. After 20 d of drought treatment, the osmotic potential of leaves reduced 78% and 8% in drought susceptible rice cultivar Zhenshan97B and tolerant rice cultivar IRAT109, respectively. The panicle lengths had no obvious changes in drought stressed Zhenshan97B and IRAT109, suggesting that drought stress impose less effect on assimilate translocation from leaf to vegetative growth of panicles.

Oka and Saito (1999) found that there were relationships with parental values for panicle length, grains panicle^{-1} and panicle emergence date.

Ramalingam *et al.* (1994) observed that varieties with long panicles, higher no. of filled grains panicle^{-1} and more primary rachis would be suitable for selection because these characters had higher positive association with grain yield and were correlated among themselves.

2.4.3 Total grains panicle^{-1}

Yuan *et al.* (2005) studied the variation in the yield components of 75 high quality rice cultivars. Among the yield components, the greatest variation was recorded for number of grains panicle^{-1} in *indica* rice, and no. of panicles plant^{-1} in *japonica* rice.

2.4.4 Number of filled grains panicle^{-1}

Results of a pot experiment carried out by Zubaer *el al.* (2007) showed that the highest number of filled grains per panicle was found at 100% FC followed by 70% FC and the lowest number of filled grains per panicle was observed at 40%FC in all the genotypes. Binadhan 4 with 100% FC produced the highest number of filled grains per panicle and the lowest was obtained from the treatment combination, RD2585 X 40%FC. The results also showed that the number of filled grains per panicle decreased under lower soil moisture level. The decreased filled grains per panicle under lower soil moisture levels was attributed to inhibition of translocation of assimilate to the grains due to moisture stress (Hossain, 2001; O’Toole and Moya, 1981).

Srivastava and Tripathi (1998) found that the increase in grain yield in local check variety in comparison with hybrid might be attributed to the increased fertile grains panicle^{-1}.

Shrirame and Mulley (2003) conducted an experiment on variability and correlation of different biometric and morphological plant characters with grain yield. Grain yield was significantly correlated with number of filled grains panicle^{-1}.

Rahman *et al.* (2002) reported that number of filled grains per panicle and yield were decreased with stress.

Ganesan (2001) experimented with 48 rice hybrids. Filled grains panicle^{-1} (0.895) had the highest significant positive direct effect on yield plant^{-1}

followed by number of tillers plant^{-1} (0.688), panicle length (0.167) and plant height (0.149).

2.4.5 Number of unfilled grains panicle^{-1}

Results of a pot experiment carried out by Zubaer *el al*. (2007) showed that in all the rice genotypes, number of unfilled grains was increased with reduced soil moisture levels. But the degree of increment was different in different genotypes. Binadhan 4 produced relatively more unfilled grain (33.13% for 70%FC and 77.21% for 40%FC) than Basmoti and RD 2585 under water stressed condition. Increased unfilled grains per panicle under lower soil moisture level might be due to inactive pollen grain for dryness, incomplete development of pollen tube; insufficient assimilates production and its distribution to grains (Hossain, 2001; Yambao and Ingram, 1988; Begum, 1990; Islam *et al.*, 1994a).

2.4.6 1000-grain weight

1000-grain weight which is an important yield-determining component, is a genetic character least influenced by environment (Ashraf *et al.*, 1999).

Rahman *et al.* (2002) reported that 1000-grain weight and yield were decreased with stress.

Mahmod *et al*. (2014) carried out an experiment to investigate the growth performances of different rice varieties. Significantly higher values were obtained for grain weight density in aerobic ecosystem.

Zubaer *et al*. (2007) carried out a pot experiment to evaluate the performance of the genotypes under varying drought stress. Results showed that the 1000 grain weight was reduced with reduced soil moisture levels. It was anticipated that the lower soil moisture might had decreased translocation of assimilates to the grain which lowered grain size. But the degree of reduction in 1000 grain size weight was different in different genotypes. Percent reduction was lower in

Binadhan 4 (4.14 to 6.37%) than in Basmoti (6.75to 12.5%) and RD 2585 (4.57 to 14.64%). Islam *et al.* (1994b), Vijayakumar *et al.* (1997), O'Toole *et al.* (1981) and Tsuda and Takami (1991) also stated that water stress reduced grain weight.

2.4.7 Grain yield

Rahman *et al.* (2002) reported that plant height, tiller number, panicle number, panicle length, number of filled grains per panicle, 1000 –grain weight, harvest index (HI), total dry matter (TDM) and yield were decreased with stress.

Zubaer *et al.* (2007) carried out a pot experiment to evaluate the performance of the genotypes under varying drought stress. Results showed that all the genotypes produced the highest grain yield per hill at 100% FC followed by 70% FC and the lowest yield per hill was obtained at 40%FC indicating that grain yield per hill decreased in decreasing soil moisture level. Reduced grain yield under lower soil moisture levels might be due to inhibition of photosynthesis and less translocation of assimilates towards grain due to soil moisture stress (Castilo *et al.*, 1987; Hossain, 2001).

Sarvestani *et al*. (2008) stated that water stress at flowering stage had a greater grain yield reduction than water stress at other times. The reduction of grain yield largely resulted from the reduction in fertile panicle and filled grain percentage. Water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% on average in comparison to control respectively. The yield advantage of two semi-dwarf varieties, Fajr and Nemat, were not maintained under drought stress.

Mahmod *et al.* (2014) carried out an experiment to investigate the growth performances of different rice varieties. Significantly higher values were obtained for grain yield in SC.

The result of a dry season pot experiment by Sokoto and Muhammad (2014) indicated that water stress at flowering and grain filling resulted in significant ($P < 0.05$) reduction in grain yield. Yield reduction due to water stress could be as a result of reduction in photosynthesis and translocation. There was a linear relationship between available water and yield, where reduction in available water limits evapotranspiration and consequently reduced yield, as reported by several researchers (Shani and Dudley, 2001; Boonjung and Fukai, 1996) reported that drought stress at duration of filling grains period with acceleration in ripening time, casing to growth period duration and filling grains decreased. The effect of variety on grain yield indicated that Faro 44 differed significantly ($P < 0.05$) with higher grain yield, while FARO15 and NERICA 2 did not differ significantly with lower grain yield. The significant differences among genotypes for plant height indicate appreciable amount of variability among the genotypes.

Hassan *et al.* (2003) found that grain yield is a function of interplay of various yield components such as number of productive tillers plant^{-1}, spikelets panicle^{-1} and 1000-grain weight.

Shrirame and Mulley (2003) observed that grain yield exhibited a very strong positive correlation with harvest index. Grain yield was also significantly correlated with dry matter weight hill^{-1}, effective tillers hill^{-1} and no. of filled grains panicle^{-1}.

Srinivasulu *et al*. (1999) noted that planting 1 seedling hill^{-1} in case of rice gave higher grain yield comparable to that of 2 seedlings hill^{-1}.

2.4.8 Straw yield

Summers *et al.* (2003) trialed with eight common California rice cultivars at multiple sites for the 1999 and 2000 seasons and found variability in straw quantity and quality which can have critical impacts on biomass industries. The length of the pre-heading period was the strongest indicator for straw yield.

Harvested straw yield is also strongly affected by cutting height with a non-linear distribution resulting in nearly half of the straw biomass occurring in the lower third of the plant.

2.4.9 Biological yield

Peng *et al.,* (2000) concluded that the increasing trend in yield of cultivars due to the improvement in harvest index (HI), while increase in total biomass was associated with yield trends for cultivars–lines.

2.4.10 Harvest index

Senapati *et al.* (2004) observed adaptability of aman paddy under sundarban areas of West Bengal. Number of days to maturity and Grain yield were evaluated in 40 aman rice genotypes grown under rainfed lowland condition of Kakdwip, West Bengal, India during the kharif seasons of 1997, 1998, 1999 and 2000. They observed significant genetic variation and genotype-environment interaction for both traits. They found 21 genotypes were stable for number of days to maturity. Of these, CR-626-26-2-3, CR-383-10, Dudhraj, Lilabati, Dhusari and Bogamanohar were late matured variety, which was desirable for aman rice cultivation in Sundarban areas. Twenty-two genotypes were highly stable for grain yield and widely adapted to Sundarban areas.

Rahman *et al.* (2002) reported that harvest index (HI) and yield were decreased with stress.

Results of a pot experiment by Zubaer *et al*. (2007) showed that the harvest index of all rice genotypes was reduced with reduced moisture level. It might be due to the fact that water stress affected the translocation towards the grain which was also observed due to the varieties. HI value under lower moisture level was different in different genotypes. It was higher in Basmoti (13.15 to36.84%) and RD2585 (12.5 to 28.12%) than that in (11.11 to 20.0 %).

Sokoto and Muhammad (2014) conducted a dry season pot experiment and the result indicated that water stress at flowering and grain filling resulted in lower HI than water stress at tillering and no stress control which are statistically similar with higher HI. Decrease in HI could be largely due to water stress which resulted to decrease in translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. High HI indicate the efficient translocation of assimilates towards sink. Lower HI values under water stress at flowering and grain filling stages indicate that it was more harmful in translocation of assimilates towards the grains. This is in accord with that of Sharma *et al*. (2003) who observed highest HI well irrigated genotypes compared to that of the genotypes which were grown under water stress condition the result indicated that water stress at flowering and grain filling resulted in lower HI than water stress at tillering and no stress control which are statistically similar with higher HI. Decrease in HI could be largely due to water stress which resulted to decrease in translocation of assimilates to the grains, which lowered grain weight and increased the empty grains. High HI indicate the efficient translocation of assimilates towards sink. Lower HI values under water stress at flowering and grain filling stages indicate that it was more harmful in translocation of assimilates towards the grains. This is in accord with that of who observed highest HI well irrigated genotypes compared to that of the genotypes which were grown under water stress condition. The effect of variety showed that Faro 44 differed significantly ($P < 0.05$) with higher harvest index, while FARO 15 and NERICA 2 did not differ significantly with lower harvest index. The significant differences among genotypes for harvest index indicate appreciable amount of variability among the genotypes.

Jiang *et al.* (1995) evaluated 10 varieties for yield components. The yield increase of dwarf over tall varieties mainly resulted from higher harvest index, while the yield increase of hybrid rice over the dwarf varieties was mainly due to higher biomass production.

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methods of the experiment with a brief description on experimental site, climate, soil, land preparation, planting materials, experimental design, land preparation, fertilizer application, transplanting, irrigation and drainage, intercultural operation, data collection, data recording and their analysis. The details of the materials and methods have presented below:

3.1 Experimental site

The experiment was conducted at the Agronomy experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and at an elevation of 8.4 m from sea level (Anon., 1988).

3.2 Soil

The experiment was carried out in earthen pots (12 inch dia) and in land. The pot was filled with typical rice growing soil of the Madhupur Tract, AEZ No. 28 (Appendix I). It has non-calcarious dark grey soil in a medium high land with soil pH 5.6 and 0.45% organic carbon. The land was well drained with good irrigation facilities. The morphological characters of soil of the experimental plots are as following - Soil series: Tejgaon, General soil: Non-calcareous dark grey (Appendix II). The physicochemical properties of the soil are presented in Appendix III.

3.3 Climate and weather

The experimental site was under the sub-tropical climate characterized by three distinct seasons. The monsoon or rainy season extending from May to October, with high temperature and humidity with heavy rainfall; the winter or dry season from November to February, with relatively low temperature and the pre-monsoon season from March to April, with some rainfall and irregular breeze.

Information in respect of monthly maximum and minimum temperature, relative humidity, rainfall and sunshine of the experimental site for the time of experimentation was collected from Bangladesh Meteorological Department, Agargaon and is presented in Appendix IV.

3.4 Crop / Planting materials

A total of sixteen local and modern rice varieties were used as planting materials. Among them, four varieties viz. BRRI dhan33, BRRI dhan34, BRRI dhan62 and BU dhan1 were modern varieties. BRRI dhan33, BRRI dhan34 and BRRI dhan62 were collected from BRRI; BU dhan1 was collected from BSMRAU and local varieties were collected from local farmers of southern districts. The local varieties used were-

i. Kartik Shail,	vii. Changshai,
ii. Doodh Kalam,	viii. Basmati Shakkar Khanna,
iii. Nakhuchi Mota,	ix. Dholi Chikon,
iv. Kartik Balam,	x. Rani Salute,
v. Lal Mota,	xi. Ghashful Chikon and
vi. Kalo Khaia,	xii. Moulata.

3.5 Details of the Experiment

3.5.1 Experimental treatments

One factor experiment was conducted in two different condition- in pot and in plot, to evaluate the performance of local varieties comparing to the modern rice varieties in aman season in stress and normal field condition.

3.5.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications both in pot (stressed condition) and field (non-stressed condition). The layout of the experiment was prepared for distributing the variety. The experimental field was divided into 3 blocks. Each block was again divided into 16 plots. The total numbers of unit plots of the experiment were 48 (16× 3). The size of the unit plot was 2 m × 1.5 m (3 m^2). There were 0.75 m width and 10 cm depth for drains between the blocks. Each treatment was again separated by drainage channel of 0.5 m width and 10 cm depth. The treatments were randomly distributed to each block and each pot.

3.6 Growing of crops

3.6.1 Raising Seedlings

3.6.1.1 Seed collection

The seeds of the test crops were collected from BRRI, BSMRAU and trusted local farmers.

3.6.1.2 Seedling raising

Rice seeds were soaked in water for 24 hours and then incubated for 48 hours. Nursery bed was prepared on 28 July 2014, sprouted seeds were sown in the wet nursery bed. Appropriate care was taken to raise the seedlings in the nursery bed. Irrigation was done but no manuring and fertilization was done and weeds were removed from the nursery bed, as per necessity.

3.6.2 Preparation of the main field

The selected experiment plot was opened in 21 August, 2014 with a power tiller and was exposed to the sun for a week. Then the land was harrowed, ploughed and cross-ploughed several times followed by laddering on 27 August, 2014. Finally a desired tilth was obtained by removing weeds and stubbles for transplanting of seedlings.

For pot experimentation, required amount of clods and weed free, properly tilted soil were used to fill each pot.

3.6.3 Fertilizer application

Recommended doses of fertilizers such as Urea, TSP, MoP, Gypsum and Zinc sulfate were used as sources for N, P, K, S and Zn respectively, were applied to the each plot and each pot. On 27 August, 2014, the full doses of all fertilizers and one third of urea were applied as basal dose to the individual plot during final land preparation through broadcasting method and to individual pot during pot preparation. Urea was applied in two split dose at 30 and 50 days after transplanting (DAT).

The doses of fertilizers with their sources are given below:

Nutrient	**Source**	**Dose (kg ha^{-1})** **(of column 1)**
N (Nitrogen)	Urea (46% N)	200
P (phosphorus)	TSP (20% P_2O_5)	30
K (potassium)	MoP (50% K_2O)	100
S (Sulphur)	Gypsum (18% S)	75
Zn (Zinc)	Zinc sulphate (36% Zn)	15

Source: Modern Rice Cultivation, BRRI (2013)

Soil surface area was calculated to use fertilizers following the dose mentioned in above table.

As such the pots were fertilized with cow dung 40g/pot, urea 1.72g/pot, TSP 1.44 g/pot, MP 0.8g/pot corresponding to 15 ton/ha cow-dung, 215 kg urea/ha, 180 kg TSP/ha and100kg MP/ha. Whole amount of TSP, MoP and one- third of the Urea were applied as basal dose. The remaining two third of the Urea were applied in two equal splits in each pot at 30 and 50 days after transplanting (DAT).

3.6.4 Uprooting and transplantation of seedlings

Seedlings were raised on nursery bed and 30 days old seedlings were transplanted on 27 august in 2014, both in plot and pot.

3.6.5 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.6.5.1 Irrigation and drainage

In field (no drought stress condition)

The experimental field was irrigated with sufficient water which was maintained throughout the crop growth period. Flood irrigations were given when was necessary to maintain 3–5 cm water in the rice field. For immediate release of excess rainwater and to top-dress urea, a good drainage facility was maintained in the field.

In pot (drought stress condition)

The objectives of this study was to compare the yield producing capabilities of the local and some improved short duration T. aman varieties under drought stressed condition. Drought stress was imposed by limiting the supply of irrigation water in pots after the onset of reproductive stage especially at booting. Pots were irrigated once a day, but was supplemented in case of no rainfall at the vegetative stage. There was a hole at the bottom of each pot through which the irrigated water leached down due to gravitational force. At the early plant growth, there was uninterrupted supply of water in the pots as it was rainy season. However, after panicle emergence the occurrence of rainfall ceased and the plants grown in the pots suffered from water scarcity although water was provided once a day.

As this is stress condition, irrigation was not maintained throughout the crop growth period and adequate water was not supplied regularly.

3.6.5.2 Gap filling

Subsidiary gap filling was done at 7–10 days after transplanting (DAT) as per necessity.

3.6.5.3 Weeding

Three weeding done on 10, 30, 45 days after transplanting to keep the crops free from weeds.

3.6.5.4 Plant protection measures

The plants were infested with rice stem borer, leaf roller and rice bug to some extent; to control them insecticides such as Diazinon and Ripcord @ 10 ml/10 liter of water for 5 decimal lands were applied both in plot and in pot. During the grain-filling period, for controlling birds proper watching was done, especially during morning and afternoon.

3.7 Harvesting and post-harvest operation

The rice plants were harvested depending upon their maturity. Harvesting was done manually from each plot and pot. Harvesting was started at 89 DAT and continued up to 118 DAT according to varieties. Maturity of crop was determined when 80% of the grains become golden yellow in color and leaves of the local varieties dried completely. The harvested crop of each plot and each pot was bundled separately, tagged properly and brought to the threshing floor for recording grain and straw yield. Fresh weight of grain and straw were recorded plot and pot wise. The grains were cleaned and sun dried. The weight was adjusted to a moisture content of 14%. Straw was also sun dried properly.

3.8 Recording of plant data

During the study period, following data were recorded on physical characters and yield components both from plot and pot.

3.8.1 Crop growth characters

a) Plant height (cm)

b) Total tillers hill^{-1} (no.)

c) Total leaves hill^{-1}

d) Days to Panicle emergence

e) Days to maturity

3.8.2 Yield contributing characters

a) Panicle length (cm)

b) Grains panicle^{-1} (no.)

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

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

e) Weight of 1000-grains (g)

3.8.3 Harvest yields

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

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

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

d) Harvest index (%)

3.8.4 Procedure of recording data

3.8.4.1 Plant height (cm)

The height of plant was taken in centimeter (cm) at the time of 15, 45, 75 DAT. Data were recorded as the average of same 5 hills selected at random from the outer side rows of each plot and from the plants of each pot. Plant height was measured from the ground level to the top of the leaf of plant**.** The average height of five hills was considered the height of the plant for each plot.

3.8.4.2 Total tillers hill^{-1} (no.)

The number of total tillers hill^{-1} were counted from selected hills and from each pot at 15, 45, 75 DAT.

3.8.4.3 Total leaves hill^{-1} (no.)

Leaf numbers were counted from selected hills and from each pot at 15, 45, 75 DAT. At harvest, leaves of local varieties were completely dried out, so it was not possible to count leaf numbers at harvesting.

3.8.4.4 Days to Panicle emergence, DAT

Panicle emergence date was recorded from each plot when 80% plant emerges panicle. Similarly, when panicle emerges in each pot, date was recorded.

3.8.4.5 Days to maturity, DAT

Days to maturity was considered when the 80% grains of the plants within a plot or pot become golden yellow in color. The number of days to maturity was recorded from the date of sowing.

3.8.4.6 Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

3.8.4.7 Grains panicle^{-1} (no.)

The total number of grains was collected from the randomly selected 5 panicles in each plot and from plants of each pot. Then average number of grains panicle^{-1} was calculated.

3.8.4.8 Filled Grains panicle^{-1} (no.)

Presence of kernel in the spikelet was considered as filled grain. The number of total filled grains present on each panicle was recorded.

3.8.4.9 Unfilled Grains panicle^{-1} (no.)

Panicle was considered unfilled, if no kernel was present there in. The number of total unfilled grains present on each panicle was recorded.

3.8.4.10 Weight of 1000-grains (g)

One thousand cleaned dried seeds were counted randomly from the total cleaned harvested grains of each individual plot and pot. Then the air dried grains were weighed with a digital electric balance. The weight was adjusted at 14% moisture content and expressed in grams (gm).

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

Plants of central 1m^2 area were harvested and grains were separated from the plant. The grains were cleaned, threshed, dried and weighed properly. After drying the weight of the grain was measured and the weight was converted as t ha^{-1}.

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

The dry weight of straw of the whole plot was harvested, cleaned, threshed, dried and weighed. Finally, straw yield plot^{-1} was converted and expressed in t ha^{-1} on 14% moisture basis.

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

Biological yield is the summation of grain yield and straw yield. It was calculated as the following formula:

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

3.8.4.14 Harvest index (%)

Harvest Index means the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total dry weight)}} \times 100$$

It was expressed in percentage.

3.9 Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques to obtain the level of significance by using Statistix 10 computer package program. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained from the present study. The results have been presented, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

4.1 Growth parameters

4.1.1 Plant height (cm)

Significant effect on plant height was found in varieties of Aman rice in two different conditions- stressed and non-stressed (Table 1 and Appendix V). The increasing pattern of plant height was almost similar in all varieties.

Results showed that at 15 DAT, under non-stressed condition, Doodh Kalam showed the highest plant height (94.50 cm) which was statistically similar to Nakhuchi Mota, Dholi Chikon and Lal Mota (94.28, 93.85 and 93.83 cm respectively) and under stressed condition, Lal Mota showed the highest plant height (71.10 cm) which was closely followed by Basmoti Shakkar Khanna (70.47 cm). At 45 DAT, under non-stressed condition, highest plant height was also observed in Doodh Kalam (139.83 cm) which was statistically similar to Lal Mota (139.70 cm) and under stressed condition, Basmoti Shakkar Khanna showed highest plant height (117.67 cm). Kalo Khaia produced the tallest plant at 75 DAT (184.83 cm), under non-stressed condition. Under stressed condition, the highest plant height at 75 DAT was recorded from both Kartik Balam and Basmoti Shakkar Khanna (139.50 cm) which was statistically similar to Rani Salute and Ghashful Chikon (137.17 and 136.33 cm, respectively).

On the other hand, under non-stressed condition, the shortest plant was observed from BRRI Dhan62 at 15, 45 and 75 DAT (57.87, 97.67 and 102.cm, respectively) which was statistically similar to BU Dhan1 at 15 and 45 DAT (61.25 cm and 99.00 cm, respectively) . Under stressed condition BU Dhan1 produced the shortest plant (47.00 cm) at 15 DAT and BRRI Dhan62 at 45 and 75 DAT (72.33 and 76.17 cm, respectively).

The results supported the findings of Sokoto and Muhammad, (2014) who observed various plant heights due to water stress among different varieties.

4.1.2 Number of tillers hill^{-1}

The production of tillers hill^{-1} was significantly influenced by the tested different local and modern varieties. (Table 2 and Appendix VI) under stressed and non-stressed condition. The tiller number of the varieties increased with the advancement of growth stages. But it was not consistent as reduced number of tillers hill^{-1} was observed at 90 DAT, prior to harvesting in some of the varieties. Death of some tillers was the reason behind the reduction of effective tillers.

Under non-stressed condition, Nakhuchi Mota showed the highest number of tillers hill^{-1} at 15 and 45 DAT (16.67 and 20.33, respectively) which was statistically similar with Rani Salute at 45 DAT (20.00). Under stressed condition, Moulata showed highest tillers (6.33) at 15 DAT and Rani Salute showed the highest number of tillers hill^{-1} at 45 DAT (16.67), which was statistically similar with Moulata and Kartik Shail (19.67 in both). At 75 DAT, BU Dhan1 produced the highest number of tillers hill^{-1} (17.67) under non-stressed condition, that was closely followed by Doodh Kalam (15.67) and Lal Mota produced the highest number of tillers hill−1 (20.33) under stressed condition, which was statistically similar with Rani Salute and Ghashful Chikon.

On the other hand, under non-stressed condition, minimum tillers hill^{-1} at 15 DAT and 45 DAT were recorded in Kartik Balam (7.67 and 10.00, respectively). At 45 DAT, that was statistically similar with Ghashful Chikon and Basmoti Shakkar Khanna (10.67 and 11.67, respectively). At 75 DAT minimum tillers hill^{-1} were recorded in Moulata and BRRI Dhan33 (8.67). Under stressed condition, Nakhuchi Mota and BRRI Dhan33 showed the minimum tillers hill^{-1} (3.33), at 15 DAT and BRRI Dhan33 produced the lowest number of tillers hill^{-1} (10.00) which was statistically similar with Nakhuchi Mota (10.33) and at 75 DAT lowest number of tillers hill^{-1} (9.00) was observed in BRRI Dhan33.

Similar trend of tillering habits with different varieties of rice due to water stress has been reported by Murty (1987), Castilo et al. (1987), Cruz et al. (1986), IRRI (1974) and Islam et al. (1994a).

4.1.3 Number of leaves hill^{-1}

Number of leaves hill^{-1} was significantly influenced by the tested varieties (Table 3 and Appendix VII) under stressed and non-stressed condition. The leaf number of the varieties increased with the advancement of growth stages, but it was not consistent as the leaves of local varieties were completely dried of at maturity.

Under non-stressed condition, Rani Salute showed the highest number of leaves hill^{-1} at 15 and 45 DAT (10.67 and 71.67, respectively). The lowest number of leaves hill^{-1} was recorded in Kartik Balam at 15 and 45 DAT (6.00 and 41.00, respectively).

On the other hand, under stressed condition, maximum leaves hill^{-1} was recorded in Dholi Chikon (11.00), at 15 DAT, which was statistically similar with Kartik Balam and Changshai (10.33 and 10.00, respectively). At 45 DAT, Moulata produced maximum leaves hill^{-1} (70.00), which was statistically

Table 1: Plant height of selected local and modern varieties of T. aman rice under stressed and non-stressed condition

Treatment	Plant height (cm)					
	15 DAT		45 DAT		75 DAT	
	Stressed condition	Non-stressed condition	Stressed condition	Non-stressed condition	Stressed condition	Non-stressed condition
Kartik Shail	57.33	75.76	105.00	117.67	114.50	152.50
Doodh Kalam	62.17	94.50	105.00	139.83	131.67	177.17
Nakhuchi Mota	61.70	94.28	105.67	137.00	131.33	181.17
Kartik Balam	62.17	85.60	104.00	127.83	139.50	175.33
Lal Mota	71.10	93.83	106.00	139.70	129.00	176.00
Kalo Khaia	63.13	87.96	113.00	133.83	135.50	184.83
Changshai	64.03	77.62	110.67	120.17	135.50	155.83
Basmoti Shakkar Khanna	70.47	80.52	117.67	122.00	139.50	172.00
Dholi Chikon	65.37	93.85	100.67	138.00	120.50	158.33
Rani Salute	61.83	87.42	108.67	130.17	137.17	170.67
Ghashful Chikon	60.30	81.29	104.33	123.70	136.33	166.33
Moulata	65.73	88.17	110.67	131.17	127.50	148.67
BRRI Dhan34	64.37	73.52	106.67	114.67	115.00	131.33
BRRI Dhan33	56.27	68.11	92.13	109.33	92.67	119.67
BRRI Dhan62	61.13	57.87	72.33	97.67	76.17	102.00
BU Dhan1	47.00	61.25	86.67	99.00	102.83	109.50
LSD at 5% level	8.6906	3.4339	9.8401	8.3030	15.236	10.559
CV (%)	8.39	2.53	5.73	4.02	7.44	4.08

Mean (±SD) was calculated from three replicates for each treatment. Values in a column are significantly different at $p \leq 0.05$ applying LSD.

Table 2: Number of tillers hill^{-1} of selected local and modern varieties of T. aman rice under stressed and non-stressed condition

Treatment	Tiller no/plant					
	15 DAT		45 DAT		75 DAT	
	Stressed condition	Non-stressed condition	Stressed condition	Non-stressed condition	Stressed condition	Non-stressed condition
Kartik Shail	5.33	13.00	19.67	16.33	19.33	13.67
Doodh Kalam	5.33	14.67	16.33	18.00	16.33	15.67
Nakhuchi Mota	3.33	16.67	10.33	20.33	12.67	13.00
Kartik Balam	5.33	7.67	16.00	10.00	14.67	15.33
Lal Mota	5.33	11.33	17.33	14.00	20.33	12.00
Kalo Khaia	5.67	13.67	18.67	17.00	18.67	11.00
Changshai	4.67	10.33	18.00	13.00	19.00	11.00
BasmotiShakkar Khanna	4.67	9.67	18.67	11.67	17.67	15.00
Dholi Chikon	5.00	10.33	17.67	13.00	18.00	13.67
Rani Salute	5.33	16.00	21.33	20.00	20.00	10.33
GhashfulChikon	5.67	8.67	18.67	10.67	19.67	11.00
Moulata	6.33	13.00	19.67	16.33	19.00	8.67
BRRI Dhan 34	5.67	12.33	13.67	15.00	13.67	15.00
BRRI Dhan 33	3.33	11.33	10.00	14.00	9.00	8.67
BRRI Dhan 62	4.00	14.00	11.33	17.67	13.67	14.00
BU Dhan1	5.33	14.00	10.67	17.67	10.67	17.67
LSD at 5% level	2.1047	6.6075	8.2343	8.0007	6.8113	6.7891
CV (%)	25.14	32.24	30.62	31.38	24.91	31.67

Mean (±SD) was calculated from three replicates for each treatment. Values in a column are significantly different at $p \leq 0.05$ applying LSD.

Table 3: Number of leaves hill^{-1} of selected local and modern varieties of T. aman rice under stressed and non-stressed condition

Treatment	Leaf no/plant			
	15 DAT		45 DAT	
	Stressed condition	Non-stressed condition	Stressed condition	Non-stressed condition
Kartik Shail	8.00	10.33	59.67	67.00
Doodh Kalam	9.33	9.33	61.00	63.00
Nakhuchi Mota	6.00	9.33	49.33	60.33
Kartik Balam	10.33	6.00	64.33	41.00
Lal Mota	9.00	10.00	62.67	58.33
Kalo Khaia	9.67	9.33	66.67	63.33
Changshai	10.00	7.67	66.33	53.00
Basmoti Shakkar Khanna	9.67	7.33	57.67	48.00
Dholi Chikon	11.00	7.33	69.33	49.33
Rani Salute	9.00	10.67	62.67	71.67
Ghashful Chikon	7.67	7.00	61.00	47.33
Moulata	9.67	10.00	70.00	66.33
BRRI Dhan34	8.00	7.67	50.33	52.67
BRRI Dhan33	6.33	7.33	32.67	47.67
BRRI Dhan62	6.33	8.00	30.33	54.00
BU Dhan1	8.00	8.67	48.67	58.33
LSD at 5% level	3.4438	2.99	15.718	20.203
CV (%)	23.94	21.10	16.52	21.51

Mean (±SD) was calculated from three replicates for each treatment. Values in a column are significantly different at $p \leq 0.05$ applying LSD.

similar with Dholi Chikon, Kalo Khaia and Changshai (69.33, 66.67 and 66.33, respectively). At 15 DAT, Nakhuchi Mota showed the minimum leaves hill^{-1} (6.00) and at 45 DAT BRRI Dhan62 showed lowest number of leaves hill−1 (30.33) which was statistically similar with BRRI Dhan33 (32.67).

The result have supported Hossain, (2001) who have suggested that water stress might inhibit photosynthesis and produce less amount of assimilates which resulted in lower number of leaves.

4.1.4 Days to panicle emergence

The number of days taken for panicle emergence differs significantly in different varieties, under stressed and non-stressed condition, under the present study (Table 4 and Appendix VIII). Under stressed condition, among the local varieties, Kartik Shail showed minimum days to panicle emergence (40 days) and among the modern varieties, BRRI Dhan62 showed earlier panicle emergence (33 days). Lal Mota showed delayed panicle emergence (79 days).

Under non-stressed condition, Kartik Shail showed minimum days to panicle emergence (38 days), among the local varieties and among the modern varieties, BRRI Dhan62 showed earlier panicle emergence (28 days). Both Lal Mota and Rani Salute showed delayed panicle emergence (76 days).

4.1.5 Days to Maturity

Both under stressed and non-stressed condition, days to maturity among the local varieties ranged from 89 days (Kartik Shail, Doodh Kalam, Kartik Balam and Moulata) to 118 days (Nakhuchi Mota, Lal Mota and Basmoti Shakkar Khanna) (Table 4 and Appendix VIII). In case of modern varieties; BRRI Dhan33, BRRI Dhan34, BRRI Dhan62 and BU Dhan1 matured early (90 days). From the table it can be said that most of the local varieties mature at the same time or slightly late compared to the modern varieties under the present study.

Table 4: Days to panicle Emergence and growth duration of selected local and modern varieties of T. aman rice under stressed and non-stressed condition

Treatment	Days to panicle Emergence, DAT		Days to Maturity, DAT	
	Stressed condition	**Non-stressed condition**	**Stressed condition**	**Non-stressed condition**
Kartik Shail	40	38	89.67	89.00
Doodh Kalam	68	67	89	88.33
Nakhuchi Mota	76	74	116.67	116.67
Kartik Balam	66	64	90.67	89.33
Lal Mota	79	76	117.33	116.67
Kalo Khaia	69	66	110.33	109.67
Changshai	70	70	111.33	110.33
Basmoti Shakkar Khanna	73	69	117.67	117.00
Dholi Chikon	70	70	109.67	109.67
Rani Salute	78	76	110.33	109.33
Ghashful Chikon	73	71	111.67	111.33
Moulata	70	68	89.33	90.33
BRRI Dhan34	51	51	88.67	89.33
BRRI Dhan33	45	43	91.33	89.67
BRRI Dhan62	33	28	89.67	90.67
BU Dhan1	64	61	91.00	88.67
LSD at 5% level	3.6807	1.6001	1.4534	1.1873
CV (%)	3.45	1.55	0.86	0.70

Mean (±SD) was calculated from three replicates for each treatment. Values in a column are significantly different at $p \leq 0.05$ applying LSD.

4.2 Yield contributing parameters

4.2.1 Panicle length (cm)

Panicle length was significantly influenced by different rice varieties under stressed and non-stressed condition (Figure 1 and Appendix IX). Different length of panicle was observed due to varietal performance.

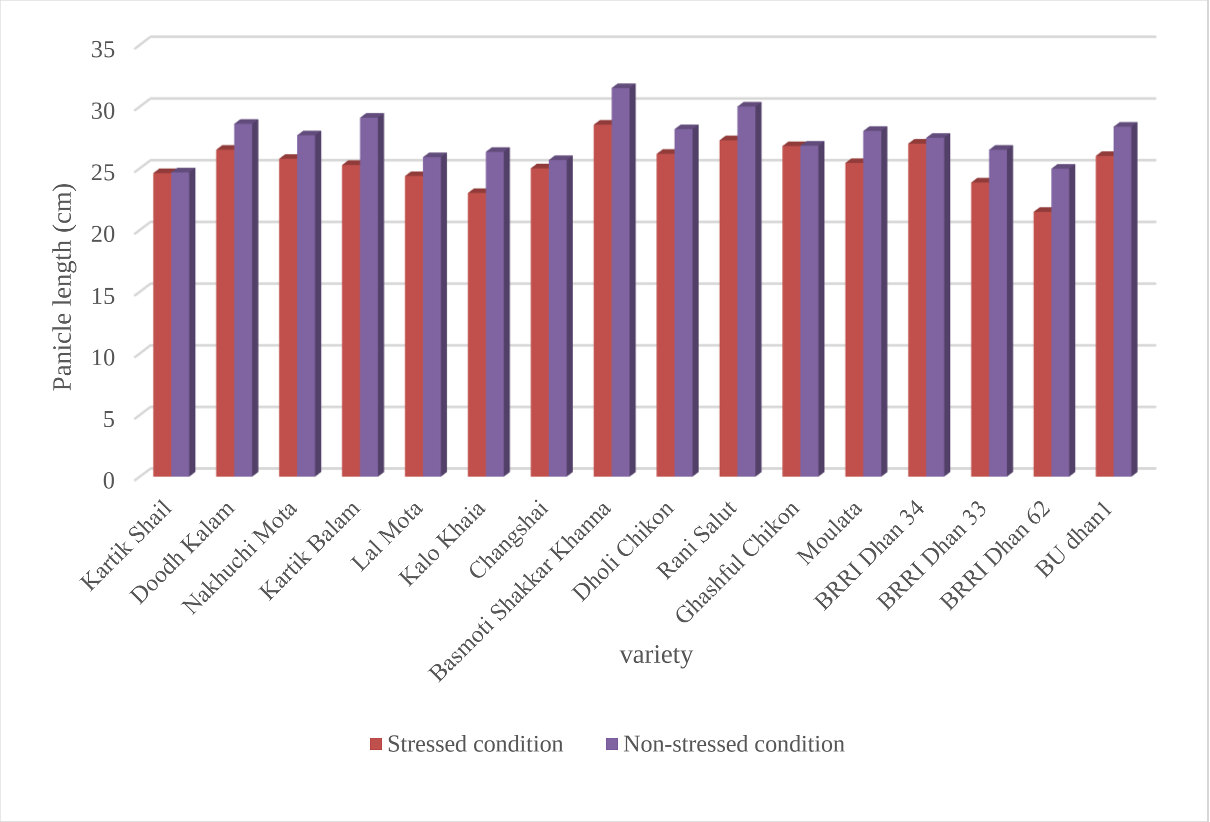

Figure 1: Panicle length (cm) of different local and modern T. aman rice under stressed and non-stressed condition (Stressed condition LSD $_{(.05)}$ =2.8301 and non-stressed condition LSD $_{(.05)}$ =3.0559)

Results showed that, both under stressed and non-stressed condition, the longest panicle (28.53 cm and 31.50 cm, respectively) was produced by Basmoti Shakkar Khanna which was closely followed by Rani Salute (27.27 and 30.00, respectively). On the other hand, under stressed condition, the shortest panicle length was found in BRRI Dhan62, (21.47 cm). Under non-stressed condition, the shortest panicle length was recorded in Kartik Shail (24.97 cm) which was statistically similar to BRRI Dhan62 (24.97 cm).

The results obtained under the present study were in conformity with the findings of Rahman et al. (2002) and Wang et al. (2006).

4.2.2 Total grains panicle^{-1}

Performance of test varieties under stressed and non-stressed condition under the present study showed a significant difference in respect of total grains panicle^{-1} (Figure 2 and Appendix IX).

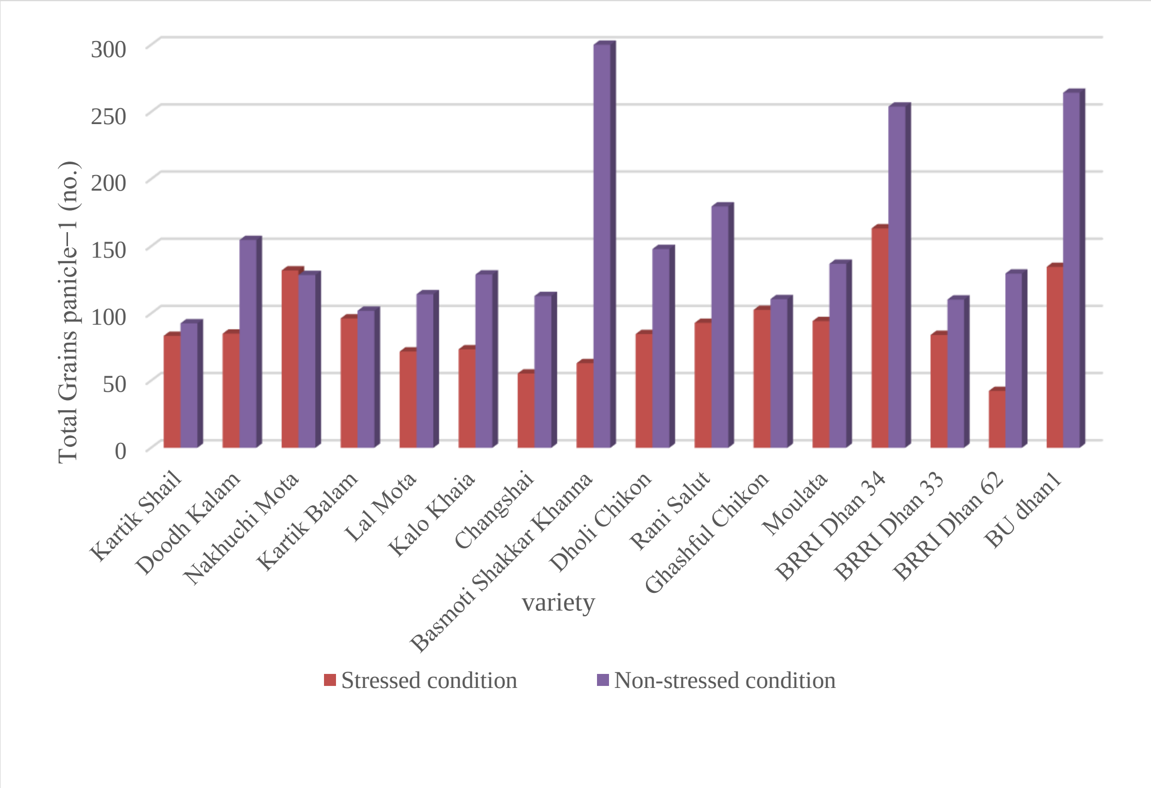

Figure 2: Total grains panicle^{-1} of different local and modern T. aman rice under stressed and non-stressed condition. (Stressed condition LSD $_{(.05)}$ = 46.892 and non-stressed condition LSD $_{(.05)}$ = 38.284)

Under stressed condition, the highest number of total grains panicle^{-1} (163.33) was observed in BRRI Dhan34 and among the local varieties, Nakhuchi Mota showed better performance for grains panicle^{-1} than all the other local varieties

(132.00) which was statistically similar to modern variety BU Dhan1 (134.67). BRRI Dhan62 produced the lowest number of total grains panicle^{-1} (42.33).

In case of non-stressed condition, highest number of total grains panicle^{-1} (300.00) was recorded in Basmoti Shakkar Khanna and Kartik Shail produced lowest number (92.67) of total grains panicle^{-1}. The results are in agreement with the findings of Rahman *et al.* (2002) who observed the varied 1000-grains weight among different varieties of rice.

4.2.3 Filled grains panicle^{-1}

Number of filled grains panicle^{-1}was significantly influenced by test varieties under stressed and non-stressed condition under the present study (Figure 3 and Appendix IX).

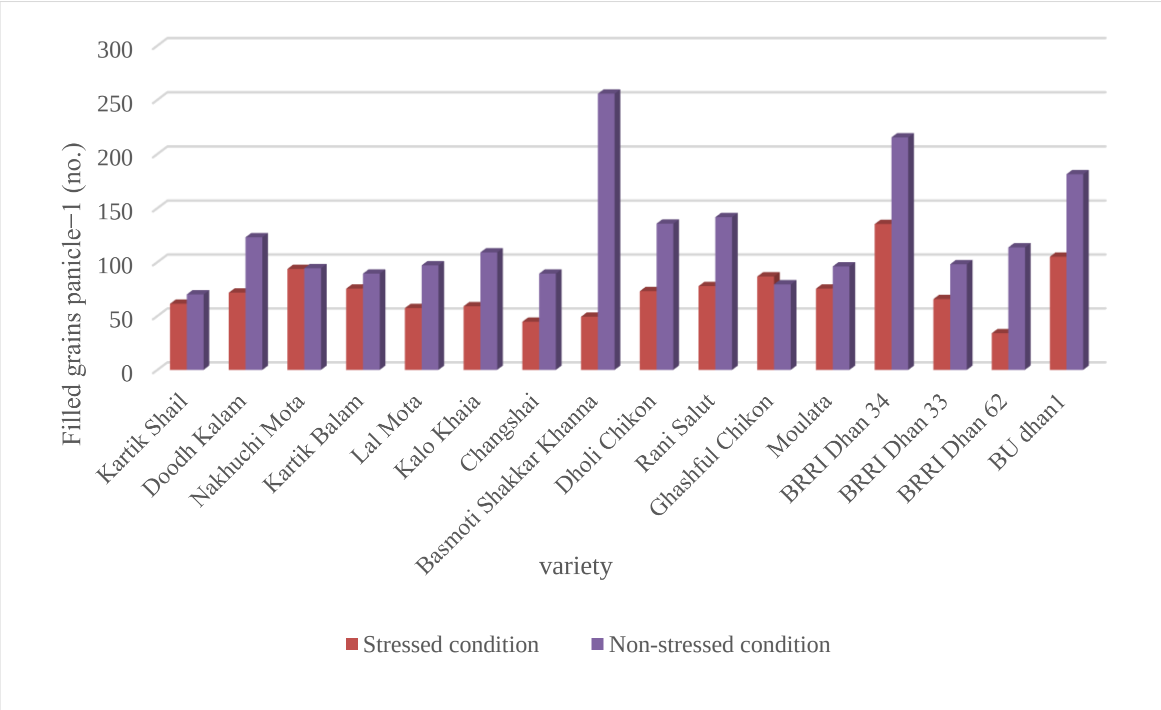

Figure 3: Filled grains panicle^{-1} of different local and modern T. aman rice under stressed and non-stressed condition. (Stressed condition LSD $_{(.05)}$ = 36.970 and Non-stressed condition LSD $_{(.05)}$ = 19.082)

Under stressed condition, BRRI Dhan34 produced the highest number of filled grains panicle^{-1} (135.33). Among the local varieties, Nakhuchi Mota showed the best performance (93.67) for filled grains panicle^{-1} which was statistically similar to Ghashful Chikon (86.67). On the other hand, the lowest number of filled grains panicle^{-1} (34.00) was observed in BRRI Dhan62.

Under non-stressed condition, highest number of filled grains panicle^{-1} (255.67) was observed in Basmoti Shakkar Khanna which was significantly different from all other test varieties. Lowest number of filled grains panicle^{-1} (70.00) was produced by Kartik Shail under the same codition.

The results obtained by Hossain (2001) and O'Toole and Moya, (1981) were in agreement with findings of present study.

4.2.4 Unfilled grains panicle^{-1}

Different varieties had significant effect on unfilled grains panicle^{-1} (Table 5 and Appendix IX) under stressed and non-stressed condition. Under stressed condition, results showed that the highest number of unfilled grains panicle^{-1} was observed in Nakhuchi Mota (38.33) and the lowest number of unfilled grains panicle^{-1} (8.33) was recorded from BRRI Dhan62.

In case of non-stressed condition, BU Dhan1 produced the highest number of unfilled grains panicle^{-1} (65.00). On the other hand, the lowest number of unfilled grains panicle^{-1} (12.33) was observed both in Dholi Chikon and BRRI Dhan33.

The results are in agreement with the findings of Hossain (2001), Yambao and Ingram (1988), Begum (1990) and Islam *et al*. (1994a) who stated that the increased unfilled grains panicle^{-1} is due to water stress condition.

It seems that, among the tested 16 varieties, Kartik Shail (25.42 %) and Moulata (30.21%) showed the highest value for unfilled grains under stressed and non-stressed condition, respectively. On the other hand, Dholi Chikon produced lower no. of unfilled grains both under stressed and non-stressed condition (13.39 % and 8.33 %, respectively) compared to other tested varieties under study.

Table 5: Number of unfilled grains Panicle^{-1} of selected local and modern varieties of T. aman rice under stressed and non-stressed condition

Treatment	Unfilled grains Panicle^{-1} (no.)	
	Stressed condition	**Non-stressed condition**
Kartik Shail	22.00 (25.42 %)	22.67 (22.83 %)
Doodh Kalam	13.33 (15.56 %)	31.67 (20.54 %)
Nakhuchi Mota	38.33 (26.38 %)	34.33 (23.97 %)
Kartik Balam	21.00 (21.41 %)	12.67 (11.72 %)
Lal Mota	14.33 (19.37 %)	17.33 (15.34 %)
Kalo Khaia	14.33 (20.46 %)	20.00 (15.42 %)
Changshai	10.67 (19.24 %)	23.67 (25.42 %)
Basmoti Shakkar Khanna	13.67 (20.84 %)	44.33 (18.69 %)
Dholi Chikon	11.67 (13.39 %)	12.33 (8.33 %)
Rani Salute	15.33 (16.18 %)	38.00 (20.33 %)
Ghashful Chikon	16.00 (16.03 %)	31.33 (27.12 %)
Moulata	19.00 (20.09 %)	41.00 (30.21 %)
BRRI Dhan34	28.00 (17.45 %)	38.67 (15.13 %)
BRRI Dhan33	18.33 (21.72 %)	12.33 (11.24 %)
BRRI Dhan62	8.33 (19.09 %)	16.00 (12.65 %)
BU Dhan1	29.67 (24.57 %)	65.00 (23.60 %)
LSD at 5% level	19.051	31.867
CV (%)	62.18	66.28

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD**.** Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.2.5 Weight of 1000 grains (g)

Both under stressed and non-stressed condition, significant influence of different varieties was observed on 1000-grain weight (Figure 4 and Appendix IX). Under stressed condition, the highest 1000-grain weight (29.60 g) was recorded from Moulata which was significantly different from all other test varieties. Changshai (29.25 g), BRRI Dhan 62 (28.76 g), Kartik Balam (28.67 g) and Kalo Khaia (28.43 g) also produced comparatively higher 1000-grain weight from other varieties which were all significantly different from one another. The lowest 1000-grain weight (10.11 g) was observed from BRRI Dhan34.

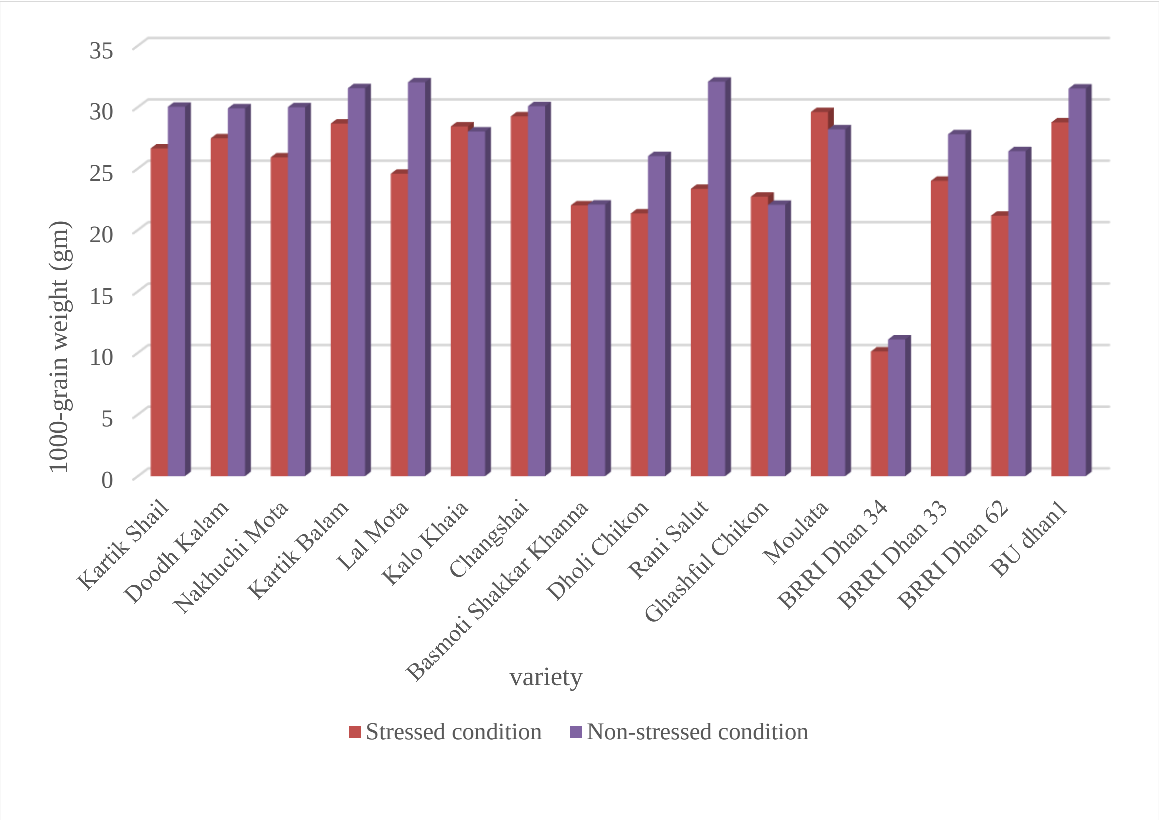

Figure 4: 1000-grain weight (g) of different local and modern T. aman rice under stressed and non-stressed condition. (Stressed condition LSD $_{(.05)}$ = 0.0876 and Non-stressed condition LSD $_{(.05)}$ = 0.3155)

On the other hand, under non-stressed condition, Rani Salute showed the highest value (32.07 g) for 1000-grain weight, which was statistically similar to

Lal Mota (32.03 g). The lowest 1000-grains weight (11.09 g) under non-stressed condition was recorded in BRRI Dhan34.

The results are in agreement with the findings of Rahman *et al.* (2002) and Zubaer *et al.* (2007) who observed that water stress reduced grain weight in different varieties of rice.

4.3 Yield parameters

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

Different varieties produced significantly variable grain yield (Figure 5 and Appendix X) under stressed and non-stressed condition.

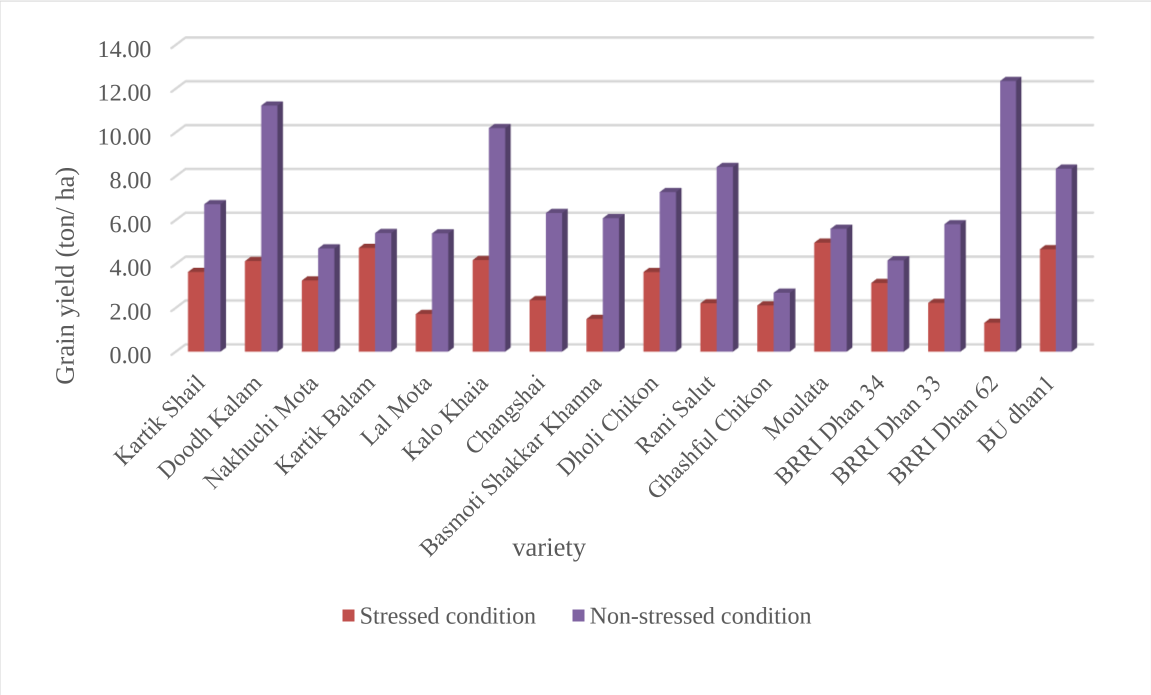

Figure 5: Grain yield (t ha^{-1}) of different local and modern T. aman rice under stressed and non-stressed condition. (Stressed condition LSD $_{(.05)}$ = 2.1506 and Non-stressed condition LSD $_{(.05)}$ = 2.0778)

Among the tested sixteen varieties, under stressed condition, Moulata showed its superiority in highest grain yield (4.91 t ha^{-1}) which was statistically similar to BU Dhan1 (4.76 t ha^{-1}). Under non-stressed condition, BRRI Dhan62 gave highest grain yield (12.35 t ha^{-1}) which was closely followed by Doodh Kalam (11.23 t ha^{-1}), one of the local varieties.

The results are in agreement with the findings of Islam *et al*. (2009), Bisne *et al.* (2006) and Siddique *et al.* (2002) who stated that grain yield differed significantly among the varieties.

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

Due to varietal difference, straw yield differed significantly (Table 6 and Appendix X) under stressed and non-stressed condition. Under stressed condition, highest straw yield (16.98 t ha^{-1}), was observed in Moulata. The lowest straw yield (5.71 t ha^{-1}) was obtained from BRRI Dhan62 which was statistically similar to BRRI Dhan34 (5.79 t ha^{-1}). On the other hand, under non-stressed condition, Moulata produced highest straw yield (20.98 t ha^{-1}), which was significantly different from all other test varieties. BRRI Dhan34 showed lowest straw yield (8.24 t ha^{-1}) under the same condition.

The differences in straw yield among the varieties may be attributed to the genetic make-up of the varieties. The results uphold with the findings of Patel (2000) and Om *et al.* (1999) where they concluded that straw yield differed significantly among the varieties.

Table 6: Straw production of selected local and modern varieties of T. aman rice under stressed and non-stressed condition

Treatment	Straw yield (ton/ ha)	
	Stressed condition	**Non-stressed condition**
Kartik Shail	12.07	15.26
Doodh Kalam	15.65	19.65
Nakhuchi Mota	11.38	14.39
Kartik Balam	11.61	14.34
Lal Mota	13.38	16.14
Kalo Khaia	12.11	15.72
Changshai	13.42	16.78
Basmoti Shakkar Khanna	13.20	16.50
Dholi Chikon	13.63	16.70
Rani Salute	14.06	17.58
Ghashful Chikon	10.92	13.65
Moulata	16.98	20.98
BRRI Dhan34	5.79	8.24
BRRI Dhan33	6.41	9.43
BRRI Dhan62	5.71	9.30
BU Dhan1	8.46	10.57
LSD at 5% level	0.4098	0.5245
CV (%)	2.13	2.14

Mean (±SD) was calculated from three replicates for each treatment. Values in a column are significantly different at $p \leq 0.05$ applying LSD.

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

Significant influence of different varieties under stressed and non-stressed condition was observed on biological yield (Figure 6 and Appendix X). Under stressed condition, Moulata showed the highest value (21.90 t ha^{-1}). The lowest value of biological yield (7.05 t ha^{-1}) was seen in BRRI Dhan62 which was statistically similar to BRRI Dhan33 and BRRI Dhan34 (8.42 t ha^{-1} and 8.64 t ha^{-1}, respectively).Most of the local varieties showed higher biological yield than the modern varieties under stressed condition.

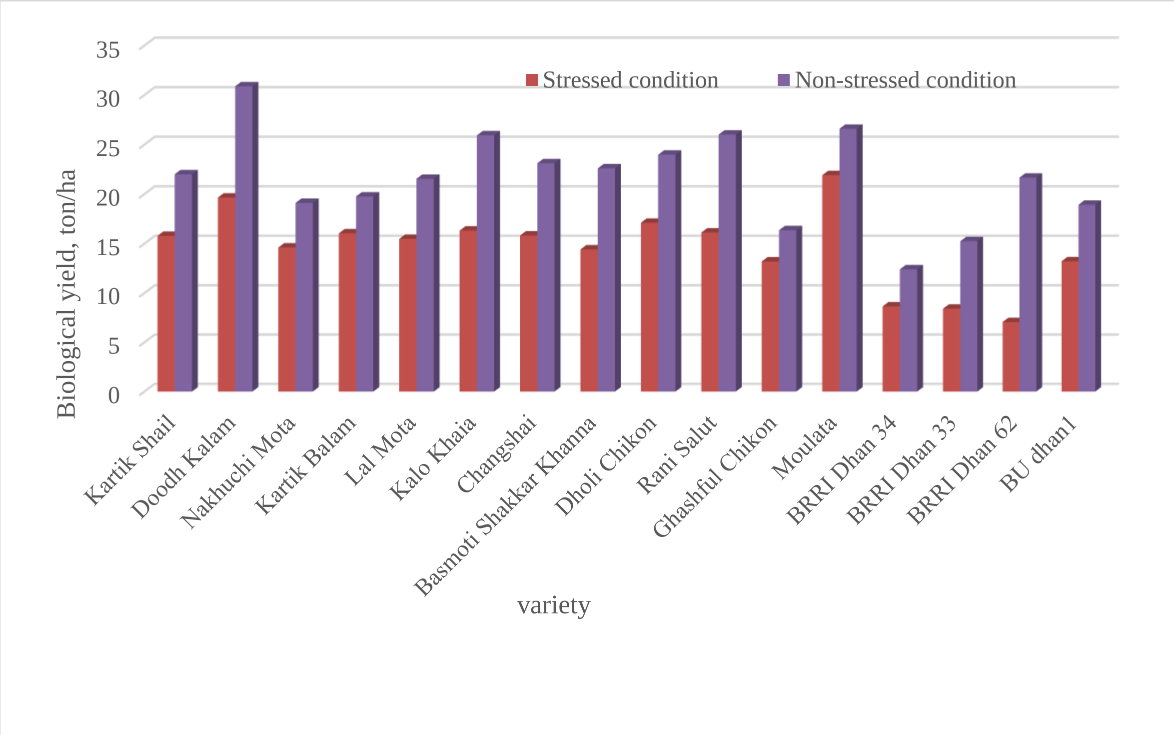

Figure 6: Biological yield (t ha^{-1}) of different local and modern T. aman rice under stressed and non-stressed condition. (Stressed condition LSD $_{(.05)}$ = 2.1845 and Non-stressed condition LSD $_{(.05)}$ = 2.0029)

Under non-stressed condition, among all the tested varieties, the highest value (30.87 t ha^{-1}) was observed in Doodh Kalam. BRRI Dhan34, showed lowest value of biological yield (12.40 t ha^{-1}). Almost all the local varieties exhibited better biological yield than the modern varieties except Ghashful chikon, under non-stressed condition. The differences in biological yield may be attributed to the genetic make-up of the varieties.

4.3.6 Harvest index (%)

Harvest index was significantly influenced by different varieties, under stressed and non-stressed condition, under the present study (Figure 7 and Appendix X). Results showed that, under stressed condition, the highest harvest index (32.49%) was observed in BRRI Dhan34. Among the local varieties, the highest harvest index (27.44%) was observed in Kartik Balam. The lowest harvest index (8.22 %) was observed in Basmoti Shakkar Khanna.

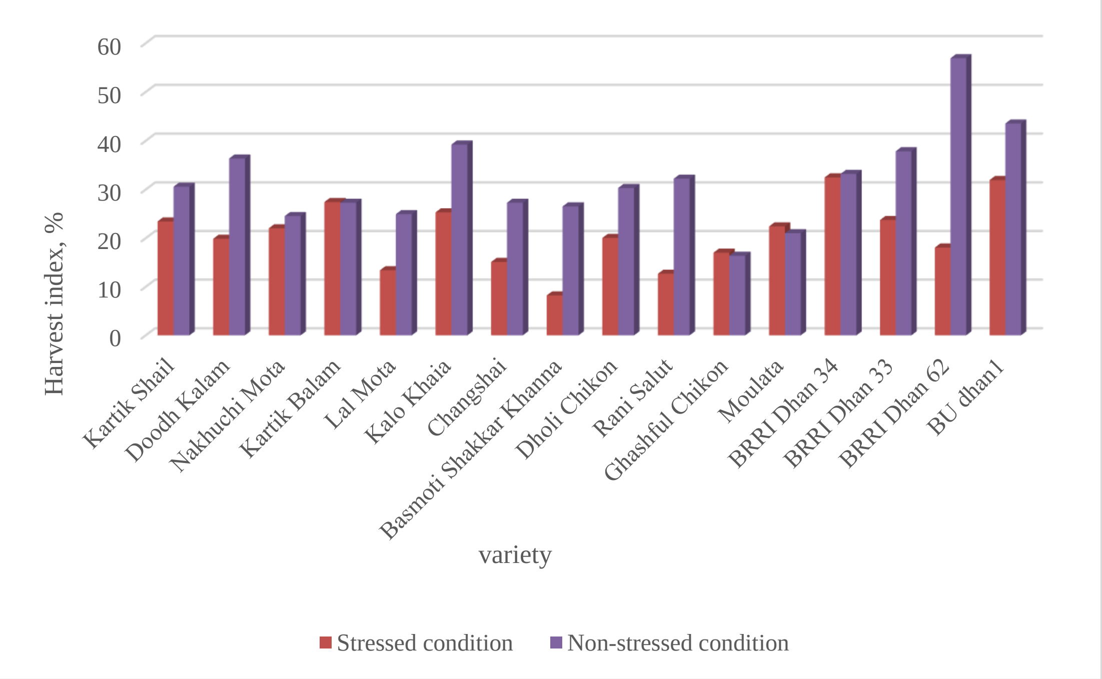

Figure 7: Harvest index (%) of different local and modern T. aman rice under stressed and non-stressed condition (Stressed condition LSD $_{(.05)}$ = 11.520 and Non-stressed condition LSD $_{(.05)}$ = 6.8396)

Under non-stressed condition, the highest harvest index (56.92%) was observed in BRRI Dhan62. Among the local varieties, the highest harvest index (39.22%) was observed in Kalo Khaia. Ghashful Chikon gave the lowest harvest index (16.38 %) among all the tested varieties.

Singh and Singh (2008) reported varietal differences among the cultivar for moisture stress which is also in agreement with the findings of Sharma *et al.* (2003) Zubaer *et al.* (2007) and Rahman *et al.* (2002).

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from August 2014 to December 2015 to study the 'performance of local and modern T. aman varieties under drought stress condition'.

The experiment comprised of 16 varieties viz. (i) Kartik Shail (local), (ii) Doodh Kalam (local), (iii) Nakhuchi Mota (local), (iv) Kartik Balam (local), (v) Lal Mota (local), (vi) Kalo Khaia (local), (vii) Changshai (local), (viii) Basmati Shakkar Khanna (local), (ix) Dholi Chikon (local), (x) Rani Salute (local), (xi) Ghashful Chikon (local), (xii) Moulata (local), (xiii) BRRI dhan34 (modern), (xiv) BRRI dhan33 (modern), (xv) BRRI dhan62 (modern) and (xvi) BU dhan1 (modern).

The size of the unit plot for non-stressed condition was 2 m × 1.5 m (3 m^2) and unit pot for stressed condition was 12 inch in diameter, both having 16 treatments for the present study with three replications. The total number of unit plots and unit pots of the experiment was 48 each (16 × 3). All management practices were done in proper time.

The treatments of the experiment were assigned at random into each replication following the experimental design. The experiment was laid out in Randomized Complete Block Design (RCBD). Seedlings of 30 days old were transplanted in field and pot with 1 seedling $hill^{-1}$ and following line to line distance 25 cm and hill to hill distance 20 cm in field.

Significant variation was recorded for data on growth, yield and yield contributing parameters of experimental materials. Data were collected on crop growth characters like plant height (cm), tillers $hill^{-1}$, total leaves $hill^{-1}$(g) and days to panicle emergence were recorded at different days after transplanting in the field and yield as well as yield contributing characters like panicle length (cm), grains panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, weight of 1000-grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were recorded after harvest. Five hills (excluding border hills) were randomly selected from each plot prior to harvest for collecting data on different parameters. After sampling the whole plots were harvested at maturity. Data on different parameters were recorded from the randomly selected hills in each plot and from each definite pot. Grain and straw yields were recorded after harvest of whole plot. The analysis was performed using the Statistix 10 computer package program. The mean differences among the treatments were compared by least significant difference test (LSD) at 5 % level of significance.

Records on plant height at 15 DAT revealed that under non-stressed condition, Doodh Kalam showed the highest plant height (94.50 cm) and under stressed condition, Lal Mota showed the highest plant height (71.10 cm). At 45 DAT, under non-stressed condition, highest plant height was observed also in Doodh Kalam (139.83 cm) and under stressed condition, Basmoti Shakkar Khanna showed highest plant height (94.50 cm). At 75 DAT Kalo Khaia produced the tallest plant (184.83 cm), under non-stressed condition and under stressed condition, the highest plant height was recorded from both Kartik Balam and Basmoti Shakkar Khanna (139.50 cm). Under non-stressed condition, the shortest plant was observed from BRRI dhan62 at 15, 45 and 75 DAT (57.87, 97.67 and 102.cm, respectively), whereas; under stressed condition, the shortest plant was produced by BU dhan1 at 15 DAT (47.00 cm) and by BRRI dhan62 at 45 and 75 DAT (72.33 and 76.17 cm, respectively).

In terms of total tillers hill^{-1}, under non-stressed condition, Nakhuchi Mota showed the highest number of tillers hill^{-1}at 15 and 45 DAT (16.67 and 20.33, respectively). Under stressed condition, Moulata showed highest tillers (6.33) at 15 DAT and Rani Salute showed the highest number of tillers hill^{-1} at 45 DAT (16.67). At 75 DAT, under non-stressed condition, BU Dhan1 produced the highest number of tillers hill^{-1} (17.67) and under stressed condition, Lal

Mota produced the highest number of tillers hill^{-1} (20.33). The minimum tillers hill^{-1}, under non-stressed condition, at 15 DAT and 45 DAT were recorded in Kartik Balam (7.67 and 10.00, respectively) and at 75 DAT, minimum tillers hill^{-1} were recorded in Moulata and BRRI dhan 33 (8.67). Under stressed condition, at 15 DAT Nakhuchi Mota and BRRI dhan 33 showed the minimum tillers hill^{-1} (3.33). BRRI dhan 33 produced the lowest number of tillers hill^{-1} at 45 DAT and 75 DAT (10.00 and 9.00, respectively).

In case of panicle length, both under stressed and non-stressed condition, the longest panicle (28.53 and 31.50 cm, respectively) was produced by Basmoti Shakkar Khanna. On the other hand, under stressed condition, the shortest panicle length was found in BRRI Dhan62, (21.47 cm) and under non-stressed condition, the shortest panicle length (24.97 cm) was recorded in Kartik Shail.

Under stressed condition, the highest number of total grains panicle^{-1} (163.33) was observed in BRRI dhan34 and BRRI dhan62 produced the lowest number of total grains panicle^{-1} (42.33). In case of non-stressed condition, highest number of total grains panicle^{-1} (300.00) was recorded in Basmoti Shakkar Khanna and Kartik Shail produced lowest number of total grains panicle^{-1} (92.67).

From the experiment, it was observed that under stressed condition, BRRI dhan34 produced the highest number of filled grains panicle^{-1} (135.33). On the other hand, the lowest number of filled grains panicle^{-1} (34.00) was observed in BRRI Dhan62. Under non-stressed condition, highest number of filled grains panicle^{-1} (255.67) was observed in Basmoti Shakkar Khanna and lowest number of filled grains panicle^{-1} (70.00) was produced by Kartik Shail.

Results showed that under stressed condition, the highest number of unfilled grains panicle^{-1} was observed in Nakhuchi Mota (38.33) and the lowest number of unfilled grains panicle^{-1} (8.33) was recorded from BRRI Dhan62. In case of non-stressed condition, BU Dhan1 produced the highest number of unfilled grains panicle^{-1} (65.00) and the lowest number of unfilled grains panicle^{-1} (12.33) was observed both in Dholi Chikon and BRRI Dhan33. Among the tested 16 varieties, Kartik Shail (25.42 %) and Moulata (30.21%) showed the highest value for unfilled grains in stressed and non-stressed condition, respectively and Dholi Chikon produced lower no. of unfilled grains both in stressed and non-stressed condition (13.39 % and 8.33 %, respectively).

It is attained that under stressed condition, the highest 1000-grain weight (29.60 g) was recorded from Moulata and the lowest 1000-grain weight (10.11 g) was observed from BRRI Dhan34. Under non-stressed condition, Rani Salute showed the highest value (32.07 g) for 1000-grain weight and BRRI dhan34 showed the lowest 1000-grains weight (11.09 g).

Among the tested sixteen varieties under stressed condition, Moulata showed its superiority in highest grain yield (4.91 t ha^{-1}) and under non-stressed condition, BRRI Dhan62 gave highest grain yield (12.35 t ha^{-1}). Meanwhile, under stressed condition, Basmoti Shakkar Khanna (1.21 t ha^{-1}) produced the lowest grain yield and Ghashful Chikon showed lowest grain yield (2.69 t ha^{-1}) under non-stressed condition.

In terms of straw yield, both under stressed and non-stressed condition, highest straw yield (16.98 t ha^{-1} and 20.98 t ha^{-1}, respectively), was observed in Moulata. The lowest straw yield was obtained from BRRI Dhan62 (5.71 t ha^{-1}) and BRRI Dhan34 (8.24 t ha^{-1}), under stressed and non-stressed condition respectively.

In case of biological yield, under stressed condition, Moulata showed the highest value (21.90 t ha^{-1}) and under non-stressed condition, the highest value (30.87 t ha^{-1}) was observed in Doodh Kalam. The lowest value of biological yield was seen in BRRI dhan62 (7.05 t ha^{-1}) and BRRI dhan34 (12.40 t ha^{-1}), under stressed and non-stressed condition respectively.

Results focused that under stressed condition, the highest harvest index (32.49%) was observed in BRRI Dhan34 and the lowest harvest index (8.22 %) was observed in Basmoti Shakkar Khanna. Under non-stressed condition, the highest harvest index (56.92%) was observed in BRRI Dhan62 and Ghashful Chikon gave the lowest harvest index (16.38 %) among all the tested varieties.

In case of required days to panicle emergence, under stressed condition, BRRI dhan62 showed earlier panicle emergence (33 days) and Lal Mota showed delayed panicle emergence (79 days). Under non-stressed condition, BRRI dhan62 showed earlier panicle emergence (28 days) and both Lal Mota and Rani Salute showed delayed panicle emergence (76 days). Among the local varieties, Kartik Shail showed minimum days to panicle emergence both under stressed and non-stressed condition (40 and 38 days, respectively).

Both under stressed and non-stressed condition, days to maturity among the local varieties ranged from 89 days (Kartik Shail, Doodh Kalam, Kartik Balam and Moulata) to 118 days (Nakhuchi Mota, Lal Mota and Basmoti Shakkar Khanna). In case of modern varieties; BRRI dhan33, BRRI dhan34, BRRI dhan62 and BU Dhan1 matured early (90 days).

From the above summary of the study, it can be concluded that, under stressed condition, among the local varieties, Moulata, Kartik Balam, Kalo khaia, Doodh Kalam and Kartik Shail and among the modern varieties, BU Dhan1 showed comparatively better performance in respect of yield. Under non-stressed condition, BRRI Dhan62 demonstrated the best performance followed by Doodh Kalam. On the other hand, regarding growth, yield and yield contributing characters Basmoti Shakkar Khanna, BRRI Dhan62 and BRRI Dhan33 showed lower performance under stressed condition; whereas, Ghashful chikon and BRRI Dhan34 showed lower performance under non-stressed condition. It seems that, under stressed condition, most of the local varieties showed comparatively better performance than the modern varieties in respect of yield.

Conclusion:

Based on the experimental results, it may be concluded that-

i) Under drought-stressed condition at the grain filling stage among the local varieties, Moulata, Kartik Balam, Kalo khaia, Doodh Kalam and Kartik Shail and among the modern varieties, BU Dhan1 gave higher seed yields than others.

ii) In non-stressed condition BRRI dhan62 and Doodh Kalam were found to be the best varieties among the sixteen varieties tested in the present study.

Recommendation:

To reach a specific conclusion and recommendation, the same study needs to be repeated under different agro-ecological zones of Bangladesh.

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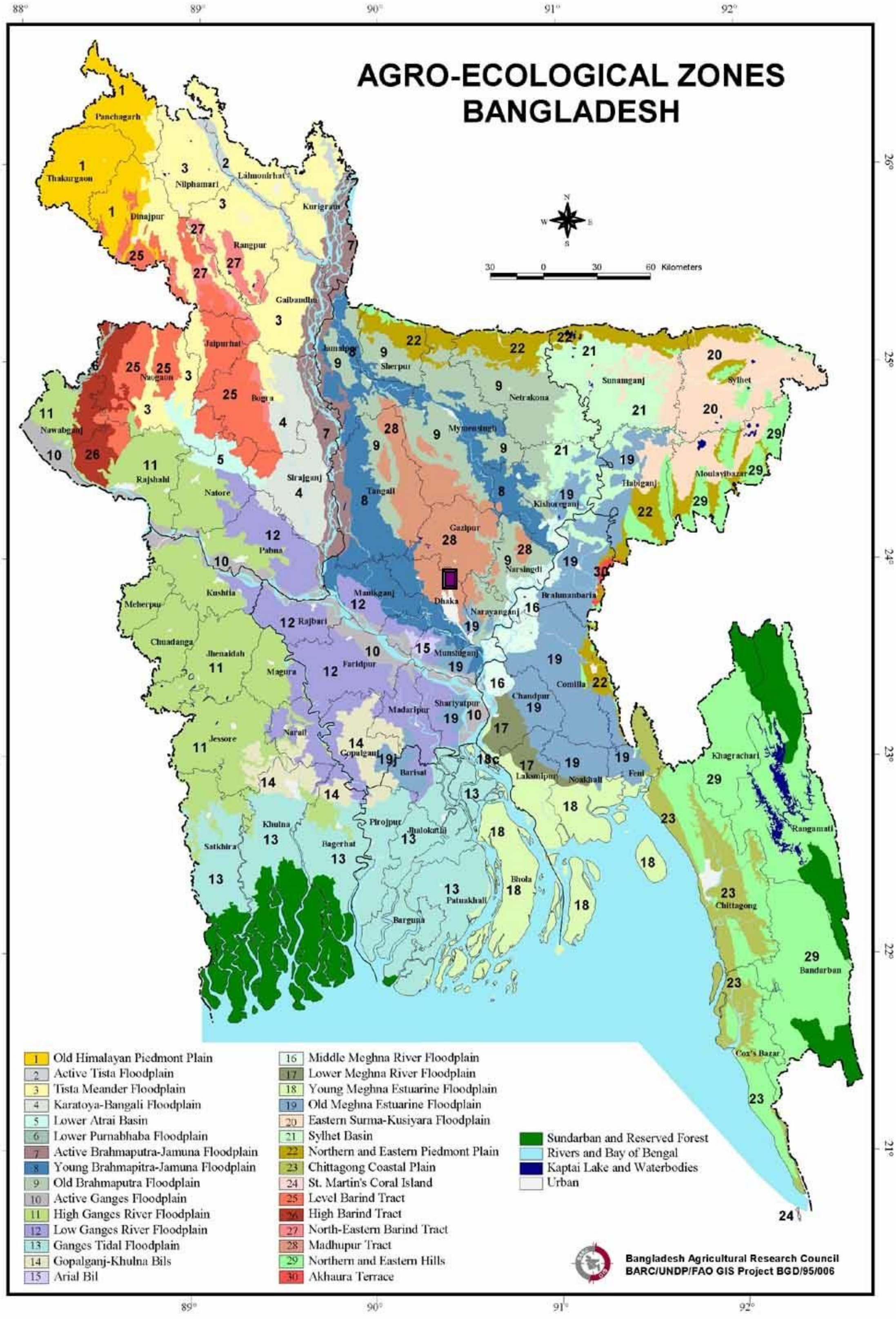
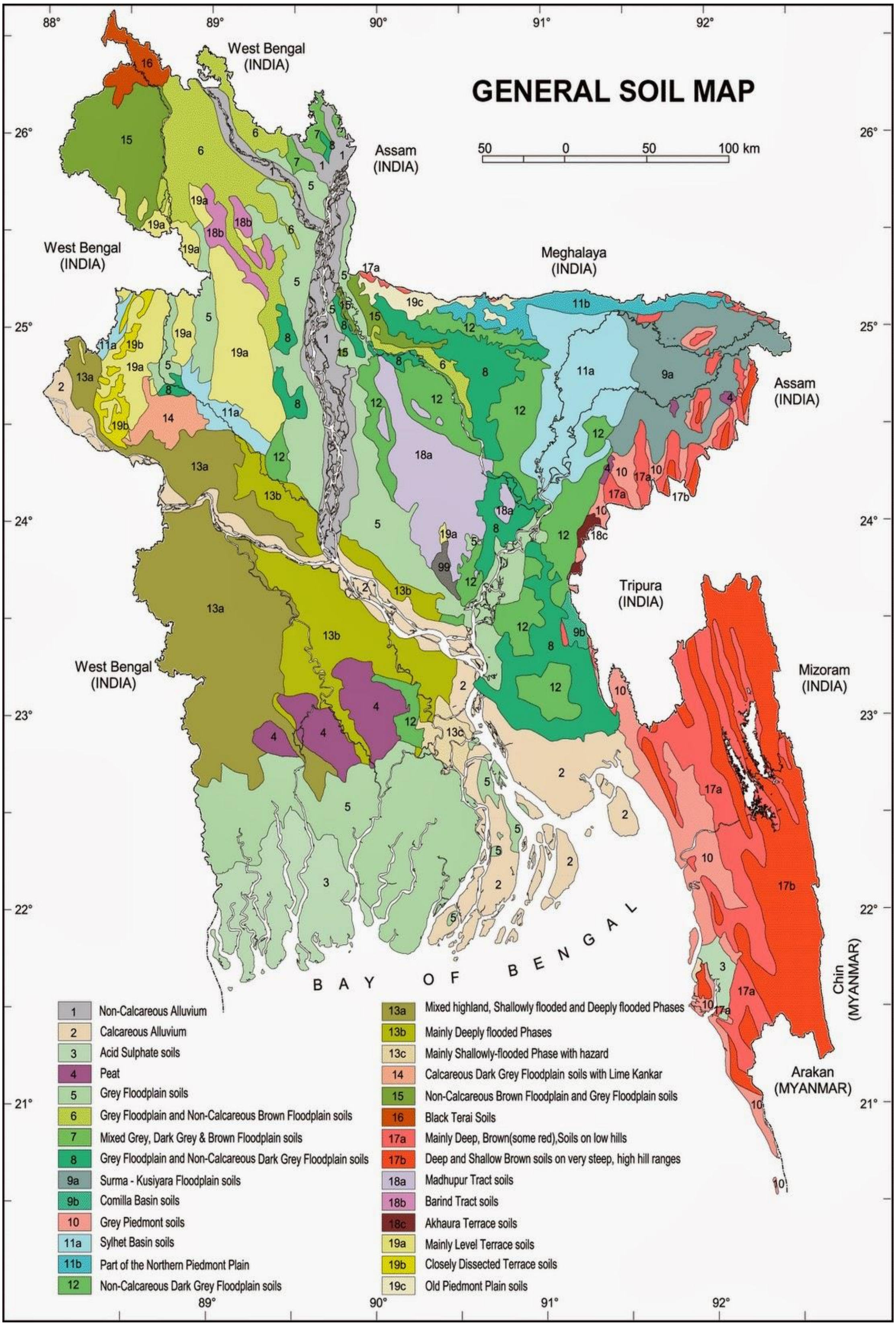
APPENDICES

Appendix I: Map showing the experimental sites under study



The experimental site under study

Appendix II: Map showing the general soil sites under study



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

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro–Aman–Boro

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1.00 g soil)	0.10
Available S (ppm)	45

Source: SRDI, 2014

Appendix IV: Monthly average of Temperature, Relative humidity, total Rainfall and sunshine hour of the experiment site during the period from August 2014 to November 2014

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm day-1)	Sunshine (hr day-1)
		Maximum	Minimum	Mean			
2015	August	31.02	15.27	23.15	74.41	5.1	5.11
	September	31.46	14.82	23.14	73.20	6.3	4.15
	October	30.18	14.85	22.51	67.82	4.2	7.48
	November	28.10	6.88	17.49	58.18	1.56	7.85

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

Appendix V: Analysis of variance (mean square) of plant height of T. amon varieties under stressed and non-stressed condition at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of plant height at different days after transplanting					
		15 DAT		45 DAT		75 DAT	
		stressed	Non-stressed	stressed	Non-stressed	stressed	Non-stressed
Replication	2	104.738	3.968	77.600	10.775	199.63	15.02
Treatment	15	94.795**	407.045**	367.156**	548.441**	1019.65**	2065.86**
Error	30	27.162	4.241	34.822	24.793	83.48	40.09

* indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VI: Analysis of variance (mean square) of tiller hill^{-1} of T. amon varieties under stressed and non-stressed condition at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of tiller number hill^{-1} at different days after transplanting					
		15 DAT		45 DAT		75 DAT	
		stressed	Non-stressed	stressed	Non-stressed	stressed	Non-stressed
Replication	2	2.77083	42.1458	64.5625	65.0208	41.3958	16.0208
Treatment	15	2.10972	19.6389	41.7722	29.5500	38.0097*	20.3097
Error	30	1.59306	15.7014	24.3847	23.0208	16.6847	16.5764

* indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VII: Analysis of variance (mean square) of leaves hill^{-1} of T. amon varieties under stressed and non-stressed condition at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of leaf number hill^{-1} at different days after transplanting			
		15 DAT		45 DAT	
		stressed	Non-stressed	stressed	Non-stressed
Replication	2	20.6875	11.4375	335.646	400.521
Treatment	15	6.7944**	5.7778	427.017**	221.200
Error	30	4.2653	3.2153	88.846	146.787

* indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VIII: Analysis of variance (mean square) of days to panicle emergence and maturity of T. Amon varieties under stressed and non-stressed condition at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of days to panicle emergence and maturity			
		Days to panicle emergence		Days to Maturity	
		stressed	non-stressed	stressed	non-stressed
Replication	2	4.000	3.521	1.271	8.063
Treatment	22	586.439**	624.933**	448.976**	447.644**
Error	44	4.889	0.921	0.760	0.507

* indicates significant at 5% level of probability.
** indicates significant at 1% level of probability.

Appendix IX: Analysis of variance (mean square) of yield components of T. Amon varieties under stressed and non-stressed condition at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of yield components									
		Panicle length (cm)		Grains panicle^{-1} (No.)		Filled grains panicle^{-1} (No.)		Unfilled grains panicle^{-1} (No.)		1000-grain weight (gm)	
		stressed	non-stressed	stressed	non-stressed	stressed	non-stressed	stressed	non-stressed	stressed	non-stressed
Replication	2	0.6617	1.2065	685.75	996.9	715.75	9.77	70.750	1193.58	0.0054	0.0014
Treatment	15	9.1208**	10.139**	2858.67**	11492.3**	1814.49**	8186.13**	187.861	633.42	70.7321**	86.3053**
Error	30	2.8805	3.3585	790.79	527.1	491.55	130.95	130.528	365.21	0.0028	0.0358

* indicates significant at 5% level of probability.
** indicates significant at 1% level of probability.

Appendix X: Analysis of variance (mean square) of yield of T. Amon varieties under stressed and non-stressed condition at different days after transplanting

Sources of variation	Degrees of freedom	Mean square of yields and harvest index							
		Grain yield ($t\ ha^{-1}$)		Straw yield ($t\ ha^{-1}$)		Biological Yield ($t\ ha^{-1}$)		Harvest index (%)	
		stressed	non-stressed	stressed	non-stressed	stressed	non-stressed	stressed	non-stressed
Replication	2	1.61499	2.5907	0.1442	0.1310	2.4994	3.4123	67.844	30.260
Treatment	15	4.31073*	20.4531**	34.1548**	40.8271**	46.1252**	65.4747**	135.958**	281.857**
Error	30	1.66339	1.5526	0.0604	0.0989	1.7163	1.4427	47.729	16.824

* indicates significant at 5% level of probability.
** indicates significant at 1% level of probability.

PLATES

Kartik Balam at panicle emergence

Kartik Balam at maturity

Dholi Chikon at panicle emergence

Dholi Chikon at maturity

Kalo Khaia at panicle emergence

Kalo Khaia at maturity

Moulata at panicle emergence

Moulata at maturity

Plate 1: Different rice varieties in stressed condition

BRRI Dhan62

Doodh Kalam

Bashmoti Shakkar Khanna

Dholi Chikon

Plate 2: Different rice varieties in non-stressed condition

BRRI Dhan62

Basmoti Shakkar Khanna

BU Dhan1

Changshai

Doodh Kalam

Kartik balam

Nakhuchi Mota

Rani Salute

Kartik Shail

Plate 3: Grains of different rice varieties