# YIELD AND QUALITY ANALYSIS OF SOME ADVANCED LINES OF BASMATI RICE

BY

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## CERTIFICATE

This is to certify that thesis entitled, **"Yield and Quality Analysis of Some Advanced Lines of Basmati Rice"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS AND PLANT BREEDING,** embodies the result of a piece of bona fide research work carried out by **MAHMUDA RATNA, Registration No. 04-01298** 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, as has been availed of during the course of this investigation has duly been acknowledged.

Hossain

Dated: December, 2009
Place: Dhaka, Bangladesh

**Prof. Dr. Md. Sarowar Hossain**
Supervisor

DEDICATED
TO
MY BELOVED
PARENTS

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## LIST OF ABBREVIATED TERMS

| ABBREVIATION | FULL NAME |
|---|---|
| AEZ | Agro-Ecological Zone |
| *et al.* | and others |
| BBS | Bangladesh Bureau of Statistics |
| cm | Centimeter |
| °C | Degree Celsius |
| DAS | Date After Sowing |
| etc | Etcetera |
| g | Gram |
| ha | Hectare |
| hr | Hour |
| kg | Kilogram |
| m | Meter |
| Mm | Millimeter |
| Mo | Month |
| MP | Muriate of Potash |
| no. | Number |
| % | Percent |
| RCBD | Randomized Complete Block Design |
| $m^2$ | Square meter |
| TSP | Triple Super Phosphate |

# YIELD AND QUALITY ANALYSIS OF SOME ADVANCED LINES OF BASMATI RICE

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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 December 2008 to July 2009. Six advanced lines of Basmati rice S1, S2, S5, 42(i), 42(ii), 44(i) and BRRI dhan29 as check were evaluated. Highly significant variations present among the advanced lines and check for plant height, days to 50% flowering, days to maturity, number of effective tillers/ plant, number of ineffective tillers/plant, number of total tillers/plant, panicle length, number of filled spikelets/panicle, number of unfilled spikelets/panicle, total spikelets/panicle, 1000-grain weight etc. All the tested 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. The advanced line 42 (ii) had highest plant height, panicle length but earliest days to maturity and 42 (i) had highest number of effective tillers. Among the lines 42 (i) gave highest yield (7.56 t/ha) and 42 (ii) gave the lowest yield (4.28 t/ha). However , the check BRRI Dhan 29 exhibited better performance in respect to number of filled spikelets per plant, yield per plant and yield (t/ha). All the lines showed significant positive correlation between plant height and panicle length, number of effective tillers per plant with yield, number of filled spikelets/ panicle with yield. Highly significant variation was observed among the lines for hulling percentage, milling outturn, head rice recovery per cent, grain length, grain breadth, length/breadth ratio of grain, length before cooking, length after cooking, alkali spreading value, water absorption, elongation ratio and cooking time. Most of the lines showed lower hilling percent, milling percent and head rice recovery per cent than the check BRRI Dhan 29. But, the S2 advanced line showed superior performance in respect of hilling percent, milling percent and head rice recovery (HRR) per cent than the check BRRI Dhan 29. All lines had long slender grains. Superior cooking performance over BRRI Dhan 29 was observed in all the lines for length of cooked rice elongation, kernel elongation ratio and one line for volume expansion. All the lines were identified having acceptable grain quality with translucent endosperm appearance but overall performance in relation to cooking and eating point of view S2 advanced line performed better. Correlation coefficient analysis showed significant positive correlation between hulling and milling percent, HRR per cent and kernel breadth of milled rice, kernel breadth of milled rice and L/B ratio of cooked rice.

# Chapter 1

# Introduction

# 1. INTRODUCTION

Rice (*Oryza sativa*) belongs to the family Gramineae, the staple food for at least 63% of planet inhabitants and contributes on an average 20% of apparent caloric intake of the world population and 30% of population in Asia (Calpe and Prakash, 2007). Ninety per cent of this crop is grown and consumed in south and southeast Asia, the highly populated area (Catling, 1992).

Aromatic rice (*Oryza sativa* L.) is known for its characteristics fragrance after being cooked. This constitutes a small but special group of rice, which is considered best in quality. Among the aromatic (fine) rice varieties, Basmati rice are the most preferred in the international market and the trade is exclusively shared between India and Pakistan. The superiority is due to its superfine long grains that have a distinct aroma and excellent elongation, with cooked rice having a soft and flaky texture (Khush *et al*., 2002). The price of Basmati rice is about 2-3 times higher than the coarse rice (Biswas *et al*., 1992). Though, the low yielding aromatic rice have been the major casualty of green revolution Basmati rice holds the unique position for its higher demand in the international market. Typically the delicately curved long grained, highly aromatic rice which elongate and cook soft and fluffy were the ones which were falling within the Basmati category enjoying a preferential treatment both in domestic and international markets generating three times higher price. Basmati is known as the "crown jewel" of South Asian rice. Approximately 1 million hectares in India and 0.75 million hectares in Pakistan are planted with basmati varieties, where it is cultivated by hundreds of thousands of small farmers.

In Bangladesh, rice dominates over all other crops and covers 75% of the total cropped area (Rekabdar, 2004) of which around 27% is occupied by fine rice varieties (BBS, 2003). Consumer demand for the fine rice varieties is high due to its good nutritional quality, palatability and due to special flavor and taste. The demand of basmati rice has been increasing in our country as the country is being more prosperous and approaching self-sufficiency in rice production (BRRI, 2004). The climatic condition of Bangladesh is also suitable to produce quality Basmati rice.

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 spikelets per panicle and percent filled grains per panicle being of secondary and tertiary importance (Jones and Synder, 1987). 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/ lines of rice with increased yield potential.

Besides 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. Juliano and Duff (1991) 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, tenderness and flavour 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*., 1964). 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 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).

Grain quality performance in rice varies from region to region and country. More than twenty years of consumer preference studies indicated that Filipinos prefer rice grains which are long, slender, translucent, non-glutinous, white and aromatic (Zaman *et al*., 2002). However, no universal standard of rice grain can be set because of wide variety of consumer's choices both between and within the country (Kaosa-ard and Juliano, 1991). In Bangladesh consumer's demand for rice, as reflected by price, is mostly influenced by grain size and shape (Choudhury, 1991). The amylose content of rice is considered as the main parameter of cooking and eating quality (Juliano, 1972). Intermediate to high amylase rice with low to intermediate gelatinization temperature is preferred. Therefore, 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.

Most of the scented rice varieties in Bangladesh are of traditional type, photoperiod sensitive, and cultivated during the Aman season. Majority of these indigenous aromatic rice cultivars are low yielding but its higher price and low cost of cultivation generate higher profit margins compared to other varieties. Most of high quality rice cultivars are low yielding. Locally adapted varieties are Chiniatop, Kalizira and Kataribhog. BRRI Dhan 34, BRRI Dhan 37 and BRRI Dhan 38 are high valued rice varieties released by Bangladesh Rice Research Institute (BRRI), having small grain and pleasant aroma.

Varietal improvement for Basmati started in Bangladesh in early 70's resulting insignificant success because of poor combining ability, lack of desirable segregates and selection tools. However, during 90's a total of 70 accessions of Indian and Pakistani Basmati collected from IRRI were evaluated at BRRI but no promising lines were selected for cultivation at Bangladesh condition. Recently, BRRI developed export quality long grain aromatic rice is BRRI dhan50 (first HYV as aromatic long grain), which showed higher yield than Pakistani and Indian Basmati varieties. Moreover, this export quality rice also known as Banglamati may meet the demand of international market. Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University has recently developed some dwarf advanced lines of Basmati rice which are grown well in both Aman and Boro seasons. But the quality and yield performance of these lines were not evaluated. Conceiving the above scheme in mind, the present research work has been undertaken in order to fulfill the following objectives:

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

# Chapter 2

# Review of Literature

# 2. REVIEW OF LITERATURE

Rice is the staple food for most of the planet inhabitants. Bangladesh produces several fine aromatic rice varieties with excellent eating qualities for regular consumption. Most of the rice varieties have been developed traditionally by selection, hybridization and back crossing with locally adapted high-yielding lines. But very few research works related to yield and quality analysis of Basmati rice have been carried out. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to the yield and quality of basmati rice, so far been done at home and abroad, have been reviewed in this chapter under the following heads-

## 2.1 Evaluation of yield performance of different advanced lines of basmati rice:

### 2.1.1 Plant height

Dwarfness may be one of the most important agronomic characters, because it is often accompanied by lodging resistance and thereby adapts well to heavy fertilizer application (Futsuhara and Kikuchi, 1984). Zahid *et al.*, (2005) studied 14 genotypes of basmati rice and observe high heritability couple with high genetic advance for plant height and 1000-grain weight. He also reported that plant height has negative correlation with yield. In addition he observed the positive relationship of plant height with grain quality. Prasad *et al.*, (2001) observed that days to flowering are negatively correlated with plant height. Grain yield is negatively correlated with plant height (Amirthadevarathinam, 1983). Patnaik *et al.*, (1990) found that hybrids with intermediate to tall plant height having non-lodging habit could be developed gave more than 20% grain yield than the standard checks.

### 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 (Verma *et al*., 2002). 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 be identified early by comparing their tiller number, plant height and days to 50% flowering with those of their respective restorers.

### 2.1.3 Number of effective tillers/plant

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/hill showed significant positive correlations with grain yield (Reddy and Kumar, 1996).

### 2.1.4 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 41 aromatic 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.

### 2.1.5 Panicle length

Associations of various yield components in rice (Padmavathi *et al.*, 1996) indicate that the plants with large panicles tend to have a high number of fertile grains. Similarly, a positive correlation was observed between number of panicle/plant and panicle length.

### 2.1.6 Number of filled spikelets/panicle

Rajesh and Singh (2000) reported that 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. Number of effective tillers per plant and fertile grains per panicle remained constant and common in explaining heterosis for yield of most of the hybrids. The heterosis for grain yield was due to the significant heterosis for the number of spikelets/panicle, test weight and total dry matter accumulation (Patnaik *et al*., 1990).

### 2.1.7 Total number of spikelets/panicle

Chen-Liang *et al*., (2000) showed that the cross between Peiai 64s and the new plant type lines had strong heterosis for filled grains per plant, number of spikes per plant and grain weight per plant, but heterosis for spike fertility was low. Xiao *et al*., (1996) indicated that heterosis in $F_1$ hybrids for spikelets/panicle showed a positive and significant correlation with genetic distance in indica × indica but not in indica × japonica crosses. Choi (1985) reported that grain yield was positively correlated with spikelet numbers/panicle.

### 2.1.8 1000-grain weight

Sitaramaiah *et al*., (1998) showed negative and significant standard heterosis for 1000 grain weight because the check had bold grains. Mishra and Pandey (1998) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Heterosis for seed yield was due to the positive and significant heterosis for components like panicle length and 1000 grain weight. Haque *et al*., (1991) reported negative association of 1000 grain weight and yield per plant in traditional varieties. Li and Yuan (1998) reported that parental genotype divergence had a relatively low impact on heterosis for panicle number and 1000 grain weight. Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties (Saha Ray *et al*., 1993). Kumar *et al*., (1994), noted that grain weight was highly correlated to grain size, which is the product of grain length and width.

### 2.1.9 Grain yield

Improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. However, grain yield is a complex trait, controlled by many genes and highly affected by environment (Jennings *et al.*, 1979). In addition, grain yield also related with other characters such as plant type, growth duration, and yield components (Yoshida, 1981). 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. Rice yield is a product of number of panicles per unit area, number of spikelets per panicle, percentage of filled grains and weight of 1000 grains (Yoshida, 1981; De Datta, 1981). It is therefore important to know the factors or traits that influence grain yield directly or indirectly or both, and to determine heritability and genetic advance under selection of those traits so that response to selection can be predicted. Improving rice (*Oryza sativa* 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. Bai *et al.*, (1992) reported that grain yield per plant positively correlated with numbers of productive tillers and number of grains per/panicle.

## 2.2 Study of milling quality and grain appearance

The milling quality of rice variety is said to be better if gives more whole kernel and less of broken when subjected to milling. Milling outturn depends on grain shape and appearance, which has direct effect on the percentage of milling. Milling yield is one of the most important criteria of rice quality, especially from a marketing standpoint. A variety should possess a high turnout of whole grain (head) rice and total milled rice (Webb, 1985). 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. Tan *et al.*, (2001) reported that milling properties, protein content, and flour color are important factors in rice. The milling properties were controlled by the same few loci that are responsible for grain shape. He *et al.* (2001) 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. A study of the genetic effects of parents showed that parents with high amylose content were unfavorable for eating and cooking quality improvement (Bao *et al.*, 2003). Adu-Kwarteng *etal.* (2003) found good grain size and shape (L/W-3.12), good endosperm appearance, milling quality (TMR-67.2%) and higher amylose content (22.87-30.78%) in the breeding lines. A brief review of literature available on various quality traits is given below:

### 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 posses 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 (Chauhan and Singh, 1882). Gravois (1994) 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 $F_1$ plants and $F_2$ seeds. Zhu (1992) showed 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) found milling outturn some Binni rice varieties and compared with BR25 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 milling 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. Chalky grains are not as hard as the translucent one and more prone to breakage during milling (Islam, 1983). The substantially improved the milling properties of rice by eliminating white belly and reducing grove depth on the kernel surface (Srinivas and Bhashyam, 1985).

### 2.2.2 Head rice recovery

Head rice yield indicates the weight of whole grains obtained after industrial processing. This is one of the most important parameters in rice commercial value determination (Arf *et al.*, 2002). 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 slender 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. Tomar (1985) 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% grain 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.

Gravois (1994) 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. Improvement of this trait is increasingly evident with many recently tasted experimental hybrids exhibiting high head rice yields (Shobha Rani *et al.*, 2002).

### 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 affect 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 BRRI 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. Biswas *et al.* (2001) estimated the length and L/B ratio of milled rice samples range from 4.7 to 6.2 and 2.1 to 3.2mm, respectively in some Binni rice varieties and compared with BR25 and Nizersail.

### 2.2.4 Endosperm translucency

Consumers prefer white, translucent grains and pay a 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. Igbeka *et al.,* (1991) observed that translucency is affected mainly by soaking and steaming parameters for example colour 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 after cooking, but 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 90% 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 Shafi, 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 Shafi, 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. Tomar and Nanda (1982) 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. Significant association of L/B ratio with kernel elongation was reported by Deosarker and Nerker (1994).

The hybrid rice combination with good quality of appearance and cooking, the genetic improvement of parents could be 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 (Gua *et al.*, 2003). 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 BRRI 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 (1988) 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 *et 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. Later on, it becomes more popular for its high cooked kernel elongation ratio (Hadjim *et al.*, 1994; Faruq *et al.*, 2003).

### 2.3.2 Water absorption (uptake) percentage and volume expansion

Marzempi and Edi (1990) concluded that expansion volumes also 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 al.* (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 al.*, 2005). Lower VER is preferred than higher VER. On the other hand, higher ER is preferred than lower ER for quality of cooked rice (Singh *et al.*, 2000).

### 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, 1967), 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 amylose 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 74°) 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 soft when overcooked, elongates less and remains 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, 1978). 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).

An estimate of the gelatinization temperature is indexed by the alkali digestion test (Little *et al.,* 1958). It is measured by the alkali spreading value. The degree of spreading value of individual milled rice kernels in a weak alkali solution (1.7% KOH) is very closely correlated with GT. Rice with a low GT disintegrates completely, whereas rice with an intermediate GT shows only partial disintegration. Rice with a high GT remains largely unaffected in alkali solution. Although the gelatinization temperature and cooking time of milled rice positively correlated (Juliano, 1967), GT does not correlate with the texture of cooked rice (IRRI 1968). Gelatinization temperature is not associated with other important plant or grain traits except for certain useful correlations with amylose content (Jennings *et al.,* 1979). Varieties with a high GT generally have low amylase content. No varieties are known with a high GT and high amylase content. The varietal difference in gelatinization temperature is due to the micellar structure of molecules in the starch granules and the gelatinization temperature effects the orderly arrangements of molecules in the granules and perhaps of the whole endosperm. Rices that have low gelatinization temperature such as, *japonica* varieties start to swell at low temperature during cooking than rice varieties that have intermediate or high gelatinization temperature (Nagato and Kishi,1966).

# Chapter 3

# Materials and Methods

# 3. MATERIALS AND METHODS

The present investigation on "Yield and quality analysis of some advanced lines of basmati rice" was conducted with the following objectives:

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

The experiment was conducted during the period from December 2008 to July 2009. A brief description about the locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, are presented as follows:

## 3.1 Experimental site

The study was conducted in the experimental Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh.

## 3.2 Geographical location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004). The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in (Appendix I).

## 3.3 Characteristics of soil

Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.0-6.6 and had organic matter 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. Physicochemical properties of the soil are presented in (Appendix II).

### 3.4 Climatic condition of the experimental site

The experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October. Information regarding monthly maximum and minimum temperature, rainfall, humidity as recorded by Bangladesh Meteorological Department, Agargon, Dhaka, during the period of study have presented in Appendix III.

### 3.5 Experimental materials

Six different advanced lines of Basmati rice collected from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207, were studied under the proposed research work. BRRI Dhan-29 collected from Bangladesh Rice Research Institute used as check variety.

### 3.6 Design and layout

The experiment was laid out in single factor Randomized Complete Block Design with three replications. The layout of the experiment was prepared for distributing the advanced line. There were 21 plots of size 1.5 m × 3.5 m in each. The 7 treatment of the experiment was assigned at random into 7 plots of each replication. A field view of the experimental plot and close preview of basmati rice is presented in Plate 1 and Plate 2.

### 3.7 Land preparation

The plot selected for conducting the experiment was opened in the second week of December 2008 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for transplanting rice seedlings. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.

Plate 1. A field view of the experimental plot

Plate 2. A close view of Basmati rice at flowering stage

### 3.8 Fertilizers and manure application

The fertilizers N, P, K, S and B in the form of urea, TSP, MP, Gypsum and borax, respectively were applied. The entire amount of TSP, MP, Gypsum, Zinc sulphate and borax were applied during the final preparation of land. Urea was applied in two equal installments at tillering and panicle initiation stage. The dose and method of application of fertilizer are shown in Table 1.

**Table 1. Dose and method of application of fertilizers in rice field**

| Fertilizers | Dose (kg/ha) | Application (%) | | |
|---|---|---|---|---|
| | | Basal | 1st installment | 2nd installment |
| Urea | 160 | 33.33 | 33.33 | 33.33 |
| TSP | 100 | 100 | -- | -- |
| MP | 100 | 100 | -- | -- |
| Gypsum | 60 | 100 | -- | -- |
| Borax | 10 | 100 | -- | -- |

Source: Adunik Dhaner Chash, BRRI, Joydebpur, Gazipur

### 3.9 Transplanting of seedlings in the field

Rice seedlings were transplanted in lines each having a line to line 30 cm and plant to plant 25 cm distance in the well prepared plot at January, 2009.

### 3.10 After care

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

#### 3.10.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water upto 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

### 3.10.2 Gap filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT).

### 3.10.3 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by mechanical means.

### 3.10.4 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 2 equal installments. The fertilizers were applied on both sides of seedlings rows with the soil.

### 3.10.5 Plant protection

Furadan 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

## 3.11 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%.

## 3.12 Data recording

The data were recorded under the following heads:

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

### 3.12.1 Evaluation of the yield performance of different advanced lines of basmati rice.

Data were recorded on physiological characters and yield components for all the entries on five randomly selected plants from the middle two rows in each replication.

#### 3.12.1.1 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.

#### 3.12.1.2 Days to 50% flowering

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

#### 3.12.1.3 Days to maturity

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

#### 3.12.1.4 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.

#### 3.12.1.5 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.

#### 3.12.1.6 Number of total tillers per plant

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

#### 3.12.1.7 Panicle length (cm)

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

#### 3.12.1.8 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.

#### 3.12.1.9 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.

#### 3.12.1.10 Number of total spikelets per panicle

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

#### 3.12.1.11 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.

#### 3.12.1.12 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.

#### 3.12.1.13 Grain yield per plot (kg)

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 $3.5\text{m} \times 1.5\text{m} = 5.25\text{m}^2$ in kg.

#### 3.12.1.14 Grain yield per hectare (t)

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

### 3.12.2 Study of the milling and grain appearance

#### 3.12.2.1 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,

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

#### 3.12.2.2 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,

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

#### 3.12.2.3 Head Rice Recovery

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,

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

#### 3.12.2.4 Kernel 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.

#### 3.12.2.5 L/B ratio of uncooked rice

L/B ratio was computed according to following formula:

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

**3.12.2.6 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:

On the basis of average length of kernel, milled rice is classified into following categories

**Table 2. 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 estimated by length/breadth ratio of kernels as:

**Table 3. Classification of milled rice on the basis of length/breadth ratio of kernels**

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

Ahuja *et al*., (1995)

Grain types were classified by using the following classification proposed by Ramaiah committee in 1965:

**Table 4. 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 6 mm | 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 6 mm | Length/Breadth ratio less than 2.5 |

(Source: Shobha Rani, 2003)

### 3.12.3 Determination of cooking and eating characteristics of the grain

**3.12.3.1 Kernel 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.

#### 3.12.3.2. Kernel Length/ Breadth ratio of cooked rice

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

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

#### 3.12.3.3 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.

#### 3.12.3.4 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.

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

#### 3.12.3.5 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,

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

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 minutes.

### 3.12.3.6 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-

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

**3.12.3.7 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) and IRRI (1980a).

**Table 5. 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<br>Collar cottony or cloudy | Low or intermediate | High or intermediate |
| 4 | Kernel swollen with collar complete and wide | Centre cottony;<br>Collar cloudy | Intermediate | Intermediate |
| 5 | Kernel split or segmented with collar complete and wide | Centre cottony;<br>Collar clearing | Intermediate | Intermediate |
| 6 | Kernel dispersed merging with collar | Centre cloudy;<br>Collar clear | High | Low |
| 7 | Centre and collar clear | Centre and collar clear | High | Low |

According to the alkali spreading score the G.T. types were classified as follows:

**Table 6. 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 |

### 3.12.3.8 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.

## 3.13 Statistical analysis:

**3.13.1 Analysis of variance:** Differences between genotypes for the characters studied were tested for significance by the 'Analysis of Variance' technique. Analysis of variance was done on the basis of following model:

Yij = m+gi+rj+eij

Where, Yij = Phenotypic observation on ith genotype in jth replication

m = General mean

gi = Effect of ith genotype

rj = Effect of jth replication

eij = Random error associated with ith genotype and jth replication

The structure of Analysis of Variance (ANOVA) table was as follows:

**Table 7. The structure of Analysis of Variance (ANOVA)**

| Source of variation | df | MSS | Expected MSS | F-value |
|---|---|---|---|---|
| Replication | (r-1) | Mr | $\sigma e^2 + g\sigma r^2$ | |
| Treatments | (g-1) | Mg | $\sigma e^2 + r\sigma g^2$ | Mg/Me |
| Error | (r-1) (g-1) | Me | $\sigma e^2$ | |
| Total | (rg-1) | | | |

Where,

r = Number of replication,

g = Number of genotypes (treatments)

Mr, Mg and Me = Mean sum of squares due to replications, genotypes and error respectively

$\sigma e^2$ = Error variance=Me

$\sigma r^2$ Genotypic variance=(Mg-Me)/r and

$\sigma p^2$ Phenotypic variance = $\sigma g^2 + \sigma e^2$

MSS due to genotypes were tested against the error variance using 'F' test at $p = 0.05$ or $p = 0.01$ with V1 and V2 degrees of freedom, where V1 is the degree of freedom for higher value of variance and V2 is the degree of freedom for lower value of variance.

### 3.13.2 Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.* (1955).

$$\text{Genotypic variance } (\sigma^2_g) = \frac{\text{GMS} - \text{EMS}}{r}$$

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of square

r = number of replications

$$\text{Phenotypic variance } (\sigma^2_{ph}) = \sigma^2_g + \text{EMS}$$

Where,

$\sigma^2_g$ = Genotypic variance

EMS = Error mean sum of square

### 3.13.3 Estimation of genotypic and phenotypic correlation co-efficient

For calculating the genotypic and phenotypic correlation co-efficient for all possible combinations the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1996) were adopted.

The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

Genotypic correlation ($r_{gxy}$) = $\frac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx} . \sigma^2_{gy})}}$

Where,

$\sigma_{gxy}$ = Genotypic co-variance between the traits x and y

$\sigma^2_{gx}$ = Genotypic variance of the trait x

$\sigma^2_{gy}$ = Genotypic variance of the trait y

Phenotypic correlation ($r_{pxy}$) = $\frac{\sigma_{pxy}}{\sqrt{(\sigma^2_{px} . \sigma^2_{py})}}$

Where,

$\sigma_{pxy}$ = Phenotypic covariance between the traits x and y

$\sigma^2_{px}$ = Phenotypic variance of the trait x

$\sigma^2_{py}$ = Phenotypic variance of the trait y

### 3.14 Statistical packages used:

The various statistical packages were used for data analysis and these are MS Excel 2000 (Microsoft), Microsoft Word, Microsoft power point and MSTATC (CIMMYT) for windows. For each character, analysis of variance (ANOVA), means, range were calculated by computer using MSTATC software; the mean values were separated by DMRT then analyzed for genotypic and phenotypic variance, genotypic and phenotypic coefficient of variation, genotypic an phenotypic correlation coefficient.

# Chapter 4

# Results and Discussion

# 4. RESULTS AND DISCUSSION

One of the main objectives of any breeding program is to produce high yielding and better quality lines for release as cultivars to farmers. The present study was conducted to evaluate the performance of different yield and quality attributes of six advanced lines of basmati rice. The experimental results obtained from the present investigation are presented here under the following heads:

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

The results obtained have been discussed here head wise:

## 4.1 Evaluation of the yield performance of different advanced lines of Basmati rice

Generally a breeder aims at accumulating favourable genes from diverse resources in a particular genotype, which would largely depend 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 Talwar and Guad (1974), Reddy and Ramchandraiah (1990), Basak and Ganguli (1996) and Peng *et al.,* (2000).

A total of six selected advanced lines of Basmati rice and one 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 8. 'F' test revealed highly significant variation among seven 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 rice lines.

#### 4.1.2 Mean performance for yield and yield components

Mean performance of yield and yield components of the lines of basmati rice with check variety have been presented character wise in Table 9.

##### 4.1.2.1 Plant height (cm)

Plant height of different advanced line of rice varied significantly (Table 9). The tallest plant height (108.20 cm) was recorded from advanced line 42(ii) which was statistically identical (103.67 cm) with 44(i), while the shortest plant height (95.30 cm) recorded from advanced line S2. The comparison of different plants of basmati rice and check variety is presented in Plate 3. 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. Hussain *et al.*, (2005) reported that transplantation time, water and soil condition, planting and sowing method affect plant height in rice. Zahid *et al.*, (2005) studied 14 genotypes of basmati rice and observe high heritability couple with high genetic advance for plant height and 1000-grain weight. He also reported that plant height has negative correlation with yield. In addition he observed the positive relationship of plant height with grain quality. A comparative performance of basmati advanced lines and check variety for plant height is presented in Figure 1.

##### 4.1.2.2 Days to 50% flowering

Days to 50% flowering of different advanced line of rice varied significantly (Table 9). The maximum days for 50% flowering (120 days) were recorded from BRRIdhan29 whereas the minimum days (101 days) recorded from advanced line S2 and 42(ii). This

**Table 8. Analysis of variance (ANOVA) for yield and its related characters in Basmati advanced lines and check**

| Sl. No. | Characters | Mean Sum of Squares (MSS) | | |
|---|---|---|---|---|
| | | Replication | Genotype | Error |
| | d.f. | 2 | 6 | 12 |
| 1. | Plant height (cm) | 2.512 | 50.385* | 15.204 |
| 2. | Days to 50 % flowering | 7.762 | 127.413** | 12.817 |
| 3. | Total tiller | 12.610 | 22.915** | 3.734 |
| 4. | Effective tillers/plant | 11.337* | 14.733** | 2.693 |
| 5. | Ineffective tillers/plant | 0.061 | 3.938** | 0.443 |
| 6. | Days to maturity | 3.571 | 203.857** | 37.905 |
| 7. | Panicle length (cm) | 1.234 | 8.906** | 1.806 |
| 8. | Filled pikelets/ panicle | 40.939 | 2214.769** | 106.734 |
| 9. | Unfilled spikelet/ panicle | 11.726 | 171.790 | 23.388 |
| 10. | Total spikele/ plant | 63.259 | 2018.795** | 81.396 |
| 11 | 1000-seed wt. (g) | 2.905 | 19.206 | 1.516 |
| 12 | Yield (kg/plot) | 0.820* | 1.659** | 0.161 |
| 13 | Yield (t/ha) | 2.986* | 6.026** | 0.588 |

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

**Table 9. Mean performance of yield and yield contributing characters of some advanced lines of basmati rice**

| Advanced lines/check | Plant height (cm) | Days to 50% flowering | Days to maturity | Number of effective tillers/ plant | Number of ineffective tillers/ plant | Total number of tillers/plant | Panicle length (cm) |
|---|---|---|---|---|---|---|---|
| S1 | 100.40 bc | 108.70 b | 146.00 bcd | 14.13 bc | 5.53 ab | 19.67 bc | 30.53 bc |
| S2 | 95.30 c | 101.00 c | 150.00 abc | 14.20 bc | 6.53 a | 20.73 ab | 28.43 c |
| S5 | 99.90 bc | 109.30 b | 154.00 ab | 15.73 b | 6.13 a | 21.87 ab | 29.01 c |
| 42 (i) | 98.21 bc | 106.00 c | 152.00 abc | 19.00 a | 4.67 b | 23.67 a | 30.02 bc |
| 42 (ii) | 108.20 a | 101.00 bc | 135.00 d | 12.47 c | 3.20 c | 15.67 d | 33.45 a |
| 44 (i) | 103.67 ab | 107.70 bc | 142.00 cd | 12.67 bc | 4.33 bc | 17.00 cd | 31.72 ab |
| BRRI Dhan 29 | 100.83 bc | 120.30 a | 160.00 a | 14.20 bc | 4.60 b | 18.80 bcd | 29.50 bc |
| Range | 108.20-95.30 | 101-120.30 | 135.00-160.00 | 12.47-19.00 | 3.20-6.53 | 15.67-23.67 | 28.43-33.45 |
| Mean | 100.930 | 107.762 | 148.429 | 14.63 | 5.00 | 19.63 | 30.38 |
| CV (%) | 5.56 | 3.2 | 4.15 | 11.22 | 13.30 | 9.85 | 4.42 |

**Table 9. (Continued)**

| Advanced lines/check | Number of filled spikelets/panicle | Number of unfilled spikelets/ panicle | Total spikelets/ panicle | 1000-grain weight (g) | Yield (g/plant) | Yield (kg/plot) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|
| S1 | 97.80 b | 30.20 b | 128.00 b | 22.67 b | 328.33 ab | 3.41 ab | 6.51 ab |
| S2 | 84.67 bc | 37.20 ab | 121.87 bc | 27.67 a | 286.67 b | 3.50 a | 6.66 a |
| S5 | 60.40 d | 43.27 a | 103.67 d | 26.33 a | 310.00 b | 2.73 bc | 5.20 bc |
| 42 (i) | 90.40 bc | 19.27 c | 109.67 cd | 22.67 b | 328.67 ab | 3.97 a | 7.56 a |
| 42 (ii) | 79.87 bc | 37.73 ab | 117.60 bcd | 21.67 b | 340.00 ab | 2.25 c | 4.28 c |
| 44 (i) | 74.33 cd | 35.40 ab | 109.73 cd | 23.00 b | 386.67 a | 2.45 c | 4.67 c |
| BRRI Dhan 29 | 145.83 a | 34.33 ab | 180.17 a | 20.67 b | 383.33 a | 4.15 a | 7.91 a |
| Range | 60.40-145.83 | 19.25-43.27 | 103.67-180.17 | 20.67-27.67 | 386.67-286.67 | 2.25-4.15 | 4.28-7.91 |
| Mean | 90.47 | 33.91 | 124.38 | 23.52 | 337.67 | 3.21 | 6.112 |
| CV (%) | 11.42 | 14.26 | 7.25 | 5.23 | 9.55 | 12.52 | 12.52 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

**Plate 3. Comparison of plant of different basmati lines and check variety**

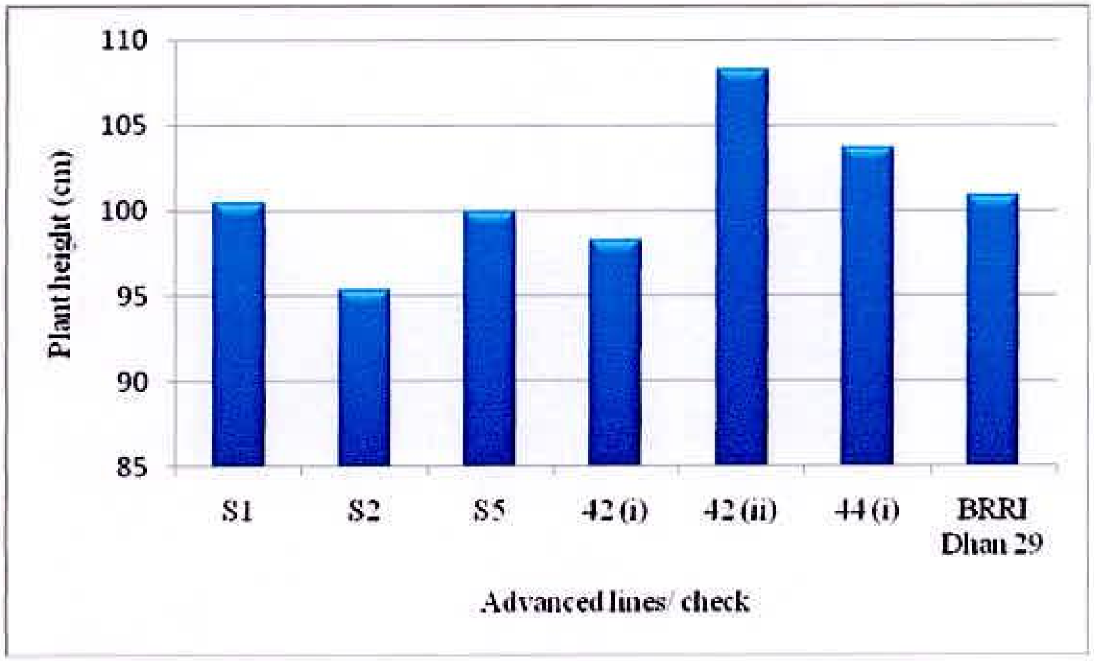


Figure 1. Relative performance of advanced lines and check for plant height

lines definitely would mature earlier and ultimately reduce crop duration. As a result, 2 to 3 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 line of rice varied significantly (Table 9). The maximum days for maturity (160 days) were recorded from BRRI Dhan 29 whereas the minimum days (135 days) recorded from advanced line 42(ii). 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. Karim *et al.*, (2007) studied 41 aromatic 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. Short duration lines can a good source for breeder to use as parents. A comparative performance of Basmati advanced lines and check variety for days to 50% flowering and days to maturity is presented in Figure 2.

#### 4.1.2.4 Number of effective tillers per plant

Number of effective tillers per plant of different advanced line of rice varied significantly. The maximum number of effective tillers per plant (19.00) was recorded from basmati advanced line 42(i) whereas the minimum number (12.47) recorded from advanced line 42(ii) (Table 9). 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 modern 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 tliller number are also reported to produce a larger proportion of heavier grains (Padmaja Rao, 1987). A comparative performance of

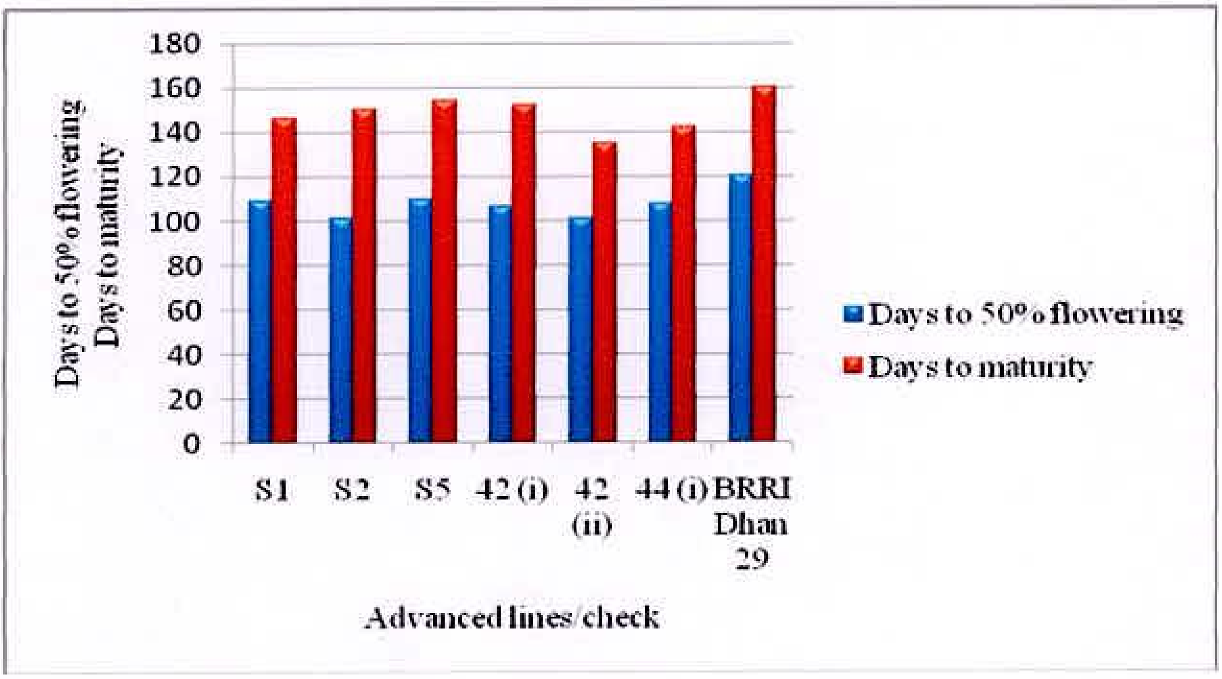


**Figure 2. Relative performance of advanced lines and check for days to 50 % flowering and days to maturity**

Basmati advanced lines and check variety for number of effective tillers per plant and ineffective tillers per plant is presented in Figure 3.

#### 4.1.2.5 Number of ineffective tillers per plant

Number of ineffective tillers per plant of different advanced line of rice varied significantly. The minimum number of ineffective tillers per plant (3.20) was recorded from basmati advanced line 42(ii), whereas the maximum number (6.53) recorded from advanced line S2 (Table 9).

#### 4.12.6 Number of total tillers per plant

Number of total tillers per plant of different advanced line of rice varied significantly. The maximum number of total per plant (23.67) was recorded from basmati advanced line 42(i) whereas the minimum number (15.67) recorded from advanced line 42(ii) (Table 9). Similar trend is also observed in case of effective tillers per plant.

#### 4.1.2.7 Panicle length (cm)

Panicle length of different advanced line varied significantly (Table 9). The longest panicle (33.45 cm) was recorded from basmati advanced line 42(ii) whereas the shortest panicle length (28.43 cm) recorded from advanced line S2. 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 *indica/japonica* 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. Tahir *et al.*, (2002) studied genetic variability for various traits. He found that these traits are under the genetic control and could be use in the selection of a desirable trait. A comparative panicle appearance is presented in Plate 4.

#### 4.1.2.8 Number of filled spikelet/panicle

Number of filled spikelet per panicle of different advanced line of rice varied significantly (Table 9). The maximum number of filled spikelet per panicle (145.83) was recorded from BRRI dhan29, while the minimum number (60.40) recorded from advanced line S5. 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. A comparative performance for filled and unfilled spikelet per plant is presented in Figure 4.

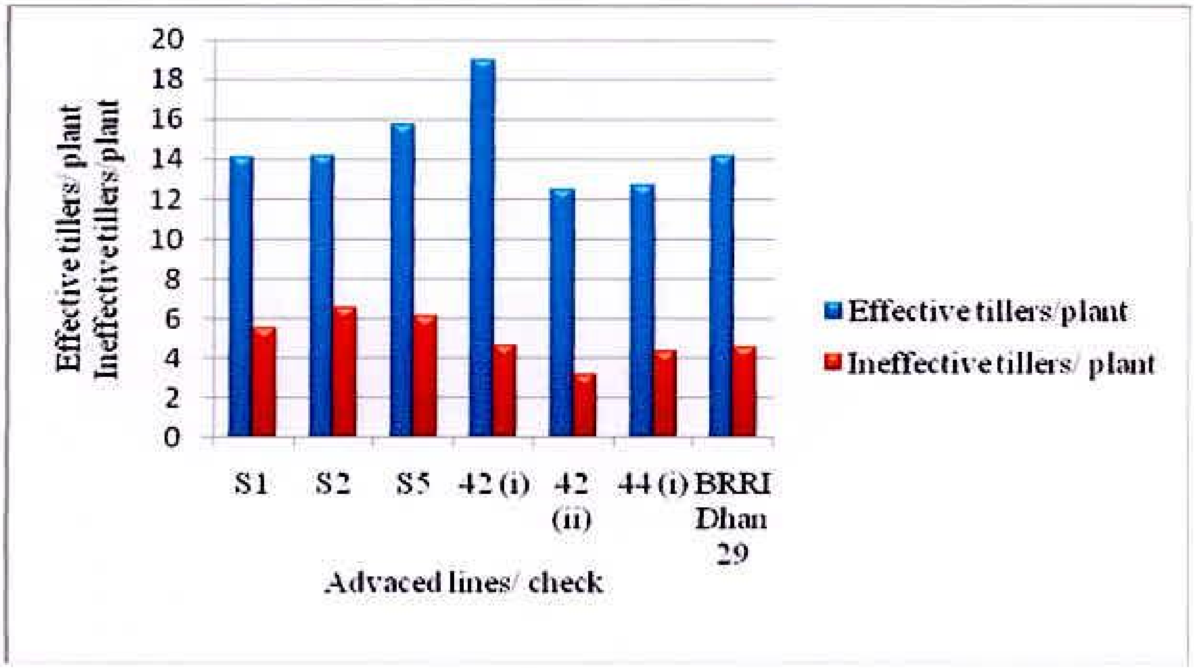


**Figure 3. Relative performance of advanced lines and check for number of effective tillers/plant and number of ineffective tillers/ plant**

Plate 4. Comparison of panicle appearance of basmati lines and check

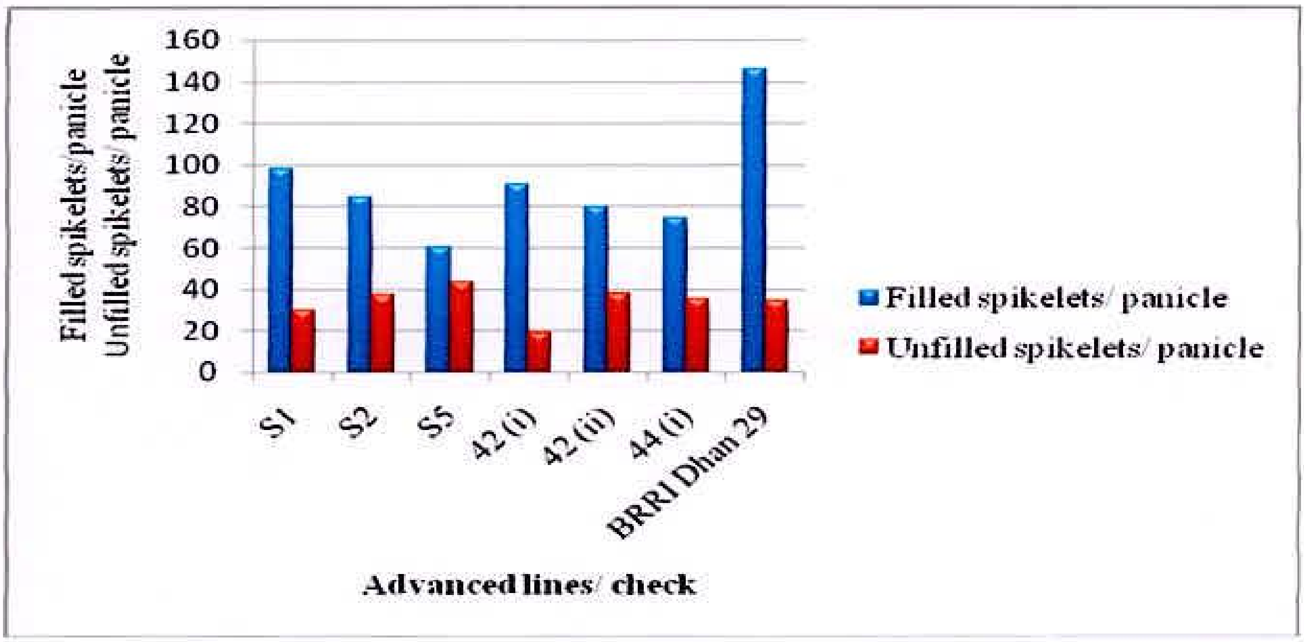


**Figure 4. Relative performance of advanced lines and check for number of filled spikelets/plant and number of unfilled spikelets/plant**

### 4.1.2.9 Number of unfilled spikelet/panicle

Number of unfilled spikelet per panicle of different advanced line of rice varied significantly (Table 9). The minimum number of unfilled spikelet per panicle (19.27) was recorded from 42(i), and the maximum number (43.27) recorded from advanced line S5.

### 4.1.2.10 Total spikelets/panicle

Number of total spikelet per panicle of different advanced line of rice varied significantly (Table 9). The maximum number of total spikelet per panicle (180.17) was recorded from BRRI dhan29, while the minimum number (103.67) recorded from advanced line S5. Positive association between grain number per panicle and grain yield has been reported by number of workers (Chauhan *et al.*, 1986; Janagle *et al.*, 1987' Kalaimani and Kadambavanaundaram, 1988). Interstingly it is observed that total number of filled spikelets, total number of spikelets and spikelet fertility show positive but non significant association among those characters.

### 4.1.2.11 Weight of 1000 Seeds (g)

Weight of 1000 seeds of different advanced line of rice varied significantly (Table 9). The highest weight of 1000 seeds (27.67 g) was recorded from S2, which was statistically identical (26.33 g) with S5 and the lowest weight (20.67 g) recorded from BRRIdhan29. 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. Vijayakumar *et al.*, (1997) and Hossain (2004) reported high correlation between 1000 grain weight and grain yield per plant. A comparative performance for 1000-grain weight is presented in Figure 5.

### 4.1.2.12 Grain yield (g/plant)

Grain yield per hill of different advanced line of rice varied significantly. The highest grain yield (386.67 g/plant) was recorded from 44(i), which was statistically identical (383.33 g/plant) with BRRIdhan29 and the lowest yield (286.67 g/plant) recorded from S2 (Table 9). Varietal differences of grain yield were reported by Biswas *et al.*, (1998). This variation in the grains yield might be due to the environment (Mahpattra, 1993) or

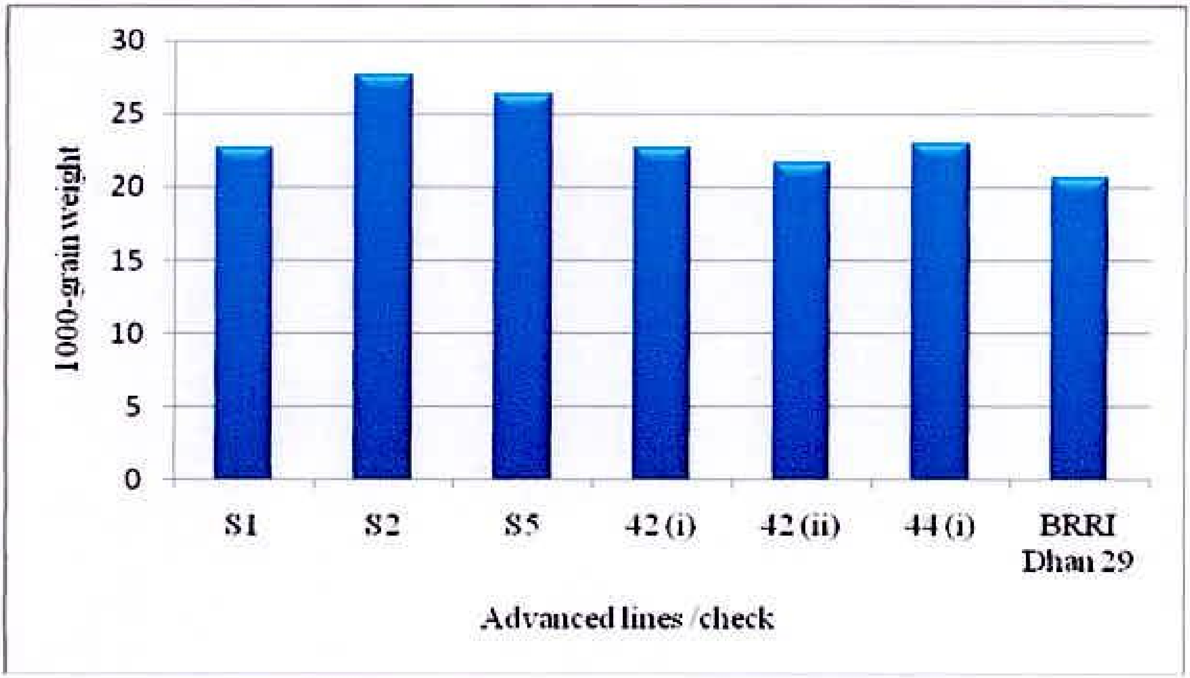


Figure 5. Relative performance of advanced lines and check for 1000-grain weight (g)

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. The genotypes, which produced higher number of effective tillers per hill and higher number of grains per panicle also showed higher grain yield in rice (Kusutani *et al*., 2000).

#### 4.1.2.13 Grain yield (kg/plot)

Grain yield per plant of different advanced line of rice varied significantly. The highest grain yield (4.15 kg/plant) was recorded from BRRI Dhan 29, and the lowest yield (2.25 kg/plant) recorded from 42 (ii) (Table 9).

#### 4.1.2.14 Grain yield (t/ha)

Grain yield per hectare of different advanced line of rice varied significantly (Table 9). The highest grain yield (7.91 t/ha) was recorded from BRRI Dhan 29, and the lowest yield (4.28 t/ha) recorded from 42 (ii) (Table 9). 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.

### 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*., 1973).This indicates that suppressing effect of the environment, which modified the phenotypic expression of these characters by reducing phenotypic coefficient values.

Correlation was done to measure the mutual relationship between eight different yield and yield contributing characters and to determine the component characters on which selection could be based for improvement in yield of basmati rice genotypes (Table 10).

#### 4.1.3.1 Plant height (cm)

Plant height showed significant and positive relationship with panicle length (Table 10). The results revealed that plant height ensured longest panicle. Plant height was positively correlated with panicle length also reported by Mirza *et al.*, 1972. Plant height showed insignificant positive relationship with days to 50% flowering. But this character showed insignificant negative correlation with number of effective tillers/hill, 1000 seed weight and yield (t/ha). Subramanian and Rathinam (1984) and Amirthadevarathinam (1983) also 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 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 significant positive association with number of filled spikelet/plant, unfilled spikelet/plant and yield (t/ha) (Table 10). Significant positive association of grain yield with days to flowering was observed by Manuel and Palanisamy (1989). On the other hand days to 50% flowering showed the negative correlation with effective tillers/hill, ineffective tillers/hill, panicle length and weight of 1000 seed

#### 4.1.3.3 Number of effective tillers/plant

Number of effective tillers/plant showed insignificant positive association with yield ineffective tillers/plant, spikelet/plant and 1000 seed weight. 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. On the other hand, the correlation of this character with

**Table 10. Genotypic and phenotypic correlation among yield and yield contributing characters**

| | | Days to 50 % flowering | Number of effective tillers/plant | Number of ineffective tillers/plant | Panicle length (cm) | Number of filled spikelets /panicle | Number of unfilled spikelets /panicle | 1000-seed wt. (g) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| **Plant height (cm)** | $r_g$ | 0.491 | -0.878** | -0.998** | 0.981** | -0.082 | 0.390 | -0.747* | -0.783* |
| | $r_p$ | 0.009 | -0.208 | -0.500 | 0.764* | -0.120 | 0.100 | -0.436 | -0.473 |
| **Days to 50 % flowering** | $r_g$ | | -0.341 | -0.189 | -0.024 | 0.740* | 0.275 | -0.572 | 0.234 |
| | $r_p$ | | -0.263 | -0.169 | -0.059 | 0.542 | 0.320 | -0.442 | 0.101 |
| **Number of effective tillers/plant** | $r_g$ | | | 0.281 | -0.654* | 0.056 | -0.752* | 0.162 | 0.652* |
| | $r_p$ | | | 0.272 | -0.285 | -0.091 | -0.405 | 0.151 | 0.538 |
| **Number of ineffective tillers/plant** | $r_g$ | | | | -0.994** | -0.171 | 0.239 | 0.957** | 0.367 |
| | $r_p$ | | | | -0.674* | -0.165 | 0.154 | 0.597* | 0.197 |
| **Panicle length (cm)** | $r_g$ | | | | | -0.180 | 0.011 | -0.693* | -0.732* |
| | $r_p$ | | | | | -0.155 | -0.051 | -0.457 | -0.436 |
| **Number of filled spikelets /panicle** | $r_g$ | | | | | | -0.285 | -0.640* | 0.756* |
| | $r_p$ | | | | | | -0.313 | -0.498 | 0.666* |
| **Number of unfilled spikelet /panicle** | $r_g$ | | | | | | | 0.549 | -0.554 |
| | $r_p$ | | | | | | | 0.358 | -0.495 |
| **1000-seed wt. (g)** | $r_g$ | | | | | | | | -0.258 |
| | $r_p$ | | | | | | | | 0.035 |

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

panicle length and number of unfilled spikelet/plant is negative insignificant (Table 10).

### 4.1.3.4 Number of ineffective tillers/plant

Number of ineffective tillers/hill showed significant positive relationship with weight of 1000 seeds (Table 10). This character showed insignificant positive relationship with unfilled spikelet/plant and yield (t/ha). On the other hand it showed highly significant but negative correlation with panicle length and significant negative relationship. Again, number of ineffective tillers/hill showed insignificant negative relationship with filled spikelet/plant.

### 4.1.3.5 Panicle length (cm)

Panicle length showed insignificant positive association with unfilled spikelets/plant at genotypic level (Table 10). On the other hand, this character showed significant negative association with 1000 seed weight and yield (t/ha) at genotypic level. Further it showed insignificant negative correlation with filled spikelets/plant at both genotypic and phenotypic level and with unfilled spikelets/plant, 1000 seed weight and yield. Negative genotypic correlation of yield /plant was reported with panicle length by Saini and Gagneja, (1975).

### 4.1.3.6 Number of filled spikelet/panicle

Number of filled spikelets/panicle showed significant positive association with yield (Table 10). Gravois and Helms (1992) reported the importance of number of filled grains per panicle in determination of rice yield. In addition, Silitonga (1989) and Bai *et al.*, (1992) reported the positive association of grain yield with filled grains/panicle. This character showed insignificant negative correlation with 1000 seed weight. Iftikharuddaula *et al.*, (2002) also noted similar kind of result.

### 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 10). Yolanda and Das (1995), Prasad *et al.*, (2001) and Iftikharuddaula *et al.*, (2002) also found the similar result. Kenedy & Rangasamy (1988) reported highly significant correlation between 1000-grain weights at the phenotypic level.

#### 4.1.3.10 Grain yield (t/ha)

Grain yield showed significant positive association with spikelets/plant and effective tillers/plant (Table 10). The correlation of yield was insignificantly positive with days to 50% flowering, effective tillers/plant and 1000 seed. 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.

### 4.1.4 Path analysis

Causal relationship between predictor variables and response variable can be defined by path analysis (Samonte *et al.*, 1998). Using path analysis, correlation coefficient is partitioned into two components, which are direct effect of a predictor variable on the response variable through other related variables (Williams *et al.*, 1990). Path analysis has been intensively used to estimate contribution of yield related traits to grain yield of rice and assisted breeders to determine selection criteria to improve yield (Gravios and Helms 1992; Samonte *et al.*, 1998; Oad *et al.*, 2002 and Babar *et al.*, 2007). By path analysis the interrelation between grain yield and yield contributing character are presented in Table 12. Here grain yield was considered as effect (dependent) variable and plant height, days to 50% flowering, effective tillers/hill, ineffective tillers/hill, panicle length, filled spikelets/plant, unfilled spikelets/plant, 1000-seed wt. were treated as causes or in insignificant independent variables.

The cause and effect of relationship between yield and yield related characters have been presented in Table-11. Residual effects of other independent variables, which have influence to yield to a small extent, have been denoted as 'R'.

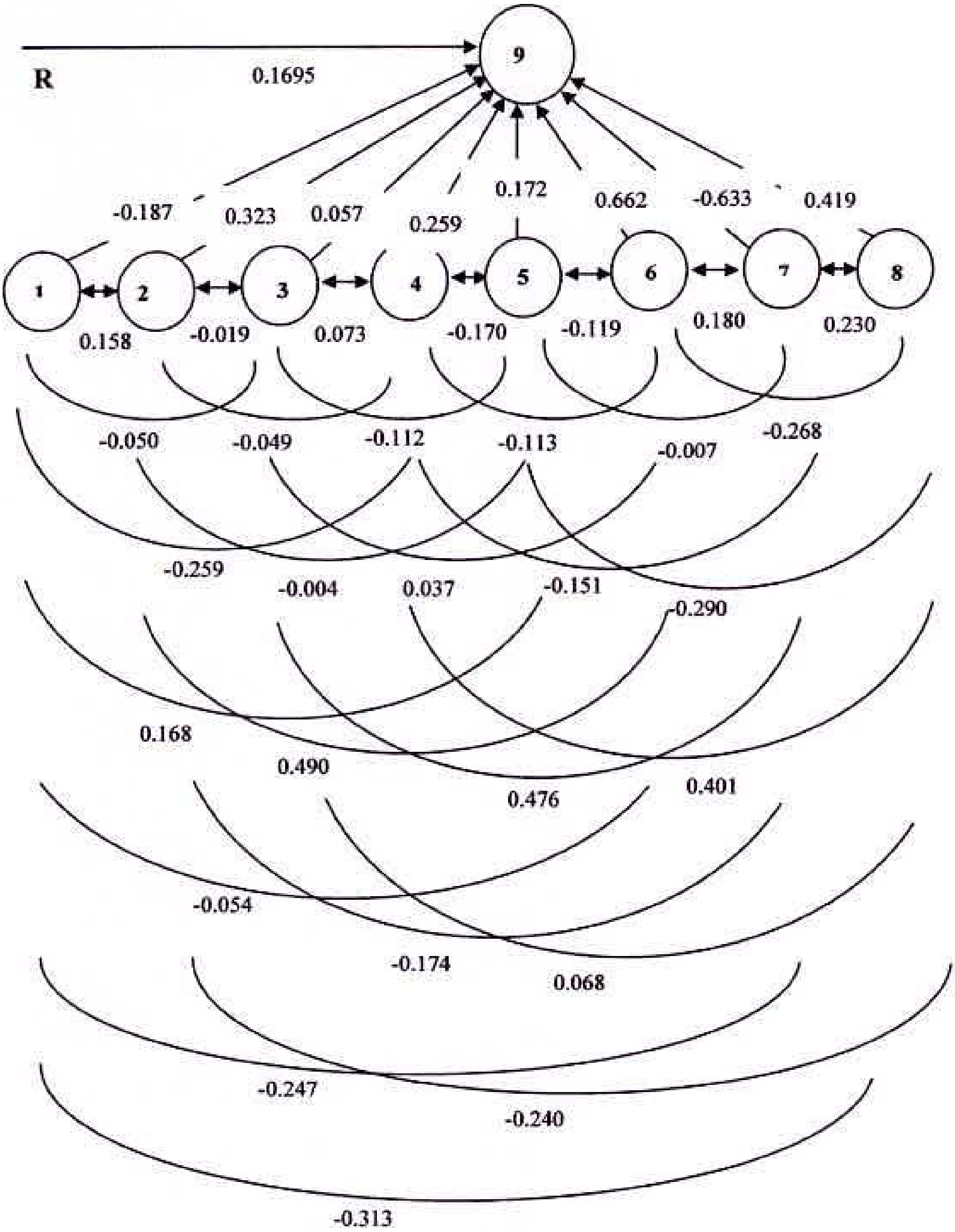
#### 4.1.4.1 Plant height

Plant height had negative direct effect on yield (Table 11). But, positive direct effect of plant height on grain yield was found by Babu *et al.*, (2002). Plant height had positive indirect effect on yield through days to 50% flowering, panicle length and negative indirect effect through effective tillers/plant, ineffective tillers/plant, filled spikelets/panicle, unfilled spikelets/panicle and 1000-seed wt. The cumulative effects of these characters produced a negative genotypic correlation on yield. So selection should be done not only based on plant height but other associated characters must also be

**Table 11. Path coefficients of different yield contributing characters on yield of rice**

| | **Plant height (cm)** | **Days to 50 % flowering** | **Number of effective tillers/plant** | **Number of ineffective tillers/plant** | **Panicle length (cm)** | **Number of filled spikelets /panicle** | **Number of unfilled spikelets /panicle** | **1000-seed wt. (g)** | **Genotypic correlation with yield** |
|---|---|---|---|---|---|---|---|---|---|
| **Plant height (cm)** | **-0.187** | 0.158 | -0.050 | -0.259 | 0.168 | -0.054 | -0.247 | -0.313 | -0.7831* |
| **Days to 50 % flowering** | -0.092 | **0.323** | -0.019 | -0.049 | -0.004 | 0.490 | -0.174 | -0.240 | 0.2342 |
| **Number of effective tillers/plant** | 0.164 | -0.110 | **0.057** | 0.073 | -0.112 | 0.037 | 0.476 | 0.068 | 0.6520* |
| **Number of ineffective tillers/plant** | 0.187 | -0.061 | 0.016 | **0.259** | -0.170 | -0.113 | -0.151 | 0.401 | 0.3665 |
| **Panicle length (cm)** | -0.184 | -0.008 | -0.037 | -0.259 | **0.172** | -0.119 | -0.007 | -0.290 | -0.7319* |
| **Number of filled spikelets/panicle** | 0.015 | 0.239 | 0.003 | -0.044 | -0.031 | **0.662** | 0.180 | -0.268 | 0.7564* |
| **Number of unfilled spikelets/panicle** | -0.073 | 0.089 | -0.042 | 0.062 | 0.002 | -0.189 | **-0.633** | 0.230 | -0.5539 |
| **1000-seed wt. (g)** | 0.140 | -0.185 | 0.009 | 0.248 | -0.119 | -0.423 | -0.347 | **0.419** | -0.2583 |

R=0.1695



Path diagram of 8 yield contributing traits in rice
1=Plant height, 2=Days to 50 % flowering, 3= Number of effective tillers/ plant, 4=Number of ineffective tillers/plant, 5=Panicle length, 6= Number of filled spikelets/panicle, 7= Number of unfilled spikelets/panicle, 8=1000-seed wt. and 9 = Yield (t/ha)
R= residual effects.

considered. The plant height had positive indirect effect on grain yield through filled spikelets and grains per panicle, which was reported by Janardhanam *et al.*, (2001). Since the direct effect and correlation coefficient both were negative, so the direct selection for this trait to improve the yield will not be desirable.

#### 4.1.4.2 Days to 50% flowering

Days to 50% flowering had positive direct effect on yield (Table 11). Thaware *et al.*, (1999) reported positive direct effect of days to 50% flowering, which is in accordance with the present finding. Negative direct effect of days to flowering was reported by Prasad *et al.*, (2001), which is not in line with present finding. Days to 50% flowering contributed indirectly on grain yield through positive effect of filled spikelets/plant and negative effect of plant height, effective tillers/plant, ineffective tillers/plant, panicle length, unfilled spikelet/panicle and 1000-seed wt. The cumulative effects of these characters produced a positive genotypic correlation on yield that indicates the true relationship and direct selection through this trait can be effective.

#### 4.1.4.3 Effective tillers/plant

Effective tillers/hill had positive direct effect on yield (Table 11). It had positive indirect effect on yield through plant height, ineffective tillers/plant, filled spikelets/panicle, unfilled spikelets/panicle and 1000-seed wt. and negative indirect effect through days to 50% flowering and panicle length. The cumulative effects of these characters produced a significant positive genotypic correlation on yield. Gupta *et al.*, (1999) found the positive direct effect and highly significant positive correlation coefficient between productive tillers per plant and grain yield per plant.

#### 4.1.4.4 Panicle length (cm)

Panicle length had positive direct effect on yield. It had negative indirect effect on yield through plant height, effective tillers/plant, ineffective tillers/plant, thousand seed weight, days to 50% flowering, filled spikelets/panicle and unfilled spikelets/panicle (Table 11). The cumulative effects of these characters produced a significant negative genotypic correlation on yield.

### 4.1.4.5 Filled spikelets/panicle

Spikelets/panicle had positive direct effect on yield (Table 11). Filled spikelets/panicle had high direct effect on single plant yield was reported by Janardhanam *et al*., (2001) ; Cheema *et al*., (1998).It had positive indirect effect on yield through plant height, days to 50% flowering, unfilled spikelets/panicle and negative indirect effect through ineffective tillers/plant, panicle length and 1000 seed weight. The cumulative effects of these characters produced a significant positive genotypic correlation on yield. Since the direct effect and correlation coefficient between total spikelets per panicle and grain yield are positive, so it is an indication of true relationship among these traits. It suggests that the direct selection for total spikelets per panicle would likely to be effective in improving the grain yield. Choudhury and Das (1997) and Kim *et al*., (1999) reported positive contribution of total spikelets towards grain yield, which supports the present finding. Sarker *et al*., (2001) showed filled spikelets/panicle is the most important character for rice because of grain yield is highly influenced by it directly as well as indirectly. Pathak *et al*., (1998) reported that grains per panicle was the main component which affected yield directly.

### 4.1.4.6 1000 seed weight (g)

1000 seed weight had positive direct effect on yield. It had positive indirect effect on yield through plant height, effective tillers/plant and ineffective tillers/plant and negative indirect effect through days to 50% flowering, panicle length, filled spikelets/plant and unfilled spikelets/panicle. The cumulative effects of these characters produced a negative genotypic correlation on yield.

Therefore, path analysis revealed that positive path coefficients of number of filled grains per panicle, 1000-seed weight, days to 50% flowering indicated the importance of these characters as a secondary trait in the selection to increase grain yield. In addition, plant height character which had negative direct effect on grain yield should be considered in the selection process by selecting rice plant type with semi-dwarf or intermediate plant height.

The residual effect of the present study was 0.1695 indicating that 84 percent of the variability in yield was contributed by the six characters studied in the path analysis. This residual effect towards yield in the present study might be due to other characters which were not studied, environmental factors and sampling errors.

### 4.2 Study of milling and grain appearance

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 chemical traits. Interestingly, both are inter-dependent.

#### 4.2.1 Analysis of variances

The analysis of variance (ANOVA) presented in Table 12 showed highly significant variation for all the milling quality characters studied. A wide range of variation was observed for characters like, milling per cent, hulling per cent, head rice recovery (HRR %), grain L/B ratio of rough rice, grain L/B ratio of milled rice. 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 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.

#### 4.2.2 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 characterwize in Table 13. The discussion is as follows:

**Table 12. Analysis of variance (ANOVA) for different quality traits (before cooking)**

| Sl. No. | Characters | df | | Mean sum of square | |
|---|---|---|---|---|---|
| | | Genotypes | Error | Genotypes | Error |
| 1. | Hulling (%) | 6 | 12 | 49.865** | 7.56 |
| 2. | Milling outturn (%) | 6 | 12 | 63.719** | 9.667 |
| 3. | HRR (%) | 6 | 12 | 95.862** | 9.667 |
| 4. | Grain length of rough rice (mm) | 6 | 12 | 5.661** | 0.042 |
| 5. | Grain breadth of rough rice (mm) | 6 | 12 | 0.084** | 0.009 |
| 6. | Grain length/breadth ratio | 6 | 12 | 0.556** | 0.031 |
| 7. | Grain length of brown rice (mm) | 6 | 12 | 3.312** | 0.006 |
| 8. | Grain breadth of brown rice (mm) | 6 | 12 | 0.005 | 0.003 |
| 9. | Grain length/breadth ratio of brown rice | 6 | 12 | 0.778** | 0.013 |
| 10. | Grain length of milled rice (mm) | 6 | 12 | 1.530** | 0.021 |
| 11. | Grain breadth of milled rice (mm) | 6 | 12 | 0.015** | 0.001 |
| 12. | Grain length/breadth ratio of milled rice | 6 | 12 | 0.490** | 0.011 |

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

**Table 13. Mean performance of quality characteristics before cooking in different lines and check**

| Lines/ check | Hulling (%) | Milling (%) | HRR (%) | Rough rice | | | Brown rice | | | Milled rice (uncooked rice) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Length (mm) | Breadth (mm) | L/B ratio | Length (mm) | Breadth (mm) | L/B ratio | Length (mm) | Breadth (mm) | L/B ratio |
| S1 | 63.85 d | 51.00 c | 63.01 d | 12.25 a | 2.24 cd | 5.48 a | 8.57 d | 1.85 ab | 4.64 b | 7.25 c | 1.59 c | 4.57 ab |
| S2 | 76.20 a | 66.00 a | 79.34 a | 12.61 a | 2.63 a | 4.79 c | 9.48 a | 1.90 ab | 5.00 a | 8.05 a | 1.79 a | 4.50 b |
| S5 | 67.30 cd | 56.00 bc | 65.82 bcd | 12.43 a | 2.43 b | 5.11 bc | 9.06 b | 1.87 ab | 4.84 a | 7.77 b | 1.64 bc | 4.75 a |
| 42 (i) | 69.20 bc | 56.75 bc | 67.50 bcd | 12.27 a | 2.34 bc | 5.25 ab | 8.73 c | 1.92 a | 4.55 b | 7.60 b | 1.69 b | 4.49 b |
| 42 (ii) | 69.00 bc | 56.50 bc | 73.18 ab | 11.45 b | 2.25 bcd | 5.08 bc | 8.43 d | 1.89 ab | 4.45 bc | 7.26 c | 1.66 b | 4.39 b |
| 44 (i) | 69.45 bc | 56.93 bc | 65.07 cd | 11.66 b | 2.31 bc | 5.04 bc | 8.19 e | 1.91 ab | 4.29 c | 7.22 c | 1.58 c | 4.56 ab |
| BRRI Dhan -29 | 73.80 ab | 60.50 ab | 71.05 bc | 8.65 c | 2.19 d | 4.13 d | 6.20 f | 1.81 b | 3.43 d | 5.82d | 1.66b | 3.51 c |
| Range | 63.85-76.20 | 51-66 | 65.07-79.34 | 12.61-8.65 | 2.19-2.63 | 4.13-548 | 6.20-9.48 | 1.81-1.92 | 3.43-5.00 | 5.82-8.05 | 1.58-1.79 | 3.51-4.75 |
| Mean | 69.829 | 57.669 | 69.28 | 11.615 | 2.33 | 4.983 | 8.38 | 1.878 | 4.458 | 7.281 | 1.658 | 4.395 |
| CV (%) | 6.94 | 5.39 | 5.57 | 5.77 | 4.10 | 7.54 | 6.89 | 7.80 | 9.54 | 5.98 | 6.95 | 7.37 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

#### 4.2.2.1 Hulling (%)

Hulling of rice for different advanced line of rice varied significantly (Table 13). The maximum hulling (76.20%) was recorded from S2, which was statistically identical (73.80%) with BRRIdhan29 and the lowest hulling (63.85%) recorded from S1. Sandeep (2003) found 71.67% to 84.56% hulling per cent during characterization of 20 new plant type genotypes in rice.

#### 4.2.2.2 Milling outturn (%)

The total yield of milled rice which can be obtained from a unit 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 13). The maximum milling return (66%) was recorded from S2, which was statistically identical with BRRIdhan29 (60.50%) and the lowest recorded from S1 (51.00%). But, Ahuja *et al.*, (1995) reported a range of 67 to 71% for milling recovery in Basmati varieties. Hariprasanna (1998) reported a range of 61.50 to 72.60%. A Comparative view of rough rice and milled rice is presented in Plate 5.

#### 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 13). The maximum head rice recovery (79.34%) was recorded from S2, which was statistically identical with 42(ii) (73.18%), while the lowest (65.07%) recorded from 44(i). 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

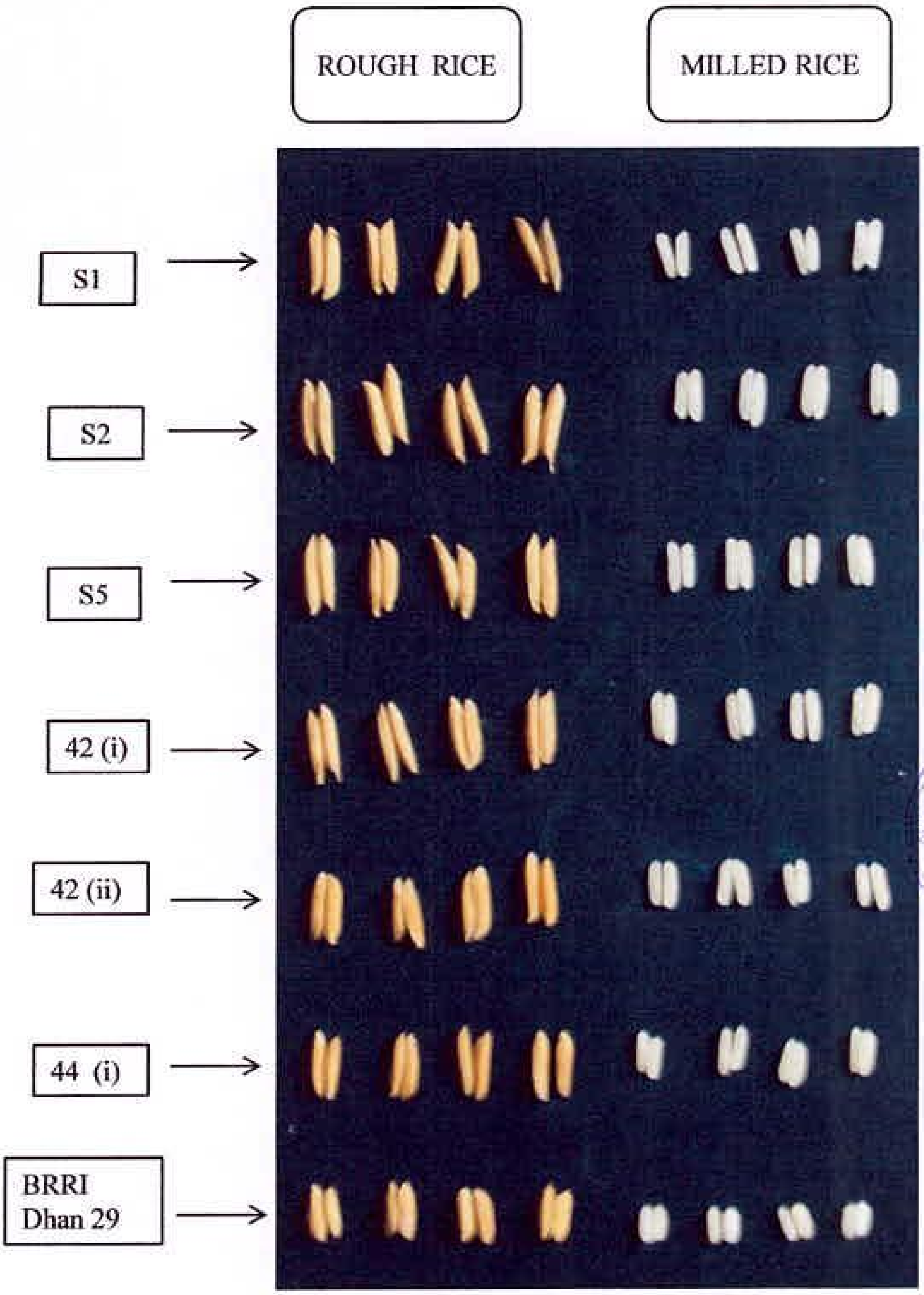


**Plate 5. A comparative view of rough rice and milled rice of different basmati advanced lines and check**

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. A relative performance of different advanced lines of Basmati rice and check for hulling, milling and head rice recovery percentage is presented in Figure 6.

#### 4.2.2.4 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, where as 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 13). 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.*, 1973). Grain length is an important physical property, which attracts consumer's attention. The people of Bangladesh like long, slender, shiny grain. Length breadth ratio of the grains indicates the fineness of the grain.

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 be visually classified, more precise measurement are needed for classification and for critical

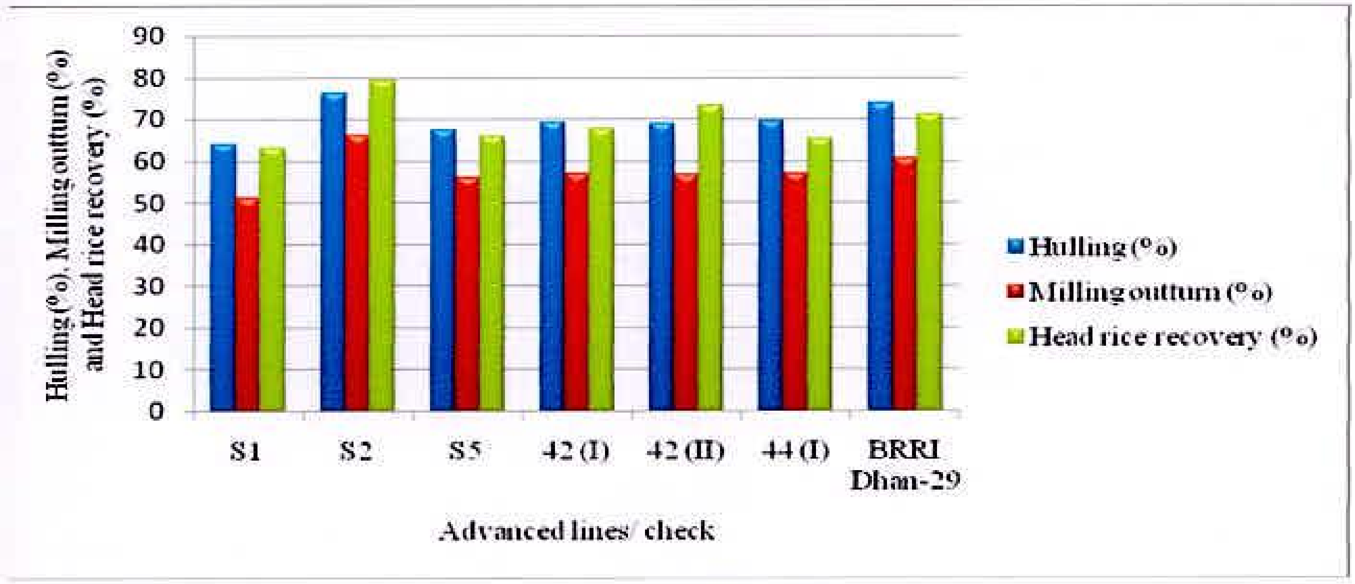


**Figure 6. Relative performance of advanced lines and check for hulling percent, milling percent and head rice recovery**

comparison of hybrids/ lines. In present study, the grain shape and size are characterized following Ramaiah Committee classification (1965). The lines or hybrids are classified into long slender (LS), short slender (SS), long bold (LB) and short bold (SB). In the present study, all lines have been grouped into class long slender and the check are in the short slender group (Table 14).

### 4.2.2.5 Kernel 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 advanced line of Basmati rice varied significantly (Table 13). The longest kernel of rough rice (12.61 mm) was recorded from S2 and the shortest kernel (8.65 mm) recorded from BRRIdhan29. The highest ratio of kernel length and breadth of rough rice (5.48) was recorded from S1 and the lowest ratio (4.79) recorded from S2. The longest kernel breadth of rough rice (2.63 mm) was recorded from S2 and the shortest (2.11 mm) recorded from BRRIdhan29. Vraktamath (1987) observed that kernel breadth enhanced the milling output and HRR was strongly associated with milling percentage.

### 4.2.2.6 Kernel 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 13). The longest kernel of brown rice (9.48 mm) was recorded from S2 and the shortest kernel (6.20 mm) recorded from BRRIdhan29. The longest kernel breadth of brown rice (1.92 mm) was recorded from S2 and the shortest (1.81 mm) recorded from BRRIdhan29. The highest ratio of kernel length and breadth of brown rice (5.00) was recorded from S2 and the lowest ratio (3.43) recorded from BRRIdhan29.

### 4.2.2.6 Kernel length, breadth and ratio of milled rice

Kernel length, breadth and their ratio of milled rice for different advanced line of rice varied significantly (Table 13). The longest kernel of milled rice (8.05 mm) was recorded from S2 and the shortest kernel (5.82 mm) recorded from BRRIdhan29. The longest kernel breadth of milled rice (1.79 mm) was recorded from S2 and the shortest (1.58 mm) recorded from 44(i). The highest ratio of kernel length and breadth of milled rice

**Table 14. Classification of grain types of basmati advanced lines and check variety on the basis of systematic classification of rice proposed by Ramaiah Committee (1965)**

| Classification group | | | | |
|---|---|---|---|---|
| **Long slender (LS) (Length 6 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 3.0)** | **Long Bold (LB) (Length 6 mm & above L/B ratio less than 3.0)** | **Short Bold (SB) (Length less than 6 mm L/B ratio less than 2.5)** |
| S1 | BRRI Dhan 29 | - | - | - |
| S2 | - | - | - | - |
| S5 | - | - | - | - |
| 42 (i) | - | - | - | - |
| 42 (ii) | - | - | - | - |
| 44 (i) | - | - | - | - |

(4.75) was recorded from S5 and the lowest ratio (3.51) recorded from BRRIdhan29.

#### 4.2.2.7 Endosperm translucency and chalkiness

Among the six lines, all showed clear-cut translucent endosperm appearance (Table 15). The check also showed translucent grain. The endosperm appearance of all line was good. Grain appearance is largely determined by endosperm opacity, the amount of chalkiness. Khush *et al.*, (1986) classified the endosperm of rice based on endosperm opacity as waxy or non waxy. Waxy rice devoid of or have only trace of amylose content and are opaque. Non waxy rices have varying amylose level (2.1 to32%) and are dull, hazy or translucent. Dull and hazy kernels have amylose content ranging from 10-32%. He also reported that mixture of different endosperm appearance grains (due to varying level of amylose 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. The nature of endosperm appearance of advanced lines and the check has been presented in Table 15.

## 4.3 Cooking and eating characteristics of the grain

### 4.3.1 Analysis of variances

The analysis of variance (ANOVA) presented in Table 16 showed highly significant variation for all the 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 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.

**Table 15. Endosperm appearances in basmati advanced lines and check variety**

| Lines/check | Endosperm appearance |
|---|---|
| S1 | Translucent |
| S2 | Translucent |
| S5 | Translucent |
| 42 (i) | Translucent |
| 42 (ii) | Translucent |
| 44 (i) | Translucent |
| BRRI Dhan 29 | Translucent |

**Table 16. Analysis of variance (ANOVA) for different quality traits in rice lines/variety (After cooking)**

| Sl.No. | Characters | df | | Mean sum of square | |
|---|---|---|---|---|---|
| | | Genotypes | Error | Genotypes | Error |
| 1 | Length of cooked rice (mm) | 6 | 12 | 12.522** | 0.098 |
| 2 | Breadth of cooked rice (mm) | 6 | 12 | 0.236** | 0.041 |
| 3 | Length/breadth ratio of cooked rice | 6 | 12 | 1.762** | 0.058 |
| 4 | Cooking time (minutes) | 6 | 12 | 5.857* | 1.286 |
| 5 | Elongation index | 6 | 12 | 0.032* | 0.009 |
| 6 | Water uptake (%) | 6 | 12 | 2913.714** | 329.33 |
| 7 | Volume expansion (%) | 6 | 12 | 0.065** | 0.008 |
| 8 | Alkali spreading value | 6 | 12 | 0.195** | 0.024 |

#### 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 characterwize in Table 17. The discussion is as follows:

##### 4.3.2.1 Kernel length, breadth and ratio of cooked rice

Kernel length, breadth and their ratio of cooked rice for different advanced line varied significantly (Table 17). The longest kernel of cooked rice (13.36 mm) was recorded from $S_2$ and the shortest (6.68 mm) from BRRIdhan29. 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 (3.12 mm) was recorded from $S_2$ and the shortest (2.19 mm) from BRRIdhan29. The highest ratio of kernel length and breadth (5.21) was recorded from 42(ii) and the lowest ratio (3.05) from BRRIdhan29. 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 advanced lines and check for kernel length and breadth before and cooking is presented in Figure 7 and Figure 8.

##### 4.3.2.2 Kernel elongation ratio

Kernel elongation ratio for different advanced line of rice varied significantly (Table 17). The highest kernel elongation ratio (1.72) was recorded from S5 and the lowest ratio (1.14) recorded from BRRI Dhan 29. Elongation ratio ($L_1$ /$L_0$) is a measure of kernel elongation upon cooking resulting from swelling of starch granules by uptake of water

**Table 17. Mean performance of quality characteristics after cooking in different lines and check**

| Lines/check | Cooked rice | | | Kernel el. Ratio | Water uptake (%) | Volume expansion (%) | ASV | Cooking time (minute) |
|---|---|---|---|---|---|---|---|---|
| | Length (mm) | Breadth (mm) | L/B ratio | | | | | |
| S1 | 11.95 c | 2.96 a | 4.04 b | 1.64 a | 214.00 c | 4.30 a | 6.01 b | 17 b |
| S2 | 13.36 a | 3.12 a | 4.28 b | 1.66 a | 214.00 c | 4.10 b | 7.00 a | 16 b |
| S5 | 13.38 a | 2.97 a | 4.50 b | 1.72 a | 254.00 b | 4.41 a | 4.25 d | 17 b |
| 42 (i) | 12.67 b | 2.44 b | 5.21 a | 1.67 a | 250.00 b | 4.10 b | 4.59 cd | 18 ab |
| 42(ii) | 10.15 d | 2.39 b | 4.25 b | 1.39 b | 260.00 b | 4.29 a | 4.25 d | 17 b |
| 44 (i) | 11.80 c | 2.75 ab | 4.32 b | 1.63 a | 294.00 a | 4.00 b | 4.25 d | 17 b |
| BRRI Dhan -29 | 6.68 e | 2.19 a | 3.05 c | 1.14 c | 210.00 c | 4.30 a | 3.83c | 20 a |
| Range | 6.68-13.36 | 2.19-3.12 | 3.05-5.21 | 1.14-1.72 | 210-294 | 4.00-4.41 | 3.83-7.00 | 16-20 |
| Mean | 11.57 | 2.792 | 4.18 | 1.55 | 242.27 | 4.214 | 5.026 | 17.429 |
| CV (%) | 5.70 | 7.21 | 5.74 | 8.60 | 7.49 | 6.10 | 5.38 | 6.51 |

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

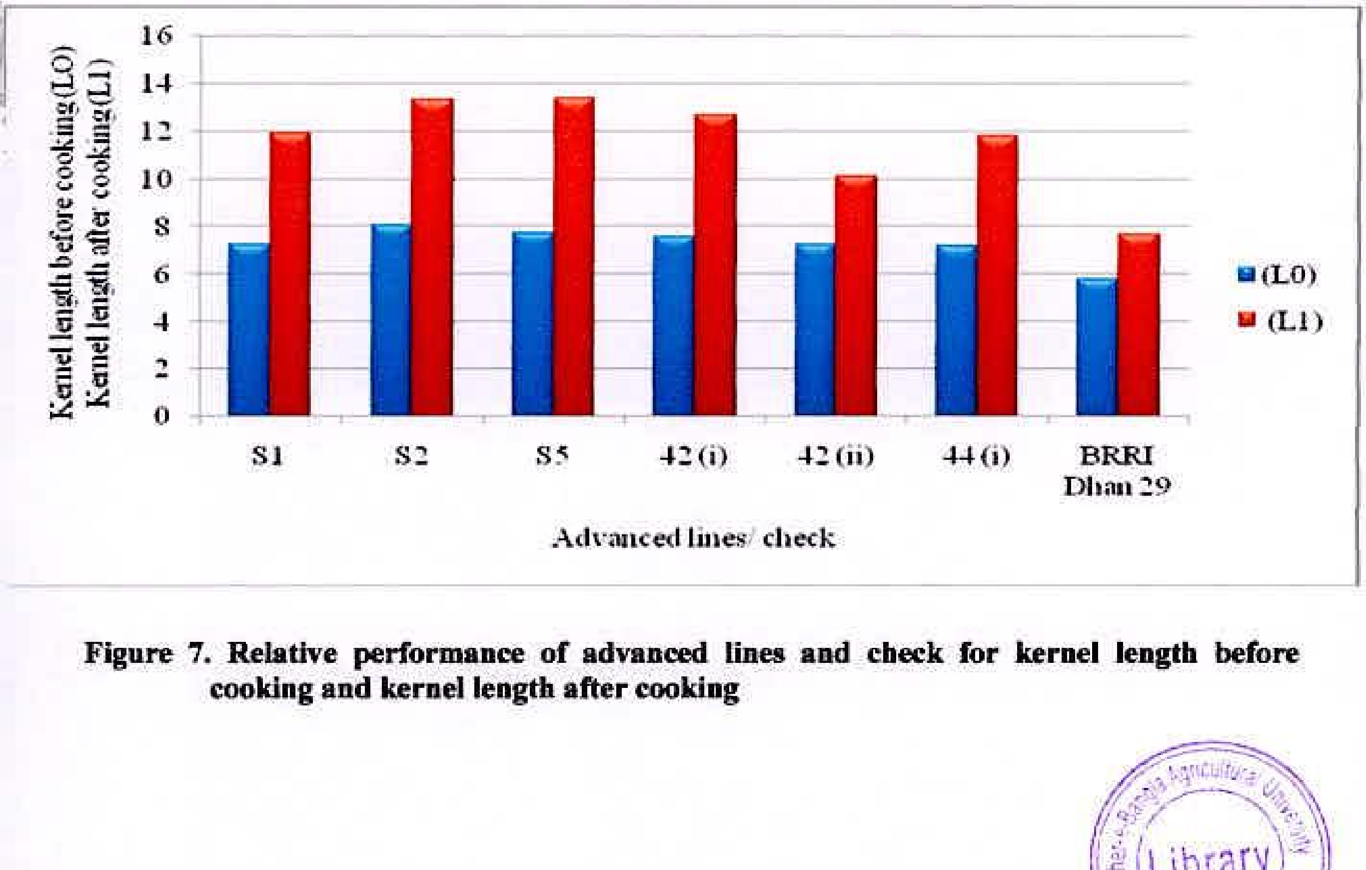


**Figure 7. Relative performance of advanced lines and check for kernel length before cooking and kernel length after cooking**

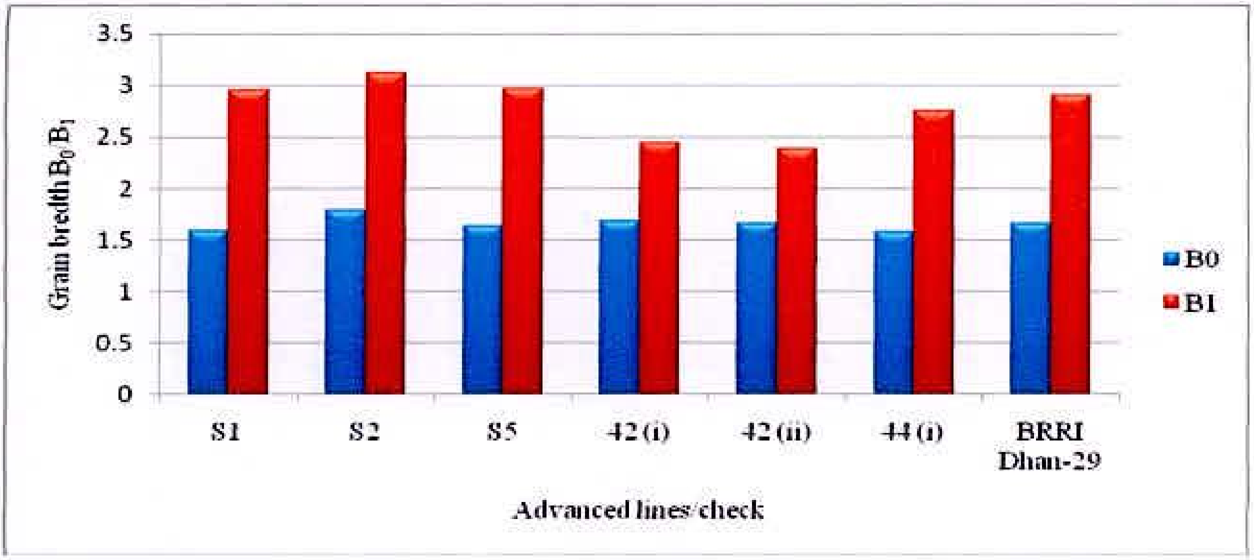


**Figure 8. Relative performance of advanced lines and check for kernel breadth before cooking and kernel breadth after cooking**

(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 kernel elongation and cooked kernel length. Kernel elongation was primarily influenced by kernel shape and size. A comparative view of milled and cooked rice of Basmati advanced lines and check is presented in Plate 6.

Therefore, elongation ratio ($L_1/L_0$) 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 (1990). Urban people prefer varieties that expand more in length than breadth (Choudhury, 1979). Relative performance of advanced lines and check for elongation ratio is presented in Figure 9.

#### 4.3.2.3 Water absorption (%)

Water absorption for different advanced line of rice varied significantly (Table17). The highest water absorption (294%) was recorded from 44(i) and the lowest (210%) recorded from BRRIdhan29. 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 (1980) have reported still wider range (74-439%) of variation for this character. Zaman (1981) 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.

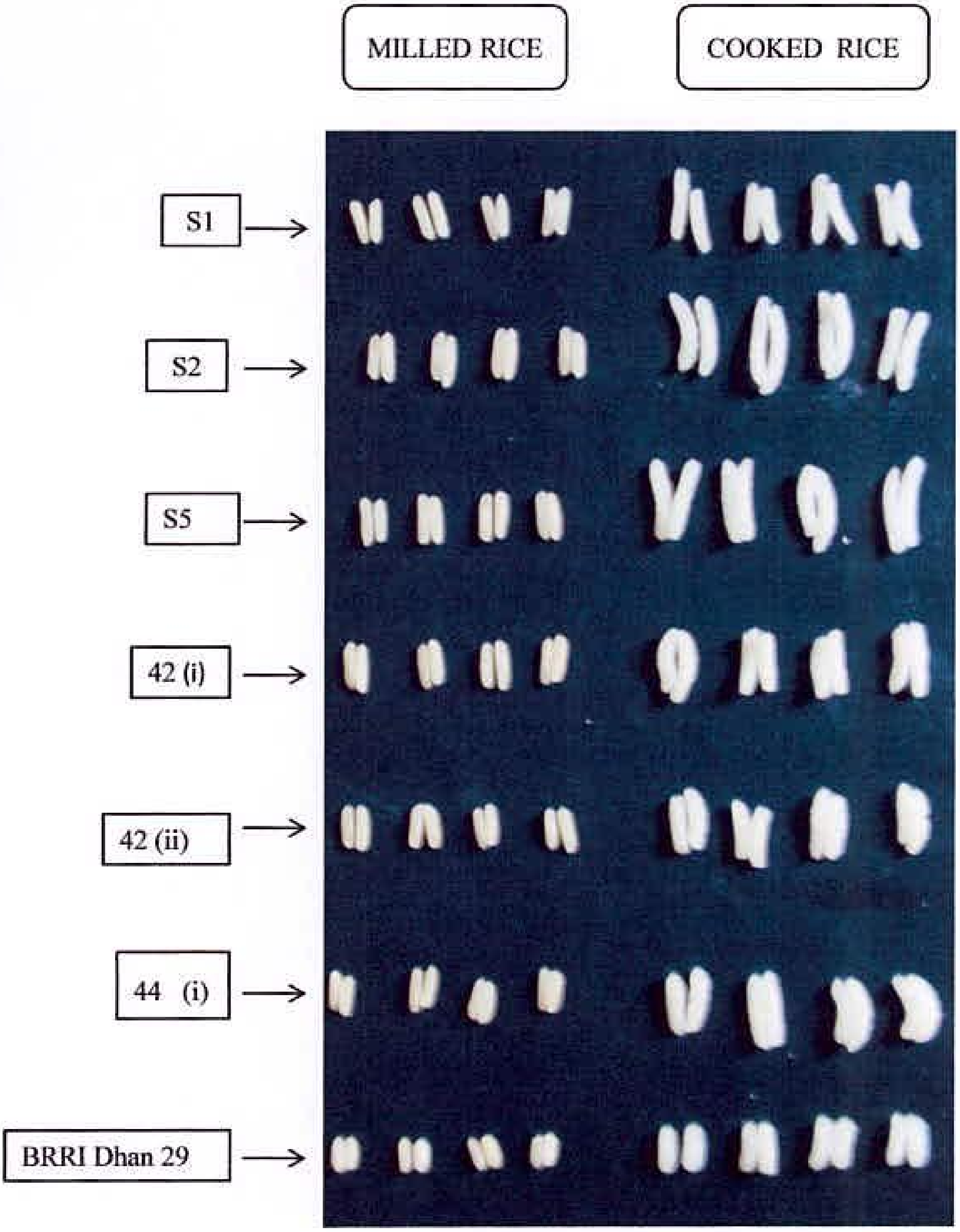


**Plate 6. A comparative view of milled rice and cooked rice of different basmati advanced lines and check**

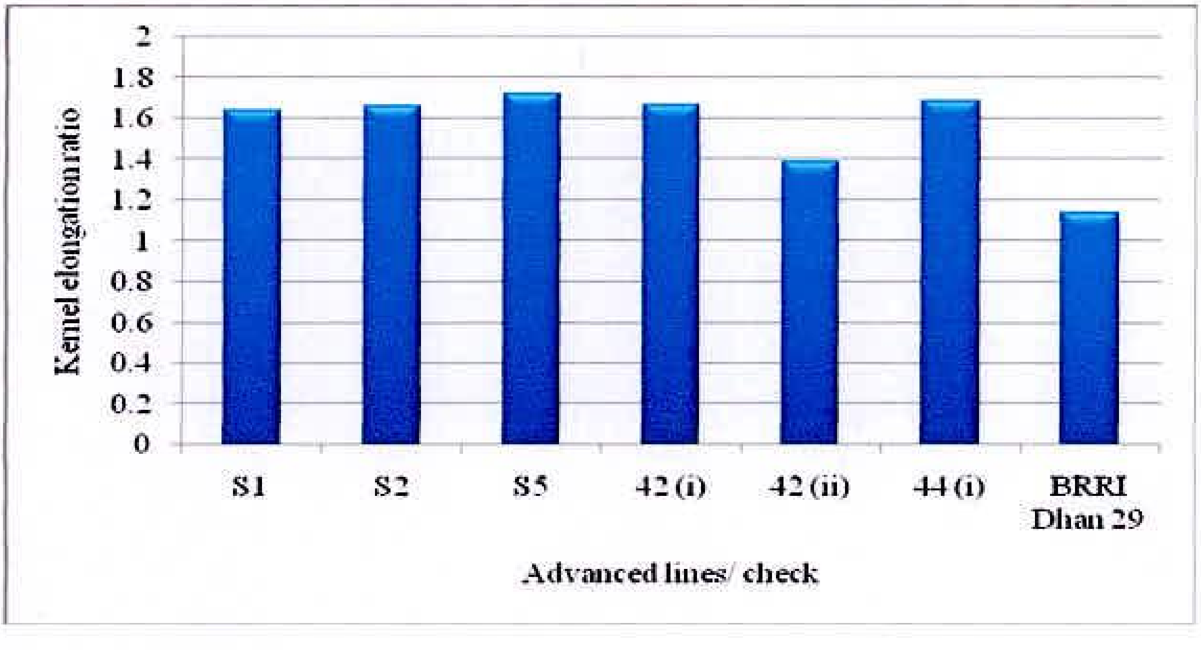


**Figure 9. Relative performance of advanced lines and check for kernel elongation ratio**

#### 4.3.2.4 Volume expansion (%)

Volume expansion for different advanced line of rice varied significantly (Table 17). The maximum volume expansion (4.41%) was recorded from S5 and the minimum (4.00%) recorded from 44(i). Volume expansion of kernels on cooking is considered another important measure of consumer preference. More volume of cooked rice from a given quantity is a matter of great satisfaction to an average rice consumer irrespective of the fact whether the increased volume is due to length-wise or breadth-wise expansion. 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.

#### 4.3.2.5 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. 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) (Beachell and Stansel, 1963;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 18). The highest alkaline spreading value (7.00) was recorded from S2 and the lowest (3.83) was recorded from BARIdhan29.

Study of world collection of rice at IRRI reveals that traditional tropical rice varieties, in general, are of intermediate GT with the exception of Bulk and Waxy rices that are

**Table 18. Classification of basmati advanced lines and check variety on the basis of Alkali spreading score, Alkali spreading value and GT types**

| Sl.No. | Lines/check | Alkali spreading value | Range | Alkali digestion | GT types |
|---|---|---|---|---|---|
| 1 | S1 | 6.00 | 5.66-6.33 | High | Low |
| 2 | S2 | 7.00 | 7.00 | High | Low |
| 3 | S5 | 4.25 | 4.17-4.33 | Intermediate | Intermediate |
| 4 | 42 (i) | 4.59 | 4.50-4.67 | Intermediate | Intermediate |
| 5 | 42 (ii) | 4.25 | 4.17-4.33 | Intermediate | Intermediate |
| 6 | 44 (i) | 4.25 | 4.17-4.33 | Intermediate | Intermediate |
| 7 | BRRI Dhan 29 | 3.83 | 3.83 | Intermediate | Intermediate |

GT= Gelatinization temperature

characterized with low GT with low GT (IRRI, Annual Report, 1977). A comparative view of alkali spreading value of Basmati advanced line and check is presented in Plate 7.

### 4.3.2.6 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 its 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 17). The highest cooking time (20 minutes) was recorded from BRRI Dhan 29 and the lowest (16 minutes) recorded from S2. The linear kernel elongation after cooking is compared with the original length of kernel before cooking (Irshad, 2001). Relative performance of advanced lines and check for alkali spreading value and cooking time is presented in Figure 10.

### 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 19).

Correlation study reveals that in lines hulling percent has highly significant positive relationship with milling percent and HRR percent and significant positive relationship with kernel breadth 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 HRR per cent is found with kernel breadth of milled rice and insignificant positive relationship with kernel breadth of rough rice, kernel length, breadth and L/B ratio of brown rice, kernel length of milled rice, kernel breadth of cooked rice and alkali spreading value and insignificant negative relationship with

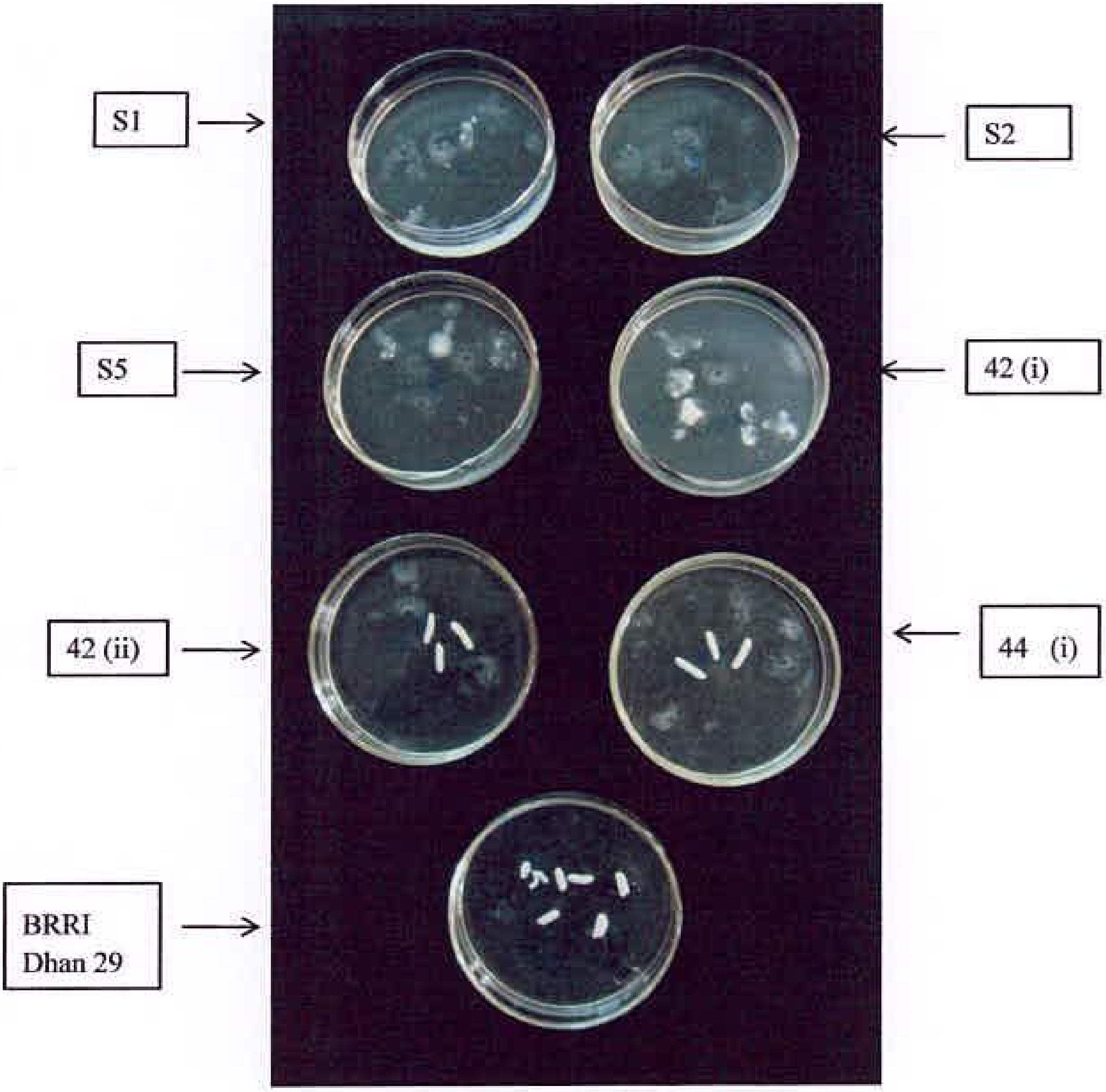


**Plate 7. Showing Alkali spreading value (GT) of basmati lines and the check variety**

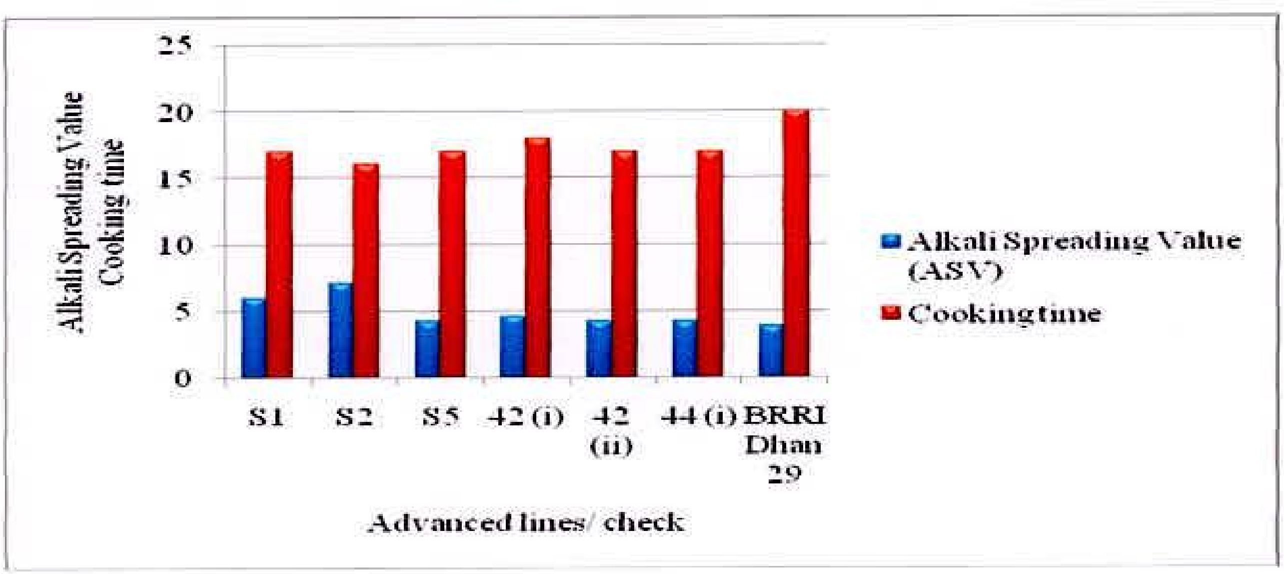


**Figure 10.Relative performance of advanced lines and check for Alkali spreading value and cooking time**

## Table 19. Genotypic and phenotypic correlation of various quality characters

| | | M | HRR | KLRR | KBRR | l/b RR | KLBR | KBBR | l/b BR | KLMR | KBMR | l/b MR | KLCR | KBCR | l/b CR | WU | VE | ER | ASV |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | $r_g$ | 0.978** | 0.845** | -0.345 | 0.345 | -0.777* | -0.183 | 0.005 | -0.215 | -0.123 | 0.768* | -0.497 | -0.21 | 0.249 | -0.327 | -0.273 | -0.361 | 0.259 | 0.344 |
| | $r_p$ | 0.921** | 0.487 | -0.293 | 0.33 | -0.671* | -0.156 | -0.01 | -0.176 | -0.118 | 0.562 | -0.402 | -0.193 | 0.166 | -0.282 | -0.194 | -0.185 | 0.212 | 0.269 |
| M | $r_g$ | | 0.874** | -0.162 | 0.528 | -0.668* | 0.011 | 0.098 | -0.015 | 0.070 | 0.837** | -0.323 | -0.021 | 0.324 | -0.199 | -0.26 | -0.351 | 0.119 | 0.428 |
| | $r_p$ | | 0.493 | -0.136 | 0.499 | -0.604* | 0.01 | -0.02 | 0.007 | 0.069 | 0.662* | -0.252 | -0.011 | 0.223 | -0.161 | -0.243 | -0.21 | 0.162 | 0.341 |
| HRR | $r_g$ | | | -0.087 | 0.466 | -0.503 | 0.113 | 0.108 | 0.097 | 0.133 | 0.876** | -0.275 | -0.087 | 0.119 | -0.157 | -0.347 | -0.162 | -0.006 | 0.478 |
| | $r_p$ | | | -0.077 | 0.331 | -0.39 | 0.106 | 0.102 | 0.082 | 0.110 | 0.742* | -0.253 | -0.07 | 0.093 | -0.121 | -0.152 | -0.238 | 0.007 | 0.407 |
| KLRR | $r_g$ | | | | 0.731* | 0.822** | 0.976** | 0.689* | 0.966** | 0.965** | 0.160 | 0.956** | 0.951** | 0.024 | 0.862** | 0.247 | -0.207 | -0.821** | 0.311 |
| | $r_p$ | | | | 0.666* | 0.773* | 0.968** | 0.469 | 0.939** | 0.930** | 0.150 | 0.908** | 0.929** | 0.026 | 0.817** | 0.23 | -0.206 | -0.648* | 0.31 |
| KBRR | $r_g$ | | | | | 0.212 | 0.83 | 0.553 | 0.82** | 0.860** | 0.657* | 0.608* | 0.818** | 0.375 | 0.54 | 0.01 | -0.301 | -0.583 | 0.543 |
| | $r_p$ | | | | | 0.043 | 0.744* | 0.528 | 0.679* | 0.742* | 0.563 | 0.506 | 0.735** | 0.373 | 0.439 | 0.055 | -0.292 | -0.312 | 0.467 |
| l/b RR | $r_g$ | | | | | | 0.706* | 0.522 | 0.700* | 0.663* | -0.315 | 0.859** | 0.674* | -0.274 | 0.777* | 0.337 | -0.051 | -0.702* | 0.008 |
| | $r_p$ | | | | | | 0.663* | 0.181 | 0.679* | 0.610* | -0.284 | 0.786* | 0.614* | -0.285 | 0.717* | 0.261 | -0.035 | -0.603* | 0.024 |
| KLBR | $r_g$ | | | | | | | 0.684* | 0.992** | 0.994** | 0.329 | 0.906** | 0.933** | 0.064 | 0.819** | 0.184 | -0.172 | -0.792* | 0.373 |
| | $r_p$ | | | | | | | 0.451 | 0.976** | 0.977** | 0.306 | 0.880** | 0.919** | 0.056 | 0.784* | 0.169 | -0.156 | -0.617* | 0.365 |
| KBBR | $r_g$ | | | | | | | | 0.584 | 0.732* | 0.246 | 0.665* | 0.638* | -0.477 | 0.872** | 0.649* | -0.660* | -0.537 | -0.07 |
| | $r_p$ | | | | | | | | 0.249 | 0.419 | 0.076 | 0.401 | 0.434 | -0.025 | 0.476 | 0.406 | -0.404 | -0.353 | -0.038 |
| l/b BR | $r_g$ | | | | | | | | | 0.975** | 0.312 | 0.895** | 0.926** | 0.152 | 0.759* | 0.096 | -0.073 | -0.789* | 0.422 |
| | $r_p$ | | | | | | | | | 0.958** | 0.303 | 0.861** | 0.892** | 0.075 | 0.731* | 0.084 | -0.061 | -0.589 | 0.405 |
| KLMR | $r_g$ | | | | | | | | | | 0.365 | 0.896** | 0.946** | 0.047 | 0.844** | 0.233 | -0.229 | -0.752* | 0.335 |
| | $r_p$ | | | | | | | | | | 0.342 | 0.885** | 0.922** | 0.028 | 0.799** | 0.173 | -0.18 | -0.577 | 0.317 |
| KBMR | $r_g$ | | | | | | | | | | | -0.086 | 0.23 | 0.163 | 0.136 | -0.42 | -0.218 | -0.038 | 0.567 |
| | $r_p$ | | | | | | | | | | | -0.134 | 0.184 | 0.011 | 0.164 | -0.313 | -0.277 | 0.080 | 0.527 |
| l/b MR | $r_g$ | | | | | | | | | | | | 0.902** | -0.024 | 0.837** | 0.449 | -0.141 | -0.786* | 0.089 |
| | $r_p$ | | | | | | | | | | | | 0.882** | 0.022 | 0.762* | 0.339 | -0.056 | -0.645* | 0.073 |
| KLCR | $r_g$ | | | | | | | | | | | | | 0.198 | 0.818** | 0.211 | -0.241 | -0.702* | 0.325 |
| | $r_p$ | | | | | | | | | | | | | 0.196 | 0.784* | 0.167 | -0.208 | -0.526 | 0.318 |
| KBCR | $r_g$ | | | | | | | | | | | | | | -0.399 | -0.537 | 0.166 | -0.153 | 0.630* |
| | $r_p$ | | | | | | | | | | | | | | -0.443 | -0.44 | 0.189 | -0.276 | 0.527 |
| l/b CR | $r_g$ | | | | | | | | | | | | | | | 0.491 | -0.342 | -0.541 | -0.058 |
| | $r_p$ | | | | | | | | | | | | | | | 0.425 | -0.329 | -0.285 | -0.047 |
| WU | $r_g$ | | | | | | | | | | | | | | | | -0.373 | -0.169 | -0.685* |
| | $r_p$ | | | | | | | | | | | | | | | | -0.408 | -0.021 | -0.625* |
| VE | $r_g$ | | | | | | | | | | | | | | | | | 0.363 | -0.18 |
| | $r_p$ | | | | | | | | | | | | | | | | | 0.128 | -0.172 |
| ER | $r_g$ | | | | | | | | | | | | | | | | | | -0.517 |
| | $r_p$ | | | | | | | | | | | | | | | | | | -0.409 |

H=Hulling %, M=Milling outturn%, HRR=Head rice recovery %, KLRR=Kernel length of rough rice, KBRR=Kernel breadth of rough rice, l/b RR=l/b ratio of rough rice, KLBR=Kernel length of brown rice, KBBR=Kernel breadth of brown rice, l/b BR=l/b ratio of brown rice, KLMR=Kernel length of milled rice, KBMR=Kernel breadth of milled rice, l/b MR=l/b ratio of milled rice, KLCR=Kernel length of cooked rice, KBCR=Kernel breadth of cooked rice, l/b CR=l/b ratio of cooked rice, WU=Water uptake %, VE=Volume expansion %, ER=Elongation ratio, ASV=Alkali Spreading Value

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

other characters. Yadav and Singh (1989) found that hulling and milling percentage was independent of grain shape whereas HRR was negatively associated of length/breadth ratio of rough rice.

Kernel length of rough rice exhibited highly significant positive relationship with L/B ratio of rough rice, kernel length and L/B ratio of brown rice, kernel length and L/B ratio of milled rice, kernel length and L/B ratio of cooked rice and significant positive relationship with kernel breadth of rough rice but it showed highly significant negative relationship with elongation index. Kernel breadth of rough rice showed L/B ratio of brown rice, kernel length of milled rice and kernel length of cooked rice and significant positive relationship with kernel breadth of milled rice and L/B ratio of milled rice. However, it showed insignificant negative relationship with volume expansion %. Kernel L/B ratio of rough rice exhibited highly significant positive relationship with L/B ratio of milled rice and significant positive association with kernel length of brown rice, L/B ratio of brown rice, kernel length of milled rice, L/B ratio of milled rice, kernel length of cooked rice, L/B ratio of cooked rice. It showed significant negative relationship with elongation index and insignificant positive association with other characters.

Kernel length of brown rice exhibited exhibited highly significant positive relationship with L/B ratio of rough rice, kernel length of brown rice, L/B ratio of milled rice, kernel length of cooked rice, L/B ratio of cooked rice and significant positive relationship with kernel breadth of brown rice but significant negative relationship with elongation index and insignificant relationship with other character. Kernel breadth of milled rice showed highly significant positive relationship with L/B ratio of cooked rice and significant positive relationship with kernel breadth of brown rice, L/B ratio of milled rice, kernel length of cooked rice and water uptake %. L/B ratio of brown rice exhibited highly significant positive relationship with kernel length of milled rice, L/B ratio of milled rice, kernel length of cooked rice and significant positive relationship with L/B ratio of cooked rice but insignificant relationship with other characters.

Kernel length of milled rice exhibited highly significant positive relationship with L/B ratio of milled rice, kernel length of cooked rice, L/B ratio of cooked rice and significant negative relationship with elongation index and insignificant positive relationship with other characters.

Kernel length of cooked rice exhibited highly significant positive relationship with L/B ratio of cooked rice but significant negative relationship with elongation index. It showed insignificant relationship with other characters. Kernel breadth of cooked rice showed significant positive relationship with alkali spreading value and insignificant relationship with other characters. Kernel L/B ratio of cooked rice showed insignificant positive relationship with water uptake % but insignificant negative relationship with all characters.

Water uptake % exhibited significant negative relationship with alkali spreading value and insignificant negative relationship with volume expansion % and elongation index. Juliano et al., (1965) have reported negative relationship between water absorption and GT with low correlation coefficient., Sood and siddiq (1996) reported that water uptake shows positive and significant influence on volume expansion. Volume expansion % showed insignificant negative relationship with alkali spreading value but positive insignificant relationship with elongation index. Elongation index showed insignificant positive relationship with alkali spreading value.

# Chapter 5

# Summary and Conclusions

# 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 consumer acceptance, it is essential the variety/ 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 carried out with the following objectives:

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

The present investigation was carried out at the experimental Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December 2008 to July 2009. The advanced line of basmati rice S1, S2' S5, 42(i), 42(ii), 44(i) and the check variety BRRIdhan29 used for the evaluation. 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 check 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.
- Wide range of mean values for different characters showed presence of wide variability in the experimental.
- All the lines were superior to best yielding check in man performance with respect to number of effective tillers per plant, panicle length and 1000-grain weight.
- However , the check BRRI Dhan 29 exhibited better performance in respect to number of filled spikelets per plant, yield per plant and yield (t/ha).

- Correlation coefficient analysis showed significant positive correlation between-
    - ✓ Plant height and panicle length
    - ✓ Number of effective tillers per plant with yield
    - ✓ Number of filled spikelets/ panicle with yield
- Correlation coefficient analysis showed significant negative correlation between-
    - ✓ Plant height and yield
    - ✓ Panicle length and yield
- Path analysis revealed that positive path coefficients of number of filled grains per panicle, 1000-seed weight, days to 50% flowering indicated the importance of these characters as a secondary trait in the selection to increase grain yield. In addition, plant height character which had negative direct effect on grain yield should be considered in the selection process by selecting rice plant type with semi-dwarf or intermediate plant height.
- The study also revealed existence of variability in respect of quality traits in the material. This offers a scope for exploitation of quality traits in improvement of quality of basmati advanced lines.
- Most of the lines showed lower hilling percent, milling percent and head rice recovery per cent than the check BRRI Dhan 29. This is because of their breakage during milling due to long grain. But, the S2 advanced line showed superior performance in respect of hilling percent, milling percent and head rice recovery per cent than the check BRRI Dhan 29.
- All lines had long slender grains.
- Superior cooking performance over BRRI Dhan 29 was observed in-
    - ✓ All the lines for length of cooked rice elongation
    - ✓ All the lines for kernel elongation ratio
    - ✓ One line for volume expansion
- Maximum lines showed intermediate GT which is preferred by the consumers.

- All the lines were identified having acceptable grain quality with translucent endosperm appearance but overall performance in relation to cooking and eating point of view S2 advanced line performed better.
- Correlation coefficient analysis showed significant positive correlation between-
  - ✓ Hulling and milling percent
  - ✓ HRR per cent and kernel breadth of milled rice
  - ✓ Kernel 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 areas may be suggested:

1. Promising lines with high level and good grain quality may further be evaluated in multilocation trial for regional adaptability;
2. The lines should be further evaluated to determine amylose content, protein content etc.
3. Keeping in view the market acceptability of the lines should be further improved for high yield with acceptable quality through breeding.

Though, yield of the tested lines is lower than the check but superior in respect to quality. Besides, the market price of Basmati rice is 2-3 times higher than coarse rice. Therefore, it is essential to develop variety possessing more stable yield performance, improved grain quality with higher yield potential.

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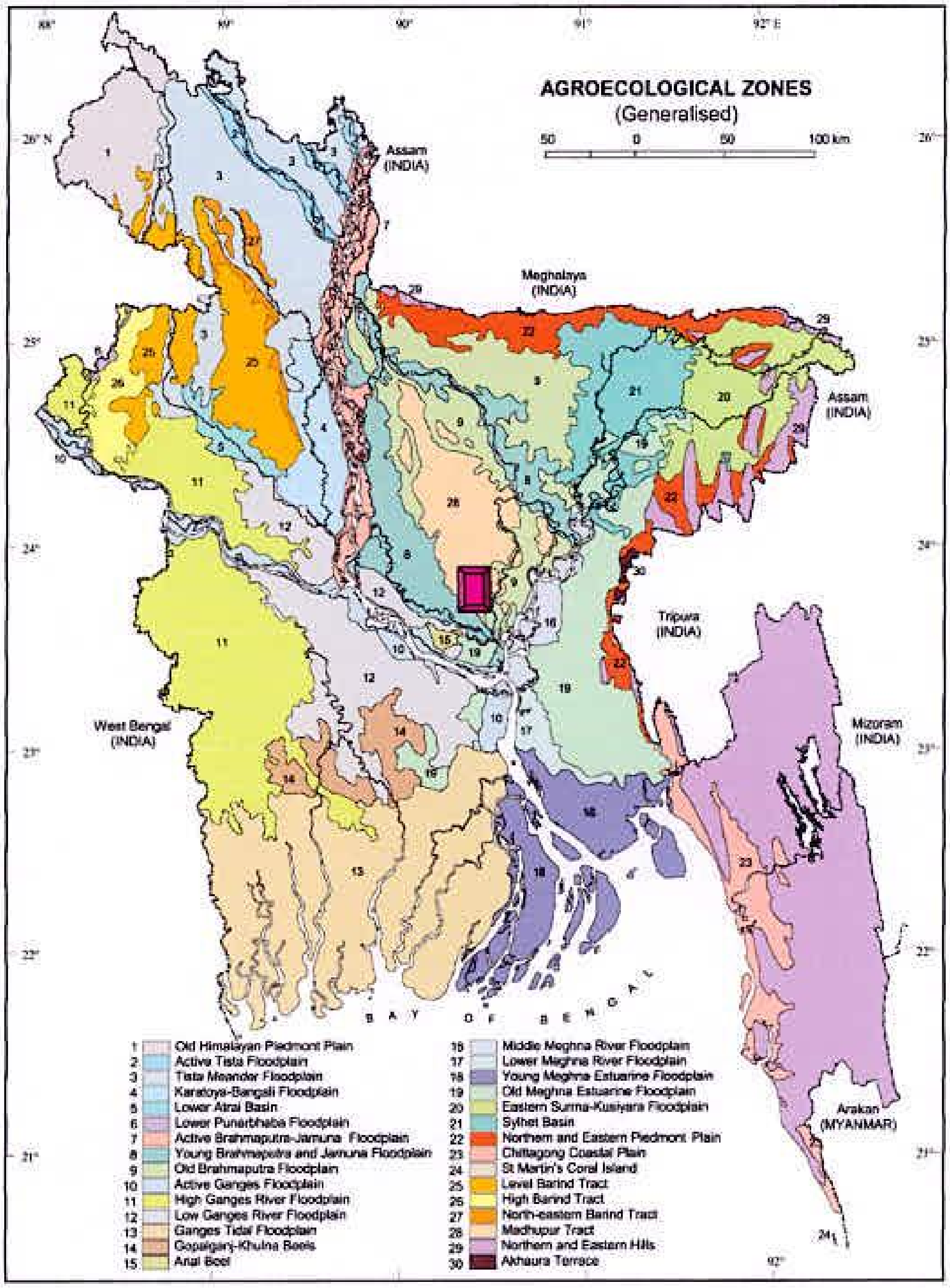
# APPENDICES

## Appendix 1. Map of the experimental site



## Appendix II. Characteristics of experimental soil is analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka

### A. Morphological characteristics of the experimental field

| Morphological features | Characteristics |
|---|---|
| AEZ | Madhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | Medium high land |
| Flood level | Above flood level |
| Drainage | Well drained |

### B. Physical and chemical properties of the initial soil

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

**Appendix III. Monthly average of temperature, humidity, total rainfall of the experiment site during the period from December 2008 to July 2009**

| Year | Month | Air temperature (°C) | | Humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|
| | | Max | Min | | |
| 2008 | December | 19.90 | 15.45 | 89.05 | 000.0 |
| 2009 | January | 14.22 | 10.55 | 90.03 | 000.0 |
| 2009 | February | 23.75 | 18.81 | 86.63 | 6.49 |
| 2009 | March | 32.2 | 26.41 | 69.74 | 6.05 |
| 2009 | April | 32.15 | 28.2 | 74.93 | 058.6 |
| 2009 | May | 31.37 | 27.90 | 76.19 | 250.64 |
| 2009 | June | 32.26 | 29.26 | 63.6 | 379.4 |
| 2009 | July | 32.19 | 25.94 | 85.07 | 363.60 |

Source: Bangladesh Meteorological Department (Climate division), Agargoan, Dhaka