YIELD AND QUALITY ANALYSIS OF ADVANCED LINES OF NEW PLANT TYPE (NPT) RICE (*Oryza sativa* L.)

BY

MD. NURUZZAMAN

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Approved by:

Prof. Dr. Md. Sarowar Hossain
Supervisor

Prof. Abu Akbar Mia
Co-supervisor

23.3.14

Dr. Mohammad Saiful Islam
Chairman
Examination Committee

Prof. Dr. Md. Sarowar Hossain

Department of Genetics and Plant Breeding

Sher-e Bangla Agricultural University
Dhaka-1207, Bangladesh

Mob: +88-01552499169
E-mail: sarowar2001@rediffmail.com

CERTIFICATE

This is to certify that thesis entitled, ***YIELD AND QUALITY ANALYSIS OF ADVANCED LINES OF NEW PLANT TYPE (NPT) RICE (Oryza sativa L.)*** *submitted to the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment 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. NURUZZAMAN****, Registration No. 06-1923 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, has been available during the course this investigation has duly been acknowledged.

Dated: June, 2013
Dhaka, Bangladesh

Prof. Dr. Md. Sarowar Hossain
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the experimental Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar. Dhaka, Bangladesh during July 2011 to December 2011. Six advanced NPT lines of rice AL-36, AL-29, Richer, AL-52, BRRI dhan-49 and BRRI dhan-57 were evaluated. Highly significant variations were found among the advanced lines for all the characters studied. The tallest plant height was recorded from advanced line of AL-52. The longest panicle, maximum yield/m^2 and yield/ha were recorded from advanced NPT line AL-29, maximum number of unproductive tillers per plant and productive tillers per plant were recorded from BRRI dhan-49 whereas the maximum number of empty grain per panicle was recorded from AL-36. All the lines showed significant positive correlation in case of plant height, panicle length and number of effective tillers per plant with yield. Plant height showed highly significant and positive relationship with panicle length and 1000 grain weight. Maximum hulling (%) and milling outturn (%) were recorded from AL-36. Longest length of rough rice, milled rice and highest head rice recovery (%) were obtained from Richer. Grain breadth of rough rice and grain breadth of milled rice were highest in BRRI dhan-57. AL-52 showed the highest value in case of length/breadth ratio of rough rice, grain length of brown rice, length/breadth ratio of brown rice and length/breadth ratio of milled rice. Correlation coefficient analysis showed significant positive correlation between hulling and milling percent. In this study, maximum 5 lines had been grouped into long slender and one check (BRRI dhan-57) into medium slender. Among the six lines, all showed clear-cut translucent endosperm appearance. Richer showed the longest length and highest length/breadth ratio of cooked rice where checks showed lowest. AL-36 responded to maximum volume expansion where minimum volume expansion was recorded from AL-52 and BRRI dhan-57. Highest alkali spreading value was recorded from Richer and AL-52 which was in the range of ASV (4-6) that was intermediate alkali digestion and intermediate gelatinization temperature which was preferable to the consumers for it's medium cooking time.

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ABBREVIATIONS AND ACRONYMS

ABBREVIATION	FULL NAME
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
IRRI	Interactional Rice Research Institute
DAT	Days after transplanting
FAO	Food and Agricultural Organization
LSD	Least Significant Difference
Max	Maximum
Min	Minimum
NS	Not Significant
T/ha	Ton per hectare
SRDI	Soil Resource Development Institute
AEZ	Agro Ecological Zone
RCBD	Randomized Complete Block Design
°C	Degree Celsius
g	Gram
ha	Hectare
m	Meter
Mm	Millimeter
Mo	Month
no.	Number
m^2	Square meter
%	Percent

CHAPTER 1

INTRODUCTION

Rice dominates over all other crops and covers 75% of the total cropped area of Bangladesh. The climatic condition of Bangladesh is also suitable to produce quality rice. Consumer demand for the quality rice varieties is high due to its good quality and palatability. The demand of quality rice has been increasing in our country as the country is being more prosperous and approaching self-sufficiency in rice production (BRRI, 2004). Rice (*Oryza sativa* L.) provides the staple food over 3 billion people, representing nearly half of the world's population and contributes on an average 20% of apparent caloric intake of the world population and 30% of population in Asia (Castro *et al.,* 2000). Ninety percent of this crop is grown and consumed in south and Southeast Asia, the highly populated area (Dilday, 1990).

In the major rice-consuming countries, grain quality characteristics dictate the market value of the commodity and play an important role in the development and adoption of new varieties (Dingkuhn *et al.,* 1991). Economic product of rice is the paddy yield, which exhibits complex genetics as it is influenced by various yield contributing characters and the environment. In general, increased panicle number is the single most important yield component associated with rice yield, number of spikelet per panicle and percent filled grains per panicle being of secondary and tertiary importance (Jiang *et al.,* 2000).

Another trait directly related to panicle is panicle density which chiefly affects the yield potential. Therefore, information about the yield contributing traits is of immense importance to the plant breeders for the development of improved varieties of rice with increased yield potential. Grain quality includes such traits as physical appearance, cooking and sensory properties, as well as nutritional value (Jackson and Lettington, 2003). The relative importance of each characteristic depends on local preferences and the kind of dish to be prepared from the rice.

Hence yield, the grain quality of rice is the most important factor for deciding the profitability of the farmers as the grain quality decides the price in the market. Grain quality may have different meanings to different operatives in the rice value chain- farmers, processors, millers, nutritionists, policy-makers, marketers, purchasers and consumers.

Each may have a slightly different opinion as to what good-quality rice is, but generally it should have the following characteristics:

• Little or no chalk, except for Arborio rice and varieties for sake production

• Translucent appearance

• Uniform coloration and good for the purpose for which it has been produced (white for raw-milled rice and with a yellowish tinge for parboiled rice)

• A high percentage of whole unbroken grains

• The shape (length and length-width ratio) should be right for the variety type

• Excellent cooking properties-should satisfy the consumers' preference for cooked rice for the particular kind of food preparation.

Grain quality should be acceptable to farmers. Greater emphasis is being given for improving eating quality of rice during development or imported from other countries. Julfiquar *et al.,* (2003) concluded that grain quality is second after yield as the major breeding objective for crop improvement. Consumers base their concept of quality on the grain appearance, size and shape of the grain behavior upon cooking, taste, tendemess and favor of cooked rice. The cooking quality preferences vary within the country within ethnic groups and from one country to another within different geographical regions (Juliano *et.al.,* 1997). Quality of rice may be considered from the view point of size, shape and appearance of grain, milling quality and cooking properties (Dela Cruz and Khush, 2000). The breeders and nutritionists seek rice grain with higher content of protein, vitamins and minerals.

Quality of rice mainly depends on its intended end use by the consumers. All consumers want the best quality that they can afford. Traditionally, plant breeders concentrated on breeding for high yields. The quality of rice grain is not only dependent on the variety genotype, but it also depends on the crop production environment, harvesting, processing and milling systems. The amylose content of rice is considered as the main parameter of cooking and eating quality (Juliano et al., 1997). According to its grain shape, rice is primarily classified into long, medium and short categories. The cooking quality of rice grain is associated with grain shape (Yang *et al.,* 2001). In most cases, long grain rice has a high grain amylose content and after cooking, it is often firm and fluffy (not sticky); medium grain rice has a low amylose content and after cooking, it is often soft, moist and sticky in texture.

The cooking quality and amylose content in short grain rice are similar to those of rice in the medium grain category. Grain shape has attracted significant attention in rice breeding programs due to its contributions to rice yield and quality. The rice millers prefer varieties with high milling whereas consumers consider physicochemical characteristics (Merca and Juliano, 1981). The consumers judge the quality of rice on the basis of size and shape of rice grain. The preference for grain size and shape can vary from one group of consumer to another group of consumers (Khush *et al.,* 1979).

In Bangladesh consumer's demand for rice, as reflected by price, is mostly influenced by grain size and shape (Choudhury, *et al.,* 1991). More than twenty years of consumer preference studies indicated that Filipinos prefer rice grains which are long, slender, translucent, non-glutinous, white and aromatic. However, no universal standard of rice grain can be set because of wide variety of consumer's choices both between and within the country.

The belief among rice breeders that tropical cultivars of the Indica type have reached a yield plateau of 10 t/ha, has caused the breeders at Interactional Rice Research Institute (IRRI) to switch their programme to the breeding of a radically different ideotype, known as New Plant Type (NPI) for direct seeded, Irrigated rice crop which would yield 13-15 t/ha, in lowland tropics. The chief characteristics of the NPT, were determined considering several different perspectives (Virmani, 2003), such that the plant should produce 3-4 tillers, all of which produce panicles containing 200-250 grains on very sturdy stems, should bear dark green leaves, should be about 90 cm in height and 100-130 days growth duration and should have multiple pest and disease resistance and a harvest index of 0.6.

Therefore the NPT breeding programme has been initiated from the crosses between japonica and javanica (Glaszmann (1968), refers to as tropical japonica) varieties (IRRI, 1989). Most of high quality rice cultivars are low yielding, on the other hand low quality rice cultivars are high yielding.

The objectives of the research work were:

1. To evaluate the yield performance of different advanced lines of new plant types (NPT) of rice.
2. To study the milling quality and grain appearance of these NPT lines.
3. To determine the cooking and eating quality of these NPT lines.

CHAPTER 2

REVIEW OF LITERATURE

Bangladesh produces a large number of rice varieties for regular consumption. Mostly rice varieties have been developed traditionally by selection, hybridization and back crossing with locally adapted high-yielding lines. Some of the important and informative works and research findings related to the yield and quality of new plant type (NPT) rice, so far been done at home and abroad, have been reviewed in this chapter.

2.1 Evaluation of yield performance of new plant type (NPT) rice:

2.1.1 Plant height (cm)

Water logging is one of the most important agronomic characters and by lodging resistance and thereby adapts well to heavy fertilizer application (Badan et al., 2005). Chatel and Guimara, (1997) studied 11 genotypes of new plant type rice and observe high heritability couple with high genetic advance for plant height and thousand grain weight and reported that plant height has negative correlation with yield. In addition he observed the positive relationship of plant height with grain quality.

2.1.2 Days to 50% flowering

A few crosses showed heterobeltiosis for days to 50% flowering. The correlation between heterosis over better parent and inbreeding depression showed that yield can be improved by direct selection for days to 50% flowering and number of productive tillers per plant (Wang *et al.,* 1991). Vijayakumar *et al.,* (1997) found that hybrids out yielded than their parents when their days to 50% flowering were similar or more than their respective restorers. They concluded that superior hybrids could he identified early by comparing their tiller number, plant height and days to 50% flowering with those of their respective restores.

Rice tillering is a major determinant for panicle production (Miller *et al.,* 1991) and as a consequence affects total yield (Gallagher and Biscoe. 1978). The high tillering capacity is considered as a desirable trait in rice production, since number of tillers per plant is closely related to number of panicles per plant. To some extent, yield potential of a rice variety may be characterized by tillering capacity. On the other hand, it was reported that the plants with more tillers showed a greater inconsistency in mobilizing assimilates and nutrients among tillers. Moreover, grain quality could be also affected by tillering ability due to different grain development characteristics. It has been well documented that either excessive or insufficient tillering is unfavorable for high yield. Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield. Ghosh and Hossain (1988) reported that effective tillers/plant, number of grains/panicle and grain weight as the major contributory characters for grain yield it had positive correlations with number of productive tillers/plant. Jiang *et al.,* (2000) observed the importance of number of tillers/plant influencing yield. Productive tillers/bill showed significant positive correlations with grain yield (Reddy and Kumar, 1996).

2.1.3 Days to maturity

The number of days to reach maturity plays a significant role in the cropping system. Early maturing crops evacuate the land early for the next crops and escape from insect pest attack and timely handled. Karim *et al.,* (2007) studied 40 different new rice genotypes for variability and genetic parameter analysis and found highly significant mean sum of square due to genotypes for Days to maturity. He reported that variation for days to maturity was attributed by genetic constituent rather than environment.

2.1.4 Number of productive tillers/plant

Tillering is a major determinant for panicle production in rice (Guohui and Longping, 2003) and as a consequence affects total yield (Hoan and Nghia, 2001). Grain quality could be also affected by tillering ability due to different grain development characteristics. It has been well documented that either excessive or insufficient tillering is unfavorable for high yield. Choudhury *et al.,* 1991) reported that effective tillers/plant, number of grains/panicle and grain weight as the major contributory characters for grain yield it had positive correlations with number of productive tillers/plant.

2.1.5 Number of filled grains/panicle

In hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant (Ismachin and Sobrizal, 2006).

2.1.6 Panicle length (cm)

Guimara (2002) indicate that the plants with cooperatively large panicles tend to have a high number of filled gains. However, most of the cases a positive correlation were observed between number of panicle/plant and panicle length.

2.1.7 1000-grain weight

Kaneda (1985) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Heterosis for grain yield was due to the positive and significant heterosis for components like panicle length and 1000 grain weight. Huang *et al.,* (1997) reported negative association of 1000 grain weight and yield per plant in traditional varieties.

2.1.8 Grain yield

Yield improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. In addition, grain yield also related with other characters such as plant type, growth duration, and yield components (Mao, 2001).

Yield per hectare is the most important consideration in rice breeding program, but yield is a complex character in inheritance and may involve several related components. To get better rice (*Oryza saliva* L.) grain yield per unit land area is the only way to achieve increased rice production because of the reduction in area devoted to rice production.

2.2 Study of milling quality and grain appearance

Milling yield of rough rice is an estimation of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. It is generally expressed as percentage (Khush *et al.,* 1979). Thus, the milling quality of rice may be defined as the ability of rice grain to stand milling and polishing without undue breakage so as to yield the greatest amount of total recovery and the highest proportion of head rice to broken. The milling properties were controlled by the same few loci that are responsible for grain shape. Latha *et al.,* (2004) reported that the inheritance of grain quality is more complicated than that of other agronomic traits in cereals due to epitasis, maternal and cytoplasmic effects, and the triploid nature of endosperm.

Khush *et al.,* (1997) studied milling outturn varied from 68 to 72% and most of the varieties had more than 70% milling outturn. Yang *et al.,* (2001) reported that milling quality was slightly affected by locality, moderately affected by year and mostly affected by grain type. Chalky grains are not as hard as the translucent one and more prune to breakage during milling. In general, varieties with long or long bold grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long slender and translucent grains give high head rice yields. Marassi *et al.,* (2004) observed that long kernel varieties had lower hulling and milling recovery percentage than short kernel varieties, but better water uptake during cooking.

Varieties with high protein content also suffer less breakage. Sun cracking is caused by alternate drying and wetting of grains due to delayed harvest also aids in more breakage of grain. High gelatinization temperature types are less prone to cracking. Peng *et at.,* (2005) reported that threshing on the day of harvest gave highest HRR and lowest broken rice, and delay will lead to reduction in milling recovery and also studied the relationship between milling recovery and grain moisture at harvesting and reported that high recoveries of total milled and head rice and good cooking quality were obtained from grains harvested at 20-23% grain moisture content. Rangel *et al.,* (1996) observed that percentage of high density grains was significantly and positively associated with 1000-grain weight, hulling, milling and head rice recovery. Grain fissuring was highly related with relative humidity and average temperature during crop maturity and grain moisture content at harvest and they proposed to maintain optimum harvest moisture of 15-17% for high HRR.

Grain dimension is expressed as length, breadth and thickness, whereas shape is generally expressed as the ratio between the length and breadth. Rangel *et al.,* (2005) found that length of the grain is more variable and important than width and thickness or shape. Bold grains give low head rice recovery because of high breakage. Grains with short to medium length break less than long grains during milling.

Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production. Consumers prefer rice with a translucent endosperm and pay a premium price for it, even though opacity disappears during cooking and does not alter eating quality. Preference for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, some prefer medium long grains and others highly prize long slender grains.

Cooking and eating characteristics are largely determined by the properties of the starch that makes up 90% of milled rice. Gelatinization temperature, amylase content and gel consistency are the important starch properties that influence cooking and eating characteristics. Cooking and eating qualities of rice are largely depends upon the properties of starch that makes up 90% of milled rice. Cooking quality preferences vary in different countries of the whole planet. Rice is one cereal that is consumed mainly as whole milled and boiled grain.

2.2.1 Milling outturn (%)

Milling recovery is one of the most important criteria of rice quality especially from the standpoint of marketing. A variety should possess a high turnout of whole grain (head) rice and total milled rice (Webb *et al.*, 1985). Milling recovery of rough rice is an estimation of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. It is generally expressed as percentage (Khush *et al.*, 1979). The proportions of the various components vary according to the method of milling used and the variety of rice. Generally, the hulls vary from 20% to 22% of the rough rice although variation of 18% to 26% has been recorded. Barn and embryos constitute another 8% to 10%. Thus, from a given sample of rough rice, about 70% milled rice is obtained.

The proportion of whole rice is known as head rice recovery and is expressed as percentage of rough rice. Thus, if from a sample of 100g of rough rice, 70g of milled rice is obtained and 20g of this is broken, head rice recovery is 50%. The head rice recovery may very form as low as 25% to as high as 65% (Khush *et al.*, 1979). The objective of milling is to improve appearance and palatability of rice grain with minimum loss in weight and nutritive value. Factors like grain moisture at harvest, post-harvest operations such as threshing, winnowing, drying, storage, efficiency of the mill used and degree of polishing also contribute for the major part of loss during milling (Tahir *et al.*, 2002).

Sharma (2002) reported that the value of rough rice is often determined by the percentage of head rice and total milled rice produced after milling. Chun and Jun (2001) reported that the milling quality characters in F_2 are influenced by genes of F1 plants and F2 seeds. Saini *et al.,* 1975showed that milling-quality characters are controlled by both seed genotype and maternal genotype. Derived from the cross Jaya Mahsuri Jaymati is recommended for summer cropping, milling recovery is 66.5% (Ahmed et al., 1998). Begum *et al.,* (2001) found that milling outturn of Iranian varieties ranged from 61 to 70% and BRRI varieties from 66 to 71%. Biswas *et al.,* (2001) round milling outturn some Binni rice varieties and compared with BR 25 and Nizersail varied 67 to 71% and head rice outturn from 88 to 97%.

Barbar and de Barbar (1980) stated that 'morphological characters of grains such as shape, size and topography markedly influenced rice milling outturn. Biswas *et al.,* (1992) studied mining outturn varied from 68 to 72% and most of the varieties had more than 70% milling outturn. Lanignelet and Marie (1983) reported that milling quality was slightly affected by locality, moderately affected by year and mostly affected by grain type.

2.2.2 Head rice recovery (HRR %)

Head rice yield indicates the weight of whole grains obtained after industrial processing. Head rice recoverability is an inherited trait, although environmental factors such as temperature and humidity during ripening and post-harvest stages are known to influence grain breakage during milling. Grain size and shape, hardness, presence or absence of abdominal white, moisture content, harvest precision, storage conditions, processing and type of mills employed have direct bearing on head rice recovery (Bhattacharya, 1980). In general, varieties with long grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long ender and translucent grains give high head rice yields. In general, varieties with long or long bold grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long slender and translucent grains give high head rice yields. Rui *et al.*, (2005) observed that long kernel varieties had lower hulling and milling recovery percentage than short kernel varieties, but better water uptake during cooking. Varieties with high protein content also suffer less breakage. Sun cracking is caused by alternate drying and wetting of grains due to delayed harvest also aids in more breakage of grain. High gelatinization temperature types are less prone to cracking. Ali *et al.*, (1993a) reported that threshing on the day of harvest gave highest HRR and lowest broken rice, and delay will lead to reduction in milling recovery. Ali *et al.*, (1993b) also studied the relationship between milling recovery and grain moisture at harvesting, and reported that high recoveries of total milled and head rice and good cooking quality were obtained from grains harvested at 20-23% gram moisture content. Sarkar *et al.*, (1994) observed that percentage of high density grains was significantly and positively associated with 1000-grain weight, hulling, milling and head rice recovery.

Jodari and Linscombe (1996) studied the influence of environmental condition on grain fissuring and milling yields of rice cultivars and reported that milling was influenced by both genotype and environmental conditions prior to harvest. Grain fissuring was highly related with relative humidity and average temperature during crop maturity and grain moisture content at harvest and they proposed to maintain optimum harvest moisture of 15-17% for high HRR. Sandeep (2003) reported that the value of rough rice is often determined by the percentage of head rice and total milled rice produced after milling. GCA effects were more important than SCA effects for head rice percentage, indicating the importance of additive genetic effects in the inheritance of head rice percentage. Although in the initial years, some of the hybrids recorded low head rice recovery, studies have shown that hybrids with higher head rice recovery can be obtained when the parents are selected carefully. If the parents are prone to enhance grain breakage, the F_1 would normally record lower head rice recovery than the better parent.

2.2.3 Grain dimensions

The milling and marketable qualities depend upon the size and the shape of the grain. Grain dimension is expressed as length, breadth and thickness, whereas shape is generally expressed as the ratio between the length and breadth. Biswas *et al.*, (1992) found that length of the grain is more variable and important than width and thickness or shape. Bold grains give low head rice recovery because of high breakage. Grains with short to medium length break less than long grains during milling. Thus, grain size and shape have direct effect of head rice (Shobha Rani, 2003). Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production (Adair *et al.*, 1966). A length breadth ratio from 2.5 to 3.0 has been considered widely acceptable as long as the length is more than 6mm (Kaul, 1970). Consumers prefer rice with a translucent endosperm and pay a premium price for it, even though opacity disappears during cooking and does not alter eating quality.

Preference for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, some prefer medium long grains and others highly prize long slender grains. In general, long grains are preferred in the Indian subcontinent, but in Southeast Asia, the demand is for medium to medium long rice. In temperate areas, short grain varieties are prevalent. There is a strong demand for long grain rice on the international market. The milling and marketable qualities depends upon the size and shape of the grain. Grain size as length and breadth, whereas shape is generally expressed as length/ breadth ratio. Begum *et al.*, (2001) reported on some Iranian and BRR1 rice varieties and found that length of Iranian varieties varied from 6.19 to 7.83mm and L/B ratio from 3.0 to 4.1. BRRI varieties were from 3.60 to 6.82mm long and had L/B ratio from 2.10 to 3.61.

2.2.4 Endosperm translucency

Consumers prefer white, translucent grains and pa premium for it. Grain appearance is also largely determined by endosperm opacity, the amount of chalkiness on the dorsal side of the grain (white belly), on the ventral side (white back), or in the centre (white centre) and the condition of the "eye" or pit left by the embryo when it is milled. Based on endosperm opacity, the rice endosperm is classified as waxy or non-waxy. Waxy rices are devoid of or have only traces of amylase content and are opaque. Non-waxy rices have varying amylose level (2.1 to 32%) and are dull, hazy or translucent. Shobha Rani (2003) reported that as waxy and low amylose rices with dull endosperm are not preferred in India and the chalky white spots which often appear in the starchy endosperm lower the market value of the variety. Rice samples with damaged eyes have a poor appearance and low market value. Similarly, the greater the chalkiness, the lower market acceptability. Soft textured, white spots occurring in the different parts of the endosperm tend to break more frequently at these chalky areas portions or pit left by the embryo when it is milled.

The starch granules in the chalky areas are less densely packed than those in translucent areas (Del Rosario *et al.*, 1968) and there are air spaces between the starch granules. Therefore, the chalky areas are not as hard as the translucent areas and the grains with chalkiness are more prone to breakage during milling. Therefore, the chalky areas are not as hard as the translucent areas and the grains with chalkiness are more prone to breakage during milling, Igheka *et at.*, (1991) observed that translucency is affected mainly by soaking and steaming parameters for example color by soaking, steaming and drying; broken grain mainly by drying; and deformed grain; only by soaking parameters and equilibrium time. Kumar *et al.*, (1994) concluded that endosperm appearance is primarily dedicated by the amylose content. It varies from waxy to dull to translucent as amylose content increases. If one parent has waxy or dull endosperm and the other has translucent. Waxy, dull and translucent grains cannot be identified individually alter cooking, hut still consumers do not like the variation of endosperm appearance.

The heritability of this character seems to be low, because the various agronomic practices and pre-harvest handling, together with the other maturity factors are found to influence the expression of chalkiness to some extent (Kaul, 1970).

2.3 Cooking and eating characteristics of the grain

The cooking and eating quality of rice has attracted more attention recently. Cooking and eating characteristics are largely determined by the properties of the starch that makes up 900/0 of milled rice. Gelatinization temperature, amylose content and gel consistency are the important starch properties that influence cooking and eating characteristics. In combination with previous reports, confirmed that either the waxy gene the waxy gene itself or a genomic region tightly linked to it plays a major role in determined the cooking and eating quality of rice (Rui *et al.*, 2005). Cooking and eating qualities of rice are largely depends upon the properties of starch that makes up 90% of milled rice. Cooking quality preferences vary in different countries of the world (Azeez and Shall, 1986). Rice is one cereal that is consumed mainly as whole milled and boiled grain. The desired properties may vary from country to country (Juliano *et al.*, 1964). Quality in rice may therefore be considered from the viewpoint of milling quality; grain size, shape and appearance and cooking characteristics. Several component traits collectively determined cooking and eating qualities of rice are reviewed below:

2.3.1 Kernel elongation ratio

Kernel elongation, in general, is given as kernel elongation ratio, which is the ratio of mean length of cooked kernel to the original length. Kernel elongation is the result of swelling of starch granules by uptake of water upon cooking (Juliano, 1979). Some rice show extreme elongation on cooking particularly in presoaked grain while in most varieties the expansion is relatively more breadth wise (Azeez and Shall, 1986; Juliano, 1972 and Sadhukhan and Chattopadhay, 2001) during storage, grain hardness and gelatinization temperature increase which allows more swelling and elongation during cooling (Ahuja *et al.*, 1995), Pilaiyar (1988) proposed elongation ratio as best index of quality compared to elongation index and proportionate change.

Kumar (1989) concluded that proportionate change and elongation index which involve both length-wise and breadth-wise component are reliable measure of kernel elongation. Kongseree and Juliano (1972) reported that kernel elongation has significant positive correlation with amylose content but not with gelatinization temperature. Reddy and Kumar (1996) reported that water uptake at 77°C showed significant positive correlation with kernel elongation. They also reported that alkali value much more important than amylose content in determining kernel elongation, which was contradictory to the report of Kongseree and Juliano (1972). Sood and Siddiq (1986) concluded that the characters such as volume expansion, kernel length and breadth which were positively related to water uptake did not show significant association with kernel elongation, so all such characters were independent of each other as far their contribution to kernel elongation was concerned and only those kernel types were capable of absorbing more water during cooking were considered to possess better kernel elongation property. The hybrid rice combination with good quality of appearance and cooking, the genetic improvement of parents could he conducted through the increase of length/width and decrease of amylase content and chalkiness, and the differences of endosperm character between parents should be small (Pandey *et al.,* 1995). Biswas *et al.,* (2001) studied the ratio of elongation of cooked to uncooked rice ranged from 1.2 to 1.6 and 3.0 to 4.3, respectively.

Biswas *et al.,* (1992) found that elongation ratio and volume expansion ratio varied from 1.3 to 1.9 and from 3.4 to 3.9 respectively. Begum *et al.,* (2001) reported that Iranian varieties had elongation ratio of 1.18 to 1.60 and that of BRR1 rice varied from 1.35 to 1.39. Chauhan *et al.,* (1995) point out significant positive correlation between kernel elongation and cooked kernel length. Singh (1989) established that long duration varieties (145-150 days) have more L/B ratio after cooking.

Kumar (1989) concluded that proportionate change and elongation index which involve both length-wise and breadth-wise component are reliable measure of kernel elongation. Lengthwise expansion (grain elongation) upon cooking without increase in girth is considered a high desirable trait in high quality rice such as Basmati, which elongate almost 100 per cent upon cooking (Khush *el al.,* 1979: Sidhu, 1989). Different type of Indian and Pakistani Basmati. Afghanistan's Sadri and Myanmar's D25-4 (Nga Kyee) posses this extreme elongation property.

2.3.2 Water absorption (uptake) percentage and volume expansion

Expansion volumes of rice affected by the change of amylase content. Water uptake showed a positive and significant influence on grain elongation, while volume expansion did not influence grain elongation as reported by Sood and Siddiq (1986). Chauhan *et at.,* (1992) found wide range of variability for grain length, shape, water uptake and head rice recovery. Correlation co-efficient of grain physical characters were correlated with uptake and volume expansion (Choi *et al.*, 1999; and Chauhan, 2000). The traits of elongation water absorption are very important in determining the quality of cooked rice grains (Ge *et at.,* 2005).

2.3.3 Gelatinization temperature (GT)

The time required for cooking is determined by the gelatinization temperature (GT). It is the range of temperature within which starch granules being to swell irreversibly in hot water and ranges from 55 to 79 °C. The GT is correlated with the extent of disintegration of milled rice in dilute alkali solution and hence an indirect estimate of the GT. The gelatinization temperature is positively co-related with the cooking time (Juliano, *et al.,* 1965), but GT does not show a relationship with the texture of 25 cooked rice (IRRI, 1968). Mostly the rice varieties with higher GT may have low amylase content (AC). No varieties have been found with higher GT and higher AC (Jennings *et al.,* 1979).

The GT is correlated with the extent of disintegration of milled rice in dilute alkali solution and hence an indirect estimate of the GT. Gelatinization temperature may be classified as low (Below 70°), intermediate (70° to 740) or high (above 74°) (Little *et al.,* 1958) Gelatinization temperature is estimated by extent of spreading and clearing of milled rice kept in alkali (1.7% KOH) solution for 16 hours at 30 ±1 °C (Zaman, 1981).

At high GT, rice becomes extensively soil when overcooked, elongates less and remain under cooked under standard cooking procedures, Rice varieties with a high GT require more water and more time to cook than those with low or intermediate GT. Rice with intermediate GT is most preferred (Khush *et al.,* 1979). Indian consumers like rice with intermediate GT (Bhattacharya, 1980). The degree of gelatinization varied among the different parts of the grain and cultivars. The gelatinization in the dorsal side was the most complete, with cells that were decomposed totally into puff like of flocculent materials. High quality cultivar had more thoroughly gelatinized cells on all sides than low quality ones. Varietal differences in the dorsal sides were less distinct than those at the middle and ventral sides. Grain quality was positively correlated with the rate of water absorption and extension (Yang *et al.*, 2003).

CHAPTER 3

MATERIALS AND METHODS

3.1. Site of the experiment

The experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from June 2011 to December 2011. The location of the site is 23°74' N latitude and 90° 35'E longitude with an elevation of 8.2 meter from sea level.

3.2. Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from June to December (Rabi season). The total rainfall of the experimental site was 209 mm during the period of the experiment. The average maximum and the minimum temperature were 26.5°C and 12.9°C respectively during the experimental period. Rabi season is characterized by plenty of sunshine presented in Appendix I.

3.3. Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Dhaka have been presented in Appendix II.

The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots are given below -

AEZ No. 28

Soil series -Tejgaon.

General soil- Shallow red brown terrace soil.

3.4. Planting materials

The seeds of selected rice varieties were collected from Dept. of Genetics and Plant Breeding, SAU, Bangladesh Agricultural Development Corporation (BADC) office, Kashimpur, Gazipur and Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur.

3.5. Different varieties of Rice

i. AL36
ii. AL29
iii. Richer
iv. AL52
v. BR49 (Check)
vi. BR57 (Check)

3.6. Preparation of seedbed and main field

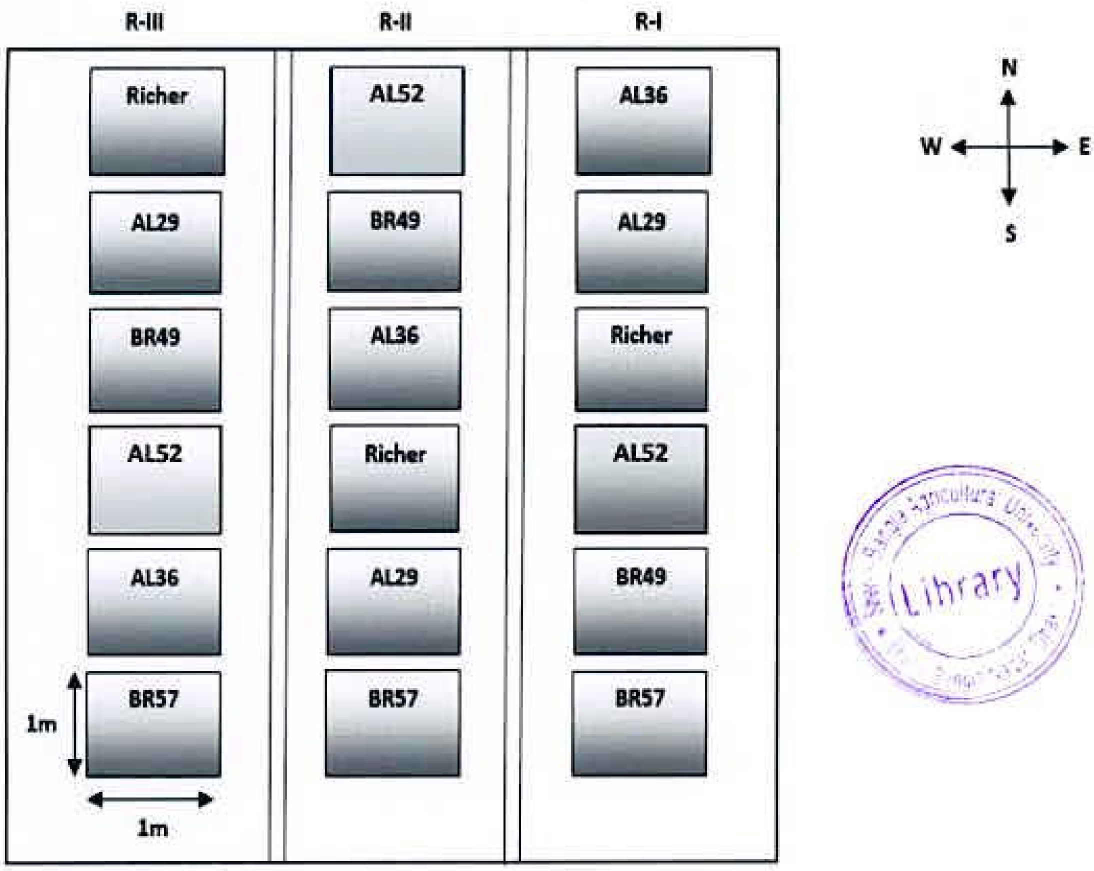
The land was opened on 12th June 2011 with a power tiller and was exposed to the sun for 7 days prior to next ploughing. It was prepared afterwards by ploughing and cross ploughing followed by laddering. Big clods were broken by hand mallet. The weeds and stubbles were completely removed from the field. The soil particles were well pulverized and the land was leveled evenly during final land preparation. The seedlings were transplanted to the main field on 22th August 2011 (Figure 1 & 2).

Figure 1: A field view of experimental plot

Figure 2: A close view of new plant type rice at flowering stage

3.7. Design and layout of the experiment

The main field was laid out in the Randomized Complete Block Design (RCBD) with three replications (R-I, R-II, R-III). The total number of plots was 18. The plots of the experiment were assigned randomly.



3.8. Intercultural operations

3.8.1. Weeding

Weeding was done in all the plots as and when required to keep the plant free from weeds.

3.9. Evaluation of yield performance of different advance lines of new plant type rice

3.9.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time harvest for all the entries on 5 randomly selected plants from the middle rows. The height was measured from the ground level to the tip of the plant.

3.9.2 Days to 50% flowering

Numbers of days required for 50% of the plants show panicle emergence from the date of sowing were recorded.

3.9.3 Days to maturity

Number of days required from sowing to physical maturity was recorded.

3.9.4 Number of effective tillers per plant

The total number of effective tiller per plant was counted as the number of panicle bearing tillers per plant. Data on effective tiller per plant were counted from 5 selected plants at harvest and average value was recorded.

3.9.5 Number of ineffective tillers per plant

The total number of ineffective tillers per plant was counted as the number of no panicle bearing tillers per plant. Data on ineffective per plant were counted from 5 selected plants at harvest and average value was recorded.

3.9.6 Number of total tillers per plant

Number of total tillers per plant as counted by adding effective and in-effective tillers per plant.

3.9.7 Panicle length (cm)

The length of panicle was measured with a meter scale from 5 selected panicles and the average value was recorded.

3.9.8 Number of filled spikelet per panicle

The total number of filled spikelet was collected randomly from selected 5 plants of a plot and then average number of filled spikelet per panicle was recorded.

3.9.9 Number of unfilled spikelets per panicle

The total number of unfilled spikelets was collected randomly from selected 5 plants of a plot on the basis of not grain in the spikelet and then average number of unfilled spikelets per panicle was recorded.

3.9.10 Number of total spikelets per panicle

Number of total spikelets per panicle was counted by adding filled and unfilled spikelets per panicle.

3.9.11 Weight of 1000 seeds (g)

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

3.9.12 Grain yield per plant (g)

Grains obtained from each plant were sun-dried and weighed carefully. The dry weight of grains per plant was then recorded.

3.9.13 Grain yield per plot (g)

Grain yield in g per five plants of each replication was taken after harvesting, threshing, cleaning and drying the produce to 14% moisture level and calculated for $1m \times 1m = 1m^2$ in gm.

3.9.14 Grain yield per hectare (t/ha)

Grains obtained from each unit plot were sun-dried and weighed carefully and converted to t ha^{-1}.

3.10 Study of the milling and grain appearance

3.10.1 Hulling percent

The samples of 200g well dried paddy from each entry were hulled in a mini "Satake Rice Machine" and the weight of brown rice was recorded. Hulling percentage was worked out as,

$$\text{Hulling \%} = \frac{\text{Weight of brown rice}}{\text{weight of rough rice}} \times 100$$

3.10.2 Milling outturn

The brown rice obtained after hulling was passed through "Satake Rice Whitening and Caking Machine" for 5 minutes to obtain uniformly polished grains and the weight of polished grains was recorded. Milling outturn was calculated as.

$$\text{Milling outturn} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100$$

3.10.3 Head Rice Recovery (HRR %)

The milled samples were sieved to separate whole kernels from the broken ones. Small proportion of whole kernels which passed along with broken grains was hand separated. Head rice recovery was calculated in percentage as,

$$\text{HRR \%} = \frac{\text{Weight of whole milled rice}}{\text{Weight of rough rice}} \times 100$$

3.10.4 Grain length and breadth of uncooked rice

Ten rough kernels, ten brown kernels and five polished kernels from the bulk sample of each entry were measured for their length by slide calipers. Ten rough kernels, ten brown kernels and five polished kernels from the bulk sample of each entry were measured for their breadth slide calipers.

3.10.5 L/B ratio of uncooked rice

L/B ratio was computed according to following formula:

$$\text{L/B ratio} = \frac{\text{Grain length}}{\text{Grain breadth}}$$

3.10.6 Grain type

Grain types (polished rice) were classified by using the following classification proposed by Ramaiah committee in 1965 for the purpose of trade and commerce, approved by Ministry of Food, Govt. of India, is given below (Table 1 & Table 2): (On the basis of average length of kernel, milled rice is classified into following categories)

Table 1: Classification of milled rice on the basis of average length

Scale	Size	Length (mm)
1	Extra long	>7.50
2	Long	6.61 to 7.50
3	Medium	5.51 to 6.60
4	Short	5.50 to less

Grain shape is determined by length/breadth ratio of kernels as:

Table 2: Classification of milled rice on the basis of length/breadth ratio of kernels

Scale	Size	Length/Breadth ratio
1	Slender	>3.0
2	Medium	2.1 to 3.0
3	Bold	1.1 to 2.0
4	Round	1.0 to less

(Ahuja *et al.*, 1995)

Grain types were classified by using the following classification proposed by Ramaiah committee in 1965 (Table 3):

Table 3: Systematic classification of grain types of rice proposed by Ramaiah committee in 1965

Class	Designation	Description	
		Length	Length/Breadth ratio
Long Slender	LS	Length 6 mm and above	Length/Breadth ratio 3 and above
Short Slender	SS	Length less than 6 mm	Length/Breadth ratio 3 and above
Medium Slender	MS	Length less than 6mm	Length/Breadth ratio 2.5 to 3
Long Bold	LB	Length 6 mm and above	Length/Breadth ratio less than 3
Short Bold	SB	Length less than 6mm	Length/Breadth ratio less than 2.5

(Shobha Rani, 2003)

3.11 Determination of cooking and eating characteristics of the grain

3.11.1 Grain length and breadth of cooked rice

Individual kernels of the sample were taken separately in long labeled test tubes and presoaked in 5 ml of tap water for 30 minutes. After that, the tubes were placed in a water bath maintained at boiling temperature, for 8-9 minutes. After cooking the test tube were taken out and cooled under running water for two minutes. Cooked kernels were taken out of the tubes and excess water was removed with a blotting paper. Length and breadth of cooked kernels were measured as above.

3.11.2. Grain Length/ Breadth ratio of cooked rice

L/B ratio of cooked kernel was computed according to following formula:

$$\text{L/B ratio} = \frac{\text{Grain length}}{\text{Grain breadth}}$$

3.11.3 Kernel elongation ratio

Elongation ratio was calculated by dividing the length of cooked kernel by its original length.

$$\text{Elongation ratio (ER)} = \frac{(L_1)}{(L_0)}$$

Where, L_0 and L_1 are kernel length before and after cooking, respectively.

3.11.4 Kernel elongation index

Elongation index was calculated by dividing the length/breadth ratio of the cooked kernel by length breadth ratio of the original raw kernel.

$$\text{Elongation index (EI)} = \frac{L_1/B_1}{L_0/B_0}$$

Where, B_0 and B_1 are kernel breadth before and after cooking, respectively.

3.11.5 Water absorption (uptake) percentage

It is measured as the volume of water needed to cook 1 gm of rice in a definite period of time and temperature. Sample comprising one gram milled rice kernels was used of the study of this character. Weight of the samples was recorded before and after cooking. Water absorption was calculated in percentage as,

$$\text{Water absorption \%} = \frac{W_2 - W_1}{W_1} \times 100$$

Where w_1 and w_2 are weight of rice before and after cooking, respectively.

Care was taken to remove excess of water from the cooked samples with the help of blotting papers before weight. For cooking, the rice samples were taken in long test tube and pre-soaked in slightly excess but uniform quantity of water (10 ml) for five minutes and were placed over a water bath maintained at boiling temperature (100°C) for 6 to 7 minutes. The sample tubes were then out and cooled under room temperature for 10

3.11.6 Volume expansion (%)

The same sample of one gram rice kernels that was used for the study of water absorption was used for this study as well. After recording the weight of uncooked samples, their volume was determined by displacement of water method using a finely graduated narrow cylinder of 5 ml capacity. After cooking, final volume of the above sample was recorded and volume expansion percentage was calculated as,

$$\text{Volume expansion \%} = \frac{V_2 - V_1}{V_1} \times 100$$

Where v_1 and v_2 are volume of 1gm rice before and after cooking, respectively.

3.11.7 Gelatinization temperature (GT)

A sample of eight whole milled rice kernels from each entry was placed in small pertriplates (5 cm wide) containing 10 ml of 1.7% potassium hydroxide (KOH) solution. The petriplates were covered and placed in an incubator maintained at 30 ± 1 °C for 16 hours as suggested by Zaman (1981).

After 16 hours of incubation, the petriplates were gently taken out from the incubator. Alkali spreading values of six grains of each entry were recorded separately and mean was calculated on a 7 point numerical scale proposed by Jennings *et al.*, (1979) (Table 4).

Table 4: Numerical scale for scoring gelatinization temperature of rice

Score	Spreading	Clearing	Alkali digestion	Gelatinization temperature
1	Kernel not affected	Kernel chalky	Low	High
2	Kernel Swollen	Kernel chalky; Collar powdery	Low	High
3	Kernel Swollen with collar incomplete and narrow	Kernel chalky Collar cottony or cloudy	Low or Intermediate	High or Intermediate
4	Kernel Swollen with collar complete and wide	Centre cottony; Collar cloudy	Intermediate	Intermediate
5	Kernel split or segmented with collar complete and wide	Center cottony; Collar clearing	Intermediate	Intermediate
6	Kernel dispersed merging with collar	Center Cloudy; Collar clear	High	Low
7	Center and collar clear	Center and collar clear	High	Low

According to Alkali spreading score the GT. Types were classified as follows (Table 5):

Table 5: Classification of GT types according to the Alkali spreading score

Alkali spreading value/code	G.T. Types
1-3	High
4-6	Intermediate
6-7	Low

3.11.8 Cooking time

For determination of cooking time, the rice samples were taken in long test tube with water and placed in water at boiling temperature (100°C) on Hot plate. When the starch granules are disappeared then rice samples were seems to be cooked. Time was determined by stop watch and recorded in record book.

3.11.9 Statistical analysis

The collected data were statistically analyzed to find out the significance of the difference among the treatments. Microsoft Excel 2007, Microsoft Word 2007, Microsoft Power Point 2007 and SPSS 16 for windows were used. For each character, analysis of variance (ANOVA), means, range were calculated by computer using SPSS 16 statistical software. The analysis was performed by F-test and the significance of the difference between pairs of treatment means were evaluated by the Least Significance Difference (LSD) test at 5% level of significance.

CHAPTER 4
RESULTS AND DISCUSSION

Mean performance for yield and yield components of different advanced lines of new plant type are presented here to understand the overall scenarios of the research work. A total of four selected advanced lines of new plant type and two check variety were evaluated for yield and some yield contributing characters.

4.1. Evaluation of the yield performance of different advanced lines of new plant type rice

Generally a breeder aims at accumulating favorable gene from divers resources in a particular genotype, which would largely depends upon the availability of genetic variability in the germplasm in respect of any particular character and genetic potential of a crop plant is estimated on the basis of yield of economic part. In case of rice, it is grain yield. This grain yield has been defined by Podhi and Singh (1991) as a function of number of panicles per plant, number of grains per panicle, percentage of filled grains and weight of kernels. Venkateswarlu *et al.*, (1986) have proposed enhancement of grain yield potential in rice by increasing the proportion of high density grains. Many different morphological and yield components contributing to yield have been proposed by various worker, but the most recognized components are days to flowering, number of effective tillers per plant, number of filled grains per panicle, grain size as viewed by Tawlar and Guad (1974), Reddy and Ramchandraiah (1990), Basak and Ganguli (1996) and Peng *et al.*, (2000).

A total of four selected advanced lines of new plant type rice and two commercial checks were evaluated for yield and some yield contributing characters. The results of mean performance for various yield contributing characters are presented under the following heads:

4.1.1. Analysis of variance

Analysis of variance was carried out and the mean sum of squares for various characters is presented in Table 6. 'F' test revealed highly significant variation among six genotypes for all the characters studied. Existence of significantly high level of variation for the various yield and yield component characters in the materials studied is indicative of possibilities of improving the genetic yield potential of new plant type rice (Table 6).

4.1.2. Mean performance for yield and yield components

Mean performance for yield and yield components of the lines of new plant type rice with check variety have been presented character wise in Table 7.

4.1.2.1 Plant height (cm):

Plant height of different advanced line of new plant types of rice varied significantly (Table 7). The tallest plant height (117.5 cm) was recorded from advanced line AL-52 which was statistically identical while the shortest plant height (90.53 cm) was recorded from check variety and BRRI dhan-57. Khush (1999) reported that short stature reduces the susceptibility of rice crop to lodging and leads to higher harvest index. Ponnuthurai *et al.*, (1984) reported that taller plants may have better plant canopy for photosynthesis. For optimally managed and multiple crop growing situation earliness and short height are generally preferred where as in ill drained and deep water situation generally late and taller hybrids fit better. Choudhury *et al.*, (1991) reported that transplantation time, water and soil condition, planting and sowing method affect plant height in rice. Relative performance of plant height and panicle length is presented in Figure 3.

4.1.2.2 Days to 50% flowering

Days to 50% flowering of different advanced line of rice varied significantly (Table 7). The maximum days for 50% flowering (108 days) were recorded from BRRI dhan-57 whereas the minimum days (95 days) recorded from Richer. This line Richer definitely would mature earlier and ultimately reduce crop duration. As a result 2 to 3

Table 6. Analysis of variance (ANOVA) of different characters of selected new plant types and check varieties of rice.

Characters	Mean Sum of Squares (MSS)		
	Replication	Genotype	Error
d.f.	2	5	12
Plant height (cm)	2.431	48.125*	14.223
Days to 50% flowering	6.712	121.113**	11.231
Days to maturity	11.520	22.109**	3.198
Productive tiller	11.126*	13.245**	2.145
Unproductive tiller	0.045	3.125**	0.412
No of total tillers per plant	3.21	198.781**	35.882
Panicle length (cm)	1.321	8.102**	1.765
No of filled grains per panicle	38.813	2012.982**	103.220
No of unfilled grain per panicle	11.363.2344	168.172	22.127
No of total grains per panicle	61.234	2109.238**	78.397
1000 grain weight (gm)	2.871	18.209	1.378
Grain yield per plot (gm)	0.792*	1.498**	0.141
Grain yield per ha (t/ha)	2.569*	6.234**	0.422

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

Table 7: Mean performance of yield and yield contribution characters of some new plant type (NPT) rice genotypes

Treatments	Plant height (cm)	Days to 50% flowering	Days to maturity	Productive tillers/plant	Un-productive tillers/plant	Number of total tillers per plant	Panicle length (cm)
AL-36	98.53bc	106a	133a	23.33ab	1.00b	24.3ab	26.20ab
AL-29	102.90b	96c	130b	22.40ab	2.33ab	24.7ab	27.77a
Richer	115.43a	95c	130b	12.06c	3.33ab	15.4b	26.90a
AL-52	117.50a	97c	130b	16.40bc	0.33b	16.7b	27.70a
BRRI dhan-49	102.63b	103b	133a	25.73a	5.00a	30.7a	24.61b
BRRI dhan-57	90.53c	108a	133a	23.66ab	1.33b	25.0ab	24.26b
P	0.001	0.005	0.029	0.001	0.006	0.005	0.001

Table 7. (continued)

Treatments	Filled spikelets/ panicle	Un-filled spikelets/ panicle	Number of total spikelets/ panicle	1000 grain weight (gm)	Yield/plant (gm)	Yield/m^2 (gm)	Grain yield/ ha (ton)
AL-36	154.00a	57.06a	211.0a	19.7bc	54.26ab	486.33b	4.86b
AL-29	163.60a	16.53b	180.0a	19.0bc	59.86a	750.66a	7.50a
Richer	149.00a	36.66ab	185.0a	26.2a	29.35b	502.33ab	5.02ab
AL-52	172.13a	19.66b	191.0a	21.0b	38.26ab	604.00ab	6.05ab
BRRI dhan-49	174.46a	19.10b	193.0a	17.8bc	62.00a	531.00ab	5.31ab
BRRI dhan-57	157.66a	28.40ab	186.0a	16.0c	63.13a	479.33b	4.79b
P	NS	0.005	NS	0.001	0.006	0.028	0.003

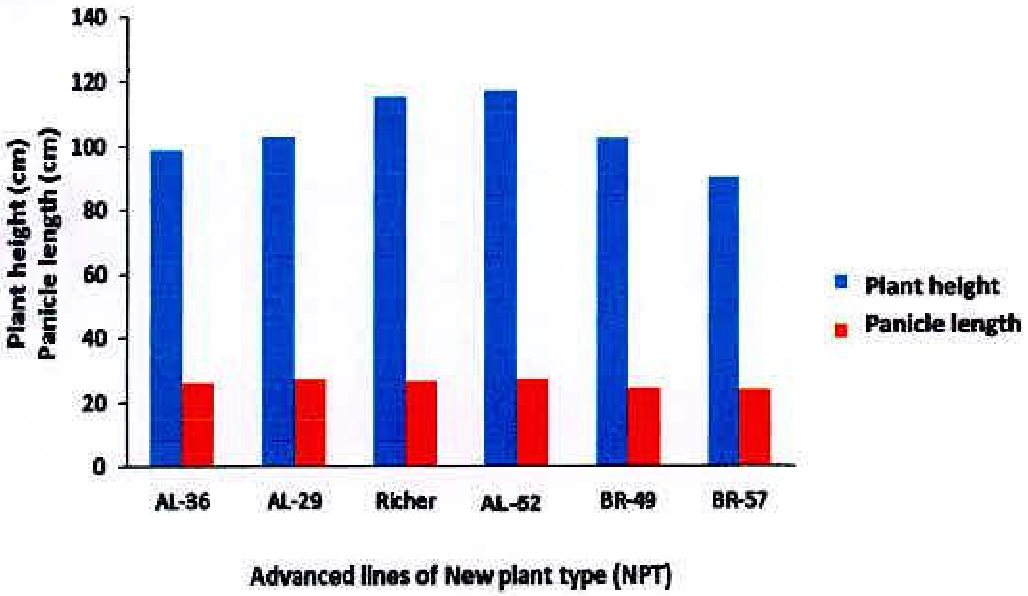


Figure 3. Relative performance of advanced lines of new plant type rice and check for plant height and panicle length

irrigation would be saved and crop would be also escape from insect infestation especially from leaf roll which attack at the late stage of crop maturity.

4.1.2.3 Days to maturity

Days to maturity of different advanced lines of rice varied significantly (Table 7). The maximum days for maturity (133 days) were recorded from BRRI dhan-57, BRRI dhan-49 and AL-36 whereas the minimum days (130 days) recorded from Al-29, Richer and AL-52. Khush (1999) reported that the optimum growth duration for maximum rice yields in the tropics is thought to be 120 days from seed to seed. Growth duration of about 120 days allows the plant to utilize more soil nitrogen and solar radiation and resulting in high yield. However, for adaptation of various cropping system, varieties with varying growth duration of 100-130 days are required. Short duration lines can a good source for breeder to use as parents.

4.1.2.4 Number of productive tillers per plant

Number of productive tillers per plant of different advanced lines of rice varied significantly. The maximum number of productive tillers per plant (23.66) was recorded from BRRI dhan-57 whereas the minimum number (12.06) recorded from Richer (Table 7). Earlier many workers reported that higher numbers of productive tillers are responsible for higher yield (Pandey *et al.*, 1995; Reddy and Ramachandraiah, 1995; Padmavathi *et al.*, 1996; Rao *et al.*, 1996). According to new plant type concept of Khush (1999) reduced tillering habit (6-10 tillers/plant) would give higher yield than the modem varieties having 20-25 tillers. He observed that only 14-15 of these tillers produce panicles which are small and rest remaining unproductive. Reduced tillering facilitates synchronous flowering and maturity and more uniform panicle size. Genotypes with lower Oilier number are also reported to produce a larger proportion of heavier grains (Padmaja Rao, 1987).

4.1.2.5 Number of un-productive tillers per plant

Number of un-productive tillers per plant of different advanced lines of rice varied significantly (Table 7). The minimum number of un- productive tillers per plant (0.33) was recorded from line AL-52, whereas the maximum number (5.00) recorded from advanced line BRRI dhan-49 (Table 7). Relative performance of productive and unproductive tiller number is presented in Figure 4.

4.1.2.6 Number of total tillers per plant

Number of total tillers per plant of different NPT advanced lines of rice varied significantly. The maximum number of total tillers per plant (30.7) was recorded from BRRI dhan-49 whereas the minimum number (15.4) recorded from Richer (Table 7). Similar trend is also observed in case of productive tillers per plant.

4.1.2.7 Panicle length (cm)

Panicle length of different NPT advanced lines varied significantly (Table 7). The longest panicle length (27.77 cm) was recorded from AL-29 whereas the shortest panicle length (24.26 cm) recorded from BRRI dhan-57. Sharma (2002) worked with fine grain rice and reported that there had been significant variation in panicle length. Wang *et al.*, (1991) reported that the length of panicle varied from 26.30 cm to 27.50 cm among the jaixmica hybrids. But in the present study, the range of panicle length of lines was from 28.43-33.45 cm.

The increased panicle length could be due to the materials used. A comparative panicle appearance is presented in Plate 1.

4.1.2.8 Number of filled spikelets/panicle

Number of filled spikelet, per panicle of different advanced lines of rice varied significantly (Table 7). The maximum number of filled spikelet per panicle (174.46) was recorded from BRRI dhan-49, while the minimum number (149.00) recorded from Richer. Similarly Tahir *et al.*, (2002) reported highly significant variation for the grain per panicle for different genotypes. Other factors i.e. soil fertility, plant nutrients, translocation and weather condition might also responsible.

4.1.2.9 Number of unfilled spikelet/panicle

Number of unfilled spikelet per panicle of different advanced line of rice varied

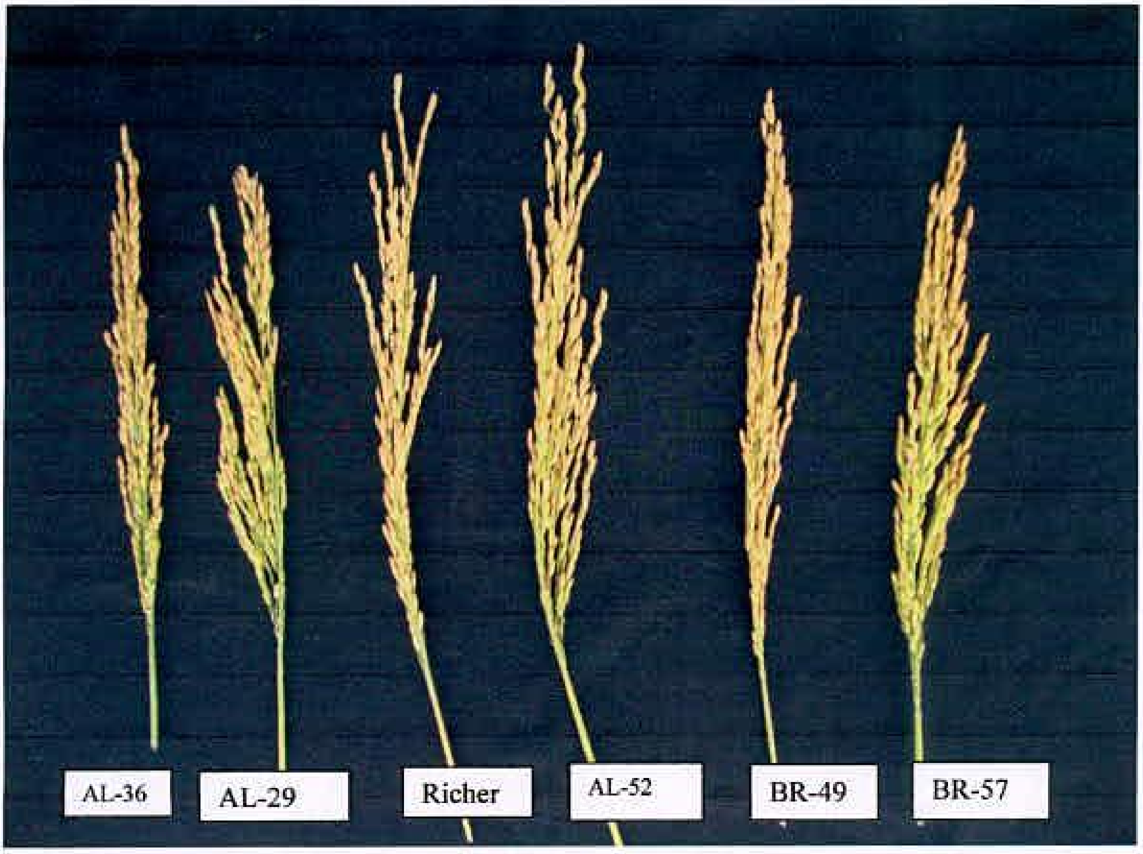


Plate 1: Comparative panicle appearance of new plant type Lines and checks

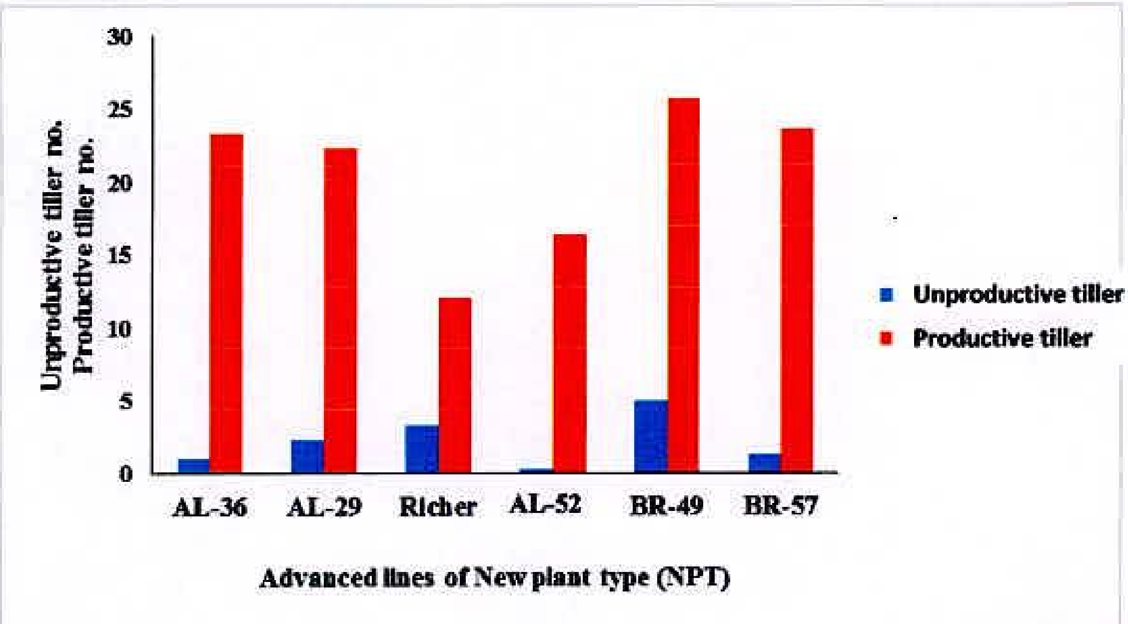


Figure 4. Relative performance of advanced lines of new plant type rice and check for unproductive and productive tiller numbers

significantly (Table 7). The minimum number of unfilled spikelets per panicle (16.53) was recorded from AL-29 and the maximum number (57.06) recorded from AL-36.

4.1.2.10 Number of spikelets/panicle

Number of total spikelets per panicle of different advanced lines of rice varied significantly (Table 7). The maximum number of total spikelets per panicle (211) was recorded from AL-36, while the minimum number (180) recorded from AL-29. Positive association between grain number per panicle and grain yield has been reported by number of workers (Chauhan *et al.*, 1986; Janagle *el al.*, 1987; Kalaimani and Kadambavanaundaram, 1988).

4.1.2.11 Weight of 1000 seeds (g)

Weight of 1000 seeds of different advanced lines of rice varied significantly (Table 7). The highest weight of 1000 seeds (26.2 g) was recorded from Richer and the lowest weight (16.0 g) recorded from BRRI dhan-57. Tahir *et al.*, (2002) reported highly significant variation among different traits and observe that these traits are under the control of genotypic difference among the genotypes. Other factors like: adapyibility, temperature, soil fertility, transplantation season and time might also be responsible for thousand seed weight.

4.1.2.12 Grain yield (g/plant)

Grain yield per hill of different advanced lines of rice varied significantly. The highest grain yield per plant (63.13 g) was recorded from BRRI dhan-57 and the lowest yield (29.35 g) recorded from Richer (Table 7). Varietal differences of grain yield were reported by Biswas *et al.*, (1998). This variation in the grains yield might be due to the environment (Chaudhury *et al.*, 1997) or the correlation of grain yield per plant with various yield contributing characteristics like: number of grains per panicle, grain weight and correlation with these traits.

4.1.2.13 Grain yield (g/m^2)

Grain yield per meter square of different advanced line of rice varied significantly.

The highest grain yield per square meter (604 g) was recorded AL-52, and the lowest yield (479.33 g/plant) recorded from BRRI dhan-57 (Table 7). Relative performance of yield per plant and yield per square meter is presented in Figure 5.

4.1.2.14 Grain yield (t/ha)

Grain yield per hectare of different advanced lines of rice varied significantly (Table 7). The highest grain yield (7.50 t/ha) was recorded from AL-29, and the lowest yield (4.79 t/ha) was recorded from BRRI dhan-57. The performance of any line is finally estimated on the basis of grain yield, which in turn is the result of contributions by many characters. Hossain (2004) reported that higher biological yield does not always contribute higher yield. He also suggested that it is desirable to select lines having higher spikelet fertility combined with high biomass and harvest index, than those producing lower biological yield with higher harvest index.

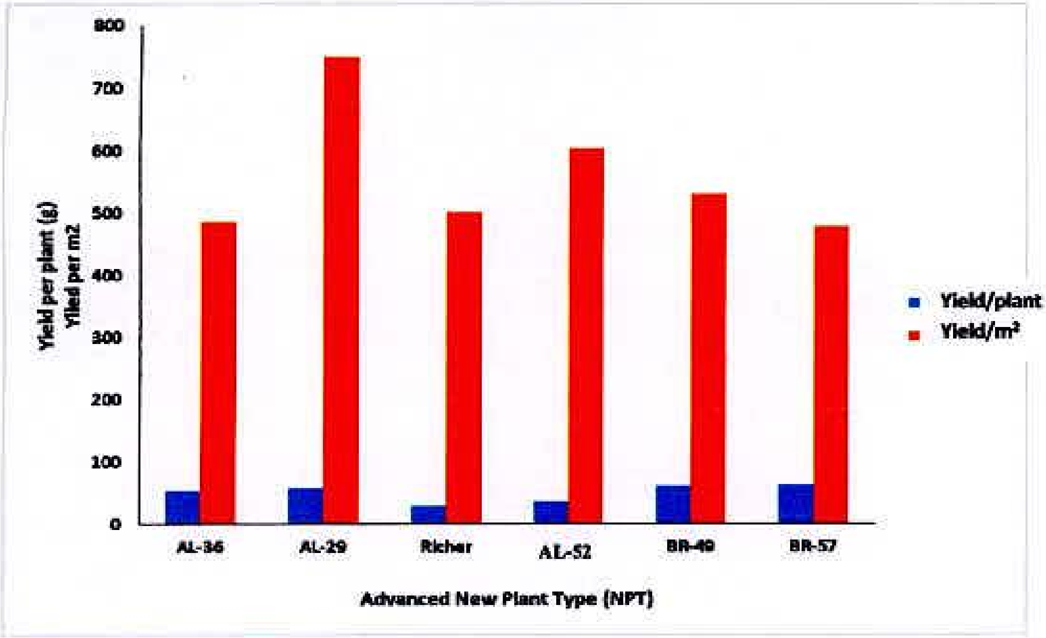


Figure 5. Relative performance of advanced lines of new plant type rice and check for yield per plant and yield per m^2

4.1.3 Analysis of correlation of co-efficient

Yield is a complex product being influenced by several interdependent quantitative characters. Selection for yield may not be effective unless the directly or indirectly influences of other yield components are taken into consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated traits. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeder for making improvement through selection provide a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors. Higher genotypic correlations than phenotypic one might be due to modifying or masking effect of environment in the expression of the character under study. Character association analysis among yield and yield contributing traits revealed that all the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation coefficients (Chaudhury *et al.*, 1997).

Correlation was done to measure the mutual relationship between six different yield and yield contributing characters and to determined the component characters on which selection could be based for improvement in yield of new plant type genotypes (Table 8).

4.1.3.1 Plant height (cm)

Plant height showed highly significant and positive relationship with panicle length and 1000 grain weight (Table 8). The results revealed that plant height ensured longest panicle. Plant height was positively correlated with panicle length also reported by Biswas *et al.*, (1998). Plant height showed highly significant negative relationship with days to 50% flowering and number of productive tillers/hill. Bhattacharya and Sowbhagya (1971) found that grain yield was negatively correlated with plant height. Tahir *et al.*, (1988) and Prasad *et al.*, (2001) found that plant height was negatively correlated with no. of tillers per plant and grain yield. But, Gomathinayagam *et al.*, (1988) and Rasheed *et al.*, (2002) obtained positive and significant correlation of grain yield with plant height

Table 8: Phenotypic correlations among yield and yield contributing characters

Phenotype	Days to 50% flowering	No. Productive tillers/Plant	No. of Unproductive tillers/Plant	Panicle length (cm)	No. of filled grains/panicle	No. of Unfilled grains/ Panicle	1000 grain weight (g)	Grain yield (t/ha)
Plant height (cm)	-0.79**	-0.74**	0.003	0.69**	0.23	-0.29	0.74**	0.12
Days to 50% flowering		0.69**	-0.21	-0.67**	-0.19	0.60*	-0.59*	-0.4
No. Productive tillers/plant			0.06	-0.75**	0.09	-0.52*	-0.59*	0.41
No. of Unproductive tillers/plant				-0.54*	-0.19	0.01	-0.78**	-0.02
Panicle length (cm)					0.08	-0.19	0.18	0.01
No. of filled grains/panicle						-0.40	-0.64*	0.01
No. of unfilled grains/ panicle							0.44	-0.46
1000 grain weight (g)								0.03

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

which is not in line with present finding which might be due to the differences of the genetic constitution of the material used.

4.1.3.2 Days to 50% flowering

Days to 50% flowering showed highly significant positive association with productive tillers per plant and significant positive association with no. of unfilled grains per panicle (Table 8). Significant positive association of grain yield with days to flowering was observed by Ahuja *et al.,* (1995). On the other hand days to 50% flowering showed the negative correlation with panicle length and weight of 1000 grains.

4.1.3.3 Number of productive tillers/plant

Number of productive tillers/plant showed significant positive association with number of filled grains per panicle, grain yield and negative association with unfilled grains per panicle (Table 8). Indicating that any increase in number of effective tillers/plant should bring an enhanced in the yield. Reddy and Kumar (1996) reported that productive tillers/plant showed significant positive correlation with grain yield.

4.1.3.4 Number of unproductive tillers/plant

Number of unproductive tillers/hill showed highly significant negative relationship with weight of 1000 seeds (Table 8). This character showed insignificant negative grain yield (t/ha) and number of filled grain per panicle.

4.1.3.5 Panicle length (cm)

Panicle length showed insignificant positive association with number of filled grain per panicle, 1000 grain weight, grain yield and plant height (Table 8). Further
it showed insignificant negative correlation with unfilled grain per panicle and days to 50% flowering. Negative genotypic correlation of yield /plant was reported with panicle length by Saini and Gagneja, (1975).

4.1.3.6 Number of filled grains/panicle

Number of filled grains/panicle showed significant positive association with yield

(Table 8). Gravois and Helms (1992) reported the importance of number of filled grains per panicle in determination of rice yield.

4.1.3.7 Weight of 1000 seeds

The correlation of 1000 seed weight with yield (t/ha) was insignificant positive at phenotypic level (Table 8). Yolanda and Das (1995), Prasad *et al.*, (2001) and Iftikharuddaula *et al.*, (2002) also found the similar result.

4.1.3.8 Grain yield (t/ha)

Grain yield showed significant positive association with number of filled grains per panicle, panicle length and number of productive tillers/plant (Table 8). The correlation of yield was insignificantly negative with days to 50% flowering, number of unfilled grains per panicle and 1000 g grain weight. Yolanda and Das (1995); Prasad *et al.*, (2001) and Iftikharuddaula *et al.*, (2002) found that grain yield was positively correlated with 1000 grain weight and positively and significantly correlated with number of grains per panicle. The existence of wide range of variation for quality traits provides opportunity to choose advanced lines of desirable quality characteristics for development of variety. At the same time advanced lines can be improved for quality traits following appropriate breeding method.

4.2 Study of milling and grain appearance/quality characters of new plant type rice

When rice is threshed, the hull (lemma and palea) remains intact- this is known as 'rough rice'. The hull is removed (about 20% of the kernel weight) to produce brown rice. Further milling removes the bran (the seed coat, embryo, and some endosperm) to produce milled rice. A milled rice grain contains approximately 85% starch and 5% protein. The quality of rice is determined by grain appearance, cooking quality and nutritional value. The grain is important for farmers as it determines the market price and to consumers as it determines their acceptability. Quality in rice is a combination of several physico-chemical characters of the grain. The physical properties of the rice grain are determined by grain color, shape and size, grain weight, hardness of the endosperm, appearance of the milled kernels, hulling and milling recovery. Starch, proteins, minerals and vitamins constitute the chemical components of the rice grain. The market quality depends on physical attributes, while consumer's preference (cooking, eating and nutritive value) depends on chemicals traits. Interestingly, both are inter-dependent.

4.2.1 Analysis of variance

Analysis of variance was carried out and the mean sum of squares for various characters is presented in Table 9. 'F' test revealed highly significant variation among six genotypes for all the characters studied. Existence of significantly high level of variation for the various yield and yield component characters in the materials studied is indicative of possibilities of improving the genetic yield potential of new plant types rice.

4.2.2 Mean performance of quality characters (before cooking)

The results on mean performance of various quality characters before cooking of the lines and check variety have been presented character wise in Table 10. The discussion is as follows:

4.2.2.1 Hulling (%)

Hulling percentage of rice for different advanced line of NPT rice varied significantly (Table 10). The maximum hulling (78.7 %) was recorded from AL-36 and the lowest hulling (75.3%) recorded from AL-52. There was no significance differences were observed among the NPT lines and checks. Sandeep (2003) found 71.67% to 84.56% hulling per cent during characterization of 20 new plant type genotypes in rice.

Table 9. Analysis of variance (ANOVA) of different quality characters of selected new plant type advanced lines of rice and checks (before cooking)

Characters	Mean Sum of Squares (MSS)		
	Replication	Genotype	Error
d.f.	2	5	12
Hulling (%)	-	44.145**	7.12
Milling Outturn (%)	-	58.126**	9.19
Head Rice Recovery (%)	-	91.235**	9.81
Grain length of rough rice (mm)	-	4.561**	0.031
Grain breadth of rough rice (mm)	-	0.074**	0.007
Grain length/breadth ratio of rough rice	-	0.512**	0.022
Grain length of brown rice (mm)	-	3.127**	0.005
Grain breadth of brown rice (mm)	-	0.004	0.003
Grain length/breadth ratio of brown rice	-	0.761**	0.12
Grain length of milled rice (mm)	-	1.453**	0.023
Grain breadth of milled rice (mm)	-	0.013**	0.001
Grain length/breadth ratio of milled rice	-	0.387**	0.014

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

Table 10: Mean performance of quality characteristics before cooking in different lines and Check

Treatments	Hulling (%)	Milling Outturn (%)	Head Rice Recovery (%)	Grain length of rough rice (mm)	Grain breadth of rough rice(mm)	Grain length/ breadth ratio of rough rice	Grain length of brown rice (mm)
AL-36	78.7a	70.2a	66.5a	8.97b	2.49ab	3.60b	6.78a
AL-29	75.7a	68.5a	66.0a	8.66b	2.36bc	3.67b	6.32ab
Richer	78.0a	70.4a	68.9a	10.1a	2.52ab	4.03a	6.93a
AL-52	75.3a	68.3a	63.6a	9.78a	2.25c	4.34a	6.95a
BRRI dhan-49	76.9a	70.1a	68.8a	8.00c	2.28c	3.52b	5.98b
BRRI dhan-57	75.5a	67.3a	63.8a	7.72c	2.59a	2.97c	5.67b
P	NS	NS	NS	0.001	0.001	0.001	0.001

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

Table 10: (Continued)

Treatments	Grain breadth of brown rice (mm)	Grain length/ breadth ratio of brown rice	Grain length of milled rice (mm)	Grain breadth of milled rice (mm)	Grain length/ breadth ratio of milled rice
AL-36	2.16ab	3.14b	6.15b	2.08a	3.01cd
AL-29	2.01cd	3.14b	6.20b	1.95b	3.18bc
Richer	2.14ab	3.23b	6.79a	2.04a	3.26b
AL-52	1.91d	3.64a	6.91a	1.73c	3.99a
BRRI dhan-49	2.05bc	2.91c	5.59c	1.94b	2.87d
BRRI dhan-57	2.18a	2.59c	5.18d	2.10a	2.46e
P	0.001	0.001	0.001	0.001	0.001

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

4.2.2.2 Milling outturn (%)

The total yield of milled rice which can be obtained from amount of rough rice is termed as milling recovery and is generally expressed in percentage (Khush *et al.*, 1979). It assumes importance because it tells the actual yield of consumable product. A good milling quality includes high whole kernel recovery and less of broken rice. While milling recovery as a whole mainly depends upon the hull content which varies from 18 to 26 percent and the nature of alluron layer. Milling return of rice for different advanced line of rice varied significantly (Table 10). The maximum milling return (70.4%) was recorded from Richer and the lowest recorded from BRRI dhan-57 (67.3%). There was no significance differences were observed among the NPT lines and checks. But, Ahuja *et al.*, (1995) reported a range of 67 to 71% for milling recovery in Basmati varieties. Prasad *et al.*, (2001) reported a range of 61.50 to 72.60%. A Comparative view of rough rice and milled rice is presented in (Figure 7).

4.2.2.3 Head rice recovery (HRR %)

Head rice is the proportion of the whole grain in the milled rice. It depends on varietal characters as well as drying conditions (Adair *et al.*, 1973). Head rice recovery of rice for different advanced line of rice varied significantly (Table 10). The maximum head rice recovery (68.9 %) was recorded from Richer, while the lowest (63.6 %) recorded AL-52. There was no significance differences were observed among the NPT lines and checks. For the commercial success of a rice variety it must possess high total milled rice and whole kernel (HRR) turnout. If a variety has a higher broken percentage, its marketability will be reduced. Head rice recoverability is an inherited trait, although environmental factors such as temperature and humidity during ripening and post-harvest stages are known to influence grain breakage during milling (Shobha Rani, 2003). The higher milling percentage may not yield higher head rice recovery as it depends on grain dimension also. Grain size and shape, hardness. percentage or absence of abdominal white, moisture content, harvest precision, storage conditions, processing and type of mills employed have direct effect on head rice recovery, (Bhattacharya, 1980). In general, varieties with long bold grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long slender and translucent grains give high head rice yields. Varieties with high protein content also suffer less breakage. Sun cracking which is caused alternate drying and wetting of grains due to delayed harvest also adds more breakage of grain (Shobha Rani, 2003). Viraktamat (1987) and Yadav and Singh (1989) reported an inverse relationship between HRR% and grain L/B ratio.

4.2.2.4 Grain length, breadth and length/breadth of rough rice

Shoba Rani (2003) reported that bold grains give low head rice recovery because of high breakage. Grains with short to medium long grains break less than long grains during milling. Thus grain size and shape have direct effect on yield of head rice. Kernel length, breadth and their ratio of rough rice for different new plant types rice varied significantly (Table 10). The longest kernel length of rough rice (10.1 mm) was recorded from Richer and the shortest kernel (7.72 mm) recorded from BRRI dhan-57. The longest kernel breadth of rough rice (2.59 mm) was recorded from BRRI dhan-57 and the shortest (2.25 mm) recorded AL-52.The highest ratio of kernel length and breadth of rough rice (4.34) was recorded AL-52 and the lowest ratio (2.97) recorded from BRRI dhan-57. Vraktarnath (1987) observed that kernel breadth enhanced the milling output and HRR was strongly associated with milling percentage.

4.2.2.5 Grain length, breadth and ratio of brown rice

Kernel length, breadth and their ratio of brown rice for different advanced line of rice varied significantly (Table 10). The longest kernel of brown rice (6.95 mm) was recorded AL-52 and the shortest kernel (5.67 mm) recorded from BRRI dhan-57. The longest kernel breadth of brown rice (2.18 mm) was recorded from BRRI dhan-57 and the shortest (1.91 mm) recorded AL-52. The highest ratio of kernel length and breadth of brown rice (3.64) was recorded AL-52 and the lowest ratio (2.59) recorded from BRRI dhan-57.

4.2.2.6 Grain length, breadth and ratio of milled rice

Kernel length, breadth and their ratio of milled rice for different advanced lines of rice varied significantly (Table 10). The longest kernel of milled rice (6.91 mm) was recorded AL-52 and the shortest kernel (5.18 mm) recorded from BR-57. The longest kernel breadth of milled rice (2.08 mm) was recorded from AL-36 and the shortest (1.73 mm) recorded AL-52. The highest ratio of kernel length and breadth of milled rice (3.99) was recorded AL-52 and the lowest ratio (2.46) recorded from BRRI dhan-57. Grain appearance is largely determined by endosperm opacity, the amount of chalkiness. Khush *et al.,* (1979) classified the endosperm of rice based on endosperm opacity as waxy or non waxy. Wax rice devoid of or have only trace of amylose contented are opaque. Non waxy rices have varying amylase level (2.1 to 32%) and are dull, hazy or translucent. Dull and hazy kernels have amylase content ranging from 10-32%. He also reported that mixture of different endosperm appearance grains (due to varying level of amylase per cent) does not seem to reduce cooking and qualities, but the consumers of India prefer only translucent grain which fetch as high premium in the market. Chalkiness is undesirable in all segments of rice industry. Breeders select intensively for clear, vitreous kernels. Environmental factors such as harvesting at high moisture content can also affect chalkiness. Chalky kernels will break easily, reducing milling yields. A comparative view of rough rice and milled rice is presented in Plate 2. Relative performance of advanced lines of new plant type rice and checks for grain L/B ratio in Figure 6.

4.2.2.7 Grain dimension

The milling and marketable qualities depend largely upon the size and shape of the grain. Grain dimension is expressed as length, breadth and thickness, whereas shape is generally expressed as ratio between the length and breadth. With respect to grain dimension, variation is found in materials studied, as we can see from performance of each genotype (Table 10). Grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production (Adair, *el al.,* 1973). Grain length is an important physical property, which

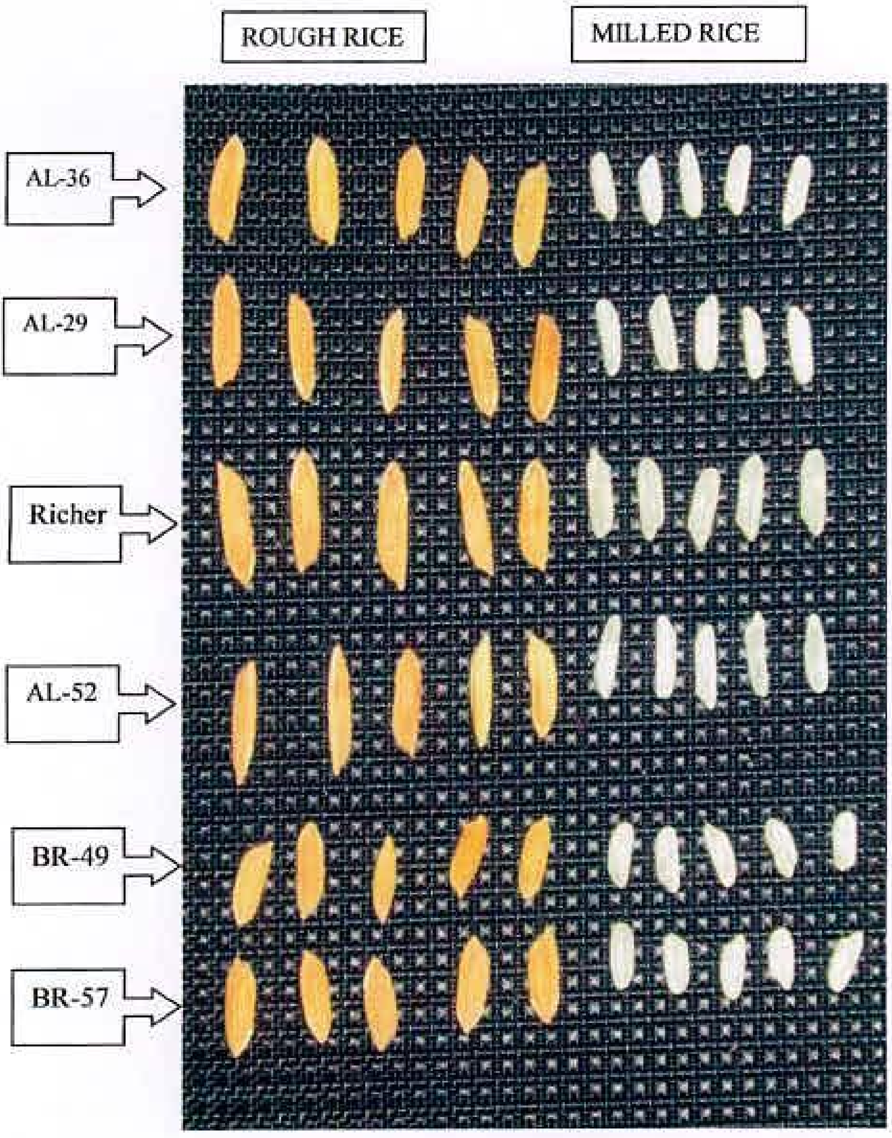


Plate 2: A comparative view of rough rice and milled rice of different advanced lines of new plant type rice and check

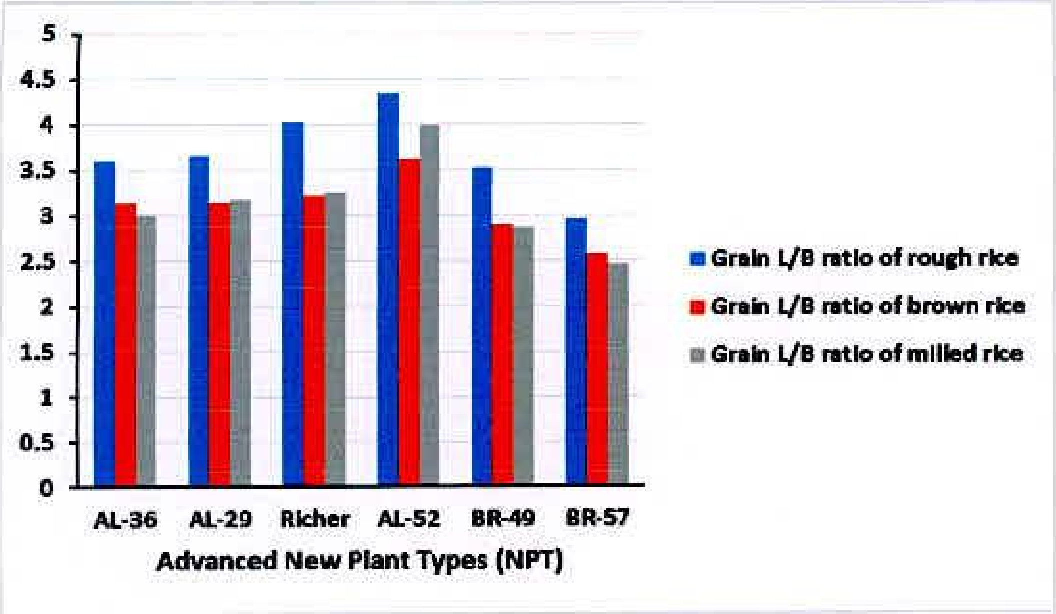


Figure 6: Relative performance of advanced lines of new plant type rice and check for grain L/B ratio

attracts consumer's attention. The people of Bangladesh like long, slender, shiny grain. Length breadth ratio of the grains indicates the fineness of the gram. The appearance of milled rice is important to the consumer, which in turn assumes importance to the producer and miller. Therefore grain size and shape of milled rice are the foremost characteristics of rice quality that breeders consider in developing new varieties for release commercial production (Adair *et al.,* 1966). Preference for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, while medium and long slender grains are preferred by others. In general, medium to long grains are preferred in the Indian subcontinent while the country is also replete with hundreds of short grain aromatic types and long basmati types the later commanding highest premium in both domestic and international markets. In temperate areas short grain varieties of *japonica* types are prevalent. Extra long grain types are preferred in Thailand. While grain size and shape of milled rice can he visual classified, more precise measurement are needed classification and for critical comparison of hybrids lines. In present study, the grain shape and size are characterized following Ramaiah Committee classification (1965). In the present study, maximum 5 lines had been grouped into long slender and one cheek (BRRI dhan-57) into medium slender group (Table 11).

4.2.2.8 Endosperm translucency and chalkiness

Among the four lines, all showed clear-cut translucent endosperm appearance (Table 12). The check also showed translucent grain. The endosperm appearance for all line was good. Grain appearance is largely determined by endosperm opacity, the amount of chalkyness. Khush *et al.,* (1979) classified the endosperm of rice based on endosperm opacity as waxy or non waxy. Waxy rice devoid of or have only trace amylase content and are opaque. Non waxy rice have varying amylase level (2.1-32%) and are dull, hazy or translucent. Dull and hazy kernels have amylase content ranging from10-32%.

Table 11: Classification of grain types of new plant type rice and check variety on the basis of systematic classification of rice proposed by Ramaiah Committee (1965)

Classification Group				
Long slender (SL) (Length6 mm & above L/B ratio 3 and above)	Short Slender (SS) (Length less than 6 mm L/B ratio 3 and above)	Medium Slender (MS) (Length 6 mm & above L/B ratio 2.5 to 3)	Long Bold (LB) (Length 6 mm & above L/B ratio less than 3)	Short Bold (SB) (Length less than 6 mm L/B ratio less than 2.5)
AL-36	-	BRRI dhan-57	-	-
AL-29	-	-	-	-
Richer	-	-	-	-
AL-52	-	-	-	-
BRRI dhan-49	-	-	-	-

Table 12: Endosperm appearances in new plant types rice and check variety

Line/check	Endosperm appearances
AL-36	Translucent
AL-29	Translucent
Richer	Translucent
AL-52	Translucent
BRRI dhan-49	Translucent
BRRI dhan-57	Translucent

He also reported that mixture different endosperm appearance grains (due to varying level of amylase per cent) does not seem to reduce cooking and qualities, but the consumers of India prefer only translucent grain which fetch as high premium in the market.

Chalkiness is undesirable in all segments of rice industry. Breeders select intensively for clear, vitreous kernels. Environmental factors such as harvesting at high moisture content can also affect chalkiness. Chalky kernels will break easily, reducing milling yields.

4.3 Cooking and eating characteristics of the grain

4.3.1 Analysis of variances

The analysis of variance (ANOVA) presented in (Table 13) Showed highly significant variation for all milling quality characters studied. A wide range of variation was observed for characters like length, breadth, L/B ratio of cooked rice, kernel elongation ratio, water uptake (%), volume expansion (%) and alkali spreading value. The present findings on wide variation for quality traits are in agreement with reports of Sood (1978) and Sandeep (2003).

The existence of wide range of variation for quality traits provide opportunity to choose advanced lines of desirable quality characteristics for development of variety. At the same time advanced lines can be improved for quality traits following appropriate breeding method.

Table 13. Analysis of variance (ANOVA) of different quality of selected new plant types of rice and check (after cooking)

Characters	Mean Sum of Squares (MSS)		
	Replication	Genotype	Error
d.f.	2	5	12
Length of cooked rice (mm)	-	11.231**	0.089
Breadth of cooked rice (mm)	-	0.198**	0.038
L/B ratio cooked rice	-	1.614**	0.045
Cooking time (minutes)	-	5.231**	1.134
Kernel Elongation Index	-	0.023*	0.008
Water absorb ratio (%)	-	2819.215**	312.98
Volume Expansion (%)	-	0.054**	0.007
ASV	-	0.174**	0.02

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

4.3.2 Mean performance of quality characters

The results on mean performance of various quality characters before cooking of the lines and check variety have been presented character wise in Table 14. The discussion is as follows:

4.3.2.1 Grain length, breadth and ratio of cooked rice

Kernel length, breadth and their ratio of cooked rice for different advanced lines varied significantly (Table 14). The longest kernel length of cooked rice (11.50 mm) was recorded from Richer and the shortest (8.71 mm) from BRRI dhan-57. During cooking rice grains absorb water and increase in volume through increase in length or breadth alone length and breadth both. Breadth wise splitting is not desirable whereas length wise splitting (grain elongation) on cooking without increase in girth is considered trait in high quality premium rices such as basmati, which elongate almost 100 per cent on cooking (Khush *et al.*, 1979; Sidhu, 1989). Some rices show extreme elongation on cooking particularly in presoaked grains while most in most varieties the expansion is relatively more breadth wise (Azeez and Shafi. 1986; Juliano, 1972 and Sadhukhan and Chattopadhay, 2001). In the present study, entire lines show higher kernel length than the check. Shoba Rani (2003) reported kernel length after cooking of nine released hybrids of India ranging from 10.2 to 12.4 mm. Soroush *et al.*, (1995) showed cooked kernel length 10.62 to 12.32 mm.

The longest kernel breadth of cooked rice (3.28 mm) was recorded from BRRI dhan-49 and the shortest (2.68 mm) from BRRI dhan-57. The highest ratio of kernel length and breadth (3.54) was recorded from Richer and the lowest ratio (3.05) from Al-36. Sandeep (2003) found kernel length/ breadth ratio after cooking of 20 new plant type genotypes which was ranged from 2.04 to 3.95. Soroush *et al.*, (1995) showed L/B ratio of cooked kernel 3.69 to 4.30. Relative performance of grain length of milled rice and cooked rice is presented in Figure 7.

Table 14: Mean performance of quality characteristics after cooking in different lines and check

Treatments	Length of cooked rice (mm)	Breadth of cooked rice (mm)	L/B ratio cooked rice	Cooking time (minute)	Kernel Elongation ratio	Kernel Elongation Index	Water Absorb ratio (%)	Volume Expansion (%)	ASV
AL-36	9.51c	3.11a	3.05c	18a	1.55c	1.01b	358a	358.3a	2.17b
AL-29	10.59b	3.25a	3.26bc	16ab	1.70ab	1.02b	270b	271.4b	3.00b
Richer	11.50a	3.25a	3.54a	15b	1.70abc	1.08b	212d	212.5d	4.17ab
AL-52	11.43a	3.26a	3.44ab	14b	1.65bc	0.80c	166e	166.6e	5.83a
BRRI dhan-49	10.21b	3.28a	3.11c	16ab	1.80a	1.08b	257c	271.4b	3.33b
BRRI dhan-57	8.71d	2.68b	3.25c	16ab	1.68abc	1.31a	166e	166.6e	3.50b
P	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

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

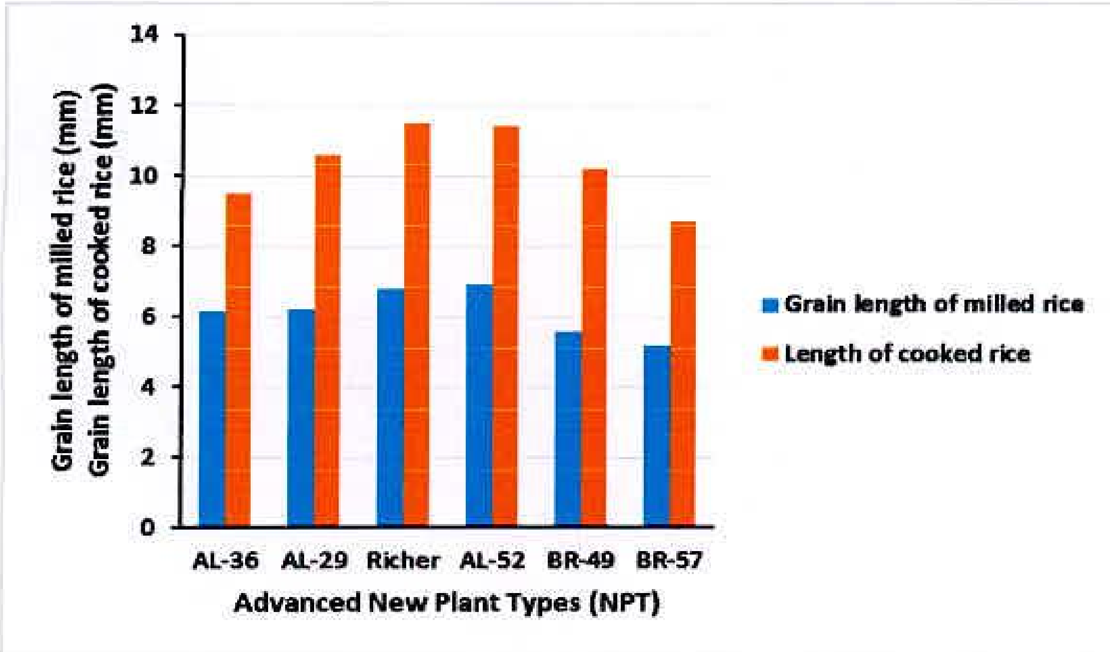


Figure 7: Relative performance of advanced lines of new plant type rice and check for grain length of milled and cooked rice

4.3.2.2 Cooking time

Cooking time is important as it determines the tenderness as well as stickiness of cooked rice to great extent. Milled rice that has a high protein content or a high GT required much water and a longer time to cook than rice with lower values (Juliano *et al.,* 1965). Cooking time of rice grain depends on coarseness of the grain and it's GT. The color and gloss of the grain was also intensively correlated to the exposure of microwave heating Cooking time for different advanced line of rice varied significantly (Table 14). The highest cooking time (18 minutes) was recorded from Al-36 and the lowest (14 minutes) recorded AL-52. The linear kernel elongation after cooking is compared with the original length of kernel before cooking (Irshad. 2001).

4.3.2.3 Kernel elongation ratio

Kernel elongation ratio for different advanced lines of rice varied significantly (Table 14). The highest kernel elongation ratio (1.80) was recorded from BRRI dhan-49 and the lowest ratio (1.55) recorded from AL-36. Elongation ratio (L_1 /L_0) is a measure of kernel elongation upon cooking resulting from swelling *of* starch granules by uptake of water (Juliano, 1979). Pilaiyar (1988) proposed elongation ratio to be best index of quality compared to elongation index and proportionate change. Significant association of L/B ratio with kernel elongation was reported by Deosarker and Nerker (1994). Chauhan *et al.,* (1995) pointed out significant positive correlation between elongation and cooked kernel length. Kernel elongation was primarily influenced by kernel shape and size. A comparative view of milled and cooked rice of new plant types and check is presented in Plate 3.

Therefore, elongation ratio (L_1/L_o) which indicates length wise elongation will be a better measure of cooking quality than elongation index which indicates both length and breadth wise elongation. Similar conclusion was also done by Singh (1989). Urban people prefer varieties that expand more in length than breadth Podhi and Singh (1991). Relative performance of L/B ratio of rough rice, brown rice and milled rice is presented in Figure 8.

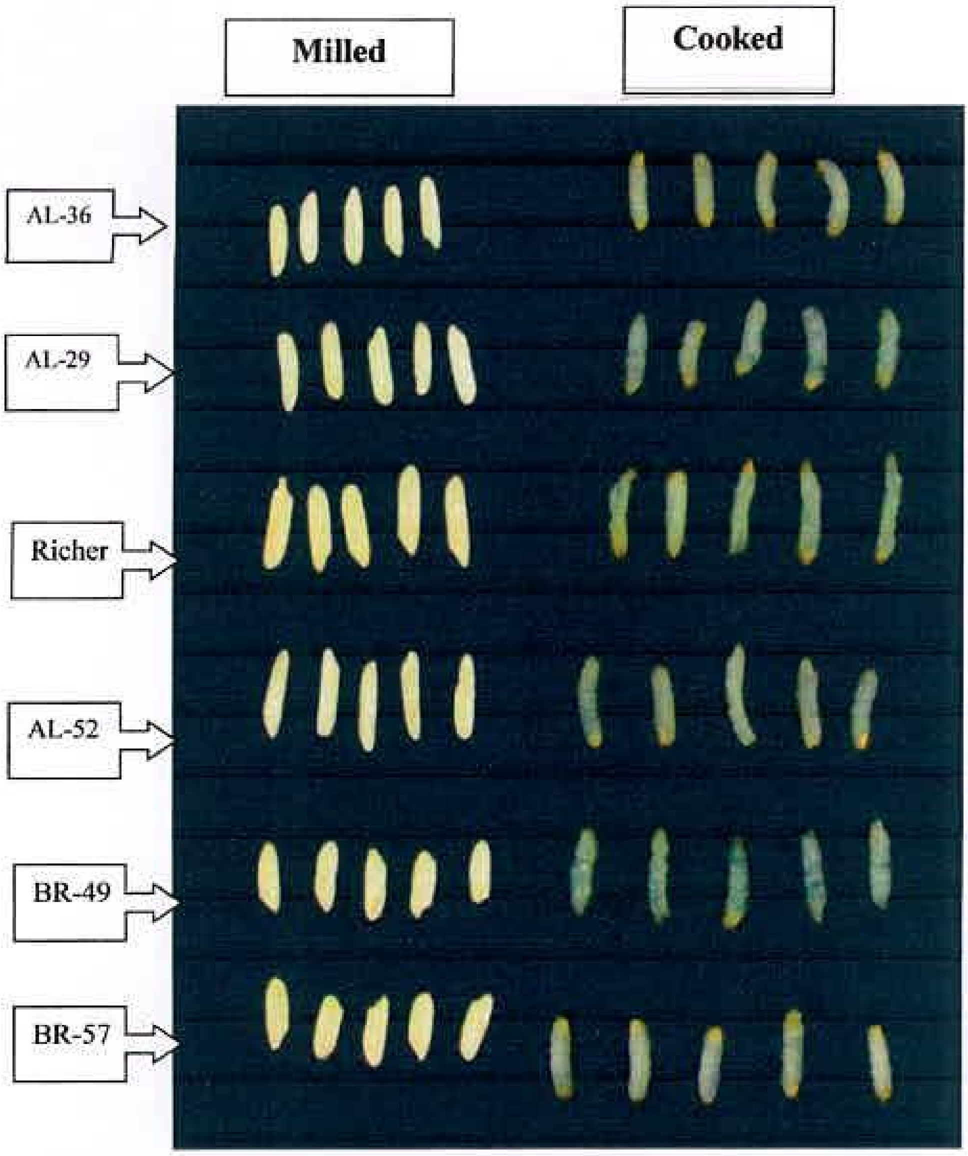


Plate 3: A comparative view of milled and cooked rice of new plant types and check

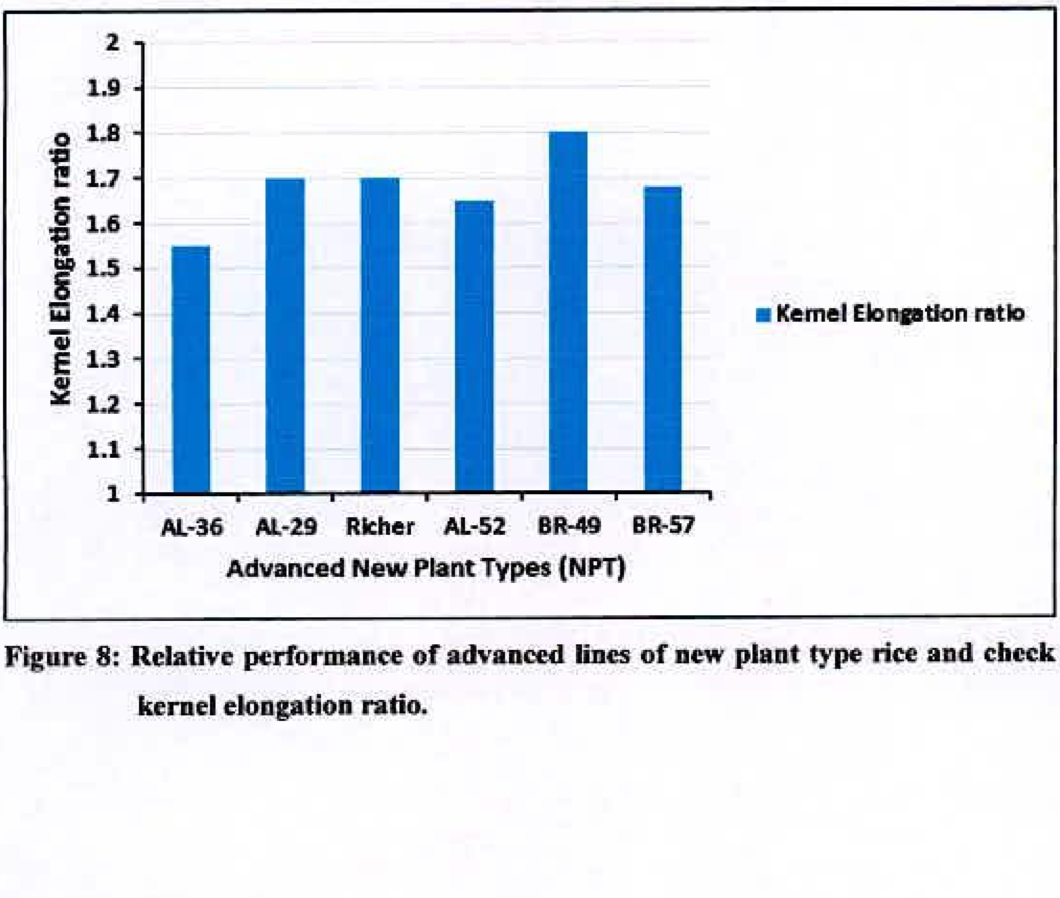


Figure 8: Relative performance of advanced lines of new plant type rice and check for kernel elongation ratio.

4.3.2.4 Kernel elongation index

Kernel elongation index for different advanced lines of rice varied significantly (Table 14). The highest kernel elongation index (1.80) was recorded from AL-52 and the lowest ratio (1.01) recorded from AL-36. Elongation index is a measure of kernel elongation upon cooking resulting from swelling *of* starch granules by uptake of water (Juliano, 1979).

4.3.2.5 Water absorption (%)

Water absorption for different advanced lines of rice varied significantly (Table 14). The highest water absorption (358 %) was recorded from AL-36 and the lowest (166 %) recorded AL-52. Water uptake is considered an important economic attribute of rice as it gives indirect measure of volume increase on cooking. Water uptake shows a positive and significant influence on grain elongation, while volume expansion did not influence grain elongation as reported by Sood and Siddiq (1986). Earlier studies of rice in general suggested the extent of variation for this character to range between 194 to 250% (Juliano *et al.,* 1965; Juliano *et al., (1969).* Hogan and Planck (1958) observed that shot and medium grain varieties of the USA have high water absorption as compared to long grain types. Working with a larger number of scented basmati varieties. Sood and Siddiq (1986) have reported still wider range (74-439%) of variation for this character. Latha *et al.,* (2004) reported that the good cooking rice varieties have water absorption value ranging between 174% *and* 275%, whereas majority of those showing pasty appearance have value as high as from 300 to 570%. He concluded that high water absorption is relatively less desirable characteristics and it would be desirable to select a variety or hybrid with moderate water absorption.

4.3.2.6 Volume expansion (%)

Volume expansion for different new plant types rice varied significantly (Table14). The maximum volume expansion (358.3 %) was recorded from Al-36 and the minimum (166.6 %) recorded from BRRI dhan-57. Volume expansion of kernels on cooking is considered another important measure of consumer preference. Volume expansion by and large is determined by water uptake, however, subject to the influence of kernel texture (Zaman, 1981). He also reported that the varieties which tend to show high volume expansion are sticky and give a pasty appearance on cooking. Invariably all the pasty cooking types have been found to be associated with higher water absorption. He concluded that pasty cooking closely related to high water absorption. Therefore, hybrids with low water absorption and high volume expansion are more desirable.

4.3.2.7 Alkali spreading value (ASV)

The gelatinization temperature (GT) is considered to be yet another major index of cooking quality of rice. The time required for cooking is determined by the gelatinization temperature. Alkali spreading value is inversely related to gelatinization temperature (Table 15). It is the range of temperature within which granules begin to swell irreversibly in hot water. The GT of rice varieties ranging from 55'C to 79°C are grouped into low (55- 69°C), intermediate (70-74°C) and high (74-79°C) (Juliano *et.al.*, 1965; Kongseree and Juliano. 1972; Juliano, 1979). High GT rice becomes excessively soft when overcooked, elongate less and requires mire water and time for cooking as compare to those with low or intermediate GT. Rice varieties that have low GT start to swell at low temperature during cooking than rice varieties that have intermediate or high GT (Nagato, and Kishi, (1966). Rice varieties having intermediate GT produces good quality cooked rice. In the present study, statistically significant variation was recorded for alkaline spreading value for different advanced line of rice (Table 15). The highest alkaline spreading value (5.83) was recorded AL-52 and the lowest (2.17) was recorded from AL-36.A comparative view of alkali spreading value of NPT advanced lines and check is presented in Plate 4.

As the alkali spreading value of Richer and AL-52 are 4.17 and 5.83 respectively, alkali digestion and gelatinization temperature of these variety is intermediate. On the other hand alkali spreading value of AL-36, AL-29, BRRI dhan-49 and BRRI dhan-57 are 2.17, 3, 3.33 and 3.5 respectively that's why alkali digestion of these variety will be low but gelatinization temperature will be high. Relative performance of NPT advanced lines and check for ASV and cooking time is presented in Figure 9.

Table 15: Classification of new plant types rice advance lines and check varieties on the basis of alkali spreading score, alkali spreading value and GT types

Sl. No.	Lines/check	Alkali spreading value	Alkali digestion	GT types
1	AL-36	2.17	Low	High
2	AL-29	3.00	Low	High
3	Richer	4.17	Intermediate	Intermediate
4	AL-52	5.83	Intermediate	Intermediate
5	BRRI dhan-49	3.33	Low	High
6	BRRI dhan-57	3.50	Low	High

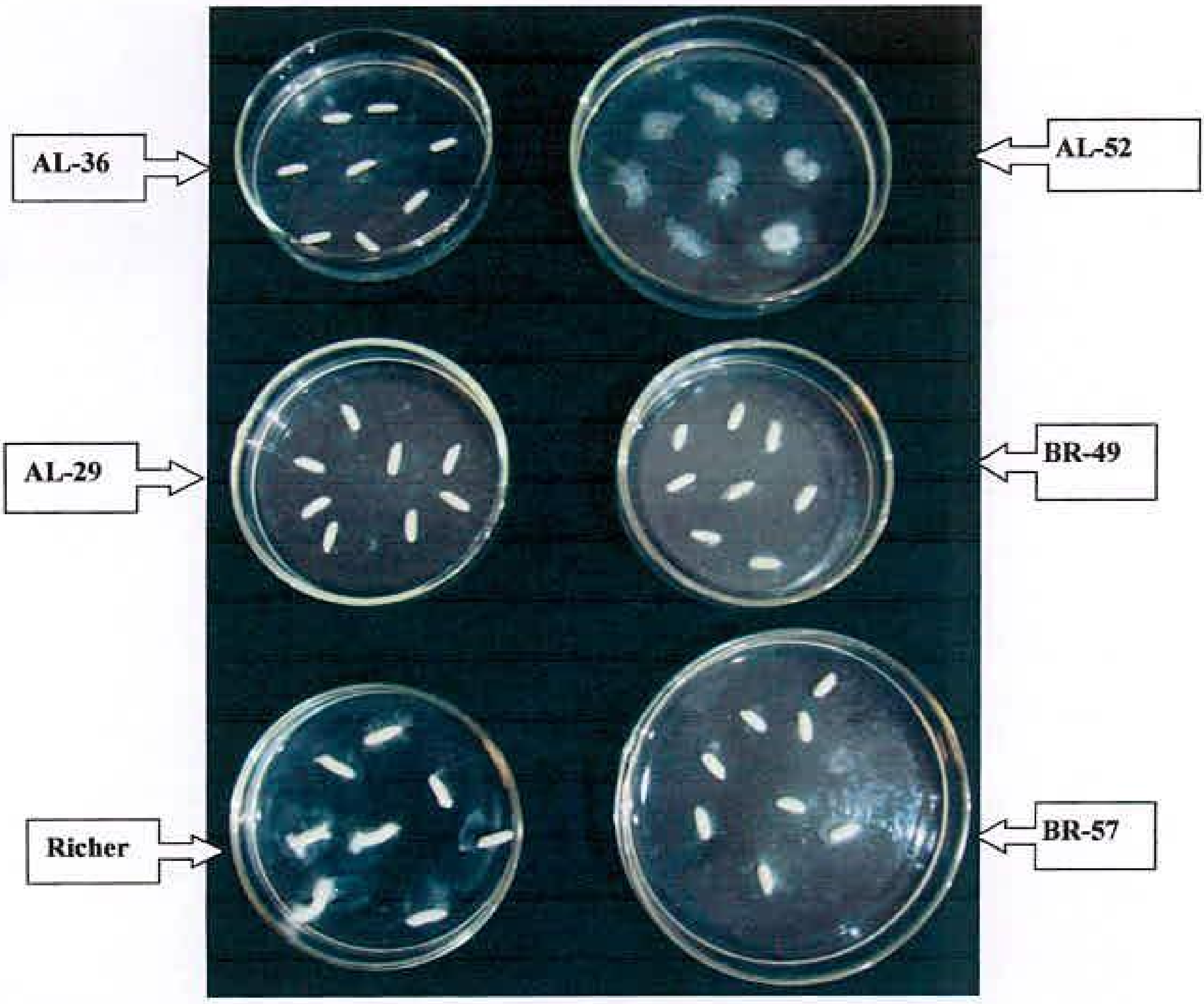


Plate 4: Showing Alkali spreading value (GT) of new plant types and check variety

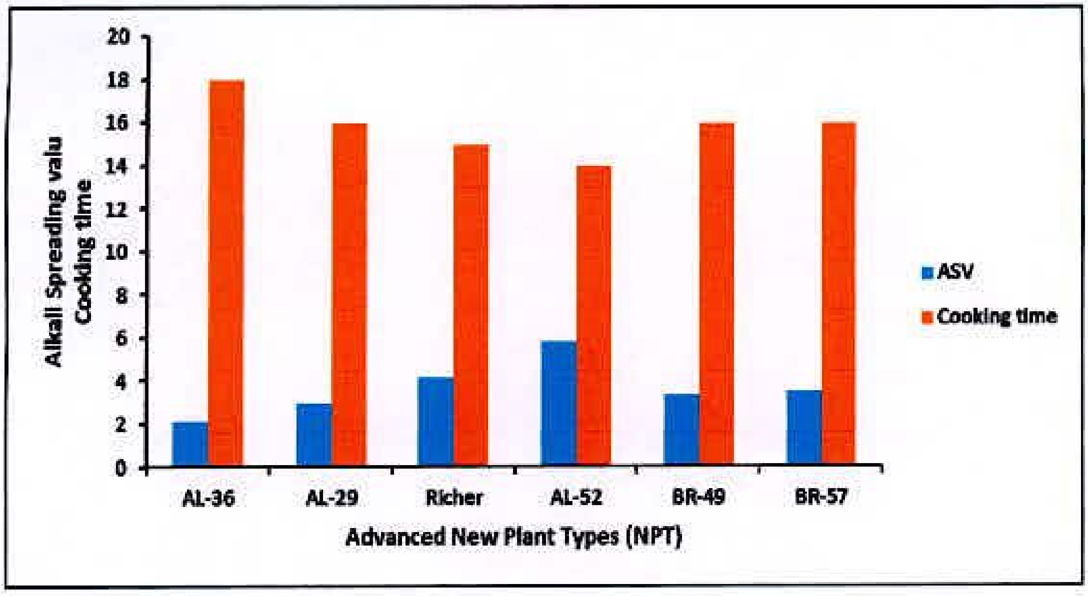


Figure 9: Relative performance of advanced lines of new plant type rice and check for ASV and cooking time.

4.3.3 Correlation analysis

Quality in rice is a complex trait. For improvement of complex traits of this kind a precise knowledge on nature and strength of relationship between different component indices is important. Such information would help not only to understand the genetic basis of such relationship but also to enable breeders to adopt appropriate breeding and selection strategies. On the point of view, an attempt has been made in the course of the present investigation to study the nature and extent of association between various character pairs relating to quality (milling recovery, grain dimension and cooking) attributes through a simple correlation analysis (Table 16).

Correlation study reveals that in lines grain breadth of milled rice has positive relationship with hulling percent, milling outturn, HRR%, grain breadth of rough rice, grain length of brown rice and negative correlationship with grain length of rough rice, grain L/B ratio of rough rice, grain breadth of rough rice and grain L/b ratio of brown rice. Hulling percent has significant positive relationship with milling percent and HRR percent and significant negative relationship with grain length of milled rice but no significant relationship is observed with other characters. Viraktamath (1987) found the similar correlation among the traits. Highly significant positive correlation of grain breadth of rough rice is found with grain length breadth ratio of milled rice, and significant positive relationship with grain breadth of rough rice, , breadth and L/B ratio of brown rice, and significant negative relationship with other characters. Yadav and Singh (1989) found that hulling and milling percentage was independent of grain shap where as HRR was negatively associated of length/breadth ratio of rough rice.

Grain length of brown rice exhibited highly significant positive relationship with grain breadth of brown rice and no significant relationship with grain length and L/B ratio of brown rice, grain length and L/B ratio of milled rice, grain length and L/B ratio of cooked rice. Grain breadth of milled rice has significant positive relationship with kernel breadth of cooked rice, kernel elongation index and water absorb ratio but it

Table 16. Genotypic and phenotypic correlation of various quality characters

		H (%)	MO (%)	HRR (%)	GLRR (mm)	GBRR mm)	Grain L/B RR	GLBR (mm)	GBBR (mm)	Grain L/B BR	GLMR (mm)	BCR (mm)	L/B CR	CT (min.)	KE ratio	KE Index	WAR (%)	VE (%)	ASV
GBMR (mm)	r_g	0.01	0.22	0.17	-0.16	0.02	-0.16	0.23	-0.35	-0.35	-0.4	0.24	-0.27	-0.02	-0.9**	0.01	0.29	-0.30	0.29
	r_p	0.24	0.01	-0.08	-0.19	-0.20	-0.19	-0.19	0.15	0.15	-0.41	0.29	0.48*	-0.26	-0.15	-0.02	-0.24	-0.4	-0.24
H (%)	r_g		0.13	0.08	0.12	-0.23	0.01	-0.09	-0.26	-0.26	-0.02	-0.24	0.25	-0.9**	0.24	-0.26	0.02	-0.41	0.02
	r_p		-0.35	-0.26	-0.07	-0.27	0.24	0.19	0.02	-0.9	0.01	0.02	0.12	-0.11	0.13	-0.9**	-0.20	-0.24	-0.20
M O (%)	r_g			0.46*	0.30	0.48	0.29	0.08	-0.20	-0.11	-0.01	-0.20	-0.4	0.12	0.21	-0.21	-0.23	0.02	-0.23
	r_p			-0.09	-0.29	0.25	-0.24	0.20	-0.23	0.22	0.46	0.01	-0.29	-0.4	-0.43	0.01	-0.27	-0.20	-0.27
HRR (%)	r_g				0.02	0.12	0.02	0.09	-0.27	0.13	0.03	0.88**	-0.30	-0.11	0.25	0.13	0.48	-0.23	0.48*
	r_p				0.02	-0.4	-0.20	-0.27	0.48*	0.21	-0.20	0.01	-0.4	0.12	0.12	-0.35	0.25	-0.27	0.25
GLRR (mm)	r_g					-0.29	0.01	0.48*	0.25	-0.43	-0.23	0.13	-0.41	-0.4	-0.4	0.15	0.12	0.48*	0.12
	r_p					-0.30	0.88**	0.25	0.12	0.25	-0.27	-0.35	-0.02	-0.4	-0.29	-0.26	-0.4	0.25	-0.4
GBRR (mm)	r_g						0.01	0.12	-0.4	0.12	0.48*	0.15	0.01	-0.29	-0.30	-0.9**	0.13	0.12	0.29
	r_p						0.13	-0.4	-0.29	-0.4	0.25	-0.26	-0.01	-0.30	-0.4	-0.31	0.01	-0.4	-0.24
Grain L/B RR	r_g							-0.29	-0.30	-0.29	0.12	-0.9**	0.46	-0.4	-0.41	0.32	0.13	-0.30	0.02
	r_p							-0.30	0.09	-0.30	-0.4	-0.11	-0.35	-0.41	-0.02	-0.2	-0.35	-0.4	-0.20
GLBR (mm)	r_g								0.83**	-0.4	-0.29	0.12	0.15	-0.02	-0.26	-0.4	0.15	-0.30	-0.23
	r_p								-0.34	-0.41	-0.30	-0.4	-0.26	0.01	-0.9**	-0.29	-0.26	-0.4	-0.27
GBBR(mm)	r_g									-0.02	-0.11	-0.4	-0.9**	-0.02	-0.19	-0.30	-0.8**	-0.41	0.48*
	r_p									0.01	0.22	-0.29	-0.11	-0.26	0.16	-0.4	-0.11	-0.24	0.25
Grain L/B BR	r_g										0.13	0.24	-0.27	-0.02	-0.9**	0.01	0.29	0.02	0.12
	r_p										0.21	0.29	0.48*	-0.26	-0.15	-0.02	-0.24	-0.20	-0.4
GLMR (mm)	r_g											0.12	0.25	-0.9**	0.24	-0.26	0.02	-0.23	0.01
	r_p											0.17	0.12	-0.11	0.13	-0.9**	-0.20	-0.27	-0.02
BCR (mm)	r_g												0.16	0.12	0.21	-0.21	-0.23	0.48*	-0.26
	r_p												0.20	-0.4	-0.43	0.01	-0.27	0.25	-0.9**
L/B CR	r_g													0.01	0.25	0.13	0.48	0.12	-0.11
	r_p													-0.02	0.12	-0.35	0.25	-0.4	0.22
CT (minutes)	r_g														0.48	0.15	0.12	-0.30	-0.24
	r_p														0.25	-0.26	-0.4	-0.4	0.13
KE ratio	r_g															-0.13	0.13	0.02	0.29
	r_p															0.12	0.01	-0.20	-0.24
KE Index	r_g																-0.24	-0.30	0.02
	r_p																0.02	-0.4	-0.20
WAR (%)	r_g																	-0.41	-0.23
	r_p																	-0.24	-0.27
VE (%)	r_g																		0.48*
	r_p																		0.25

GBMR=Grain breadth of milled rice, H=Hulling(%), MO=Milling outurrn(%), HRR=Head rice recovery(%), GLRR=Grain length of rough rice, GBRR=Grain breadth of rough rice, Grain L/B BR=Grain length/breadth ratio of brown rice, GLBR=Grain length of brown rice, GBBR=Grain breadth of brown rice, Grain L/B BR=Grain length/breadth of brown rice, GLMR=Grain length of milled rice. BCR=Breadth of cooked rice, L/B CR=Length/breadth of cooked rice, CT=Cooking time, KE ratio=Kernel elongation ratio, KE Index=Kernel elongation index, WAR%=Water absorption ratio%, VE%=Volume expansion %, ASV=Alkali spreading value

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

showed highly significant negative relationship with other characters. Breadth of cooked rice has highly negative correlationship with cooking time, kernel elongation index and positive correlationship with L/B ratio of cooked rice, kernel elongation ratio, water absorb ratio and no relationship with breadth of rough rice showed L/B ratio of brown rice, grain length of milled rice. However, it showed significant negative relationship with volume expansion%. Kernel elongation ratio exhibited significant positive relationship with volume expansion and positively correlated with kernel elongation index and water absorbs ratio percentage and no relationship with other characters.

CHAPTER 5

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. For general consumers acceptance, it is essential that the variety or cultivar possess good quality characteristics as well as high yield potential. Therefore, the lines have been critically screened for various quality parameters. The present investigation was conducted with the following objectives

- Evaluation of yield performance of different advanced lines of NPT.
- To study the milling quality and grain appearance of these lines.
- To determine the cooking and eating quality of these NPT lines.

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 June 2011 to December 2012. The advanced line of AL36, AL29, Richer, AL-52, BRRI dhan 49 and BRRI dhan 57 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 as under

- Analysis of variance revealed highly significant variation present among the advanced 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 via exploitation of heterosis.
- All the lines were superior to best yielding check in mean performance with respect to number of effective tillers per plant, panicle length and 1000-grain weight.
- In case of yield AL-29 has the best performance in comparison with all lines.
- The check BRRI dhan 49 exhibited better performance in respect to filled spikelets per panicle, number of total spikelets per panicle.

- Correlation coefficient analysis showed significant positive correlation between-
  - ✓ Plant height and panicle length
  - ✓ No of productive tillers per plant with yield
  - ✓ No of filled grains per panicle with yield
  - ✓ Panicle length with yield

- Correlation coefficient analysis showed significant negative correlation between-
  - ✓ Number of unproductive tillers per plant with yield
  - ✓ Plant height with number of unfilled grains per panicle

- AL-36 and Richer showed higher hulling percent, milling percent and Richer showed higher head rice recovery percent than the checks.
- All lines had long slender grains.
- Superior cooking performance over BRRI dhan 49 and BRRI dhan 57 was observed in-
  - ✓ AL-29, Richer and AL-52 for length of cooked rice
  - ✓ AL-29, Richer and AL-52 for L/B ratio of cooked rice
  - ✓ Richer and AL-52 for cooking time
  - ✓ Richer for kernel elongation index
  - ✓ AL-36 for volume expansion
- AL-36, AL-29, BRRI dhan-49 and BRRI dhan-57 lines showed high GT types where Richer and AL-52 lines showed intermediate GT types which are preferred by consumers.
- AL-36 showed maximum volume expansion.
- All lines were identified having acceptable grain quality with translucent endosperm appearance and overall performance in relation to cooking and eating point of view than the checks.
- Correlation coefficient analysis showed significant positive correlation between-
  - ✓ Hulling and milling percent
  - ✓ HRR percent and grain breadth of milled rice
  - ✓ grain breadth of milled rice and L/B ratio of cooked rice

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 grain quality may further be investigated in multiplications trial for regional adaptability.
2. The lines should be further evaluated to determine vitamins and protein content etc.
3. Keeping in view the market acceptability of the lines should be further improved for high yield with high quality through breeding.

Though the yield and quality of the tested advanced lines is higher and superior in respect of the checks. Therefore, it is essential to develop variety possessing more stable yield performance, improve grain quality with higher yield potential.

CHAPTER 6

REFERENCES

Adair, C.R., Bolich, C.N., Bowman, DH., Jodon, N.E. Johnston, T. H., Webb, B.D. and Atkins, J. G. (1973). Rice breeding and testing methods in U.S. **In**: Rice in the United States: Varieties and Production. U.S. dept. Agric. Hand book-289 (revised). pp.22-75.

Adair, CR., Brachell, H.M., Jodon, N.E., Johnston, T. H., Thysell, J.R., Green, V.E., Webb, B.D. and Atkins, J. G. (1966). Rice breeding and testing methods in U.S. **In**: U.S. Department of Agric. Rice in the U.S,: varieties and Production, USDA *Agri. Res. Seri*. Handbook, 289, pp 19-64.

Ahmed, T., Sarma, K.C,, Pathak, A.K., Boarah, H., Sharma, K., Hussain, S. and Ali. S. (1998). Jaymati. a high-yielding summer rice variety with good grain quality for Assam. International Rice Research Notes. **23** (2):20.

Ahuja,S.C., Panwar, D.V.S., Uma, Ahuja and gupta, K.R. (1995). Basmaii rice-The Scented Pearl. pp.63. CCS Haryna Agricultural University, Hisar, India.

Ali, A., Karim, M.A.. Ali. L., Majid. A., Hassan, G., Ali, L. and Ali, S.S. (1933b). Grain quality of rice harvested at different maturities. *IRRN.* **18**(2): 35.

Ali. A., Karim, M.A.. Ali, L., Ali, S.S., Jamil, M. and Majid, A. (1933a). Delay in threshing and mode of bearing effects on milling recovery. *IRRN.* **18**(2): 35.

Azeez, M.A. and Shall, M. (1986). Quality in rice, Dept. Agr, West Pakistan. Technical Bulletin No 13:50.

Badan, A.C., Guimara, E.P. and Ramis, C. (2005). Genetic gain for resistance to blast in a rice population. **In**: Guimara E.P. (Ed.) Population improvement, a way of exploiting rice genetic resources in Latin America. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 299–329.

Barber, S. and de Barber, C. B. (1980). Rice bran: Chemistry and Technology. pp.790- 862. **In**: Rice production and utilization. B.S. Luh, edn, Avi Pubi, Co. Inc., West Port.

Basak. A.K. and Ganguli, P.K. (1996). Variability and correlation studies on yield and yield components in induced plant type mutants on rice. *Indian Agriculturist,* **40**(3): 171-181.

Begum, F., Dipti. S. S., Karim, N.H. and Kahir, K.A. (2001). Physicochemical characteristics of some Iranian and Bangladeshi rice varieties. *Bangladesh J. Science.***7**: 11-16.

Bhattacharya K.R. and C.M. Sowbhagya. (1971). Water uptake by rice during cooking. *Cereal Sci. Todav..* **16**: 420-424.

Bhattacharya, K.R. (1980). Breakage of rice during milling: a review, *Tropical* Science. **22**:255-278.

Biswas, J.K., Hossain. M.A., Sarker. B.C., Hassan. M. and Hague, M.Z. (1998). Yield performance of several rice varieties seeded directly as late a man crops. *Bangladesh Life .Sci., **10**:47-52.*

Biswas, S.K., Banu, B., Kabir, K.A.,, Begum, F. and Choudhury, N.H. (1992). Physicochemical properties of modern and local rice varieties of Bangladesh. *Bang. Rice J.* **3** (1&2): 181-188.

Biswas, S.K., Siddique, M.A., Kabir, K.A., Banu. B. and Choudhury, N.H. (2001). Grain quality of some Binni rice varieties of Bangladesh. *Bangladesh J. life Sc.,* **13**(1&2): 181-188.

BRRI. (2004). Adhunik Dhaner Chash (Bengla), Pub. No. 5. Bangladesh Rice Res. Inst. Gazipur. pp12-35.

Castro, E. Da. M., Morais, O.P., Santana, E.P., Breseghello, F. and Neto, F.P. M. (2000). Mejoramiento poblacional de arroz de tierras altas en Brasil. **In**: Guimara, E.P. (Ed.) Avances en el mejoramiento poblacional en arroz. Embrapa Arroz e Feijao, Santo Antonio de Goias, Brasil, pp. 221–240.

Chauhan, J. S., Chauhan, V.S. and Lodh, S.B. (1995). Cooking quality components and their interrelationships with some physico-chemical characters of rainfed and upland rice grain. *Oryza.* **32**(2): 79-82.

Chauhan, S.P., Singh, R.S. Maurya, D.M. and Vaish, CP. (1986). Character association in upland rice cultivars of India. *Intl. Rice Res. News!.* **11***(4):8.*

Chauhan, V. S., Chauhan, V. S.. Lodh, S.B. and Dash. A. B. (1992). Environmental influence on genetic parameters of quality components in rainfed upland rice *(Oryza sativa* L.) *Indian J., Agric, Sci.* **62**(11):773-775.

Chauhan. J.S. (2000). Variability for high density grain index and hull weight ratio and their interrelationships with other grain traits in rice *(Oryza sativa* L.). *Indian JPl. Physiol.* **5**(1): 7-12.

Choi, H. C., Chi, J. H. and Cho, S. Y. (1999). Varietal difference in water absorption characteristics of milled rice and its relation to the other grain quality components *Korean J. Crop Sci.* **44**(3): 288-295.

Choudhury N., Kabir K A., Biswas S K. and Islam R (1991). Influence of rice grain properties on market price in Bangladesh. Pages 117-133 *in* Consumer demand for rice grain quality. International Rice Research Institute, P.O. Box 933, Manila, Philippines.

Choudhury, P,K.D. and Das. P.K. (1997). Genetic variability, correlation and path coefficient analysis in deep water rice. *Indian .1, 4gric. .Si.* **10**(I): 155-157.

Chun, H.S. and Jun. Z. (2001). Analysis of seed and maternal genetic effects on milling quality characters in Indica hybrid rice. Agronomy Department, Zhejiang Agric. University., Hangzhou, China,

Del Rosario. A.R., Briones, V.P., Vidal, A.J. and Juliano, B.O. (1968). Composition and endosperm structure of developing and mature rice kernels. *Cereal Chem*, **35**:111-126.

Dela Cruz N. Khush, G.S. (2000). Rice grain quality evaluation procedures. Pages 15-28 **In**: Aromatic rices. Ed. Singh RK, Singh US. Khush GS. Oxford and IBH publishing Co. Pvt. Ltd. Nev Delhi.

Deosarker. B.D. and Nerkar, Y.S. (1994). Correlation and path analysis for grain quality charaters in indica rice. *J. Maharastra Agric. Univ.* **19**(2): 175-177,

Dilday, R.H. (1990). Contribution of ancestral lines in the development of new cultivars of rice. *Crop Sci.* **32**:1054–1058.

Dingkuhn, M., Penning De Vries, F.W.T., De Datta, S.K. and van Laar, H.H. (1991). Concepts for a new plant type for direct seeded flooded tropical rice. **In**: Direct seeded flooded rice in the tropics. International Rice Research Institute, Manila, Philippines, pp. 17–38.

Gallagher J.N. Biscoe P.V. (1978). Radiation absorption, growth and yield of cereals. *Journal of Agricuhural Science* **91**. 47-60.

Ge. X.J., Xing, Y.Z., Xu, C.G. and He. Y.Q. (2005). QT1 analysis of cooked rice grain elongation, volume expansion, and water absorption using a recombinant inbred population. Molecular Biology Division.15:34.

Ghose. R.L.M. and Ghatge, M.B. (1960). Rice in India. Indian Council of Agricultural Research, New Delhi.

Ghosh, P.K. and Hossain, M. (1988). Genetics evaluation and regression analysis of yield and yield attributes in rice. *Oryza. 25:* 485-509.

Gomathinayagam, P., Pappiah, C.M. and Sundrapandian. G. (1988). Path coefficient analysis in upland varieties of rice. *Madras Agric. J. 75(* 11-12). 449-450,

Gravois, K.A. and Helms, R.S. (1992). Path analysis of rice yield and yield components as affected by seeding rate. *Agron. J.* **84**: 1-4.

Guimara, E.P. (2002). Genetic diversity of rice production in Brazil. **In**: Nguyen, V.N. (Ed.) Genetic diversity in rice production, Case studies from Brazil, India and Nigeria. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 11=35.

Guohui, M. and Longping, Y. (2003). Hybrid rice achievements and development in China. In: Virmani, S.S., Mao, C.X. and Hardy, B. (Eds.). Hybrid rice for food security, poverty alleviation, and environmental protection. International Rice Research Institute, Manila, Philippines, pp. 247–256.

Hoan, N.T. and Nghia, N.H. (2001). Hybrid rice development and use in Vietnam. **In**: Virmani, S. S., Mao, C.X. and Hardy, B. (Eds.). Hybrid rice for food security, poverty alleviation, and environmental protection. International Rice Research Institute, Manila, Philippines, pp. 357–371.

Hogan. J.T. and Planck,R.W. (1958). Hydration characteristics of rice as influenced by variety and drying method. *Cereal Chem.*, **35**:469-482.

Hossain, M.S. (2004). Develpoment and evaluation of three line rice hybrids using *inter* sub-specific *(indica/japonica)* derivatives. Division of Genetics. Indian Agricultural Research Institute, New Delhi.11002.

Huang, N., Parco, A., Mew, T., Magpantay, G., McCouch, S., Guiderdoni, E., Xu, J., Subudhi, P., Angeles, E.R. and Khush, G.S. (1997). RFLP mapping of isozymes, RAPD and QTLs for grain shape, brown planthopper resistance in a doubled haploid rice population. Molecular Breeding. **3**(2), 105–113.

Igheka, J.C., Verma, L.R. and Velupillai. L. (1991). Predicting selected quality attributes in parboiled rice. *App. Eng agric. (USA)*. **7**(4): 407-412.

IRRI (1968). Annual Report. Los Banos, Laguna, Philippines.

Irshad, A. (2001). Factors affecting rice grain quality. DAWN Group of Newspapers.

Ismachin, M. and Sobrizal (2006). A significant contribution of mutation techniques to rice breeding in Indonesia. Plant Mutat. Rep. **1**(1), 18–22.

Itiikharuddaula, K.M.K., Akhter, M.S.. Hasan. K., Fatima and Badshah. (2002). Genetic divergence: Character association arid selection criteria in irrigated rice. *J. Biol. Sci.*, **2**: 243-246.

Jackson, M.T. and Lettington, R.J.L. (2003). Conservation and use of rice germplasm, an evolving paradigm under the International Treaty on Plant Genetic Resources for Food and Agriculture. **In**: Sustainable rice production for food security. Proceedings of the 20th session of the International Rice Commission. Bangkok, Thailand, 23–26 July 2002, pp. 75–88.

Janagle, RD., Ugle. S.D. and Dumbre, A.D. (1987). A study of cause and effect relationship among quantitative traits in upland paddy. *J. Maharastra Agric. Univ.*, **12**(1)31-34.

Jennings. P.R., Coffman, W.R. and Kauffman, H.E. (Eds). (1979). Rice Improvement. IRRI, Manila, Philippines. p.186.

Jiang. *Z.X.*, Huang, Z.Q., Li, Y.S., Lou, Z.X. and Shi, F.Z. (2000). Relationship between quantitative and qualitative traits of population in hybrid rice. *Chinese J. Rice* **14**(3): 179-182.

Jodari, F. and Linscombe. S.D. (1996). Grain fissuring and milling yield of rice cultivars as influenced by environmental conditions. *Crop Sci.* **36**: 1496-1502.

Julfiquar, A.W., Jamil Hasan, M., Azad, A.K., Anwar Hossain, M. and Virmani, S.S. (2003). Hybrid rice research and development in Bangladesh. **In**: Virmani, S.S., Mao, C.X. and Hardy, B. (Eds.) Hybrid rice for food security, poverty alleviation, and environmental protection. International Rice Research Institute, Manila, Philippines, pp. 235–245.

Juliano, B.O. (1972). Physico-chemical properties of starch and protein and their relation to grain quality and nutritional value of rice, Rice Breed. Pub. IRRI Banos, Phillippines. pp. 389-405.

Juliano, B.O. (1979). The chemical basis of rice quality. The 'workshop on "Chemical Aspects of Rice Grain Quality". IRRI, Manilla, Philippines. pp.69-90.

Juliano, B.O., Bautista, G.M., Lugay, J.C. and Reyes A.C. (1964). Studies *on* the physiochemical properties of rice. *J. Agr. Food Technol.* **19**: 1006-1011.

Juliano, B.O. Nazareno, M. and Ramose. N.I. (1969). Properties of wax, and isogenic nonwaxy rices differing in starch gelatinization temperature. *J. Agr. Food. Chem.*, **17**:1364-1369

Juliano, N., Colowit, P.M. and Mackill, D.J. (1997). Evaluation of genetic diversity in rice subspecies using microsatellite markers. *Crop Sci.* **42**(2), 601–607.

Juliano. B.O., Onate, LU. and Del Mundo, A.M. (1965). Relation of starch composition, protein content and gelatinimition temperature to cooking and eating qualities of milled rice. *Food Technol.* **19**:1006-1011.

Kalaimani, S. and Kadambavansundaram, M. (1988). Heterosis in rice. *Madras Agric. J.* **74** (8-9): 369-372.

Kaneda, C. (1985). Development of very high-yielding rice varieties. Farming Japan **19**, 25–29.

Karim D. U., Sarkar M.N.A., Siddique M. A., Khaleque Miah and Flasnat, M. L. (2007). Variability and Genetic Parameter Analysis in Aromatic Rice. *Int. J. Sustain. Crop Prod.* (5): 15-18.

Kaul. A.K. (1970). Early generation testing for quality characteristics. **II**. Rice. *Indian J.Genei. Plant Breed.* **30**: 237-243.

Khush, G.S., Coffman, W.R. and Beachell, H.M. (1997). The history of rice breeding: IRRI's contribution. **In**: Rockwood, W.G. (Ed.) Rice research and production in the 21st century: Symposium honouring Robert F. Chandler Jr. International Rice Research Institute, Manila, Philippines, pp. 117–135.

Khush, G.S., Paule, C.M. and De la Cniz, N.M. (1979). Grain quality evaluation and improvement at IRRI. **In**: Proceedings of workshop on chemical aspect of rice grain quality. IRRI. Los Banos, Philippines. pp.22-31.

Khush. G.S. (1999). New plant type of rice for increasing the genetic yield potential. **In**: Rice breeding and Genetics-Research priorities and challenges. Jata, S. Nanda (etd), Oxford & IBH Publishing Co. Pvt. Ltd. New delhi, India, pp. 100-108.

Kim. G.S. Mahadevappa, M. and Rudraradhya, M. (1987). Genetic analysis Of is panicle characteristics in rice. *Korian J. Crop Sci.* **32**(2): 208-214.

Kongseree, N. and Juliano, R.O. (1972). Physic-chemical properties of rice grain and starch from lines differing in amylose content and gelatinization temperature. *J. Gar. Food Chem.* **20**(3): 714-776.

Kumar, R. V., Satyanarayana, P.V. and Rao, M.S. (1996). New cytoplasmic male sterile lines developed in Andhra Pradesh, India. *IRRN*. **21**(2-3) pp. 30.

Kumar. I., Maruyama, K. and Moon, H.P. (1994). Grain quality consideration in hybrid rice. In: hybrid rice technology: new development and future prospects. S.S.Virtnani, (ed.), IRRI. Manilla.Philippines. pp.123-I 30.

Kumar. M. S. (1989). Genetic analysis of hight and cooking quality traits in basmati rice. M. Sc. Thesis. IARI. New Delhi, India.

Laignelet, B. and Marie, R. (1983). Variation of technological quality in rice according to genotype and environment. *Agronomic*. **3** (2): 179-183.

Latha, R., Thiyaqarajan, K. and Senthilvel, S. (2004). Genetics, fertility behaviour and molecular analysis of a new TGMS line, TS6, in rice. *Plant Breed*. **123**(3), 235–240.

Little, R.R., Hilder, C. and Dawson. L. H. (1958). Differential el1ct of dilute alkali on 25 varieties of milled rice. *Cereal Chm*. **35**: 111-126.

Mao, C.X. (2001). Improving seed production to speed up the global commercialization of hybridrice. **In**: Peng, S. and Hardy, B. (Eds.) Rice research for food security and poverty alleviation. International Rice Research Institute, Manila, Philippines, pp. 221–229.

Marassi, M.A., Marassi, J.E., Chatel, M. and Ospina, Y. (2004). Exploiting the genetic resources of rice in Argentina through population improvement. **In**: Guimara˜es, E.P. (Ed.) Population improvement, A way of exploiting rice genetic resources in Latin America. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 113–127.

Merca and Juliano (1981). Yield performance of rice genotypes in international multi-environment trials during 1976–1997. *Curr. Sci.* **83**(5), 610–619.

Miller B.C. Hill J.E. Roberts SR. (1991). Plant population effects On growth and tied in water-seeded rice. *Agron .J*. **83**: 291 *-297*.

Nagato, K. and Kishi. Y. (1966). On the grain texture of rice. Varietal difference of cooking characteristics of milled white rice (in Japanese, English summary). *Proc. Crop Sci. Soc. Jap.* **35**: 245-256.

Padmaja, R.S. (1987). High density grain among primary and secondary tillers of short-and long-duration rices. *Intl. Rice Res.Newl.* **12**(4): 12.

Padmavathi. N., Mahadevappa, M. and Reddy, O.U.R. (1996). Association of various yield components in rice *(Oryza sativa* L.). *Crop Research (Hisar).* **12**(3):353-357.

Pandey, M.P.. Singh, J.P. and Singh, H. (1995). Heterosis breeding for grain yield and other agronomic characters in rice *(Oryza saliva* L.). *Indian J. genet.* **55**(4):438-445.

Peng, S., Cassman, K.G., Virmani, S.S., Sheehy, J. and Khush, G.S. (2005). Yield potential of Tropical rice since the release of IR8 and the challenge of increasing rice yield potential. *Crop Sci.* **39**, 1552–1559.

Peng. S., Laza, Visperas, R.M., Sanico, A.L., Cassman, K.G. and Khush, G.S. (2000). Grain yield of rice cutivars and lines developed in the Philippines, since 1996. *Crop Sci.,* **40**(2): 307-314.

Pilaiyar, P. (1988). Quality characteristics of Tamil Nadu Rices, *.Madras Agric. J.* **75**(9-10) 307-317.

Podhi, A.K., and Singh, M. (1991). Interrelationships of major quantitative traitsin some tall and dwarf varieties of rice. *Environment Ecology.* **9**(1): 15-17.

Ponnuthurai, S., Virrnani, S.S. and Vergara. B.S. (1984). Comperative studies on the growth and grain yield of some F_1 rice *(Oryza sativa L.)* hybrids. *Philipp. J. Crop Sci.* **9**(3): 183-193.

Prasad, B., Patwary, A.K. and Biswas, P.S. (2001). Genetic variability and selection criteria in fine rice *(Oryza saliva* L). *Pak. J. Biol. Sci.* **4**:1188-1190.

Rangel, P.H.N., Cordeiro, A.C.C., Lopes, S.I.G., Morais, O.P. de, Brondani, C., Brondani, R.P.V., Yokoyama, S., Schiocchet, M., Bacha, R. and Ishy, T. (2005). Advances in population improvement of irrigated rice in Brazil. **In**: Guimaras, E.P. (Ed.) Population improvement, A way of exploiting rice genetic resources in Latin America. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 145–186.

Rasheed, M.S.. Sadaqat. HA. and Babar, M. (2002). Correlation and path coefficient analysis for yield and its components in rice *(Oryza sativa L.). Asian Pl. Sci.,* **3**:241-244.

Reddy, Y.S. and Kumar, P,V.R. (1996). Studies on genetic ariability, correlation and path analysis in rice. *New Botantst. 23 (1-4):* 129-133.

Reddy. C.D.R. and Nerker, Y.S. (1995). Heterosis and inbreeding depression in upland in rice crosses. *Indian J. Genet,* **55**(4):389-393.

Reddy. C.D.R. and Ramachandraiah. D. (1990). Genotypic correlation of components of yield in parents and their F_1 in rice (Oryza *sativa L.). Orissa Agric. Res.,* **3**(2): 136-142.

Rui, T., Gong, H., Jiang, L., Huan,S., Ling, Q. and Wang, Y.H. (2005). Mapping quantitative trait loci underlying the cooking and eating quality of rice using a DH population. Molecular Biology Division. **18**:10-20.

Sadhukhan. R.N. and Chattopadhyay, P. (2001). Some agronomic and grain quality characters in aromatic rice genotypes under West Bengal condition. *J. interacademicia* **5**(1):19-24.

Saini, S.S. and Gagneja, M.R. (1975). Interrelationship between yield and some agronomic characters in short statured rice cultivars. *Indian Journal of Genelics and Mani Breeding.* **35:** 441-445.

Sandeep, K. (2003). Characterization and genetic analysis of new plant type traits in rice *(Oryza sativa* L.) Ph. D. Thesis. IARI, New Delhi. India.

Sarkar, R.K. Nanda, B.B., Dash, A.B. and Lodh, S.B. (1994). Grain characteristics and cooking quality of aromatic and non-aromatic long and slender varieties of rice *(Oryza sativa* L.) *Indian J. Sci.* **64**(5): 305-309.

Sharma, N. (2002). Quality characteristics of non-aromatic and aromatic rice (Oryza *sativa* L.) varieties of Punjab. *Indian J. Agric. Sci.* **72:** 445447.

Shobha Rani, N. (2003). Quality considerations in developing rice hybrids, **In**: Winter school on advances in hybrid rice technology. org. DRR, Hyderabad, India.pp.145-159.

Sidhu. G.S. (1989). Quality rice for export purpose. Ann. ACIRIP Workshop held at CCS HAU Hisar, India, April 19-22.

Singh. S. (1989) Panicle mass an index for grain yield in rice. *Crop improve* **15** 113- I 14.

Sood, B.C. (1978). Studies on cooking and nutritive quality of cultivated rice (*Oryzo sativa* L.) with special references to genetics of kernel elongation, aroma and protein content. Ph.D. Thesis. IARI, New Delhi, India.

Sood, B.C. and Siddiq, E.A. (1986). Current status and future outlook for hybrid rice technology in India. **In**: Hybrid Rice Technology Directorate of rice research, Hyderabad, India. pp.1-26.

Soroush, H.R., Eshraghi, A., Mohammad Salehi. M.S., Jauhar Ali, A., Naln.i. M. Allahgholipour, M., Erfani. A.. Tarang. A., Eghlidi, A., Padasht, F., Alinia, I. *and* Khush, (1995). Kadous: an aromatic, high yielding variety with good cooking quality. Rice Research Institute of Iran, P.O. Box 1658, Rasht, Iran. 68.

Tahir, M., Waden, D. and Zada, A. (2002). Genetic Variability' of Different plant Yield Characters in Rice. *Sarhad J. Agric.* **18** (2).

Talwar, S.N., and Goud, J.V. (1974). Pattern of association between yield and yield attributes in rice. *Indian J. Agric. Sci.*, **44** (11): 712-717.

Venkateswarlu, B. Vergara. B.S., Parao, F.T. and Visperas, R.M. (1986). Enhanching grain yield potentials in rice by increasing the number of high density grain. *Philippi J. Crop Sci.*, **11**(3): 145-152.

Vijaykumar. C.H.M., Ahmed, Mi., Virdktamath, B.C. and Ramesha, M.S. (1997). Heterosis early prediction and relationship with reproductive phase. *Int. Rice es. newsl.* **22** (2): 8-9.

Viraktarnath. B.C. (1987). Heterosis and combining ability studies in rice with respect to yield, yield components and some quality characteristics. Ph. D. Thesis. IARI, New Delhi.

Virmani, S.S. (2003). Advances in hybrid rice research and development in the tropics. **In**: Virmani, S.S., Mao, C.X. and Hardy, B. (Eds.) Hybrid rice for food security, poverty alleviation, and environmental protection. International Rice Research Institute, Manila, Philippines, pp. 7–20.

Wang, C., Zou, J., Wang. Z., Li, C. and Li, H. (1991). Identification of wide compatibility and heterosis in rice strain '02428 Xuanl [in Chinese, with English summary.]. *Chin.J. Rice Sci.* **5**(1): 19-24.

Webb, B.D., Bollich, C.N., Carnahan, H.L. Kuenzel, K.A. and Mckensie. K.S. (1985). Utilization characteristics and qualities of United States rice. **In**: Rice grain quality and marketing. Los Baons, Philippines. International Rice Research Institute. 25-35.

Yadav, T.P. and Singh, V,P. (1989). Milling characteristics of aromatic rices. *IRRN*, **14**(6):7-8.

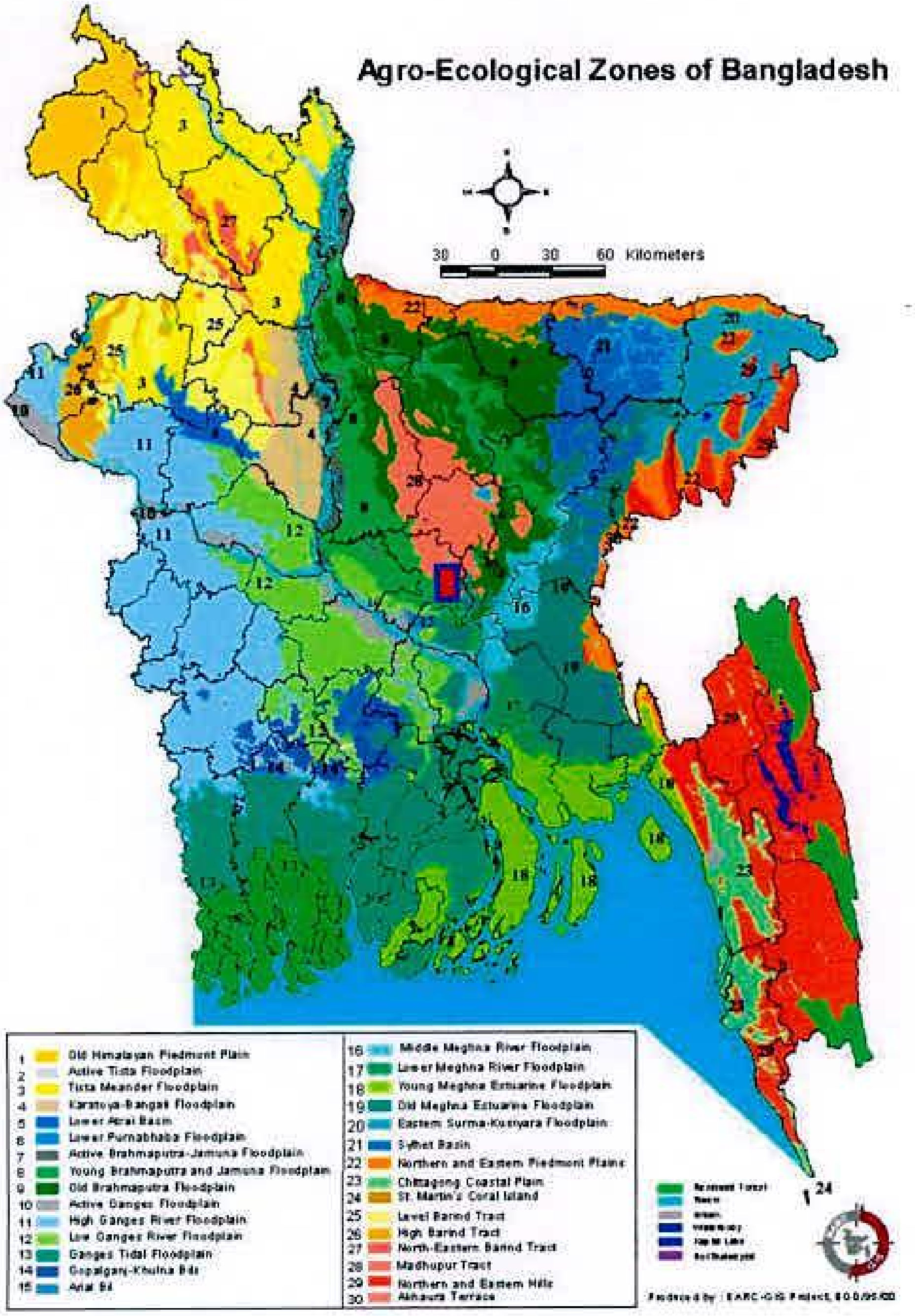
Yang. Z.M., Wang, W.J. Lan, s.Y., Xu, Z.x., Zhou, Z.Q. and Wang, M. (2003). Microscopic structures of endosperm before and alter gelatinization in rice varieties with varied grain quality. *Agric. Sci. Chaina.* **2**(1): 113-118,

Yolanda, J.L. and Das, L.D.V. (1995). Correlation and path analysis in rice (*Oryza sativa L.). Madras. Agric .J.*, **82** : 576-578.

Zaman, F.U. (1981). Genetic studies of some of the cooking and nutritive qualities *of* cultivated rice (*Oryza sativa* L.) Ph.D. Thesis. University of Bihar. BuzalTarpur. India.

CHAPTER 7
APENDICES

Appendix I:
A. Map of Experimental site



B. Monthly record of air temperature, rainfall, relative humidity and sunshine hours during the period from September 2011 to December 2011

Year	Month	Average air temperature (°C)			Total rainfall (mm)	Average humidity (%)
		Maximum	Minimum	Mean		
2011	July	32.19	25.94	29.06	363.60	85.07
	August	32.0	26.6	29.30	361	82
	September	31.2	25.6	28.4	144	69.41
	October	30.1	21.2	25.65	64	58.3
	November	28.5	18.1	23.3	24	49.2
	December	24.5	13.6	19.05	15	38.6

Source: Bangladesh Meteorology Department (climate division), Agargaon, Dhaka

Appendix II:

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental Filed, SAU, Dhaka
AEZ	Modhupur tract (28)
General Soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	N/A

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.