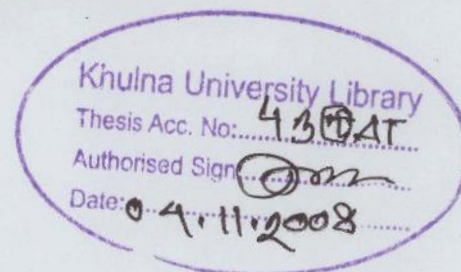


PERFORMANCE OF SALT TOLERANT RICE GENOTYPES IN
COASTAL SALINE SOILS OF KHULNA REGION
DURING BORO SEASON



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April, 2008

Dedicated to
My
Beloved Ma



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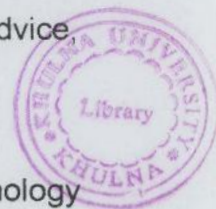
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The Author

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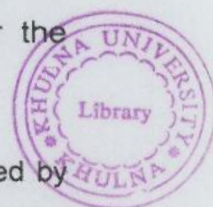
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ABSTRACT

The experiment was carried out at Kismat Fultola village under Batiaghata upazila in Khulna district during the Boro season 2004-05 to study the performance of five salt tolerant Participatory Variety Selection (PVS) materials and 2 somaclones. As the coastal saline area in Khulna region is mostly monocropped, these salt tolerant genotypes were chosen to investigate for adoption as boro rice variety. The experiment was laid out in randomized complete block design with three replications. BRRI recommended fertilizer doses were applied for cultivation of rice. The data on agronomic characters viz. plant height, effective tillers hill⁻¹, panicle length (cm), filled grains panicle⁻¹, unfilled grains panicle⁻¹, 1000 grains weight, grain yield, biological yield and harvest index were recorded. Also the phenotypic acceptance like penultimate leaf angle, flag leaf angle, culm length, culm angle, panicle type, panicle exertion, etc. were also recorded. Results showed that tested genotypes had significant effect on different yield contributing characters and phenotypic acceptance. Among the five PVS materials, two somaclones and the check variety the highest grain yield was obtained from the PVS material, PVS-B3 (5.84 t ha⁻¹) and the lowest from the somaclone, BRRI dhan29-SC³-22 (2.59 t ha⁻¹). The maximum biological yield and the highest harvest index were also recorded from PVS-B3 (10.87 t ha⁻¹ and 53.73% respectively). Since, PVS-B3 performed well and produced the highest yield in the coastal saline soil, it can be considered the most suitable genotype for the development of salt-tolerant rice varieties for boro season.

From the point of view of phenotypic acceptance, the longest panicle was produced by PVS-B3 (24.44 cm) and the shortest panicle was produced by PVS-B8 (21.29 cm). The panicle length of PVS-B9 (23.67 cm) was almost similar to PVS-B3. Though the grain length of PVS-B3 (7.7 mm) was not maximum but its width was maximum (3.37 mm) which is more acceptable as coarse-grained rice in the coastal zone. On the other hand, the grain length and grain width of PVS-B9 was 9.2 mm and 2.8 mm respectively. Although grain length of PVS-B9 was longer than that of PVS-B3 but the grain width was almost similar with PVS-B8. The grain yield of PVS-B9 (5.10 t ha⁻¹) was close to that of PVS-B3 (5.84 t ha⁻¹). Again PVS-B13 produced the second highest grain yield (5.29 t ha⁻¹) though its panicle length (22.09 cm), grain length (8.7 mm) and grain width (2.6 mm) were medium. So like PVS-B3 material PVS-B9 and PVS-B13 can be suggested to cultivate in the coastal region of Khulna district.



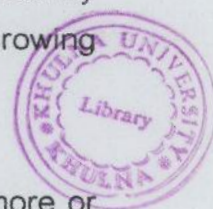
CHAPTER I

INTRODUCTION

Rice is the most important cereal crop of the world. It is the staple food for about two third of the world's population. Bangladesh is the fourth largest producer and consumer of rice in the world with an annual production ranging from 20 to 25 million tons. Rice occupies 92.24% of total cropped area (BBS, 2004); in which boro rice is cultivated in 4.15 million ha area in 2003-2004 (AIS, 2005). The average total production of rice in Bangladesh is 26.80 million m ton (AIS, 2005). Compared with mid sixties, Bangladesh has almost doubled its production during the past three decades and the growth in production came mainly from reallocation of land from traditional to high yielding modern varieties (HYVs). HYVs at present cover 95.37 % of boro, 37.52 % of aus and 51.71 % of aman rice area (BBS, 2004), while Bangladesh has attained a near self-sufficiency in food, a continuous gain in rice production is essential to meet the increasing food demand. Population of Bangladesh was 147 million in the year 2007, which increases at a rate of 1.4% per annum. A modest estimate suggests that the demand for rice in Bangladesh will have to increase by over 80% in the next 20 years to feed the growing population (Zaman, 1996). Further estimate is rather more precise to feed the population by the year 2025, which is about 21% higher than the production of 2000 (Bhuiyan *et al.*, 2002). To produce the required quantity, the only option remains open is to increase production per unit area, as there is scarcity of land and most of the lands are exhausted except the coastal rice lands.

To meet this challenge rice scientists have been working to develop new and modern varieties since early sixties starting with IRRI dwarf varieties the BRRI has so far released 46 modern and 1 hybrid rice varieties for cultivation in different growing season in different agro-ecological zones of Bangladesh (BRRI, 2007). Many research works also have been conducted in the coastal saline areas of Bangladesh to develop salt tolerant high yielding varieties (HYVs) of rice.

Soil salinity is a major and the most persistent threat to boro rice in coastal region. In Bangladesh, more than 30% of the net cultivable land is in the coastal area. Of the 2.85 million ha of coastal and off-shore areas, about 1.0 million ha of arable land are affected by varying degrees of soil salinity (Karim *et al* 1990). The coastal saline soils of Bangladesh are at present mono cropped with rice. Mostly low yielding local rice varieties are grown by farmers during the wet season spanning July/August to November/December. In 60-100% of these areas, local rice varieties are grown, which yield about 2.0-2.5 t ha⁻¹ (Karim *et al.* 1990). But a substantial increase in rice area and yields is possible in boro season with the introduction of high yielding rice varieties, if continuous and responsible research work is conducted. As there are about 1 million hectares of coastal salinity-prone rice areas that produce very low yields, needs attention to boot-up production by growing salinity tolerant rice varieties. In the coastal region there are many big rivers where tidal water flows. But this water becomes saline during the dry season. Beside this, in the boro season the soil becomes too much saline which is harmful to crop. Under this situation, it needs introduction and culture of salinity tolerant rice varieties for increasing yield to ensure food scarcity of the growing population of Bangladesh.



There exist some traditional local rice varieties in Bangladesh which are more or less salt tolerant, BRRI has developed few salt tolerant somaclones through *in vitro* seed culture with NaCl stress at salinity levels of 8-15 ds m⁻¹ and some selected advanced lines with farmers' participatory varietal selection (PVS) process. These genotypes need to be tested in the farmer's field to evaluate their performance of producing higher yield in the coastal saline environment in boro season. The present study was conducted in the farmers' field with the following objectives.

1. To document the agronomic and phenotypic characteristics of salt tolerant rice genotypes under study in the coastal saline soil of Khulna district.
2. To identify the suitable genotype(s) for the salt-affected soils of Khulna district on higher yield basis.

CHAPTER II

REVIEW OF LITERATURE

A brief review of literature related to the present study has been presented in this chapter.

2.1 Effect of variety on yield and yield contributing characters

Variety may have variable effect on different plant characters of rice. Sawant *et al.* (1986) conducted an experiment with the new rice cv. R-73-1-1, R-711 and traditional cv. Ratna and reported that the traditional cv. Ratna was shortest. BRR1 (1991) also reported that plant height differed among the varieties. Shamsuddin *et al.* (1988) conducted an experiment with 9 different rice varieties and observed that plant height differed significantly among the varieties.

The number of effective tillers i.e., number of panicles per hill may also be influenced by variety. Babiker (1986) carried out an experiment with rice cv. Giza 171 and Giza 180 and observed that total tillers per hill were significantly affected by the cultivars. The variable effects of cultivar on number of panicles per hill were also observed by Kamal *et al.* (1988) and Shamsuddin *et al.* (1988). Idris and Matin (1990) reported that total number of tillers per hill was identical among the varieties studied.

Babiker (1986) reported that panicle length differed among the varieties. Idris and Matin (1990) conducted an experiment with 6 different rice varieties and obtained different panicle length. The length was greater in IR20 than in indigenous high yielding varieties (HYVs). Kamal *et al.* (1988) carried out an experiment with BR20 and Pajam2 and found that number of grains per panicle were 107.6, and 170.9 respectively, for the two varieties. Vergara *et al.* (1974) also reported about the variable effect of variety on the number of grains per panicle.

Weight of 1000 grains may be influenced by variety. Shamsuddin *et al.* (1988) reported that 1000 grain weight of 9 cultivars ranged from 21.1 g to 31.4 g. Choudhury and Ghosh (1978) carried out a number of field trials with 62 lines and

observed that 1000 grain weight was highly variable, ranging from 9.0 to 23.0g, but 1000 grain weight was identical in BR3, BR8 and IR8 varieties. Rafey and Khan (1989) conducted an experiment with 3 different rice cultivars and reported that weight of 1000 grains differed among them.

Different workers reported the effect of rice varieties on rice grain yield. Idris and Matin (1990) reported that the rice varieties BAU 29, BAU 92, BAU 110, BAU 128, BR2 and BR8 gave different yield values. Kamal *et al* (1988) found that among three rice varieties BR3 produced the highest yield and Pajam2 yielded the lowest. Babiker (1986) reported from field trails that grain yield was significantly influenced by rice cultivars. Cho and Han (1985) reported that grain yields of line IR 7167-33-2-3-3 and RPKN-2 were 6-10 and 5-8 t⁻¹, respectively. Lipon(2003) reported in the Dainik Purbanchal that grain yield of Jatai Balam was 5-7 t/ha in Morolgang. IRRI (1978) found that that rice cv. IR36 was the highest yielder among the 276 rice cultivars studied. IRRI (1978) found that among the rice cv. IR8, IR26, and IR480-5-6, IR8 gave the highest grain yield.

Choudhury and Bhuiyan (1991) observed that grain yield was the highest in a promising line BR-802-118-3-1 followed by BR14, BR3 and BR1.

Grain quality may be differed in different varieties. Begum, *et al* (1993) reported that IR8 had less than 7%, BR3, BR8, BR12, BR15 and Pajam had 7-7.9%, BR4, BR5, BR9, BR11, BR14, HB 11 and Purbachi had 8-9% and HB IV and HB VI had more than 9% protien in the grain. Lysine content in brown rice was 3-4 g/100 g proteins in most of the varieties. Indica varieties tended to have higher protien content. Amylose content in japonica varieties was generally lower than that in indica varieties as reported by Hsich (1991). Protein content ranged from 4.94% in Ratna and Sona to 12.86% in ADT21 (Jayaprogasam *et al.*, 1988).

Badrinath *et al.* (1988) reported that CP (crude protein) content was highest in rice cv. Annampurna (7.66%) and lowest in Jaya (4.54%). Allaga-Morell (1987) compared embryo protein composition in 43 cultivars and reported that only 2 varietal grouping a similrity. Mridulasaikia (1987) reported that high yielding varieties contained more protein than local varieties. Vianna *et al.* (1984) reported

that cv. Bluebelle had the lowest protein content (6.17%) and BRIRGA 409 and RS 16-7-516-1-1-1 T2 the highest (8.09 and 7.42% respectively).

Number of spikelets per square meter decreased with increased grain size (IRRI, 1976). Yield potential is correlated positively with grain. Yield potential is defined as the product of spikelet number per square meter and average weight per grain. Spikelet number per square meter decreased linearly with increasing grain size (IRRI, 1977).

The grain size of rice is physically restricted by the hull and is considered as the most stable yield component. However, single grain weight can vary greatly within a plant and among cultivars. Increasing kernel density can increase its weight and enhance potential yield (IRRI, 1986).

The percentage of filled spikelets is determined by yield contributing factor and it is highly affected by variety, nitrogen management, soil and climate (Yoshida and Parao, 1976).

The harvest index is the ratio of the yield of grain to the biological yield. The total dry weight of a good rice crop is around 10-20 t/ha depending on variety, management and environments. The harvest index is about 0.3 for traditional tall varieties and 0.5 for improved short varieties (Yoshida, 1981). The harvest index for rice is negatively correlated with plant height (Tanaka *et al.*, 1966).

The grain-straw ratio, similar to the harvest index and extensively used in the past, is a ratio of dry grain yield to dry straw weight.

$$\text{Grain-straw ratio} = \text{Dry Grain weight} / \text{Dry straw weight.}$$

The grain-straw ratio of rice crops ranges from about 0.5 for traditional, tall varieties to about 1 for improved, short varieties. Tall plants and excessive vegetative dry matter production reduced HI. The physiological causes for variation in HI within a variety and among varieties of rice are not well understood (Yoshida, 1972). Increase in plant height is related to decrease in harvest index (HI), which is defined in the equation (IRRI, 1976).

$$\text{Grain yield} = \text{HI} \times \text{Total dry matter.}$$

Individually, the increase in the plant height as a resultant of wet-season planting or high nitrogen level resulted in a decrease in the HI. The decrease in HI was greater in the tall than in the short lines. Increase in growth duration increase the amount of dry matter produced, but does not necessarily increase grain yields. HI actually decreases with increase in growth duration, so that the resulting grain is not any lighter than that of the medium growth duration varieties. The results from the wet season show a clear negative relationship between HI and growth duration. However, growth duration of less than 100 days might still give a higher HI (IRRI, 1977). Short stature, short duration to flowering, early formation and longer maintenance of efficient canopy and large ear size or storage capacity are properties effective in increasing the harvest Index (Tsunoda, 1984).

2.2 Effect of salt on crop

The effect of salt on crop growth is believed to be largely of an osmotic nature (ASCE 1990 and Somani, 1991). If excessive quantities of soluble salts accumulate in the root zone, the crop has extra difficulty in extracting enough water from the salty solution, thereby affecting yield adversely.

Plant growth is governed by the salinity of soil solution in the field moisture range. However, due to difficulty of uptaking of soil solution and field moisture range being directly related to saturation percentage, EC of the soil extract (EC_e) has been widely recognized as an index to evaluate plant growth (ASCE, 1990 and Somani, 1991).

Plants uptake water from the soil by exerting an absorptive force greater than that which holds the water to the soil. If the plant cannot make sufficient internal adjustment and exert enough force, it will not be able to extract sufficient water and it will suffer water stress. Salts in the soil water increases the force the plant must exert to extract water and this additional force is referred to as the osmotic effect or osmotic potential (FAO, 1985).

Salts have an affinity for water. If the water contains salt, more energy per unit of water must be expended by the plant to absorb relatively salt-free water from a salty soil-water solution (FAO, 1985). FAO (1985) reported that the added energy required to absorb water from the salty soil (osmotic potential) is additive to the energy required to absorb water from a salt-free soil (soil-water potential). The cumulative effect results in an important reduction in water available to the crop as salinity increases.

Salinity effects are closely analogous to those of drought as both result in water stress and reduced growth. Stunting, leaf damage, and necrosis or obvious injury to the plant are only noticeable after prolonged exposure to relatively high salinity (FAO 1985 and Somani, 1991). Shalhevet (1994) mentioned that salinity and water stress may be additive in their effect on plant growth.

2.3 Rating of crop salt tolerance

Crop plants differ widely in their capacity to grow and develop under saline conditions. Some crops are very sensitive to salinity while others can tolerate considerable salinity. This is because some are better able to make the needed osmotic adjustments, enabling them to extract more water from a saline soil (FAO, 1985). The tolerance of a plant to salinity is a measure of its ability to withstand the effects of salt concentration in its root zone. There are some plants, which require certain amounts of salt in the growth medium and will grow and develop better under moderate salinity conditions as compared with salt demand condition. This necessitates rating of crop salt tolerance for efficient management of salt-affected soils and saline water for irrigation.

Ecologists have widely used plant survival in saline environment as a criterion to judge the salt tolerance of plants growing on uncultivated lands (Somani, 1991). Plant survival without an economic yield is of little value to a farmer. An agronomist rates the crop by knowing the yields under saline and non-saline environment. The effect of salinity on crop yield is measured either by absolute plant growth or relative plant growth.



Reeve and Fireman (1967) reviewed the available salt tolerance data, selecting only those studies, which related some known soil salinity parameters to yield and developed a relationship of yield response to salinity in the form:

$$Y_r = 100 - B (EC_e - A)$$

Where,

Y_r = relative yield of crops (%)

EC_e = mean soil salinity ($dS\ m^{-1}$)

A = salinity level at which yield begins to decline (threshold value)

B = yield loss per unit increase in salinity level beyond the threshold value (at which yield decrease linearly with rising salinity).

Somani (1991) mentioned that presumptions of uniform salinity distribution with depth and time, and linear decrease in yields with increase in salinity are serious limitations which restrict the salt tolerance ratings suggested by Mass and Hoffman (Mass and Hoffman, 1977, Mass, 1986). FAO (1985) however mentioned that the linear decrease in yield is in good agreement with field data throughout the usual range of salinity. Deviations from the linear decrease occur at yields, considerably less than 50% of potential, at which level yields are commercially unacceptable (FAO, 1985).

2.4 Factors influencing salt tolerance ratings

Crop salt tolerance ratings cannot provide an accurate estimate of the expected yield as they depend not only on salinity level but also on many other factors. The tolerance values proposed by FAO (1985) represent production potential when salinity is the only limiting factor. Such conditions, however, do not always exist. Other conditions may also limit production. Salt tolerance depends on factors such as plant, soil and environmental variables (FAO, 1985 ; Somani ,1991).

2.4.1 Plant factors

Although salinity affects plant at all stages of development, yet for some crops, sensitivity varies from one growth stage to another. Bernstein and Hayward (1958)

studied salt tolerance of several crops at different stages and observed that although grain yields in general, tend to parallel declining vegetative growth with rising salinity, noteworthy exceptions to this relationship have been observed. General crop showed distinct variation. It was reported that rice is tolerant during germination, becomes very sensitive during early seedling growth, and then becomes increasingly more tolerant with maturation (Pearson and Bernstein 1959; Kaddah, 1963). Likewise, barley, wheat, and maize are also more sensitive to salinity during emergence and seedling growth than during germination and later stages of growth and grain development (Puntamkar *et al.*, 1970; Maliwal and Paliwal 1970; Das and Meherotra 1971; Sharma *et al.*, 1971). For crops that are most sensitive during germination and early seedling development, it is of utmost importance to use cultural and management practices that enhance stand establishment (Somani, 1991).

Although salinity may delay germination and emergence, most crops are capable of germinating at higher salinity levels than they would tolerate at later stages of growth. Shalhevet *et al.* (1969) showed that peanut germinated well under high salinity, but subsequent seedling growth was severely restricted. They observed 50% reduction in seed germination at 13.0 dS^{-1} , while seedling growth and crop yield were reduced by 50% at 7.5 and 4.7 dS m^{-1} , respectively. Aich *et al.* (1994) mentioned that growth and yield of modern rice varieties decreased significantly with increasing salinity from 1.80 to 10.65 dSm^{-1} . Over this salinity range, seedling survival decreased from about 99 to 47%, while plant height decreased from about 81 to 59 cm, and yield decreased from about 5.54 to 0.85 t ha^{-1} . They obtained threshold salinity values for some high yielding varieties-BR3, Purbachi, and Iratom24 of 2.6 , 4.0 , and 2.6 dS m^{-1} and expected 50% yield reduction at EC_e of 5.95 , 7.03 , and 5.75 dS m^{-1} , respectively.

Varietal differences also exist among cultivars of annual crops. The greatest difference in tolerance appears to be among selection from cultivars of the more salt-tolerant crops. FAO (1985) reported that a careful screening of available varieties is essential if salinity of applied water makes tolerance critical. Yamakawa and Izumi (1966) observed that indica varieties of rice was more

tolerant at the germination stage than japonica ones; but at the seedling stage, while tolerance increases in indica, it further decreases in japonica varieties.

2.4.2 Soil factors

Apparently, salt tolerance may vary with soil fertility. Crops grown in fertile soils generally have abnormally high salt tolerance as compared with crops grown on soils with poor fertility (ASCE, 1990; Somani, 1991). Unless salinity causes special nutritional imbalances, added fertilizer generally had little effect or reduce salt tolerance, if the initial soil fertility was adequate (Bernstein *et al.*, 1974). However, if both salinity and low fertility are limiting yields, correction of the more limiting factors should give a yield increase (Somani, 1991). Shalhevet (1994) mentioned that at high levels of soil fertility, there would be a larger yield reduction per unit increase in salinity than at low fertility levels. Thus plants are more sensitive to salinity when conditions are conducive to high absolute yields. At extremely low fertility levels, when yields are very low, increase in salinity may have little additional damaging effect on yield.

Shalhevet (1994) mentioned that the effects of soil texture and structure are revealed through their influence on infiltration capacity, water holding capacity, and ratio of saturation water content to field capacity. Generally, soil moisture will be at its maximum immediately after irrigation and the salinity level will be at its minimum. Due to the evapotranspiration process, most of the salts are left behind in a reduced amount of soil water (ASCE, 1990; Somani, 1991). The drier the soil become becomes before the next irrigation, the higher the average salt concentration for the irrigation cycle. Since plants respond to total osmotic potential of the soil solution, the more saline the soil water, the more frequent the irrigation must be to minimize plant water stress (Somani, 1991).

2.4.3 Environmental factors

Plant response to salinity may also be influenced by Climate significantly. Three elements of climate such as temperature, humidity, and rainfall influence soil salinity. Of these temperature is the most critical (Shalhevet, 1994). In general, crops grown in cooler weather or during the cooler time of the year will have a higher tolerance for salinity than similar crops grown during warmer, drier periods

(FAO, 1985; ASCE, 1990). High temperature increases ET and decreases the salt tolerance of crops. High temperature increases the stress level to which a crop is exposed, either because of increased transpiration rate or because of the effect of temperature on the biochemical transformation in the leaf (Shalhevet, 1994). Since crop demand for water is less during the cooler periods, the effect of reduced water availability due to salinity is not so critical.

Generally there is increased depression in salt-induced growth damage under high than under low light intensities (Neinman and Poulsen, 1971). High light intensity reduced salinity-induced photosynthesis in beans (Gale *et al.*, 1967). In those plant species where osmotic adjustment is incomplete, high levels of radiation will intensify salinity damage by producing water imbalance (Somani, 1991).

High atmospheric humidity decreases the rate of transpiration and is thus expected to alleviate the effect of any water imbalance due to salinity (Hoffman and Phene, 1971, Prisco and Oleray, 1973). The salinity level at which growth was reduced by 50% was increased by each increase in the level of atmospheric humidity, but onion was unaffected (Hoffman and Phene, 1971). Somani (1991) reported that whether or not high humidity will alleviate the effect of salinity depends upon the ability of plants to adjust internal osmotic pressure and to reduce loss of water, thus maintaining its internal water balance.

Rainfall indirectly helps to reduce the effect of soil irrigated with saline water. The salt accumulated during the summer crop season under saline water irrigation gets leached during the ensuing rainy season. The annual rainfall governs the salt balance of irrigated soil and seasonal rainfall controls the irrigation needs during the crop season. Gupta (1979) reported that the upper permissible limit of salinity of irrigation water for wheat is 10, 8, and 6 dS m⁻¹ for regions receiving an annual rainfall of 50, 40, and 30 cm, respectively, in light-textured soils.

2.5 Productivity of local and modern rice

Ahmed (1992) compiled experiment results of BRRI about yield of rice and non-rice crops from different agro ecological zones of Bangladesh. In the Southwestern part of Bangladesh, yield of modern and local rice varied from 3.0- to 5.3 t ha⁻¹ and from 1.7- to 3.0 t ha⁻¹ respectively.

Mondal *et al.* (1992) mentioned that yield of modern rice under irrigated conditions varied from 3.10 to 6.03 t ha⁻¹ with water productivity of about 2.30-3.49 kg ha⁻¹ mm⁻¹ in the Ganges-Kobadak irrigation system in Bangladesh.

Aich *et al.* (1994) conducted experiments to determine salt tolerance limits of modern rice varieties and observed that yield of rice varied from 0.85 to 5.54 t ha⁻¹ at various salinity levels. They found Purbachi to be more salt tolerance than BR3 and Iratom 24 and expected 25% yield reduction at salinity levels of 4.03-5.95 dS m⁻¹.

Panaullah (1993) conducted experiments under varying salinity levels and found that yield of local rice was higher than that of modern rice. Salinity at the time of sowing, active tillering, and at flowering were 1.57, 5.25, and 2.57 dS m⁻¹, respectively. Yield of local rice varied from 2.07 to 2.61 t ha⁻¹ and that of modern varieties varied from 0.91- to 1.95 t ha⁻¹.

Biswas (1988; 1990) reported that yield of modern rice varied from 2.92 to 4.96 t ha⁻¹ in the coastal saline soils of West Bengal. Yields of modern rice varieties were higher than those of traditional rice varieties when transplanted from mid-July to mid-August. But with late transplanting after the first week of September, traditional varieties yielded more than modern rice varieties and suggested that yield compensation due to delayed planting could be achieved by increasing the number of seedlings per hill from 2 to 5 for modern varieties. He also observed that seedling age higher than 5 weeks produced lower yield in modern rice, while this age was highly desirable to obtain higher yields from traditional rice varieties.

Bandyopadhyay and Maji (1993) reported from long-term Fertility studies in coastal saline soils of West Bengal that K fertilizer can be omitted without any detrimental effect on crop growth and yield, but a basal dose of P is necessary to maintain P fertility of soils. The recommended N and P fertilizer rate was 100 and 22 kg ha⁻¹, respectively.

BRRI (1997) reported an average yield of 2.0 t ha⁻¹ for local rice. Yield of modern rice varied from 2.5-to 4.5 t ha⁻¹ under recommended management practices in the Khulna district.

Seven rice genotypes were tested in these studies. Of them BRRI tested PVS-B3, PVS-B8, PVS-B9, PVS-B13 and PVS-B19 in Satkhira region in collaboration with farmeres. The farmers identified them as salt tolerant varieties. In the present study they were also found as salt tolerant up to 6-8 ds/m. Reports on the salt tolerant ability of these materials are not available. However, other workers tested many rice materials. Most of the cases salt tolerant materials were not identified (BRRI, 2007).

3.1.3 Climate

The experimental field was characterized by subtropical climate moderately high temperature and heavy rainfall during the Kharif season (April-October) and scanty rainfall with moderately low temperature during the Rabi season (November-March). The monthly total precipitation, daily average maximum temperature and evaporation and sunshine hours received during the study period are shown in Table 2. There was no rainfall in November and December 2004 and February 2005. But January and April 2005 received less than 50 mm and March 2005 received about 150 mm rainfall. The highest maximum temperature was recorded in April 2005 and the lowest maximum daily average temperature was observed in January 2005, whereas the lowest minimum temperature was recorded in January 2005 and highest in April 2005. Relative humidity of December 2004 and February 2005 was almost similar and that of November 2004 and January, March and April of 2005 was more or less similar. The maximum daily sunshine hours was recorded in December 2004 and the minimum in January 2005.

Table2. Weather data of Khulna district from November 2004 to April 2005

Month	Precipitation (mm)	Daily Average Temperature (°C)		Relative Humidity (%)	Daily Sunshine Hours
		Max	Min		
November 2004	0	29.8	18.4	81	8.110
December 2004	0	27.2	15.8	72	9.840
January 2005	15	25.2	13.5	83	6.900
February 2005	0	30.0	17.3	70	8.682
March 2005	148	32.6	22.1	82	7.522
April 2005	47	34.9	25.2	81	7.826

Source: Bangladesh Meteorological Station, Gollamari, Khulna

3.2 Experimental materials

There were five PVS (Participatory Variety Selection) materials, two salt tolerant somaclones developed through *in vitro* seed culture with NaCl stress at salinity



levels of 8-15 dS/m and a standard check variety. These genotypes were tested in the farmers' field and the treatments were:

V₁ = PVS-B3

V₂ = PVS-B8

V₃ = PVS- B9

V₄ = PVS- B13

V₅ = PVS- B19

V₆ = BRRIdhan 29-SC₃-22 (Somaclone)

V₇ = BRRIdhan 29-SC₃-25 (Somaclone)

V₈ = BRRIdhan 28 (Cheak variety)

3.3 Experimental design

The experiment was laid in Randomized Complete Block Design (RCBD) with three replications (Gomez and Gomez, 1984). The size of experimental unit was 2.0 x 5.1 m and that of the total experimental area was 21.0 x 17.0 m.

3.4 Land preparation

The land was prepared by 6 ploughing and subsequently leveled by 3 repeated laddering. The field layout was made on 29 December 2004, immediately after final land preparation. Individual plots were cleared off weeds and stubble and were finally leveled properly that no water pocket could remain in the puddle field.

3.5 Fertilizer application

The experimental plots were fertilized with Urea, Triple Super Phosphate (TSP), Murate of Potash (MP), Gypsum and Zinc Sulfate and as manure cow dung (at the rate of 2100 kg ha⁻¹) was applied. Fertilizers were applied at the rate of 100-60-40-60-10 kg N-P-K-S-Zn ha⁻¹. The whole amounts of P, K, S, Zn and cow dung were applied during final land preparation as basal. Urea was topdressed in 3 splits; first at 10 days after transplanting (DAT) at the rate of 104 g plot⁻¹, second at 28 DAT and the third one at 54 DAT at the rate of 119g plot⁻¹ per topdressing.

3.6 Crop establishment

3.6.1 Transplanting

Forty-seven days old seedlings of 5 PVS materials, 31 days old seedlings of 2 somaclones and the check variety were transplanted on 3 January 2005 using 1-2 seedlings per hill with the spacing of 25 x 15 cm. Soil of the plot was kept moist but devoid of standing water right after transplanting.

3.6.2 Intercultural operations

Weeding was done only once throughout the growing season of rice. In order to keep crop weed free one hand weeding was done at 10 DAT synchronizing with the first topdressing of urea. No remarkable infestation of insect or infection due to disease organism was noticed in the field and as a result no plant protection measure was taken.

3.6.3 Harvest and post harvest activities

Different varieties matured at different dates. The plots were harvested at their full maturity when 90% of the seeds turned golden yellow in color. The harvested crop was bundled separately, tagged properly and brought to clean threshing floor. The bundles were dried in open sunshine, threshed and the seeds were cleaned. Grain and straw yield were recorded on the whole plot basis after cleaning and sun drying. Finally, the grain yield was adjusted to 14% moisture content.

3.7 Agronomic and yield contributing characters

During harvesting randomly selected 15 plants from each plot were cut at the bottom carefully for collecting data on yield contributing characters. To avoid border effect plants were sampled from the inner rows of the experimental unit. Analysis of grain and straw and nutrient content of soil after harvest were done. A brief outline on data recording procedure followed during the study is given below.

3.7.1 Growth and development

The plant height at maturity stage was measured from ground level to the tip of the upper most panicle and the mean of 15 hills was taken as the plant height.

The number of days from soaking the seeds to 50% heading was measured and was considered the days to heading. And the number of days from soaking the seeds to the day that at least one spikelet of each plant was flowered was measured and considered as the time of flowering. The number of days from soaking to the day that 80% of all the grains of every plant were yellow was recorded and considered as the duration of maturity.

3.7.2 Yield and yield components

3.7.2.1 Panicle length

Panicle length was recorded from the basal node of rachis to the apex of each panicle. The length of each panicle from 15 selected hills was measured and the mean panicle length was calculated by averaging the panicle lengths of 15 hills.

3.7.2.2 Number of grains per panicle

Presence of food materials in the spikelet was considered as grain and total number of grains present in each panicle was counted and the means were calculated. It included both filled and unfilled grains per panicle. Grains, which were properly filled with food materials and have no damage by any means, were considered as filled grains. Empty, damaged and improperly filled grains were considered as unfilled grains. All the panicles of 15 hills were used to determine filled and unfilled grains per panicle.

3.7.2.3 Weight of 1000-grains

One thousand clean and dried grains from the seed stock of each plot were counted separately and weighed by an electrical balance. The moisture content was also measured with moisture meter. Grain moisture content was adjusted to 14% moisture content (MC) by using the following formula.

$$1000 \text{ Grain weight at } 14\% \text{ MC} = \frac{\{(100 - \text{Sample MC}) \times 1000 \text{ grains weight at sample MC}\}}{(100 - 14)}$$

3.7.2.4 Grain yield

Grains obtained from whole plot were sun dried and weighed carefully. Grain yield was measured using a Triple Beam Balance. The moisture contents (MC) of the grains in each plot were also measured by a Grain Moisture Meter. Grain yield of each variety was measured and finally expressed at 14% moisture content by using the following formula:

$$\text{Grain yield at (kg/ha)14\% MC} = \frac{\text{Plot yield (gm)}}{\text{Plot area (m}^2\text{)}} \times \frac{10(100-\text{MC})}{86}$$

3.7.2.5 Straw yield

Straw yield was also measured from each experimental unit. All the straw obtained from each plot was sun dried and weighed separately by a Triple Beam Balance. The straw yield for each variety was determined and was finally converted to kg per hectare

3.7.2.6 Biological yield

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated by summing up of grain and straw yield.

3.7.2.7 Harvest index

Harvest index is the ratio of grain yield to biological yield and was calculated with the following formula:

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

3.8 Phenotypic acceptance at different growth stages of rice

3.8.1 Penultimate leaf angle

Penultimate leaf angle of the tested rice genotypes was measured. The angle between culm and the line between collar and tip of the blade of the leaf below the

flag leaf is called the penultimate leaf angle. It was measured in degrees at two stages, first at early booting and second at late boot stage.

3.8.2 Flag leaf angle

Flag leaf angle of the tested rice genotypes was measured when the first spikelet was just visible. It was measured near the collar as the angle of attachment between the flag leaf blade and the main panicle axis and expressed in degree.

3.8.3 Culm length

Culm length was measured twice at 2 stages of rice plant. First, it was measured at half way to anthesis and secondly it was measured in between anthesis complete and watery ripe caryopsis. It was measured from the point where the highest roots started up to the neck of the panicle.

3.8.4 Culm angle

The angle between the culm and the ground level is called the culm angle and it was measured by standard angle measuring device used in geometry box. The culm angle was measured twice during the growth span of rice. First it was measured when the anthesis was completed and then at medium milk stage.

3.8.5 Panicle type

Panicle type was observed visually and recorded when the anthesis was completed and at medium milk stage of the rice plant.

3.8.6 Panicle exertion

Panicle exertion was observed visually and recorded twice during the growth span of rice. First was recorded in between anthesis completed and caryopsis watery ripe, and secondly at medium milk stage.

3.8.7 Strength (lodging resistance)

The lodging resistance of culm was observed by gently pushing the tillers back and forth a few times oscillating about at an angle of 45 degrees. After some time of pushing the tillers the plants stood erectly. Thus by observing the lodging condition of culm the final observation was recorded.

3.8.8 Secondary branching of panicle

The appearance of secondary branches bearing the spikelets of panicles was observed at soft dough stage. Depending on the number of secondary branches bearing the spikelets present on the panicle observation were made and termed as absent or light or heavy or clustering.

3.8.9 Spikelet sterility

The spikelet sterility was determined in between hard dough and caryopsis stage by pressing the thumb nail on the spikelet. Five plants per experimental unit were taken to document spikelet sterility. All the spikelets from the sampled plants were checked individually and filled and unfilled spikelets were identified and counted. Finally spikelet sterility was determined by calculating the percentage of unfilled grains present in the sample.

3.8.10 Panicle shattering

Panicle shattering was observed visually at the stage at caryopsis loosening in daytime. The panicles were shattered and the lost caryopsis was recorded. The panicle shattering was determined as percentage of lost caryopsis. It was designated as low when 1-5% caryopsis lost from the panicle, as moderate when 6-25% caryopsis lost and as high when more than 25% caryopsis was lost.

3.8.11 Threshability

The threshability was determined at the stage of caryopsis loosening at daytime. One panicle was grasped by hand and a slight rolling pressure was applied with palm and fingers. The removal of grains from the panicle was recorded. All the panicles of five hills per plot were used to determine threshability. The threshability was termed difficult when a few or no grain was removed from the panicle, intermediate when 25-50% grains removed and easy when more than 50% grains were removed from the panicle.

3.8.12 Leaf senescence

At the harvesting time the leaf color (retention of greenness) below the flag leaf was observed and the final observation was recorded as late or slow, intermediate, and early and first. When two or more leaves retained their green

color at maturity it was termed as late and slow, when leaves were nearly ripe it was termed as intermediate and when the leaves were dead it was termed as early and first.

3.8.13 Grain width and length

The length of the grain was measured at caryopsis loosening in daytime. The distance between the base of lowermost sterile lemma and the tip of the fertile lemma or palea was taken as the length of the grain. Five grains from each panicle of five samples were measured per unit plot to determine the grain length.

The width of that grains which were taken for measuring grain length was measured and for this the distance across the fertile lemma and the palea at the widest point was measured.

3.8.14 Dormancy

The dormancy was determined after harvest. One hundred matured seeds from each treatment were tested for germination percentage and the percentage was recorded to document the dormancy of rice. From one hundred seeds of the check variety BRR1 dhan 28, 82 seeds germinated that means 18% seeds were dormant. Thus the dormancy of the rest seven treatments was recorded.

3.8.15 Data analysis

The data on agronomic characters were analyzed for analysis of variances (ANOVA) by using MSTAT program and the mean values were compared by Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984) and for the data on phenotypic acceptance the average values of the data were calculated manually.

CHAPTER IV

RESULTS AND DISCUSSIONS

The experiment was conducted in Boro season 2004-05 with five PVS materials, two salt tolerant somaclones and a check variety, BRRI dhan 28 to evaluate the performance of these genotypes in the salt affected areas of Khulna district. The experiment was conducted in the farmers field at Batiaghata upazila and the research findings have been presented and discussed in the following sections:

4.1 Plant growth and development

4.1.1 Plant height

The plant height was measured at 20, 50 and 90 days after transplanting (DAT). At 20 DAT, PVS-B3 produced the tallest plant (25.10 cm) followed by PVS-B9, PVS-B13, PVS-B8, BRRI dhan28, PVS-B19, BRRI dhan29-SC₃-22 and BRRI dhan29-SC₃-25. At 50 DAT, PVS-B3 produced the tallest plant (52.9cm) which was followed by PVS-B13, PVS-B8, PVS-B9, PVS-B19, BRRI dhan28, BRRI dhan29-SC₃-25 and BRRI dhan29-SC₃-22 respectively. At 90 DAT, PVS-B9 produced the tallest plant (87.15cm) followed by PVS-B3 (86.15cm). The shortest plant height was observed in PVS-B13 (75.55 cm).

Initially the growth was faster in almost all the PVS materials than the check variety, BRRI dhan28 (Table 3), but at maturity PVS-B8 and PVS-B19 produced similar plants as the check variety and other PVS materials maintained higher plant height than the check variety. Although the somaclones produced the shortest plant initially (20 DAT), they were able to produce taller plants at maturity (90 DAT) than the check variety. Among the tested genotypes, PVS-B3 produced the tallest plant at 20 DAT and 50 DAT but finally at maturity, PVS-B9 produced the tallest plant. The tested genotypes can be grouped into two categories in terms of plant height. Among them, PVS-B3, PVS-B9, PVS-B19, BRRI dhan29-SC₃-22 and BRRI dhan29-SC₃-25 could be grouped as the tallest category rice plants and the rest three genotypes (BRRI dhan28, PVS-B8 and PVS-B13) could be considered as the medium category plants (Table 3).



Table 3. Plant height (cm) at different stages of growth of rice genotypes in Batighata upazila, Khulna, Boro season, 2004-05.

Genotypes	Plant height (cm)		
	20 DAT	50 DAT	90 DAT
PVS-B3	25.1	52.9	86.15 a
PVS-B8	19.7	48.3	76.96 e
PVS-B9	22.0	46.6	87.15 a
PVS-B13	21.8	51.5	75.55 e
PVS-B19	15.8	42.8	81.81 bc
BRRIdhan 29-SC3-22	11.5	35.1	81.07 cd
BRRIdhan 29-SC3-25	10.9	36.8	85.34 ab
BRRIdhan 28	18.1	38.8	77.47 de

4.1.2 Flowering and maturity period

The days to 50 percent heading, 100 percent flowering and days to maturity of the tested genotypes are shown in Figure 1. It was observed that 50% heading was completed early (71 DAT) in PVS B3. The two somaclones took the longest time (96 DAT) for heading. The fifty percent heading in all PVS materials including the check variety was completed in the second half of March and that occurred around mid-April in somaclones (Table 4). On the average the heading of PVS B3, PVS B8, PVS B9, PVS B13, PVS B19, BRRIdhan29-SC₃-22, BRRIdhan29-SC₃-25 and BRRIdhan 28 occurred in between 71 to 96 DAT (Table 4).

The flowering of PVS materials including the check variety was completed around the end of March, whereas that happened during mid-April for the somaclones (Table 4). Among the tested genotypes PVS B3 flowered early (82 DAT) i.e., earlier than other tested genotypes. BRRIdhan 29-SC₃-22 and BRRIdhan 29-SC₃-25 took longest time to complete flowering (about 103 DAT) (Figure 1). On an average, flowering of tested genotypes were completed in between 82 to 104 DAT.

The highest growth duration was observed in two somaclones (158 days) and the lowest in the check variety, BRRI dhan 28 (142 days) (Figure 1). The growth duration of PVS-B3, PVS B8, PVS B9 and PVS B13 were almost similar, about 6-10 days more than the check variety (Table 4). But the growth duration of PVS B19 was almost at par with the two somaclones, which was 12-16 days more than BRRI dhan28. Since the soil and river water salinity remain unsuitable for rice cultivation during March to May (Mondal et al 2004 and Mondal et al 2006), the growth duration is very important for crop intensification and productivity improvement in the coastal region of Bangladesh. Genotypes with longer growth duration than the check variety should be avoided for developing rice varieties for the Boro season. Therefore, none of the entries qualified for the development of Boro variety as far as the growth duration is concerned, but PVS-B3, PVS B8, PVS B9 and PVS B13 may be preliminarily selected for this purpose, if they out yielded the check variety, BRRI dhan28.

Table 4. Flowering and maturity periods of the rice genotypes at Batiaghata upazila, Khulna, Boro Season, 2004-05.

Genotypes	Date of sowing	Date of transplanting	Date of 50% heading	Date of 100% heading	Growth duration
PVS-B3	17. 11. 04	03. 01. 05	15. 03. 05	28. 03. 05	150
PVS-B8	17. 11. 04	03. 01. 05	21. 03. 05	31. 03. 05	152
PVS-B9	17. 11. 04	03. 01. 05	28. 03. 05	31. 03. 05	152
PVS-B13	17. 11. 04	03. 01. 05	21. 03. 05	26. 03. 05	148
PVS-B19	17. 11. 04	03. 01. 05	26. 03. 05	31. 03. 05	154
BRRI dhan 29-SC3-22	02. 12. 04	03. 01. 05	09. 04. 05	16. 04. 05	158
BRRI dhan 29-SC3-25	02. 12. 04	03. 01. 05	09. 04. 05	17. 04. 05	158
BRRI dhan 28	02. 12. 04	03. 01. 05	28. 03. 05	03. 04. 05	142

4.2.2 Panicle length

The panicle length of 5 PVS materials, 2 somaclones and the check variety varied from 21.29 to 24.44 cm (Table 5). On an average, PVS-B3 produced the longest and PVS-B8 produced the shortest panicle. Although PVS-B3 produced the longest panicle, it was at par with that produced by PVS B9, BRRI dhan29-SC₃-25 and the check variety, BRRI dhan28 at 5 % level of significance. Apparently, the panicle length of PVS B13, PVS B19 and BRRI dhan29-SC₃-22 was shorter than BRRI dhan28 but the difference was not significantly different at 5% level of significance (Table 5).

4.2.3 Filled and unfilled grains panicle⁻¹

Filled grains per panicle of 5 PVS materials, 2 somaclones and the check variety ranged from 41.25 to 92.47 (Table 5). The maximum number of filled grains per panicle was found in PVS-B13 and the minimum in BRRI dhan29-SC₃-22. Filled grains per panicle of PVS-B3, PVS-B8, PVS-B13 and PVS-B19 was statistically similar at 1% level of significance, but other PVS materials and 2 somaclones produced statistically less number of filled grains per panicle including the check variety, BRRI dhan28. Overall, the PVS materials produced significantly higher number of filled grains per panicle than the somaclones and the check variety. Even the percentage of filled grain was higher in PVS materials than the somaclones. Therefore, the PVS materials are more preferred than the somaclones in developing salt tolerant rice varieties as far as the filled grains are concerned.

The unfilled grains per panicle of 5 PVS materials, 2 somaclones and the check variety varied from 4.55 to 29.88 (Table 5). The maximum number of unfilled grains per panicle was produced by BRRI dhan29-SC₃-22 and the minimum was produced by BRRI dhan28. Overall, more unfilled grains per panicle were observed in somaclones than

Table 5. Agronomic and yield contributing characters of rice at Batiaghata, Khulna, Boro season 2004-05.

Genotypes	Effective tillers hill ⁻¹	Panicle length (cm)	Filled grains panicle ⁻¹	Unfilled grains panicle ⁻¹	1000 grain weight (gm)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index (%)
PVS-B3	12.40 d	24.44 a	91.54 a	17.49 b	21.39 b	5.84 a	5.03 ab	10.87 a	53.73 a
PVS-B8	12.60 cd	21.29 d	87.25 a	18.64b	19.27 c	4.79 ab	4.80 bc	9.60 ab	50.57 a
PVS-B9	14.87 a	23.67 ab	67.71b	17.66 b	23.52 a	5.10 ab	5.27 ab	10.37 a	49.20 a
PVS-B13	13.20 bc	22.09 bcd	92.47 a	16.15 b	19.02 c	5.29 ab	5.18 ab	10.47 a	50.44 a
PVS-B19	13.27 b	21.84 bcd	82.21 a	18.37 b	17.23 d	4.34 bc	4.04 cd	8.38 b	51.86 a
BRRI dhan29-SC ₃ -22	13.47 b	21.47 cd	41.24 d	29.88 a	19.71 c	2.59 d	5.83 a	8.42 b	30.34 b
BRRI dhan29-SC ₃ -25	12.53 d	22.77 abcd	56.82 bc	29.18 a	16.03 e	3.23 d	5.60 ab	8.83 b	36.40 b
BRRI dhan28	9.87 e	23.27 abc	53.98 c	4.55 c	12.41 f	3.59 cd	3.44 d	7.03 c	51.38 a
Level of significance	**	*	**	**	**	**	**	**	**
CV (%)	2.75	4.33	9.19	12.36	2.04	13.54	9.96	8.16	10.05

Mean values in a column having the same letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

* = significant at 0.05. ** = significant at 0.01 PVS = Participatory Variety Selection.

other tested genotypes. The unfilled grains per panicle in BRRI dhan29-SC₃-22 and BRRI dhan29-SC₃-25 was statistically similar, but the PVS materials and the check variety produced less number of unfilled grains per panicle than the somaclones and the difference was highly significant.

4.2.4 1000-grain weight

The weight of 1000 grains of the 5 PVS materials, 2 somaclones and the check variety ranged from 12.41 g to 23.52 g (Table 5). The heaviest grain was produced by PVS-B9 and lightest grain was produced by BRRI dhan28. The second heaviest grain was produced by PVS B3, followed by BRRI dhan29-SC₃-22, PVS-B8, PVS-B13, PVS-B19 and BRRI dhan29-SC₃-25, respectively. The 1000-grain weight of PVS-B9 was significantly higher than the other PVS materials, 2 somaclones and the check variety at 1% level of significance. It was observed that grains of the PVS materials and somaclones were bold and were significantly heavier than the test variety, which means BRRI dhan28 is considered as the fine-grained rice than the other tested materials. Since the farmers in the coastal region of Bangladesh prefer bold grains, the PVS materials and the somaclones are preferred in variety development for the coastal saline environments as far as the grain weight is concerned.

4.2.5 Grain yield

Grain yield of rice mainly depended on yield contributing characters like number of effective tillers hill⁻¹, number of filled and unfilled grains per panicle, number of grains hill⁻¹ and weight of individual grains. Grain yield of 5 PVS materials, 2 somaclones and the check variety ranged from 2587 to 5837 kg ha⁻¹ (Table 5). The highest and lowest grain yield was obtained from PVS B3 and BRRI dhan29-SC₃-22, respectively. The yields of PVS-B3 were statistically similar with other PVS materials at 1% level of significance, except PVS-B19. The grain yield of PVS-B19 was significantly lower than PVS -B3, but was similar with other PVS materials and with that of check variety at 1% level of significance. The somaclones produced the lowest yield, may be because of higher number of unfilled grains, but was at par with the check variety.

Since the yield of PVS materials was significantly higher than the check variety, these materials may be used for the development of salt tolerant HYV rice varieties for the boro season.

4.2.6 Straw yield

The straw yield of 5 PVS materials, 2 somaclones and the check variety varied from 3.44 to 5.83 t ha⁻¹ (Table 5). The highest straw yield was produced by BRRI dhan29-SC₃-22 and the lowest by the check variety, BRRI dhan28 and the difference in straw yield between the highest and the lowest was highly significant. Apparently, the straw yield production of BRRI dhan29-SC₃-22 was followed by BRRI dhan29-SC₃-25, PVS-B9, PVS-B13, PVS-B3, PVS-B8, and PVS-B19. The amount of straw produced by the genotypes PVS-B3, PVS-B9, PVS-B13, and BRRI dhan29-SC₃-25 was at par with that produced by BRRI dhan29-SC₃-22. But other tested genotypes including the check variety produced significantly lower straw yield than BRRI dhan29-SC₃-22 at 1% level of significance.

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4.2.7 Biological yield

The biological yield of the tested 5 PVS materials, 2 somaclones and the check variety ranged from 7.03-to 10.87 t ha⁻¹ (Table 5). Among the genotypes, PVS-B3 produced the highest biological yield and the check variety, BRRI dhan28 produced the lowest, and the difference was highly significant. The biological yield of PVS-B3, PVS-B8, PVS-B9 and PVS-B13 was statistically similar at 1% level of significance but the PVS material PVS B19 and the two somaclones produced statistically lower biological yield than PVS-B3, PVS-B9 and PVS-B13. BRRI dhan28 produced the lowest biological yield, which was significantly lower than the tested PVS and somaclone materials (Table 5).

4.2.8 Harvest index

The harvest index of the tested 5 PVS materials, 2 somaclones and the check variety varied from 30.34 to 53.73% (Table 5). The highest value of harvest index was observed in PVS-B3 and the lowest in BRRI dhan 29-SC₃-22. The harvest index of 5

PVS materials was at par with that of BRRI dhan28. But the harvest index of 2 somaclones was statistically lower than the tested PVS materials and the check variety at 1% level of significance.

4.3 Phenotypic Acceptance at Different Growth Stages of Rice Plant

4.3.1 Penultimate Leaf Angle

The penultimate leaf angle at early booting stage varied from 7.00 to 12.00 degree (Table 6). On an average the highest leaf angle was observed in BRRI dhan28 and the lowest in PVS B13. Apparently penultimate leaf angle of all the tested genotypes were almost similar and was lower than the check variety, BRRI dhan28. The penultimate leaf angle of the 5 PVS materials and 2 somaclones varied in between 7.00 to 8.13 degree.

The penultimate leaf angle at late boot stage of the tested rice genotypes ranged from 4.60 to 9.93 degree (Table 6). On an average BRRI dhan29-SC₃-25 showed the highest and PVS B3 showed the lowest penultimate leaf angle. The second highest leaf angle was 8.4 degree was produced by BRRI dhan29-SC₃ -22 and this was followed by PVS B13, BRRI dhan28, PVS B9, PVS B19 and PVS B8 (Table 6). Apparently the penultimate leaf angle of all the PVS materials was at par with the check variety.

4.3.2 Flag leaf angle

The flag leaf angle was recorded when the first spikelet was just visible and ranged from 15.07 to 40.0 degree (Figure 2). On an average, the highest flag leaf angle was shown by PVS-B8 and the lowest by BRRI dhan29-SC₃-22. It was evident that, BRRI dhan28 showed the second highest flag leaf angle, which was followed by PVS-B19, PVS-B3, PVS-B9, PVS-B13 and BRRI dhan29-SC₃-25.



Table 6. Penultimate leaf angle at early and late booting stages of rice at Batiaghata, Khulna, Boro season 2004-05.

Genotypes	Penultimate leaf angle at early booting stage (degree)	Penultimate leaf angle at late boot stage (degree)
PVS-B3	7.27	4.60
PVS-B8	7.13	5.87
PVS-B9	7.07	6.33
PVS-B13	7.00	6.67
PVS-B19	8.13	6.13
BRRI dhan29-SC ₃ -22	7.93	8.40
BRRI dhan29-SC ₃ -25	7.53	9.93
BRRI dhan28	12.00	6.47

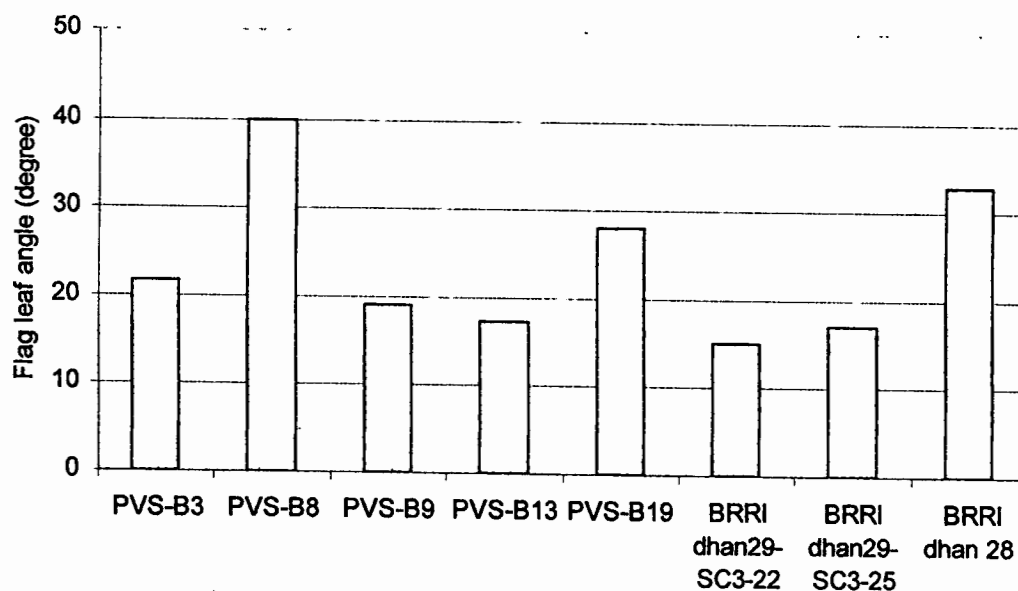


Fig. 2. Flag leaf angle at first spikelet just visible of the rice genotypes in Boro season 2004-05.

4.3.3 Culm length

The culm length at the half way of anthesis of 5 PVS materials, 2 somaclones and the check variety ranged from 44.80 to 56.64 cm (Table 8). On an average the tallest culm was produced by BRRI dhan29-SC₃-25 and the shortest was shown by the check variety, BRRI dhan28. The second highest culm length was observed in PVS-B3, which was followed by PVS-B9, PVS-B13, PVS-B8, BRRI dhan29-SC₃-22 and PVS-B19. The culm length of the PVS materials and somaclones at the halfway of anthesis was higher than the check variety (Table 7).

Table 7. Culm length of rice genotypes at different stages of growth

Genotypes	Culm length at stage anthesis half way (cm)	Culm length in between anthesis complete and watery ripe caryopsis (cm)
PVS-B3	54.17	61.70
PVS-B8	49.53	55.67
PVS-B9	50.00	53.47
PVS-B13	50.00	53.47
PVS-B19	45.73	59.97
BRRI dhan29-SC ₃ -22	49.10	59.60
BRRI dhan29-SC ₃ -25	56.64	62.57
BRRI dhan28	44.80	54.20

The culm length in between complete anthesis and watery ripe caryopsis stage of 5 PVS materials, 2 somaclones and the check variety ranged from 53.47 to 62.57 cm (Table 7). At this stage, the tallest culm was produced by BRRI dhan29-SC₃-25 and the shortest by PVS-B9 and PVS-B13. The second highest culm length was observed in PVS-B3, which was followed by PVS-B19, BRRI dhan29-SC₃-22, PVS-B8 and then BRRI dhan28. The culm length in between complete anthesis and watery ripe caryopsis stage of the PVS materials and the somaclones were either at par or higher than the check variety (Table 8).

4.3.4 Culm angle

Culm angle at complete anthesis of 5 PVS materials, 2 somaclones and the check variety ranged from 4.07 to 11.93 degree (Table 8). On an average the largest culm angle was shown by BRRI dhan28 and the smallest by BRRI dhan 29-SC₃-22. Apparently PVS-B19 showed the second largest culm angle, which was followed by BRRI dhan29-SC₃-25, PVS-B9, PVS-B3, PVS-B8 and PVS-B13. The culm angle at complete anthesis of the tested genotypes was smaller than the check variety, BRRI dhan28 (Table 8).

Table 8. Culm angle of rice genotypes at different stages of growth

Genotypes	Culm angle at complete anthesis stage (degree)	Culm angle at medium milk stage(degree)
PVS-B3	8.00	5.20
PVS-B8	6.73	7.00
PVS-B9	8.20	6.47
PVS-B13	6.00	6.73
PVS-B19	9.40	5.87
BRRI dhan29-SC ₃ -22	4.07	4.07
BRRI dhan29-SC ₃ -25	8.73	7.00
BRRI dhan28	11.93	6.00

The culm angle at medium milk stage of the tested genotypes varied from 4.07 to 7.00 degree (Table 8). On an average, PVS-B8 and BRRI dhan29-SC₃-25 showed the largest culm angle whereas BRRI dhan29-SC₃-22 showed the smallest culm angle. The second largest culm angle was observed in PVS-B13 which was followed by PVS-B9, BRRI dhan28, PVS-B19 and PVS-B3, respectively. At medium milk stage, the culm angle of the tested genotypes was almost similar with that of the check variety, except PVS-B3 and BRRI dhan29-SC₃-22 (Table 8).

4.3.5 Panicle type

The panicle types were recorded at two growth stages of rice plant. At the complete anthesis stage of the tested genotypes (5 PVS materials, 2 somaclones and the check variety) showed two types of panicles, intermediate and compact (Table 9). PVS-B3, PVS-B8, PVS-B9, PVS-B13 and PVS-B19 showed intermediate panicle type, which was similar with that of the check variety. But the tested somaclones showed compact type panicles at complete anthesis stage. But at medium milk stage, all the genotypes showed intermediate type panicles (Table 9).

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Table 9. Panicle type of rice genotypes at different stages of growth

Genotypes	Panicle type at complete anthesis stage	Panicle type at stage medium milk
PVS-B3	Intermediate	Intermediate
PVS-B8	Intermediate	Intermediate
PVS-B9	Intermediate	Intermediate
PVS-B13	Intermediate	Intermediate
PVS-B19	Intermediate	Intermediate
BRR1 dhan29-SC ₃ -22	Compact	Intermediate
BRR1 dhan29-SC ₃ -25	Compact	Intermediate
BRR1 dhan28	Intermediate	Intermediate

4.3.6 Panicle exertion

The tested 5 PVS materials, 2 somaclones and the check variety expressed 3 types of panicle exertion in between complete anthesis and caryopsis watery ripe stage of the plant (Table 10). On an average, PVS-B3, PVS-B8, and BRR1 dhan29-SC₃-22 expressed enclosed type of panicle exertion, where PVS-B9, PVS-13 and PVS-B19 expressed well exerted type and the rest BRR1 dhan29-SC₃-22 and BRR1 dhan28 expressed moderately well exerted panicles (Table 10).

At the medium milk stage, PVS-B3 and PVS-B8 expressed enclosed type of panicle exertion, PVS-B19 expressed well exerted and the rest PVS-B9, PVS-B13, BRRI dhan29-SC-22, BRRI dhan29-SC₃-25 and BRRI dhan28 expressed moderately well panicle exertion (Table 10). It was observed that 2 PVS material and 2 somaclones expressed similar exertion type panicles with that of the check variety.

Table 10. Panicle exertion of rice genotypes at different stages of growth

Genotypes	Panicle exertion in between anthesis complete and caryopsis watery ripe stage	Panicle exertion at medium milk stage
PVS-B3	Enclosed	Enclosed
PVS-B8	Enclosed	Enclosed
PVS-B9	Well Exerted	Moderately Well Exerted
PVS-B13	Well Exerted	Moderately Well Exerted
PVS-B19	Well Exerted	Well Exerted
BRRI dhan29-SC ₃ -22	Enclosed	Moderately Well Exerted
BRRI dhan29-SC ₃ -25	Moderately Well Exerted	Moderately Well Exerted
BRRI dhan28	Moderately Well Exerted	Moderately Well Exerted

4.3.7 Strength (lodging resistance)

At medium milk stage the culm strength was recorded which indicated the lodging resistance of the tested genotypes. It was observed that all the genotypes showed strong lodging resistance and were at par with that of the check variety (Table 11).

Table 11. Strength (lodging resistance) of rice genotypes at medium milk stage

Genotypes	Lodging resistance at medium milk
PVS-B3	Strong
PVS-B8	Strong
PVS-B9	Strong
PVS-B13	Strong
PVS-B19	Strong
BRRl dhan29-SC ₃ -22	Strong
BRRl dhan29-SC ₃ -25	Strong
BRRl dhan28	Strong

4.3.8 Secondary branching of panicle at soft dough stage

At the soft dough stage, the tested genotypes showed light and heavy typed panicles based on the number of secondary branches bearing the spikelets present on the panicle (Table 12). Only 3 PVS materials PVS B3, PVS B8, and PVS B13 showed similar branching of panicles with that of the check variety, which was light. The two somaclones BRRl dhan29-SC₃-22 and BRRl dhan29-SC₃-25 and PVS B9 and PVS B19 showed similar secondary branching of panicle, which was heavy.

Table 12. Secondary branching of panicle of rice genotypes

Genotypes	Secondary branching of panicle at soft dough stage
PVS-B3	Light
PVS-B8	Light
PVS-B9	Heavy
PVS-B13	Light
PVS-B19	Heavy
BRRl dhan29-SC ₃ -22	Heavy
BRRl dhan29-SC ₃ -25	Heavy
BRRl dhan28	Light

4.3.9 Spikelet sterility

Spikelet sterility of tested 5 PVS materials, 2 somaclones and the check variety at stage in between hard dough and caryopsis ranged from 8.42 to 51.11% (Figure 3). The maximum sterility was recorded in BRRl dhan29-SC₃-25 and the minimum in BRRl dhan28. The second highest sterility was recorded in case of PVS-B9, which was followed by PVS-B19, PVS-B8, BRRl dhan29-SC₃-22, PVS-B13 and PVS-B3. Overall, the sterility was much higher in the tested genotypes than the check variety, BRRl dhan28 (Figure 3).

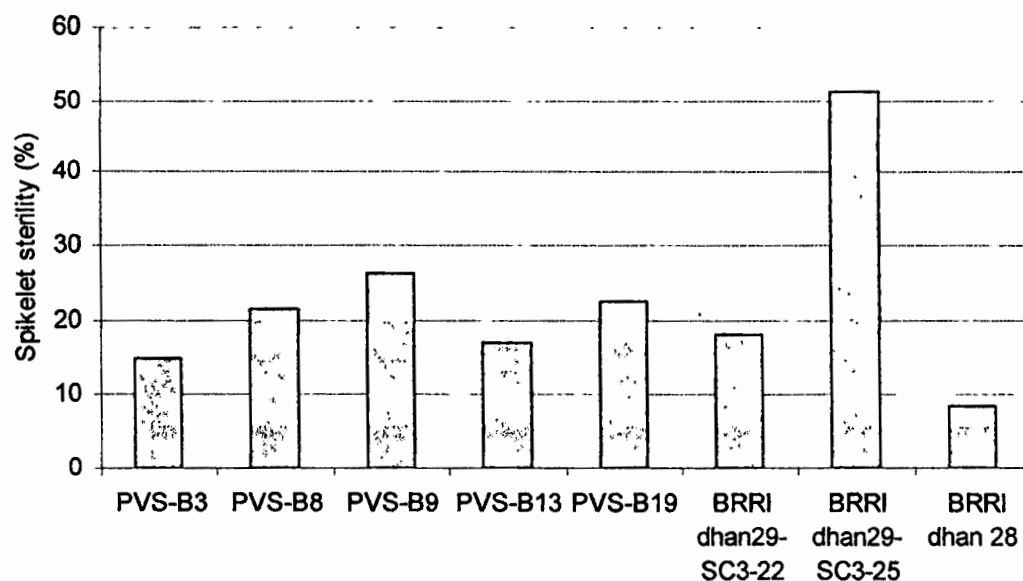


Fig. 3. Spikelet sterility in between hard dough and caryopsis stage of rice genotypes in Boro season 2004-05.

4.3.10 Panicle shattering

The tested 5 PVS materials, 2 somaclones and a check variety showed 2 types of panicle shattering, moderate and low (Table 13). Over all, panicle shattering of PVS-B3, PVS-B8, PVS-B13, PVS-B19 and BRRI dhan28 was moderate but that of PVS-B9, BRRI dhan29-SC₃-22 and BRRI dhan29- SC₃-25 was low. Most of the PVS materials showed similar panicle shattering with that of the check variety, BRRI dhan28; but the somaclones behaved differently (Table 14).

Table 13. Leaf senescence at harvest, panicle shattering and threshability at caryopsis loosening in daytime of the rice genotypes in Boro season 2004-05.

Genotypes	Panicle shattering	Threshability	Leaf senescence at harvest
PVS-B3	Moderate	Intermediate	Late and slow
PVS-B8	Moderate	Intermediate	Early and fast
PVS-B9	Low	Difficult	Late and slow
PVS-B13	Moderate	Difficult	Late and slow
PVS-B19	Moderate	Difficult	Late and slow
BRRi dhan29-SC ₃ -22	Low	Difficult	Late and slow
BRRi dhan29-SC ₃ -25	Low	Difficult	Late and slow
BRRi dhan28	Moderate	Difficult	Early and fast

4.3.11 Threshability

Threshability at caryopsis loosening in daytime of the cultivated 5 PVS materials, 2 somaclones and the check variety were observed and were classified into 2 types as intermediate and difficult (Table 13). On average, PVS-B3 and PVS-B8 maintained intermediate type of threshability and the rest PVS-B9, PVS-B13, PVS-B19, BRRi dhan29-SC₃-22 BRRi dhan29-SC₃-25 and BRRi dhan28 maintained difficult type of threshability.

4.3.12 Leaf senescence

At harvesting time leaf senescence of tested 5 PVS materials, 2 somaclones and the check variety was observed. Only one genotype (PVS B8) showed similar leaf senescence of the check variety (Table 13) and other genotypes showed leaf senescence as late and slow. Among the tested genotypes, only PVS-B8 and BRRi dhan28 showed early and fast leaf senescence, whereas PVS-B3, PVS-B9, PVS-B13, PVS-B19, BRRi dhan29-SC₃-22 and BRRi dhan29-SC₃-25 showed late and slow leaf senescence.

4.3.13 Grain width and length at caryopsis loosening in daytime

Grain length of cultivated 5 PVS materials, 2 somaclones and the check variety at stage caryopsis loosening in daytime ranged from 7.10 to 9.20 mm (Table 14). On an average, the highest grain length was recorded in PVS-B9 and the lowest in BRRI dhan29-SC₃-22. The grain length of PVS-B8 and BRRI dhan28 was the same, but other tested genotypes produced shorter grains than the check variety. The grain length of 2 somaclones and PVS-B19 was much shorter than other genotypes.

Table 14. Grain length and width at caryopsis loosening in daytime

Genotypes	Grain length (mm)	Grain width (mm)
PVS-B3	7.70	3.37
PVS-B8	9.10	2.83
PVS-B9	9.20	2.80
PVS-B13	8.70	2.60
PVS-B19	8.07	2.53
BRRI dhan29-SC ₃ -22	7.10	2.20
BRRI dhan29-SC ₃ -25	8.00	2.13
BRRI dhan28	9.10	2.50

Grain width of tested 5 PVS materials, 2 somaclones and the check variety ranged from 2.13 mm to 3.37 mm (Table 14). On an average, the widest grain was recorded in PVS-B3 and the most slender grain was found in BRRI dhan29-SC₃-25. The second widest grain was found in PVS-B8, which was followed, by PVS-B9, PVS-B13, PVS-B19, BRRI dhan28 and BRRI dhan29-SC-22. The grain width of the tested genotypes was almost similar with that of the check variety, except PVS-B3.

4.3.14 Seed dormancy

The dormancy of seed was observed after the harvest of rice. Among the cultivated genotypes the highest dormancy was observed in BRRI dhan29-SC₃-22 and the lowest in PVS-B19 and PVS-B3 (Figure 4). Dormancy percentage of BRRI dhan28

and BRRI dhan29-SC₃-25 was almost similar. Only one genotype (BRRI dhan29-SC₃-22) showed higher seed dormancy and other tested genotypes showed lower dormancy than the check variety. Overall seed dormancy of the PVS materials was lower than the somaclones and the check variety, BRRI dhan28 (Figure 4)

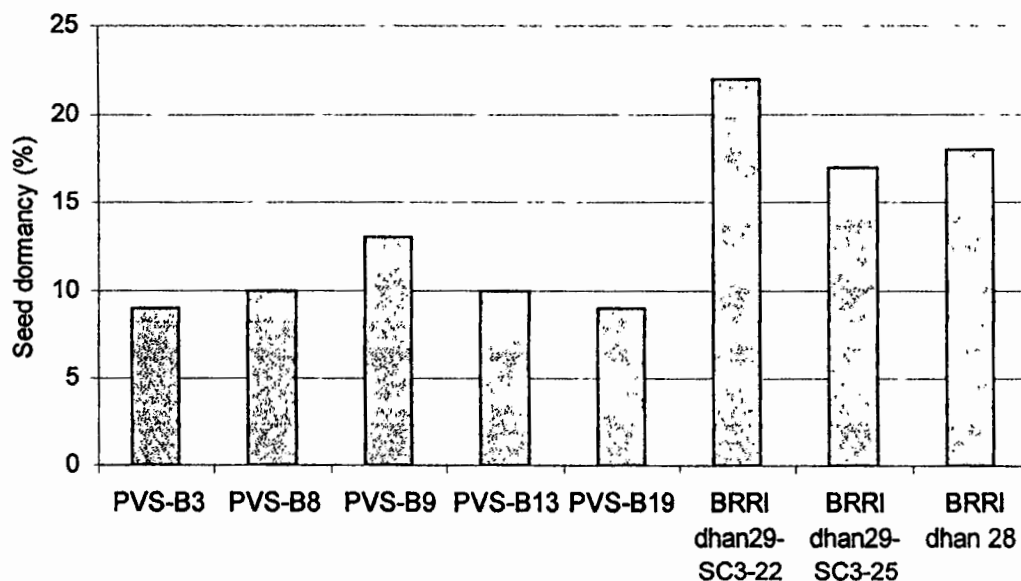


Fig. 4. Dormancy of seed after harvest of rice in Boro season 2004-05.

CHAPTER V

SUMMARY AND CONCLUSION

With a view to study the performance of 5 participatory variety selection (PVS) materials and 2 somaclones with respect of a check variety in coastal environment, a field study was carried out at Kismat Fultola village under Batiaghata upazila of Khulna district during boro season 2004-05. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The unit plot size was 5.1 x 2.0 m and the total experimental area was 21 x 17 m. Forty-seven days old seedlings of 5 PVS materials and 31 days old seedlings of 2 somaclones and the check variety, BRRI dhan28 were transplanted on 3 January 2005. Intercultural operations were done as and when necessary. Data on yield components were recorded at harvest and data on phenotypic acceptance were recorded at different growth stages of rice plant.

The data on agronomic characters like plant height, effective tillers hill⁻¹, panicle length, filled grains panicle⁻¹, unfilled grains panicle⁻¹, 1000-grain weight, grain yield, straw yield, biological yield and harvest index were recorded at maturity and analyzed by using MSTAT-C software and values were evaluated through Duncan Multiple Range Test. And the data on phenotypic acceptance at different growth stages like penultimate leaf angle, flag leaf angle, culm length, culm angle, panicle type, panicle exertion, lodging resistance, secondary branching of panicle, spikelet sterility, panicle shattering, threshability, leaf senescence, grain width and length, seed dormancy after harvest, time of 50% heading, 100% flowering and time of maturity were recorded and their average values were calculated.

Results showed that varieties had significant difference at 1.0 % level of significance for all characters except panicle length, which showed significant difference at 5.0 % level of significance. Among the five PVS materials, two somaclones and the check variety, PVS-B3 produced the highest grain yield (5.84 t ha⁻¹). The lowest grain yield (2.59 t ha⁻¹) was obtained from BRRI dhan29-SC₃-22. Crop character like panicle



length (24.44cm) and yield component like biological yield (10.87 t ha^{-1}) and harvest index (53.73%) were also the highest in PVS-B3. But PVS-B13 produced the maximum filled grain panicle⁻¹ (92.47) and plant height (87.15 cm), effective tillers hill⁻¹ (14.9) and 1000 grains weight (23.52) were maximum in PVS-B9 material.

In case of phenotypic acceptance of cultivated five PVS materials, two somaclones and the check variety at different growth stages, the maximum penultimate leaf angle (12.0°) at early boot stage was shown by BRRl dhan28. BRRl dhan29-SC₃-25 showed the maximum penultimate leaf angle (9.93°) at late boot stage, highest culm length (62.57 cm) at complete anthesis, maximum culm angle (7.0°) at stage medium milk and maximum spikelet sterility (51.11%) at stage hard dough and caryopsis. The maximum flag leaf angle (40.0°) at first spikelet just visible and maximum culm angle (7.0°) at stage medium milk were obtained from PVS-B8. PVS-B9 produced longest grain (9.2 mm) at stage caryopsis loosening at daytime whereas the widest grain (3.37 mm) was produced by PVS-B3. Maximum dormancy was obtained in BRRl dhan29-SC₃-22 (22%).

Overall, all the tested genotypes showed intermediate panicle type at complete anthesis except the 2 somaclones, but at medium milk stage all the genotypes showed panicle was intermediate. Panicle exertion at complete anthesis of PVS-B3, PVS-B8 and BRRl dhan29-SC₃-22 was enclosed; PVS-B9, PVS-B13, PVS-B19 was well exerted and BRRl dhan29-SC₃-25, BRRl dhan28 was moderately well exerted; whereas at medium milk stage the panicle exertion of PVS-B3, PVS-B8 was enclosed, PVS-B19 was well exerted and that of the rest was moderately well exerted. All the cultivated genotypes were lodging resistant observed at medium milk stage. At soft dough stage, the secondary branching of panicle of PVS-B3, PVS-B8 PVS-B13 and BRRl dhan28 was light and that of PVS-9, PVS-B19, BRRl dhan29-SC₃-22 and BRRl dhan29-SC₃-25 was heavy. The panicle shattering at caryopsis loosening at daytime of PVS-B3, PVS-B8, PVS-B13 and BRRl dhan28 was moderate and that of PVS-9, BRRl dhan29-SC₃-22 and BRRl dhan29-SC₃-25 was low. At caryopsis loosening at daytime, the threshability of PVS-B3 and PVS-B8 was

intermediate and that was difficult for the other tested genotypes. At harvesting stage, leaf senescence was late and slow for all varieties except PVS-B8 and BRRIdhan28 and they showed early and fast leaf senescence.

The following conclusion can be made from this study:

1. PVS-B3 produced longer panicle, higher grain yield, biological yield and harvest index than the other PVS materials, two somaclones and the standard check variety, BRRIdhan28. Therefore, PVS-B3 material can be selected as a salt-tolerant rice variety for growing in the coastal saline area of Khulna region in boro season. (Note: PVS-B3 has already been released as BRRIdhan 37 from Bangladesh Rice Research Institute as salt tolerant boro rice variety for the coastal region of Bangladesh.)
2. The most phenotypic character such as panicle length, grain length, and grain width of PVS-B9 and PVS-B13 were very close the standard check variety, BRRIdhan28 and PVS B3. Therefore, these genotypes could be used as advance line for further testing their suitability for the development of salt-tolerant rice varieties for boro season.

CHAPTER VI

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