GENETIC EVALUATION OF BORO RICE (*Oryza sativa* L.) UNDER IRRIGATED AND RAINFED CONDITION

MD. NAYEEM JOMADDER

DEPARTMENT OF GENETICS AND PLANT BREEDING

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

MD. NAYEEM JOMADDER

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Approved by:

Prof. Dr. Kazi Md. Kamrul Huda
Supervisor

Prof. Dr. Mohammad Saiful Islam
Co-supervisor

Prof. Dr. Kazi Md. Kamrul Huda
Chairman
Examination Committee

Prof. Dr. Kazi Md. Kamrul Huda
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Mobile No.: 01783391872
E-mail: mashnuk@gmail.com

CERTIFICATE

This is to certify that the thesis entitled "GENETIC EVALUATION OF BORO RICE (Oryza sativa L.) UNDER IRRIGATED AND RAINFED CONDITION" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in GENETICS AND PLANT BREEDING, embodies the result of a piece of bonafide research work carried out by MD. NAYEEM JOMADDER, Registration number: 17-08266 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2018

Place: Dhaka, Bangladesh

Prof. Dr. Kazi Md. Kamrul Huda
Supervisor

DEDICATION

I dedicate this thesis to my parents, teachers and friends without whom it was almost impossible for me to complete my thesis work.

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ABSTRACT

Drought is a major abiotic constraint for growing rain-fed rice in Bangladesh. A set of twenty rice genotypes including local boro rice genotypes viz., Poshusail, Gorchihail, Birion, Soilerpuna, Pankaich, Gopal Deshi, Borail were evaluated under irrigated and rainfed condition at farm of the Sher-e- Bangla Agricultural University, Dhaka-1207 during December 2018 – May 2019. Ten morphological characters viz, plant height (cm), flag leaf length (cm), flag leaf width (cm), number of primary branches per panicle, number of secondary branches per panicle, panicle length (cm), number of filled grain per panicle, number of unfilled grain per panicle, thousand seed weight (g) and yield (ton/ha) were recorded. Analysis of variance revealed highly significant variation among the genotypes for all the characters under study in both conditions (irrigated and rainfed). The effects of water deficit on various morphological traits associated with drought tolerance were also studied. Result revealed that significant yield decline was observed almost in all rice genotypes grown under rainfed condition compared to normal irrigated situation. Out of twenty rice genotypes, BRRI dhan36, BRRI dhan59, BRRI dhan55 showed superior performance in terms of grain yield and yield attributes under normal irrigated condition. Under rainfed condition, the genotypes namely BRRI dhan55, Gopal Deshi, Soilerpuna showed superior performance in terms of grain yield and yield attributes. Significant variation was also observed among the genotypes for plant height, flag leaf length (cm), flag leaf width (cm), number of primary branches per panicle, number of secondary branches per panicle, panicle length (cm), number of filled grain per panicle, number of unfilled grain per panicle, thousand seed weight (g) and yield (ton/ha) and drought tolerance index under both normal (irrigated) and rainfed condition. The present study also indicated the agro-morphological traits had direct and indirect effect on yield performance of rice genotypes under rainfed condition at reproductive stage.

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LIST OF ABREVIATIONS

FULL WORD	ABBREVIATION
Percent	%
Degree Celsius	ºC
At the rate	@
Phenotypic variance	$\sigma^2_{(ph)}$
Genotypic variance	$\sigma^2_{(g)}$
Heritability in broad sense	$h^2 b$
Agro Ecological Zone	AEZ
Analysis of variance	ANOVA
Bangladesh Bureau of Statistics	BBS
Bangladesh	BD
Centimeter	cm
Percentage of coefficient of variation	CV%
Cultivars	cv.
Degrees of freedom	df
And others	*et al.*
Etcetera	etc.
Food and Agriculture Organization	FAO
Gram	g
Genotype	G
Genetic advance	GA
Genotypic coefficient of variation	GCV
Harvest Index	HI
Kilogram	Kg
Meter	M
Distinctness, Uniformity and Stability	DUS
Molecular	Mol.
Murate of Potash	MoP
Ministry of Agriculture	MoA
Square meter	m^2
Phenotypic coefficient of variation	PCV
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Triple Super Phosphate	TSP

CHAPTER I

INTRODUCTION

Bangladesh is at 4th position among rice producing countries though this country produces 4.5 tons rice per hector of land. The production is 6.5 ton/ha in China, Japan and Korea. In China, Japan and Korea there are only one rice crop is produced in a single year where as there are three rice crops produced in Bangladesh within a single year. In that sense, our production of rice is not less enough than other countries. We need more rice production for our gradually increasing population. If we use traditional methods and ancient varieties, we will be unable to fulfill our needs and demands. For this reason, we need more practices of high yielding varieties and modern technologies. Our country faces climate challenges. So we must need more climate resistance rice modern technologies (BRRI, 2019).

Rice (*Oryza sativa* L.) is the most important food in tropical and subtropical regions (Singh *et al.* 2012). It is a major food crop, ranking second after wheat (the most cultivated cereals in the world). Rice (*Oryza sativa* L.) is sensitive to water stress and shows several morphological changes at different growth stages in response to drought stress (Henry *et al.* 2016). These involve plant height reduction, leaf rolling, leaf senescence, stomatal closure, decreased leaf elongation and lower dry matter production (Kumar *et al.* 2015).

Rice (*Oryza sativa* L.) is the staple food for over half the world's population (Singh *et al.* 2012). It provides 27 per cent of dietary energy and 20 per cent of dietary protein in the developing countries. It is cultivated in at least 114 developing countries and it is the primary source of income and employment for more than 100 million house hold in Asia (Singh *et al.* 2015). It is being cultivated under diverse ecologies ranging from irrigated to rainfed and upland to lowland to deep water system. Drought is considered one of the main constraints that limit rice yield in rainfed and poorly irrigated areas. At least 23 million hectares of rainfed rice area in Asia are estimated to be drought prone, and drought is becoming an increasing problem even in traditionally irrigated areas (Pandey *et al.* 2005). Drought is a common feature in Bangladesh especially in dry season (Winter and Pre monsoon), which causes a substantial reduction of rice yield. It occurs mainly for uneven distribution of rainfall and thus, north-western part of the country is treated as drought-prone (Pervin, 2015).

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 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 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-September). 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. In Bangladesh, Rajshahi division is highly drought affected. Chittagong and Khulna divisions are known as drought prone area (Appendix II). 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).

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 phenomenon both for the local land races as well as for modern rice. The effect of drought at the grain filling stage on the local rice yield has not so far been evaluated; and so it needs to be tried. Moreover, the performance of both the local and modern varieties under drought stress condition at the reproductive stage should be compared (Ullah, 2014).

So, it is essentially required to know the morphological 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 rainfed at reproductive stage of different local Boro rice varieties.

The objectives of this study were to:

1. To evaluate Boro rice lines based on morphology and quality traits,
2. To compare the variation among 20 lines of Boro rice,
3. To compare the growth and yield performances of selected hybrid rice lines with a known inbred one as a check variety and
4. To select suitable lines for further study and release.

CHAPTER II

REVIEW OF LITERATURE

Different investigators at home and abroad worked with different rice lines and studied their performance regarding the drought stress as well as rainfed condition. Numerous studies on the growth, yield, variability, correlation, heritability and genetic advance have been carried out in many countries of the world. The work so far done in Bangladesh is not sufficient and conclusive. However, some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter under the following headings:

2.1 Drought susceptibility of rice plants

2.2 Effect of drought on rice varieties

2.3 Morphological attributes

2.4 Yield contributing characters and yield

2.1 Drought susceptibility of rice plants

Jaleel *et al*. (2008a) observed that severe water stress may result in the arrest of photosynthesis, disturbance in metabolism and finally the death of plant. 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.

Nam *et al*. (2001) and Martinez *et al.* (2007) observed that 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. Chaves *et al*. (2002) and Jaleel *et al*. (2008c). estimated that 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.

Jaleel *et al*. (2007) studied that drought stress is characterized by reduction of water content diminished leaf water potential, turgor pressure, stomata activity and decrease 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. 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.

Lone *et al.* (2019) found that drought is a major abiotic stress factor affecting the growth and development of plants at all stages. Significant moisture stress × genotype interactions were found for most of the parameters measured.

Adhiari *et al.* (2017) found that drought is the most critical abiotic factor reducing rice yield in rainfed and drought prone areas. Majority of rice cultivated area in south Asia are under rainfed, where water stress at any of the critical growth stage causes sharp de- cline in yield.Different drought tolerance indices like stress tolerance (TOL), Stress tolerance index (STI), Stress susceptibility index (SSI), were tested in screening superior rice cultivars. Significant reduction in mean grain yield was observed under drought stress in all rice cultivars under the study.

Garget *et al.* (2017) found that climate change needs us to look at various alternatives for more drought tolerant and tougher strains. Rice (*Oryza sativa* L.) is the most important food crop of the world; drought stress is a serious limiting factor to rice production and yield stability in rainfed areas. In order to design efficient varieties with virtues of drought tolerance and high yielding ability is necessary.

Pervin *et al.* (2017) found that drought is a major abiotic constraint for growing rain-fed rice in Bangladesh. Among the 12 studied characters percent yield reduction contributed maximum towards total divergence in the genotypes, which revealed that these parameters contributed more to grain yield under drought stress.

Ahmed *et al*. (2017) found that drought stress has become a regular phenomenon for the rice farmers during late aman season (June to October) in the north-western part of Bangladesh.

Kumar *et al.* (2015) found that agro-morphological and physiological traits that have direct and indirect effect on yield performance of rice genotypes under drought stress condition.

Allah *et al.* (2010) found that many promising lines were found to be tolerant against drought stress at different growth stages i.e. seedling stage, early and late vegetative stage, panicle initiation stage and heading stage. These lines possess useful traits associated with drought tolerance such as early maturity (drought escape mechanism), medium tillering ability, medium plant height, root depth, root thickness, root volume, dry root: shoot ratio, plasticity in leaf rolling and unrolling (drought avoidance mechanism), in addition to crop water use efficiency and water application efficiency.

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. Zhenshan 97B (*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

Islam *et al.* (2018) found that Seedling height and dry weight also decreased in all rice genotypes with the increase in water stress level.

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 south eastern, 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.

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 grain yield were found when water stress was imposed at tillering stage. Pramanik and Grupta (1989) identified promising lines tolerance to water stress.

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).

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.

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.

zee *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 panicles numbers as well as grain yield when water stress was imposed at tillering stage.

2.4.2 Panicle length (cm)

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 per panicle

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 per panicle

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 per plant. 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 per panicle

Results of a pot experiment carried out by Zubaer *et 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. Bina Dhan4 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 Thousand seed weight (g)

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 Bina Dhan4 (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

Garg *et al.* (2017) found that significant yield decline was observed almost in all rice genotypes grown under water stress condition compared to normal irrigated situation.

Parveen *et al.* (2017) found that there was a trend for the reduction in grain yield to be greater when the stresses were imposed at all three stages compared with a single stage, but the differences were not significant. There was a consistent trend for irrigation water productivity (WPi) to decrease as the irrigation threshold increased, with significantly lower values for a 40 kPa threshold at any stage, in comparison with CF. This was because the decline in water input to the pots was less than the decline in yield as the threshold increased.

Kumar *et al.* (2014) reported that drought stress at reproductive stage caused reduction in grain yield (55.31%), leaf area (34.87%), number of spikelet (15.9%), spikelet fertility (17.13%), plant height (8.87%), relative water content (31.57%), harvest index (29.2%), while increase in sterility percentage (51.5%) and proline content (55.9%).

Sakai *et al.* (2017) found that experiments conducted under field conditions indicated that rice genotypes Curinga and CT6241 performed much better in terms of grain yield under water-limited conditions than varieties Azucena, Nerica, CICA8 and Palmar.

Ahmed *et al.* (2017) found that Ganja and BRRI Dhan56 gave the highest value for grain yield in both conditions. Yield reduction percentage was lower in both Ganja and BRRI Dhan56. STI was also found to be higher in these two varieties, which indicate the ability to give stable yield performance under stress condition.

Zou *et al*. (2007) Grain yield under drought stress conditions was associated with yield under well-watered conditions (r = 0.47∗∗, and r = 0.61∗∗ during 2 years of tests). The delay of heading date ranged from –1 (no delay) to 24 days, and was negatively associated with grain yield (r = –0.40∗), spikelet fertility percentage (r = –0.40∗∗), harvest index (r = –0.58∗∗), but positively associated with yield reduction percentage (r = 0.60∗∗).The DRI of genotypes was strongly associated with grain yield (r = 0.87∗∗ , and r = 0.77∗∗), fertility percentage (r = 0.66∗∗ and r = 0.54∗∗), harvest index (r = 0.67∗∗ and r = 0.61∗∗), and negatively associated with grain reduction percentage (r = –0.70∗∗ , and r = –0.73∗∗) under drought stress.

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 t han 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.

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.

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.

CHAPTER III

MATERIALS AND METHODS

The present investigation “Genetic evaluation of boro rice (*Oryza sativa* L.) under irrigated and rainfed condition” was carried out during the Boro season 2018. The techniques followed and materials used during the course of investigation are presented below:

3.1 Experimental site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during November 2018 to June 2019. The location of the site was situated at 23°41’ N latitude and 90°22’ E longitude with an elevation of 8.6 meter from the sea level. The experiment area has been presented in Appendix I.

3.2 Climate and soil

The experimental site was medium high land belonging to old Madhupur tract (AEZ-28) and the soil series was Tejgaon. The soil of the experimental plot was clay loam in texture and olive gray with common fine to medium distinct dark yellowish-brown mottles. The pH around 6.5 and organic carbon content is 0.84%. The experiment area was above flood level and having available irrigation and drainage system and has been presented in Appendix III.

The experimental site was under the subtropical climate. It is characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October. Details of the metrological data on air temperature, relative humidity, rainfall and sunshine hour at the time of experiment was collected from the weather station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix IV.

Table 1. List of germplasm used for the experiment

SL.	Name of Genotypes	Season of Cultivation	Source
1	Poshusail	Boro	Gene Bank of BRRI
2	Gorchihail	Boro	Gene Bank of BRRI
3	Birion	Boro	Gene Bank of BRRI
4	Soilerpuna	Boro	Gene Bank of BRRI
5	Pankaich	Boro	Gene Bank of BRRI
6	Gopal Dehsi	Boro	Gene Bank of BRRI
7	Borail	Boro	Gene Bank of BRRI
8	BRRI dhan28	Boro	Gene Bank of BRRI
9	BRRI dhan55	Boro & Aus	Gene Bank of BRRI
10	Aus Boro	Boro	Bakerganj, Barishal
11	Aus IRRI	Aus	Bakerganj, Barishal
12	BRRI dhan45	Boro	Gene Bank of BRRI
13	BRRI dhan50	Boro	Gene Bank of BRRI
14	BR 25	T. Aman	Gene Bank of BRRI
15	BRRI dhan86	Boro	Gene Bank of BRRI
16	BRRI dhan29	Boro	Gene Bank of BRRI
17	BRRI dhan35	Boro	GEPB, SAU
18	BRRI dhan36	Boro	GEPB, SAU
19	BRRI dhan58	Boro	GEPB, SAU
20	BRRI dhan59	Boro	Gene Bank of BRRI

3.3 Experimental materials

The healthy seeds of twenty local lines of Boro rice collected from BRRI and the Dept. of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka which were used as experimental materials. The materials used in that experiment is shown in Table 1.

3.4 Design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD). The field was divided into four blocks; each block was sub-divided into 20 plots where lines were randomly assigned in total 80 plots (Plate 9). The experimental field size was 15 m x 13 m = 195 m^2 where 1m boarder was maintained surrounding the field in every block. The unit plot size was 1 m x 1 m. Twenty local lines were distributed randomly in the plot in each block.

3.5 Germination of seeds

Seeds of all collected rice lines were soaked separately for 24 hours in cloth bags on 08 December 2018. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination (Plate 2). Seeds were sprouted properly after 72 hours.

3.6 Preparation of seedbed and raising of seedlings

The seed bed was prepared by puddling the wetland with repeated ploughing followed by laddering. Germinated seeds were sown on 12 December 2018 in the seed bed separately and proper tags were maintained (Plate 3). Beds were protected from birds and others pest.

Plate 1. Cleaning of seeds with water to separate healthy seeds

Plate 2. Soaking of seeds for germination

Plate 3. Ploughing with kodal for seed bed preparation

Plate 4. Irrigating for making mud and leveling of seed bed

Plate 5. Sowing of seeds and seedbed covered with net for protction

Plate 6. Supervision by Prof. Dr. Kazi Md. Kamrul Huda at early seedling stage

3.7 Preparation of main land

The land was prepared thoroughly by 3-4 ploughing followed by laddering to attain a good puddle. Weeds and stubbles were removed and the land was finally prepared by the addition of basal dose of fertilizers recommended by BRRI. (Plate 8)

3.8 Application of fertilizer

The fertilizers N, P, K were applied in the form of urea, TSP and MP, respectively. The entire amount of cow dung, TSP and MP were applied during

Plate 7. Fertilization by field labour

Plate 8. Tillage for main field preparation

final preparation of field. The dose and method of application of fertilizer are sown in Table 2. The entire cow dung, TSP and half of MoP were applied at the time of final land preparation on 14 January 2019. The total urea and remaining MoP were applied in three installments, at 15 days after transplanting (DAT), 30 DAT and 45 DAT recommended by BRRI, (2014). (Plate 7)

Table 2. Dose and method of application of fertilizers in rice field

Fertilizers	Dose (per ha)	Application (%)			
		Basal	1st installment	2nd installment	3rd installment
Cow dung	6 ton	100	--	--	--
Urea	135 Kg	--	33.33	33.33	33.33
TSP	55 Kg	100	--	--	--
MP	85 Kg	50	16.67	16.67	16.67

3.9 Transplanting of seedling

Healthy seedlings of 25 days old were transplanted on 17 January 2019 in separate strip of experimental field. Water level was maintained properly after transplanting. The distance between row to row was 20 cm and plant to plant was 10 cm.

Plate 9. Making plots according to layout

Plate 10. Field inspection by supervisor Prof. Dr. Kazi Md. Kamrul Huda at transplanting day

3.10 Intercultural operation and after care

After establishment of seedlings, various intercultural operations and after care were accomplished for better growth and development of the rice seedling.

3.11 Gap filling

Necessary gap filling was done within seven days of transplanting on 25 January 2019. (Plate 11)

Plate 11. Gap filling and tagging of plots

3.12 Irrigation and drainage

In irrigated condition, flood irrigation was given to maintain a constant level of standing water up to 2 cm in the early stages to enhance tillering, proper growth and development of the seedlings and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting. In rainfed condition, drain out water from rainfed maintained plots at reproductive stage. The plots are maintained as a way that's why no water could pass into it as the plots were bordered from surroundings in the reproductive stage. The other stages are same as irrigated condition.

Plate 12. A view of field at tillering stage

Plate 13. Tagging of the plots

3.13 Weeding

The crop was kept weed free throughout the growth period. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by mechanical means. Hand weeding was done at 25 and 40 days after transplanting. 1st weeding and mulching was done on 19 January 2019.

3.14 Tagging

The tagging was placed in every plot on 20 January 2019. (Plate 14)

3.15 Plant protection measure

Proper control measures were taken against rice stem borer during tillering and heading stage of rice. Diazinon 50EC was applied for controlling stem borer on 14 June 2017. Furadan 5G @ l kg per bigha was applied at active tillering stage and panicle initiation stage of rice for controlling rice yellow stem borer on 22 Jan 2019. Cupravit 80 WP @ 2.5 g per liter water was applied against bacterial leaf blight of rice.

3.16 Harvest

The rice is harvested manually according to their maturity. Harvested crop from each crop are bundled separately and tagged were properly maintained.

Plate 14. Transporting of harvested rice for data collection and threshing

Plate 15. Threshing of rice by hand

3.17 Data Collection

3.17.1 Plant height (cm)

The average height of the 5 plants/hill in ten hills is measured from the base of the plant to the top of the latest spikelet on the panicle excluding awn. The length of stem was measured in centimeter and categorized into following five groups **(**Table 4). Figure 10 represented the rice culm length.

3.17.2 Flag leaf length (cm)

Flag leaf length is measured length from the leaf base to the leaf tip of the fully expanded leaves in centimeter.

3.17.3 Flag leaf width (cm)

Flag leaf width is measured at the widest point of the leaf in centimeter.

3.17.4 Number of primary branches per panicle

Number of primary branches per panicle was counted from each of the sample plants and the average was taken.

3.17.5 Number of secondary branches per panicle

Number of secondary branches per panicle was counted from each of the sample plants and the average was taken.

3.17.6 Panicle length (cm)

Panicle length was measured in centimeters at the time of plant maturity from the base of panicle to the tip, excluding awn of last spikelet prior to harvesting. Panicle length was classified into four groups with codes according to guided descriptors as per follows (Table 4).

3.17.7 Number of filled grains per panicle

Total number of spikelets per panicle was measured by adding filled and unfilled grains per panicle.

3.17.8 Number of unfilled grains per panicle

The number of filled grains of ten randomly selected panicles of main tiller from the hills was counted filled grains and then averaged.

3.17.9 Thousand seed weight (g)

After threshing and recording the net yield, a random sample of fully grown 1000 seeds were counted and weighed at 12% moisture content to record the test weight. According to test weight, the lines were categorized into five different groups as per the guided descriptors.

3.17.10 Yield (ton/ha)

Yield per plant was converted into yield per hectare and denoted as ton.

3.18 Statistical analysis

Analysis of variance was done for all the characters under study using the mean values (Singh and Chaudhury, 1985). Least Significant Difference (LSD) test was performed for all the characters to test the difference between the means of the genotypes.

Estimation of Stress Tolerance Index (STI)

Stress tolerance index (STI) were calculated according to Fernandez (1992):

$$STI = \frac{Y_{pi} \times Y_{si}}{{Y_p}^2}$$

Y_{pi}= yield of individual genotypes under irrigated condition (without stress),

Y_{si}= yield of individual genotypes under rainfed condition (with stress),

Y_p = average yield of all genotypes under irrigated condition (without stress).

Higher rates for the stress tolerance index (STI) indicate higher potential yield.

Estimation of correlation co-efficient

Genotypic and phenotypic correlation co-efficient were estimated using the formula suggested by Johnson *et al.* 1955; Miller *et al.* 1958; Singh and Chaudhury, 1985.

Genotypic correlation coefficient $r_g = \frac{Cov_{(g)1.2}}{\sqrt{\sigma^2_{(g)1}\sigma^2_{(g)2}}}$

Where,

$Cov_{(g)\,1.2}$ = Genotypic covariance between the variable X_1 and X_2

$\sigma^2_{(g)1}$ = genotypic variance of the variable X_1

$\sigma^2_{(g)2}$ = genotypic variance of the variable X_2

Similarly, phenotypic correlation co-efficient $r_{ph} = \frac{Cov_{(ph)1.2}}{\sqrt{\sigma^2_{(ph)1}\sigma^2_{(ph)2}}}$

Where,

$Cov_{(ph)\,1.2}$ = phenotypic covariance between the variable X_1 and X_2

$\sigma^2_{(ph)1}$ = phenotypic variance of the variable X_1

$\sigma^2_{(ph)2}$ = phenotypic variance of the variable X_2

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was undertaken with a view to screen promising lines by comparing the performance of twenty lines on ten characters of boro rice. The study was also conducted to find out performance, stress tolerance index, correlation coefficient and path coefficient to estimate direct and indirect effect of yield contributing traits on yield. The data were recorded on ten (10) different yield and yield contributing characters such as plant height, number of primary branches per panicle, number of secondary branches per panicle, flag leaf length (cm), flag leaf width (cm), Panicle length (cm), number of filled grain per panicle, number of unfilled grain per panicle, 1000 grains weight and yield per hectare. The data were statistically analyzed and thus obtained results are described below under the following headings:

4.1 Performance of growth parameters

4.1.1 Plant height(cm)

Significant effect on plant height was found in varieties of Boro rice in two different conditions- irrigated and rainfed (Table 3). The increasing pattern of plant height was almost similar in all varieties.

Results showed that, under irrigated condition, Gopal Deshi showed the highest plant height (141 cm) which was statistically similar to Birion, BR 25and Soilerpuna (140, 138, and 134.90 cm respectively) and under rainfed condition, Gopal Deshi and BR 25 showed the highest plant height (126 cm) which was closely followed BR 25 (119 cm).

On the other hand, under irrigated condition, the shortest plant was observed from BRRI Dhan36 (79 cm) which was statistically similar to BRRI Dhan59 (80 cm), BRRI Dhan50 (82 cm), BRRI Dhan35 (84 cm) respectively.

Table 3 (a). Performance of different genotypes / varieties under irrigated and rainfed condition

Line	Plant Height (cm)		Flag leaf length (cm)		Flag leaf width (cm)		Number of primary branches per panicle		Number of secondary branches per panicle	
	IR	RC	IR	RC	IR	RC	IR	RC	IR	RC
Poshusail	119.00 ^{g}	115.00 ^{d}	26.00 ^{j}	23.40 ^{h}	1.75 ^{ab}	1.60 ^{a}	9.00 ^{e}	7.50 ^{gh}	21.00 ^{j}	19.00 ^{l}
Gorchihail	118.00 ^{h}	111.00 ^{f}	27.80 ^{g}	24.00 ^{g}	1.50 ^{hi}	1.44 ^{cdef}	7.00 ^{i}	6.50 ^{j}	23.00 ^{hi}	25.00 ^{fg}
Birion	140.00 ^{b}	126.00 ^{a}	27.60 ^{g}	26.00 ^{d}	1.55 ^{fghi}	1.45 ^{bcde}	10.50 ^{b}	11.90 ^{a}	27.00 ^{d}	28.50 ^{de}
Soilerpuna	134.90 ^{d}	118.00 ^{c}	24.50 ^{m}	25.00 ^{ef}	1.60 ^{cdefgh}	1.50 ^{abcd}	10.00 ^{c}	11.00 ^{c}	24.00 ^{gh}	29.00 ^{cd}
Pankaich	134.00 ^{e}	106.00 ^{h}	25.50 ^{k}	20.00 ^{l}	1.65 ^{abcdefg}	1.25 ^{g}	8.00 ^{gh}	9.20 ^{e}	24.00 ^{gh}	22.50 ^{i}
Gopal Deshi	141.00 ^{a}	126.00 ^{a}	29.20 ^{d}	27.00 ^{b}	1.77 ^{a}	1.55 ^{abc}	12.00 ^{a}	11.50 ^{b}	27.00 ^{d}	27.50 ^{e}
Borail	108.90 ^{j}	92.00 ^{l}	28.80 ^{e}	26.80 ^{bc}	1.56 ^{fghi}	1.36 ^{defg}	9.00 ^{e}	9.50 ^{e}	32.00 ^{b}	33.80 ^{b}
BRRI dhan28	89.63 ^{n}	84.83 ^{m}	33.00 ^{a}	25.00 ^{ef}	1.58 ^{defghi}	1.42 ^{cdef}	9.40 ^{d}	8.23 ^{f}	26.00 ^{def}	22.00 ^{ij}
BRRI dhan55	100.50 ^{l}	94.00 ^{j}	32.00 ^{b}	28.00 ^{a}	1.64 ^{abcdefg}	1.44 ^{cdef}	8.50 ^{f}	10.60 ^{d}	36.00 ^{a}	38.00 ^{a}
Aus Boro	120.00 ^{f}	112.00 ^{e}	25.10 ^{l}	20.10 ^{kl}	1.45 ^{i}	1.32 ^{efg}	8.00 ^{gh}	7.00 ^{i}	26.00 ^{def}	23.00 ^{hi}
Aus IRRI	110.00 ^{i}	107.00 ^{g}	23.20 ^{n}	21.20 ^{j}	1.57 ^{efghi}	1.30 ^{fg}	7.00 ^{i}	9.40 ^{e}	22.00 ^{ij}	26.00 ^{f}
BRRI dhan45	100.00 ^{l}	93.00 ^{k}	25.20 ^{kl}	20.40 ^{k}	1.71 ^{abcd}	1.47 ^{abcd}	9.50 ^{d}	8.20 ^{f}	35.00 ^{a}	30.00 ^{c}
BRRI dhan50	82.00 ^{q}	80.00 ^{p}	28.23 ^{f}	26.60 ^{c}	1.66 ^{abcdef}	1.50 ^{abcd}	9.00 ^{e}	7.80 ^{g}	26.00 ^{def}	22.20 ^{ij}
BR 25	138.00 ^{c}	119.00 ^{b}	27.22 ^{h}	24.80 ^{f}	1.52 ^{ghi}	1.37 ^{defg}	8.00 ^{gh}	7.70 ^{g}	23.00 ^{hi}	20.60 ^{k}
BRRI dhan86	106.00 ^{k}	95.00 ^{i}	25.96 ^{j}	23.20 ^{h}	1.73 ^{abc}	1.52 ^{abc}	9.00 ^{e}	10.50 ^{d}	26.00 ^{def}	24.20 ^{gh}
BRRI dhan29	91.03 ^{m}	82.00 ^{n}	23.35 ^{n}	22.50 ^{i}	1.59 ^{defgh}	1.36 ^{defg}	8.22 ^{fg}	7.50 ^{gh}	26.80 ^{de}	22.00 ^{ij}
BRRI dhan35	84.00 ^{p}	81.00 ^{o}	26.00 ^{j}	21.20 ^{j}	1.62 ^{bcdefgh}	1.43 ^{cdef}	8.00 ^{gh}	7.20 ^{hi}	25.00 ^{efg}	20.00 ^{kl}
BRRI dhan36	79.00 ^{s}	76.00 ^{s}	27.00 ^{h}	25.30 ^{e}	1.70 ^{abcde}	1.59 ^{ab}	8.40 ^{f}	7.50 ^{gh}	24.80 ^{fgh}	21.00 ^{jk}
BRRI dhan58	85.00 ^{o}	78.00 ^{q}	30.00 ^{c}	23.40 ^{h}	1.50 ^{hi}	1.36 ^{defg}	9.47 ^{d}	8.20 ^{f}	29.33 ^{c}	25.00 ^{fg}
BRRI dhan59	80.00 ^{r}	77.00 ^{r}	26.50 ^{i}	22.20 ^{i}	1.64 ^{abcdefg}	1.46 ^{abcde}	7.80 ^{h}	8.30 ^{f}	24.13 ^{gh}	22.20 ^{ij}
LSD Value	0.7129	0.7944	0.3387	0.3347	0.1383	0.1478	0.3387	0.3222	1.801	1.238
Level of significance	**	**	**	**	**	**	**	**	**	**
% CV	10.40%	10.49%	10.76%	10.85%	15.08%	16.29%	12.33%	12.23%	14.13%	12.99%

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

Table 3 (b). Performance of different genotypes / varieties under irrigated and rainfed condition

Line	Panicle length (cm)		Number of filled grains per panicle		Number of unfilled grains per panicle		Thousand seed weight (g)		Yield (ton/ha)	
	IR	RC	IR	RC	IR	RC	IR	RC	IR	RC
Poshusail	21.13 hij	20.78 f	170.0 b	100.0 c	22.00 de	22.67 de	30.00 cd	19.00 hi	5.700 i	2.570 ij
Gorchihail	22.23 defghi	21.51 de	110.0 h	30.0 k	28.00 b	38.67 a	29.00 de	23.00 e	6.240 efg	2.873 hi
Birion	23.46 cde	23.04 a	210.0 a	130.0 a	11.67 i	12.33 j	26.00 gh	26.50 ab	5.800 hi	3.630 cd
Soilerpuna	22.52 cdefgh	22.09 bc	120.0 g	85.0 d	12.33 i	12.33 j	28.00 ef	26.00 b	6.400 def	4.150 ab
Pankaich	20.50 j	22.00 bc	80.0 j	60.0 i	34.33 a	38.33 a	29.30 de	22.00 f	5.900 ghi	3.080 gh
Gopal Deshi	20.93 ij	21.67 d	110.0 h	80.0 e	18.33 fg	17.56 hi	31.00 bc	26.30 b	6.200 efgh	4.260 a
Borail	20.97 ij	23.05 a	130.0 de	85.0 d	17.67 g	18.33 ghi	29.60 cde	27.20 a	6.380 def	3.850 bc
BRRI dhan28	22.97 cdef	21.79 cd	125.9 f	110.0 b	21.37 def	27.43 c	28.00 ef	23.00 e	6.133 efgh	3.160 efgh
BRRI dhan55	22.10 efghi	20.00 g	120.0 g	112.0 b	23.17 cd	25.78 cd	26.27 gh	24.00 d	7.000 bc	4.420 a
Aus Boro	22.30 defghi	21.20 e	104.0 i	55.0 j	23.57 cd	27.53 c	23.50 jk	19.00 hi	4.560 j	1.250 l
Aus IRRI	23.88 bc	21.35 e	140.0 c	70.0 g	14.33 hi	22.00 ef	25.00 hij	16.80 j	5.600 i	1.300 l
BRRI dhan45	25.21 ab	22.14 b	130.0 de	65.0 h	26.00 bc	20.33 efgh	31.00 bc	24.00 d	6.500 de	1.470 l
BRRI dhan50	23.23 cdef	21.29 e	128.0 ef	70.0 g	12.67 i	21.00 efg	34.00 a	25.00 c	6.000 fghi	3.450 de
BR 25	21.22 ghij	22.05 bc	122.0 g	65.0 h	19.00 efg	31.00 b	32.00 b	26.00 b	4.500 j	2.300 jk
BRRI dhan86	25.96 a	20.70 f	119.0 g	76.0 f	12.33 i	18.33 ghi	29.00 de	23.00 e	4.500 j	2.250 k
BRRI dhan29	23.64 cd	19.28 i	132.2 d	68.0 gh	8.33 j	16.00 i	23.23 k	18.50 hi	6.500 de	2.750 i
BRRI dhan35	21.91 fghij	19.25 i	130.0 de	80.0 e	19.30 efg	23.40 de	25.73 gh	18.20 i	6.700 cd	3.100 fgh
BRRI dhan36	22.64 cdefg	19.67 h	129.5 de	102.0 c	21.53 def	17.60 hi	26.90 fg	19.30 gh	7.637 a	3.400 def
BRRI dhan58	22.12 efghi	20.10 g	142.3 c	82.0 de	23.50 cd	23.20 de	25.37 ghi	21.20 f	7.027 bc	3.880 bc
BRRI dhan59	22.00 efghi	19.00 i	129.9 de	79.0 ef	17.43 gh	19.30 fgh	24.03 ijk	20.00 g	7.220 b	3.210 efg
LSD Value	1.468	0.3179	3.392	3.310	3.310	3.271	1.611	0.818 1	0.4149	0.3136
Level of significance	**	**	**	**	**	**	**	**	**	**
% CV	13.94%	10.91%	11.59%	12.55%	20.35%	18.73%	13.50%	12.21%	14.09%	16.24%

In a vertical column mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ at 1 or 5% level of significance as indicated

Under stress condition BRRI Dhan59 (77.00 cm), BRRI Dhan58 (78 cm), BRRI Dhan50 (80cm), BRRI Dhan35 (81 cm) produced the shortest plant 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 Flag leaf length (cm)

Under irrigated condition, flag leaf length was varied from 23.35 cm to 33 cm. The average flag leaf length was 28.175 cm. BRRI dhan28 (33 cm) produced the highest flag leaf length which was similar in statistically with BRRI Dhan55 (32 cm) and BRRI Dhan58 (30 cm). The lowest flag leaf length was observed by the Aus IRRI (23.2 cm).

Under rainfed condition, flag leaf length was varied from 20 to 28. The average flag leaf length was 23.815 cm. BRRI Dhan55 (28 cm) produced the highest flag leaf length which was similar in statistically with Gopal Deshi (27 cm) and Borail (26.8 cm). The lowest flag leaf length was observed by the Pankaich (20 cm). The results obtained by (2001) Ranawake *et al. (*2013) were in agreement with findings of present study.

4.1.3 Flag leaf width (cm)

Under irrigated condition, flag leaf width was varied from 1.45 cm to 1.77 cm. The average flag leaf width was 1.61 cm. Gopal Deshi (1.77 cm) produced the highest flag leaf width which was similar in statistically with Poshusail (1.75 cm) and BRRI Dhan86 (1.73 cm). The lowest flag leaf width was observed by the Aus Boro (1.45 cm).

Under rainfed condition, flag leaf width was varied from 1.25 cm to 1.6 cm. The average flag leaf width was 1.43 cm. Poshusail (1.6 cm) produced the highest flag leaf width which was similar in statistically with BRRI Dhan36 (1.5).

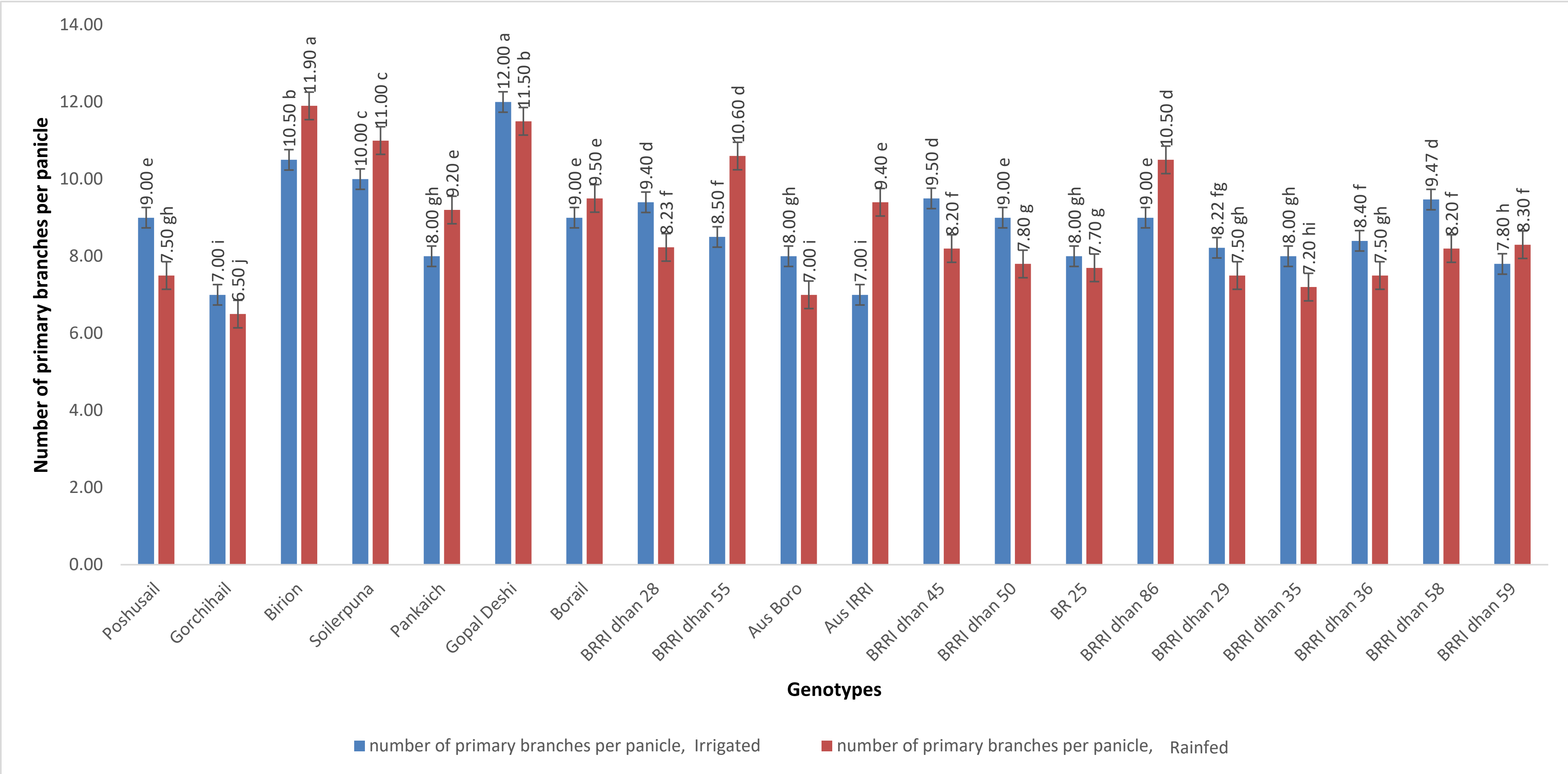

Figure 1. Relative performance of rice genotypes for number of primary branches per panicle under irrigated and rainfed condition

and BRRI Dhan86 (1.52cm). The lowest flag leaf width was observed by the Pankaic (1.25 cm). The results obtained by Ranawake *et al.* (2013) were in agreement with findings of present study.

4.1.4 Number of primary branches per panicle

Under irrigated condition, number of primary branches/panicle was varied from 7 to 12. The average of number of primary branches per panicle was 8.8. Gopal Deshi (12) produced the highest number of primary branches/panicle which was similar in statistically with Birion (10.50) and Soilerpuna (10). The lowest number of primary branches per panicle was observed by the Aus IRRI (7).

Under rainfed condition, number of primary branches/panicle was varied from 6.5 to 11.9. The average of number of primary branches per panicle was 8.67. Birion (11.9) produced the highest umber of primary branches/panicle which was similar in statistically with Gopal Deshi(11.50)and Soilerpuna (11). The lowest number of primary branches per panicle was observed by the Gorchihail (6.5) (Figure 1).

4.1.5 Number of secondary branches/panicle

Under irrigated condition, the important yield contributing trait number of secondary branches/panicle was ranged from 21 to 36 with a mean value of 26.204. The highest and lowest number of secondary branches/panicle was exhibited by BRRI Dhan55 (36) and Poshusail (21), respectively (Figure 2).

Under rainfed condition, the important yield contributing trait number of secondary branches/panicle was ranged from 19 to 38 with a mean value of 25.025. The highest and lowest number of secondary branches/panicle was exhibited by BRRI Dhan55 (38) and Poshusail (19), respectively.

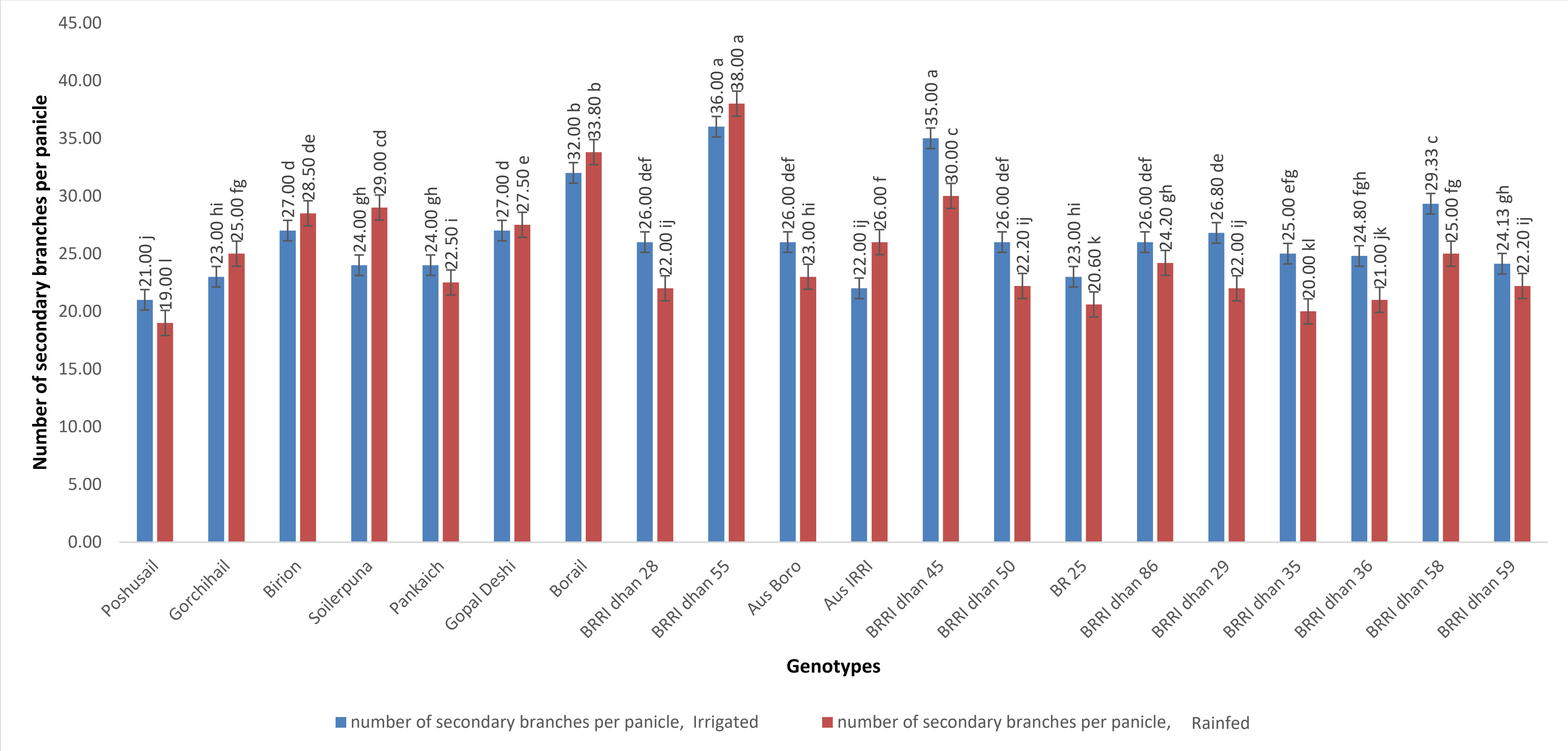

Figure 2. Relative performance of rice genotypes for number of secondary branches per panicle under irrigated and rainfed condition

4.1.6 Panicle length (cm)

Panicle length was significantly influenced by different rice varieties under stressed and irrigated condition (Table 1). Different length of panicle was observed due to varietal performance.

Results showed that, under stressed the longest panicle (23.05 cm) was produced by Borail and and under irrigaed condition, BRRI Dhan86 produced the longest panicle (25.96 cm), which was closely followed by Borail (23.04 cm) under rainfed condition and BRRI Dhan45 (25.21 cm) under irrigated condition respectively.

On the other hand, under rainfed condition, the shortest panicle length was found in BRRI Dhan59 (19 cm). Under irrigated condition, the shortest panicle length was recorded in Pankaich (20.5 cm) which was statistically similar to Gopal Deshi (20.93 cm). The results obtained under the present study were in conformity with the findings of Rahman *et al.* (2002) and Wang *et al.* (2006).

4.1.7 Number of filled grains per panicle

Number of filled grains panicle^{-1}was significantly influenced by test varieties under irrigated and rainfed condition under the present study (Figure 3).
Under rainfed condition, among the local varieties, Birion produced the highest number of filled grains panicle^{-1} (130). BRRI Dhan55 showed good performance (112) for filled grains panicle^{-1} which was statistically similar to BRRI Dhan28(110). On the other hand, the lowest number of filled grains panicle^{-1} (30) was observed in Gorchihail.

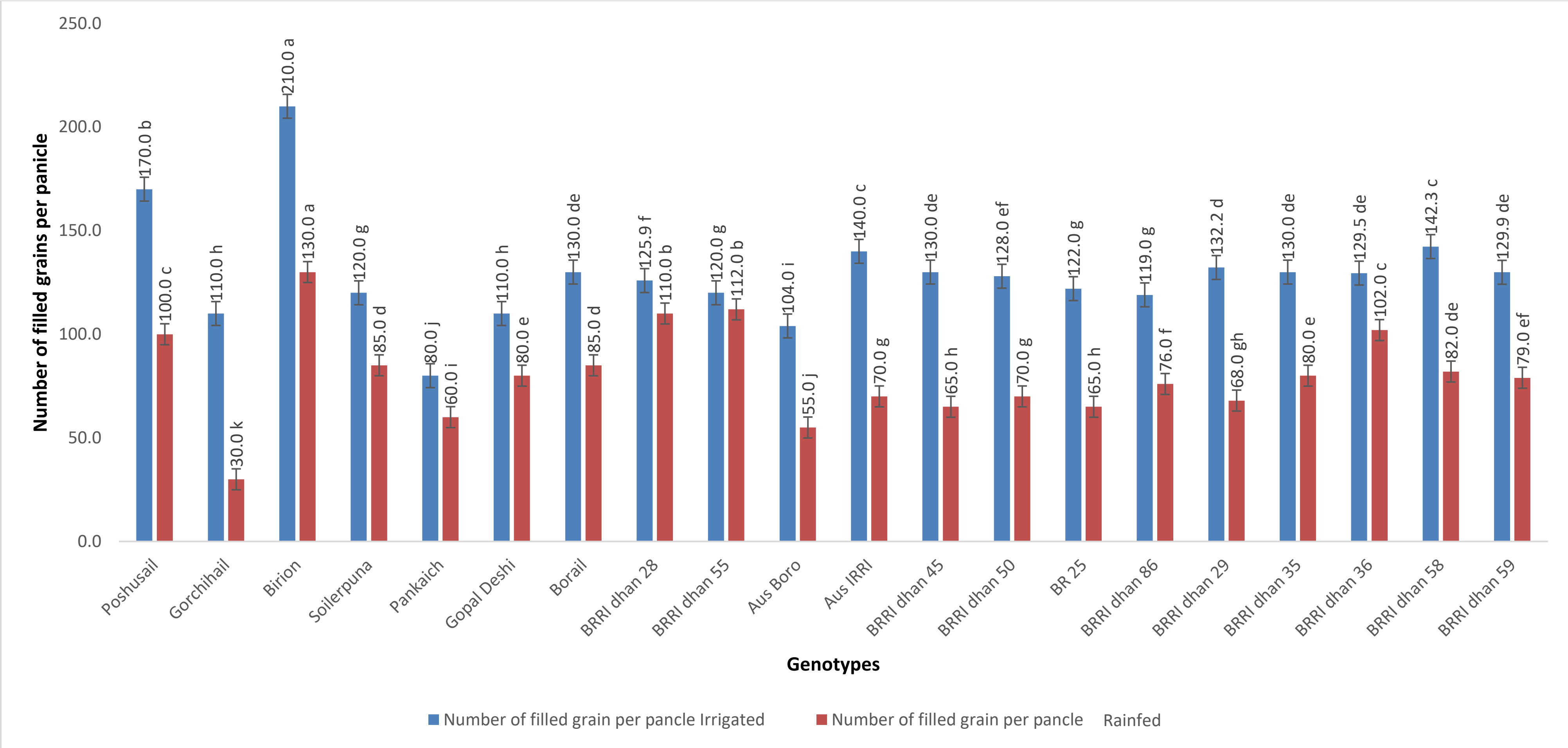

Figure 3. Relative performance of rice genotypes for number of filled grains per panicle under irrigated and rainfed condition

Under irrigated condition, highest number of filled grains panicle^{-1} (210) was observed in Birion which was significantly different from all other test varieties. Lowest number of filled grains panicle^{-1} (80.00) was produced by Pankaich under the same condition. The results obtained by Hossain (2001) and O'Toole and Moya, (1981) were in agreement with findings of present study.

4.1.8 Number of unfilled grains per panicle

Different lines had significant effect on unfilled grains panicle^{-1} (Figure 4) under stressed and irrigated condition.
Under rainfed condition, results showed that the highest number of unfilled grains panicle^{-1} was observed in Pankaich (38.33) and the lowest number of unfilled grains panicle^{-1} (12.33) was recorded from Soilerpuna.

In case of irrigated condition, Pankaich produced the highest number of unfilled grains panicle^{-1} (34.33). On the other hand, the lowest number of unfilled grains panicle^{-1} 8.33 and 11.67 were observed in BRRI Dhan29 and Birion respectively. 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.

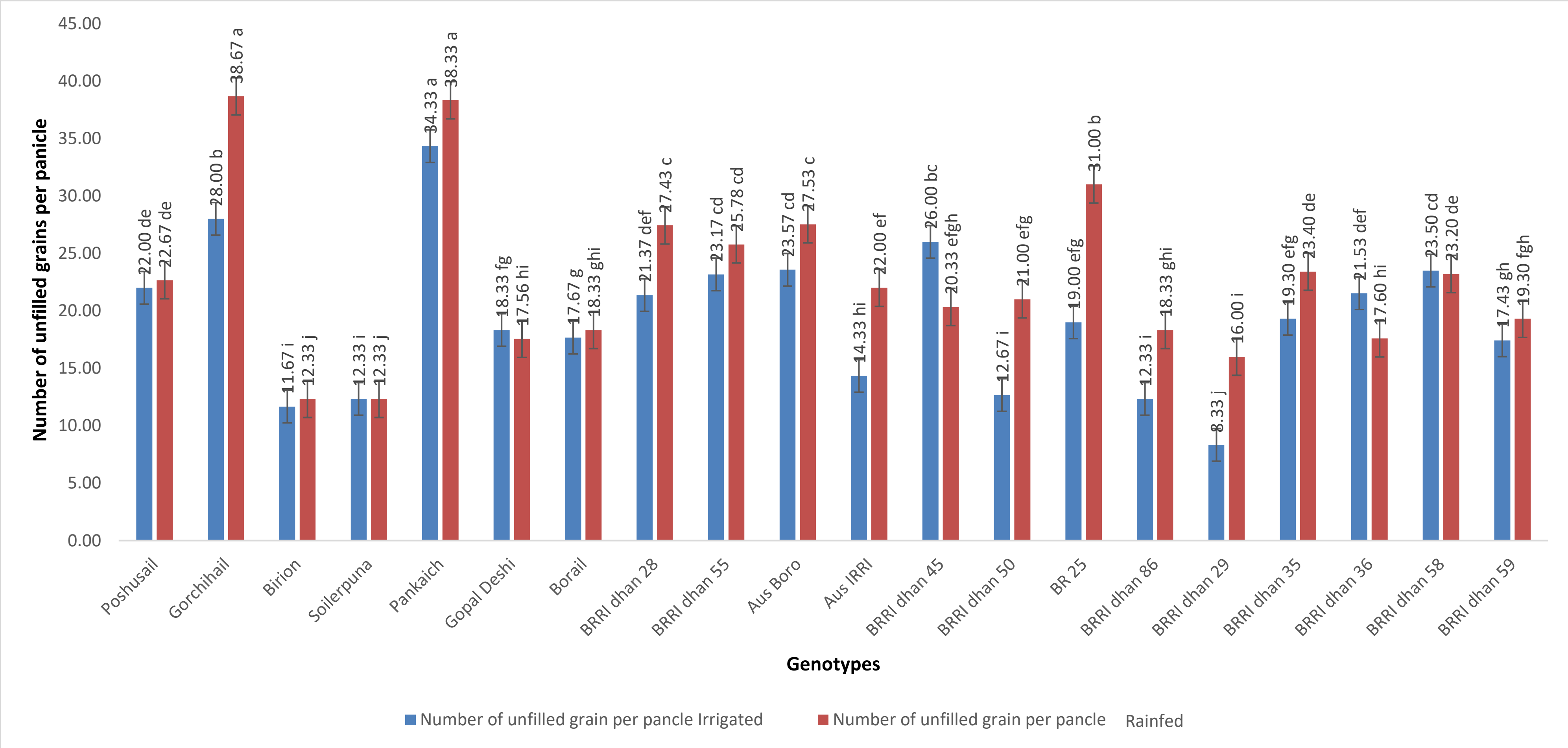

Figure 4. Relative performance of rice genotypes for number of unfilled grains per panicle under irrigated and rainfed condition

4.1.9 Thousand seed weight (g)

Both under rainfed and irrigated condition, significant influence of different varieties was observed on 1000-grain weight (Table 3).

Under rainfed condition, the highest 1000-grain weight (27.2 g) was recorded from BRRI Dhan50 which was significantly different from all other test varieties. Gopal Deshi (26.3 g), Soilerpuna (26 g), BR 25 (26 g), Birion (26.5 g) also produced comparatively higher 1000-grain weight from other varieties which were all significantly different from one another. The lowest 1000-grain weight (16.8 g) was observed from Aus IRRI.

On the other hand, under irrigated condition, BRRI Dhan 50 showed the highest value (34 g) for 1000-grain weight, which was statistically similar to BR 25 (32 g),Gopal Deshi (31 g) respectively. The lowest 1000-grains weight (23.23 g) under irrigated condition was recorded in BRRI Dhan29.

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.

4.1.10 Grain yield (ton/ha)

Different varieties produced significantly variable grain yield (Figure 5 and Appendix X) under rainfed and irrigated condition.

Among the tested twenty varieties, irrigated condition, BRRI Dhan36 showed its superiority in highest grain yield (7.637 t ha^{-1}) which was statistically similar to BRRI Dhan59 (7.22 t ha^{-1}) BRRI Dhan58 (7.027 t ha^{-1}), BRRI Dhan55 (7.00 t ha^{-1}) respectively.

Under rainfed condition, BRRI Dhan55 gave highest grain yield (4.42 t ha^{-1}) which was closely followed by Gopal Deshi (4.26 t ha^{-1}),Soilerpuna (4.15 t ha^{-1}),

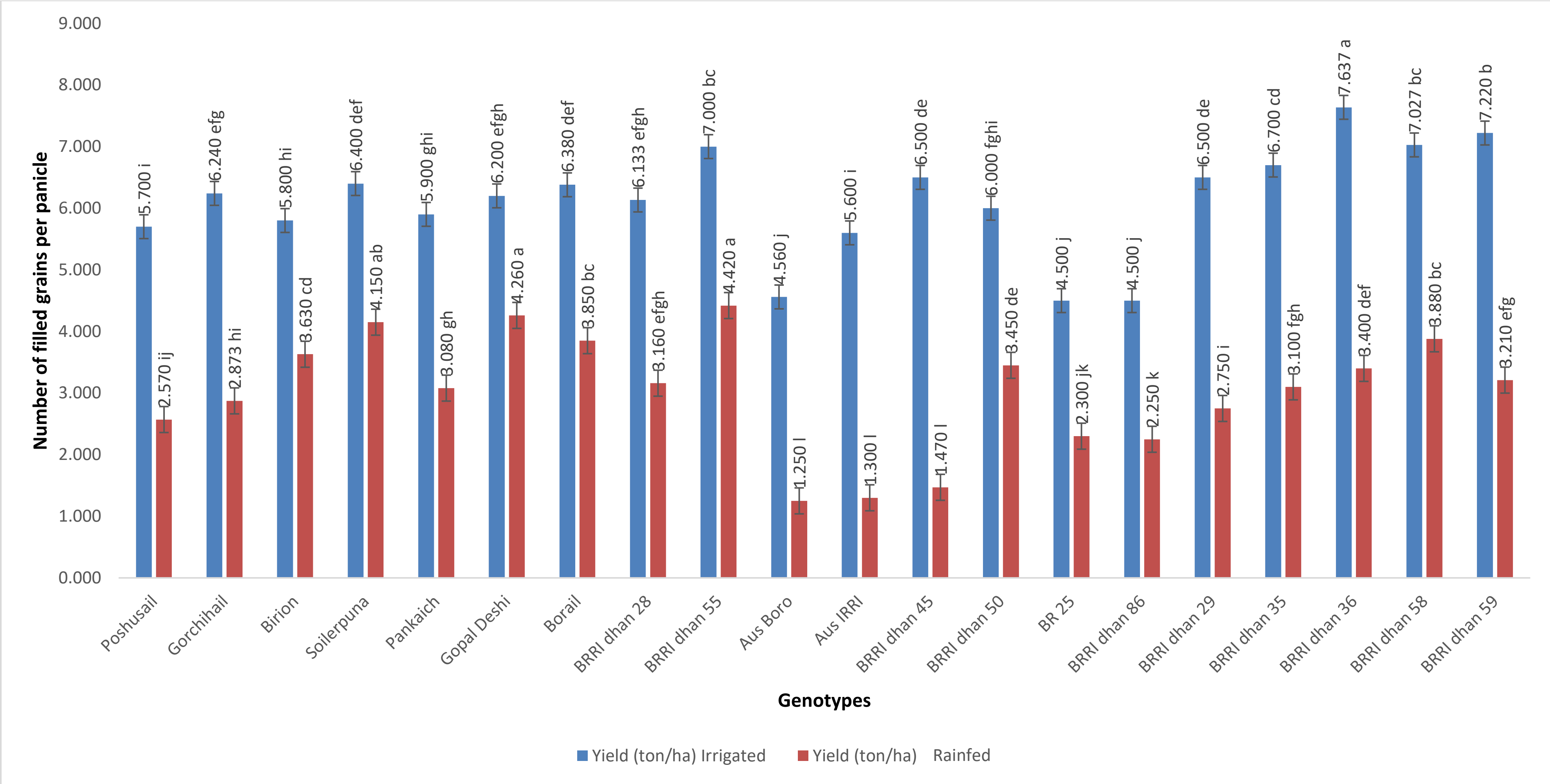

Figure 5. Relative performance of rice genotypes for yield (ton/ha) under irrigated and rainfed condition

BRRI Dhan58 (3.88 t ha^{-1}), Borail (3.85 t ha^{-1}), Birion (3.63 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.

4.2 Stress Tolerance Index (STI)

Stress is a disadvantageous influence on the plant exerted by an external factor. The ability to maintain functioning when exposed to a wide range of conditions is called stress tolerance. Several drought indices have been suggested based on various mathematical relationship between yield under irrigated and rainfed conditions. These indices vary with resistance and susceptibility of genotypes. STI can be used to identify genotypes that perform well under both stress and non-stress conditions. Higher rates for the stress tolerance index (STI) indicate higher potential yield. Here BRRI Dhan55 (0.824), BRRI Dhan59 (0.726), Soilerpuna (0.707), Gopal Deshi (0.703), BRRI Dhan36 (0.692) showed higher yield in ton per ha for stress tolerance indices gradually. The results are in agreement with the findings of Kumar *et al*. (2014).

(a) 1000 seeds of Soilerpuna (b) 1000 seeds of Gopal Deshi (c) 1000 seeds of BRRI dhan55

Plate16. Some genotypes which shows higher stress tolerance index (STI) for yield (ton/ha)

Table 4 (a). Stress Tolerance Index (STI)

Line	Plant height (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Number of primary branches per panicle	Number of secondary branches per panicle
Poshusail	1.189 d	0.828 j	1.077 a	0.874 hi	0.571 l
Gorchihail	1.112 e	0.908 i	0.830 fghij	0.589 m	0.824 fgh
Birion	1.511 a	0.977 f	0.860 efghi	1.617 b	1.105 c
Soilerpuna	1.394 b	0.834 j	0.918 cdef	1.423 c	0.997 d
Pankaich	1.260 c	0.694 n	0.794 hij	0.953 fg	0.776 ghij
Gopal Deshi	1.518 a	1.073 c	1.050 ab	1.787 a	1.066 cd
Borail	0.865 g	1.050 d	0.817 ghij	1.107 e	1.553 b
BRRI dhan28	0.664 h	1.123 b	0.863 efghi	1.002 f	0.820 fghi
BRRI dhan55	0.818 g	1.219 a	0.903 defg	1.166 de	1.963 a
Aus Boro	1.148 de	0.687 no	0.737 j	0.725 l	0.857 ef
Aus IRRI	1.022 f	0.669 o	0.780 ij	0.852 hij	0.822 fghi
BRRI dhan45	0.811 g	0.700 mn	0.967 bcd	1.008 f	1.505 b
BRRI dhan50	0.550 i	1.022 e	0.953 bcde	0.909 gh	0.828 efgh
BR 25	1.430 b	0.919 hi	0.796 hij	0.797 jk	0.678 k
BRRI dhan86	0.851 g	0.820 j	1.006 abc	1.224 d	0.904 e
BRRI dhan29	0.660 h	0.715 m	0.832 fghij	0.798 jk	0.845 efg
BRRI dhan35	0.571 i	0.750 l	0.891 defgh	0.746 kl	0.718 jk
BRRI dhan36	0.526 i	0.930 h	1.034 ab	0.816 ij	0.747 ijk
BRRI dhan58	0.582 i	0.955 g	0.785 ij	1.005 f	1.052 cd
BRRI dhan59	0.536 i	0.801 k	0.921 cdef	0.838 ij	0.768 hij

Table 4 (b). Stress Tolerance Index (STI)

Line	Panicle length (cm)	Number of filled grains per panicle	Number of unfilled grains per panicle	Thousand seed weight (g)	Yield (ton/ha)
Poshusail	0.864 hij	1.020 b	1.340 de	0.736 g	0.391 h
Gorchihail	0.940 cdef	0.198 n	2.901 b	0.861 ef	0.477 g
Birion	1.063 ab	1.637 a	0.378 j	0.889 de	0.561 ef
Soilerpuna	0.978 cd	0.612 gh	0.403 ij	0.938 cd	0.707 bc
Pankaich	0.887 efghi	0.288 m	3.524 a	0.830 f	0.484 g
Gopal Deshi	0.893 efghi	0.528 ij	0.853 gh	1.051 ab	0.703 bc
Borail	0.951 cde	0.663 f	0.873 gh	1.039 b	0.656 cd
BRRI dhan28	0.985 cd	0.830 c	1.574 cd	0.830 f	0.518 fg
BRRI dhan55	0.869 ghij	0.806 cd	1.604 cd	0.814 f	0.824 a
Aus Boro	0.930 defg	0.343 l	1.727 c	0.575 jkl	0.151 k
Aus IRRI	1.003 bc	0.588 h	0.846 gh	0.541 l	0.195 jk
BRRI dhan45	1.098 a	0.507 j	1.416 cde	0.960 c	0.255 ij
BRRI dhan50	0.973 cd	0.538 i	0.718 ghi	1.097 a	0.551 f
BR 25	0.921 defgh	0.476 k	1.581 cd	1.074 ab	0.277 i
BRRI dhan86	1.057 ab	0.542 i	0.611 hij	0.861 ef	0.271 i
BRRI dhan29	0.896 efgh	0.539 i	0.349 j	0.555 kl	0.476 g
BRRI dhan35	0.830 ij	0.624 g	1.200 ef	0.603 jk	0.554 f
BRRI dhan36	0.876 fghij	0.792 d	1.020 fg	0.670 hi	0.692 bc
BRRI dhan58	0.875 ghij	0.700 e	1.453 cde	0.695 gh	0.726 b
BRRI dhan59	0.822 j	0.616 gh	0.892 fgh	0.619 ij	0.619 de

4.3 Correlation among character for irrigated condition

4.3.1 Plant height(cm)

Plant height showed nonsignificant positive correlation with number of unfilled grains per panicle (r=0.080) and with thousand seed weight (g) (r=0.261). This character had nonsignificant negative correlation with flag leaf length (cm) (-0.161), flag leaf width (cm) (-0.065) number of primary branches per panicle (-0.309), number of secondary branches per panicle (-0.204), panicle length (cm) (-0.53), number of filled grains per panicle (-0.004). Plant height showed significant negative correlation with yield (ton/ha) (r = -0.535) which indicated that increased of plant height decreased Yield (ton/ha). Afrin *et al.*, Rahman *et al.* (2014) also reported same negative correlation results for panicle length.

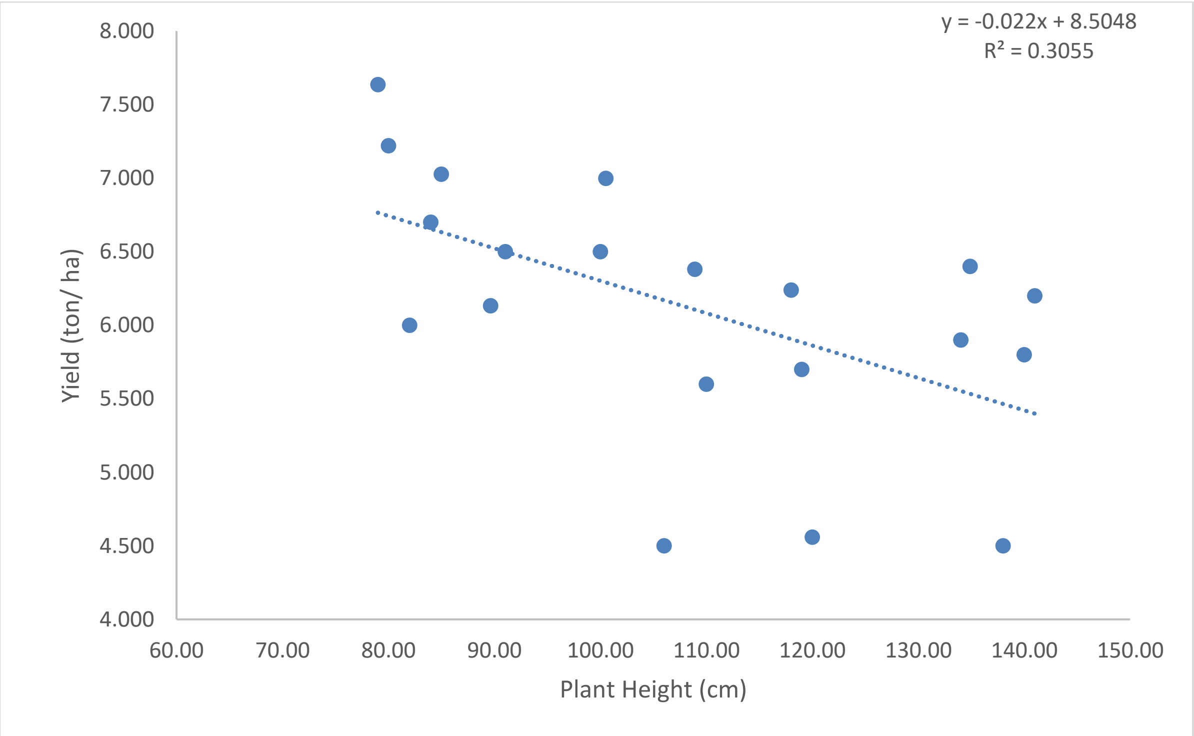

Figure 6. Correlation between plant height (cm) and yield (ton/ha) under irrigated condition

Table 5. Correlation co-efficient among different characters under irrigated condition

	Plant height (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Number of primary branches per panicle	Number of secondary branches per panicle	Panicle length (cm)	Number of filled grains per panicle	Number of unfilled grains per panicle	Thousand seed weight (g)	Yield (ton/ha)
Plant height (cm)	1	-0.161 ns	-0.065 ns	0.309 ns	-0.204 ns	-0.253 ns	-0.004 ns	0.080 ns	0.261 ns	-0.535 **
Flag leaf length (cm		1	-0.028 ns	0.330 *	0.407 *	-0.227 ns	0.017 ns	0.225 ns	0.211 ns	0.249 ns
Flag leaf width (cm)			1	0.260 ns	0.022 ns	0.190 ns	-0.001 ns	0.017 ns	0.304 ns	0.091 ns
Number of primary branches per panicle				1	0.299 ns	0.001 ns	0.271 ns	-0.228 ns	0.294 ns	0.063 ns
Number of secondary branches per panicle					1	0.120 ns	-0.017 ns	0.122 ns	0.029 ns	0.316 ns
Panicle length (cm)						1	0.195 ns	-0.395 *	-0.050 ns	-0.152 ns
Number of filled grains per panicle							1	-0.441 **	-0.141 ns	0.067 ns
Number of unfilled grains per panicle								1	0.129 ns	0.097 ns
Thousand seed weight (g)									1	-0.219 ns
Yield (ton/ha)										1

4.3.2 Flag leaf length (cm)

Flag leaf length (cm) showed nonsignificant positive correlation with number of filled grains per panicle (r=0.017), number of unfilled grains per panicle (r=0.225), thousand seed weight (g) (r=0.221) and with yield (ton/ha) (r = 0.249). This character had nonsignificant negative correlation with flag leaf width (cm)(r = -0.028), panicle length (cm) (-0.227). Flag leaf length (cm)showed significant positive correlation with number of primary branches per panicle (r = 0.330), number of secondary branches per panicle which indicated that increased of flag leaf length (cm) increase number of primary branches per panicle , number of primary branches per panicle. Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for flag leaf length.

4.3.3 Flag leaf width (cm)

Flag leaf length (cm) showed nonsignificant positive correlation with number of primary branches per panicle (r = 0.260), number of secondary branches per panicle (r = 0.022), panicle length (cm) (0.190), number of unfilled grains per panicle (r=0.17), thousand seed weight (g) (r=0.304) and with yield (ton/ha) (r = 0.091). This character had nonsignificant negative correlation with number of filled grains per panicle (r=-0.001). Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for flag leaf width.

4.3.4 Number of primary branches per panicle

Flag leaf length (cm) showed nonsignificant positive correlation with number of secondary branches per panicle (r = 0.299), panicle length (cm) (0.001), number of filled grains per panicle (r=0.271), thousand seed weight (g) (r=0.294) and with yield (ton/ha) (r = 0.063). This character had nonsignificant negative correlation with number of unfilled grains per panicle (r=-0.228). Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for number of primary branches per panicle.

4.3.5 Number of secondary branches per panicle

Flag leaf length (cm) showed nonsignificant positive correlation with panicle length (cm) (0.120), number of unfilled grains per panicle (r=0.122), thousand seed weight (g) (r=0.029) and with yield (ton/ha) (r = 0.316). This character had nonsignificant negative correlation with number of filled grains per panicle (r=-0.017). Afrin *et al*. Rahman *et al.* (2014) also reported same negative correlation results for number of secondary branches per panicle.

4.3.6 Panicle length (cm)

Panicle length **s**how positive nonsignificant correlation with number of filled grains per panicle (r=0.195) and negative nonsignificant correlation thousand seed weight (g) (r=-0.050) and with yield (ton/ha) (r = -0.152). This character had significant negative correlation with number of unfilled grains per panicle (r= -0.395). Rahman *et al.* (2014) also reported same results for panicle length.

4.3.7 Number of filled grains per panicle

Number of filled grains per panicle show positive correlation with yield (ton/ha) (r = -0.067) negative correlation with thousand seed weight (g) (r=-0.141). This character had significant negative nonsignificant correlation with number of unfilled grains per panicle (r= -0.441).

4.3.8 Number of unfilled grains per panicle

Number of filled grains per panicle show nonsignificant positive correlation with thousand seed weight (g) (r=0.129) and yield (ton/ha) (r = 0.97).

4.3.9 Thousand seed weight (g)

Thousand seed weight shows nonsignificant negative correlation with yield (ton/ha) (r = -0.219). Afrin *et al*. (2017) also reported same results thousand seed weight.

4.4 Correlation among characters under rainfed condition

4.4.1 Plant height(cm)

Plant height showed nonsignificant positive correlation with flag leaf length (cm) (0.076), flag leaf width (cm) (0.002), number of secondary branches per panicle (0.153), number of unfilled grains per panicle (r=0.095). This character had nonsignificant negative correlation with number of filled grains per panicle (-0.035), yield (ton/ha) (r = -0.090). Plant height showed significant positive correlation with number of primary branches per panicle (-0.309), panicle length (cm) (-0.53), thousand seed weight (g) (r=0.221) which indicated that increased of plant height decreased Yield (ton/ha). Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for panicle length.

4.4.2 Flag leaf length (cm)

Flag leaf length (cm) showed nonsignificant positive correlation with panicle length (cm) (0.213) and nonsignificant negative correlation with number of unfilled grains per panicle (r=-0.297). This character had significant positive correlation with flag leaf width (cm)(r=0.334), number of primary branches per panicle (r = 0.439), number of secondary branches per panicle (r = 0.442), number of filled grains per panicle (r=0.510), thousand seed weight (g) (r=0.634). Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for flag leaf length.

4.4.3 Flag leaf width (cm)

Flag leaf width (cm) showed nonsignificant positive correlation with number of primary branches per panicle (r = 0.091), number of filled grains per panicle (r=0.277), thousand seed weight (g) (r=0.186), yield (ton/ha) (r = 0.223). and with. This character had nonsignificant negative correlation with number of secondary branches per panicle (r=-0.039), panicle length (cm) (-0.119), number of unfilled grains per panicle (r=-0.308)

Table 6. Correlation co-efficient among different characters under rainfed condition

	Plant height (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Number of primary branches per panicle	Number of secondary branches per panicle	Panicle length (cm)	Number of filled grains per panicle	Number of unfilled grains per panicle	Thousand seed weight (g)	Yield (ton/ha)
Plant height (cm)	1	0.076 ns	0.002 ns	0.423 **	0.153 ns	0.616 **	-0.035 ns	0.095 ns	0.357 *	-0.090 ns
Flag leaf length (cm			1	0.334 *	0.439 **	0.442 **	0.213 ns	0.510 **	-0.297 ns	0.634 **
Flag leaf width (cm)			1	0.091 ns	-0.039 ns	-0.119 ns	0.277 ns	-0.308 ns	0.186 ns	0.223 ns
Number of primary branches per panicle				1	0.601 **	0.395 *	0.499 **	-0.479 **	0.525 **	0.438 **
Number of secondary branches per panicle					1	0.340 *	0.241 ns	-0.206 ns	0.528 **	0.370 *
Panicle length (cm)						1	0.014 ns	0.046 ns	0.655 **	-0.026 ns
Number of filled grains per panicle							1	-0.521 **	0.167 ns	0.472 **
Number of unfilled grains per panicle								1	-0.102 ns	-0.237 ns
Thousand seed weight (g)									1	0.480 **
Yield (ton/ha)										1

4.4.4 Number of primary branches per panicle

Flag leaf length (cm) showed significant positive correlation with number of secondary branches per panicle (r = 0.601), panicle length (cm) (0.395), number of filled grains per panicle (r=0.499), thousand seed weight (g) (r=0.525) and with yield (ton/ha) (r = 0.438). This character had significant negative correlation with number of unfilled grains per panicle (r=-0.479). Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for number of primary branches per panicle.

4.4.5 Number of secondary branches per panicle

Number of secondary branches per panicle showed nonsignificant positive correlation with number of filled grains per panicle (r=0.241). This character had nonsignificant negative correlation with number of unfilled grains per panicle (r=-0.206). This character had significant positive correlation with panicle length (cm) (0.340), thousand seed weight (g) (r=0.528) and with yield (ton/ha) (r = 0.370). Afrin *et al.* Rahman *et al.* (2014) also reported same negative correlation results for number of secondary branches per panicle.

4.4.6 Panicle length (cm)

Panicle length show positive nonsignificant correlation with number of filled grains per panicle (r=0.014), number of unfilled grains per panicle (r=0.046), and negative nonsignificant correlation with yield (ton/ha) (r = -0.026). This character had significant positive correlation with thousand seed weight (g) (r=0.655). Rahman *et al.* (2014) also reported same results for panicle length.

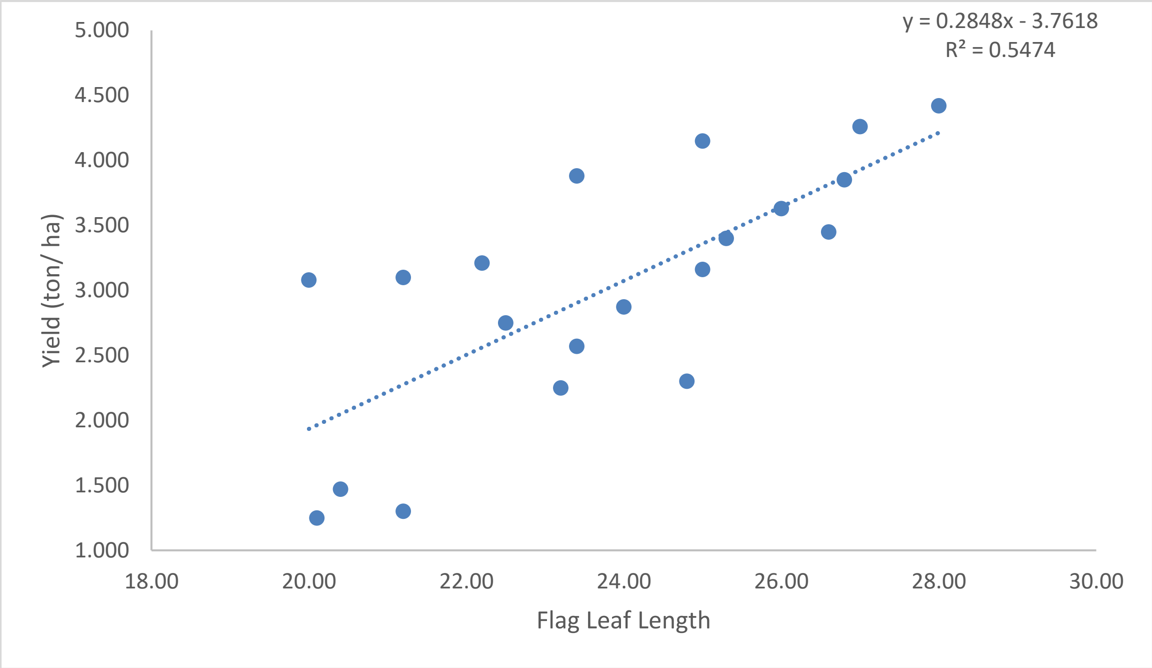

Figure 7. Correlation between flag leaf length and yield (ton/ha) under rainfed condition

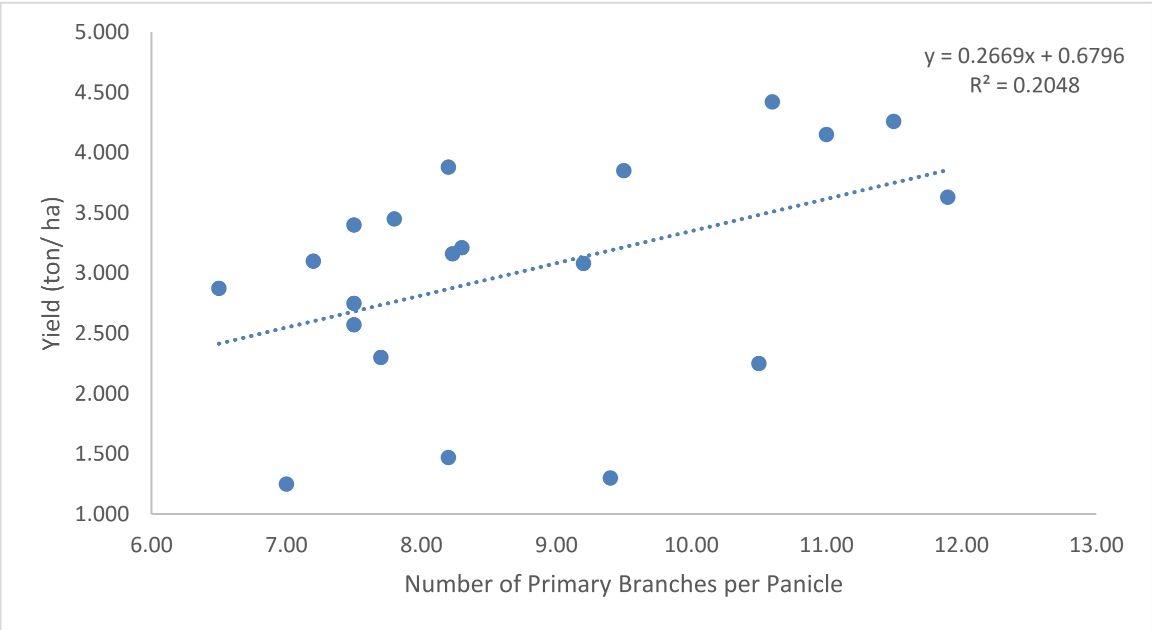

Figure 8. Correlation between number of primary branches and yield (ton/ ha) under rainfed condition

4.4.7 Number of filled grains per panicle

Number of filled grains per panicle show positive nonsignificant correlation with thousand seed weight (g) (r=-0.141) and negative significant correlation with number of unfilled grains per panicle (r= -0.521). This character had significant positive correlation with yield (ton/ha) (r = -0.067).

4.4.8 Number of unfilled grains per panicle

Number of filled grains per panicle show nonsignificant negative correlation with thousand seed weight (g) (r=-0.102) and yield (ton/ha) (r = -0.237).

4.4.9 Thousand seed weight (g)

1000 grain weight shows significant positive correlation with yield (ton/ha) (r =0.480). Afrin *et al.* (2017) also reported same results 1000 grain weight.

4.4.10 Correlation between grain yield and other traits

Correlations revealed that grain yield had significant positive association with flag leaf length (cm), number of primary branches per panicle, number secondary branches per panicle, number of filled grains per panicle and with thousand seed weight.

Correlation revealed that grain yield nonsignificant negative association with plant height (cm), panicle length (cm), number of unfilled grains per panicle and nonsignificant positive association with flag leaf width (cm).

Afrin *et al.* Rahman *et al.* (2014) also reported same negative results for Correlation between grain yield and other traits.

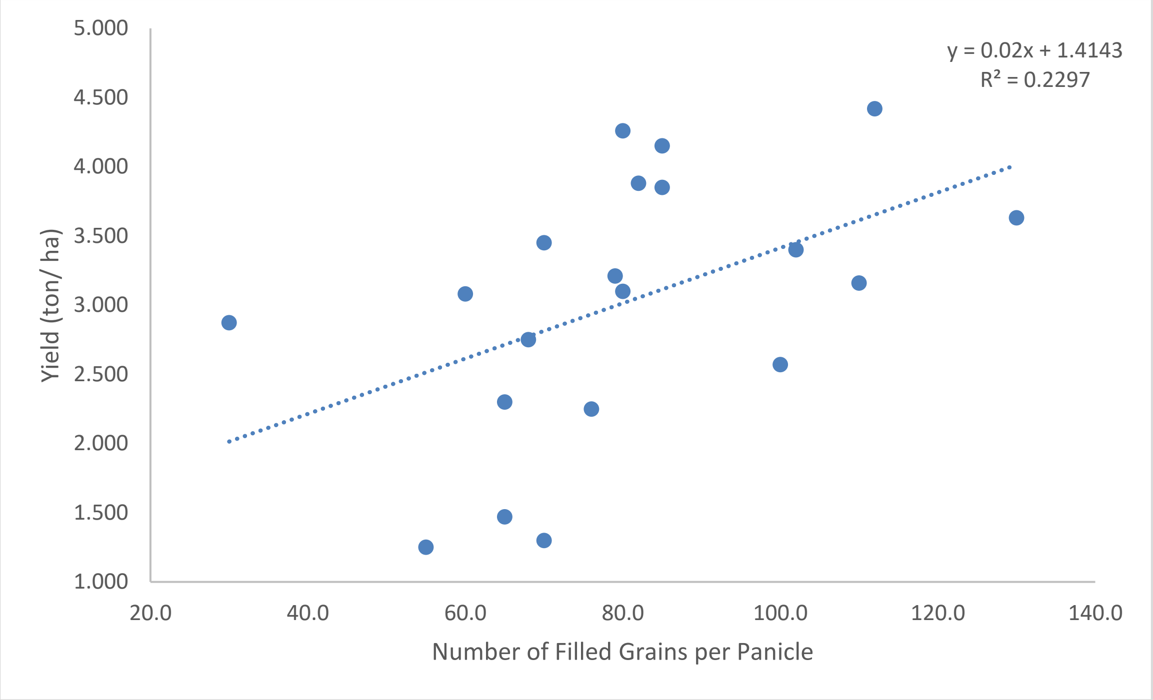

Figure 9. Correlation between number of filled grains per panicle and yield (ton/ha) under rainfed condition

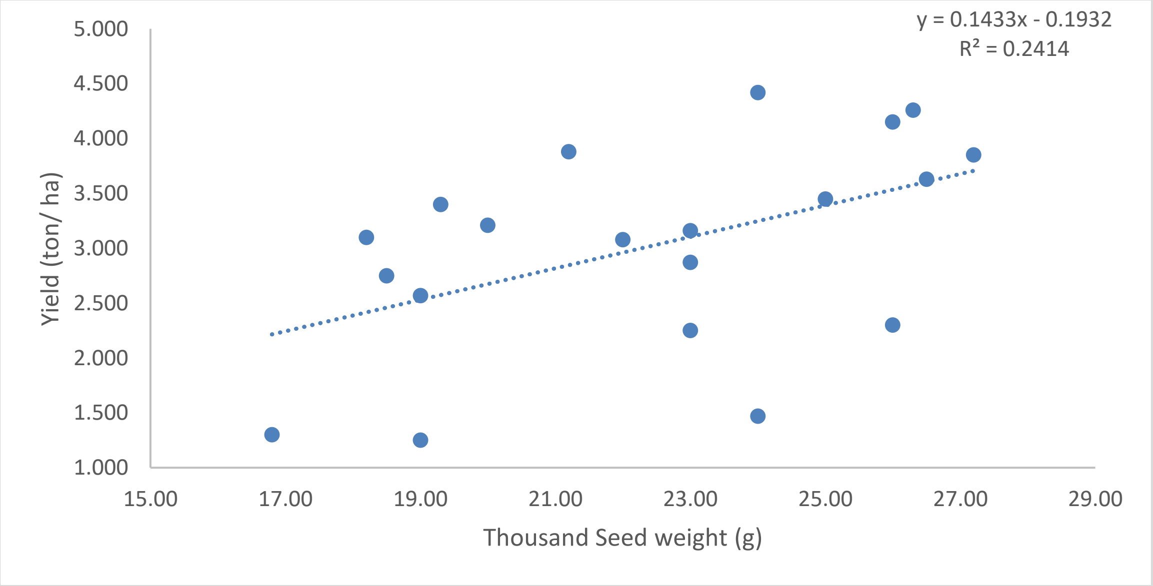

Figure 10. Correlation between thousand seed weight (g) and yield (ton/ha) under rainfed condition

4.5 Path Coefficient Analysis under Irrigated Condition

Association of character determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on yield (ton/ha). In order to find out a clear picture of the inter-relationship between yield (ton/ha) and other yield attributes, direct and indirect effects were determined out using path analysis at genotypic level which also measured the relative importance of each component. yield (ton/ha) was considered as a resultant (dependent) variable and plant height (cm), flag leaf length (cm), flag leaf width (cm), number of primary branches per panicle, number of secondary branches per panicle, panicle length (cm), number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight (g) were causal (independent) variables. Estimation of direct and indirect effect of Path coefficient among different characters under irrigated condition is presented in Table 7.

4.5.1 Plant height (cm)

Path analysis revealed that plant height had negative direct effect (-0.650) on yield (ton/ha). It had positive indirect effect on flag leaf length (0.014), number of primary branches per panicle (0.085), panicle length (0.088) and number of unfilled grains per panicle (0.011) (Table 7). Plant height had negative indirect effect via flag leaf width (-0.005), number of secondary branches per panicle (-0.034), and thousand seed weight (-0.042) (Table 7). These results indicated that if plant height is increased then yield (ton/ha) would be increased mostly through the positive indirect effect of plant height with other characters. Rokonuzzaman *et al.* (2008) and Habib *et al.* (2005) also reported direct positive result for this character.

Table 7. Path coefficient among different characters under irrigated condition

	Plant Height (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Number of primary branches per panicle	Number of secondary branches per panicle	Panicle length (cm)	Number of filled grains per panicle	Number of unfilled grains per panicle	Thousand seed weight (g)	Yield (ton/ha)
Plant Height (cm)	**-0.650**	0.014	-0.005	0.085	-0.034	0.088	0.000	0.011	-0.042	-0.535
Flag leaf length (cm	0.105	**-0.088**	-0.002	0.090	0.068	0.078	0.002	0.031	-0.034	0.249
Flag leaf width (cm)	0.042	0.002	**0.084**	0.071	0.004	-0.066	0.000	0.002	-0.049	0.091
Number of primary branches per panicle	-0.201	-0.029	0.022	**0.274**	0.050	0.000	0.027	-0.032	-0.048	0.063
Number of secondary branches per panicle	0.133	-0.036	0.002	0.082	**0.166**	-0.041	-0.002	0.017	-0.005	0.316
Panicle length (cm)	0.165	0.020	0.016	0.000	0.020	**-0.346**	0.020	-0.055	0.008	-0.152
Number of filled grains per panicle	0.002	-0.002	0.000	0.074	-0.003	-0.068	**0.101**	-0.061	0.023	0.067
Number of unfilled grains per panicle	-0.052	-0.020	0.001	-0.063	0.020	0.137	-0.044	**0.138**	-0.021	0.097
Thousand seed weight (g)	-0.170	-0.019	0.026	0.080	0.005	0.017	-0.014	0.018	**-0.162**	-0.219

Residual effect = 0.699

4.5.2 Flag leaf length (cm)

Path analysis revealed that flag leaf length had negative direct effect (-0.088) on yield (ton/ha). It had positive indirect effect on plant height (0.105), number of primary branches per panicle (0.090), number of secondary branches per panicle (0.068), panicle length (0.078), number of filled grains per panicle (0.002) and number of unfilled grains per panicle (0.031) (Table 7). Flag leaf length had negative indirect effect via thousands seed weight (-0.034) (Table 7). These results indicated that if flag leaf length is increased then yield (ton/ha) would be increased mostly through the positive indirect effect of flag leaf length with other characters. Rokonuzzaman *et al.* (2008) and Habib *et al.* (2005) also reported direct positive result for this character.

4.5.3 Flag leaf width (cm)

Path analysis revealed that flag leaf width had positive direct effect (0.084) on yield (ton/ha). It had positive indirect effect on plant height (0.105), flag leaf length (0.002), number of primary branches per panicle (0.071), number of secondary branches per panicle (0.004) and number of unfilled grains per panicle (0.002) (Table 7). Flag leaf width had negative indirect effect via panicle length (-0.066) and thousands seed weight (-0.049) (Table 7).

4.5.4 Number of primary branches per panicle

Path analysis revealed that number of primary branches per panicle had direct positive effect (0.274) on yield (ton/ha). This trait had positive indirect effect through flag leaf width (0.022), number of secondary branches (0.050) and number of filled grain per panicle (0.027) (Table 7). On the other hand, it had negative indirect effect via plant height (-0.201), flag leaf length (-0.029), number of unfilled grain per panicle (-0.032) and thousand seed weight (-0.048). Finally it made positive correlation with yield (ton/ha) (0.063) (Table 7).

4.5.5 Number of secondary branches per panicle

Path analysis revealed that number of secondary branches per panicle had direct positive effect (0.166) on yield (ton/ha). This trait had positive indirect effect through plant height (0.133), flag leaf width (0.002), number of primary branches (0.082) and number of unfilled grain per panicle (0.017) (Table 7). On the other hand, it had negative indirect effect via flag leaf length (-0.036), panicle length (-0.041) and number of filled grain per panicle (-0.002) and thousand seed weight (-0.005) and. Finally it made positive correlation with yield (ton/ha) (0.316) (Table 7).

4.5.6 Panicle length

Path analysis revealed that Panicle length had direct negative effect (-0.346) on yield (ton/ha). This trait had positive indirect effect through plant height (0.165), flag leaf length (0.020), flag leaf width (0.016), flag leaf width (0.002), number of secondary branches per panicle (0.020), number of filled grains per panicle (0.020) and thousand seed weight (0.008) (Table 7). On the other hand, it had negative indirect effect via number of unfilled grains per panicle (-0.055). Finally it made negative correlation with yield (ton/ha) (-0.152) (Table 7).

4.5.7 Number of filled grains per panicle

Path analysis revealed that number of filled grains per panicle had direct positive effect (0.101) on yield (ton/ha). This trait had positive indirect effect through plant height (0.002), number of primary branches per panicle (0.074) and thousand seed weight (0.023) (Table 7). On the other hand, it had negative indirect effect via flag leaf length (-0.002), number of secondary branches per panicle (-0.003), Panicle length (-0.068) and number of unfilled grains per panicle (-0.061). Finally it made positive correlation with yield (ton/ha) (0.067) (Table 7).

4.5.8 Number of unfilled grains per panicle

Path analysis revealed that number of unfilled grains per panicle had direct positive effect (0.138) on yield (ton/ha). This trait had positive indirect effect through flag leaf width (0.001), number of secondary branches per panicle (0.020) and panicle length (0.137) (Table 7). On the other hand, it had negative indirect effect via plant height (-0.052), flag leaf length (-0.020), number of primary branches per panicle (-0.063), number of filled grains per panicle (-0.044) and thousand seed weight (-0.021). Finally it made positive correlation with yield (ton/ha) (0.097) (Table 7).

4.5.9 Thousand seed weight

Path analysis revealed that thousand seed weight had direct negative effect (-0.162) on yield (ton/ha). This trait had positive indirect effect through flag leaf width (0.026), number of primary branches per panicle (0.080), number of secondary branches per panicle (0.005), panicle length (0.017) and number of unfilled grains per panicle (0.018) (Table 7). On the other hand, it had negative indirect effect via plant height (-0.170), flag leaf length (-0.019) and number of filled grains per panicle (-0.014). Finally it made negative correlation with yield (ton/ha) (-0.219) (Table 7).

4.6 Path Coefficient Analysis Under Rainfed Condition

4.6.1 Plant Height

Path analysis revealed that plant height had direct negative effect (-0.143) on yield (ton/ha). This trait had positive indirect effect through flag leaf length (0.039), number of primary branches per panicle (0.131), number of unfilled grains per panicle (0.014) and thousand seed weight (0.125) (Table 8). On the other hand, it had negative indirect effect via number of secondary branches per panicle (-0.011), panicle length (-0.241) and number of filled grains per panicle (-0.004). Finally it made negative correlation with yield (ton/ha) (-0.090) (Table 8).

4.6.2 Flag Leaf Length

Path analysis revealed that flag leaf length had direct positive effect (0.509) on yield (ton/ha). This trait had positive indirect effect through number of primary branches per panicle (0.136), number of filled grains per panicle (0.060) and thousand seed weight (0.221) (Table 8). On the other hand, it had negative indirect effect via flag leaf width (-0.025), number of secondary branches per panicle (-0.031), panicle length (-0.083) and number of unfilled grains per panicle (-0.045). Finally it made positive correlation with yield (ton/ha) (0.731) (Table 8).

4.6.3 Flag Leaf Width

Path analysis revealed that flag leaf width had direct negative effect (-0.075) on yield (ton/ha). This trait had positive indirect effect through flag leaf length (0.170), number of primary branches per panicle (0.028), number of secondary branches per panicle (0.003), panicle length (0.047), number of filled grains per panicle (0.033) and thousand seed weight (0.065) (Table 8). On the other hand, it had negative indirect effect via number of unfilled grains per panicle (-0.047). Finally it made positive correlation with yield (ton/ha) (0.223) (Table 8).

Table 8. Path coefficient among different characters under rainfed condition

	Plant height (cm)	Flag leaf length (cm)	Flag leaf width (cm)	Number of primary branches per panicle	Number of secondary branches per panicle	Panicle length (cm)	Number of filled grains per panicle	Number of unfilled grains per panicle	Thousand seed weight (g)	Yield (ton/ha)
Plant height (cm)	**-0.143**	0.039	0.000	0.131	-0.011	-0.241	-0.004	0.014	0.125	-0.090
Flag leaf length (cm	-0.011	**0.509**	-0.025	0.136	-0.031	-0.083	0.060	-0.045	0.221	0.731
Flag leaf width (cm)	0.000	0.170	**-0.075**	0.028	0.003	0.047	0.033	-0.047	0.065	0.223
Number of primary branches per panicle	-0.061	0.223	-0.007	**0.310**	-0.042	-0.154	0.059	-0.073	0.183	0.438
Number of secondary branches per panicle	-0.022	0.225	0.003	0.186	**-0.070**	-0.133	0.028	-0.032	0.184	0.370
Panicle length (cm)	-0.088	0.108	0.009	0.122	-0.024	**-0.391**	0.002	0.007	0.229	-0.026
Number of filled grains per panicle	0.005	0.259	-0.021	0.155	-0.017	-0.006	**0.117**	-0.080	0.058	0.472
Number of unfilled grains per panicle	-0.014	-0.151	0.023	-0.148	0.014	-0.018	-0.061	**0.153**	-0.036	-0.237
Thousand seed weight (g)	-0.051	0.323	-0.014	0.162	-0.037	-0.256	0.020	-0.016	**0.349**	0.480

Residual effect = 0.5

4.5.4 Number of primary branches per panicle

Path analysis revealed that number of primary branches per panicle had direct positive effect (0.310) on yield (ton/ha). This trait had positive indirect effect through flag leaf length (0.223), number of filled grains per panicle (0.059) and thousand seed weight (0.183) (Table 8). On the other hand, it had negative indirect effect via plant height (-0.061), flag leaf width (-0.007), number of secondary branches per panicle (-0.042), panicle length (-0.154) and number of unfilled grains per panicle (-0.073). Finally it made positive correlation with yield (ton/ha) (0.438) (Table 8).

4.5.5 Number of secondary branches per panicle

Path analysis revealed that number of secondary branches per panicle had direct negative effect (-0.070) on yield (ton/ha). This trait had positive indirect effect through flag leaf length (0.225), flag leaf width (0.003), number of primary branches per panicle (0.186), number of filled grains per panicle (0.028) and thousand seed weight (0.184) (Table 8). On the other hand, it had negative indirect effect via plant height (-0.022), panicle length (-0.133) and number of unfilled grains per panicle (-0.032). Finally it made positive correlation with yield (ton/ha) (0.370) (Table 8).

4.5.6 Panicle length

Path analysis revealed that panicle length had direct negative effect (-0.391) on yield (ton/ha). This trait had positive indirect effect through flag leaf length (0.108), flag leaf width (0.009), number of primary branches per panicle (0.122), number of filled grains per panicle (0.002) and thousand seed weight (0.229) (Table 8). On the other hand, it had negative indirect effect via plant height (-0.088), number of secondary branches per panicle (-0.024) and number of unfilled grains per panicle (-0.007). Finally it made negative correlation with yield (ton/ha) (-0.026) (Table 8).

4.5.7 Number of filled grains per panicle

Path analysis revealed that number of filled grains per panicle had direct positive effect (0.117) on yield (ton/ha). This trait had positive indirect effect through plant height (0.005), flag leaf length (0.259), number of primary branches per panicle (0.155) and thousand seed weight (0.058) (Table 8). On the other hand, it had negative indirect effect via flag leaf width (-0.021), number of secondary branches per panicle (-0.017), panicle length (-0.006) and number of unfilled grains per panicle (-0.080). Finally it made positive correlation with yield (ton/ha) (0.472) (Table 8).

4.5.8 Number of unfilled grains per panicle

Path analysis revealed that number of unfilled grains per panicle had direct positive effect (0.153) on yield (ton/ha). This trait had positive indirect effect through flag leaf width (0.023) and number of secondary branches per panicle (0.014) (Table 8). On the other hand, it had negative indirect effect via plant height (-0.014), flag leaf length (-0.151), number of primary branches per panicle (-0.148), panicle length (-0.018), number of filled grains per panicle (-0.061) and thousand seed weight (-0.036). Finally it made negative correlation with yield (ton/ha) (-0.237) (Table 8).

4.5.9 Thousand seed weight

Path analysis revealed that thousand seed weight had direct positive effect (0.349) on yield (ton/ha). This trait had positive indirect effect through flag leaf length (0.323), number of primary branches per panicle (0.162) and number of filled grains per panicle (0.020) (Table 8). On the other hand, it had negative indirect effect via plant height (-0.051), flag leaf width (-0.014), number of secondary branches per panicle (-0.037), panicle length (-0.256) and number of unfilled grains per panicle (-0.016). Finally it made positive correlation with yield (ton/ha) (0.480) (Table 8).

CHAPTER V

SUMMARY AND CONCLUSION

Rice is the world's most important food crop and a primary source of food for more than half of the world's population. Drought has long been considered to be a hazard responsible for ups and downs of many civilizations in the world. In Bangladesh, drought in the northern districts is very common. Therefore, the lines have been critically screened for drought tolerance under rainfed condition for various growth parameters.

The present investigation was carried out at the experimental Farm of Sher-e-Rangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. Bangladesh during the period from December 2018 to April 2019. The local boro lines Poshusail, Gorchihail, Birion, Soilerpuna, Pankaich, Gopal Deshi, Borail and some BRRI rice varieties were used for the evauation. The experiment was laid out Randomized Complete Block Design (RCBD) with three replications. The outcome of the investigation is summarized here.

Superior grain yield (ton/ha) performance under irrigated condition was observed in Soilerpuna, Gorchihail, Borail, Gopal Deshi, Pankaich respectively among local boro rice varieties. Superior grain yield (ton/ha) performance under rainfed condition was observed in Gopal Deshi, Soilerpuna, Borail, Birion, Pankaich respectively among local boro rice varieties.
Higher rates for the stress tolerance index (STI) indicate higher potential yield. Here BRRI dhan55 (0.824), BRRI dhan59 (0.726), Soilerpuna (0.707), Gopal Deshi (0.703), BRRI dhan36 (0.692) showed higher yield in ton per ha for stress tolerance indices gradually.

Analysis of variance revealed highly significant variation present among the local lines and checks for all the characters studied. Existing of significant level of variation present in the materials indicated the possibility of improving genetic yield potential.

Some of the lines were superior to best yielding check in mean performance with respect to plant height, flag leaf length (cm), flag leaf width (cm), number of primary branches per panicle, number of secondary branches per panicle, Panicle length (cm), number of filled grain per pancle, number of unfilled grain per pancle, thousand seed weight (g) and yield per hectare under both irrigated and rainfed condition. Among local varieties Gopal Deshi and Soilerpuna showed better yield performances under both irrigated and rainfed condition.

Correlation coefficient analysis for irrigated condition showed significant positive correlation between number of primary branches per panicle with flag leaf length (cm) and number of secondary branches per panicle with flag leaf length (cm).

Correlation coefficient analysis for irrigated condition showed significant negative correlation between number of unfilled grains per panicle with panicle length (cm), number of filled grains per panicle.

Correlation coefficient analysis for rainfed condition showed significant positive correlation between flag leaf width (cm) with flag leaf width (cm); number of primary branches per panicle with plant height (cm), flag leaf length (cm); number of secondary branches per panicle with flag leaf length (cm), number of primary branches per panicle; panicle length (cm) with plant height (cm), number of primary branches per panicle, number of secondary branches per panicle; number of filled grains per panicle with flag leaf length (cm), number of primary branches per panicle; thousand seed weight (g) with plant height (cm), flag leaf length (cm), number of primary branches, number of secondary branches per panicle, panicle length (cm); yield (ton/ha) with flag leaf length (cm), number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, thousand seed weight (g).

Correlation coefficient analysis for rainfed condition showed significant negative correlation between number of unfilled grains per panicle with number of primary branches per panicle, number of filled grains per panicle.

Conclusion

This study concludes that, water stress during critical growth stage of rice significantly reduces rice yield in all cultivars. Further, it also indicates that selection based on drought tolerance indices can be efficient tool in identification of superior drought tolerant cultivars with higher yield potential and stability. Based on results assessed from various parameters of drought tolerance indices, it revealed that Soilerpuna and Gopal Deshi of local rice cultivars, and BRRI dhan55 possessed high level of drought tolerance since these cultivars exhibited with high STI values. These cultivars showed the highest yield (ton/ha) under irrigated condition as well as performed better in rainfed conditions. Thus, these drought-tolerant rice cultivars can be better substitute of traditional, primitive and un-tested varieties in rainfed and drought-prone belts for rice cultivation.

Future suggestions

Considering the situation of the present experiment further studies in the following area may be suggested:

1. Promising lines with high level and good drought tolerance may further be investigated in different locations in multiplications trial for regional adaptability.
2. The lines should be further evaluated with more indicator of drought tolerance such as stress tolerance level (TOL), stress susceptibility index (SSI), drought tolerant efficiency (DTE) etc.
3. Screening of rice for drought stress can be done under vegetative stage.
4. Analysis with Intra-cluster means for morpho-physiological characters in rice genotypes can be done.

CHAPTER VI

REFERENCES

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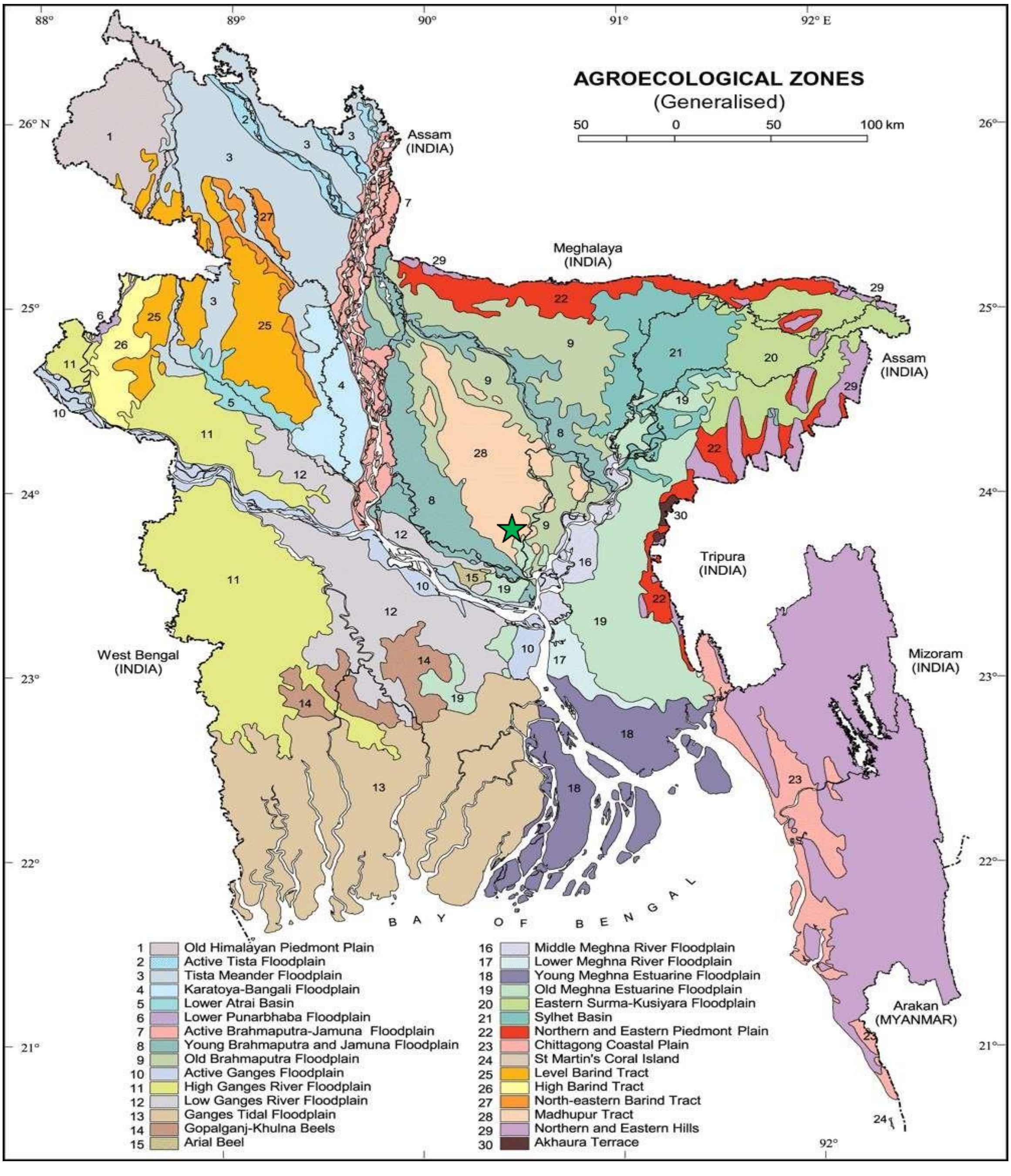
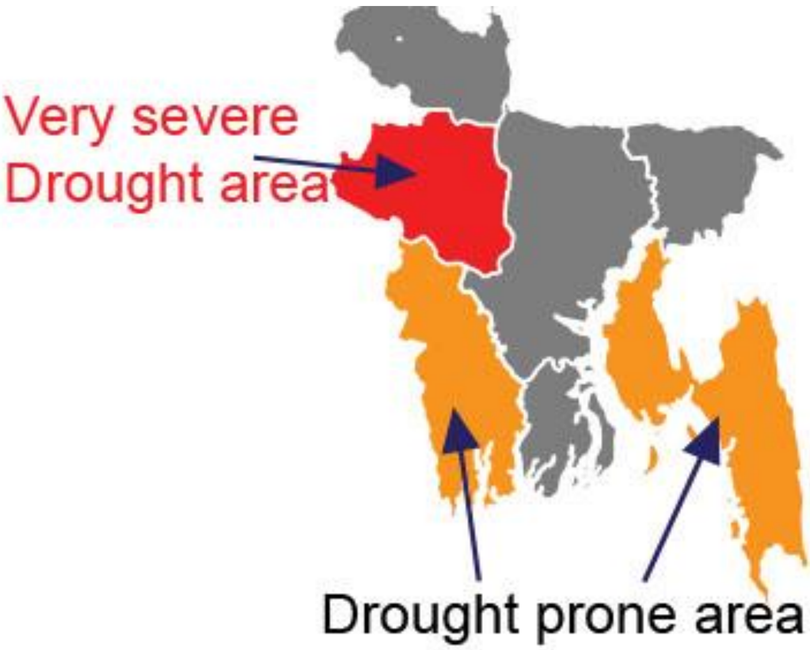
CHAPTER VII

APPENDICES

Appendix I. Map showing the experimental site under the study



Appendix II. Map showing the Status of drought in Bangladesh



Appendix III: Morphological, Physical and chemical characteristics of initial soil (0- 15 cm depth) of the experimental site

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Appendix III: Morphological, Physical and chemical characteristics of initial soil (0- 15 cm depth) of the experimental site

B. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

C. Physical composition of the soil

Soil separates	%	Methods employed
Sand	26	Hydrometer method (Day, 1915)
Silt	45	Do
Clay	29	Do
Texture class	Silty loam	Do

D. Chemical composition of the soil

Sl. No	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.45	Walkley and Black, 1947
2	Total N (%)	0.03	Bremner and Mulvaney,1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (ppm)	20.54	Olsen and Dean, 1965
7	Exchangeable K (me/100 g soil)	0.10	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.6	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix IV. Monthly average temperature, relative humidity and total rainfall and sunshine of the experimental site during the period from November, 2018 to March, 2019.

Month	Air temperature (ºc)		Average RH (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2018	23.8	31.6	77	172.3	11.6
December, 2018	19.2	29.6	64	34.4	8
January, 2019	14.1	26.4	73	12.8	9
February, 2019	16	28.1	56	28.9	8.1
March, 2019	20.4	32.5	56	65.8	7

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1212