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Effect of Water Regime and Seed Rate on the Productivity of Wet-Seeded Boro Rice

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ABSTRACT

On-farm field experiment was conducted in Boro seasons 2005-06 and 2006-07 to determine the suitable water regime and seed rate in wet seeded rice. The treatments consisted of six water regimes: irrigation 3 days after disappearing of water up to dough stage, continuous saturation up to 10, 20, 30 and 40 days after seeding and continuous saturation up to dough stage and two seed rates: 25 and 40 kg ha^{-1}. The experiment was laid out split-plot design with four replications. The water regime, saturation up to dough stage produced the highest grain yield followed by saturation up to 40 DAS. The decreasing the saturation period from 40 to 10 DAS decreased the grain yield of 27%. The continuous saturation required 125% more water than that of irrigation 3 days after disappearing water up to dough stage but with a 92% yield advantage. Water use efficiency (WUE) in different water regimes was identical. The higher seed rate of 40 kg ha^{-1} using single thick row of drum seeder produced significantly higher grain yield and WUE than 25 kg ha^{-1} using single thin row system.

Key words: Water regime, seed rate, productivity, wet seeded rice.

INTRODUCTION

Transplanting is the widely adopted crop establishment practice for rice cultivation in Asia including Bangladesh. Economic factors and recent changes in rice production technology have increased the desirability of direct-seeding methods. The rising labour cost and the need to intensify rice production through double and triple cropping are the main reasons for a switch to direct seeding. Direct seeding of rice offers some advantages such as faster and easier planting, reduced labour and less drudgery, more efficient water use and often higher profit in areas with an assured water supply (Balasubramanian *et al.*, 2003; Balasubramanian and Hill, 2002). The introduction of drum seeder makes the wet seeding easier. One hectare of land can be seeded in a day by one person with a drum seeder (Hossain *et al.*, 2005). Wet seeding of rice (WSR) is spreading rapidly in different countries of Asia like Vietnam, Malaysia, Thailand, Korea, China, India, and Lao PDR.

Traditional transplanted rice with standing water is most common in Asia, which needs relatively high water input. But water is becoming increasingly scarce in rice growing areas (Tuong, *et al.*, 2005). Per capita availability of water resources declined by 40-60 percent in many Asian countries between 1955 and 1990 (Gleick, 1993). In 2025, per capita available water resources in these countries are expected to decline by 14-54 percent compared with 1990 (Guerra *et al.*, 1998). Thus water scarcity threatens the sustainability of irrigated rice ecosystems (Johnson and Mortimer, 2005). Because of increasing water scarcity, there is a need to develop alternative systems that require less water. It is reported that wet seeded rice required less water compared to transplanted rice (Tabbal *et al.*, 2002). Water

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management is commonly recognized as one of the most important cultural practices that determine the plant establishment in WSR especially during the first 7-10 DAS. During this period, soil should be kept saturated but not flooded to facilitate root and seedling establishment (Lim *et al.* 1991, Awang 1995, Ho 1995, Jaafar *et al.* 1995, Pablico *et al.* 1995). As water saving technology, BRRI (2004) recommended irrigating the rice fields three days after disappearing of water from the soil surface. This irrigation system may affect the stand establishment of wet seeded rice. Again, seed rate is another factor for adequate stand establishment which may be integrated with water management options. Therefore, the study was undertaken to determine the effect of water regime and seed rate on the productivity of wet seeded rice.

MATERIALS AND METHODS

On-farm experiment was conducted in the Boro season during 2005-06 (Yr 1) and 2006-07 (Yr 2) at Sarojgonj village in Sadar Upazila of Chuadanga district. The area belongs to the agro-ecological zone of High Ganges River Floodplain (AEZ 11). The climate of the area is subtropical, with an average annual rainfall of 1,570 mm (90% of which is received during May to September), minimum temperature of 6 to 9 °C in January, and maximum temperature of 36 to 44 °C in April and May. The soils of the experimental fields at 0–15-cm depth were sandy loam in texture, with a bulk density of 1.52 g cm^{-3}, pH of 7.64, organic C of 0.86 %, total N of 0.09 %, available P of 34 ppm, exchangeable K of 0.27 meq 100 g^{-1}, S of 9 ppm and Zn of 0.78 ppm.

The treatments consisted of six water regime: (i) irrigation 3 days after disappearing of water (DADW) up to dough stage (I_1), (ii) saturation up to 10 days after seeding (I_2), (iii) saturation up to 20 days after seeding (I_3), (iv) saturation up to 30 days after seeding (I_4), (v) saturation up to 40 days after seeding (I_5) and (vi) continuous saturation up to dough stage (I_6) and two seed rates: (i) 25 kg ha^{-1} using single thin row and (ii) 40 kg ha^{-1} using single thick row of drum seeder. The experiment was laid out in a split-plot design with four replications placing the water regime in the main plot and seed rate in the sub-plot. The unit plot size was 7 m x 4.5 m. Experimental plots were isolated by 0.2 m high and 0.2 m wide levees. The levees were covered with polythene sheet inserted into the soil both sides of levee to prevent the movement of irrigation water. In the treatments I_2 - I_5, the plots were kept saturated as per treatment by irrigating on the day of disappearing water from the surface of the soil. During rest of the crop growth period, the plots were irrigated three days after disappearing of water as per recommendation (BRRI, 2004). This was continued up to hard dough stage. In the treatment I_6, the crop was grown under saturation i.e. irrigation was given on the day of disappearing water from the surface of the soil and continued up to hard dough stage while the plots under I_1 treatment were irrigated three days after disappearing of water. At the earlier stages, the growth of the crop was slower due to low temperature. During the slower growth stages of about six weeks, irrigation was given one to two centimeter and was increased two to five centimeter in the later stages.

The sprouted seeds were sown onto puddled soils through single thin and thick row of drum seeder at the rate of 25 and 40 kg ha^{-1}, respectively, on 12 December in 2005 and 7 December in 2006. Fertilizer application and all other crop management practices were done as per BRRI recommendation (BRRI, 2004). The fertilizer rates were 15, 30, 8 and 2 kg P, K, S and Zn ha^{-1}, respectively. The total amounts of P as triple superphosphate, K as KCl, S as gypsum, and Zn as zinc sulfate were applied as basal. Nitrogen was applied as urea at the rate of 120 kg ha-1 in 4 equal splits on 20, 35, 55 DAS and at the booting stage. The crop was needed manually thrice by hand as and when necessary. The crop was harvested on 2 May in 2006 and on 5 May in 2007.

The number of irrigation and time required for each irrigation in different treatments were recorded. The applied irrigation water was measured by discharge through 90° V-notch following the procedure of Mishra and Ahmed (1987). The discharge through a 90° V-notch weir was computed by the following formula:

$$Q = 0.0138 H^{5/2},$$

where Q = discharge, litres sec^{-1}, H = head, cm

The applied water was computed multiplying the discharge and the time required for each plot as follows:

WA = Qt,

where WA = water applied, litres; Q = discharge, litres sec^{-1} and t = time, second

Rainfall data were recorded from the weather station very near to the experimental plots. The total amount of water applied was computed as the sum of water received through irrigations and rainfall. The water use efficiency (WUE) was computed by dividing the grain yield by water used in the field and was expressed as kg ha^{-1}- mm.

Number of panicles at maturity was counted from three samples of one square meter each. Central 5 m^2 area of each plot was selected for measuring grain and straw yields. The grain weights were adjusted to 14 % moisture content. All the collected data were analyzed with IRRISTAT for Windows (IRRI, 2005). Duncan's Multiple Range Test (DMRT) was used at the $P < 0.05$ level of probability to test the differences between the treatment means.

RESULTS AND DISCUSSION

The number of panicles m^{-2}, number of grains $panicle^{-1}$ and 1000 grain weight were significantly influenced by water regimes (Table 1). Continuous saturation up to dough stage produced significantly higher number of panicles m^{-2} and grains $panicle^{-1}$ than other water regimes. The higher number of panicles m^{-2} and grains $panicle^{-1}$ in the same water regime were also reported by Subbulaksmi and Pandian (2002). The increased saturation period of rice fields from 10 to 40 DAS increased the number of panicles m^{-2} than the irrigation 3 DADW up to dough stage (I_1). Significantly the lowest number of panicles was recorded in I_1 treatment. The number of grains $panicle^{-1}$ mostly followed the similar trend as number of panicles m^{-2}. The lower number of grains $panicle^{-1}$ was observed in I_1 and I_2 treatments. The higher 1000 grain weight was observed in continuous saturation treatment than other water regimes, which produced the grain of similar weight. In case of seed rate, 40 kg ha^{-1} produced significantly the higher number of panicle m^{-2} and grains $panicle^{-1}$ than that of 25 kg ha^{-1} (Table 2). However, seed rate did not affect the 1000 grain weight.

Water regime significantly affected the grain yield of wet seeded rice in both the years (Table 3). It was found that continuous saturated field (I_6) gave the highest grain yield (5.24 t ha^{-1} in 2005-06 and 5.01 t ha^{-1} in 2006-07) followed by saturation up to 40 DAS (I_5). The decreasing of saturation period decreased the grain yield. However, the treatments, saturation up to 20 DAS (I_3) and saturation up to 30 DAS (I_4) produced identical grain yield. The lowest yield was found in irrigation 3 days after disappearing of water (I_1) and saturation up to 10 DAS, I_2 (Table 3). The lowest grain yield in I_1 might be due to water stress condition during the higher dry days for the treatment during plant establishment and booting to flowering stages. Grain yield decreased in I_5 compared to I_6 might be for the same reason in the later stages only. The

Table 1. Effect of water regime on the yield components and grain yield of WSR in Boro season.

Water regime	Panicles m^{-2} (no.)		Grainspanicle^{-1} (no.)		1000-grain wt (g)	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
Irrigation 3 days after disappearing of water (I_1)	219 d	213 e	65.02 c	63.20 d	18.16 b	17.63 b
Saturation up to 10 DAS (I_2)	242 c	239 d	67.93 c	64.39 d	18.20 b	17.74 b
Saturation up to 20 DAS (I_3)	250 bc	258 c	73.79 b	67.56 c	18.25 b	17.61 b
Saturation up to 30 DAS (I_4)	259 b	271 bc	75.56 b	73.34 b	18.38 b	17.67 b
Saturation up to 40 DAS (I_5)	263 b	286 b	77.11 b	73.84 b	18.45 b	17.63 b
Continuous saturation (I_6)	337 a	325 a	82.02 a	79.90 a	18.84 a	18.36 a
CV (%)	6.0	6.1	4.6	3.1	1.4	1.6

Figures in a column followed by common letter(s) do not differ significantly at the 5% level of significance. Yr 1 = 2005-06, Yr 2 = 2006-07.

Table 2. Effect of seed rate on the yield components and grain yield of WSR in Boro season.

Seed rate (kg ha^{-1})	Panicles m^{-2} (no.)		Grainspanicle^{-1} (no.)		1000-grain wt (g)	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
25	248 b	250 b	69.49 b	68.73 b	18.37	17.79
40	278 a	281 a	77.65 a	72.02 a	18.39	17.76
CV (%)	6.0	6.1	4.6	3.1	1.4	1.6

Figures in a column followed by different letter(s) differ significantly at the 5% level of significance.

Table 3. Grain and straw yield of WSR in *Boro* season as affected by water regimes.

Water regime	Grain yield(t ha^{-1})		Straw yield(t ha^{-1})	
	2005-06	2005-06	2005-06	2006-07
Irrigation 3 days after disappearing of water (I_1)	2.78 d	2.56 e	3.80 e	41.72 b
Saturation up to 10 DAS (I_2)	2.89 d	2.82 d	4.06 d	41.69 b
Saturation up to 20 DAS (I_3)	3.47 c	3.22 c	4.32 c	42.87 b
Saturation up to 30 DAS (I_4)	3.56 bc	3.41 c	4.50 c	42.05 b
Saturation up to 40 DAS (I_5)	3.72 b	3.80 b	4.76 b	42.95 b
Continuous saturation (I_6)	5.24 a	5.01 a	6.11 a	44.24 a
CV (%)	6.1	6.3	4.2	2.9

Figures in a column followed by common letter (s) do not differ significantly at the 5% level of significance.

higher grain yield in wet seeded rice under irrigation on disappearance of water or irrigation one day after disappearing water was also reported by Subbulaksmi and Pandian (2002), BRRI (2005c) and Balasubramanian and Krishnarajan (2003). The highest yield might be the contribution of higher number of panicles m^{-2}, grains panicle^{-1} and weight of 1000 grains.

The effect of seed rate on grain yield was significant in both the years (Table 4). The seed rate of 40 kg ha^{-1} produced higher grain yield (3.98 and 3.87 t ha^{-1}, in 2005-6 and 2006-07, respectively) than that of 25 kg ha^{-1} using single thin row (3.24 and 3.07 t ha^{-1}, in 2005-06 and 2006-07, respectively). The higher grain yield from the higher seed rate was the result of more number of panicle m^{-2} and grains panicle^{-1}.

The highest straw yield was recorded in continuous saturation treatment (6.11 t ha^{-1} in 2005-06 and 5.61 t ha^{-1} in 2006-07), which was statistically higher than all other water regimes (Table 3). The higher number of tillers m^{-2} and taller plant height might be responsible for higher straw yield. Difference in seed rate caused significant difference in straw yield also (Table 4).

Continuous saturation required more number of irrigation than all other water regimes (Table 5). On the other hand, irrigation 3 days after disappearing of water throughout the crop growth period required the lowest number of irrigation. The continuous

Table 4. Grain and straw yield of WSR in Boro season as affected by seed rate.

Seed rate(kg ha^{-1})	Grain yield(t ha^{-1})		Straw yield(t ha^{-1})	
	Yr 1	Yr 2	Yr 1	Yr 2
25	3.24 b	3.07 b	4.26 b	3.58 b
40	3.98 a	3.87 a	4.92 a	4.37 a
CV (%)	6.1	6.3	4.2	7.1

Figures in a column followed by different letter(s) differ significantly at the 5% level of significance.

Table 5. Irrigation and rain water received and water use efficiency by WSR in Boro season as affected by water regime.

Water regime	Number of irrigation		Irrigation water received (mm)		Rainfall received (mm)		Total water received (mm)		Water use efficiency (kg ha^{-1}- mm)	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
I_1	24	24	483 f	315 f	29	206	512 f	521 f	5.42	4.92
I_2	27	27	544 e	373 e	29	206	573 e	579 e	5.05	4.86
I_3	30	29	589 d	423 d	29	206	618 d	629 d	5.62	5.12
I_4	32	31	634 c	453 c	29	206	663 c	658 c	5.38	5.19
I_5	34	33	686 b	503 b	29	206	715 b	709 b	5.21	5.36
I_6	53	52	978 a	782 a	29	206	1007a	988 a	5.20	5.07
CV (%)	-	-	3.4	3.2	-	-	3.3	2.2	7.3	8.8

Figures in a column followed by common letter(s) do not differ significantly at the 5% level of significance.

saturation condition required significantly the highest amount of irrigation water which was higher than all other water regimes. The irrigation 3 days after disappearing of water throughout the crop growth period received the lowest amount of irrigation water and the amount of received water increased with the increased of saturation period. Irrespective of treatments the number of irrigation was higher might be due to sandy loam soil texture, shallow irrigation water depth during plant establishment (about six weeks) and higher evaporation rate due to clear sunshine with high air temperature at the experimental site at the later growth stages of crop.

On an average, the wet seeded rice received 29 and 206 mm of rain water in 2005-06 and 2006-07, respectively, during the crop growing period. The total water showed the similar trend found in received irrigation water (Table 5). Continuous saturation received the highest total water (1007 and 988 mm in 2005-06 and 2006-07, respectively). Water use efficiency (WUE) was not affected by water regime. The WUE was ranged from 5.05 to 5.62 in 2005-06 and 4.86 to 5.36 in 2006-07. Difference in irrigation and total water received was not influenced by seed rate but the WUE was affected (Table 6). The seed rate 40 kg ha^{-1} showed higher water use efficiency (6.08 and 5.70 kg ha^{-1}-mm in 2005-06 and 2006-07, respectively) than that of 25 kg ha^{-1} (4.89 kg ha^{-1}-mm in 2005-06 and 4.47 kg ha^{-1}-mm in 2006-07) might be due to higher grain yield with similar amount of total received water (Tables 2 and 6).

CONCLUSION

Continuous saturation of wet seeded rice field up to dough stage performed better in terms of grain yield. The seed rate 40 kg ha^{-1} is the better option for plant establishment and higher yield. These options might be validated in different locations before large scale adoption.

Table 6. Irrigation and rain water received and water use efficiency by WSR in Boro season as affected by seed rate.

Seed rate (kg ha^{-1})	Number of irrigation		Irrigation water received (mm)		Rainfall received (mm)		Total water received (mm)		Water use efficiency (kg ha^{-1}- mm)	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
25	33.33	32.67	650	474	29	206	679	679	4.89 b	4.47 b
40	33.33	32.67	655	476	29	206	684	682	6.08 a	5.70 a
CV (%)	-	-	3.4	3.2	-	-	3.3	2.2	7.3	8.8

Figures in a column with different letter differs significantly at the 5% level of significance

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Mineralogical Composition of the BRRI Farm Soil

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ABSTRACT

The Bangladesh Rice Research Institute (BRRI) farm soils were studied for the identification and quantification of minerals using X-ray diffraction technique (XRD). The XRD patterns were obtained with Ni-filtered Cu K α-radiation at a scanning speed of 2°2θ and mineral content was estimated by XRD peak intensities. Mica, kaolinite, interstratified kaolinite-smectite and mica-vermiculite-smectite constituted the major minerals of BRRI farm soils. The soils contained low amount of clay and have small amount of weatherable clay. The test soils may be termed as poor potential soil with respect to fertility not only because of low clay but also less weatherable clay. Due to the lower amount of K-bearing and weatherable minerals, the availability of K was found poor.

Key words: X-ray diffraction, minerals, farm soil

INTRODUCTION

BRRI is a national institute with the research strategy of developing high yielding rice varieties and their production technologies. The BRRI farm soils belong to Madhupur tract, an uplifted terrace with dissected valleys. Four pedons, namely Genda, Bhatpara, Chhiata and Naga were identified in the BRRI farm area (Evengelista *et al.*, 1999). Madhupur tract soil consists of homogeneous, unconsolidated clay of Plio-pleiostocene age and has been broken into a number of fault blocks, some of which are slightly tilled (Brammer, 1971). A part of the clays in Madhupur soil has undergone alteration by weathering while the other is less altered clays of shallowly weathered terrace sediment (Hasan, 1999).

Potassium availability to plant varies with the clay content (texture) and mineralogy of soils (Brady, 1996). Potassium availability to plants is regulated in soils by (i) its relatively weak adsorption on non-specific site charge of the cation exchange capacity (CEC), (ii) its stronger adsorption to specific site charges (edge) of the CEC and (iii) its fixation in non-exchangeable form in the lattice of the clay crystals (Mclean, 1978). Among the clay minerals, kaolinite possesses restricted surface and limited adsorptive capacity for cations and water molecules and does not exhibit colloidal properties of high order intensity (Brady, 1996). On the other hand, the smectite group commonly shows interlayer expansion, high surface area and a high cation exchange capacity, perhaps 20-40 times that of kaolinite (Brady, 1996). The CEC of vermiculite usually exceeds that of all other silicates.

Information on mineralogical composition is very important and useful with regard to availability of plant nutrients, and other physico-chemical soil properties. This study on soil mineralogy was, therefore, taken to gather information on the mineralogical composition of BRRI farm soil by X-ray diffraction technique, which is widely used for identification and quantification of clay minerals.

MATERIALS AND METHODS

The BRRI farm soil belongs to Genda, Bhatpara, Chhiata and Naga soil series (Evangelista *et al.*, 1999). The soil from each series were opened up and studied in the field, collected on natural soil horizon basis

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and preserved for physicochemical and mineralogical studies. The pH of the soils was determined at a soil water ratio of 1:2·5 using glass electrode. Cation exchange capacity of soils was determined with 1N NH_4Ac buffered at pH 7 (Jackson, 1962). The particle size analysis of soils was carried out by hydrometer method as described by Day (1964). Textural class of the soils was determined by Marshal's triangular co-ordinate diagram as described by Soil Survey Staff (1993).

For mineralogical analysis only the surface soil from four soil series were used. In order to separate clay fraction the following steps were followed: the soil samples were treated with sodium acetate and hydrogen peroxide (Jackson, 1962). Free oxides of Fe and Mn were removed from soils by the citrate-bicarbonate-dithionite extraction method as described by Mehra and Jackson (1960). After removing soluble salts, carbonate organic matter, MnO_2 and Fe_2O_3 the soils were dispersed with dilute sodium carbonate solution at pH 9.5 and the clay fraction (<2μm) was separated by sedimentation decantation processes as described by Jackson (1975). The clay samples were treated with Mg and K saturated solution of $MgCl_2.H_2O$ and KCl normal solution by repeated washing. The excess of the saturating solution was washed out with 99% alcohol and acetone until the removal of Cl. One ml of Kα-clay suspension and one ml of Mg-clay suspension were smeared on glass slide (2.5 x 4.0 cm) to prepare oriented clay suspension. Duplicate specimens were prepared for glycerol solvated heat treated slides. All these clay samples were subjected to X-ray diffraction (XRD) analysis using X-ray diffractrometer with Ni-filtered Cu K α-radiation at 40 KV and 30 mA and at a scanning speed of 2°2θ. The X-ray diffractogram of clay fractions was obtained by 5 treatments: Mg-saturated, glycerol solvated, K-saturated air dried, K-saturated heated at 550°C, K-saturated heated at 300°C. Reflection of the 14Å peak of K-saturated air dried specimen and the 10Å peak of the K-saturated heated at 550°C specimen were used for calculation of approximate quantity two minerals. For major number of minerals X-ray diffractrogram results of Mg-saturated glycerol solvated treatments have been used to calculate the quantity of minerals.

Approximate mineral contents of clay minerals were determined on the basis of the relative peak intensities in the X-ray patterns (Islam and Lotse, 1986). The intensity ratio of two components P and Q in a multi component mixtures can be related to their weight ratio as follows: $\frac{Ip}{Iq} = K_{p\cdot q}\cdot\frac{Wp}{Wq}$ where Ip and Iq are the intensities of the P and Q component in X-ray pattern, Wp and Wq are the weight proportion of P and Q components and $K_{p\cdot q}$ with constant value (0) is the intensity weight co-efficient of P and Q components.

We determined the inherent potentiality of potassium availability of soil from the particle size distribution and the nature and amount of minerals in the clay fraction.

RESULTS AND DISCUSSION

The X-ray diffractogram of clay fractions obtained by 5 treatments (Mg-saturated, glycerol solvated, K-saturated air dried, K-saturated heated at 550°C, K-saturated heated at 300°C) for each soil series of Genda, Bhatpara, Chhiata are presented in Table 1 and Figs. 1, 2, 3, 4. The peak at 18Å in the glycerol solvated specimen was taken as an indication of the presence of smectite mineral. The peak at 14Å in the glycerol solvated samples which collapsed when heated to 550°C indicated the occurrence of vermiculite. The peak at 14Å in Mg-saturated glycerol solvated samples, which did not collapse on heating at 550°C, indicated the presence of chlorite. Illite-mica minerals yielded a strong peak at the d value of 90.0Å in the glycerol solvated slide. The peak at 7.2 Å which collapsed when heated to 550°C, confirmed the presence of Kaolinite. A number of small peaks in the region of 7 to 14Å, some of which persisted on glycerol salvation of the clay specimen were indicative of the presence of interstratifying minerals. Peak at 4.25 Å indicated the presence of quartz, while goethite, feldspar and

Table: 1. Peak information of X- ray diffractogram pattern of the studied soil.

Peak no.	2θ (Degree)	D-value (Å)	FWHM* (Degree)	Integrated intensity (Count.)
		Genda		
3	5.1500	17.11295	0.50000	515
7	7.6800	11.50208	0.66660	971
8	9.1200	10.97078	0.92000	1447
10	9.4200	9.38104	0.36000	635
13	11.9600	7.99941	0.64000	690
22	17.3600	5.10417	0.68000	930
34	24.3000	3.65987	0.56000	2088
38	25.9300	3.43339	0.55000	3110
39	26.7000	3.33609	0.38660	504
		Bhatpara		
3	3.9600	22.29481	0.36000	2020
4	5.0000	17.65958	0.56000	2153
6	5.9533	14.83372	0.33330	1012
7	7.7800	9.6087	0.37600	885
13	10.2600	8.61481	0.8000	914
18	4.9800	7.38154	0.48800	2034
19	12.2400	7.22532	0.22000	1776
20	17.5572	5.04728	0.30950	4079
22	18.5000	4.79213	0.31340	1063
23	20.6065	4.30677	0.22480	1342
28	24.2600	3.60488	0.51000	4701
33	26.4400	3.37181	0.28050	12954
22	24.5800	3.61881	0.84660	11333
24	26.1868	3.4003Q	0.58970	8784
		Chhiata/Naga		
3	4.6000	19.19426	0.68000	957
6	7.8000	11.32539	0.70000	1839
7	8.3800	10.54279	0.76000	5515
10	11.8800	7.44345	0.64000	5250
13	17.800	5.03511	0.80000	3396
14	18.1800	4.87576	0.66000	1602
15	19.4650	4.55668	0.47000	620
17	20.4133	4.34709	0.45330	640
21	23.6000	3.76682	0.33340	905
22	24.5800	3.61881	0.84660	11333
24	26.1868	3.40030	0.58970	8784
		Chhiata/Naga		
3	4.5600	19.36254	0.42000	1040
4	5.2800	16.72370	0.44000	744
5	8.0400	10.98785	0.87000	1879
6	8.5900	10.28552	0.72000	3873
14	12.1400	7.28461	0.47600	2601
17	17.7196	5.00139	0.55490	4716
19	18.2400	4.73180	1.06660	3557
24	22.0000	4.03702	0.28000	623
27	23.6000	3.76682	0.53340	733
28	24.0000	3.70494	0.76000	2092
29	24.7200	3.59863	0.72000	6961
31	26.4564	3.36625	0.45290	15555

*FWHM= Full width half maxima.

Genda

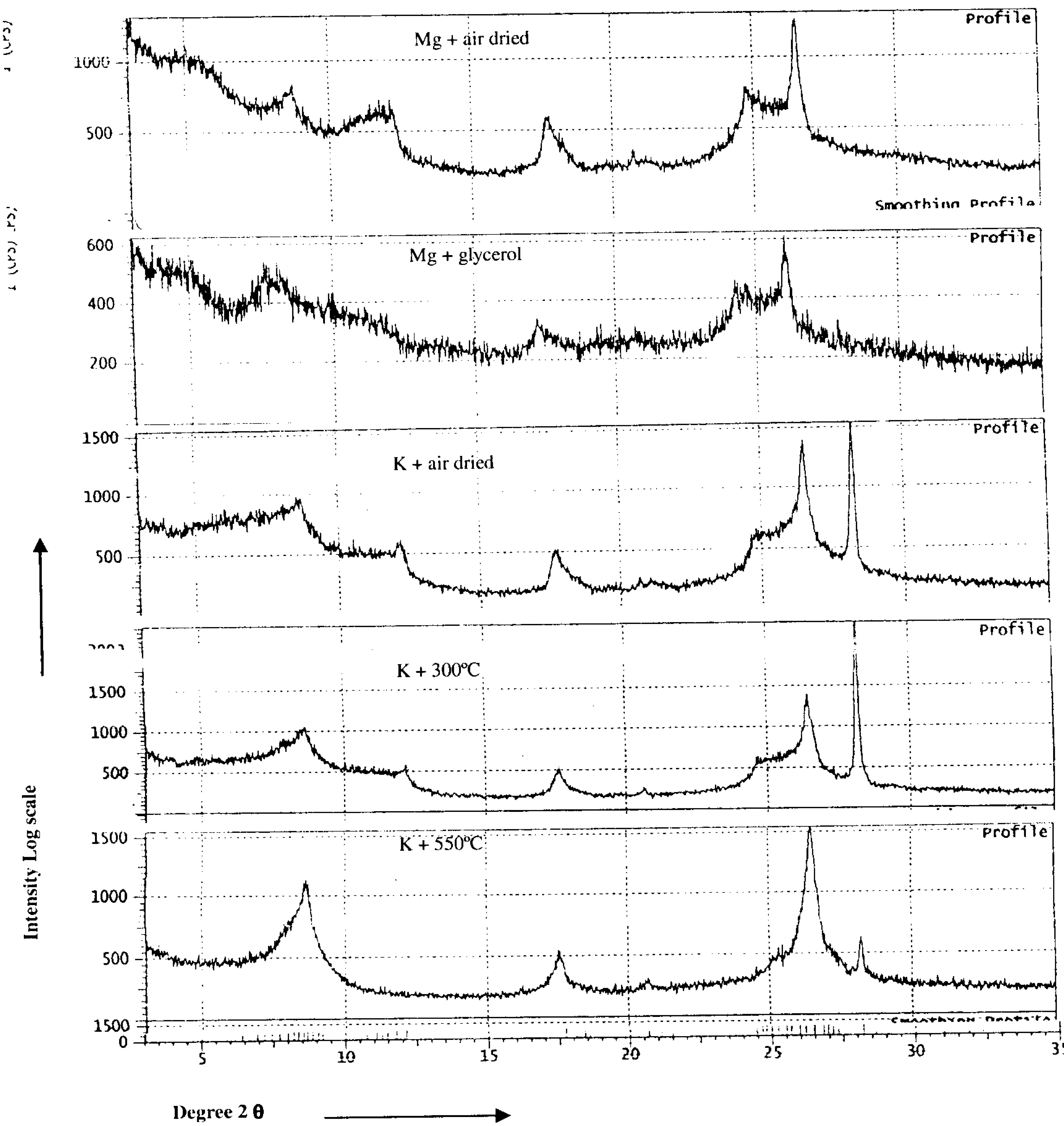

Fig. 1. X-ray diffraction of Genda soil series of BRRI farm.

gibbsite gave peaks at 4.16, 3.2 and 4.84 Å, respectively.

Type of clay minerals. Mica was the dominant mineral and its content was 33.0, 37.5, 27.0 and 42.0 percent in Genda, Bhatpara, Chhiata and Naga soils respectively (Table 2). Bhatpara, Chhiata and Naga soils have 7.2, 13 and 14.0 percent kaolinite respectively, while, Genda soil possessed only 2 percent kaolinite. In terrace soil mica and kaolinite are the dominant minerals (Karim, 1984). However, Moslehuddin and Egashira (1996) mentioned that mica and interstratified kaolinite-smectite and mica-

Bhatpara

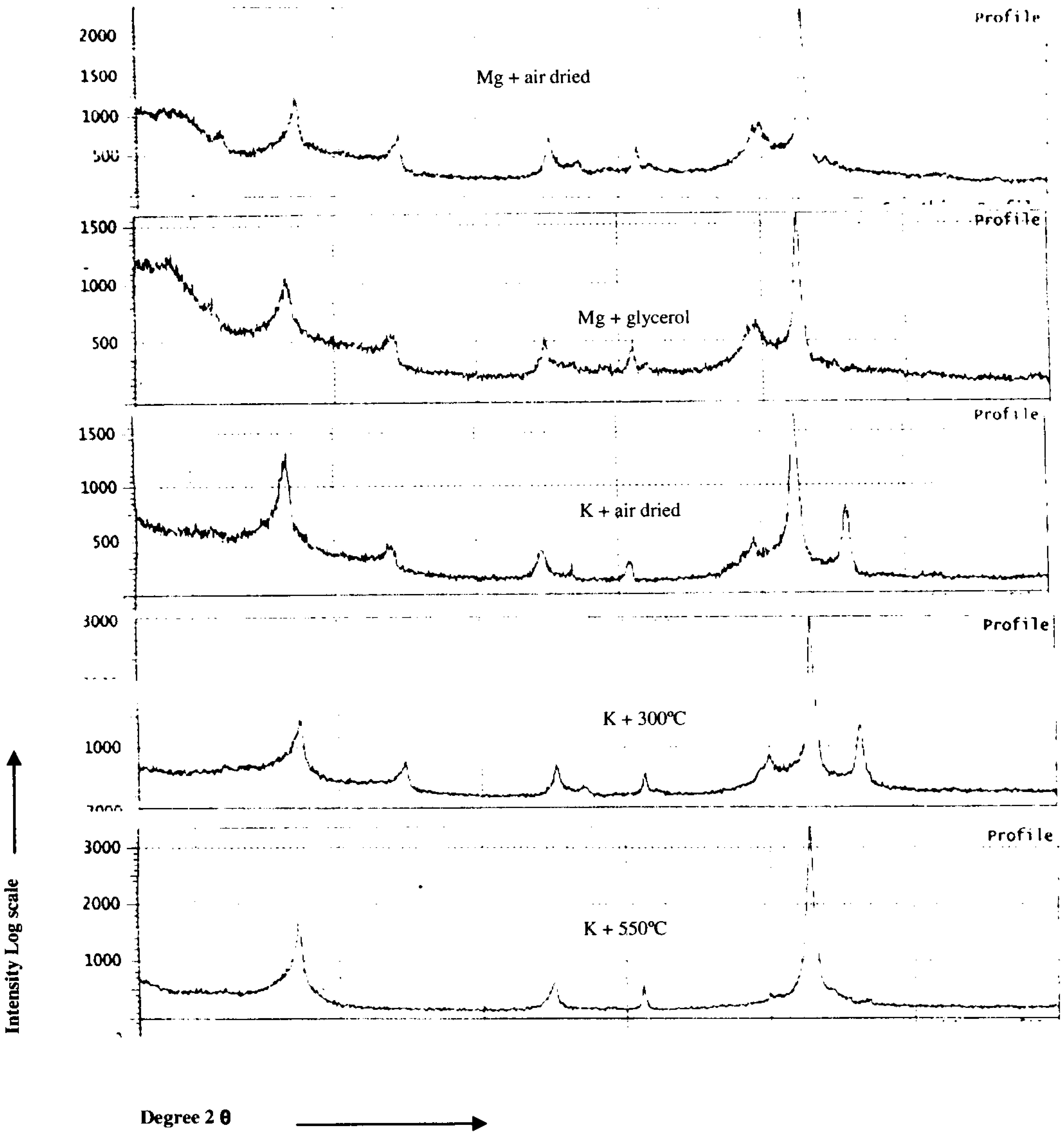

Fig. 2. X-ray diffraction of Bhatpara soil series of BRRI farm.

vermiculite-smectite constituted the major minerals of terrace soils. Interstratified mica-vermiculite-smectite is a weathering product of mica, which is further transformed to kaolinite. The studied soils contained low amount (2-6%) of smectite attributed to the presence of unweathered Madhupur clay (Brammer, 1971).

Vermiculite-chlorite integrate mineral content in Genda, Bhatpara and Chhiata soils, were 5, 5 and 13% respectively (Table 2). Mica-vermiculite interstratified mineral in Genda and Chhiata was 5 and 6% respectively. In Genda soil 10.5% kaolinite-smectite were present while in Bhatpara soil 11% mica-vermiculite-smectite interstratified minerals were

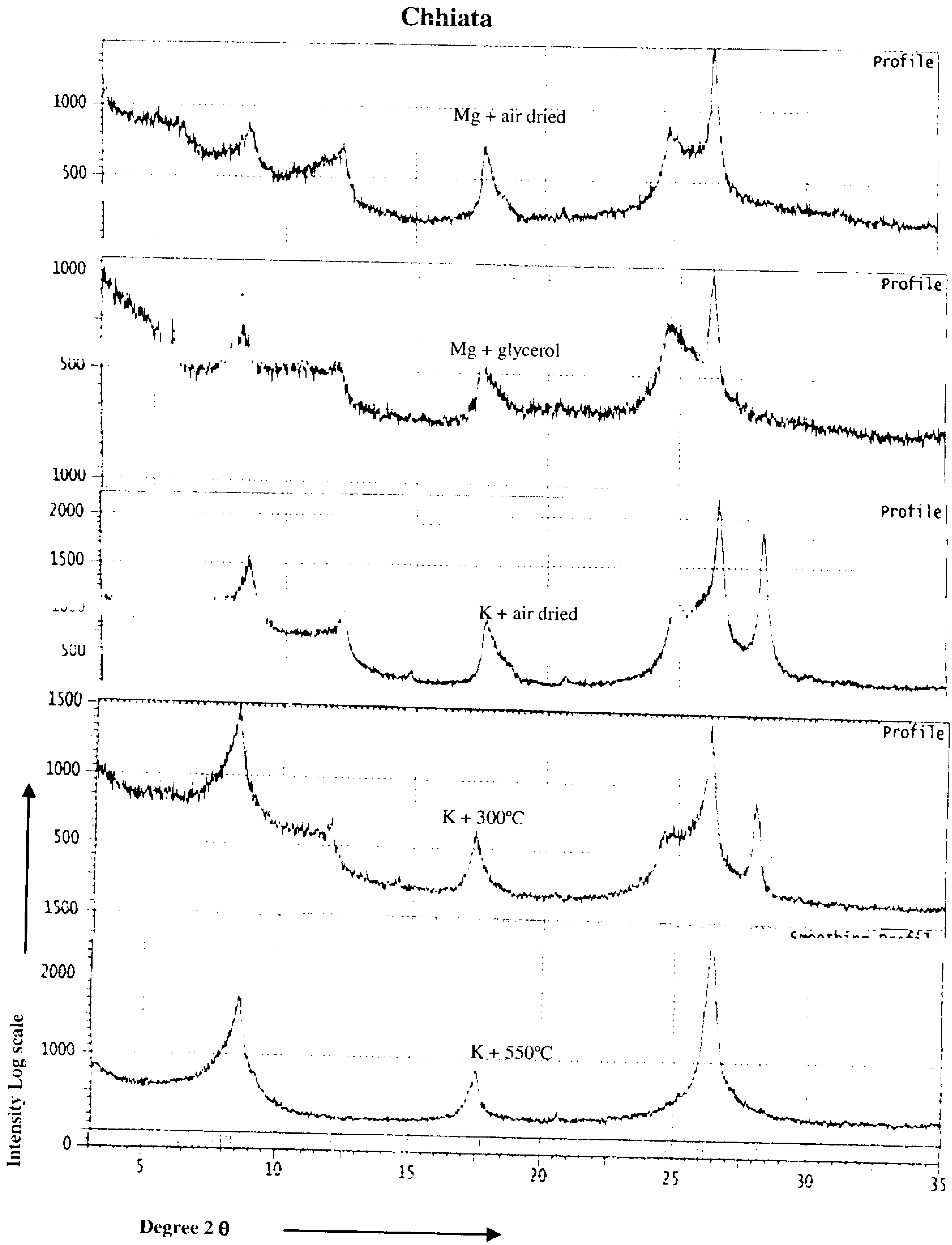

Fig. 3. X-ray diffraction of Chhiata soil series of BRRI farm.

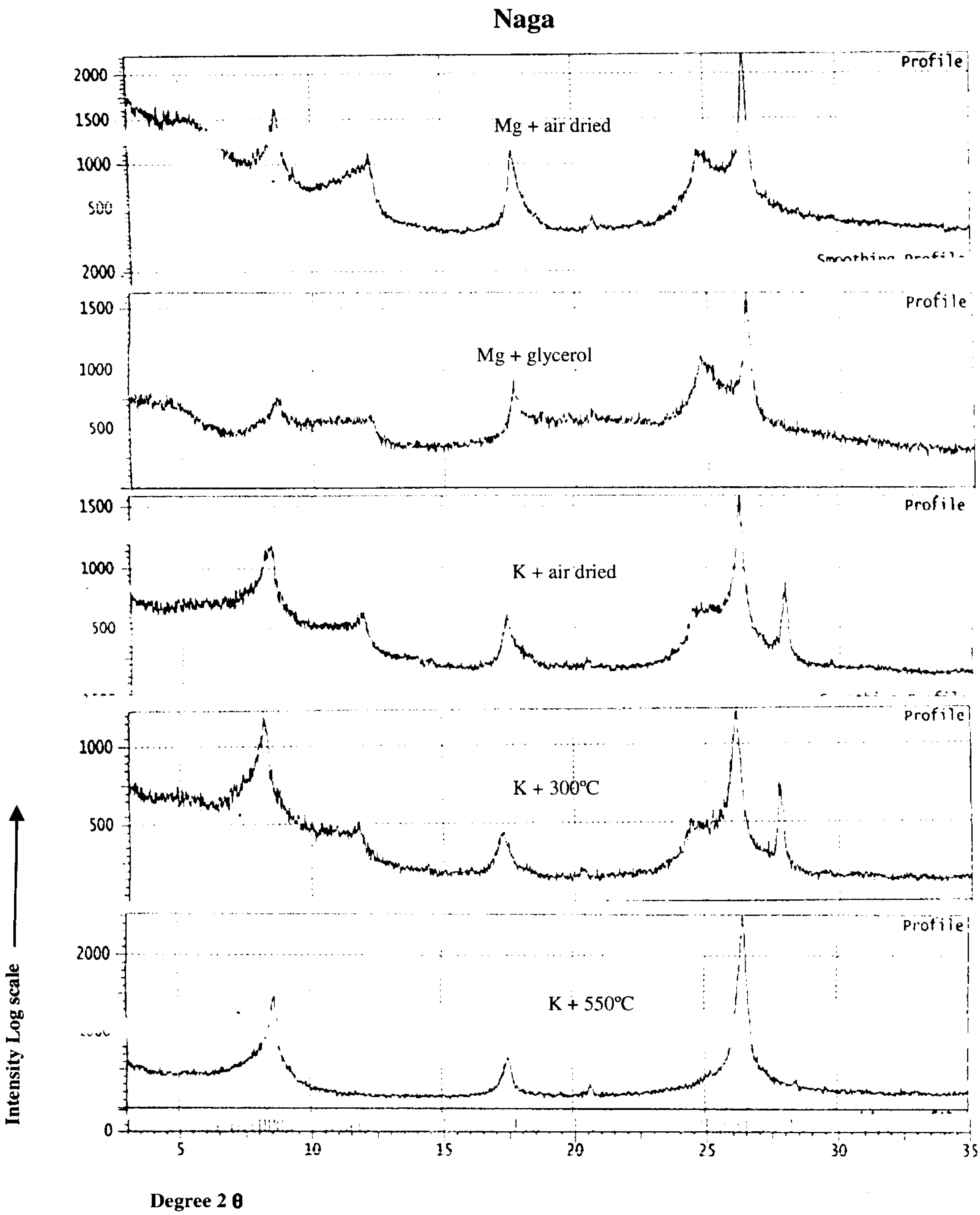

Fig. 4. X-ray diffraction of Naga soil series of BRRI farm.

present. Quartz, goethite and gibbsite were identified as mineral other than layer silicates. The contents of quartz in Genda, Bhatpara and Chhiata soils were 33, 33 and 18%, respectively. Goethite constituted approximately 1% in Genda and 2% in Chhiata soil, respectively. Feldspar constituted 4 and 22% in Genda and Naga soils, respectively. Likewise gibbsite contents were 3 and 22% gibbsite in Genda and Chhiata soils, respectively. High content of mixed layer minerals and kaolinite in the soil indicates longer

Table: 2. Semi-quantitative estimates (%) of minerals in the clay fraction of the studied soil.

Soil series	M	Sm	V	C	K	V/C	M/V	K/S	M/N/S	Q	G	F	Gi
Genda (Ap1)	33	4	-	-	2	5	5	10.5	-	33	1	4	3
Bhatpara (Ap1)	37.5	6.0	Trace	-	7.2	5.0	-	-	11.0	33.0	-	-	-
Chhiata (Ap1)	42.0	4.0	19.0	-	14.0	-	-	-	-	-	-	22.0	-
Naga (Apg)	27.0	2.0	12.0	-	13.0	13.0	6	-	-	18.0	2	-	8

M=Mica; Sm= Smectite, V=Vermiculite, C=Chlorite, K=Kaolinite, V/C= Vermiculite & Chlorite integrate, M/V=Mica and Vermiculite interstratified, K/S=Kaolinite-Smectite interstratified, M/V/S= Mica-Vermiculite-Smectite interstratified, Q=Quartz, G=Geothite, F=Feldspar, Gi=Gibbsite.

duration of weathering. It has been observed in the mineralogical studies by different authors (Egashira and Yasmin, 1990; Moslehuddin and Egashira, 1996; Ahmed *et al.*, 2003) that high content of mixed layer mineral and kaolinite is the common feature of terrace soils of Bangladesh.

Clay size particle content. Clay content in subsoil of the BRRI farm soil was higher than in the corresponding top soil giving loam to clay loam texture (Table 3). Egashira and Yasmin (1990) and Moslemuddin and Egashira (1996) reported higher clay content in subsoil of terrace soils. Lower clay content in top soil of terrace soils may be attributed to removal of clay particles in various ways. Clay might be dispersed and washed through irrigation and rainwater. It might be lost through the processes of ferrolysis as explained by Brinkman (1977) in case of gray terrace soils. In rainy season these soils hold water on the surface due to the presence of plow pan and thus the top soil is greatly reduced which is again oxidized in dry season. Clay particles may partially decompose through alternate oxidation and reduction of ferrous iron, associated with seasonal flooding.

In temperate humid region higher total phosphorous, potassium and calcium content is commonly found in clay compared to sand and silt (Brady, 1996). Cation and anion exchanges take place on the surface of finer fraction of soil (clays and humus). Also, clays have swelling and shrinkage property that varies with the type of clay. Soils containing smectite have high level of swelling and

Table: 3. Physico-chemical properties of the BRRI farm soils at the different depth.

Soil series	Horizon	pH	OM (%)	CEC (meq/100g)	Exch. K (meq/100g)	Sand (%)	Silt (%)	Clay (%)	Textural class
Genda	Ap1	6.02	1.85	11.0	0.15	52	32	16	Loam
	Ap2	6.12	0.67	10.0	0.14	50	30	20	Loam
	AB	5.80	0.63	9.0	0.15	48	30	22	Loam
	B	5.55	0.63	9.5	0.15	42	32	26	Loam
	C	5.40	0.63	9.0	0.14	41	32	27	Loam
Bhatpara	Ap1	6.10	1.70	11.0	0.16	56	30	14	Silt Loam
	II A1	7.02	1.16	10.0	0.13	36	36	28	Loam
	II A3 g	6.85	0.59	9.0	0.12	36	30	34	Clay Loam
	IIB2 g	6.95	0.55	8.0	0.13	33	32	35	Clay Loam
	IIC g	6.80	0.50	8.0	0.12	33	34	33	Clay Loam
Naga	A p g	6.85	1.35	12.0	0.16	43	34	23	Loam
	A3g	6.40	0.43	10.0	0.15	42	34	24	Loam
	B2gt	5.88	0.32	9.0	0.14	40	18	42	Clay
	C g t	5.80	0.25	9.0	0.13	36	30	34	Clay
Chhiata	Ap1	6.95	1.75	13.0	0.18	36	30	34	Clay Loam
	Ap2g	6.85	0.60	10.0	0.15	36	36	28	Clay Loam
	A B g	5.78	0.48	9.0	0.16	35	35	30	Clay Loam
	IIC1	5.32	0.40	9.5	0.15	31	32	37	Clay Loam
	IIC 2	5.35	0.35	9.0	0.14	32	34	34	Clay Loam

shrinkage while those with vermiculite are intermediate in swelling and shrinkage characteristics. Thus the quantity and quality of clays determine the fertility of a soil.

Egashira and Yasmin (1990) attempted to grade inherent potentiality of some Bangladesh soil based on type and amount of clay. As the BRRI soils contain very low amounts of weatherable minerals it indicates advanced leaching and weathering of potassium. Egashira and Yasmin (1990) also graded the soils as 'good' having high smectite and clay content and 'poor' having no or little smectite and medium to low clay content. The studied soils had very low amounts of weatherable minerals indicating advanced leaching and weathering to be graded in poor class of low inherent potassium supplying potentiality. In this context, BRRI soil may be classed as the low inherent potential potassium supplying soil.

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Drought Probability in T. Aman Rice in Northwest Region of Bangladesh

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ABSTRACT

The study was conducted to find out suitable distribution as well as predicting probability of drought in T. Aman season. Drought severity was simulated by a conceptual daily water balance model. Data of 30 years (1978-2008) on daily rainfall and evapotranspiration, soil texture, seepage and percolation rate, growth duration of the crop, transplanted date and bund height of plot were used in simulation. It was simulated at the vegetative, reproductive and ripening phases and the entire growing period of T. Aman rice. In this study, Gamma distribution was found suitable through Kolmogorov-Smirnove goodness of fit test for graduating probability distribution of drought. Therefore, Gamma distribution was used for determining exceedence and non-exceedene probabilities of drought occurrence at different probability levels. At 90% non-exceedene probability during the reproductive stage, drought will not exceed 72.84 mm 9 times in 10 years. There will be drought for once out of 10 years (10% non exceedence probability) in the study area. The drought forecast of this study could be useful to create farmers' awareness about severity and occurrence. According to forecast farmers could take necessary measures for mitigating drought by supplemental irrigation.

INTORDUCTION

Duration and severity of drought are uncertain events. In any geographical location, mainly the rainfall, the most uncertain climatic variable, governs occurrence of drought in terms of its duration and severity. Thus, the duration and severity of drought over the years can be considered to be as random variables and hence be best described by fitting them to the underlying probability distributions. A general approach used to describe drought characteristics is to derive the distribution of drought duration and the distribution of drought severity separately (Sen, 1977; Matheir *et al.*, 1992).

Agriculture often encounters drought and flood with some recurrence intervals. Transplanted Aman (T. Aman) rice in Bangladesh is vulnerable to both of these calamities. About two million hectares of land are prone to very severe to moderate drought. Food self-sufficiency and sustainable development in Bangladesh is being threatened by devastating drought. Present cropping pattern and management practices may be seriously affected by the intensifying drought conditions because of climatic changes (Ibrahim, 2001).

Uneven distribution of rainfall causes drought in Bangladesh. Specially, manifestation of drought is comprehensive in northwest region of the country. As rainfall is the lowest, this region is the driest part of the country. The average annual rainfall ranges from 1500 to 2000 mm in this region. More than 200 mm of rainfall per month occurs between June and September (Brammer, 1985). In monsoon period, mainly T. Aman rice is grown mostly using rainwater. So T. Aman rice still gambles on rains. Deficit rainfall causes drought in rainfed ecosystem and the resulting yield loss is many times higher than the damage from flood loss of grain production. For example, loss of crop yield (T. Aman) due to 1978 drought was 60% more than that of 1974 flood. As a

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result of drought in 1994, over 0.8 Mha of crop was damaged and 0.12 Mha of T. Aman could not be transplanted (Iqbal, 2000). Iqbal also mentioned that in Bangladesh, drought of 5 yrs return period was common, but during the last half decade drought of 3 yrs return period is being observed.

Agricultural activities could not be planned based on an average value of seasonal rainfall (Ribeiro and Lunardi, 1997). For addressing agricultural drought, macro level study based on comparison of lumped values of rainfall and evaporation in specific time interval, is not enough. Detail study in micro level ie at the farm level is essential for proper investigation of drought in relation to crop production. Designing effective drought mitigation plan in T.Aman cultivation requires adequate knowledge on the risk of drought occurrence at different growth stages, particularly at the critical growth stages of rice plants. As the farmers are not very much aware about time and severity of drought occurrence, very often they can not take any preparation to confront drought, consequently a poor harvest of crop is collected in their fate. Keeping it in mind, in this work a study was undertaken with the objective of determining the suitable distribution and probability of drought occurrence in T. Aman.

MATERIALS AND METHODS

Determination of drought severity

Drought in this study is defined as an event (occurred at any growth stage of the crop) during which rainfall and soil moisture together fail to meet consumptive use of the crop. Two important properties, drought amount and drought duration, were quantified in this study. Drought amount was considered as deficit water in the soil being equal to unfulfilled the demand of consumptive use of crop and drought duration was the period of time during which crop suffered from drought. Drought severity was the cumulative amount of drought for that duration. The amount and duration of drought in rainfed Aman rice cultivation were simulated on daily basis by a conceptual water balance model (Islam, 2007). Daily rainfall and evapotranspiration data of 30 years (1978-2008), soil texture, seepage and percolation rate, growth duration of the crop, transplanted date and bund height of the rice plot were used for simulation. The schematic of the water balance model is shown in Figure 1.

Nine locations in the northwest region of Bangladesh were selected for this study based on extent and severity of drought. In this region, most of the farmers generally transplant a medium duration (140 days) rice variety on 15 July during Aman season (monsoon rice) keeping levee height 150 mm. This is the existing practice in this region.

Probability distribution of drought

Two continuous distributions, Gamma and Exponential are, in general, found to be suitable for analysing probability distribution of the drought severity (Zelenhestic and Salvi 1987; Matheir *et al.*, 1992). Another continuous distribution namely Log-Pearson Type III may also be thought as other possible distribution for the same. Sharma (1998) mentioned that the occurrence of drought could be reflected by the deficiency of rainfall or stream flow sequences below the long-term mean value, which is generally taken as truncation level for identification of drought. He suggested that the sequences of drought variable, such as annual rainfall or stream flow, might follow Normal, Lognormal or Gamma distribution and might evolve in a Markavian fashion. However, in this study, only two distributions, namely Gamma and Lognormal were chosen as the possible candidates for the probability distribution of drought severity.

Gamma distribution. The density function of this distribution is given by

$$f(x) = \frac{x^a e^{-x/b}}{a\Gamma b^{a+1}} = 0 \quad \text{for } 0<x<\alpha \qquad (1)$$

Where a and b are the two parameters which affect the shape of the distribution.
Here $\mu = b(a+1)$ and $\sigma^2 = (a+1)$

Lognormal distribution. The density function of the distribution is given by

$$f(x) = \frac{1}{x\sigma_y\sqrt{2\pi}} \exp\left(- \frac{(y-\mu_y)^2}{2\sigma_y} \right) \qquad (2)$$

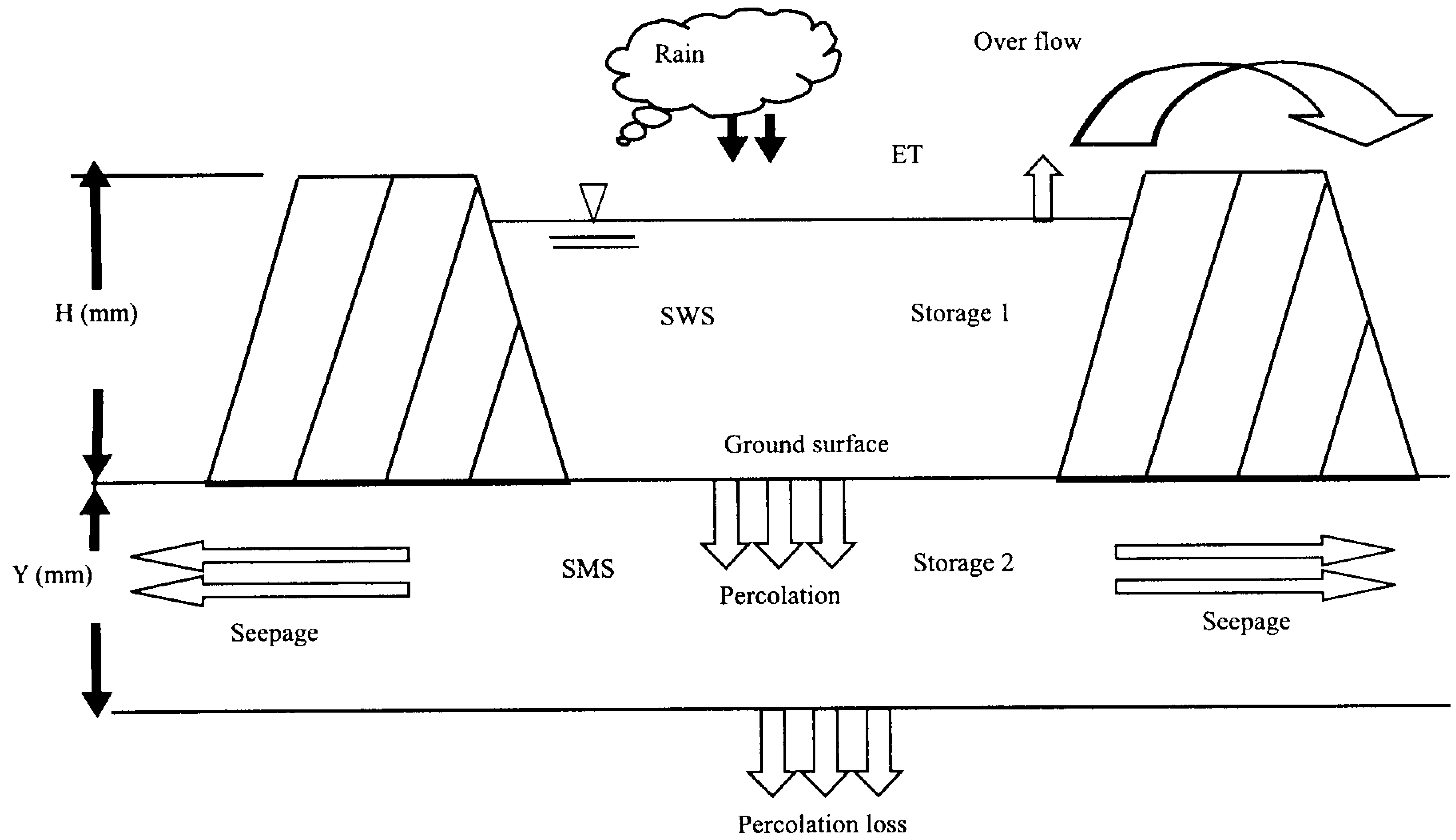

Fig. 1. Schematic representation of the water balance model.

where, $y = \ln x$, $x > 0$, μ_y = Mean of y , σ_y = Standard deviation of y and x is the variate under consideration.

Goodness of fit test. Hydrologic information to quantify drought are derived from sample data. Goodness of fit of the observed data (derived data) to different hypothesized probability distributions were assessed. Two widely used tools in testing the goodness of fit are chi-square test and Kolmogorov-Smirnove test. These two tests were tried to adopt in this study in order to select the most suitable distribution for drought analysis.

Chi- square (χ^2) test. The chi-square test statistics is defined as

$$\chi^2 = \sum_k^n \frac{(O_k - E_k)^2}{E_k} \qquad (3)$$

where O_k is the number of observations (observed frequency) in the kth class interval; E_k is the number of observations expected in the kth class interval (according to the distribution being tested); n is the number of class intervals. The number of classes is determined from (Sturges, 1926)

$$n = 1 + 3.3 \log_{10} m$$

where m is the sample size.

The computed value of χ^2 is compared with the tabulated value using (k - r - 1) degrees of freedom, where r is the number of parameters estimated for the hypothesized distribution. The null hypothesis of the proposed probability model is rejected if the computed value of χ^2 falls inside the critical zone defined by the 10% level of significance.

Kolmogorov-Smirnov test. An alternative to the chi-square goodness of fit is the Kolmogorov-Smirnove test. The Kolmogorov-Smirnove test statistic D is based on the maximum difference between the sample cumulative distribution function and the theoretical cumulative distribution function defined by

$$D = \max | F_\varepsilon - S_\varepsilon | \qquad (4)$$

where F_ε is the estimated cumulative distribution function under the null hypothesis of claimed theoretical distribution and S_ε is the sample cumulative distribution function based on ε observations. The critical values of D are available in Kolmogorov-Smirnove.

The Kolmogorv-Smirnove test is superior to the χ^2 test. Unlike the χ^2 test, this does not lose information through combining of categories, and that is why, finally, the Kolmogorov-Smirnove statistics was used to cheek the goodness of fit of the selected two distributions in this work.

Computation of return period

Sharma (1998) suggested a formula in terms of extremal severity and return period "T" in years, in parallel to the flood frequency formula, commonly cited in hydrological text.

Return period or recurrence interval (T) of a drought amount was calculated as the reciprocal of its exceedence probability. Therefore, the return period or recurrence interval is

$$T = \frac{1}{p} \qquad (5)$$

where, p = exceedence probabitity of drought

RESULTS AND DISCUSSION

Selection of distribution through goodness of fit test

The drought amount is a continuous variable. Two continuous probability distributions, Gamma and Lognormal, widely used for graduating probability distribution of rainfall were examined using Kolmogorov-Smirnove (K-S) goodness of fit test to identify which of the distributions fitted well to the drought amount. At each of nine study locations, four sets of drought amount were generated. These were drought at the vegetative, reproductive and ripening stages, and during whole growing period of T. Aman rice. Thus, there were 36 data sets in nine locations- four cases in each location. The drought amount at each growth stage and during whole growing period was considered as a case. The results of K-S goodness of fit test are presented in Table 1. Of the 36 cases, K-S test was found to be non-significant (ns) in 32 for Gamma distribution and in 26 cases for Lognormal distribution. In two cases, K-S statistic was significant for Gamma at 5% and for Lognormal distribution at the 1% level. It is noted that in 31 cases, value of K-S statistic for Gamma distribution was lower than that for Lognormal distribution. Thus, it appears from the results that drought amount can be assumed to follow Gamma distribution fairly well and hence the gamma distribution was used for computing probabilities of occurrence of drought with different levels (amount of drought) at different growth stages and for the whole crop season (T. Aman).

Probability and return period of drought

In this study, Gamma distribution was found suitable for graduating probability distribution of drought. Therefore, Gamma distribution was used for determining exceedence and non-exceedene probabilities of drought occurrence at different probability levels. Exceedence probability relates to an event of drought severity and is defined as the probability that the drought amount will exceed a particular level. Similarly non-exeedence probability is the probability that the drought amount will not exceed particular level. Probabilities and return periods of drought were determined during every growth stage, as well as for the crop season in all the selected locations of the study area (Tables 1-5).

Drought amount for different probabilities and return periods

Vegetative stage. Table 2 shows drought amounts at different probabilities (both exceedence and non-exceedence) and return periods during the vegetative stage for the selected locations. Results indicate that drought amount increases with the increase of non-exceedence probability. In Dupchachia, drought amount was 94.33 mm at 90% non-exeedence probability. This means that there is a 90% probability that the drought will not exceed this amount at the vegetative stage in any year. In other words, drought is expected to be less than this value 9 times in 10 years. But, any amount of drought from 0 to 94.33 mm may occur in any of those 9 years. Again, drought is expected to be more than 94.33 mm once in 10 years i.e. return period of drought of this amount is 10 years. The result also indicates that in 7 out of 9 locations, drought will exceed zero mm once in 1.1 years (90% exceedence probability). In other words, there will be no drought in one out of 10 years (10% non exceedence probability). Depending on the severity and duration, early drought stress (stress at

Table 1. Goodness of fit test for Gamma and Lognormal distributions.

Location	Stage	Gamma distribution		Lognormal distribution	
		Calculated value	Significant level	Calculated value	Significant level
Lalpur	Vegetative	0.183519	ns	0.232108	ns
	Reproductive	0.130403	ns	0.23107	ns
	Ripening	0.162189	ns	0.199338	ns
	Seasonal	0.095926	ns	0.101452	ns
Dupchachia	Vegetative	0.058811	ns	0.289537	*
	Reproductive	0.170385	ns	0.217515	ns
	Ripening	0.166749	ns	0.244748	ns
	Seasonal	0.104605	ns	0.116974	ns
Godagari	Vegetative	0.101614	ns	0.215075	ns
	Reproductive	0.083524	ns	0.326824	**
	Ripening	0.138946	ns	0.236586	ns
	Seasonal	0.069763	ns	0.12291	ns
Naogaon	Vegetative	0.171241	ns	0.22255	ns
	Reproductive	0.231923	ns	0.241402	ns
	Ripening	0.27707	*	0.2926	**
	Seasonal	0.128151	ns	0.164406	ns
Natore	Vegetative	0.21428	ns	0.30729	**
	Reproductive	0.14338	ns	0.2139	ns
	Ripening	0.16457	ns	0.2361	ns
	Seasonal	0.17344	ns	0.136	ns
Nandigram	Vegetative	0.2889	*	0.29731	**
	Reproductive	0.19514	ns	0.2441	ns
	Ripening	0.20086	ns	0.2396	ns
	Seasonal	0.11819	ns	0.09648	ns
Nachole	Vegetative	0.23472	ns	0.23184	ns
	Reproductive	0.26474	*	0.211146	ns
	Ripening	0.21587	ns	0.26174	*
	Seasonal	0.1553	ns	0.194609	ns
Mohadebpur	Vegetative	0.11654	ns	0.2501	*
	Reproductive	0.30157	**	0.23333	ns
	Ripening	0.24158	ns	0.2648	*
	Seasonal	0.101115	ns	0.3073	**
Shibgang	Vegetative	0.164401	ns	0.22523	ns
	Reproductive	0.23243	ns	0.24231	ns
	Ripening	0.12654	ns	0.28994	*
	Seasonal	0.117204	ns	0.13194	ns

*Significant at the 5% level. **Significant at the 1% level.

the vegetative stage) induces leaf rolling or drying, reduces photosynthetic activity and plant height and delays the onset of reproductive stage. These injuries may be compensated in yield if the duration of water deficit is short.

Reproductive stage. Table 3 shows that drought amount is 72.84 mm at 10% exeedence probability and its return period was 10 years. It implies that drought will exceed this amount once in 10 years during the reproductive stage. In other words, drought will not exceed 72.84 mm in 9 times in 10 years. This result indicates that if the farmers in Dupchachia have preparation of 183 mm water (72.84 mm drought needs 183 mm supplemental irrigation including seepage and percolation amount) for supplemental irrigation during reproductive period, they will be able to mitigate drought 9 times in 10 years at this stage. In one out of 10 years, this amount of water is likely to be inadequate to mitigate drought. Similarly, the farmers in Nandigram and Mohadebpur need 106 and 73 mm water respectively including seepage and percolation amount for supplemental

Table 2. Drought amount (mm) for different probabilities and return periods at the vegetative stage in different locations of the study area.

Location	Return periods (Years) of drought								
	1.1	1.3	1.4	1.7	3.3	5.0	6.7	10.0	20.0
	Exceedence probability of drought								
	90%	80%	70%	60%	30%	20%	15%	10%	5%
	Non-exceedence probability of drought								
	10%	20%	30%	40%	70%	80%	85%	90%	95%
Dupchachia	5.59	10.84	16.55	22.98	51.77	67.09	78.43	94.33	121.37
Lalpur	2.79	6.08	9.98	14.64	38.31	50.28	59.36	72.18	94.11
Godagari	0.00	2.42	6.46	11.17	32.65	45.38	54.51	67.46	89.78
Natore	0.00	1.29	4.00	7.40	24.81	36.02	44.21	56.04	76.81
Nandigram	0.00	0.00	0.74	2.69	19.75	32.81	34.76	45.86	62.70
Nachole	0.00	0.00	2.13	4.87	19.42	28.70	35.72	45.90	63.87
Noagaon	0.00	0.00	4.14	6.55	20.23	26.40	30.53	35.96	43.95
Shibgang	0.00	0.00	0.48	1.15	13.45	22.39	29.54	40.24	59.80
Mohadebpur	0.00	0.00	0.38	1.40	10.81	17.46	22.56	30.13	43.87

Table 3. Drought amount (mm) for different probabilities and return periods at the reproductive stage in different locations of the study area.

Locations	Return periods (Years) of drought								
	1.1	1.3	1.4	1.7	3.3	5.0	6.7	10.0	20.0
	Exceedence probability of drought								
	90%	80%	70%	60%	30%	20%	15%	10%	5%
	Non-exceedence probability of drought								
	10%	20%	30%	40%	70%	80%	85%	90%	95%
Dupchachia	0.00	4.62	10.06	15.68	38.60	51.35	60.31	72.84	94.09
Lalpur	0.00	0.38	1.80	4.42	24.32	39.26	50.71	67.71	98.55
Godagari	0.00	0.00	1.62	2.84	15.84	23.70	29.68	38.40	53.88
Natore	0.00	0.16	0.99	2.64	15.19	24.79	32.17	43.14	63.08
Nandigram	0.00	0.00	0.97	2.99	18.87	30.66	32.41	42.36	57.38
Nachole	0.00	0.00	0.42	1.54	11.45	19.04	25.11	34.19	50.78
Noagaon	0.00	0.00	0.40	1.56	12.07	20.17	26.66	36.38	54.15
Shibgang	0.00	0.00	0.29	0.69	8.11	13.52	17.83	24.30	36.11
Mohadebpur	0.00	0.00	0.34	1.33	10.19	16.94	21.99	29.16	40.55

irrigation to mitigate drought during reproductive stage, which will be adequate in 9 out of 10 years. The table also reveals that drought will exceed zero mm once in 1.1 years (90% exceedence probability). In other words, no drought is likely to occur in one out of 10 years (10% non-exceedence probability) in the study area.

Ripening stage. In this period, drought amount will exceed 40.9 mm once in 10 years. In other words, drought will not exceed this amount at this stage and this will happen 9 out of 10 years (Table 4). Therefore, if the farmers in Dupchachia have preparation for 103 mm water (40.9 mm drought needs 103 mm supplemental irrigation including seepage and percolation amount) for supplemental irrigation during ripening period, they will be able to mitigate drought 9 times in 10 years at this stage. In one out of 10 years, this amount will be possibly inadequate to mitigate drought. The Table also shows that there will be no drought once in 10 years (10% non-exceedence probability).

Crop season. During whole growing period of crop, drought amount at different probabilities and return periods are shown in Table 5. It shows that at 10% exceedence probability, maximum and minimum amount of drought are 190.53 and 69.19 mm in the study area. These amounts were observed in Dupchachia and Shibganj respectively. The result

Table 4. Drought amount (mm) for different probabilities and return periods at the ripening stage in different locations of the study area.

Locations	Return periods (Years) of drought								
	1.1	1.3	1.4	1.7	3.3	5.0	6.7	10.0	20.0
	Exceedence probability of drought								
	90%	80%	70%	60%	30%	20%	15%	10%	5%
	Non-exceedence probability of drought								
	10%	20%	30%	40%	70%	80%	85%	90%	95%
Dupchachia	0.00	0.00	1.13	3.26	18.18	29.59	31.28	40.90	55.44
Lalpur	0.00	0.33	1.60	3.98	22.21	35.72	46.05	61.39	89.19
Godagari	0.00	0.00	0.55	1.30	14.93	24.81	32.71	44.53	66.12
Natore	0.00	0.00	0.30	1.32	10.72	18.06	23.85	32.65	48.77
Nandigram	0.00	0.00	0.34	1.25	9.17	15.23	16.13	21.29	29.11
Nachole	0.00	0.00	0.18	0.71	5.53	9.24	12.21	16.67	24.81
Noagaon	0.00	0.00	0.40	1.47	10.90	18.13	23.90	32.55	48.35
Shibgang	0.00	0.00	0.10	0.24	2.77	4.61	6.08	8.29	12.32
Mohadebpur	0.00	0.00	0.26	1.00	7.63	12.72	16.54	21.94	30.52

Table 5. Drought amount (mm) for different probabilities and return periods during crop season in different locations of the study area.

Locations	Return periods (Years) of drought								
	1.1	1.3	1.4	1.7	3.3	5.0	6.7	10.0	20.0
	Exceedence probability of drought								
	90%	80%	70%	60%	30%	20%	15%	10%	5%
	Non-exceedence probability of drought								
	10%	20%	30%	40%	70%	80%	85%	90%	95%
Dupchachia	16.95	29.48	42.07	55.57	110.75	140.68	161.57	190.53	239.10
Lalpur	13.72	23.95	34.25	45.32	90.73	115.34	132.57	156.46	196.55
Godagari	9.01	16.35	23.97	32.33	67.99	87.16	100.92	120.11	152.51
Natore	0.00	10.25	18.35	26.56	58.72	76.05	88.09	104.77	132.81
Nandigram	0.00	3.55	9.80	15.67	59.08	78.79	92.66	112.06	145.02
Nachole	0.00	5.24	11.25	19.37	42.06	55.70	65.26	78.61	101.21
Noagaon	3.51	7.61	12.42	18.15	46.07	61.64	73.44	90.23	119.23
Shibgang	0.00	0.00	1.32	2.72	24.39	39.48	51.42	69.19	101.47
Mohadebpur	0.00	0.00	2.16	5.68	29.43	46.20	59.30	78.66	113.56

indicates that drought amounts during the crop season are expected to be exceeded 190.53 and 69.19 mm once in 10 years in Dupchachia and Shibganj respectively. The Table also shows that, no drought can be expected one out of ten years during the crop season in five locations of the study area. However, the results show that, in a particular probability, drought amounts vary from one place to another and one growth stage to another.

CONCLUSION

During reproductive stage, drought will not exceed 72.84 mm 9 times in 10 years. That is why if the farmers in Dupchachia have preparation for 183 mm water (72.84 mm drought needs 183 mm supplemental irrigation) during reproductive period, they will able to mitigate drought nine times in 10 years by applying supplemental irrigation. Again, there is 20% chance that there will be no droughts during reproductive stage in six locations. It implies that drought may not occur at least once in five years in Godagari, Nandigram, Nachole, Naogaon, Shibganj and Mohadebpur.

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Genetic Analysis for Root Length, Diameter and Number in an Eight-Parent Full Diallel Cross in Upland Rice

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ABSTRACT

Genetic analysis using a full diallel cross among eight parents varing in root length, diameter and number was studied to understand their genetic basis and inheritance pattern and possibilities of transferring those into modern cultivars for the development of drought tolerant modern rice (*Oryza sativa* L.) varieties. Significant differences were observed among the genotypes, reciprocals and parents vs F_1 hybrids for all the characters. Estimates of Hayman's ANOVA and genetic components showed the presence of both additive and dominance gene actions but additive gene actions were predominant for root length. Graphical analysis (*Vr, Wr*) revealed the possible involvement of one group of gene(s) governing the expression of the traits, and the average dominance was within the range of partial dominance. Variety OS4 possessed the most dominant alleles for root length and recessive for IR20. On the other hand, BR21 and Pukhi contained most dominant alleles and IR20 the recessive for root number. In case of root diameter, Jhumkamarang had the maximum dominant and Marichboti possessed recessive genes. The genetic parameters revealed that the parents for all the characters were predominant in positive genes with high h^2 (ns) and h^2 (bs) indicated that selection for the desired level of root characters could effectively be done in the early or late segregating generations, choosing appropriate donor parents in the crosses. Some sort of recurrent selection could also be done to accumulate desired genes for development of modern drought tolerant rice varieties.

INTRODUCTION

More than half of the world's rice area is under rainfed culture. Drought is a severe constraint against growth and yield of rice in most of these areas. Drought resistance predominantly associated with root length, number and thickness of roots as well as other root characters. Long root is an important trait to avoid drought in rice by supplying water from deep soil layers. Root length could be improved through breeding (Chang *et al.*, 1982; Babu *et al.*, 2001). Root thickness plays vital role in water uptake and translocation by penetrating deeper and compact soil layers during water scarcity (O'Toole *et al.*, 1980). Loresto and Chang (1994) regarded rice root thickness as potential source for genetic improvement of drought tolerance in rice. Most rice researchers had found that the root number was positively associated with tiller number, shoot dry weight but negatively correlated with drought resistance (Armenta-Soto *et al.*, 1983; Haque *et al.*, 1988). For the development of drought resistant modern rice varieties, genetic behaviour and inheritance pattern of long root, root thickness and root number and possibilities of transferring those into modern cultivars are essential. Thus, this study experiments the inheritance pattern, genetic behaviour and genetic components of variation for root length, diameter and number in eight-parent full diallel cross, involving parents with variable root characters.

MATERIALS AND METHODS

Eight rice varieties representing different agro-ecological conditions with variable degrees of drought tolerance were used in this study. Table 1 shows the varieties, origin, cultural types, drought score and three root characters. A diallel mating

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Table 1. The eight parents with some relevant information used in making diallel cross.

Variety	Country of origin	Varietal type[a]	Drought score[b]	Root length (cm)	Root dia. (mm)	Root No.
Marichboti	Bangladesh	Aus/Upland	3	68.2	0.94	26.9
Patuakhali	Bangladesh	Aus/Upland	4	55.0	0.88	27.6
Pukhi	Bangladesh	Aus/Upland	4	60.0	0.75	32.4
Jhumkamarang	Bangladesh	Hill rice	3	58.2	0.92	26.7
Mijingem	Bangladesh	Hill rice	2	55.5	0.99	20.7
BR21	Bangladesh	Upland (modern)	6	46.7	0.73	29.9
OS4	Nigeria	Upland (Resistant ck)	3	57.21	1.00	22.3
IR20	IRRI (Philippines)	Lowland (Susceptible ck)	9	33.41	0.62	41.2

[a]The Aus and upland varieties are grown under direct seeding at the start of the monsoon season throughout the flat land and mature before the flood water rises rapidly as a result of heavy rainfall. On the other hand, the hill rices are grown in the hilly regions under direct seeding or in holes without standing water in the field throughout their life cycle. Lowland varieties are transplanted in the puddle field and grown in standing water. Both the aus and hill rices are early maturing, with low yield potential and resistant to drought at the vegetative stage.
[b]Drought resistance score based on the decimal score for field reactions to drought at the vegetative stage (Loresto and Chang, 1981): 2 = with tip-drying extended 1/8th length of most leaves; 3 = with tip-drying extended 1/8th to 1/4th length of all the leaves; 4 = with tip-drying extended 1/4th to 1/2 length of all the leaves; 6 = with more than 2/3rd of all leaves dried; 9 = almost all leaves dried. Score: 1-3 = resistant; 3-5 = moderately resistance; 5-7 = moderately susceptible; 7-9 = susceptible.

was made in all possible combinations and 56 F_1 hybrids were obtained at Bangladesh Rice Research Institute (BRRI). The pregerminated seeds of 64 entries (56 F_1s and eight parents) were sown on the top of 75 cm polyethylene tube filled with sand and soil (3 : 1). Twelve seeds from each entry were used and one seed was sown on each tube. The tubes were arranged in wooden frame in a triple lattice design in the Plant Physiology Division Glasshouse, BRRI. The plants were watered twice daily with cultural solution as suggested by Yoshida *et al.* (1976). Data were collected at maximum vegetative stage (35 days after seeding) on maximum root length (cm) from each plant, root diameter (mm) from the tip of five well-developed roots from each plant and total root number from the base of each plant.

Analysis of variance for genotypes, parents, crosses, reciprocals and parents vs F_1 hybrids, Hayman's ANOVA, variances (Vr) and covariances (Wr) were calculated following Hayman (1954). Vr-Wr and standardized deviation graph (Vr + Wr, Yr) was prepared following Johnson (1963). Components of genetic variations and genetic parameters were estimated using the formula of Mather and Jinks (1982).

RESULTS AND DISCUSSION

Performances of parents and F_1 hybrids

Root length. Significant variations were observed from the analysis of variance among the genotypes, parents (P), crosses (F_1), reciprocals and P vs F_1 (Table 2). Drought resistant parents had the root length, which ranged from 52.21 (Jhumkamarang) to 67.00 cm (Marichboti). Moderately resistant (BR21) and susceptible (IR20) produced 46.33 and 34.41 cm, respectively. Table 3 shows the root length of the parents and their F_1. The length of F_1s varied from 43.04 (Jhumkamarang x Patuakhali) to 67.04 cm (Marichboti x Pukhi), which were in between the parental values, but closer to the better parents, indicated the presence of unidirectional dominance. The *r* (0.931**) value between the array means and parental means revealed a high potential of the parents to transmit root length to their F_1 hybrids.

Root diameter. The genotypes, parents (P), crosses (F_1), reciprocals and parents vs crosses for root thickness were found significant (Table 2). Root diameter in eight parents varied from 0.643 mm in IR20 to 1.01 mm in OS4, whereas the trait varied from 0.660 mm (IR20 x Pukhi) to 0.993 mm (OS4 x Mijingem) among the F_1 hybrids. Table 3 shows the root

Table 2. Analysis of variance for root length, root diameter and root number in an eight-parent diallel cross in upland rice.

Source	df	Mean square		
		Root length	Root diameter	Root number
Genotype	63	127.189**	0.019**	43.823**
Parent (P)	7	290.864**	0.054**	105.310**
Cross (F_1)	55	106.390**	0.014**	36.533**
P x F_1	1	270.065**	0.050**	98.020**
Error	126	3.830	0.0005	2.601
CV (%)		3.350	2.580	5.890
r (Array mean vs. parental mean)	6	0.931**	0.977**	0.931**
b (Regression coefficient)		0.97 ± 0.23	1.11 ± 0.22	1.24 ± 0.23
b_0		4.08**	5.04**	7.74**
b_1		0.11^{ns}	0.49^{ns}	1.48^{ns}

**Significant at the 1% probability level.

Table 3. Root length (cm), root diameter (mm) and root number in an eight parent diallel cross in upland rice.

Parent	Character	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
P_1	*RL*	67.2	62.1	67.0	64.9	64.8	53.6	66.7	51.9
	RD	0.94	0.91	0.74	0.94	0.86	0.80	0.96	0.76
	RN	26.7	27.3	27.7	26.7	22.3	27.0	27.3	32.7
P_2	*RL*	60.7	55.5	65.2	57.0	59.5	57.2	63.8	54.7
	RD	0.90	0.87	0.83	0.85	0.90	0.80	0.96	0.80
	RN	25.0	27.0	30.7	26.7	25.3	26.3	24.7	30.3
P_3	*RL*	62.4	59.1	61.0	62.0	60.0	57.3	54.6	52.4
	RD	0.75	0.79	0.74	0.88	0.88	0.76	0.86	0.66
	RN	30.0	32.0	31.0	30.0	30.0	29.3	28.0	34.3
P_4	*RL*	53.8	43.0	48.7	52.2	54.4	53.8	58.2	48.3
	RD	0.84	0.87	0.82	0.93	0.81	0.82	0.86	0.75
	RN	22.3	20.0	27.3	26.0	23.3	31.0	22.0	32.0
P_5	*RL*	61.0	55.1	55.8	48.6	56.2	45.9	55.4	49.9
	RD	0.92	0.92	0.82	0.86	0.99	0.84	0.97	0.79
	RN	21.3	25.7	26.7	21.7	20.3	26.3	20.0	26.7
P_6	*RL*	58.1	51.5	52.9	50.4	48.8	46.3	54.4	47.2
	RD	0.75	0.79	0.79	0.88	0.81	0.76	0.82	0.67
	RN	22.7	25.3	31.7	25.0	30.7	30.3	24.7	28.0
P_7	*RL*	58.3	57.4	63.8	63.8	64.0	59.1	56.2	56.0
	RD	0.92	0.93	0.85	0.88	0.91	0.87	1.01	0.83
	RN	24.3	25.3	33.3	22.0	28.3	29.0	23.3	28.0
P_8	*RL*	47.5	52.0	52.2	52.3	49.0	48.3	62.9	34.4
	RD	0.78	0.81	0.71	0.78	0.83	0.76	0.81	0.64
	RN	27.7	31.0	30.0	29.0	27.0	30.3	31.0	40.0

RL = Root length; RD = Root diameter; RN = Root number; P_1 = Marichboti; P_2 = Patuakhali; P_3 = Pukhi; P_4 = Jhumkamarang; P_5 = Mijingem; P_6 = BR21; P_7 = OS4; P_8 = IR20.

diameter of the parents and their F_1. High potential of the parents to transmit the trait to their offsprings was indicated by the value of *r* (0.977**) between array means and *Yr*. The diameters of the hybrids were closer to the better parents, revealed unidirectional dominance.

Root number. Variances of root number due to genotypes, parents (P), crosses (F_1), reciprocals and P vs. F_1 were found to be highly significant (Table 2). The number varied from 20.33 (Mijingem) to 40.00 (IR20) for the parents and 20.00 (Jhumkamarang x Patuakhali and OS4 x Mijingem) to 33.33 (OS4 x Pukhi) for the crosses (Table 3.). In many of the crosses, root numbers were found to be closer to or more than the better parents indicated unidirectional dominance to over dominance. The high rooted parents had the potential to transmit their trait to their hybrids as indicated from the close association between array means and *Yr* (*r* = 0.931**).

Hayman's analysis of variance

Table 4 presents the analysis of variance for different components for all three characters, which was done as suggested by Hayman (1954). Influence of both additive and dominance gene actions were revealed from significant '*a*' and '*b*' values for all traits. Armenta-Soto *et al.* (1983) also reported both additive and dominant gene actions in controlling root length, root diameter and root number in a diallel analysis with upland rice. All three items of dominance actions viz 'b_1', 'b_2' and 'b_3' for root length and root thickness were significant and indicated unidirectional dominance as also observed from the F_1 values. Insignificant 'b_1' value for root number revealed that the F_1 values for this trait were not in one direction rather closed to both types of parents. Significant '*c*' and '*d*' values detected prominent both maternal and reciprocal effects in all traits, which were also found in the values of F_1s and reciprocals.

Graphic representation of Vr, Wr

Root length. The *Vr, Wr* graph (Fig. 1a) provided a useful means for assessing genetic relationships among the parents. The analysis of all the arrays produced a regression, $b = 0.974 \pm 0.234$, which was significantly different from zero but not from unity (Table 2), indicated the absence of epistasis (Hayman, 1954). The insignificant negative correlation coefficient between *Vr* + *Wr* and *Yr* (*r* = - 0.269) indicated that both dominance and recessive genes dispersed among the parents, where parents Marichboti, IR20 and Mijingem possessed recessive genes with positive effects and parent OS4 contained dominant genes with positive effects (Fig. 2a). The regression line intercepted the Wr axis above the origin (*a* = 12.197) suggested partial dominance governing the trait. The position of array points on the regression graph showed that the concentrations of dominant alleles were high in OS4 and recessive in IR20. The striking discontinuity between array points of the long vs shallow root group revealed the involvement of major gene(s) in the inheritance of root length.

Root diameter. The validity of the model was established by the regression coefficient ($b = 1.107 \pm 0.22$), which was significantly different from zero but not from unity (Table 2). Overall partial dominance was indicated by the regression line, which

Table 4. Hayman's analysis of variance for root length, root diameter and root number in an eight-parent diallel cross in upland rice.

Source	d.f	Mean square		
		Root length	Root diameter	Root number
a	7	685.15**	0.1328**	248.022**
b_1	1	125.41**	0.0202**	14.376
b_2	7	61.86**	0.0029**	22.873**
b_3	20	46.13**	0.0056**	14.020**
b	28	52.89**	0.0062**	16.246**
c	7	131.14**	0.0050**	29.536**
d	21	38.95**	0.0024**	17.290**

**Significant at the 1% probability level.

intercepted the Wr axis above the origin ($a = 0.272$). The parent Jhumkamarang contained the most dominant alleles followed by BR21. On the other hand, most recessive alleles concentrated in Marichboti followed by IR20 and OS4 (Fig. 1b). The insignificant correlation coefficient between $Vr + Wr$ and Yr ($r = 0.150$) means carried both dominant and recessive genes with positive effects dispersed among the parent. Parent Marichboti had recessive genes with positive effect while Jhumkamarang and BR21 had mostly dominant genes with positive effects (Fig. 2b). Armenta-Soto *et al.* (1983) also found both dominant and recessive alleles in different drought tolerant rice varieties. Patuakhali, Pukhi and Mijingem contained almost equal proportion of dominant and recessive alleles.

Root number. The *Vr, Wr* graph (Fig. 1c) provided that *Wr* was related to *Vr* by a strait regression line ($b = 1.24 \pm 0.23$, which was significantly different from zero but not from unity (Table 2) and supplied that the non-allelic interaction was absent and the genes were distributed independently among the parents. The position of regression line on Wr axis ($a = 2.837$) indicated partial dominance in the inheritance of root number. The varieties Pukhi and BR21 contained

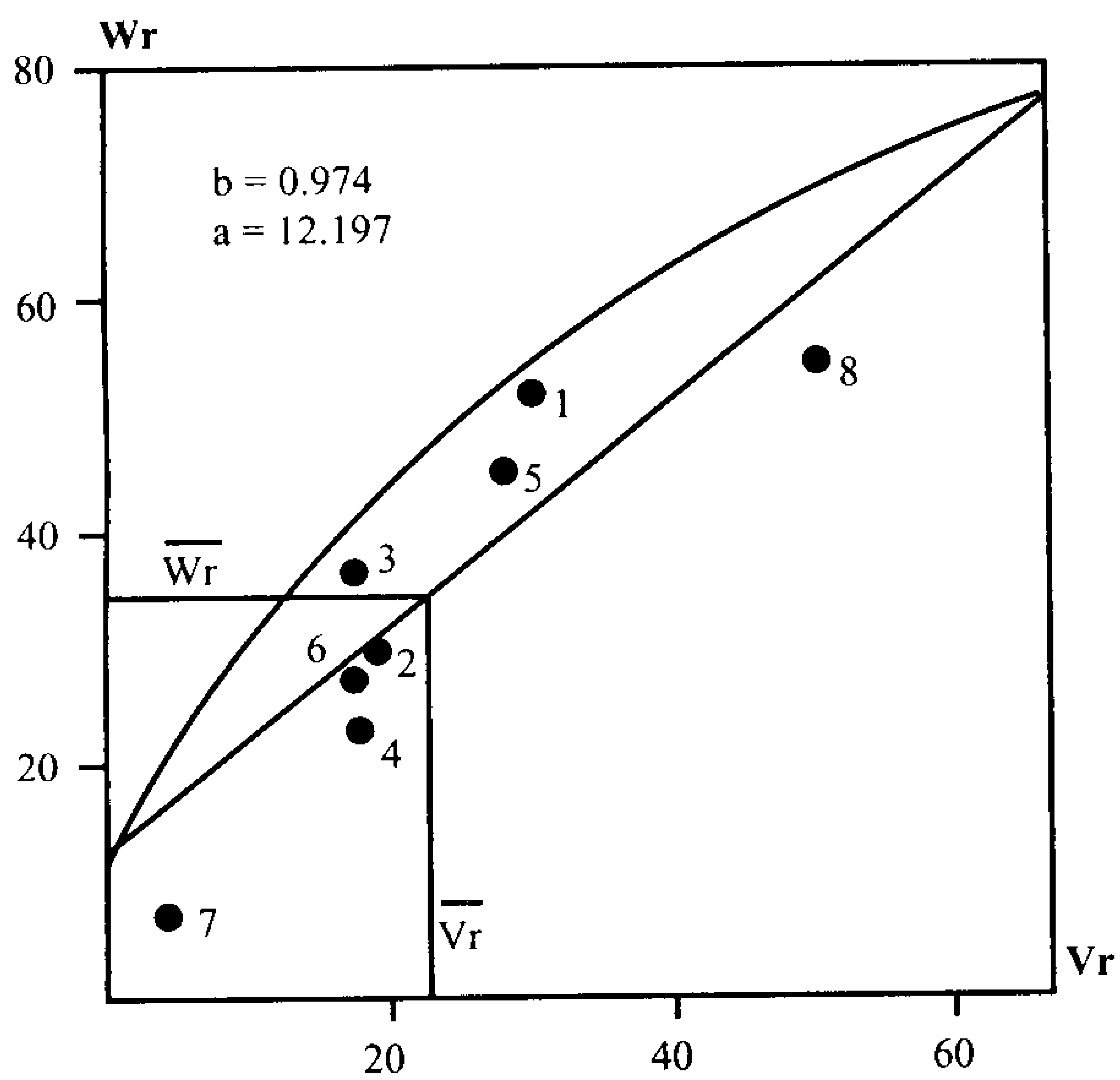

Fig. 1a. Variance and covariance (Vr-Wr) graph for root length. 1 = Marichboti; 2 = Patuakhali; 3 = Pukhi; 4 = Jhumkamarang; 5 = Mijingem; 6 = BR21; 7 = OS4; 8 = IR20.

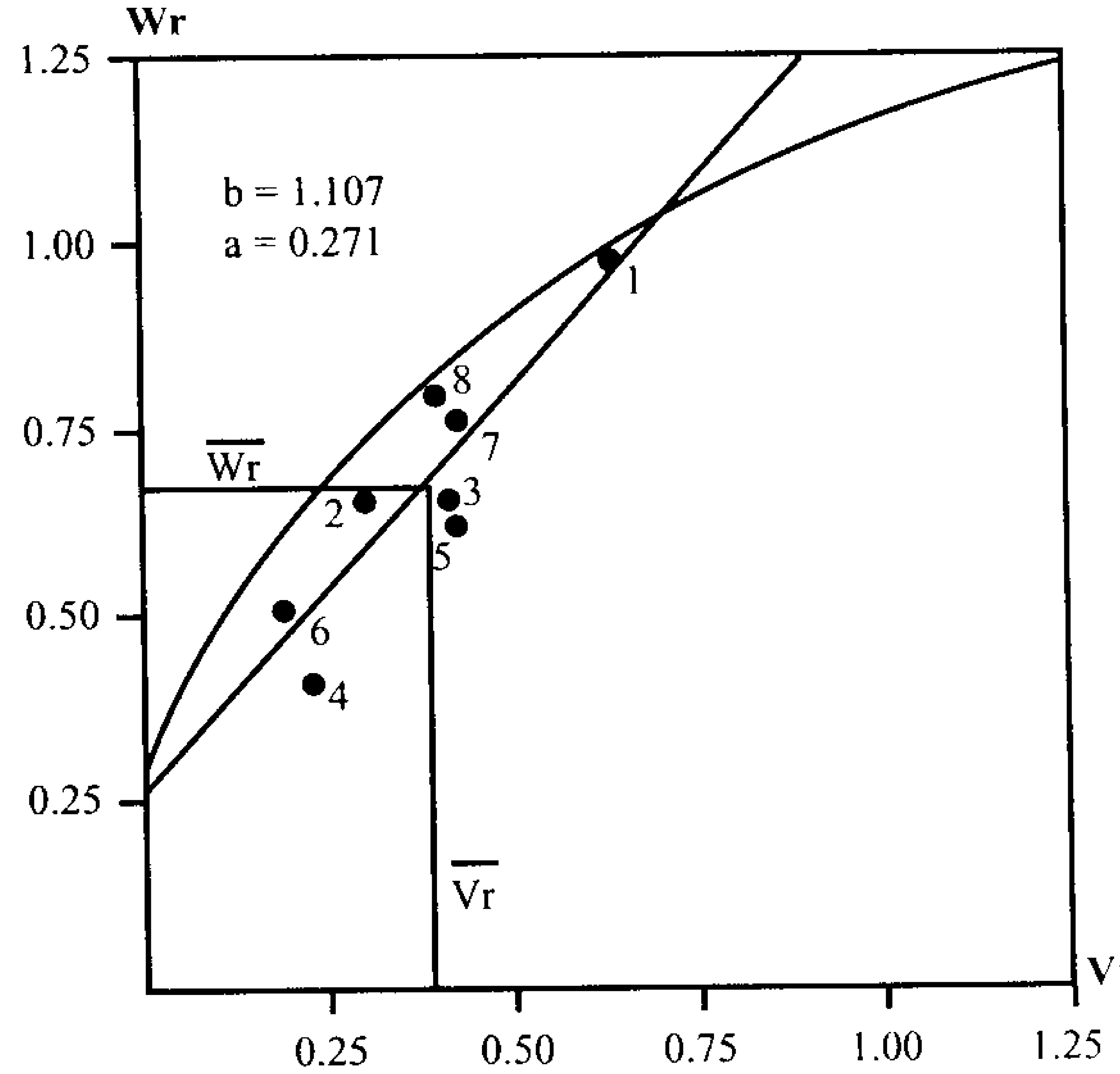

Fig. 1b. Variance and covariance (Vr-Wr) graph for root diameter. 1 = Marichboti; 2 = Patuakhali; 3 = Pukhi; 4 = Jhumkamarang; 5 = Mijingem; 6 = BR21; 7 = OS4; 8 = IR20.

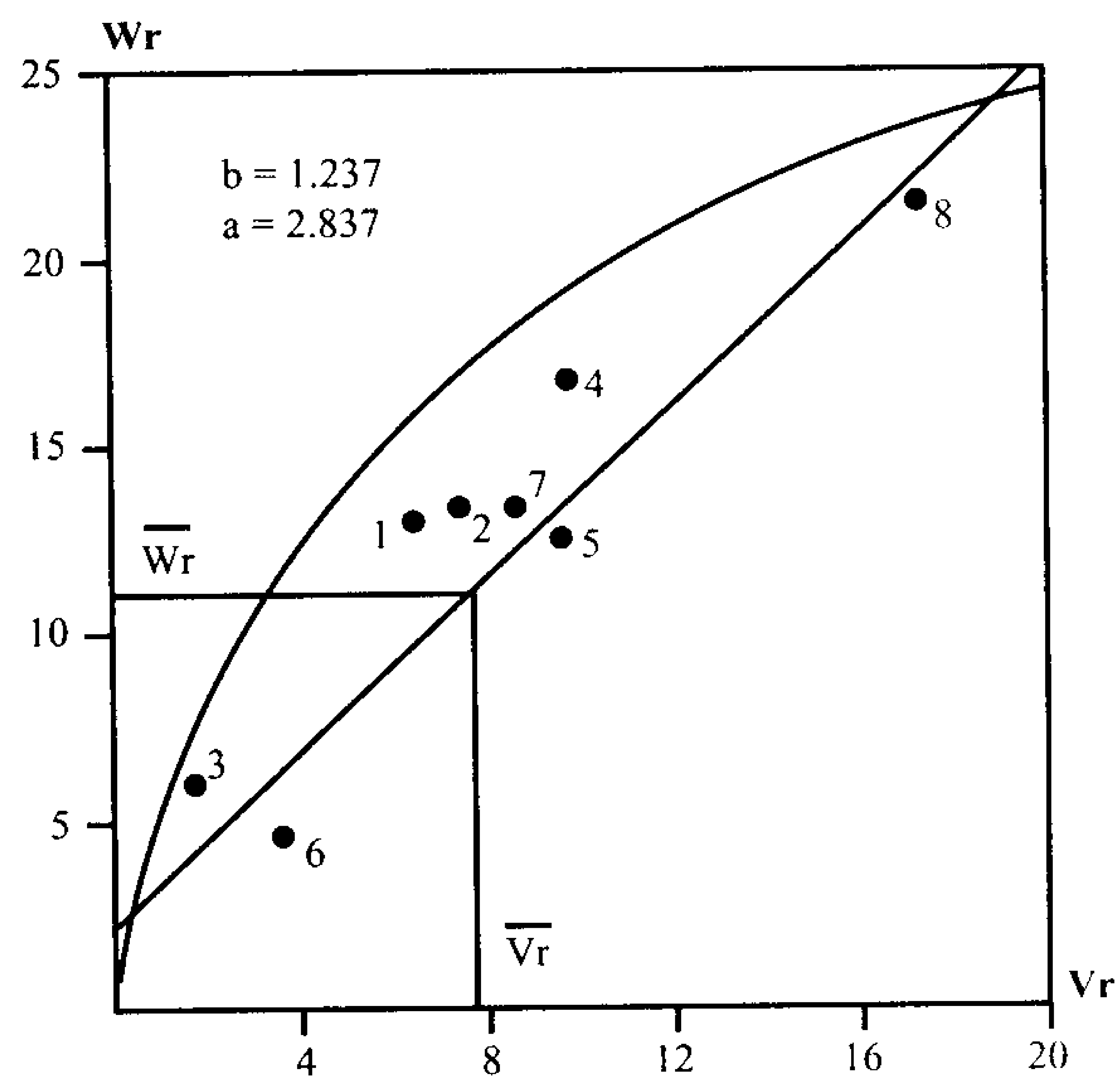

Fig. 1c. Variance and covariance (Vr-Wr) graph for root number. 1 = Marichboti; 2 = Patuakhali; 3 = Pukhi; 4 = Jhumkamarang; 5 = Mijingem; 6 = BR21; 7 = OS4; 8 = IR20.

relatively large number of dominant alleles but IR20 had most recessive genes as indicated by their distance from the origin. Prevalence of dominant genes for root number in rice was also reported by

Armenta-Soto *et al.* (1983). From insignificant r value (0.645) between $Vr + Wr$ and Yr and their position in the standardized deviation graph (Fig. 2c) showed that most of the parents possessed both dominant and recessive genes with positive effects. Parent IR20 had the most recessive genes and parents Pukhi and BR21 contained most dominant genes with positive effects.

Components of variation and genetic parameters

Root length. Table 5 presents the components of variation and genetic parameters estimated in accordance with Hayman's approach of diallel analysis. Among the components, only D value (95.615 ± 35.336**), which measured the additive and some portion of additive x additive genetic effect was found to be significant, indicated additive type of gene actions were predominant for root length. These were further confirmed by $(H_1/D)^{1/2}$, h^2(ns) and h^2(bs) values. Chang *et al.* (1982) also reported similar additive gene effect. Table 3 shows further insignificant dominance (H_1) and dominance x dominance (H_2) gene effects, whose interaction may have rendered the overall dominance (h^2) non-significant. Positive values of the ratio, $[(4DH_1)^{1/2} + F] / [(4DH_1)^{1/2} - F]$ (2.319) and F value (53.223 ± 199.058) indicated excess of dominant alleles in the parents for the trait.

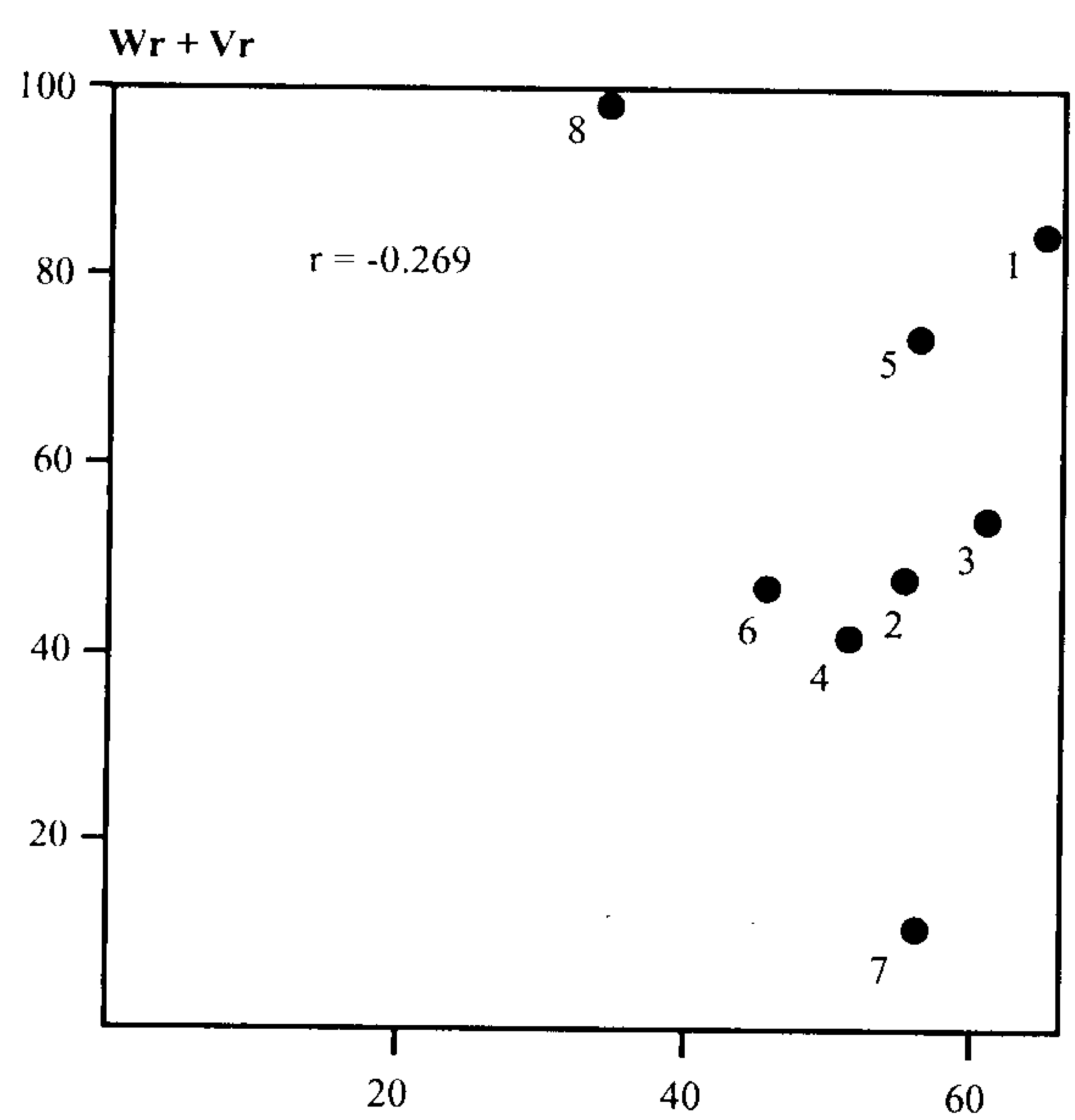

Fig. 2a. Relationship between Yr and $Vr + Wr$ for root length. 1 = Marichboti; 2 = Patuakhali; 3 = Pukhi; 4 = Jhumkamarang; 5 = Mijingem; 6 = BR21; 7 = OS4; 8 = IR20.

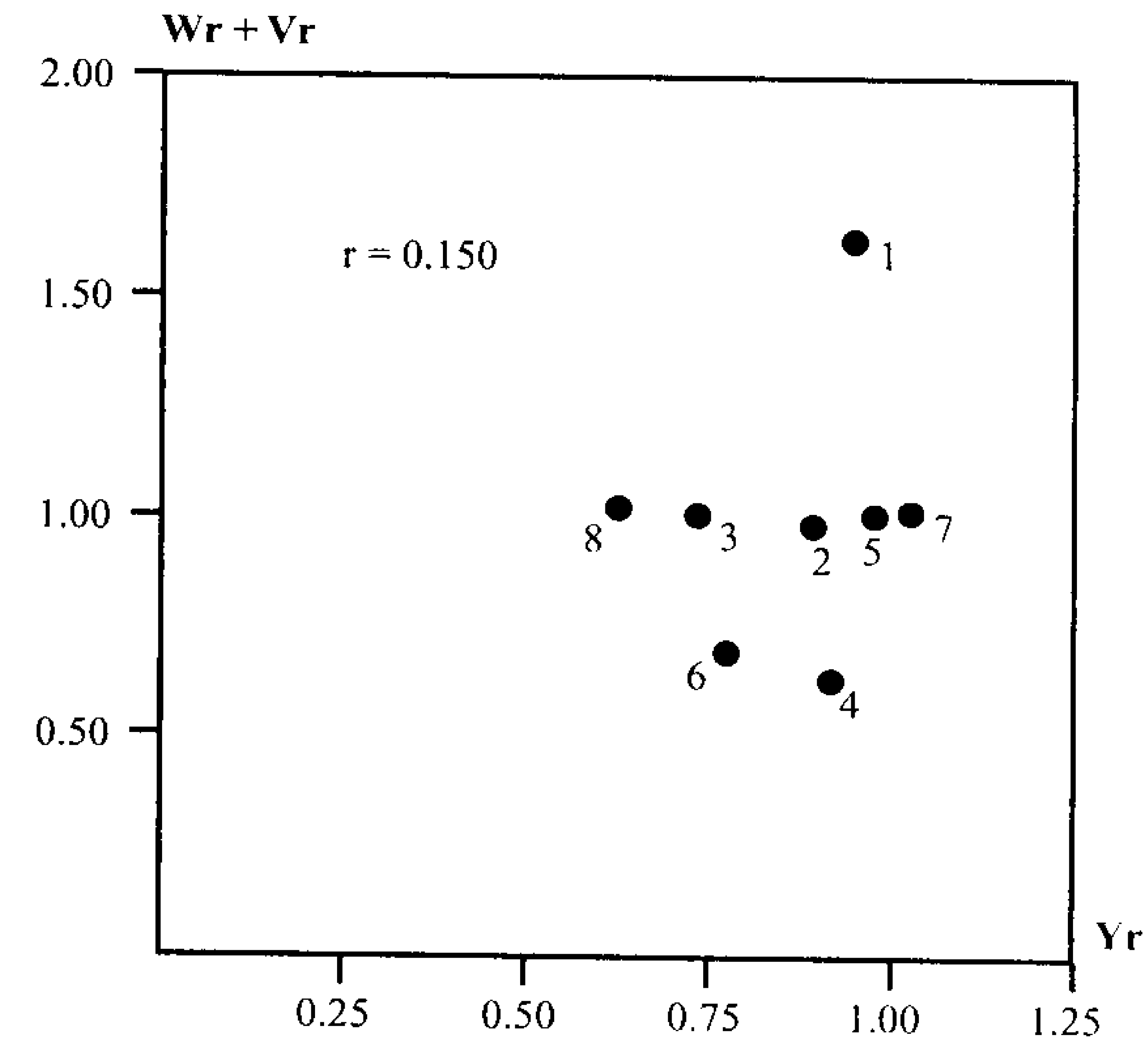

Fig. 2b. Relationship between Yr and $Vr + Wr$ for root diameter. 1 = Marichboti; 2 = Patuakhali; 3 = Pukhi; 4 = Jhumkamarang; 5 = Mijingem; 6 = BR21; 7 = OS4; 8 = IR20.

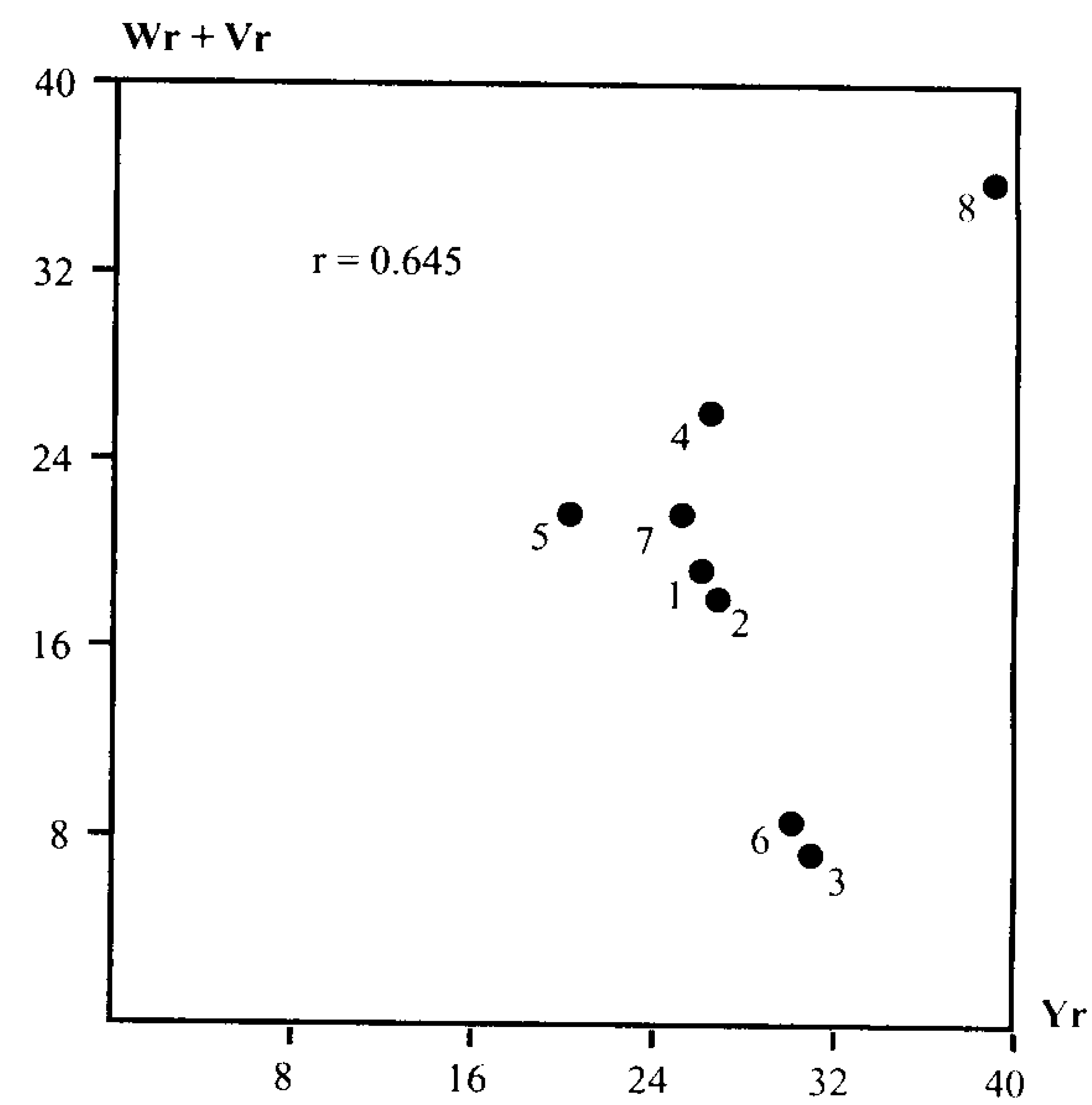

Fig. 2c. Relationship between Yr and $Vr + Wr$ for root number. 1 = Marichboti; 2 = Patuakhali; 3 = Pukhi; 4 = Jhumkamarang; 5 = Mijingem; 6 = BR21; 7 = OS4; 8 = IR20.

Table 5. Genetic parameters and their proportional values for root length, root diameter and root number in an eight-parent diallel cross in upland rice.

Genetic parameter	Estimated value ± SE		
	Root length	Root diameter	Root number
D	95.615 ± 35.336**	1.783 ± 0.047**	34.198 ± 1.393**
H_1	46.896 ± 188.409	0.502 ± 0.109**	13.870 ± 3.203**
H_2	32.523 ± 142.614	0.373 ± 0.095**	8.894 ± 2.787**
h^2	17.727 ± 63.828	0.064 ± 0.064	1.762 ± 1.869
F	53.223 ± 199.058	0.809 ± 0.112**	18.846 ± 3.293**
E	1.353 ± 3.962	0.018 ± 0.016	0.905 ± 0.464
Ratio		Proportional value	
$(H_1/D)^{1/2}$	0.700	0.531	0.637
$H_2/4H_1$	1.173	0.186	0.160
$[(4DH_1)^{1/2}+F]/[(4DH_1)^{1/2}-F]$	2.319	2.495	2.525
h^2/H_2	0.545	0.173	0.198
$r(Yr$ vs. $Vr+Wr)$	- 0.269	0.150	0.645
$h^2(ns)$	0.692	0.832	0.765
$h^2(bs)$	0.890	0.973	0.933

**Significant at the 1% probability level.

Root diameter. Table 5 shows the estimated components of variation using the model of Hayman (1954). Additive and some portion of additive x additive genetic variance (D = 1.783 ± 0.047**), dominance and dominance x dominance (H_1 = 0.502 ± 0.109** and H_2 = 0.373 ± 0.095**) and relative frequencies of dominant and recessive alleles in the parents (F = 0.809 ± 0.112**) were found to be significant indicated the presence of both additive and dominance type of genetic effects in the parents. The significant positive F value and the $[(4DH_1)^{1/2} + F] / [(4DH_1)^{1/2} - F]$ ratio (2.495) determined the presence of excess dominant alleles in the parents. Partial or incomplete dominance was indicated by $(H_1/D)^{1/2}$ = 0.531, which was confirmed from *Vr-Wr* graph. $H_2/4H_1$ (0.186) ratio indicated unequal gene frequencies for root diameter. h^2/H_2 (0.173) implies the involvement of one group dominant gene(s) for thick roots over the thin roots. High h^2(ns) value (0.832) and high h^2(bs) value (0.973) indicated that the additive genes are prominent as indicated by Chang *et al.* (1982), but Armenta-Soto *et al.* (1983) reported both additive and dominance gene actions for root thickness.

Root number. Analysis of components of variation showed that additive and additive x additive (D = 34.198 ± 1.393**), dominance (H_1 = 13.870 ± 3.203**) and dominance x dominance (H_2 = 8.894 ± 2.787**) were highly significant (Table 5), which indicated the presence of both additive and dominance gene actions in the inheritance of root number. Similar gene actions were also found both in Griffing's and Hyman's analysis of variances. Position of the parents on regression line and positive F value (18.846 ± 3.293**) indicated predominant dominant alleles controlled root number in the parents. This was also proved from the ratio (2.525) of $(4DH_1)^{1/2} + F$ and $(4DH_1)^{1/2} - F$. Existence of partial dominance as found from Vr-Wr graph, also confirmed from $(H_1/D)^{1/2}$ = 0.637. Asymmetrical distribution of the genes in the parents and presence of one group of dominant gene(s) were suggested from $H_2/4H_1$ (0.160) and h^2/H_2 (0.198) respectively. Predominance of additive genes expressing the root number was indicated from heritability both at narrow (h^2_{ns} = 0.765) and broad (h^2_{bs} = 0.933) sense, which was also, supported the findings of Monyo and Whittington (1970).

CONCLUSION

Both additive and dominance gene actions control all the three root characters viz length, diameter and number. Dominant positive genes for root length are present in OS4 and recessive positive in IR20. Marichboti contained dominant positive gene for root diameter. For root number, IR20 had the most recessive genes and Pukhi and BR21 contained most dominant genes with positive effects. These parents could be used in crossing programme and selection for the desired level of root characters could be done in the early or late segregating generations depending on the genetic behaviour of the parents. Recurrent selection could also be practiced to accumulate desired genes for the development of modern drought tolerant rice varieties.

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Eight-Parent Full Diallel Analysis for Root Xylem Vessel Number in Drought Tolerant Rice

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ABSTRACT

Combining ability and genetic analyses for xylem vessel number were done using an eight-parent full diallel cross in rice (*Oryza sativa* L.). Significant variations were observed among the tested genotypes, crosses and parents vs crosses in the analysis of variances. The test genotype Marichboti had the highest number of xylem vessel (5.63) followed by Mijingem (4.94) compared to 4.90 and 4.83 in OS4 and Jhumkamarang. On the other hand, cross Marichboti x Mijingem yielded the highest number of vessels (5.67). Variances due to general (gca), specific (sca), reciprocal combining ability analysis, Hayman's ANOVA and components of variation indicated the presence of both additive and dominant gene actions, but the gca/sca ratio (2.11) indicated only additive gene action for xylem vessel number. The association (r = 0.963) between gca and Yr demonstrated a close relation between the magnitudes of the two components. The parents Marichboti, Jhumkamarang, Mijingem and OS4 showed good general combiner. The best cross combination was BR21 x Pukhi that was reciprocal. From the single cross combinations, only four were significant and positive, which were 15 in the reciprocal cross combinations. Graphical representation (Vr-Wr) revealed partial dominance with possible involvement of one group of gene(s) governing the trait. Marichboti contained the most recessive alleles followed by Patuakhali, Mijingem and OS4. Jhumkamarang possessed almost equal number of dominant and recessive alleles. Other varieties had comparatively higher frequency of dominant genes. Comparatively higher values of h^2_{ns} (0.879) and h^2_{bs} (0.983) indicated the absence of major environmental effects on the vessel number. From the overall genetic behaviour, development of drought resistant modern rice varieties was suggested considering high vessel number using some recurrent selection methods or pedigree selection method at the later growth stages.

INTRODUCTION

The number and size of the root xylem vessel are closely related to the capacity of the drought tolerant rice plant to absorb water and nutrients from the soil. Passioura (1982) found xylem vessel number as a factor influencing water absorption. Haque *et al.* (1989) found significantly higher number of vessels in drought tolerant Aus variety, Marichboti (six) and hill rice Jhumkamarang (six), Mijingem (seven), and Mimidimalang (six), when studied under hydroponic culture. Most of the researchers had observed that the drought resistant varieties yielded more number of vessels than the susceptible varieties (Chang and Vargara, 1975; Armenta-Soto *et al.*, 1983; Haque *et al.*, 1988). They also found that the xylem vessel number were positively associated with drought resistance. Haque *et al.* (1989) found that xylem vessel number was directly and positively contributed to drought resistance. For the improvement of xylem vessel number, emphasis should be given on parent selection. For the development of drought resistant modern rice varieties, genetic behaviour and inheritance pattern of xylem vessel number and possibilities of transferring those into modern cultivars are essential. Thus, this study investigation the combining ability, inheritance pattern, genetic behaviour and genetic components of variation for xylem vessel number in eight-parent full diallel cross involving parents with variable vessel number.

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MATERIALS AND METHODS

This study used eight rice varieties viz Marichboti, Patuakhali, Pukhi, Jhumkamarang, Mijingem, BR21, OS4 and IR20 representing different agro-ecological conditions. A diallel mating was made in all possible combinations and obtained 56 F_1 hybrids at Bangladesh Rice Research Institute (BRRI). The pregerminated seeds of 64 entries (56 F_1s and eight parents) were sown on the top of 75 cm polyethylene tube filled with sand and soil (3 : 1). Twelve seeds from each entry were used and one seed was sown on each tube. The tubes were arranged in wooden frame in a triple lattice design in the Plant Physiology Division glasshouse, BRRI. The plants were watered twice daily with cultural solution as suggested by Yoshida *et al.* (1976). At maximum vegetative stage (35 days after seeding) five well-developed roots (1 cm from the tip) were collected and preserved in a glass vial containing Formalin Aceto Alcohol (FAA) solution. The preserved roots were then hand sectioned and the xylem vessel numbers were counted per root under compound microscope for statistical analysis.

Analysis of variance for genotypes, parents (P), crosses (F_1) and P vs. F_1, Hayman's ANOVA, variances (Vr) and covariances (Wr) were calculated following Hayman (1954). Vr-Wr and standardized deviation graph (Vr+Wr, Yr) were prepared (Johnson, 1963). Components of genetic variations and genetic parameters were estimated using the formula of Mather and Jinks (1982). Combining ability analyses were done as suggested by Griffing (1956).

RESULTS AND DISCUSSION

Performances of parents and F_1 hybrids

Significant variances (Table 1) were observed for xylem vessel number in all sources of variations viz. genotypes, parents, F_1s and P x F_1 interactions. The results indicated the validity of the additive-dominance model in the absence of inter-allelic interactions and suggested for further analysis to estimate the genetic behaviour of xylem vessel number. Among the parents (Table 3), drought tolerant variety Marichboti produced the highest number of vessels (5.63) followed by Mijingem (4.97), OS4 (4.90) and Jhumkamarang (4.83), which supported the findings of Haque *et al.* (1989). Figure 1 shows the differences in xylem vessel numbers of resistant variety Marichboti, susceptible variety IR20 and their F_1. It indicates that the drought tolerant varieties had the potential to produce more vessels than the susceptible ones and had the potential of the better parents to transmit the higher vessel numbers to the F_1s as suggested by the regression coefficient between the array means and parental means (r = 0.970). The highest number of vessels were found in the specific cross Marichboti x Mijingem (5.67), while the lowest number were in the reciprocal cross combination IR20 x BR21 (3.00). Vessels number of the other crosses produced intermediate number between the parents but closer to the better parents indicated the existence of strong heterosis.

Table 1. Analysis of variance for xylem vessel number in F_1 in the eight-parent diallel cross in rice.

Source	Degree of freedom	Mean square
Genotype	63	1.196**
Parents (P)	7	2.017**
Cross (F_1)	55	1.106**
P x F_1	1	1.927**
Error	126	0.020
CV (%)	3.32	

**Significant at the 1% probability level. r (array mean vs. Yr) = 0.970.

Combining ability

Analysis of variance due to combining ability (Table 2) showed highly significant variations among gca, sca and reciprocal effects. These results revealed the involvement of additive, dominance and reciprocal gene actions in the inheritance pattern of xylem vessel number. The ratio between gca and sca (2.110) indicated the prevalence additive gene effects, which was also supported by the regression between gca and Yr (r = 0.963) and a close relation between them was detected. Most of the drought resistant parents were found to be good general combiner. Table 3 shows Marichboti as the best (0.460**) drought resistant parent as well as a good general combiner followed by Mijingem (0.359**),

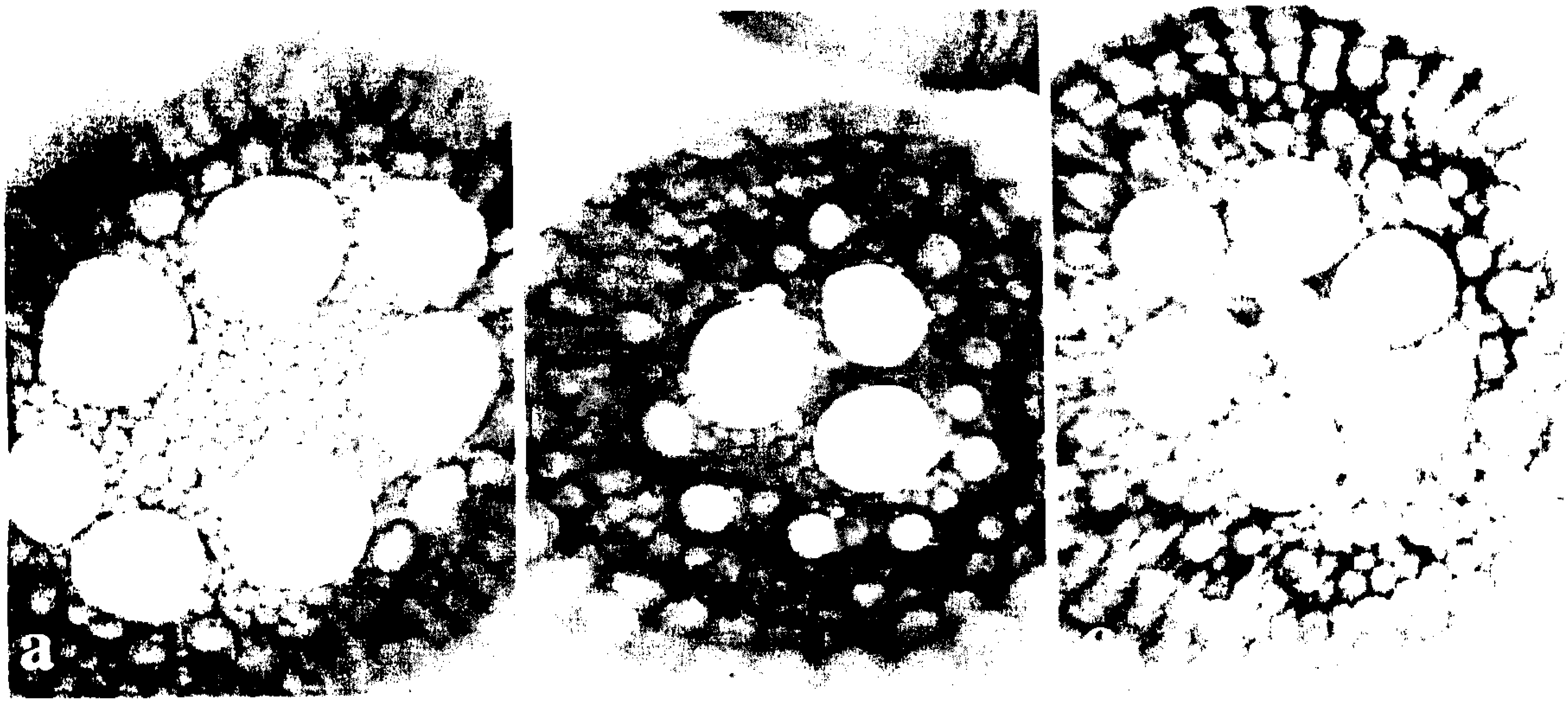

Fig. 1. Differences in xylem vessel numbers of (a) resistant- Marichboti; (b) susceptible- IR20; and (c) their F_1(Mag. 10X40).

Table 2. Analysis of variance for combining ability for xylem vessel number in eight-parent diallel cross in rice.

Source of variation	Degree of freedom	Mean square
General combining ability (gca)	7	3.049**
Specific combining ability (sca)	28	0.097**
Reciprocal (rca)	28	0.083**
Error	126	0.007
gca/sca		2.110

**Significant at the 1% probability level; r (gca vs. Yr) = 0.963; components; gca = 0.190; sca = 0.090; rca = 0.038.

Table 3. The gca (diagonal), sca (above diagonal) and reciprocal (bellow diagonal) effects and means (in parenthesis) for xylem vessel number in the eight-parent diallel cross in rice.

Parent	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
P_1	0.460**	0.029	-0.213**	0.003	0.331**	-0.154*	-0.015	-0.418**
	(5.63)	(4.67)	(4.37)	(5.17)	(5.67)	(4.17)	(5.07)	(3.83)
P_2	-0.115*	0.026	-0.129	-0.013	-0.006	-0.155*	0.384**	0.086
	(4.90)	(4.13)	(4.03)	(4.60)	(4.80)	(3.73)	(5.37)	(4.07)
P_3	0.120*	0.130*	-0.267**	-0.135	-0.033	0.103	-0.008	0.224**
	(4.13)	(3.77)	(3.93)	(4.20)	(4.23)	(3.93)	(4.17)	(3.63)
P_4	0.170**	0.050	0.065	0.267**	-0.111	-0.066	0.123	0.175*
	(4.83)	(4.50)	(4.07)	(4.83)	(4.67)	(3.93)	(5.13)	(4.33)
P_5	0.250**	0.150**	-0.100	-0.115*	0.359**	-0.038	-0.068	-0.053
	(5.17)	(4.50)	(4.43)	(4.90)	(4.97)	(4.03)	(5.10)	(3.93)
P_6	0.185**	0.180**	0.415**	0.050	0.030	-0.591**	-0.019	0.018
	(3.80)	(3.37)	(3.10)	(3.83)	(3.97)	(3.40)	(3.93)	(3.17)
P_7	0.000	0.335**	-0.180**	0.115*	0.185**	-0.085	0.355**	-0.313**
	(5.07)	(4.70)	(4.53)	(4.90)	(4.73)	(4.10)	(4.90)	(3.97)
P_8	0.130*	0.300**	0.015	0.230**	-0.035	0.085	0.270**	-0.612**
	(3.57)	(3.47)	(3.60)	(3.87)	(4.00)	(3.00)	(3.43)	(3.33)

Var (gi) = 019; Var (sij) = 0.072; Var (rij) = 0.058; Var (gi-gj) = 0.029. *, **Significant at the 5% and 1% probability level, respectively. P_1 = Marichboti; P_2 = Patuakhali; P_3 = Pukhi; P_4 = Jhumkamarang; P_5 = Mijingem; P_6 = BR21; P_7 = OS4; P_8 = IR20

OS4 (0.355**) and Jhumkamarang (0.267**) and the poorest was IR20 (- 0.612**). The best sca cross combination was BR21 x Pukhi (0.415**), while Marichboti x IR20 (- 0.418**) was the poorest. Both Marichboti and Patuakhali combined well with other parents when used as male. Other crosses showed both good as well as poor cross combinations when used either as male or as female. The results showed intermediary performances and indicated partial dominance for the trait.

Hayman's analysis of variance

All the items in Hayman's ANOVA were found highly significant (Table 4). The significant a (9.134**) and b (0.220**) values indicated the presence of additive and non-additive genetic effects respectively for xylem vessel number. Bashar *et al* (1992) also reported both additive and dominance effects for the trait. The items b_1 (0.407**), b_2 (0.194**) and b_3 (0.220**) suggested that the genes were distributed in one direction among the parents as found in F_1 as well as in sca, which also indicated that some parents had more dominant alleles. Significant c (0.418**) and d (0.110**) values suggested the involvement of both maternal as well as reciprocal influence in the inheritance of xylem vessel number.

Graphical analysis of Vr-Wr

Figure 2 shows the Vr-Wr graph that provided a unit slope of linear regression (b = 0.937) indicating the absence of inter-allelic interaction and independent distribution of the genes among the parents. The magnitude and position of Wr axis (a = 0.120) that intercepted the regression line indicated partial dominance in the inheritance of the trait. In a cross

Table 4. Hayman's analysis of variance for xylem number in a eight-parent diallel analysis in rice.

Source	Degree of freedom	Mean square
a	7	9.134**
b_1	1	0.407**
b_2	7	0.194**
b_3	20	0.220**
b	28	0.220**
c	7	0.418**
d	21	0.110**

**Significant at the 1% probability level.

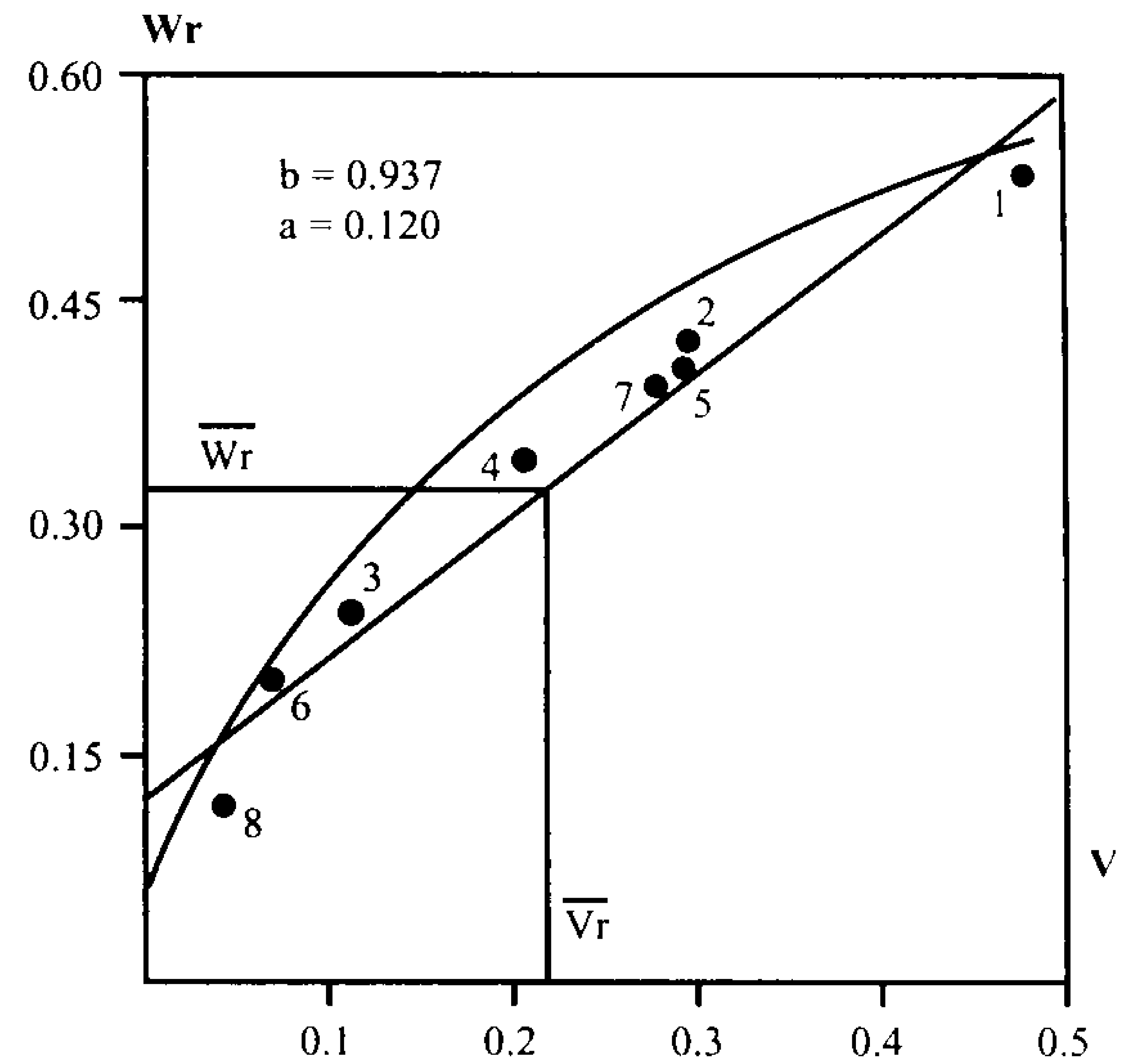

Fig. 2. Variance and covariance (Vr-Wr) regression graph of eight-parent diallel analysis for xylem vessel number.

between Moroberican and IR20, Bashar *et al.* (1992) also reported partial dominance for vessel number. IR20 was closest to the origin and carried most dominant alleles followed by BR21 and Pukhi. On the other hand, Marichboti the most tolerant variety had the large number of recessive alleles, followed by Patuakhali, OS4 and Mijingem. Figure 3 also supports the above results of parental order of dominance. Regression coefficient (r = 0.900) between Wr + Vr and Yr indicated that the lower value of Wr + Vr and Yr contained most dominant alleles and a close relationship were existed among them.

Components of variation and genetic parameters

Components due to additive (D = 0.646 ± 0.025**), dominance (H_1 = 0.198 ± 0.058**) and dominance x dominance (H_2 = 0.161 ± 0.050**) were found highly significant indicating the presence of both additive and dominance type of gene action for xylem vessel numbers as also found in earlier analyses (Table 5). The ratio (0.307) from $(H_1/D)^{1/2}$ suggested only additive type of interaction. $H_2/4H_1$ (0.203) indicated asymmetrical distribution of positive and negative genes among the parents. A single pair of dominant gene(s) controlled the vessel number as suggested by h^2/H_2 (0.301) ratio, which confirmed the findings

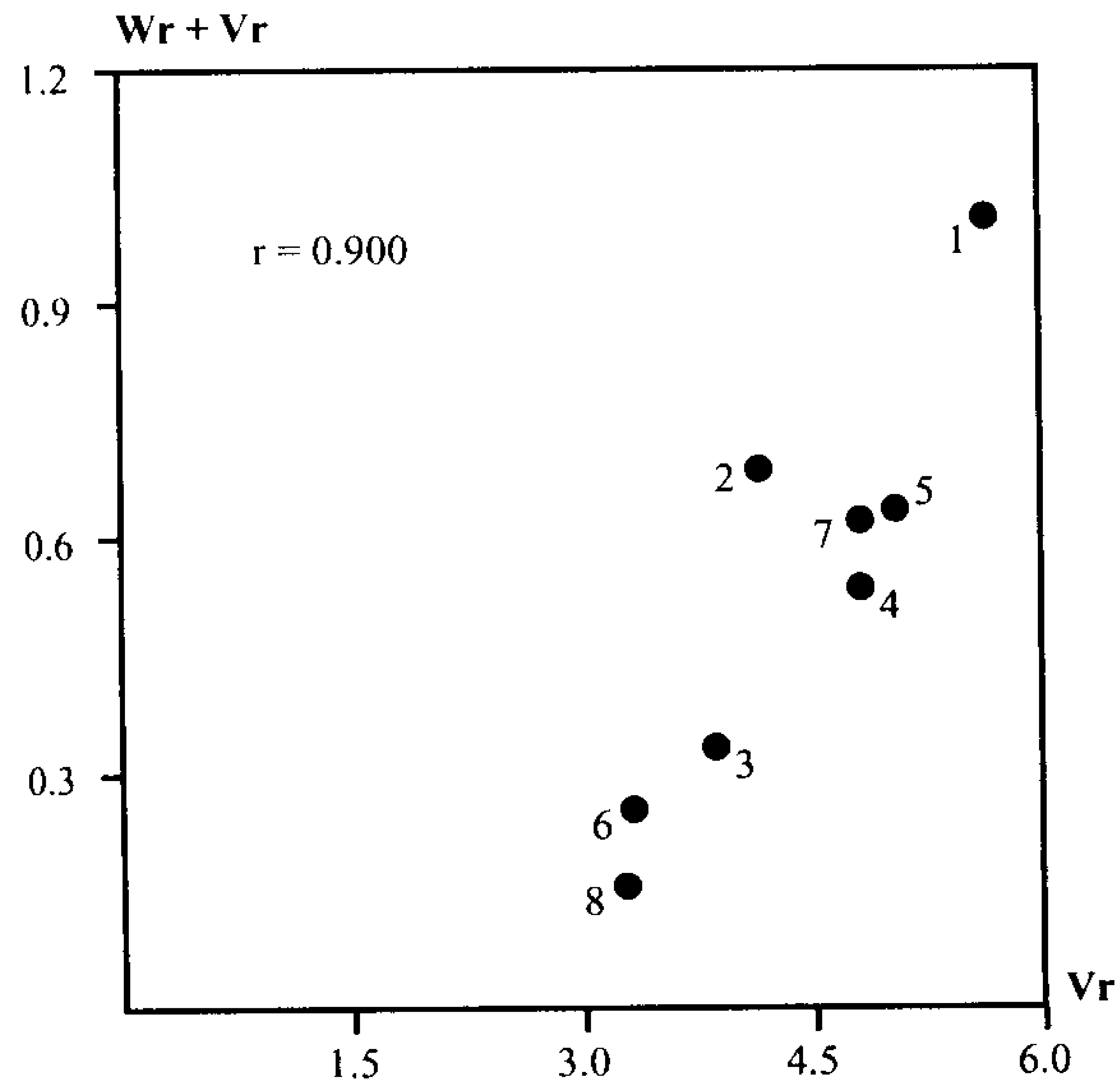

Fig. 3. Standardized deviation graph (Yr, Vr+Wr) of eight-parent diallel analysis for xylem vessel number. 1 = Marichboti, 2 = Patuakhali, 3 = Pukhi, 4 = Jhumkamarang, 5 = Mijingem, 6 = BR21, 7 = OS4, 8 = IR20.

Table 5. Genetic parameters and their proportional values for xylem vessel number in the eight-parent diallel cross in rice.

Genetic parameter	Estimated value ± SE
D	0.646 ± 0.025**
H_1	0.198 ± 0.058**
H_2	0.161 ± 0.050**
h^2	0.048 ± 0.034^{ns}
F	0.003 ± 0.060^{ns}
E	0.007 ± 0.008^{ns}
Ratio	Proportional value
$(H_1 / D)^{1/2}$	0.307
$H_2 / 4H_1$	0.203
$[(4DH_1)^{1/2} + F] / [(4DH_1)^{1/2} - F)]$	1.008
h^2/H_2	0.301
r (Yr vs. Wr + Vr)	0.900
h^2 (ns)	0.879
h^2 (bs)	0.983

**Significant at the 1% probability level.

of Bashar *et al.* (1992). The high value of h^2_{ns} (0.879) and h^2_{bs} (0.983) indicated the absence of major environmental effects and the parents showed that the vessel numbers were mainly controlled due to their additive gene effects.

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Culturability Behaviour in *Indica* and *Japonica* Rice Varieties

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ABSTRACT

An *in vitro* culturability (calllus induction and regeneration) study on *indica* and *japonica* rice (*Oryza sativa* L.) varieties were carried out using three explant types- mature seed, young panicle and immature embryo. Generally, compact, nodular and cream coloured calli showed better regeneration ability. On the other hand, loose, light yellowish and slightly watery calli were found less effective. The response in higher regeneration capability correlated to bigger size of compact calli. The regeneration ability of *indica* and *japonica* varieties interacted with explant type, variety and media combinations. Immature embryo of BR5 showed better regeneration in both MS and K media compared to other *indica* varieties and japonica variety, Taipei 309, used as experimental check. Higher number of regenerated green plants was obtained in MS medium from immature embryo of BR5 and BRRI dhan29 and in K medium from BRRI dhan32. Media-explant interaction showed better regeneration in K medium from immature embryo. Similarly, explant-variety interaction also showed better regeneration from immature embryo of BR5. Therefore, BR5 could be used as a check variety instead of *japonica* variety, Taipei 309 for future study.

Key words: *Indica*, *japonica*, rice regeneration, green plant, check variety

INTRODUCTION

Biotechnology is now considered as an important tool for crop improvement through recombinant DNA technology. The prerequisite for using this biotechnological method is the establishment of *in vitro* culturability (calllus induction and regeneration) of parts of plant that serve as the source for genetic manipulation. In rice, the parts of plants popularly called explants, which could be seeds, young panicles, mature or immature embryos, anthers, root tips and any parts in cell dividing stage are source of culture. Previous studies by several researchers confirmed better embryogenic callus induction and efficient plant regeneration in rice (Karim and Zapata, 1990; Yin *et al.*, 1993; Mohiuddin *et al.*, 2006 and Rachmawati and Anzai, 2006) and many other plant species ie cotton (Han *et al.*, 2009) that make a protocol suitable for genetic manipulation. A plethora of protocols are available for rice callus induction and plant regeneration (Visarada *et al.*, 2002). However, previous study revealed that a revised protocol was crucial when new genotype was considered for improvement (Maggioni *et al.*, 1989).

In general, rice varieties belonging to the subspecies *japonica* are highly responsive for both callus induction and plant regeneration compared to *indica* and *javanica* (Abe and Futsuhara, 1986). Taipei 309, a japonica variety, has, therefore, been commonly using as a check variety to compare the culturability behaviour of *indica* and *javanica* varieties. It is more effective to compare the culturability behaviour by a *indica* check variety when *indica* varieties are considered for studying. An *indica* or *japonica* check variety intensively helps to evaluate the agronomic characteristics of rice varieties (Luong *et al.*, 2001,

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Peng *et al.*, 2004). To develop a check variety, studies on induction of embryogenic callus from suitable explant, their totipotent ability to shoot regeneration, studies on culturibility interaction between explant type of genotypes and culture conditions are vital (Luong *et al.*, 2001, Visarada *et al.*, 2002).

This study was, therefore, undertaken to find out the best culturable explants, such as mature seed, immature embryo and young rice panicle of five widely grown indica varieties developed by the Bangladesh Rice Research Institute (BRRI). A *japonica* cultivar having high culturability was used as a control for comparative analysis. The objectives were to observe the interaction of media to species in terms of culturability and to develop the best regeneration system of test varieties, which could be used as check variety for *indica* rice.

MATERIALS AND METHODS

Preparation of explants. Different explants (eg mature seed, young panicle and immature embryo) of the five *indica* varieties- BR5, BRRI dhan28, BRRI dhan29, BRRI dhan32, BRRI dhan40 and one *japonica* variety, Taipei 309, were used as a control for comparative study on callus initiation and plant regeneration. The explants were treated to make them contaminant free before inoculation for tissue culture.

Mature seed. Mature seeds having 95% germination were dehusked manually and seeds were then treated with sterilized distilled water having 2-3 drops of Tween 20 for 10 minutes with gentle shaking followed by 70% ethanol for 2-3 minutes. Finally the seeds were sterilized with a solution containing 0.1% mercuric chloride and shaken for 20 minutes at 150 rpm. The seeds were then rinsed 3-4 times with sterilzed water under aseptic condition in a laminar airflow hood.

Young (immature) panicle. Young panicles of 3-7 cm long of both indica and japonica rice varieties were collected from the field grown plants at the early booting stage. The panicles were dissected out very carefully inside the laminar airflow hood with sterilized forceps and scissors to avoid any contamination. No sterilization agent was necessary as the young panicles inside the boots (at early booting stage) are free of contaminants.

Immature embryo. Seeds were collected at early/soft dough stage from the field grown plants. Immature seeds were dehusked manually and sterilized according to the same procedure of mature seeds. The immature embryos were dissected out from the sterilized seeds with a sharp scalpel inside the laminar flow cabinet under sterile condition before plating in culture media.

Media preparation. Two different media namely MS (Murashige and Skoog 1962) with 2mg/l 2,4-D (2,4-dichlorophenoxyacetic acid) and K (modified MS medium; Karim and Zapata, 1993) were prepared for callus induction study. On the other hand, the medium used for regeneration was consisted of MS basal salts (Murashige and Skoog, 1962) having 1mg/l each of NAA (1-naphthalene Acetic Acid) and Kinetin. Agar at a concentration of 8.0 g/l was added to solidify the media. All the media combinations were adjusted to pH 5.8 before autoclaving. Autoclave was done at 121°C for 15 min at 1.05 kg/cm^{-2} pressure (15-20 psi). Fifteen to 20 ml of both callus induction and regeneration media were dispensed into sterile glass petri dishes (60X15 mm) and test tubes (8" height), respectively.

Culture of explants. The explants were cultured in callus induction media under dark incubation at 24±1°C. After four weeks the calli developed from mature seeds were transferred to the regeneration medium. On the other hand, two weeks old calli derived from the young panicles and immature embryos were transferred to the regeneration medium. The cultures were incubated under continuous light for 4-5 weeks at 24±1°C for shoot and root formation. The regenerated plants (green/albino) were transferred to hormone free MS medium for further growth and development.

Acclimatization. Well-developed, phenotypically normal and extensively rooted plantlets were chosen for acclimatization. The acclimatized plants were then transferred to soil in pot with Yoshida's (Yoshida et al. 1962) nutrient solution for further growth and kept there until maturity.

Data collection and analysis. The experiments were set in completely randomized design (CRD) with 10-15 replications. Data on callusing and its size and structure were recorded before transferring to regeneration medium. Similarly, data on regeneration frequency and number of green and albino plant production were recorded after root shoot formation. Using the recorded data a descriptive analysis was done.

RESULTS AND DISCUSSION

Callus induction efficiency. Callus induction was observed from all the varieties including the check within 15 to 30 days, 3 to 10 and 7 to 15 days from dehusked mature seeds, young panicles and immature embryos, respectively. Both compact and loose calli were initiated from the explants tested. Most of the calli were cream coloured and occasionally white calli formed near the edge of cream coloured ones. Relatively dry, cream coloured and nodular compact calli were designated as embryogenic. The compact calli were observed in some Indonesian varieties (Rachmawati and Anzai, 2006) and some Bangladeshi varieties that are habituated to grow in deep water with better callus initiation rates (Khaleda and Al-Forkan, 2006). On the other hand, loose calli mostly looked like light yellowish, soft and slightly watery induced from all varieties. This type of callus found in our study is designated as non-embryogenic. Non embryogenic calli also obtained from some Indonesian varieties, which did not regenerate subsequently (Rachmawati and Anzai, 2006).

Comparatively higher rate of compact calli initiated from immature embryos of both *indica* and check varieties compared to mature seeds and young panicles (Table 1). Compact calli induced from immature embryos of all varieties showed 100% culturability in K medium (Table 1). Similarly, compact calli was found to initiate from same explants of all varieties on MS medium except BRRI dhan29 and BRRI dhan32. On the other hand, compact calli initiated from mature seeds on MS medium of all the varieties except BRRI dhan32. However, loose calli were initiated from *indica* varieties BRRI dhan28 and BRRI dhan32 and *japonica* variety Taipei 309 on K medium (Table 1). In terms of compact calli initiation from young panicles, less response was observed. Only BRRI dhan29 and Taipei 309 initiated compact calli from young panicle explants on both MS and K media (Table 1). No response was observed from BRRI dhan28 and BRRI dhan32 on K medium. These results on callus structure confirmed that compact calli initiation is dependent on genotype, explant and media interaction. Similar results were found in different rice varieties as reported by Khaleda and Al-Forkan, 2006 and Mohiuddin *et al.*, 2006.

The response in induction of average callus size varied greatly between varieties, explants, media composition and their interaction (Table 1). Better size of compact calli was found to be initiated from immature embryos of BR5 (Fig. 1a) and BRRI dhan40. Similarly, better size of the calli initiated from young panicles of *japonica* variety, Taipei 309 and mature seeds of *indica* variety BRRI dhan40 (Table 1). Generally, compact calli were of bigger size compared to loose calli (Table 1). These findings indicate that better compact callus initiation was influenced by genotype, explant, media and their interaction. Similar results were found in *javanica* rice varieties reported by Rachmawati and Anzai in 2006.

Among the varieties, percent callusing frequency varied between genotypes (*indica* and *japonica*), among explants and culture media and their interaction dependent (Fig. 2a, b, c). The highest callus induction was observed in mature seeds of BR5 and BRRI dhan28 (100% in both MS and K) followed by BRRI dhan29 (86% in MS and 90% in K) and Taipei 309 (93% in MS and 89% in K) (Fig. 2a). Young panicles, on the other hand, showed high callus frequency (100%) in MS medium (Fig. 1b) irrespective of all the varieties tested (Fig. 2b). Reverse result was observed in all the varieties except BRRI dhan29 from immature embryo where K medium showed high callusing frequency compared to MS medium (Fig. 2c). Our result clearly shows the better performance in respect to callus induction in *indica* varieties compared to *japonica*. However, opposite result was found by Chitra and Kumar (2006) where *japonica* variety showed better callusing performance than *indica,* earlier results showed same callus induction performance in both *indica* and *japonica* varieties (100%) as reported by Mohiuddin *et al.*, 2006.

Regeneration efficiency. In terms of shoot regeneration ability better rates were observed in

Table 1. Structure and average callus size (cm) of different explants obtained from *indica* and check *japonica* rice varieties under two different callus induction media.

Variety	Media	Mature Seed		Young panicle		Immature embryo	
		Callus size ± SE	Callus structure	Callus size ± SE	Callus structure	Callus size ± SE	Callus structure
BR5	MS	0.35±0.2	Compact	0.25±0.1	Loose	0.63±0.5	Compact
	K	0.26±0.2	Compact	0.15±0.1	Loose	0.48±0.4	Compact
BRRI dhan28	MS	0.33±0.2	Compact	0.30±0.2	Compact	0.33±0.3	Compact
	K	0.25±0.2	Loose	0.0±0.0	-	0.35±0.2	Compact
BRRI dhan29	MS	0.26±0.2	Compact	0.35±0.2	Compact	0.33±0.3	Loose
	K	0.35±0.3	Compact	0.55±0.0	Compact	0.45 ±0.2	Compact
BRRI dhan32	MS	0.31±0.3	Loose	0.30±0.2	Loose	0.23±0.2	Loose
	K	0.33±0.3	Loose	0.0±0.0	-	0.28±0.2	Compact
BRRI dhan40	MS	0.40±0.3	Compact	0.28±0.2	Loose	0.47±0.3	Compact
	K	0.35±0.3	Compact	0.15±0.1	Loose	0.45±0.3	Compact
Taipei309	MS	0.35±0.2	Compact	0.60±0.4	Compact	0.23±0.2	Compact
	K	0.28±0.2	Loose	0.45±0.3	Compact	0.21±0.2	Compact

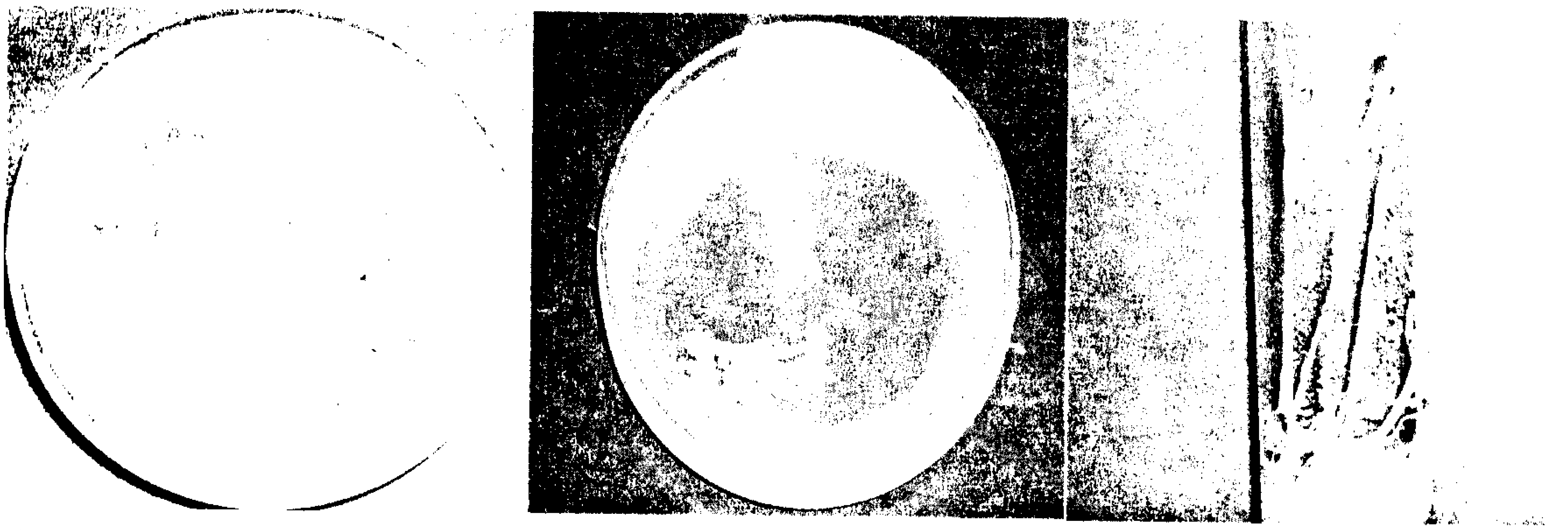

Fig. 1. (a) Compact and embryogenic calli induced from immature embryo of BR5, (b) Calli initiated from young panicles of Taipei309 and (c) Green plantlets regenerated from immature embryo of BR5.

both *indica* rice variety BR5 and check *japonica* variety Taipei 309 from mature seeds (Fig. 3a). Similar result was also found in Taipei 309 and BRRI dhan29 from calli of young panicles (Fig. 3b). In these cases, compact callus with bigger size derived from all three explants produced better shoot regeneration rate (Tables 1, Fig. 3b). These findings confirm that both compact type and bigger size calli are better for shoot regeneration. From our study, it was further observed that better regeneration was observed in callus derived from immature embryo of BR5 from both MS and K media (Fig. 3a). These findings correlating to callus size indicate that bigger size of compact calli induced better shoot regeneration (Tables 1, Fig 3c). This study confirms that shoot regeneration efficiency is correlated to the callus size initiated from different explants of six rice varieties emphasizing that future culturability observation should focus on callus size and embryogenic in nature.

Our results obviously indicate that in most of the cases compact calli (embryogenic) initiated from three different explants regenerated shoots with better rates (Tables 1, Fig. 3a, b, c). These findings are supported by the published reports on *indica* rice by Mohiuddin *et al.*, 2006, on *javanica* rice by Rachmawati and Anzai, 2006 and on deepwater *indica* rice varieties (Khaleda and Al-Forkan, 2006).

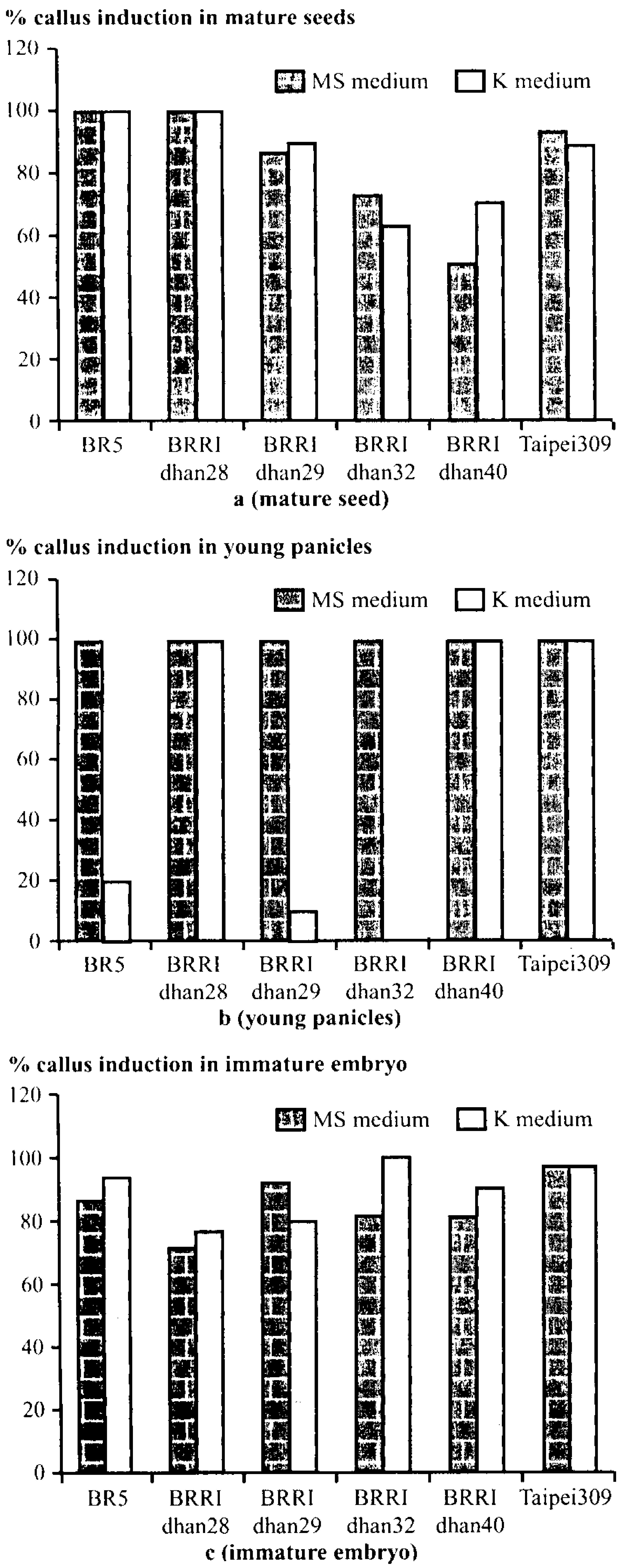

Fig. 2. Callus Induction efficiency of rice with three explants and two media components.

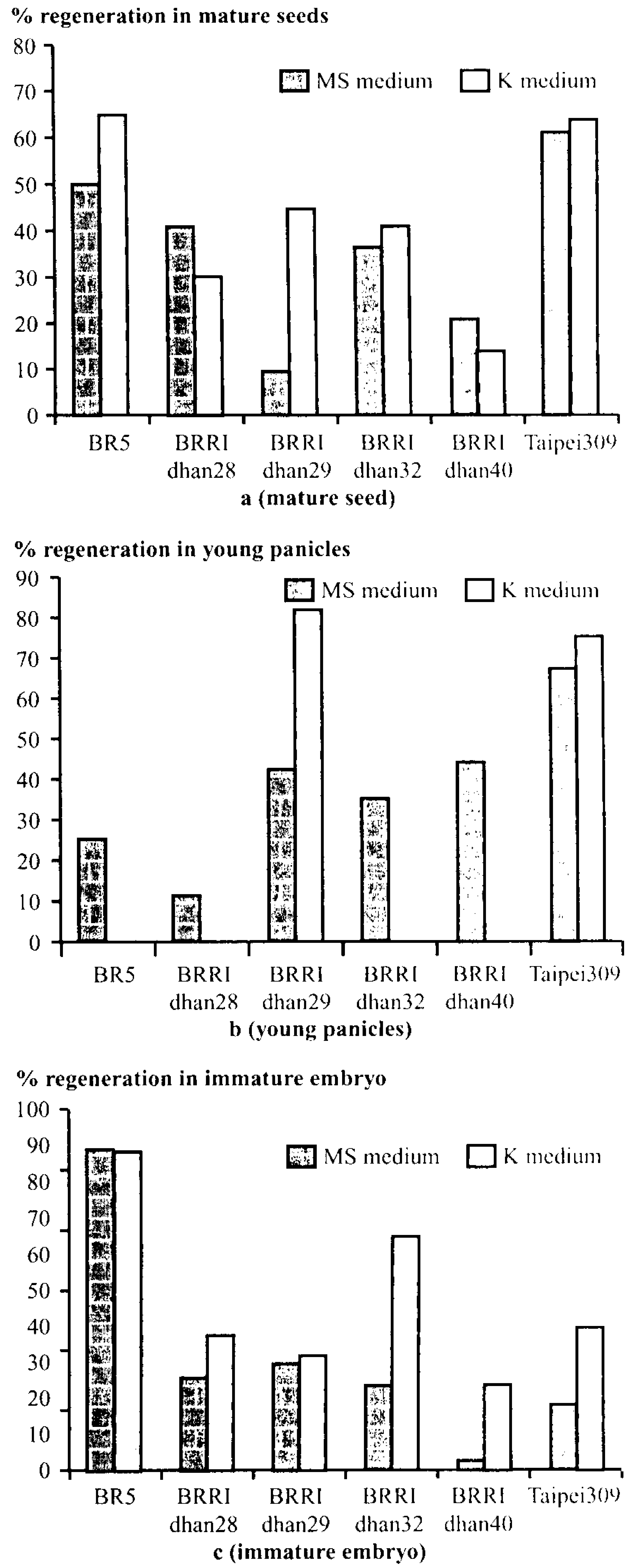

Fig. 3. Regeneration efficiency of rice with three explants and two media components.

In this study it was found that shoots also regenerated from loose, soft and slightly watery calli (reported as non-embryogenic) from both *indica* and *japonica* varieties (Tables 1, Fig. 3a, b, c). Loose, soft and slightly watery calli of Taipei 309 (*japonica* variety) induced from mature seeds produced higher percentage of regeneration compared to compact calli (Tables 1, Fig. 3a). In some cases loose, soft and slightly watery calli of *indica* varieties derived from mature seeds, young panicles and immature embryos also regenerated shoots (Tables 1, Fig. 3a, b, c). This confirms that loose, soft and slightly watery calli that were reported as non-embryogenic calli by Rachmawati and Anzai, (2006) are able to convert embryogenic calli having totipotent ability in the presence of regeneration medium with suitable hormones and their appropriate concentration. This finding is supported by Chin *et al.*, 1988. The presence of hormone 2.4-D in callus induction medium also induced somatic embryogenesis in monocot crop like wheat (Akella *et al.*, 2007).

Generally, the immature embryos of *indica* rice variety, BR5 showed better regeneration (Fig. 1c, 3c) either in MS (89%)/ or K (88%) medium compared to *japonica* variety Taipei 309 as well as other *indica* varieties (Fig. 3a, b, c). This present finding also supports the findings reported by Chitra and Kumar 2006 where Taipei 309 exhibited poor plant regeneration than *indica* rice. Furthermore, this study shows better regeneration capability than the previous studies on *javanica* rice varieties reported by Rachmawati and Anzai, (2006), and on *indica* rice varieties reported by Yin *et al.*, (1993); Visarada *et al.*, (2002); Rashid *et al.*, (2003); Mohiuddin *et al.*, (2006); Khaleda and Al-Forkan, (2006); Chitra and Kumar (2006) and Hoque *et al.*, (2007). From the present study it may be concluded that *indica* variety, BR5 with suitable explants (immature embryo) and other factors can show better regeneration proficiency than *japonica* variety Taipei 309. Therefore, this variety has extensively been used as a check variety in tissue culture experiment.

Green and albino plant production proficiency. Green plants were regenerated from all three explants of *indica* and check *japonica* varieties in both MS and K media (Table 2). From our study it was observed that both the compact and loose calli produced green plants. However, compact calli in few cases produced shoots but did not elongate or die after sometime (Table 2). Most of the calli of six *indica* and *japonica* varieties induced on MS and K media initiated green shoots (100%). On the other hand, only 5% and 1% albino shoots regenerated from calli of mature seeds and immature embryos of BRRI dhan29 in MS and K media, respectively (Table 2). No albino plants regenerated from immature panicles of BRRI dhan29. Similarly, no albino plants regenerated from all three explants of other *indica* and *japonica* varieties tested (Table 2). Poor number of albino plant regeneration was observed in the present study, which is consistent with the published report of Mohiuddin *et al.*, 2006.

Better green plant regeneration was obtained from immature embryo followed by young panicles of all varieties tested (Table 2). Mature seeds, on the other hand, induced the lowest number of green shoots. Higher number of green shoots (331+223=554) regenerated from immature embryos of BR5 variety on both MS and K media. On the other hand, young panicles of *japonica* variety, Taipei 309 and mature seeds of BR5 regenerated green shoots on both MS (318) and K (196) media, respectively (Table 2). These findings revealed that immature embryos of BR5 is the most suitable explant that produced higher number of green shoots compared to Taipei 309 that has been using a *japonica* check variety (Chitra and Kumar, 2006; Abe and Futsuhara, 1986).

Response on culturability based on media-explant interaction. This study indicates that media-explant interaction played an important role on callus induction and plant regeneration efficiency (Table 3). We find that percent shoot regeneration frequency is correlated to percent callus induction. Similarly, we also find that both callus initiation and regeneration rates varied among the explants cultured on media used for this study. It was observed that immature embryo induced higher shoot regeneration rate (48%) in K medium compared to other explants. On the other hand, mature seeds and young panicles induced 43% and 37% shoot regeneration in K and MS media, respectively (Table 3). However, these rates are lower than the rate induced from immature embryo in K medium (48%). These findings conclude that immature embryo and K medium are suitable for

Table 2. Percent Green and albino plant production from calli derived from different explants of six *indica* along with *japonica* varieties under two media conditions.

Variety	Media	Mature seed		Young panicle		Immature embryo	
		% green plant production	% albino plant production	% green plant production	% albino plant production	% green plant production	% albino plant production
BR5	MS	100±0.0 (26)	0	100±0.0 (36)	0	100±0.0 (331)	0
	K	100±0.0 (170)	0	0	0	100±0.0 (223)	0
BRRI dhan28	MS	100±0.0 (12)	0	100±0.0 (16)	0	100±0.0 (23)	0
	K	100±0.0 (9)	0	0	0	100±0.0 (27)	0
BRRI dhan29	MS	0	0	100±0.0 (145)	0	99±2.5 (323)	1±0.0 (3)
	K	95±3.0 (42)	5±0.0 (2)	100±0.0 (40)	0	100±0.0 (120)	0
BRRI dhan32	MS	100±0.0 (35)	0	100±0.0 (15)	0	100±0.0 (64)	0
	K	100±0.0 (63)	0	0	0	100±0.0 (316)	0
BRRI dhan40	MS	0	0	100±0.0 (18)	0	0	0
	K	100±0.0 (11)	0	0	0	100±0.0 (42)	0
Taipei309	MS	100±0.0 (24)	0	100±0.0 (249)	0	100±0.0 (13)	0
	K	100±0.0 (14)	0	100±0.0 (69)	0	100±0.0 (39)	0

Numbers in parentheses are total of green/albino plants.

Table 3. Mean effect of explants on callusing and regeneration frequency under MS and K media (Interaction between media and explant).

Media	Mature seed		Young panicle		Immature embryo	
	Callusing frequency (%)	Regeneration frequency (%)	Callusing frequency (%)	Regeneration frequency (%)	Callusing frequency (%)	Regeneration frequency (%)
MS	84±2.5	36±3.3	100±0.0	37±2.7	85±3.6	32±2.2
K	86±3.0	43±3.4	55±2.2	26±2.7	89±4.3	48±2.0

better shoot regeneration. However, this result is dissimilar with previous studies where different rice explants also showed better regeneration (Rachmawati and Anzai, 2006; Khaleda and Al-Forkan, 2006 and Chitra *et al.*, 2006).

Response on culturability based on explant-variety/genotype interaction. Similarly, interaction between explants and variety also pointed out a vital role in shoot regeneration frequency. Regeneration frequency varied in between 6-89% among the varieties/genotypes tested (Fig. 4a, b, c). Variation also found in regeneration frequency among the explants cultured. Better regeneration (89%) was found in immature embryo of BR5 (Fig. 4c) compared to other explants of rest of the varieties including check japonica variety, Taipei 309. It showed 63% and 71% regeneration from mature seeds (Fig. 4a) and young panicles (Fig. 4b), respectively. Lower regeneration rates were obtained from seeds and young panicles of other varieties tested. Callus induction, on the other hand, varied among the explants of six varieties tested; however, it was observed that callusing frequency was not correlated to shoot regeneration (Fig. 4a, b, c). This finding further confirms that immature embryo of BR5 is suitable for better shoot regeneration.

CONCLUSION

BR5, a modern BRRI released variety, has high callogenesis ability (100%) and produced good quality compact, and nodular embryogenic calli in both the callus induction media, can be used as check *indica* variety for immature embryo culture studies on embryogenesis/organogenesis and gene

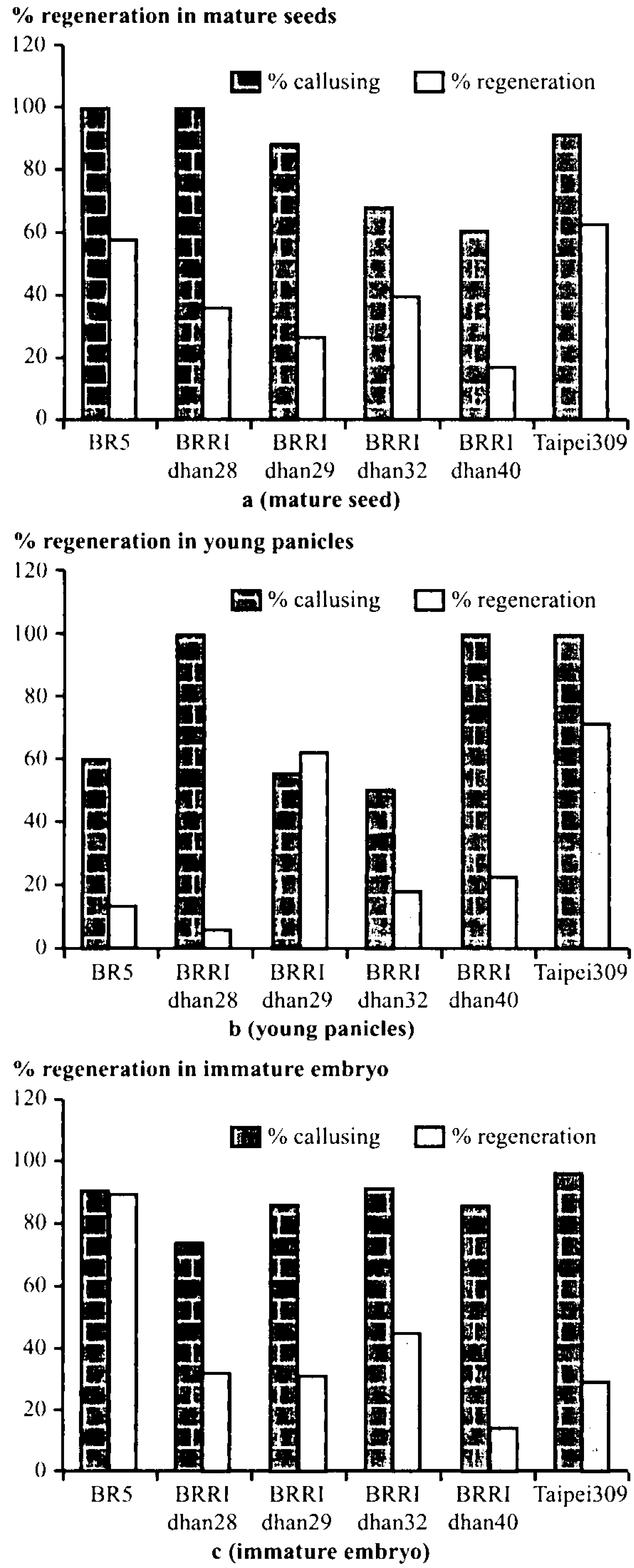

Fig. 4. Mean effect of genotypes (varieties) on callusing and regeneration under explant types (Interaction between explant and variety).

transformation technology instead of popularly used Taipei 309, a highly embryogenic *japonica* cultivar.

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Productivity of Wheat-Mungbean-T. Aman Cropping Pattern under Different Fertilizer Management Packages

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ABSTRACT

A field experiment on integrated nutrient management for Wheat-Mungbean (MB)-Transplanted Aman (T. Aman) cropping pattern was conducted at the Agriculture Research Station experimental farm, Pabna in Rabi 2000-01– T. Aman 2003. The objectives of the experiment were to find out an optimum and economic fertilizer management package for Wheat-Mungbean-T. Aman cropping pattern and effect of mungbean residue on T. Aman rice. Five different treatment- combinations of inorganic and organic fertilizers were tested. The soil test based (STB) fertilization with MB stover incorporation in soil produced the highest rice equivalent yield (REY) 8.01 t ha^{-1} followed by farmers' practice with MB stover incorporation and cow dung + integrated plant nutrient system (IPNS) based chemical fertilization with MB stover incorporation. Inclusion of mungbean crop between wheat and T. Aman crop increased 21-28% and incorporation of MB stover in soil increased 5-6% REY per year.

Key words: Productivity, wheat, mungbean, T. Aman rice, fertilizer management packages

INTRODUCTION

With introduction of modern varieties of rice and wheat, application of chemical fertilizer became inevitable to supplement soil nutrient supply for high yielding crops. Moreover, increasing cropping intensity with the increasing irrigation facility, soil becomes squirmy due to lack of sufficient fallow period to rejuvenate its nutrient supplying capacity. Long-term experiments on continuous rice culture showed increased soil organic matter content but the N supplying capacity declined (Cassman *et al.*, 1995; Dobermann *et al.*, 2000). In Bangladesh soils, like other tropical soils, the application of N, P and K fertilizer dramatically increases the yield of modern wheat and rice (Timsina *et al.*, 1998), but the factor productivity of N fertilizer for rice is decreasing (Cassman *et al.*, 1997), so, more chemical N is needed to apply than before to sustain rice yield. Raising rice crops for 10 years in a permanently laid out field irrespective of fertilization, Bhuiyan et al (1991) reported that total N and exchangeable K content of the soil decreased slightly, but there was a moderate increase in the level of available P with P fertilization. After 14 and 17 years of wheat and rice cropping, respectively, in an alluvial soil the treated plots without P fertilization (SSP) showed clear P and S deficiency (Kumar and Yadav, 2005). Continuous omission of K fertilization for 29 years resulted in about 50 and 32 % reduction in maize and wheat grain yield, respectively, over 100% NPK fertilization (Subehia *et al.*, 2005).

Most soils of Bangladesh have low organic matter content, usually less than 1.5% (BARC, 2005). After green revolution, due to intensive cropping the soil C and N in Bangladesh has decreased considerably (Ali *et al.*, 1997). Although soil organic matter in continuous Rice-Rice system tends to

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increase (Cassman *et al.*, 1995), but in Rice-Wheat system degradation of soil organic matter and subsequently reduced nutrient supplying capacity is a great concern (Yadav *et al.*, 2000). Inclusion of a grain legume, like mungbean (*Vigna radiata*), during the turn around time between wheat and rice, may improve soil N balance in rice-wheat cropping system. A legume crop after wheat, may help to restore soil mineral N during the pre-rice fallow period, which would otherwise get lost through dentrification upon soil flooding for rice (Buresh *et al.*, 1989). However, the amount of N fixation by legume crop is dependent upon many environmental and management factors such as water supply, inoculation, crop rotation, and soil fertility (Peoples and Herridge, 1990). Meelu *et al.* (1992) reported that the total N accumulation by mungbean ranged from 32 -136 $kgha^{-1}$ for a dry matter of 1.1- 4.7 tha^{-1}. From Bangladesh, Saha *et al.* (2000) reported that incorporation of mungbean stover in soil was agronomically viable and economically profitable management for rice. The mungbean stover incorporation added NPK @ 60-4-60 $kgha^{-1}$ into the soil, respectively (BRRI, 2000). Thus some amount of chemical fertilizer could be reduced to the subsequent crop. Considering these points, a field experiment was conducted with the objective to find out an optimum and economic fertilizer management package for Wheat-Mungbean-T. Aman cropping pattern and effect of mungbean residue on T. Aman rice.

MATERIALS AND METHODS

A three-year long field experiment on soil fertility management with the Wheat-Mungbean- T. Aman cropping system was initiated in Rabi 2000-01 at the Agriculture Research Station (ARS) experimental farm of Bangladesh Agriculture Research Institute (BARI), Pabna. The experimental site was medium high land (MHL) under the agro-ecological zone (AEZ)-11. The soil was silty clay loam having pH 7.4 (1:2.5), organic C 1.3%, total N 0.12%, available P (modified Olsen's) 22 ppm, exchangeable K 0.24 meq/100 g soil, available S 10 ppm and available Zn (DTPA) 12 ppm. Wheat (first crop) was grown in the randomized complete block design with three replications using five treatments. The treatments were -T_1: absolute control (Native nutrient), T_2: AEZ based fertilizer recommendation (BARC, 1997), T_3: Soil test based (STB) fertilizer recommendation for high yield goal (HYG), T_4: Cow dung (CD) @ 5 tha^{-1} as oven dry basis + IPNS based inorganic fertilizer dose for HYG; and T_5: farmers' practice (FP). Mungbean was grown in each plot without fertilizer application. After mungbean each plot was splitted into two subplots, mungbean stover was retained for one subplot (a), while it was removed from other subplot (b). T. Aman rice was grown after mungbean. So, the design of T. Aman became split-plot. The main plot was fertilizer treated and subplot was stover residues. The detailed treatment descriptions for the cropping pattern are given in the Table 1. The sources of N P K S and Zn were urea, triple super phosphate, muriate of potash, gypsum and zinc-sulphate, respectively. In treatment T_4, CD @ 5 tha^{-1} on oven dry basis was applied once a year in wheat crop at land preparation and IPNS based chemical fertilizers were applied. The land preparation for wheat, the first crop, was done by ploughing and laddering and for following crops by spading.

Wheat. The full dose of PKSZn and two-thirds of N were applied at the time of final land preparation according to the treatment. The remaining one–third N was applied at 17-21 days after sowing at the time of first irrigation. The 2nd and 3rd irrigation were given at 55-60 days and 75-80 days after sowing, respectively. The test variety of wheat was Sourav. Seeds were sown continuously in row at the depth of 4-5 cm. Row-to-row distance was 20 cm. Seed rate was 130 $kgha^{-1}$. Seeding time was 1st week of December. The sowing date delayed because of the experimental field soil was much moistened (30-35%) due to heavy rain fall. Recommended cultural and management practices were followed in each growing season. At maturity the crop was harvested from 5 m^2 area for grain yield. Straw yield was recorded from one m^2 area. Grain yield was recorded at 14 % moisture and straw yield at oven dry basis.

Mungbean. Mungbean was grown without fertilizer after harvesting wheat. The test variety of mungbean was BARI Mug-2 (Kanti). The seed rate of mungbean was 30 $kgha^{-1}$. Mungbean was sown by broadcasting on the first week of April.

Table 1. Rates of fertilizers for Wheat- Mungbean- T.Aman cropping pattern, ARS BARI, Pabna, (2000-2003).

Rabi:Wheat (Sourav)						Kharif I[1] Mungbean (Kanti)	Kharif II: T. Aman (BRRI dhan39)					
Treatment	Nutrient rates (kgha^{-1})					Treatment	Treatment 2	Nutrient rates (kgha^{-1})				
	N	P	K	S	Zn			N	P	K	S	Zn
T_1 : Native nutrient	0	0	0	0	0	T_1	T_{1a}	0	0	0	0	0
							T_{1b}	0	0	0	0	0
T_2 : Nutrient rate as per BARC Fertilizer Recommendation Guide 1997	90	20	35	10	2	T_2	T_{2a}	70	6	20	4	0
							T_{2b}	70	6	20	4	0
T_3 : Nutrient rate as per STB for HYG	90	4	0	21	0	T_3	T_{3a}	80	2	14	12	0
							T_{3b}	80	2	14	12	0
T_4 : Cow dung @ 5 tha^{-1} + IPNS based chemical fertilizer	40	0	0	14	0	T_4	T_{4a}	40	0	0	4	0
							T_{4b}	40	0	0	4	0
T_5 : Farmers' practices	77	48	28	6	1	T_5	T_{5a}	80	20	37	0	0
							T_{5b}	80	20	37	0	0

[1]In Kharif I season, mungbean (variety-Kanti) was grown without any fertilizer. [2]a=mung bean stover incorporation, b = mung bean stover removed; ***Note:*** In calculating IPNS a nutrient dose, contributions of organic residue was considered. ***Note:*** Nutrient content in 5 t CD on oven dry basis: 50-10-70-8-0 kg/ha N-P-K-S-Zn. Nutrient content in 3 t mungbean stover on oven dry basis: 40-7-50-8-0.03 kg/ha N-P-K-S-Zn.

Recommended cultural and management practices were followed. Mungbean pod was plucked two times in each crop. Stover yield of mungbean was recorded from one m^2 area. After recording grain and stover yields, the stover was returned to the respective plot. The mungbean stover was incorporated in the soil manually by spading. The grain yield was recorded at 12% moisture and stover yield at oven dry basis.

T. Aman. Two to three 35-days-old seedlings of T. Aman rice (BRRI dhan39) were transplanted per hill on 17 July (first year), on 29 July (second year) and on 31 July (3rd year). The spacing was 20- × 20-cm. According to the treatments, mungbean stover was incorporated in soil in "a" sub-plots about 3-5 days before rice transplanting. One-third of N fertilizer and the full doses of other fertilizers (PKSZn) were applied during final land preparation according to the treatments (Table 1). The remaining N fertilizer was applied in two equal splits: one at 25-30 days after transplanting (DAT) and the rest at 50-55 DAT. Recommended cultural and management practices including plant protection measures were followed. The first, second and third year crop were harvested on 1, 11 and 12 November, respectively from a 5 m^2 area for grain yield and straw yield was recorded from 16 hills. The grain yield was recorded at 14% moisture and straw yield at oven dry basis.

Statistical analyses were performed and mean values were compared by DMRT. Economic analysis was done to observe the net-return and marginal benefit cost-ratio (MBCR) for different treatment combinations.

RESULTS AND DISCUSSION

Wheat. Application of different packages of fertilizer treatments significantly increased grain and straw yield of wheat over control plot (Table 2). In 2000-01, the highest wheat yield of 1.37 tha^{-1} was obtained with the AEZ dose (T_2) and the lowest (0.85 tha^{-1}) was found in the control plot (T_1). The application of STB dose (for HYG) (T_3) and CD along with IPNS based chemical fertilizer dose (T_4) did not produced any yield benefit over the AEZ based recommended dose for maximum yield goal (MYG) (T_2). The wheat yield among the fertilizer treated plots was statistically identical, being the lowest with farmer's dose (T_5) and the highest with AEZ based dose (T_2). Generally, the grain yield was poor, most probably due to the delay sowing of seed because the soil of the

Table 2. Effect of different fertilizer packages on the wheat yield (sourav) in a Wheat-Mungbean-T. Aman cropping pattern, ARS, BARI, Pabna, 2000-2003.

Treatment	2000-01		2001-02		2002-03	
	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Grain yield (tha^{-1})	Straw yield (tha^{-1})
T_1	0.85 b	1.33 b	1.12 b	1.09 f	0.69 c	1.69 c
T_2	1.37 a	2.02 a	2.52 a	4.78 a	0.98 b	4.67 a
T_3	1.36 a	2.07 a	2.49 a	2.79 cde	1.17 a	3.70 ab
T_4	1.31 a	2.04 a	1.99 a	2.26 e	1.04 b	3.54 b
T_5	1.15 a	1.97 a	2.46 a	3.58 b	1.12 b	3.62 ab
CV (%)	12.2	15.2	13.4	14.6	11.5	17.4

Means followed by a common letter with in a column do not vary significantly at the 5% level by DMRT.

experimental field was much moistened (30-35%) due to heavy rain fall. In 2001-02, similar trend was also observed. The yield in the control plot (T_1) was 1.12 tha^{-1}, which was significantly increased to 2.52 tha^{-1} with the application of AEZ doses (T_2) and the yield with the STB (T_3) was 2.49 tha^{-1} (Table 2).

In 2002-03, the control plot yielded 0.69 tha^{-1} and that with the fertilizer applied plot varied from 0.98 tha^{-1} (T_2) to 1.17 tha^{-1} (T_3). The significantly highest yield (1.17 tha^{-1}) was obtained with the treatment STB dose (T_3) (Table 2). It was almost two times higher than that of control plot (T_1). All over the years, similar trend was also found in case of straw yield (Table 2).

Mungbean. The grain and stover yields of mungbean were little affected by the fertilizer treatments. In 2001, the highest grain yield of 203 $kgha^{-1}$ was obtained with the residual effect of T_2. But it was statistically similar to that of T_1 and T_5 (Table 3). The lowest grain yield of 148 $kgha^{-1}$ was found in T_4. In 2002, the pod was not formed due to heavy rain fall at flowering stage. In 2003, like the first year, the highest grain yield of 370 $kgha^{-1}$ was also obtained with the same treatment (T_2), but statistically it was non-significant. The significantly highest stover yield of 4.42 tha^{-1} was obtained with the residual effect of STB dose (T_3) in 2001. It was statistically similar to that of T_2 and T_5. The lowest stover yield of 2.77 tha^{-1} was found in T_4. In 2002, the significantly highest stover yield of 5.31 tha^{-1} was obtained with T_1 and T_5 over other treatments (T_2-T_4). Treatments T_2, T_3 and T_4 were found statistically identical. In 2003, like the 1st year, the highest stover yield of 4.27 tha^{-1} was obtained with the same treatment (T_3), but it was statistically non -significant (Table 3).

T. Aman rice. Fertilizer application significantly increased grain and straw yield of T. Aman rice over the control (Table 4). In 2001, the grain yield varied from 3.29 tha^{-1} (T_{1a}) to 5.20 tha^{-1} (T_{3a}) under MB stover incorporation plots, while without MB stover incorporation it varied from 2.94 tha^{-1} (T_{1b}) to 4.61 tha^{-1} (T_{5b}). The significantly highest grain yield of 5.20 tha^{-1} was obtained with T_{3a} followed by T_{5a} (5.19 tha^{-1}). The control plot without MB stover produced the lowest yield (2.94 tha^{-1}) and that with alone MB stover incorporation increased to 3.29 tha^{-1}. MB stover incorporation increased 0.35 tha^{-1} grain yield in T_1 and 0.66 tha^{-1} in T_3, however, the interaction effect of fertilizer and stover management was not significant (p=0.448).

In 2002, grain yield of T. Aman rice with MB stover was 4.03 tha^{-1} and without MB stover it was 3.80 tha^{-1} in control plot. Like previous year, the highest grain yield of 5.46 tha^{-1} was obtained with T_{3a} followed by T_{5a} (5.20 tha^{-1}). The grain yield of T_{4a} was 5.13 tha^{-1}, which was statistically at par. The lowest yield (3.80 tha^{-1}) was obtained with T_{1b}. Due to incorporation of MB stover in T_3 the yield difference was 0.41 tha^{-1}, but it was statistically non-significant (p=0.070).

In case of grain yield, like the 1st year, similar trend was also found in 2003. The highest grain yield of 5 tha^{-1} was obtained with T_{4a} followed by T_{3a} (4.81 tha^{-1})., Treatments T_{3a} and T_{4a} were found statistically identical. The lowest yield (2.88 tha^{-1}) was obtained with T_{1b}. For a given fertilizer management, the yield "with" MB stover incorporation was greater than

Table 3. Residual effect of fertilizer packages on the yield of mungbean (kanti) in a Wheat-Mungbean-T. Aman cropping pattern, ARS, BARI, Pabna, 2001-03.

Treatment	Grain yield ($kgha^{-1}$)			Stover yield (tha^{-1})(Oven dry basis)		
	2001	2002[1]	2003	2001	2002	2003
T_1	167 abc	0	270 a	3.51 b	5.31a	3.72 a
T_2	203 a	0	370 a	3.87 ab	3.70 b	3.85 a
T_3	159 bc	0	270 a	4.42 a	4.07 b	4.27 a
T_4	148 c	0	330 a	2.77 c	3.84 b	4.22 a
T_5	194 ab	0	350 a	4.12 ab	5.31 a	3.69 a
CV (%)	12.7	-	11.5	10.1	12.5	10.8

Means followed by a common letter with in a column do not vary significantly at the 5% level by DMRT. [1]*Note:* Pod was not formed due to heavy rainfall at flowering stage. *N.B.* Fresh weight of mungbean stover was about 12-15 tha^{-1} at 70% moisture content.

Table 4. Effect of fertilizer packages and crop residue management on the yield of T. Aman rice (BRRI dhan39) in a Wheat-Mungbean-T. Aman cropping pattern, ARS, BARI, Pabna, 2001-03.

Treatment	Stover management	2001		2002		2003	
		Grain yield (tha^{-1})	Straw yield (tha^{-1})	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Grain yield (tha^{-1})	Straw yield (tha^{-1})
T_{1a}	Incorporation	3.29	3.02	4.03	3.55	3.03	3.55
T_{2a}	Incorporation	4.65	4.35	4.22	5.04	3.80	4.63
T_{3a}	Incorporation	5.20	5.12	5.46	5.25	4.81	5.91
T_{4a}	Incorporation	4.30	4.31	5.13	4.74	5.00	5.73
T_{5a}	Incorporation	5.19	5.11	5.20	4.88	4.64	5.90
Average		4.53	4.38	4.81	4.69	4.26	5.14
T_{1b}	Removed	2.94	2.49	3.80	3.39	2.88	3.29
T_{2b}	Removed	4.26	4.04	4.08	4.66	3.93	4.99
T_{3b}	Removed	4.54	3.67	5.05	4.83	4.53	5.16
T_{4b}	Removed	4.48	3.16	4.86	4.81	4.50	5.02
T_{5b}	Removed	4.61	3.85	5.15	4.69	4.24	5.17
Average		4.17	3.44	4.59	4.48	4.02	4.73
$LSD_{0.05}$							
Treatment (T)		1.00	0.62	0.68	0.67	0.75	0.53
Stover (S)		0.33	0.24	ns	ns	0.14	ns
T x S		ns	0.54	ns	ns	ns	ns
CV (%)		9.4	7.7	6.4	12.2	4.1	11.0

without MB stover incorporation. This result is in agreement with other studies (Saha *et al.*, 2000; Saha *et al.*, 1998).

Different fertilizer doses significantly affected straw yield. In 2001, the interaction effect of fertilizer × MB crop residue management was highly significant (p=0.032); but in 2002 and 2003 it was non-significant (p=0.939 and p=0.374, respectively). Like the grain yield, similar trend was also observed in case of straw yield in 2001. The significantly highest straw yield of 5.12 tha^{-1} was obtained with T_{3a} followed by T_{5a} (5.11 tha^{-1}) and the lowest (2.49 tha^{-1}) with T_{1b}. MB crop residue incorporation produced 1.45 tha^{-1} more straw yield in T_3 than without incorporation. In 2002 and 2003, the highest straw yield was obtained with the same treatment (T_{3a}). In 2003, due to incorporation of MB crop residue in T_3, 0.75 tha^{-1} more straw yield was produced, but it was non-significant (p=0.059).

From the above statement, it was observed that grain and straw yield in the MB stover incorporated plot was higher than that of without MB stover. Table 5 shows that the highest REY (8.01 tha^{-1}) was obtained with the treatment T_{3a} followed by T_{5a} (7.98 tha^{-1}) and

(T_{4a}) (7.83 tha^{-1}). For incorporation MB residue in soil increased 5-6 % REY per year (Table 5).

Average, over the years, result on economic analysis showed that the application of fertilizer and MB crop residue increased net-return, which ranged from Tk 42,083 (T_{1a}) to Tk 57,818 (T_{3a}). The highest net-return of Tk 57,818 was obtained with T_{3a}. MB stover incorporation increased net-return of Tk 2597 in T_3. The highest MBCR was obtained with T_{3b} (2.11) followed by T_{3a} (2.05), which were higher than the acceptable limit (MBCR=2) (Table 6).

Growing of mungbean in between wheat and T. Aman rice increased 21-28% REY per year as compared to Wheat-Fallow-Rice cropping pattern. From this result, it may be concluded that T_{3a} is the most profitable fertilizer packages for Wheat-Mungbean-T. Aman cropping pattern at ARS, BARI, Pabna and resembling areas of the experimental site.

CONCLUSIONS

STB fertilization for high yield goal with incorporation of MB stover (T_{3a}) is the most profitable fertilizer packages for Wheat-Mungbean-T. Aman cropping pattern at ARS, BARI, Pabna and resembling areas of the experimental site. Due to introducing mungbean crop between wheat and T. Aman crop increased 21-28% REY per year. For incorporation MB residue in soil increased 5-6 % REY per year.

Table 5. Effect of fertilizer packages and crop residue management on the rice equivalent yield (REY) in a Wheat-Mungbean-T. Aman cropping pattern, ARS, BARI, Pabna, 2001-03.

Treatment	Yield of wheat (average of three years) (tha^{-1})	Yield of mungbean (average of two years) (tha^{-1})	Yield of rice (average of three years) (tha^{-1})	REY (tha^{-1})
T_{1a}	0.89	0.22	3.45	5.40 (5%)
T_{1b}	0.89	0.22	3.21	5.16
T_{2a}	1.62	0.29	4.22	7.30 (2%)
T_{2b}	1.62	0.29	4.09	7.17
T_{3a}	1.67	0.22	5.16	8.01 (6%)
T_{3b}	1.67	0.22	4.71	7.55
T_{4a}	1.45	0.24	4.81	7.49 (3%)
T_{4b}	1.45	0.24	4.61	7.29
T_{5a}	1.58	0.27	5.01	7.98 (5%)
T_{5b}	1.58	0.27	4.67	7.64

Note: Price of wheat grain=Tk 8/kg; Price of rice grain=Tk 7/kg; and Price of mungbean grain=Tk 30/kg. *In parenthesis, showed the percent increase of REY/year due to mungbean stover incorporation in soil.

Table 6. Economic analysis of Wheat-Mungbean-T. Aman cropping pattern under different fertilizer crop-residue management practices (average).

Treatment	Gross return ($Tkha^{-1}yr^{-1}$)		TVC* ($Tkha^{-1}yr^{-1}$)		Netreturn ($Tkha^{-1}yr^{-1}$)		MarginalReturn ($Tkha^{-1}yr^{-1}$)		MBCR	
	-MB (b)	+MB (a)	-MB (b)	+MB (a)	-MB (b)	+MB (a)	-MB (b)	+MB (a)	-MB (b)	+MB (a)
T_1	41833	43830	0	1747	41833	42083	0	250	-	0.14
T_2	59694	60714	7371	8596	52323	52118	10490	10285	1.42	1.20
T_3	61555	65622	6334	7804	55221	57818	13388	15985	2.11	2.05
T_4	59074	61071	8574	9796	50500	51275	8667	9442	1.01	0.96
T_5	62429	65536	11157	12756	51272	52780	9440	10947	0.85	0.86

*Total variable cost (TVC) included fertilizer cost (organic and inorganic), fertilizer application cost and labour cost for additional product. Price (Taka/kg): Urea=6.00, TSP=14.00, MP= 9.00, Gypsum=5.00, and Zinc-sulfat =25.00. Price of wheat grain=Tk 8/kg; Price of rice grain=Tk 7/kg; Price of rice and wheat straw=Tk 1/kg; Price of cowdung=Tk 1/kg (including labour cost for applying); Price of mungbean=Tk 30/kg; Price of Mungbean stover=Tk 0.30/kg. Four additional man days are required for applying chemical fertilizer per ha, eight additional man-day are required for 1 ton of additional product including by product. Labour wage/day=Tk 80.

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BRRI dhan49: A Complementary Variety to BR11 and Supplementary Variety to BRRI dhan32 in Rainfed Low Land Rice Environment

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ABSTRACT

BRRI dhan49 is a newly released improved transplant Aman variety out weighing BR11 and BRRI dhan32. The National Seed Board (NSB) has released the variety for commercial cultivation in T. Aman season in the rainfed lowland rice (RLR) ecosystem of Bangladesh. It is developed from a single cross between BRRI developed advanced breeding line BR4962-12-4-1 and IRRI developed advanced breeding line IR33380-7-2-1-3. Pedigree method of selection was followed in handling the segregating generations. Although BR11 covers maximum areas under RLR ecosystem its replacement has been demanding because of its low yield due to high disease pressure. On the other hand, lodging susceptibility of BRRI dhan32 puzzled the advantage of its short growth duration. This new variety is photo-insensitive, with stiff, culm and resistance to lodging. Its growth duration (132-135 days) is close to BRRI dhan32 and one week earlier than BR11. The yield potential is similar to BR11 (4.0-5.0 t/ha) with Nizersail brand grain type. Therefore, Nizersail brand rice will hopefully be available in the market with the adoption of BRRI dhan49.

INTRODUCTION

In Bangladesh the area under cultivation of MV rice is increasing due to the release of varieties having potential to grow at different agro-ecological zones. Among the rice seasons major areas are covered by RLR which is 5.04 m ha and about 68 % area covered by MV rices (BBS, 2008). After releasing BR10 and BR11, BRRI also released 12 varieties for RLR ecosystem. Among them some have been released with special characteristics eg strongly photoperiod sensitivity, tolerance to salinity and tidal submergence. Although a number of varieties are available in T. Aman season, at present, BR11 is the mega variety of Bangladesh occupying 40% of T. Aman rice area (BRRI 2007). We notice "Swarna" a long duration (140-145 days) variety of Indian origin becomes popular to farmers in high Barind areas of Rajshahi, northern districts (Chapai Nawabganj, Dinajpur and Thakurgaon) and also some southern districts (Kushtia, Jhinaidah and Jessore). It has growth duration and yield potential similar to BR11. It is popular because of superior grain quality and attractive husk colour over BR11. When large areas are planted with one or two varieties, they can be vulnerable to pests and diseases, which may cause instability in crop production (Kabir and Salam, 1995). Above all, both the varieties are susceptible to disease and in particular Swarna is highly susceptible to sheath blight (ShB). Farmers are still cultivating Nizersail due to its medium fine grain and consequently getting high value in the market. The major weakness of this variety is its susceptibility to lodging and low yield. On the other hand BRRI dhan32 is also another popular variety in T. Aman season but like Nizersail it is also susceptible to lodging. Therefore, replacement of these varieties became a national demand. So, a RLR variety BRRI

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dhan49 was released in 2008. This paper describes the breeding procedures, tolerance to lodging, agro-morphological characters and grain quality of BRRI dhan49.

MATERIALS AND METHODS

For the improvement of BR11 a single cross was done in 1995 between BRRI developed one advanced breeding line BR4962-12-4-1 with one IR line IR33380-7-2-1-3, which was selected from International Rainfed Lowland Observational Nursery (IRLON). The F_1 plants were grown in 1996 in the net house of BRRI along with respective parents. The cross was confirmed and registered as BR6592. In the following year (1997) individual plant selection was carried out among 4000 progenies of F_2 bulk population. About 120 desirable segregates were selected for medium growth duration, resistance to lodging and tolerance to major diseases with good grain type. In 1998, the 120 F_3 family rows were grown in the field. Pedigree selection method was used for handling the segregating materials within and among the rows in F_3-F_5 generations. Some homozygous progeny lines with desirable characteristics were isolated in F_5 generations. During the period of generation advance, progeny rows were selected, which were resistant against diseases and insects under field condition. In 1999, several homozygous lines were tested in Observational Trial against standard checks BR11 and BRRI dhan32 to observe homogeneity in heading, tolerance to lodging, resistance to diseases and overall phenotypic acceptance at field condition. Several tolerant lines were tested against BR11 and BRRI dhan32 to evaluate initial yield performance in 2000 at BRRI farm, Gazipur. In the following two years, yield evaluation was confirmed through secondary yield trials conducted at Gazipur farm. In 2003, regional yield trial was conducted in different regional stations of BRRI in RCB design with three replications. Entries of these trials were tested for different physico-chemical properties, grain cooking qualities, best planting time, disease-insect resistance in field condition, and lodging tolerance. Seedling height, plant height, tillering habit, spikelet sterility were recorded from the ten random plants excluding border rows and plants surrounded by any missing hills. Growth duration was counted from seedling to 80% grain maturity. Yield data were taken from 10 m^2 sample plot in each replication.

Based on the average result of regional trials, BR6592-4-6-4 and BR6592-4-6-5 showed outstanding performance over BRRI dhan32 and BR11 in terms of lodging tolerance, earliness, disease resistance and yield potential. In 2004, an advanced line adaptive research trial (ALART) was conducted for adaptability test by the Adaptive Research Division with above mentioned two promising lines along with BR11 and BRRI dhan32 in ten locations of BR11 growing areas of Bangladesh. According to the result of ALART, BR6592-4-6-4 was performed better than other sister line as compared with standard checks. On the basis of the result of ALART and farmer's reaction, BR6592-4-6-4 was recommended for proposed variety trial (PVT) in the farmers' field for releasing as a variety. In 2005, proposed variety trial was conducted at ten locations of BR11 growing areas of Bangladesh. The field team of NSB evaluated this trial at the vegetative and maturity stages. The team identified BR6592-4-6-4 as a superior genotype in respect to lodging tolerance, earliness BR11 and Nizersail type grain. In 2008, the NSB released BR6592-4-6-4 as BRRI dhan49.

Plants of three hills were collected from each plot at heading to milk stage when the rice plant is more vulnerable to lodging. At first, three median tillers were selected from each selected hill and data were collected from these selected individual tiller. The final data represent the average value of three selected median tillers from each plot. Internode length and thickness at different nitrogen level for each variety was measured by using scale and slide calipers. Culm strength was measured by lodging meter. Moment was computed by multiplying internode length and internode weight. For measuring the culm strength, the selected plant was slanted into 45° angle artificially created by lodging meter.

RESULTS AND DISCUSSION

Table 1 shows agro-morphological characteristics of BRRI dhan49. It has shorter plant height than BR11

Table 1. Gross morphology and grain yield of the proposed line BR6592-4-6-4 at early July seeding, T. Aman 2004.

Designation	Plant h (cm)	Growth duration (day)	No. of panicle/ plant	Panicle length (cm)	1000-grain wt (g)	Yield (t/ha)
BR6592-4-6-4 (Proposed Variety)	98*	133	14	21	19.8	5.0
BR11 (Ck)	110*	140	13	24	24.2	5.0
BRRI dhan32 (Ck)	118**	129	12	25	22.4	4.5
Nizersail (L.Ck)	125**	150	8	18	19.6	2.8

* = lodging tolerant ** = lodging susceptible.

and BRRI dhan32, which indicates lodging tolerance. BRRI dhan49 has erected flag leaf than BR11 and BRRI dhan32, which facilitates maximum solar uptake. It has a higher tillering habit (14-16 tillers per plant). The average panicle number of BRRI dhan49 is 14. The average panicle length of BRRI dhan49 is 21 cm having 120-130 fertile spikelets. On the other hand BR11 and BRRI dhan32 have longer panicles (24-25 cm) but with 2-3 less effective tiller than BRRI dhan49. As a result yield is similar to BR11 but higher than BRRI dhan32. Like pajam, its panicle shape is compact and average sterility percentage is about 8-10%.

Earliness is important in rice varieties to adjust the growing seasons. BRRI dhan49 is seven days earlier than BR11 (Table 1). Joshi *et al.* (2004) reported that most of the new varieties were preferred to the check varieties because of their early maturity, good grain quality and lodging resistance. In northern part of the country where Rice-Wheat and Rice-Potato pattern is becoming popular, BR11 and Swarna have been found less suitable due to their long growth duration. BRRI dhan49, by virtue of its medium growth duration (133 days) may be fitted well into Rice-Wheat and Rice-Potato system. BRRI dhan49 is also 7-10 days earlier than Lalswarna and Gutiswarna and grain type is similar to Lalswarna but possesses better grain type than Gutiswarna. Therefore, BRRI dhan49 can be a good replacement of different types of Swarna.

High yield is the prime objective in developing modern rice varieties. BRRI dhan49 showed significantly higher yield than BR11 and BRRI dhan32 (Fig. 1). Possibly, this high yield of BRRI dhan49 was due to its genetic potential of producing higher number of tillers per plant and grains per panicle than BRRI dhan32 as mentioned above since 1000-grain weight could have negligible effect (Table 1).

BRRI dhan49 showed satisfactory milling outturn and amylose percentage (Table 2). The length-breadth ratio of decorticated grain is 2.8, which is similar to Nizersail grade and higher than standard varieties (Table 2). This result revealed that BRRI dhan49 will get high market price as it is going to be a substitute of fine Nizersail brand rice.

Lodging tolerance

Internode thickness. Basal internode thickness is the most important criteria for lodging tolerance, which was usually influenced by higher added nitrogen and water (Mahbub *et al.*, 2006). Among the basal internodes, thickness of 4th internode has been explained for lodging tolerance (Fig. 2) due to its vulnerability. Varieties having thin basal internode are vulnerable to lodging and rice culm of susceptible variety become thinner when excessive N fertilization and water stagnation will be increased. Figure 2 shows that internode thickness of susceptible variety, BRRI dhan32 was reduced drastically at higher nitrogen level (120 kg N/ha) and stagnant water (15cm) condition. But the internode thickness of BRRI dhan32 was good upto 60 kg N/ha. In contrary, internode thickness of BRRI dhan49 and BR11 was found in satisfactory level at higher nitrogen level and water stagnated condition (Fig. 2). It might be due to the genetic make up of the variety. Chang (1964) found similar results and reported that the culm become thin and slender at high nitrogen level.

Moment. Moment is the product of internode length and internode weight of a plant. Lower moment

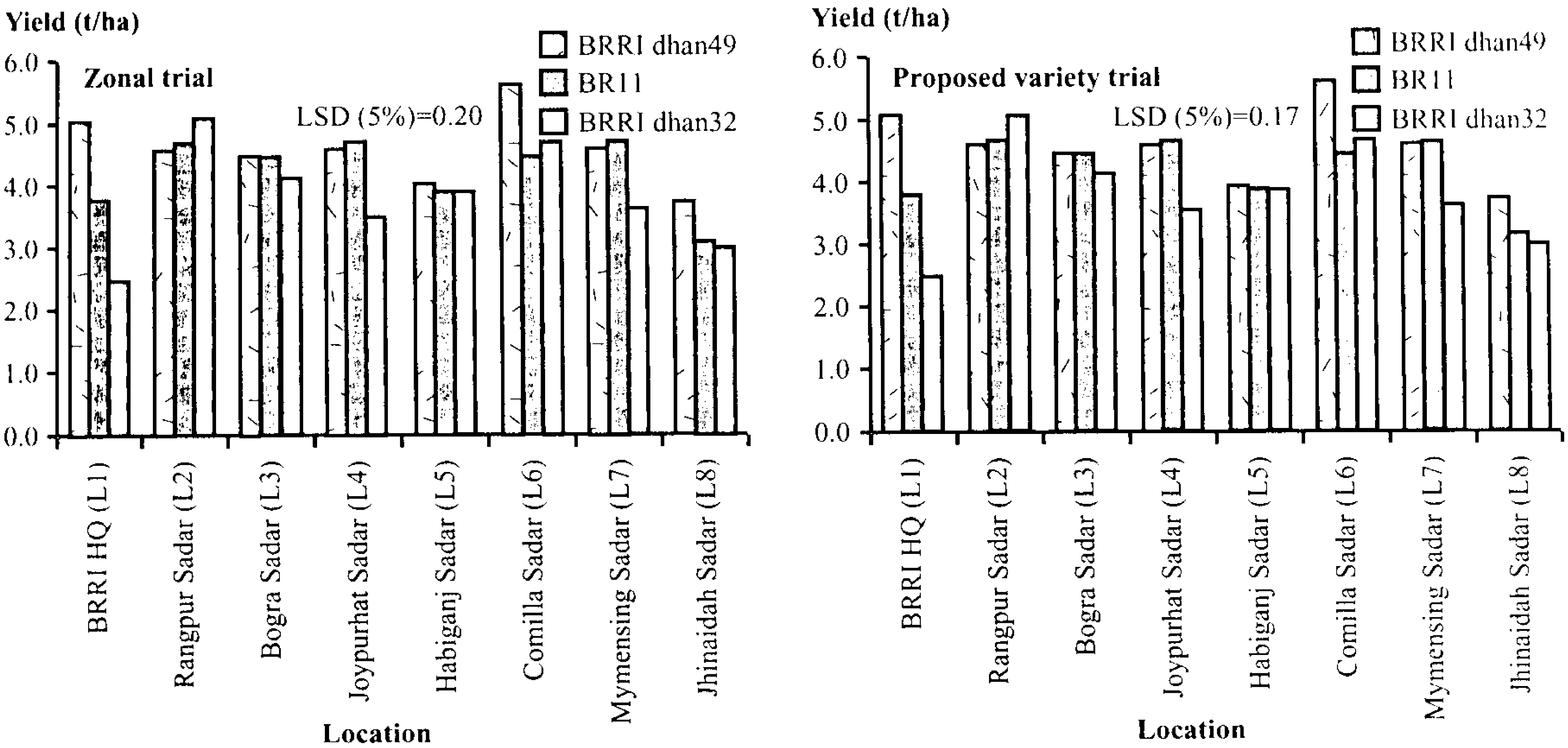

Fig. 1. Grain yield of the proposed line (BR6592-4-6-4) in Zonal Trial, T. Aman, 2005 and proposed variety trial, T. Aman, 2006.

Table 2. Grain characteristics of the proposed line and standard varieties.

Designation	Milling outturn (%)	Chalkiness	Grain length (mm)	Grain breadth (mm)	L/B ratio	Size and Shape	Amylose (%)	Protein (%)	Cook rice quality
BR6592-4-6-4 (Proposed variety)	72	Wc1	5.6	2.0	2.8	MS	27	7.5	Soft
BR11 (Ck)	73	Tr	5.2	2.4	2.2	MB	27	7.5	Medium soft
BRRI dhan32 (Ck)	72	Tr	5.4	2.2	2.5	MB	26	8.0	Soft
Nizersail	71	Tr	5.8	2.1	2.8	MS	27	7.5	Soft

WC_1= Less than 10% chalkiness, Tr = Translucent, MS= Medium selender, MB= Medium bold.

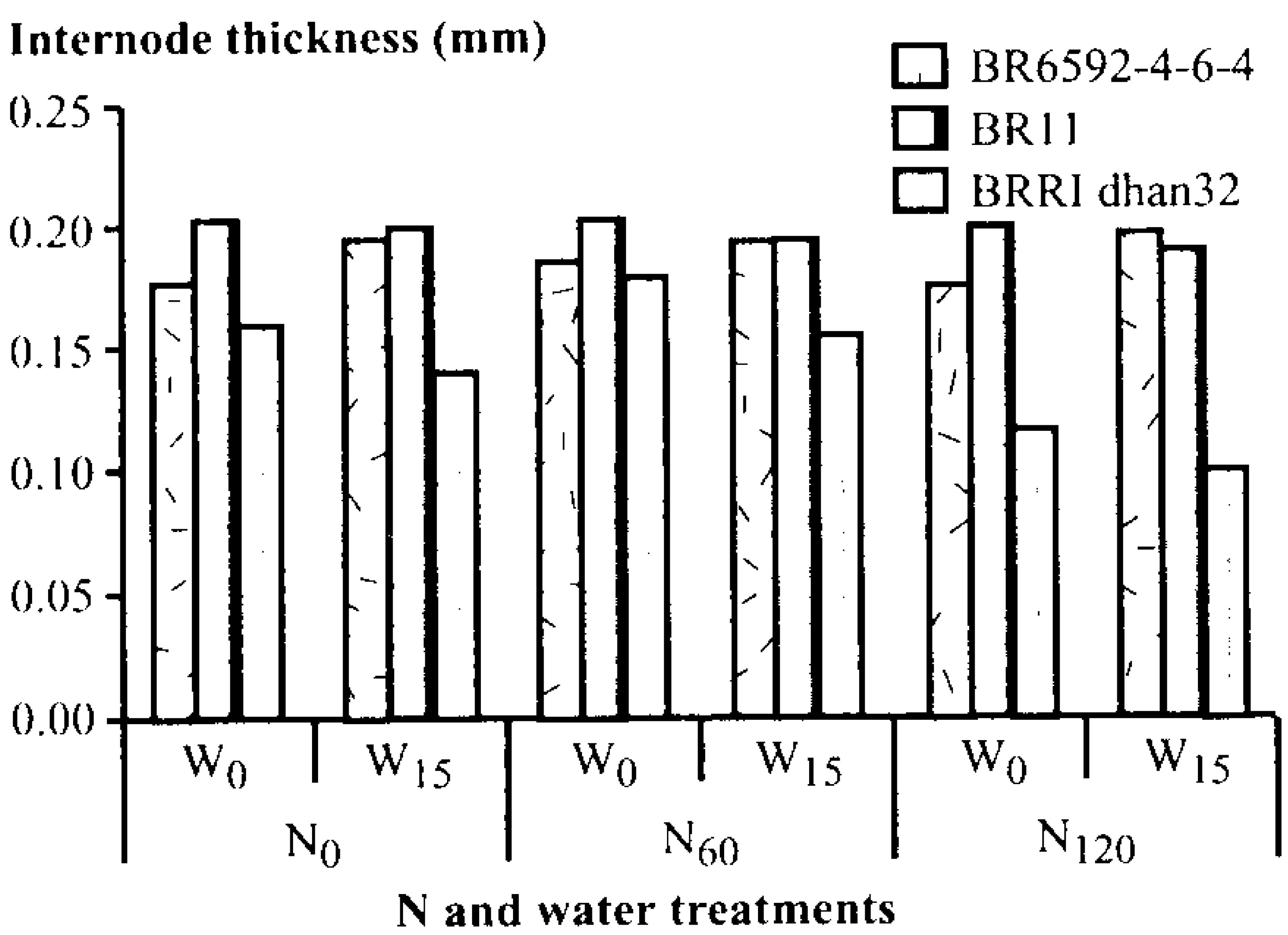

Fig. 2. Thickness of 4th internode of studied varieties as affected by nitrogen fertilizer and water stagnation.

makes a variety tolerant to lodging. The lowest moment was observed in BR11 at all the treatments (Fig. 3). The moment of BRRI dhan49 was not much affected by added nitrogen fertilizer and stagnant water. Therefore, BR11 and BRRI dhan49 showed lodging tolerance in whole growth period. On the other hand, the moment of BRRI dhan32 was gradually increased when excessive nitrogen fertilizer and water were added that influenced to make susceptible to lodging (Fig. 3). It might be due the increment of internode length of BRRI dhan32 at high N level and water stagnation condition. Mahbub *et al.* (2006) supports it.

Culm strength. Culm strength is also an important character for lodging tolerance and, more

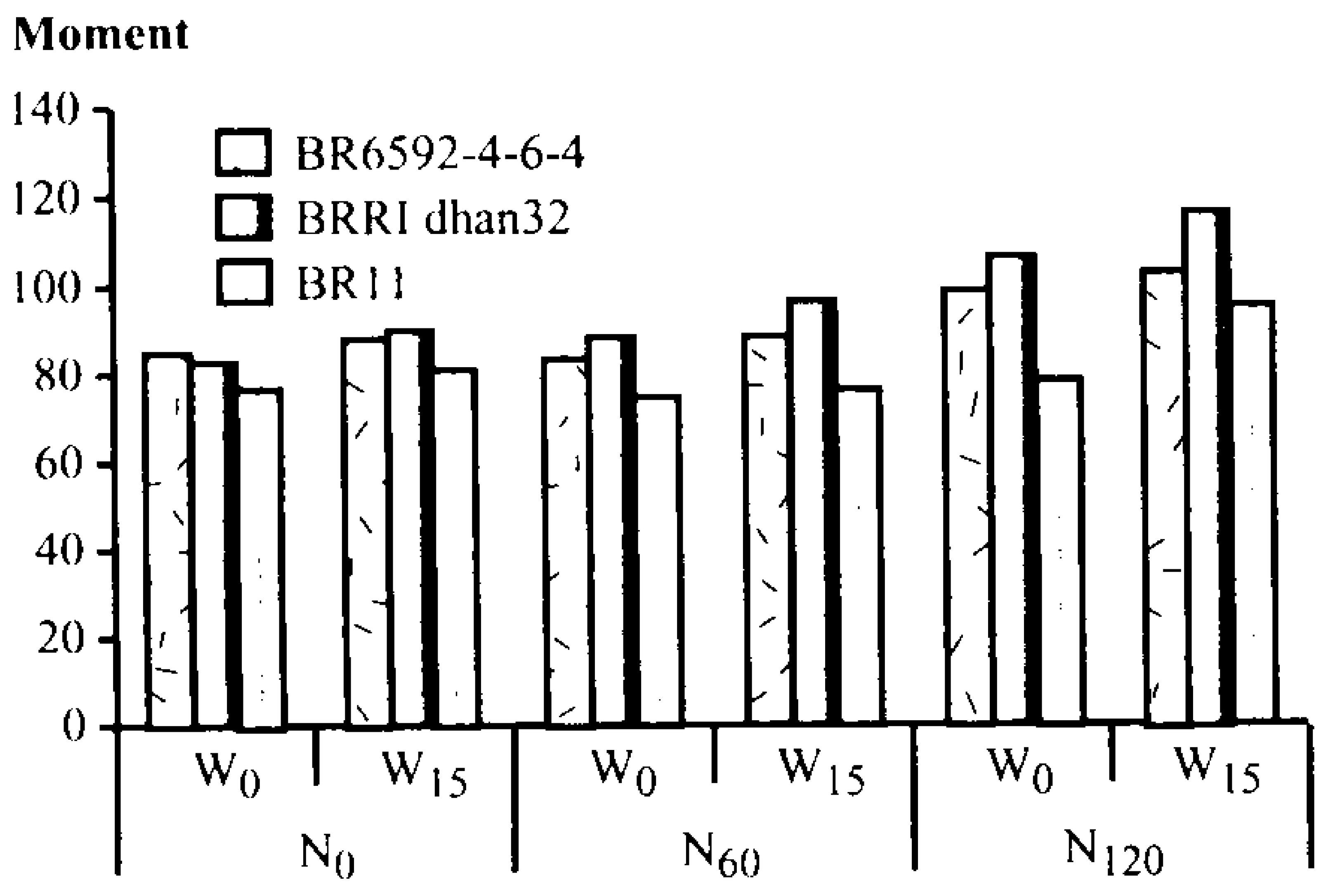

Fig. 3. Moment of studied varieties as affected by nitrogen and water stagnation.

culm strength makes a variety more tolerant to lodging. Result showed that, the culm strength for BRRI dhan49 and BR11 was higher than BRRI dhan32 at all the treatments (Fig. 4). Culm strength of BRRI dhan32 was affected remarkably by stagnant water (15cm), which influenced to lodging (Fig. 4) and it was more pronounced at higher N level.

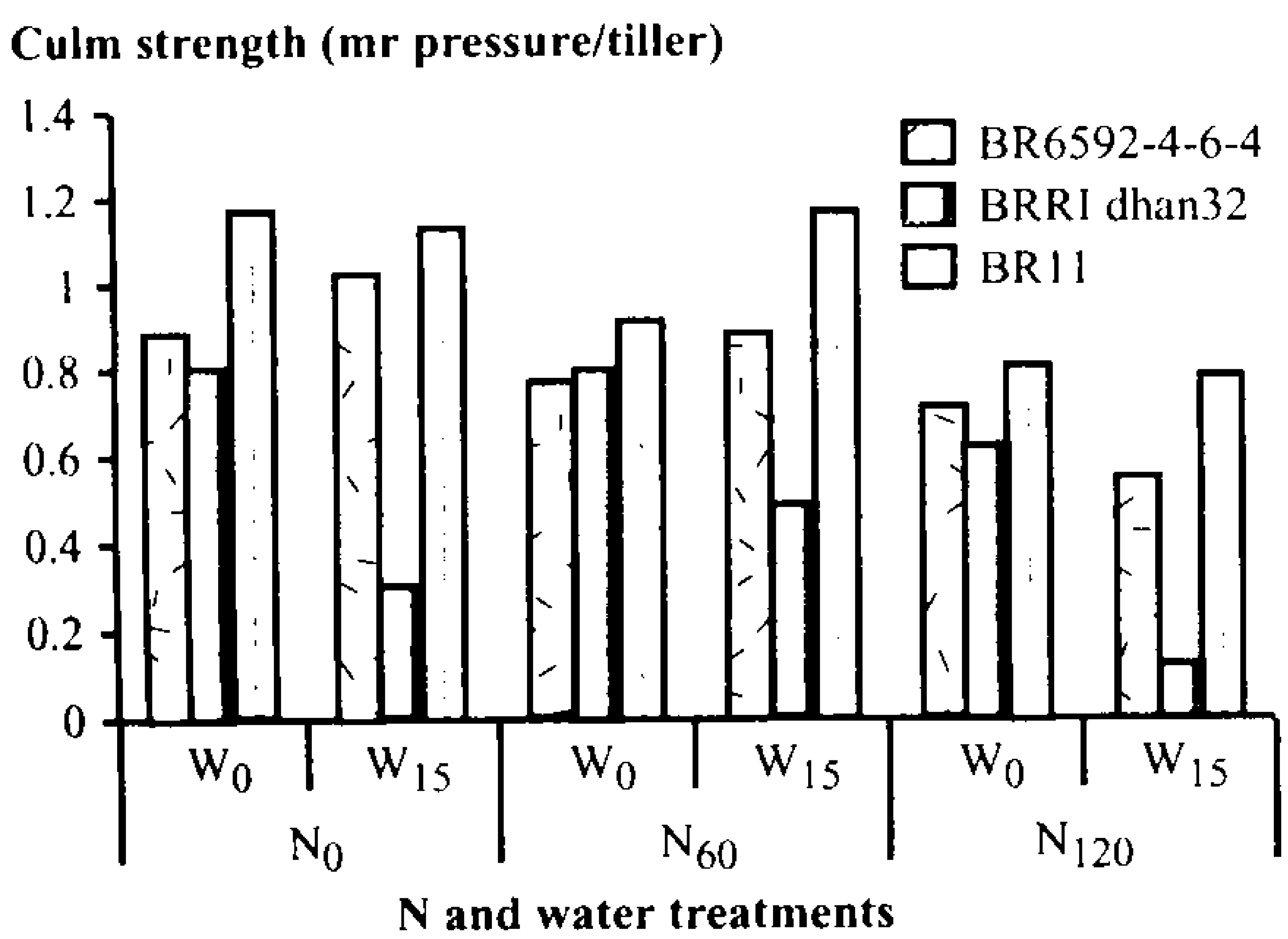

Fig. 4. Culm strength of studied varieties as affected by nitrogen and water stagnation.

Result clearly stated that BR11 and BRRI dhan49 have tolerance to lodging and excessive N fertilizer and water stagnation should be avoided for BRRI dhan32. Mahbub *et al.* (2006) also reported that BRRI dhan32 and BR11 are lodging susceptible and lodging tolerant varieties, respectively on the basis of internode thickness, moment and culm strength.

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Assessment of Water and Soil Salinity for Boro Cultivation in Coastal Region of Barisal

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ABSTRACT

Salinity in coastal soils and rivers in Barisal region was monitored to assess suitability for Boro cultivation. Soil and water samples were collected from Bakerganj of Barisal to Kuakata of Patuakhali and from Nalchiti of Jhalokathi to Haringhata of Patharghata. Both soil and water sampling was done from December 2007 to April 2008 at every 30-day interval. Water salinity in the Bishkhali river water was less than 1 dS/m, and that in the river Pyara and the river Laukathi was less than 0.75 dS/m, which is suitable for Boro cultivation throughout the study period. Other coastal rivers Harpangasia, Andermanik, Sonatola and the Fafru canal had salinity of 4.79-8.12 dS/m in December, which increased to 11.84-28.70 dS/m in April. Soil salinity at Bakerganj and Khalisakhali was 0.69-1.8 dS/m from December to April. In other places (8-50 km from the coast) soil salinity was 1.7-5.68 dS/m in December, but it increased to 9.64-29.07 dS/m in April. The investigation suggests that water and soil salinity was conducive for Boro cultivation in Bakerganj and Khalishakhali by irrigating with the water of the Payra and the Laukathi rivers. Soil and water salinity at 60 km or closer vicinity of the sea was not found suitable for Boro cultivation.

Key words: Water and soil salinity, river water, fallow land, Boro cultivation, coastal region

INTRODUCTION

Salinity is a significant factor affecting agricultural productivity in many irrigated lands of coastal region of Bangladesh. About 2,86,090 ha land in Barisal, Jhalokathi, Pirojpur, Patuakhali and Borguna is affected by varying degree (2-16 dS/m) of soil salinity. Usually intensity of soil salinity increases with the closer vicinity of coast. Soil salinity in Barisal region, like most of the saline soils of Bangladesh, is attributed to either intrusion of sea water through underground or saline water of the coastal rivers. Water quality of the coastal rivers in Barisal region is poorly understood. There are several reasons why about 35% of land in Barisal region remains fallow during Rabi season. Soil and water salinity is one of them. Most of the fallow lands in Rabi season may be brought under Boro cultivation subjected to the availability of non-saline water for irrigation. Application of non-saline water irrigation, salinity of soil may be equilibrated to less than 4 dS/m, thus the soil becomes suitable for Boro cultivation. There is an example of using non-saline underground water to grow Boro rice in Satkhira (Saleque *et al*, 2005).

Previous research indicates that soil salinity does not measurably reduce crop yields below a crop-specific tolerance value (Xie, 1993). Beyond the tolerance limit, yields decrease approximately linearly with increasing soil salinity. Sankara and Yellamanda (1995) classified water salinity based on electrical conductivity as low salinity water with less than 0.25 dS/m, medium salinity water that has EC between 0.25 to 0.75 dS/m, high salinity water with in ranges of 0.75 to 2.25 dS/m and very high salinity water with EC more than 2.25 dS/m. Crop yield losses can be 30-50% in the slightly and moderately saline areas, and reach 80% in the highly saline areas (Ramazanov and Yakubov, 1988). The major sources of secondary soil salinization are the salinity of applied irrigation water as well as the depth and salinity of the ground water.

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Salts from surface water are brought directly with that water and accumulate in the soil profile (Ghassemi *et al.*, 1995). Salinization from ground water occurs when it reaches a certain threshold level above which it rises by capillarity. So, in the southern districts of Barisal region such as Patuakhali and Barguna there is a possibility of soil salinization, which is needed to investigate.

The government of Bangladesh has taken an attempt to increase Boro rice production in this region. To cultivate Boro rice, artificial irrigation is needed and the water should be salt free. For this purpose to control its harmful effect, soil and water salinity is needed to monitor in space and time. This requires knowledge of its magnitude, temporal dynamics and spatial variability in soil and river water. The potential effects of salinity are not only on crop yield but also on factors such as salinization of lands, degrading ground and surface water and under ground migration of salts from salt laden geologic strata to rivers. All of these factors should be considered in developing new irrigation strategies (Feng *et al.*, 2003).

Some research findings show that there are salinity with water and soil of Khulna and Noakhali Region. But a little information is available on the salinity of soil and water in Barisal region. So, it is needed to investigate the level of concentration of salt in the river water and soil. The main objective of this study is to find out about the temporal and spatial dynamics of water and soil salinity along coastal region of Barisal.

MATERIALS AND METHODS

Soil and water salinity were monitored in Barisal, Jhalokathi, Pirojpur, Patuakhali and Barguna districts. Water salinity of the Bishkhali river at several points from Jhalokathi to Kakchira were monitored from December, 2007 to April, 2008. To collect soil and water samples, five districts were divided into two routs- Bakarganj-Patuakhali-Amtoli-Kolapara-Kuakata rout (A) and Jhalokathi-Razapur-Mathbaria-Patharghata-Haringhata rout (B) (Fig. 1).

In rout A, fourteen locations were selected at an average distance of five kilometers. The water sample collection was started from Bakarganj followed by Lebukhali (Pyara river), Khalishakhali (Laukathi River), Shakhariabazar, Amtoli, Sekanderkhali (Harpangasia River), Kolapara, Andharmanik river, Salimpur, Pakhimara, Sonatola river, Bipinpur, Mohipur (Fafru canal) and Kuakata sea beach. Distances of the locations were 76, 72, 60, 50, 34, 30, 25, 23, 21, 17, 11, 8, 6, and 0 kilometers respectively, from the sea. In rout B forteen locations were selected at an average distance of eight kilometers. Water sample was collected from 12 locations started from Dhanshiri followed by Razapur, Charkhali, Dhanisafa, Tushkhali, Raihanpur, Nachnapara, Kathaltoli, Charduani, Patharghata, Badurtala, and Haringhata. Distances of the locations were 75, 65, 56, 44, 40, 34, 26, 22, 18, 14, 8, 6 and 4 kilometers respectively, from the sea. From Bishkhali River 10 samples of water were collected at an equal distance of six kilometers (Rout C). The locations were Jhalokathi, Bhabanipur, Tetulbaria, Niamati, Betagi, Amua, Bamna, KalikaBari, Phuljhuri and Kakchira Ghat. Distances of the locations were 78, 72, 66, 60, 54, 48, 42, 36, 30 and 24 kilometers respectively from the sea. After Kakchira Ghat (24 km from the Coast) water sample collection was not possible due to inaccessibility.

From the rout A, soil samples were collected from nine locations, which were Bakarganj, Khalishakhali, Shakharia bazar, Amtoli bazar, Sekanderkhali, Kolapara, Salimpur, Phakhimara and Bipinpur. Distances of the locations were 76, 60, 50, 34, 30, 25, 17, 11 and 8 kilometers respectively from the sea. From the rout B, soil samples were collected from Nalchiti, Dhanshiri, Razapur, Charkhali, Dhanisafa, Tushkhali, Mathbaria, Raihanpur, Nachnapara, Kathaltoli, Charduani, Pathorghata, Badurtala and Horinghata. Distances of the locations were 88, 75, 70, 56, 44, 40, 34, 26, 22, 18, 14, 8, 6 and 4 kilometer respectively from the sea.

To collect soil sample in every location fallow land was considered. In each location, soil randomly collected from 3 or 4 places were mixed and filled in a plastic bag. Depth of soil sampling was 5 to 10 cm from ground surface. Water samples were collected in plastic bottles. Salinity of all the soil and water samples was evaluated by measuring the electrical conductivity (EC) in the laboratory. The magnitude

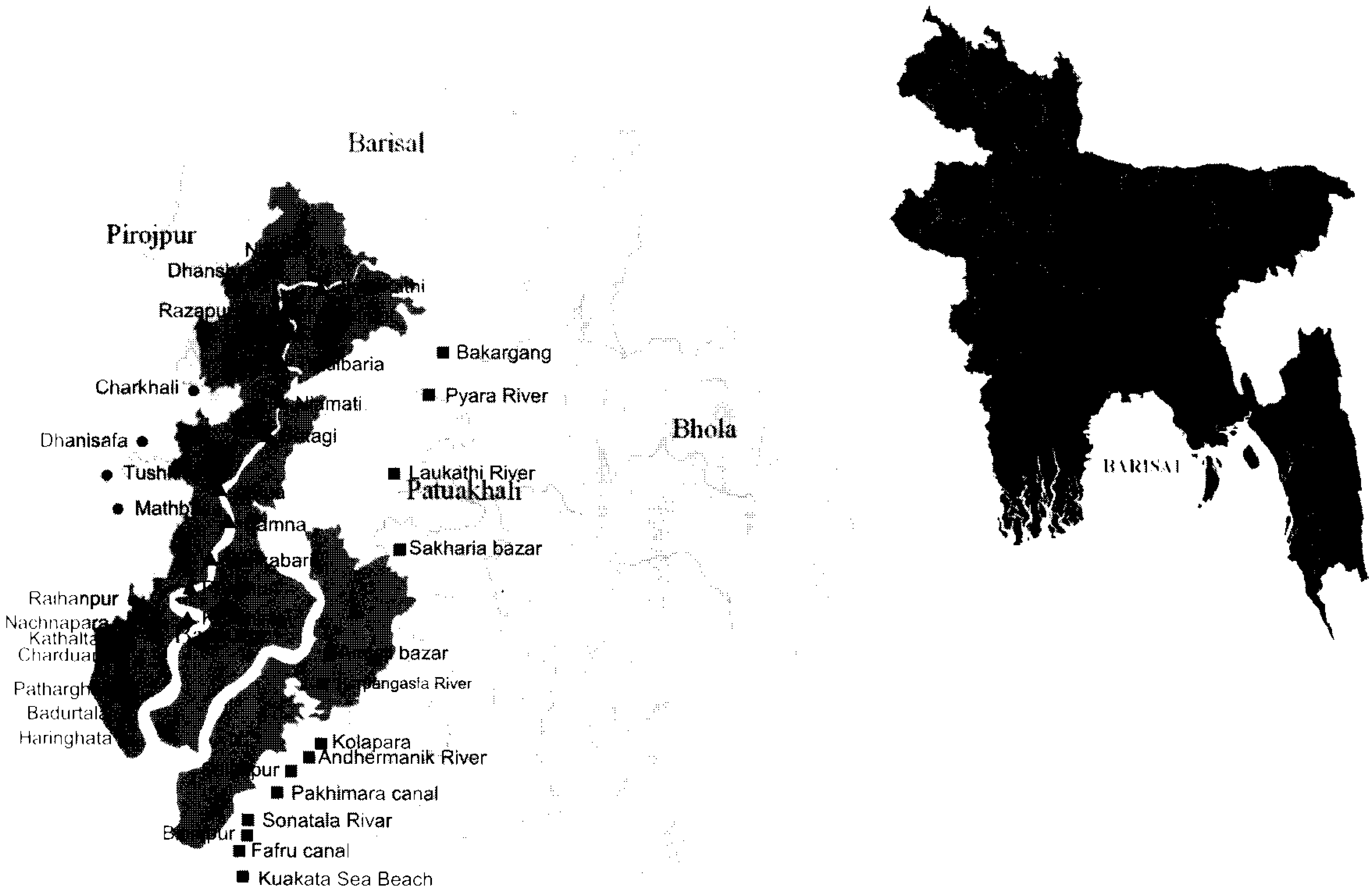

Fig. 1. Locations of soil and water sampling from Rout A, Rout B and Rout C.

of soil salinity was conventionally assessed in laboratory by determining the electrical conductivity of a saturated soil paste extract (EC_e). 1:5 soil:water saturated soil paste was made with approximately 100cc volume soil. Samples were stirred for 30 minutes before a 30 minutes equilibration period. The free water was extracted by filtration. The glass electrodes were calibrated with buffer solution of 0.01N KCl. The filtrates were measured for electrical conductance and expressed as dS/m.

RESULTS AND DISCUSSIONS

Salinity in Bishkhali river water

The salinity of Bishkhali river water varied from 0.14-0.87 dS/m during 28 November to 21 April at a distance from 24 to 78 km from the Bay of Bengal (Table 1). Change in water salinity from November to April was not noticeable. Water salinity had no definite trend with the distance from the Bay of Bengal. At any particular point salinity in February and March was slightly higher than November, but there was a fall in salinity in April. Noteworthy, inception of tidal flood in April might have contributed to lower salinity in the river water. The salinity of Bishkhali river water was <1 dS/m in November to April, which is suitable for Boro and any other crops in probable command area along the river side.

Water salinity in rivers and water bodies towards Kuakata and Haringhata coast

Figure 2 presents the water salinity of river/water bodies at different distances from the Kuakata and Haringhata coast in December to April. Water salinity increased exponentially with the decrease in distance from the coast line of the Bay of Bengal. At all the points, water salinity was the lowest in December and the highest in April. Water salinity aligned to

Table 1. Electrical conductivity (dS/m) of water collected from Bishkhali River at different points.

Location	Distance from sea (km)	Date of sampling			
		28 Nov	2 Feb	19 mar	21 Apr
Jhalokathi Ghat	78	0.19	0.60	0.30	0.25
Bhabanipur Ghat	72	0.29	0.29	0.30	0.29
Tetulbaria Ghat	66	0.17	0.30	0.30	0.25
Niamati Ghat	62	0.17	0.30	0.29	0.26
Betagi Ghat	54	0.29	0.30	0.29	0.24
Amua Ghat	48	0.18	0.27	0.30	0.27
Bamna Ghat	42	0.29	0.29	0.30	0.31
Kalika Bari Ghat	36	0.17	0.30	0.31	0.28
Phuljhuri Ghat	30	0.14	0.37	0.36	0.32
Kakchira Ghat	24	0.17	0.87	0.78	0.48

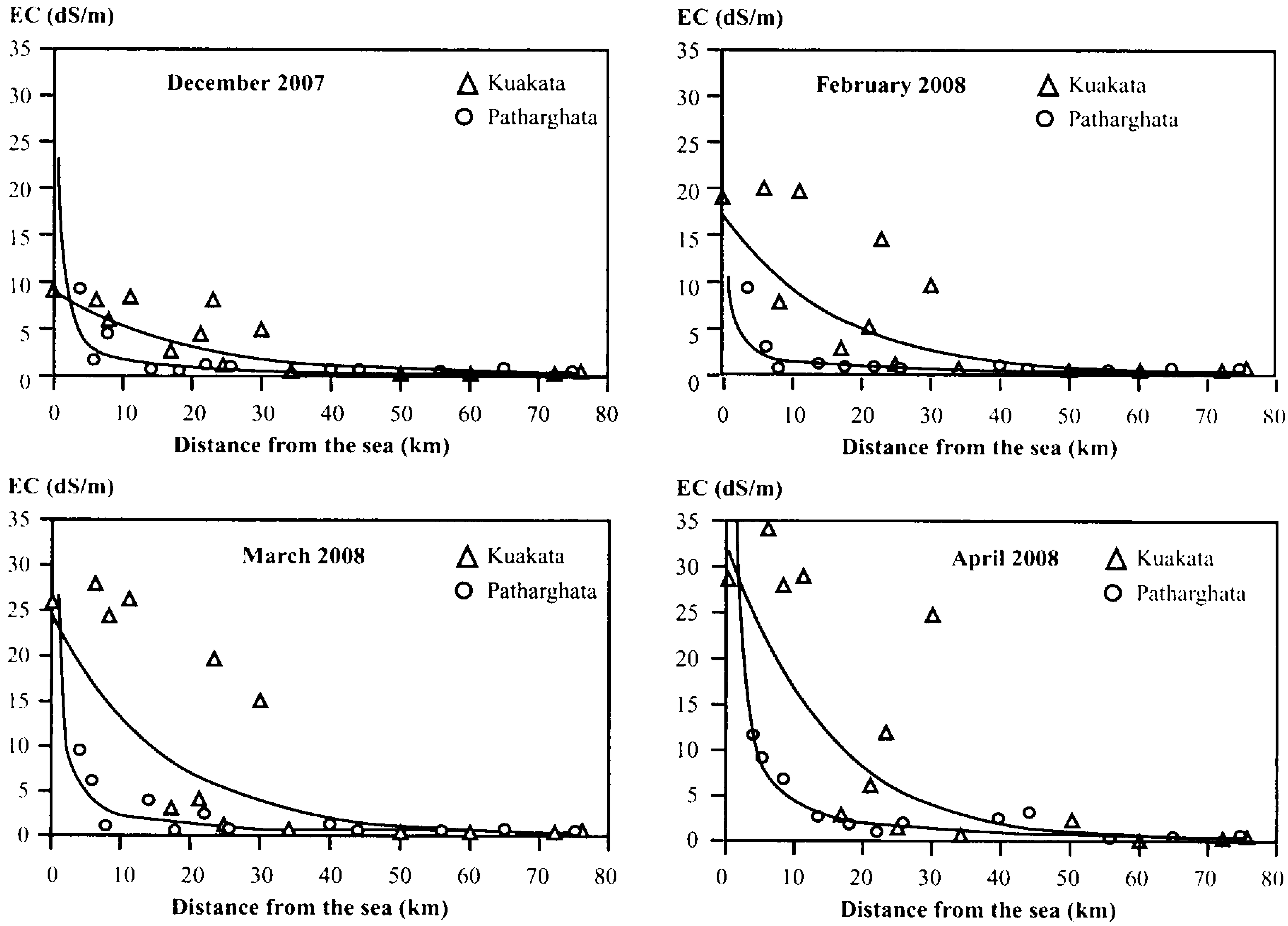

Fig. 2. Water salinity (dS/m) in river/water bodies located at different distances from Kuakata and Patharghata coasts of the Bay of Bengal.

the Kuakata coast was higher than that of Haringhata coast.

In December, water salinity at river Pyara, Laukathi, Harpangasia, Andharmanik, Sonatola and Fafru canal was 0.23, 0.23, 4.79, 8.04, 8.12 and 7.96 dS/m, which was increased to 0.36, 0.32, 14.95, 19.62, 26.4 and 27.9 dS/m, respectively in March (Fig. 3). Water salinity at river Pyara, Laukathi and

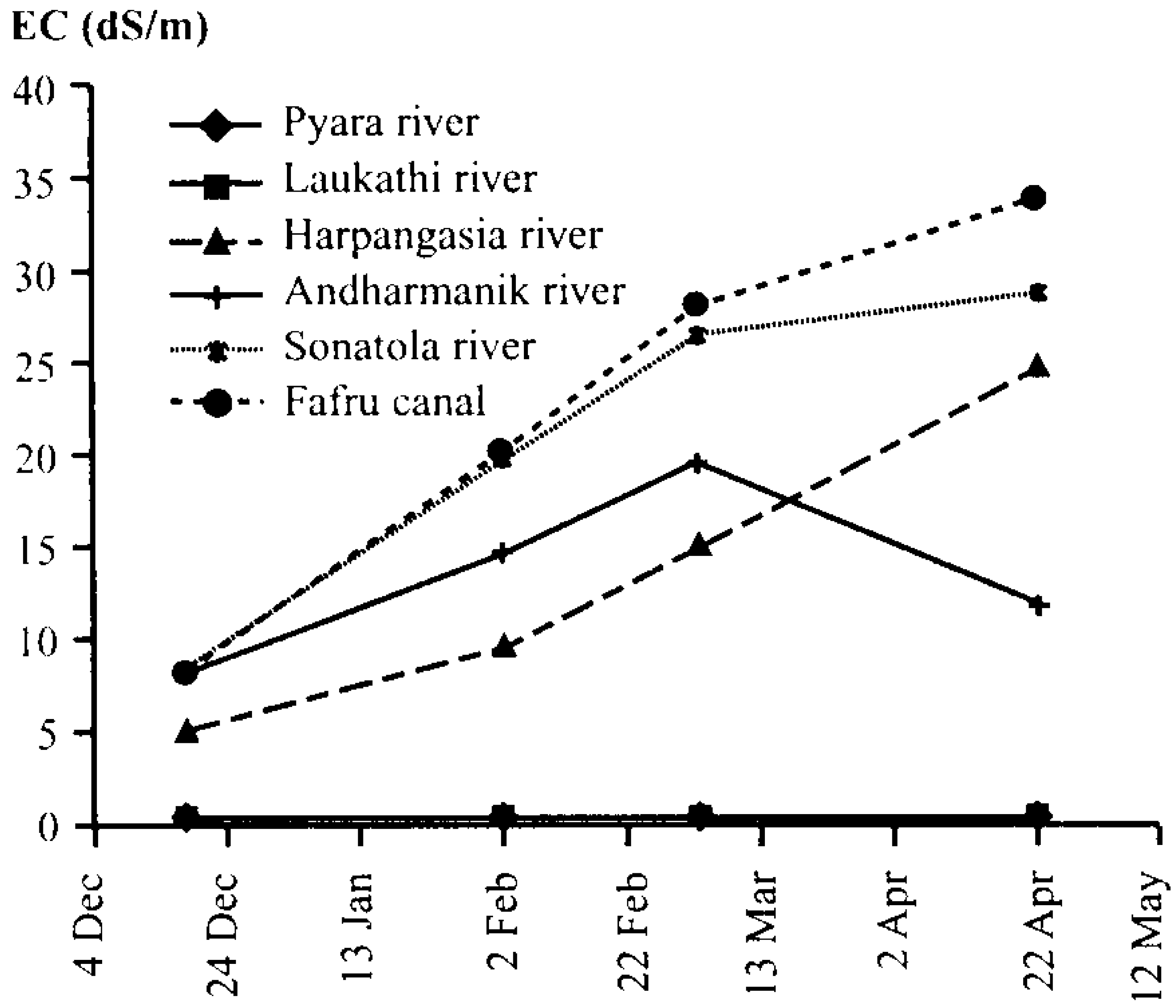

Fig. 3. Water salinity in some coastal rivers along Kuakata coast in dry season 2008.

Andharmanik decreased to 0.25, 0.12 and 11.84 dS/m but in river Harpangasia, Sonatola and Fafru canal water salinity was increased to 24.60, 28.70 and 33.90 dS/m respectively, in April. It was found that in dry season river water salinity increases with high tidal discharge compared to fresh water discharge. River water salinity increase with decrease in river fresh water discharge was also reported by Sungill et al (2006) and Vu (1996). The difference in fresh water discharge between the rainy season (from May to October) and dry season (from November to April of next year) is very large. The largest monthly average fresh water discharge from Red river, Vietnam in August is about ten times larger than the smallest one in March (Vu, 1992). In the rainy season, due to large fresh water discharge from upstream, the salinity intrusion problem does not occur. However, in the dry season, with small freshwater discharge, the salinity intrusion into river estuaries has been a main environmental problem (Vu, 1996). Figure 3 presents water salinity in rivers at distance of 60 km and above from the coast, which was suitable (less than 0.75 dS/m) in the study period.

In December, water salinity at the Kuakata beach was 8.92 dS/m; Bipinpur, Salimpur, Pakhimara, Kolapara, Amtoli bazar, Shakharia bazar and Bakarganj the water salinity in different water bodies was 5.73, 2.50, 4.31, 1.00, 0.26, 0.20 and 0.40 dS/m, respectively (Table 2). At distance 34 to 76 km from the Kuakata coast, salinity in waters were less than 1 dS/m, which are safe to crop cultivation. Water salinity increased by several fold in February, March and April compared to that of December. The increase in water salinity up to 34 km from Kuakata coast in the drier months was below 1 dS/m. However, at Skharibazar, which is 50 km away from Kuakata had water salinity of 0.20-0.58 dS/m up to March, which increased abruptly to 2.43 dS/m in April. Although Amtoli, 34 km from Kuakata, had slightly higher water salinity than at Skharibazar from December to March, the former had lower water salinity than the latter in April (Table 2).

At 4 to 75 km distance from Haringhata coast, salinity in waters varied from 0.27 to 9.00 dS/m, the safe water of less than 1.00 dS/m was found at 14 km or further from the coast in December (Table 3). In the first week of February, water salinity was below 1 dS/m up to 18 km from the Haringhata coast. The safe irrigation water (1 dS/m) pushed to 44 km in March and 56 km in April. Increase in water salinity in inlands of 44 km from the coast was attributed to the increase in salinity in the Boleshwar river in April. Characteristics of salinity intrusion into estuaries of the Red river system, Vietnam were studied by Vu (1996) based on 29 years measurement data of salinity concentration. It was found that in the dry season, the salinity intrusion length is as long as 20 km in the main river and more than 20 km for some tributaries. In the main river and tributaries with high freshwater discharge, the maximum salinity concentration is observed in January while for the tributaries with low freshwater discharge, the maximum salinity concentration is observed in March (Vu, 1996). Water salinity suitable for irrigation (below 1 dS/m) in April was found after 56 km from Haringhata coast line and 50 km from Kuakata coast line.

Soil salinity

Towards Kuakata coast, soil salinity the highest (5.68 dS/m) in December was at Sekandarkhali (30 km from the coast) and the lowest (0.69 dS/m) at Khalishakhali (60 km away from the coast) (Table 4). Salimpur (21 km from the coast) and Kolapara (25 km from the coast) had salinity of 2.11 and 1.37 dS/m, while soil

Table 2. Electrical conductivity (dS/m) of water collected from Bakarganj-Patuakhali Amtoli-Kolapara.

Location	Distance from sea (km)	Date of sampling			
		18 Dec	4 Feb	4 Mar	24 Apr
Bakarganj	76	0.40	0.43	0.62	0.42
Shakharia bazar	50	0.20	0.33	0.58	2.43
Amtoli bazar	34	0.26	0.48	0.70	0.89
Kolapara	25	1.00	1.10	1.22	1.59
Salimpur	21	2.50	2.84	3.04	3.00
Pakhimara	17	4.31	5.08	4.22	6.13
Bipinpur	8	5.73	7.90	24.10	27.70
Kuakata sea beach	0	8.92	19.08	25.70	28.50

Table 3. Electrical conductivity (dS/m) of water collected from Jhalokathi-Rajapur-Mathbaria-Patharghata-Haringhata.

Location	Distance from sea (km)	Date of sampling			
		19 Dec	3 Feb	3 Mar	18 Apr
Dhanshiri	75	0.27	0.32	0.55	0.37
Razapur	65	0.45	0.54	0.61	0.69
Charkhali	56	0.27	0.33	0.45	0.33
Dhanisafa	44	0.52	0.68	0.44	2.97
Tushkhali	40	0.51	0.66	1.19	2.25
Raihanpur	26	0.43	0.31	0.65	1.88
Nachnapara	22	0.78	0.59	2.38	0.70
Kathaltoli	18	0.52	0.76	0.50	1.76
Charduani	14	0.54	1.10	3.87	2.81
Patharghata	8	4.67	0.52	1.07	6.64
Badurtala	6	1.61	2.67	5.93	8.95
Haringhata	4	9.00	9.10	9.40	11.34

Table 4. Electrical conductivity (dS/m) of soil collected from Bakarganj-Patuakhali-Amtoli-Kolapara.

Location	Distance from sea (km)	Date of sampling			
		18 Dec	4 Feb	4 Mar	24 Apr
Bakerganj	76	1.41	1.20	1.70	1.80
Khalishakhali	60	0.69	1.15	1.15	1.06
Shakharia bazar	50	1.7	6.40	2.50	9.64
Amtoli bazar	34	1.71	3.60	3.40	16.76
Sekandarkhali	30	5.68	6.25	7.25	16.33
Kolapara	25	1.37	2.35	5.10	29.07
Salimpur	21	2.11	8.05	8.25	22.59
Pakhimara	17	4.41	2.15	7.10	25.38
Bipinpur	8	4.72	4.15	15.9	14.74

salinity at Bipinpur and Pakhimara, 8 and 17 km away from the coast, was 4.72 and 4.41 dS/m respectively. Soil salinity in the following months (February, March and April) rose to more than 4 dS/m up to Shakharibazar (50 km from the coast). Soil salinity, up to 50 km from the coast, increased several fold in April compared to that of December (Table 4). In April, soil salinity at Salimpur, Kolapara, and Shakharibazar was 22.59, 29.07 and 9.64 dS/m compared to 2.11, 1.37 and 1.70 dS/m in December. Water salinity in the nearest river or canal of the monitored places up to 50 km from the coast was 1.59-27.70 dS/m in April. However, water salinity at Amtoli (34 km from the coast) was 0.48, 0.70 and 0.89 dS/m in February, March and April, respectively, but soil salinity of 16.76 dS/m in April was great problem for Boro and other crops.

Soil salinity towards Haringhata coast varied from 0.48 at Dhanshiri (75 km from the coast) to 13.10 dS/m Haringhata (4 km from the coast) in December (Table 5). Kathaltoli (18 km from coast) had soil salinity of 6.34 and Charduani (14 km from coast) showed 4.77 dS/m, while Patharghata (8 km from coast) had only 2.13 dS/m soil salinity in December (Table 5). Nachnapara, 22 km from the coast, and further places from the Haringhata coast had soil salinity of 1.91 dS/m or less in December. Soil salinity in February was increased in all the places even at Nalchiti (88 km from the coast), except at Charduani and Harighata. In February, soil salinity of more than 4 dS/m (5.1-8.8 dS/m) was observed at Nachnapara, Kathaltoli, Badurtola and Harighata. Soil salinity in March was higher than that observed in February in all the tested site, but the highest jump was found at Mothbaria (34 km from coast). At Mothbaria, soil salinity March had increased to 6 dS/m from 3 dS/m in February, but in April it fell to 3.30 dS/m. Compared to March soil salinity in April increased at several places, but decreased at other places. Soil salinity at Dhanisafa (44 km from coast) and Tushkhali (40 km from coast) was 4.90 and 5.60 dS/m compared to 3.50 dS/m in March.

Suitable land for Boro cultivation in respect to water and soil salinities was available along Khalishakhali, 60 km from Kuakata coast, and Charkhali, 56 km from Haringhata coast. However, there are some pockets like Nachnapara toward Haringhata coast and Kolapara toward Kuakata coast, where non-saline water are available, may be used for Boro cultivation. There are some places along the Haringhata coast such as Patharghata and Raihanpur had soil salinity of less than 4 dS/m, but water salinity in these places are not suitable for Boro cultivation.

CONCLUSION

Suitable land for Boro cultivation lies after about 60 km away from the Haringhata and Kuakata coasts. However, some pocket lands within the 60 km may be suitable for Boro growing with water stored during rainy season. The Bishkhali river water salinity was found suitable for irrigation in December-April up to 24 km from the coast. Boro may be cultivated along the river side with surface water irrigation from this river.

Table 5. Electrical conductivity (dS/m) of soil collected from Jhalokathi-Rajapur-Mathbaria-Patharghata.

Location	Distance from sea (km)	Date of sampling			
		19 Dec	3 Feb	3 Mar	18 Apr
Nalchiti	88	0.69	1.40	1.90	2.10
Dhanshiri	75	0.48	1.10	1.85	1.30
Rajapur	70	0.92	1.40	2.50	2.85
Charkhali	56	1.50	1.70	2.55	2.60
Dhanisafa	44	1.42	3.15	3.50	4.90
Tushkhali	40	1.60	3.00	3.45	5.60
Mathbaria	34	1.91	3.00	6.00	3.30
Raihanpur	26	0.57	1.60	2.35	1.90
Nachnapara	22	1.71	5.10	5.00	3.30
Kathaltoli	18	6.34	8.75	5.00	7.80
Charduani	14	4.77	2.40	4.05	3.20
Patharghata	8	2.13	3.50	3.45	3.60
Badurtala	6	1.87	6.65	7.60	8.60
Haringhata	4	13.1	7.00	8.20	5.85

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Interaction Effect of Nitrogen and Planting Time on Growth and Rice Yield in Tidal Flood Ecosystem

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ABSTRACT

Field experiment was conducted in Aus season (April- August) to determine the effect of N fertilizer and planting time on BRRI dhan27 in tidal flooded soil. Higher panicle m^{-2} (330) was recorded in 35 kg N/ha in case of April planting and in 70 kg N/ha (275) in case of May planting in 2007. In 2008, 21 April and 21 May planted crop gave more panicle than other planting dates. The N control plots produced consistently higher yield than the plots received N in 2007. Transplanting on 21 May produced the highest yield (4.03-4.54 t ha^{-1}), while the lowest (1.54-2.26 t ha^{-1}) was observed in April transplanting. In 2008, 21 April planting yielded higher (3.70-4.17 t ha^{-1}) than other planting dates. The sterility was significantly higher in 6 April planting at all N level which reduced the grain yield. Higher sterility in 6 April resulted from high pest infestation and high temperature in reproductive stage during last week of May to 1st week of June. Nitrogen application did not increase the grain yield of BRRI dhan27. The results suggest that the Aus rice of about 4 t ha^{-1} yield need no N fertilizer application in tidal flooded soil containing 0.12% total N.

Key words: Growing degree days (GDD), high temperature, nitrogen, planting dates

INTRODUCTION

Aus rice (April-August) plays an important role in coastal farmers economy of Bangladesh, Indonesia, Srilanka and other Asian countries. Planting time of Aus rice plays a key role on yield and establishment of subsequent T. Aman (August-December) rice crop. Delayed establishment of Aus rice causes delay in T. Aman establishment while early establishment leads to face some biotic and abiotic stresses like drought, high temperature, and high pest infestation, which causes sterility. Seo *et al.* (2005) reported harmful effect of high temperature to rice crops. High temperature affects the plant growth and reduces the rice yield significantly (Satake and Yoshida 1978). The sterility in heat sensitive cultivars is attributed to a reduction in number of deposited pollen grains on a stigma and female sterility (Satake and Yoshida, 1978). Planting time can adjust time of flowering to avoid high temperature shock in Aus rice. Management of nitrogen fertilizer drew attention of rice scientist. Most of the N fertilizer works for Boro and T. Aman. Nitrogen fertilizer management in coastal region needs special attention.

In Coastal region, farmers generally do not use fertilizers in Aus and Aman rice; because, from May to September most of the area goes under tidal submergence. As a result, large amount of tidal sediment is added in the soil through siltation. Some times urea fertilizer application is essential especially for HYVs. The rate of $NO^{=}_{3}$ accumulation increased with increasing temperature and could be predicted across temperature regimes using GDD (Griffin and Honeycutt, 2000). So, it is needed to identify the optimum time of planting and N level for BRRI dhan27 in tidal ecosystem for higher productivity.

MATERIALS AND METHODS

Experiment was conducted in BRRI farm Sagordi, Barisal during Aus season (March to August) of 2007 and 2008. The soil was clay loam with 1.8% organic matter, 5.6 pH, 0.12 total N, 18 ppm P and 0.20

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meq K/100 soil. The trial was done with the variety BRRI dhan27 using four planting times and 3 N levels. Nitrogen levels were control (N_0), 35 kg N ha^{-1} (N_{35}) and 70 kg N ha^{-1} (N_{70}) and transplanting times were 6 April, 21 April, 6 May and 21 May. Experimental design was split-plot with three replications, transplanting time in main plot and N level in sub-plot. Unit plot size was 3 × 3m. All the plots received a flat dose of 15 kg P and 40 kg K ha^{-1}. Twenty-day-old seedlings were transplanted at 20 × 15 cm spacing. Tiller dynamics were recorded at 15, 30, 45 and 60 DAT. Plant height, tillers $hill^{-1}$, yield components, grain yield, HI and sterility% were recorded after harvest. Degree days were calculated with the following equation (Ottis and Talbert, 2005):

$$^{o}Cd = \frac{\left(^{o}C\max + ^{o}C\min\right)}{2} - 10^{o}C$$

Where *Cd* was equal to degree-days, °C max was equal to daily maximum temperature and °C min was equal to daily minimum temperature. If °C max exceeded 34.4°C then °C max was set at 34.4°C, whereas if °C min exceeded 21.1°C then °C min was set at 21.1°C.

Figure 1 shows the average maximum and minimum temperature during the study period. It indicates that there were not large differences among the maximum and minimum temperature in 2007 and 2008. However, the maximum and minimum temperature was lower in 2007 in mid March (30 and 15°C) and mid April (31 and 19°C) compared to 2008 (Fig. 1).

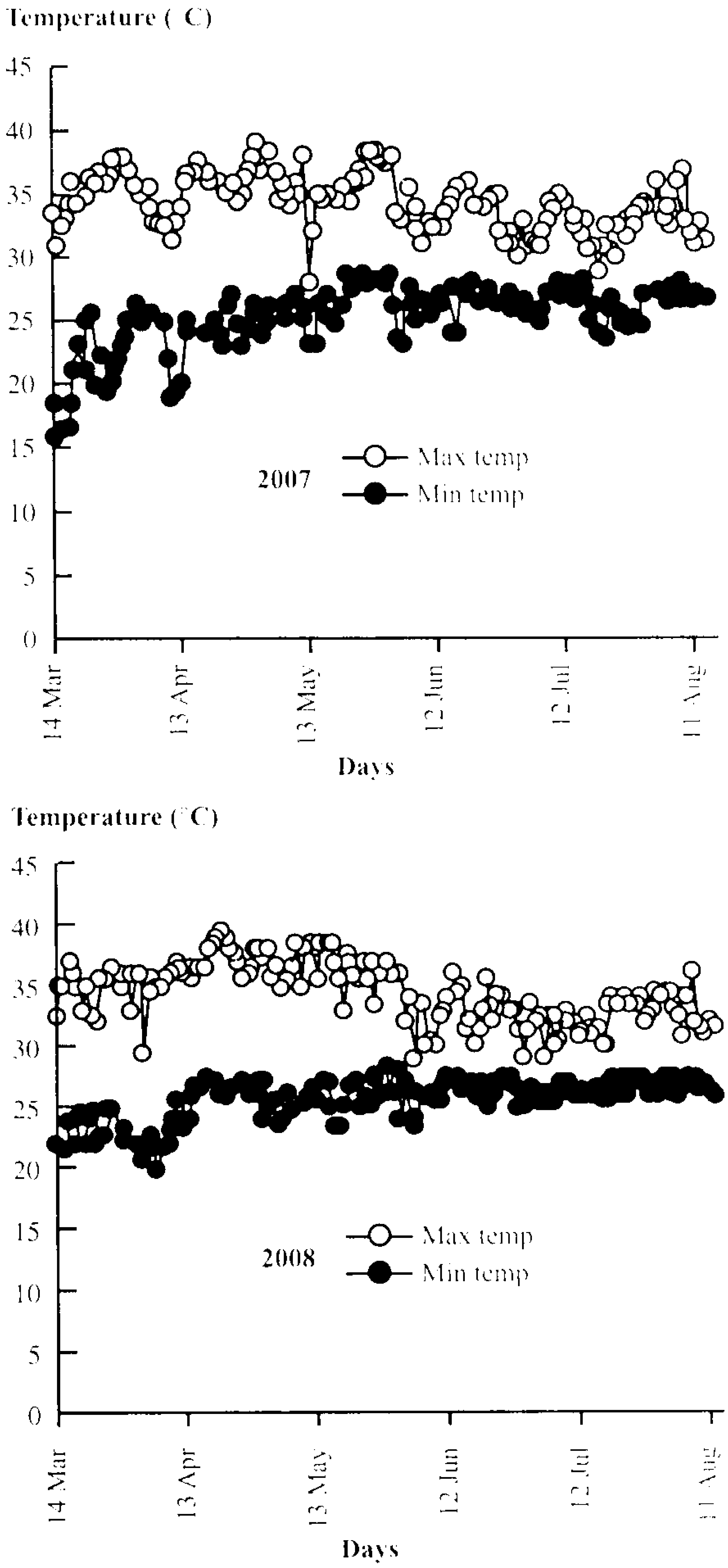

Fig. 1. Maximum and minimum temperature in 2007 and 2008 at the experimental site (Sagordi farm, BRRI, Barisal).

RESULTS AND DISCUSSION

Table 1 shows the flowering dates planted in different dates, solar radiation and growing degree days (GDD) during 2007 and 2008. It indicates that the growth duration decreased in delayed planting. Reddy *et al.*, 2000 also reported that growth duration decreased with delayed sowing. The GDD was slightly higher in 2008 compared to 2007. The GDD was the lowest in delayed planting (30 April sowing) in both the years. Samba Masuri accumulated 1898 and 2280 growing degree-days before the completion of flowering and physiological maturity, with the duration of flowering and days to maturity (Reddy *et al.*, 2000). Rice cultivars may have different cumulative degree-day threshold, the number of accumulated degree-day units for development to specific growth stages (eg, panicle differentiation and

Table 1. Date of flowering and growing degree days (GDD) of BRRI dhan27 as affected by different planting time during Aus 2007 and 2008, Sagordi farm, BRRI Barisal.

Sowing date	Transplanting date	Flowering date		GDD		Solar radiation	
		2007	2008	2007	2008	2007	2008
16 March	6 April	5 June	12 June	1428	1559	435	422
01 April	21 April	19 June	30 June	1400	1582	417	413
15 April	06 May	1 July	7 July	1366	1452	302	285
30 April	21 May	15 July	15 July	1336	1318	256	289

50% heading) remains relatively constant for a given cultivar (Norman *et al.*, 2001). GDD strongly correlated to the days to flowering for a particular year but it is constant figure for a variety and would not vary from year to year or season to season like days to flower; rice yield may not be affected by GDD (Rahman *et al.*, 2009).

Planting dates and N rates significantly influenced grain yield. Transplanting on 21 May produced significantly higher grain yield (4.03-4.54 t ha^{-1}) while the lowest (1.54-2.26 t ha^{-1}) was recorded in April transplanting (Table 2). April planting showed the lowest grain yield (1.54-2.26 t ha^{-1}) probably due to higher sterility caused by high temperature and high pest infestation. The N control plots produced consistently higher yield than the plots received N fertilizer. Increasing N level from 35 to 70 kg ha^{-1} reduced the yield of BRRI dhan27. The poor yield in earlier planting (April) may be attributed to high grain sterility. High pest (stem borer and rice bug) infestation in April transplanting compared to May caused higher sterility in the former. On the other hand, 6 and 21 April transplanting plots faced high temperature at the last week of May or the 1st

Table 2. Grain yield and yield components of BRRI dhan27 as affected by planting dates and N level, Aus 2007, Sagordi farm, BRRI Barisal.

Treatment	Grain yield (t ha^{-1})	Panicle m^{-2}	Grain $panicle^{-1}$	1000-GW (g)	HI	Sterility (%)
			6 April			
0 kg N ha^{-1}	2.26	286	49	26.1	0.45	38
35 kg N ha^{-1}	1.89	330	45	26.1	0.43	51
70 kg N ha^{-1}	1.54	275	47	25.6	0.41	45
Average	1.90	297	47	25.9	0.43	45
			21 April			
0 kg N ha^{-1}	2.22	231	55	26.1	0.45	30
35 kg N ha^{-1}	2.13	275	61	26.3	0.46	33
70 kg N ha^{-1}	1.67	253	49	26.0	0.42	46
Average	2.00	253	55	26.1	0.44	36
			6 May			
0 kg N ha^{-1}	3.96	165	68	27.3	0.48	26
35 kg N ha^{-1}	3.60	209	62	27.0	0.46	23
70 kg N ha^{-1}	3.00	275	55	26.9	0.44	35
Average	3.52	216	62	27.1	0.46	28
			21 May			
0 kg N ha^{-1}	4.54	198	82	26.8	0.48	13
35 kg N ha^{-1}	4.26	176	74	26.7	0.46	20
70 kg N ha^{-1}	4.03	209	76	26.9	0.44	25
Average	4.28	194	78	26.8	0.46	20
$LSD_{(0.05)}$						
Planting dates	0.302	65.4	9.8	0.447	0.457	9.8
Nitrogen rates	0.218	NS	NS	NS	0.14	3.73
Date ×Rate	NS	57.5	NS	NS	NS	7.47
CV (%)	8.6	13.8	12.8	2.3	3.7	13.7

week of June at booting to flower initiation stage. That high temperature might have enhanced sterility and poor grain yield. Rice genotypes ≤ 1 h exposure to ≤ 33.7°C at anthesis caused sterility (Jagadish *et al.*, 2007). The interaction effect of planting time and N rates on panicle m^{-2} was significant. April planting showed higher panicle number compared to May planting. Higher panicle m^{-2} (330) was recorded where N fertilizer was used @ 35 kg ha^{-1} in case of April planting and in N_{70} (275) in case of May planting.

Grain $panicle^{-1}$ was significantly influenced by planting time. Significantly higher number of grain was recorded in 21 May planting compared to other planting dates. There was no significant difference in grain number among the N rates. The 1000-grain weight (TGW) significantly influenced by planting dates and higher TGW was recorded in May planting. The harvest index (HI) significantly influenced by N rates and higher HI was observed in N_0. Sterility was significantly influenced by planting dates and N rates. Significantly higher sterility was observed in April planting and in N_{35} and N_{70} in all planting dates.

During 2008, grain yield, panicle m^{-2}, grain $panicle^{-1}$, TGW, sterility (%) and HI were significantly influenced only by planting dates (Table 3). Grain yield was higher (about 4 t ha^{-1}) in 21 April planting compared to other planting dates. Higher yield components ($panicle^{-2}$, grain $panicle^{-1}$ and TGW) were recorded in 21 April and 21 May planting. The sterility was significantly higher in 6 April planting at all N level, which reduced the grain yield. Higher sterility in 6 April resulted from high pest infestation (stem borer, rice bug, rates etc) and high temperature during booting to flower initiation stage. Lower temperature in March and April might be the main cause for restricted growth and lower yield in April planting during 2007. During April-June, the maximum temperature was 36-38°C in both the years in most cases, which are detrimental for rice if it is in booting to flower initiation stage.

CONCLUSION

Two year studies show transplanting in May gave constantly good yield. Tidal flooded soil containing 0.12% total N need no nitrogen fertilizer application.

Table 3. Grain yield and yield components of BRRI dhan27 as affected by planting dates and N level, Aus 2008, Sagordi farm, BRRI Barisal.

Treatment	Grain yield (t ha^{-1})	Panicle m^{-2}	Grain $panicle^{-1}$	1000-GW (g)	HI	Sterility (%)
			6 April			
0 kg N ha^{-1}	2.68	150	48	26.39	0.40	55.5
35 kg N ha^{-1}	2.73	158	52	26.66	0.42	52.4
70 kg N ha^{-1}	2.65	150	50	26.28	0.40	54.7
Average	2.69	153	50	26.44	0.41	54.2
			21 April			
0 kg N ha^{-1}	3.70	175	71	27.21	0.42	36.7
35 kg N ha^{-1}	4.17	175	78	27.42	0.46	27.9
70 kg N ha^{-1}	3.97	208	77	27.40	0.47	29.0
Average	3.95	186	75	27.34	0.45	31.2
			6 May			
0 kg N ha^{-1}	3.41	142	62	27.03	0.44	38.0
35 kg N ha^{-1}	3.36	142	64	27.21	0.43	36.2
70 kg N ha^{-1}	3.24	158	62	27.54	0.42	30.8
Average	3.34	147	63	27.26	0.43	35.0
			21 May			
0 kg N ha^{-1}	3.63	183	75	27.06	0.44	24.6

Table 3. Continued.

Treatment	Grain yield (t ha^{-1})	Panicle m^{-2}	Grain panicle^{-1}	1000-GW (g)	HI	Sterility (%)
35 kg N ha^{-1}	3.84	200	80	27.64	0.46	19.8
70 kg N ha^{-1}	3.17	183	69	27.65	0.43	25.2
Average	3.55	189	75	27.45	0.45	23.2
LSD $_{(0.05)}$						
Planting dates	0.298	20.2	5.2	0.53	0.282	5.03
Nitrogen rates	NS	NS	NS	NS	NS	NS
Date × Rate	NS	NS	NS	NS	NS	NS
CV (%)	8.8	12.0	7.9	2.0	7.9	14.0

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Growing Degree Days for Boro Rice Varieties

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ABSTRACT

Growing degree day (GDD) of Boro rice varieties has importance for nitrogen management and crop scheduling. Field experiment was conducted at BRRI regional station, Barisal aiming to determine GDD for BRRI Boro varieties. The GDD of the tested varieties varied from 2918 in BRRI dhan45 to 3420 in BR16. The tested varieties received 67-72% of the GDD after transplanting. The varieties of higher GDD got relatively higher calories in the field. Monthly contribution to heat accumulation was higher in March compared to January and February. The amount of heat that rice plant absorbed in 25 days in January equals to the heat that absorbed in 15 days of March. Days to flowering of the tested varieties varied from 128 days (in BRRI dhan45) to 146 in BR16. GDD was strongly correlated to the days to flowering for a particular year.

INTRODUCTION

GDD is defined as the amount of heat a photo insensitive variety required to flower. Understanding of GDD for Boro rice varieties is required for nitrogen application at panicle initiation stage. Considering optimum time of crop establishment of the Boro varieties their maturity time is defined in the literature (BRRI 2007). Because of large difference in temperature in January, February and March and year to year variation in temperature, flowering and panicle initiation events in rice plant cannot be tracked using calendar days of crop establishment.

Physiological development of rice has been successfully modeled using the GDD concept (Keisling *et al.*, 1984). The DD10 rice management computer programme is used to predict crop development and as a crop management aid on 60% or more of the Arkansas rice land area (Slaton *et al.*, 2003). The DD10 programme contains the cumulative degree-day thresholds for the vegetative (emergence to 1.25 cm internode elongation, IE, commonly associated with panicle differentiation) and reproductive (1.25 cm IE to 50% heading) growth phases for most released rice cultivars in the Midsouth, USA (Slaton *et al.*, 2003). Although rice cultivars may have different cumulative degree-day thresholds, the number of accumulated degree-day units for development to specific growth stages (eg, panicle differentiation and 50% heading) remains relatively constant for a given cultivar (Norman *et al.*, 2001). Development of crops can be better tracked and projected by maintaining an account of the heat accumulated during each growing season.

Because of difference in heat accumulation, transplanting of 45-day-old seedlings of a variety may mature in 160 days if transplanted in January, but growth duration of the variety may be reduced by 15-20 days if transplanted in March. Regardless of differences in temperatures from year to year GDD are used to predict the date that a variety will flower and reach maturity. This process involves a comparison of daily maximum and minimum temperatures to a base temperature, specific for a particular crop, above which development will occur. This investigation is aimed to determine GDD for BRRI varieties and re-examine tillering ability, grain and straw yield of the varieties.

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MATERIALS AND METHODS

The experiment was conducted in Boro season, November 2007 to May 2008 at Charbadna experimental farm of BRRI RS, Barisal. Twenty-one modern rice varieties were seeded on 18 November 2007 and were transplanted in 30 December 2007. The test varieties were BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan27, BRRI dhan28, BRRI dhan29, BRRI dhan35, BRRI dhan36 and BRRI dhan45. The experiment was designed as a Randomized Complete Block with three replications. Individual plot size of the experiment was 5.4×2.4 m^2 and the harvest area was 5×1 m^2. The experimental field received 85.37 kg N, 19.75 kg P and 59.24 kg K, 11.98 kg S and 3.60 kg zinc per ha from urea, triple super phosphate, muriate of potash, gypsum and zinc sulfate. Potash, phosphate, gypsum and zinc fertilizers were applied at land preparation and nitrogen fertilizer was applied in three equal splits in 16 January 2008, 3 February, 2008 and 22 February 2008. Pre-emergence herbicide was applied after 5 days of transplanting and manual weeding was done. Pesticide was applied to control stem borer. Degree days (temperature summation) were calculated with the equation (Yoshida, 1981):

$$GDD = \sum\left(\frac{^{O}C_{\max} + ^{O}C_{\min}}{2}\right)$$

Where °Cd was equal to degree days, °C max was equal to daily maximum temperature and °C min was equal to daily minimum temperature. Figure 1 presents daily maximum and minimum temperature and GDD.

Crop cutting was started at 2 May and continued till 14 May 2008. Number of tiller and panicle of 16 hills was counted and converted the number for 1m^2 area. Straw weight of 16 hills was taken after threshing and drying in the sun, and then sub samples were taken, weighed and then dried in the oven and again weighed. At last the weight was converted in t/ha. Grain sample was taken from 125 hills of each plot after cutting and threshing. Then the grain was sun dried till gaining constant moisture content and weighed and adjusted to 14% moisture.

RESULTS AND DISCUSSION

The tested rice varieties varied in GDD for flowering from 2918 in BRRI dhan45 to 3420 in BR16 (Fig. 2). The variety BR26 and BRRI dhan27 showed 2957 and 3047 GDD respectively. The tested varieties BR2, BR6, BR9, BR28 and BR36 showed 3076 GDD. BR 1, BR14 and BR17 had 3162 GDD for flowering. BR7 had GDD of 3191, while BR19 required 3244 for flowering. The variety pair BR8 and BR35 (3273 GDD), BR15 and BR18 (3357 GDD) and BR3 and BR12 (3416 GDD) were identified in the study. The highest GDD of 3420 was required for BR16 and BRRI dhan29 required 3379 GDD for flowering.

Total GDD in the seedbed, from 18 November to 30 December, was 958. The tested varieties received 67- 72% of the GDD after transplanting. The time in the seedbed for all the varieties was the same (42 days), therefore, the varieties of higher GDD got relatively higher heat in the field. For example, BR26 received 67% of GDD in the field while BR16 received 72%. GDD in the field varied from 1960 for BRRI dhan45 to 2462 for BR16. Heat summation in January contributed to 25- 32%, in February 26- 33% and in March 34-40% to the total GDD in the field.

GDD in January, February and March was 619, 643 and 866, respectively. Daily average GDD in January was 19.95 that increased to 22.16 in February, 27.92 in March and 28.49 in April (Fig. 1).

Days to flowering of the tested varieties varied from 128 days (in BRRI dhan45) to 146 in BR16 (Fig. 3). In our experiment, BR26 and BRRI dhan27 flowered in 129 and 132 days, respectively, BR2, BR6, BR9, BRRI dhan28, and BRRI dhan36 flowered in 133 days. Flowering time for BR1, BR14 and BR17 was 136 days; BR7 flowered in 137 days and BR19 in 139 days. BR8 and BRRI dhan35 flowered in 140 days, BR15 and BR18 in 143 days, and 144 days required for BRRI dhan29, while BR3 and BR12 flowered in 145 days. Flowering time of these varieties may be changed by several days or weeks depending variation temperature. Usually, flowering time is reduced by 2- 3 weeks in Aus season because of higher temperature in April and May compared to January and February. GDD is strongly correlated to the days to flowering (Fig. 4) for a particular year. However, days to flowering is dependent upon

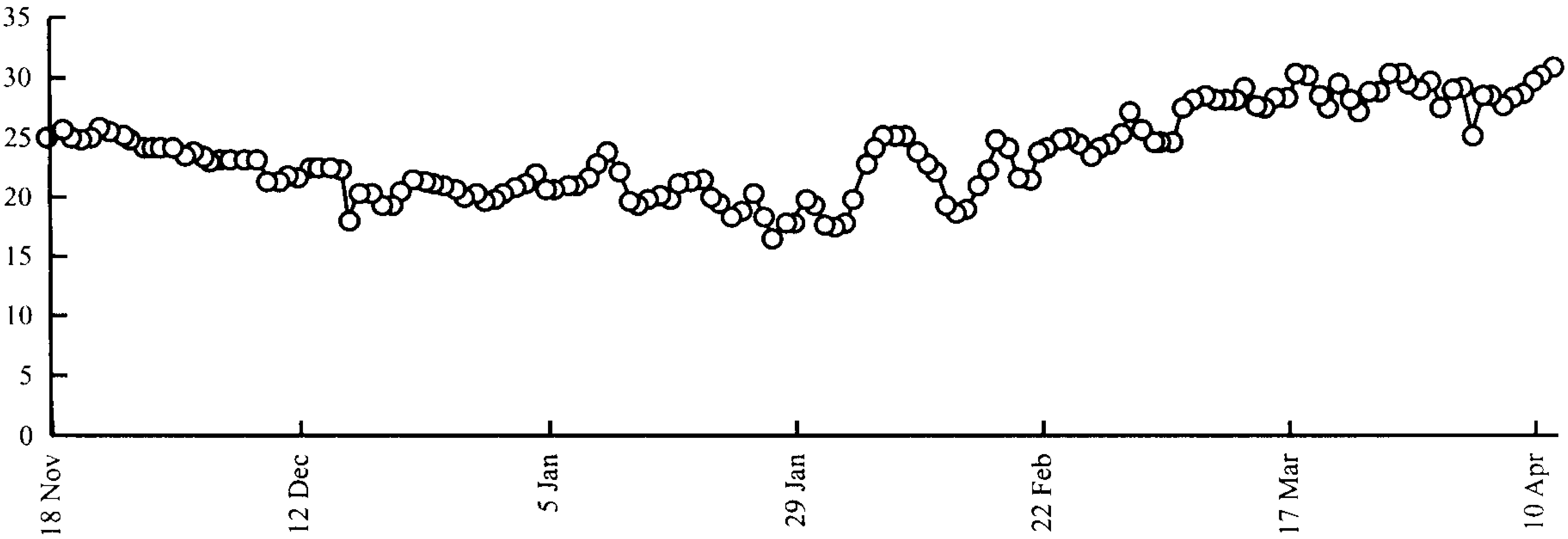

Fig. 1. Daily growing degree day from 18 November 2007 to 12 April 2008.

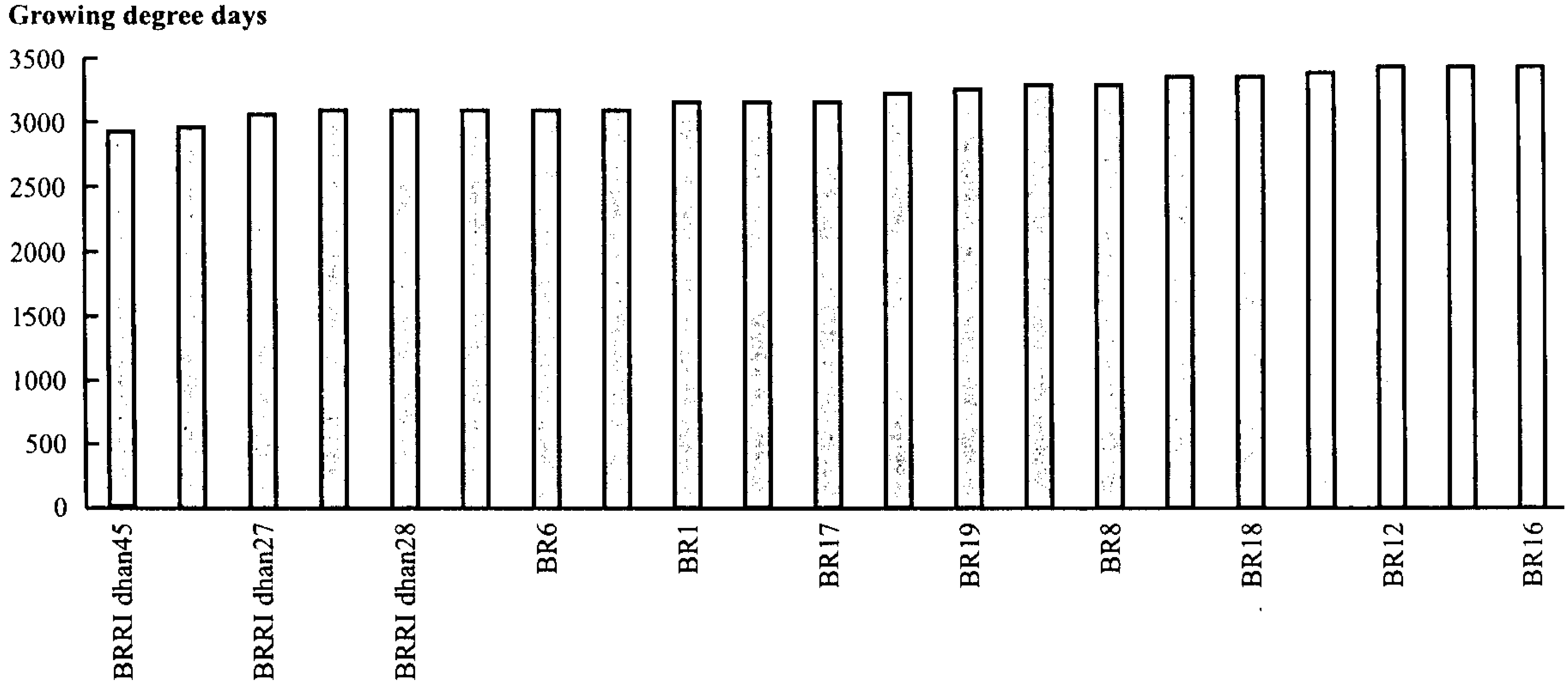

Fig. 2. Growing degree days of MV Boro varieties, BRRI RS, Barisal, Boro 2008.

temperature of the growing season while GDD is absolute figure for a variety. GDD would not vary from year to year or season to season like days to flower. Rice yield may not be correlated well with GDD (Fig. 5). Sawano et al. (2008) estimated rice crop calendar under rain-fed lowland conditions with acceptable accuracy by combining the crop calendar model with a simple phenology-based model that uses growing degree-days adjusted by a day-length factor.

CONCLUSION

There was noteworthy variation in GDD for flowering in tested Boro rice varieties. The time in the seed bed for all the varieties was the same (42 days), therefore, the varieties of higher GDD got relatively higher calories in the field. Monthly contribution to heat accumulation was higher in March compared to January and February. Days to flowering of the tested varieties varied from 128 days to 146. GDD is strongly correlated to the days to flowering for a particular year, however, days to flowering is dependent upon temperature of the growing season while GDD is absolute figure for a variety. GDD would not vary from year to year or season to season like days to flower. Rice yield may not be correlated well with GDD.

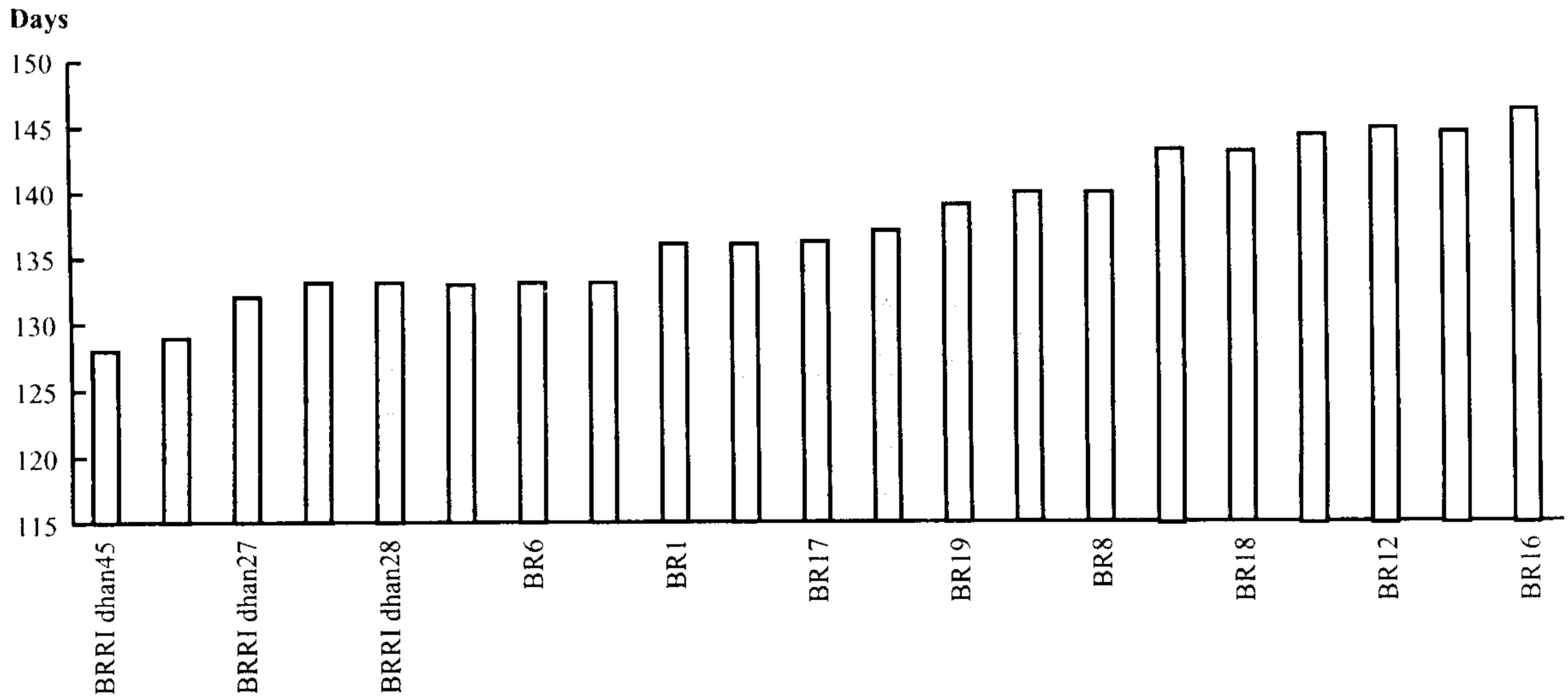

Fig. 3. Days to flowering of MV Boro varieties, BRRI RS, Barisal, Boro 2008.

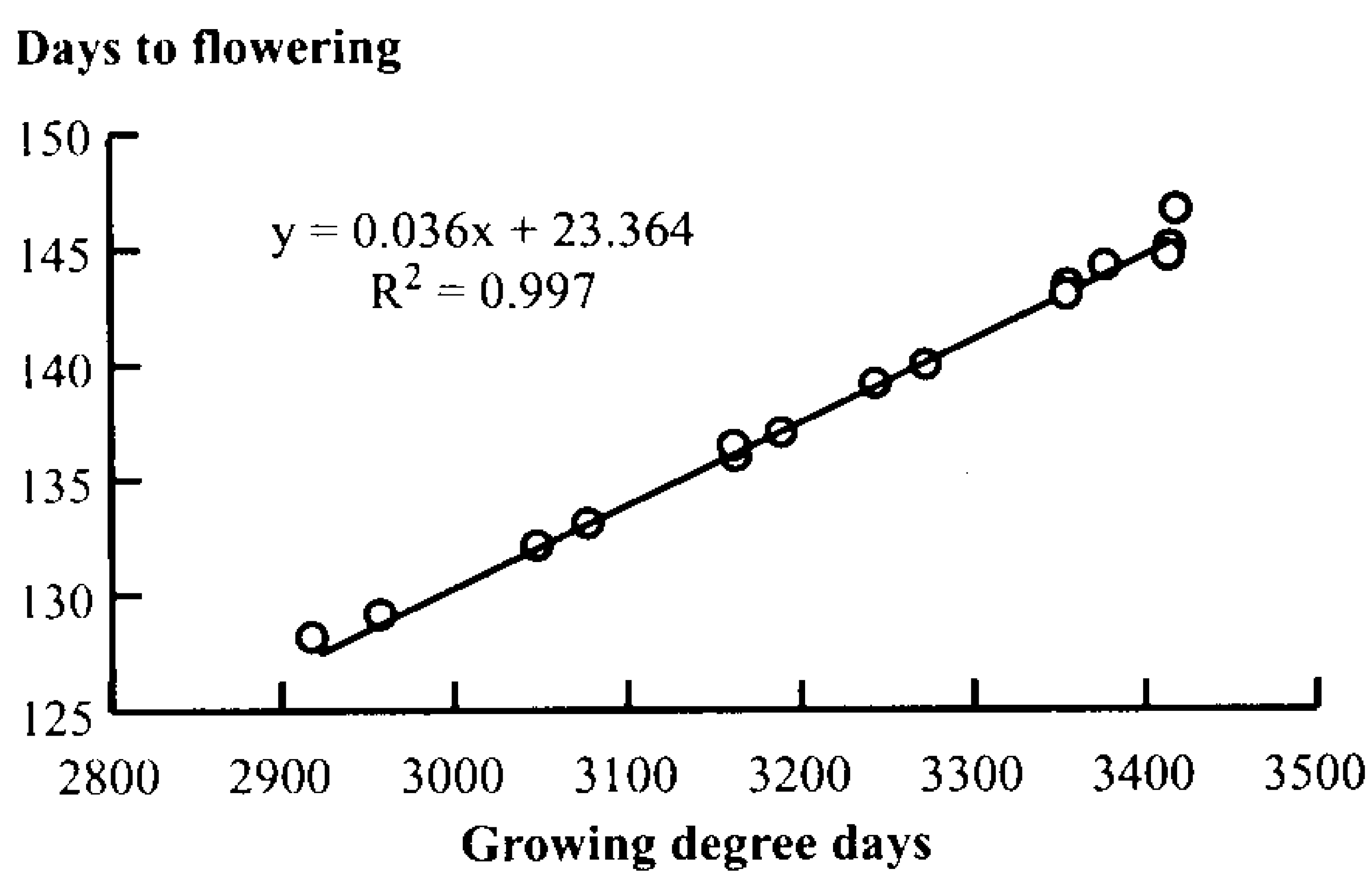

Fig. 4. Relationship between growing degree days and days to flowering of 21 Boro varieties.

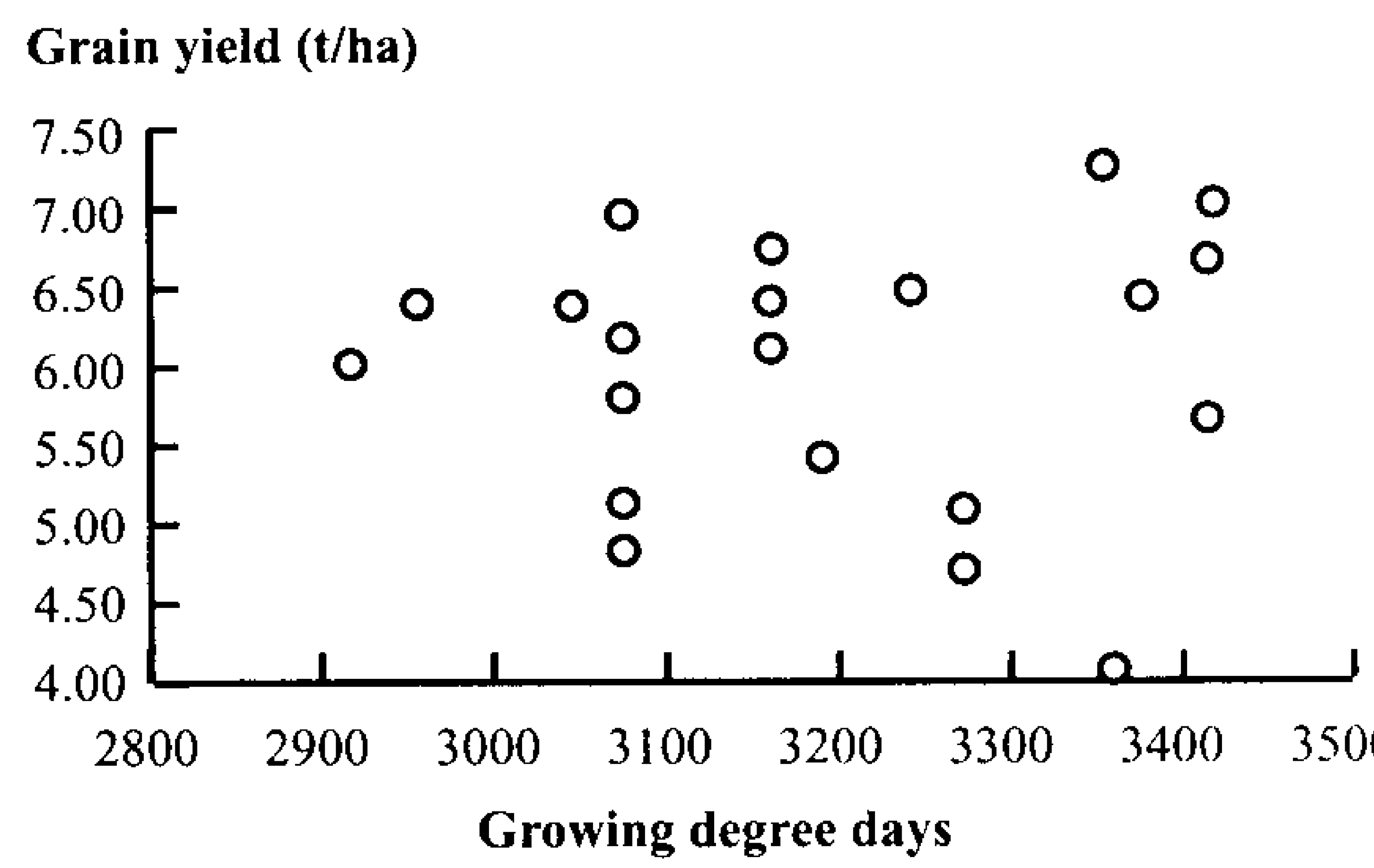

Fig. 5. Relationship between growing degree days and grain yield of 21 Boro varieties.

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Assessment of Rice Seed Quality Based on the Extent of Seed Ageing, Environment and Variety

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ABSTRACT

Laboratory experiments were carried out from February to September 2006 with freshly harvested seed of T. Aman rice to predict the varietal difference of quality seeds, based on accelerated ageing and storage conditions. Rice varieties- BRRI dhan33, BRRI dhan34, BR11, BRRI dhan37, Maloti and Kalizira were tested. Seeds were stored in two storage conditions, ambient (14-37°C) and controlled temperature (18-20°C). The seeds were subjected to accelerate ageing in nearly 100% relative humidity at 40°C temperature for 0-12 days (with 3-day interval). Seed quality (germination, seedling growth performance, electrical conductivity) were tested monthly for eight months. It was observed that initially short duration of accelerated ageing and 1-2 months storage increased germination percentage, especially for those varieties, which has low initial germination (BRRI dhan34 and Kalizira). But at elevated accelerated ageing and storage time decreased percent germination, seedling vigour and increased electrical conductivity value in ambient storage condition. Significant differences were observed among the varieties after accelerated ageing in all parameters studied. Maloti and Kalizira showed the highest storability whereas, BRRI dhan33 and BR11 showed the lowest storability. BRRI dhan37 showed good storability for four months and then deteriorated sharply and lost its viability at the seventh month of storage.

INTRODUCTION

Seed is the single most important input of rice cultivation without which other inputs are useless. So, good quality seed is an essential yield attribute for bumper harvest. Among the many factors that determine seed quality in respect to crop establishment and yield, seed vigour stands predominantly. Usually high vigour seed produces higher yield than low vigour seed, when grown in standard condition. Seed vigour includes a wide range of characteristics of seed or seed lot (Perry, 1980). In qualitative terms, aspects of seed germination and seedling field performance are some important parameters of seed vigour (Dornbos, 1995). In Bangladesh, almost 95% rice seeds are supplied by the farmers, which is stored in farmers' house in normal condition. High temperature and moisture in the storage environment (as noticed in summer season) appear to be the principal factors involved in seed deterioration (Matthews, 1985) and loss of germination capacity is the final manifestation of seed deterioration (Ali *et al.*, 2006). This deterioration process depends on the extent of initial moisture content of the seed, temperature and relative humidity of the storage environment. Viability is defined as the degree of which a seed is alive and is capable of germinating under favourable environmental conditions. Seed vigour connotes the possession of those seed properties, which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of environmental conditions. The viability of rice seed decreased with increasing relative humidity and storage time (Paricha *et al.*, 1977). Haque and Haroon (1983) observed that the rapid loss of viability in rice was a genetic trait and found that the improved variety BR9 has a longer period of viability.

In a normal storage condition, seeds deteriorate slowly with the passing of time. This deterioration

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process can be accelerated by subjecting the seeds in a closed environment of high temperature and high relative humidity. The seed quality measurement under such conditions termed as accelerated ageing test (AA), developed by Delouche and Buskin (1973) and has been used to evaluate the extent of seed vigour, related to germination, field emergence and stand establishment. When conducting the accelerated ageing test, seeds are placed at a specific high temperature (40-45°C) and high humidity (around 100%) for a specific time dependent upon species (ISTA, 2006). Accelerated ageing test can also predict the longevity of stored rice seeds as well as status of quality of seeds (Siddique *et al.*, 1988). T. Aman is the most important rice crop in Bangladesh, which occupies lion share of rice cropped area. During planting time supply of quality seeds of T. Aman rice become scarce. As such adequate supply of quality seeds must be insured for boosting rice production. The studies presented here were carried out to expand our understanding of varietal differences among rice varieties in the viability of rice seeds under accelerated ageing. In order to determine the underlying importance of seed quality, the effects of various levels of viability on the expression of important agronomic traits of some T. Aman rice varieties were studied under both ambient and controlled environmental conditions in the laboratory.

MATERIALS AND METHODS

The experiments were carried out at the Agronomy Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur and at National Seed Testing Laboratory, Gazipur during February to September, 2006. Freshly harvested seeds of six T. Aman rice varieties were tested. Among them four were modern varieties (BRRI dhan33, BRRI dhan34, BR11 and BRRI dhan37) and two were local varieties (Maloti and Kalizira). The varieties were selected on the basis of varying seed size and harvesting time (Table 1).

Seed samples of rice varieties were sun-dried to bring the moisture content to 11.5% and were subjected to Accelerated Ageing Test as described below. After accelerated ageing to specific period, 250 grams seeds from each sample were then taken in a cloth bag of 25-×14cm size and ten such bags were prepared for each variety. These bags with seed sample were then stored in the 1 February in two storage conditions i) in ambient temperature (14-37°C), and ii) in controlled temperature of 18-20°C with 60-70% relative humidity. The samples were kept in such conditions up to 30 September. The seed quality of stored seed was assessed monthly over eight months. Various qualitative tests such as germination, seedling growth performance and electrical conductivity were done in laboratory.

Accelerated ageing test

The seed samples were kept in ageing chamber at 40°C and around 100% relative humidity for 0, 3, 6, 9 and 12 days. The ageing chamber was constructed according to the following procedure-

Wire mesh net (9×9 mesh size) was used to make trays of 18.0-×3.5-×3.0cm (length×breadth× height) to contain 1200-1500 seeds. An iron sheet was used to fabricate 30.0- × 20.5- × 7.5-cm (length × breadth × height) box. The box had two inner ridges to hold the wire mesh trays above the water level. A gap of 10mm was maintained between the water surface and the wire mesh trays, contained seeds. The boxes were covered with lids and kept airtight so that no vapor could escape from the ageing box. The boxes were then put inside an oven and incubated at 40°C.

Germination test

In each month, a standard germination test was carried out using the stored aged seed samples of each variety, along with normal seed samples (non-aged). One hundred seeds of each sample were placed in a germination box (23- ×13-cm) containing filter paper soaked with distilled water. The germination boxes were then placed in a germination room at 20/30°C alternating temperature for 14 days (16 hours at 20°C in light and 8 hours at 30°C in dark) followed a completely randomized design (CRD) with four replications. Sufficient moisture was maintained in filter paper up to final count (14 days). After 14 days of placement of germination, germination percentage

Table 1. Designation, production site, harvesting time, grain size and 1000-grain weight of six rice varieties used for the experiment.

Variety	Designation	Production site	Harvesting time	Grain size	1000-grain wt (g)
BRRI dhan33	BR33	BRRI, Gazipur	Early	Large	23.39
BRRI dhan34	BR34	BRRI, Gazipur	Early	Fine	9.53
BR11	BR11	BRRI, Gazipur	Intermediate	Large	24.57
BRRI dhan37	BR37	BRRI, Gazipur	Intermediate	Fine	12.93
Maloti	Maloti	BSMRAU, Gazipur	Late	Large	27.31
Kalizira	Kalizira	BSMRAU, Gazipur	Late	Fine	11.03

was calculated according to ISTA rules (ISTA, 2006) by using the following formula:

$$\text{Germination \%} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds placed for germination}} \times 100$$

Seedling growth performance

Seedlings obtained from standard germination test were used for seedling growth evaluation. Normal and abnormal seedlings were classified according to the international rules for seed testing (ISTA, 1995). Fourteen days after placement of germination, ten normal seedlings were taken randomly from each germination box and shoot and root lengths were measured. The shoot and root dry weights of the seedlings were also recorded after dried at 70°C for 72 hours in an oven. Vigour indices were computed as suggested by Abdul Baki and Anderson (1973) as-

Vigour index = [Root length (cm)+Shoot length (cm)]×germination (%)

Measurement of electrical conductivity

Four replicates of 50 seeds of each sample were taken and weighed to nearest milligram and then soaked in 50ml deionized water in a flask. All flask containing water and seeds were covered with aluminium foil and placed at 20°C for 24 hours. A control flask containing only deionized water was included to monitor water quality. The electrical conductivity was measured with a conductivity meter (Model: CM-30 ET). The electrical conductivity meter was turned on 15 minutes prior to testing. Immediately after 24 hours soaks period, the measurements of conductivity of the solution were taken. The flask (with seeds) was gently swiveled for 10-15 seconds, the foil was removed and the conductivity was determined by immersing the measuring cell into the solution. Care was taken to avoid direct placement of the cell on the seeds. Several measurements were taken until a stable value was obtained. After testing each samples, rinsed the cell twice using deionized water and dried it by a filter paper prior to testing the next sample. Conductivity of deionized water in control flask was measured and subtracted the value from the conductivity reading already recorded for each flask, contained seeds. The conductivity per gram of seed for each sample was calculated by using the following formula as:

$$\text{Electrical conductivity} = \frac{\text{Conductivity } (\mu s) \text{ for each sample}}{\text{Weight (g) of seed sample}}$$

And expressed as $\mu s\ cm^{-1}\ g^{-1}$.

Data analysis

All data were analyzed by analysis of variance (ANOVA) (Gomez and Gomez, 1984) using MSTAT package. The means were compared by least significant difference (LSD) test. The graphs were prepared using the graphical routines in Microsoft Excel.

RESULTS AND DISCUSSION

Germination percentages of rice varieties as influenced by storage conditions, duration, and levels of accelerated ageing

Germination percentage of rice varieties with no ageing. Both in ambient and controlled temperature conditions, BRRI dhan33 and BR11 showed the highest initial germination percentage (>90%)

whereas Maloti and BRRI dhan37 showed the lowest germination percentage. BRRI dhan34 and Kalizira showed an intermediate response (Fig. 1a, b). However, within one month of storage in ambient temperature (14-37°C), BRRI dhan34 and Maloti achieved higher percent germination (around 90%). Up to four months of storage in that condition, all the varieties attained a plateau of more than 80% germination. After that period, percent germinations were started to decrease and at 7th month they attained the lowest value (Fig. 1a). On the other hand, in controlled temperature storage (18-20°C), above 80% germination was recorded with all the varieties and no marked fall in germination percentages were observed up to seven-month storage (Fig. 1b).

Germination percentage of rice varieties with 3-day ageing. In ambient storage condition, all varieties maintained a constant germination percentage from 2nd to 4th months. From 4th month of storage BRRI dhan37 deteriorated rapidly with a marked fall in germination percentage and lost its viability at 7th month (Fig. 2a) whereas BRRI dhan34 showed about 26% germination at that storage period and other varieties also performed poorly (Fig. 2a). In controlled temperature storage no significant difference was observed from the 1st to 3rd month storage. From 4th month storage significant difference in germination percentage among all varieties were observed. Kalizira showed the highest germination percentage (around 90%) at that storage period whereas BRRI dhan37 showed the lowest percentage germination (around 70%) (Fig. 2b).

Germination percentage of rice varieties with 6-day ageing. After 6-day ageing, under both storage conditions, the initial germination percentage for all varieties were more than 80% (Fig. 3a, b). Similar result was reported by Hafiz (1992), worked with rice. In ambient temperature, all the varieties showed significant difference in germination percentage throughout whole storage period. Maloti retained the highest germination (around 90%) up to four months of storage and the lowest of that (around 60%) was observed in BRRI dhan33. Then rapid fall in germination was observed in all varieties and only 0-20% germination was recorded at 7th month storage (Fig. 3a). On the other hand, in controlled temperature storage, Maloti and Kalizira maintained a constant and the highest germination (>80%) throughout the storage period where as BRRI dhan33 showed a decreased germination percentage (as low as around 60%) (Fig. 3b).

Germination percentage of rice varieties with 9-day ageing. After 9-day ageing, in ambient storage condition, significant difference in percent germination of all varieties was observed throughout the whole storage period. Kalizira produced more than 90% germination during four months storage, which was closely followed by Maloti. Throughout the storage period, Kalizira showed the better performance than the other varieties whereas BRRI

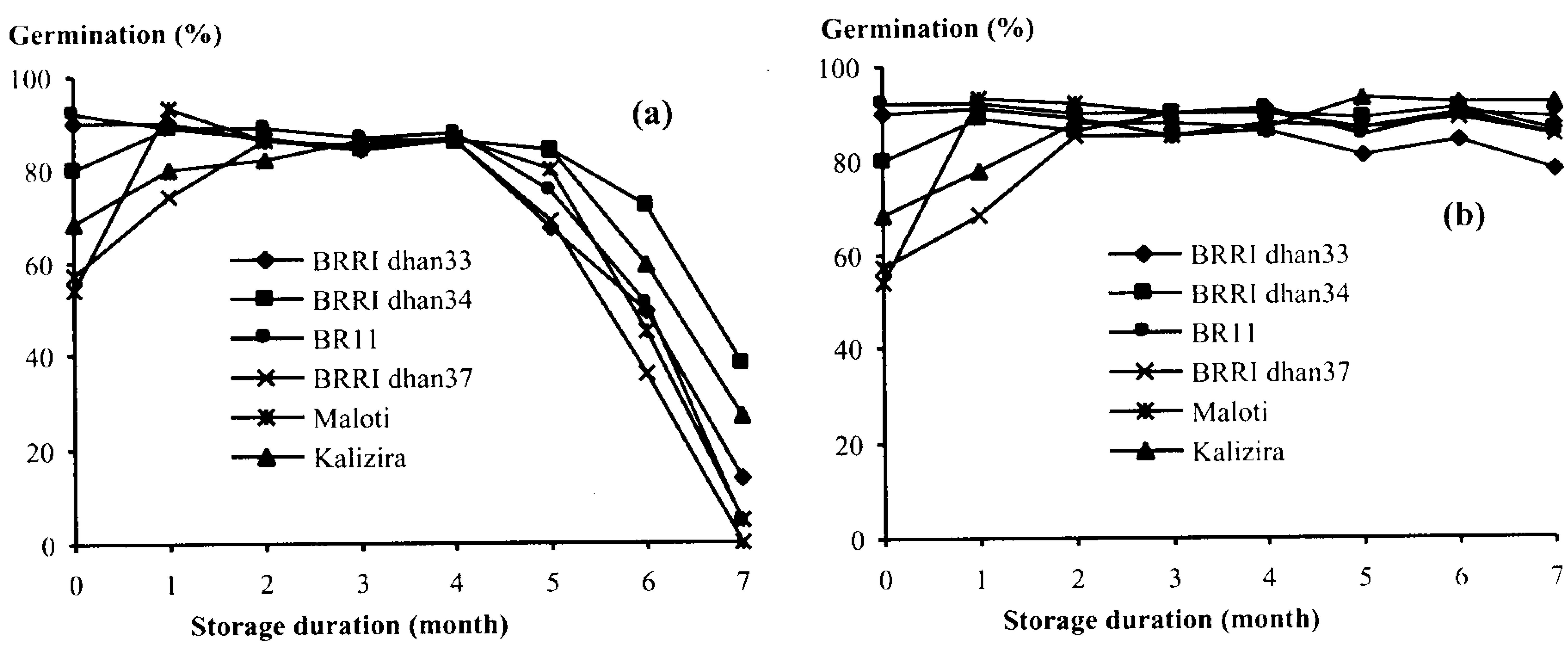

Fig. 1. Germination percentage of six rice varieties stored in (a) ambient and (b) controlled conditions at 0-day ageing (without ageing).

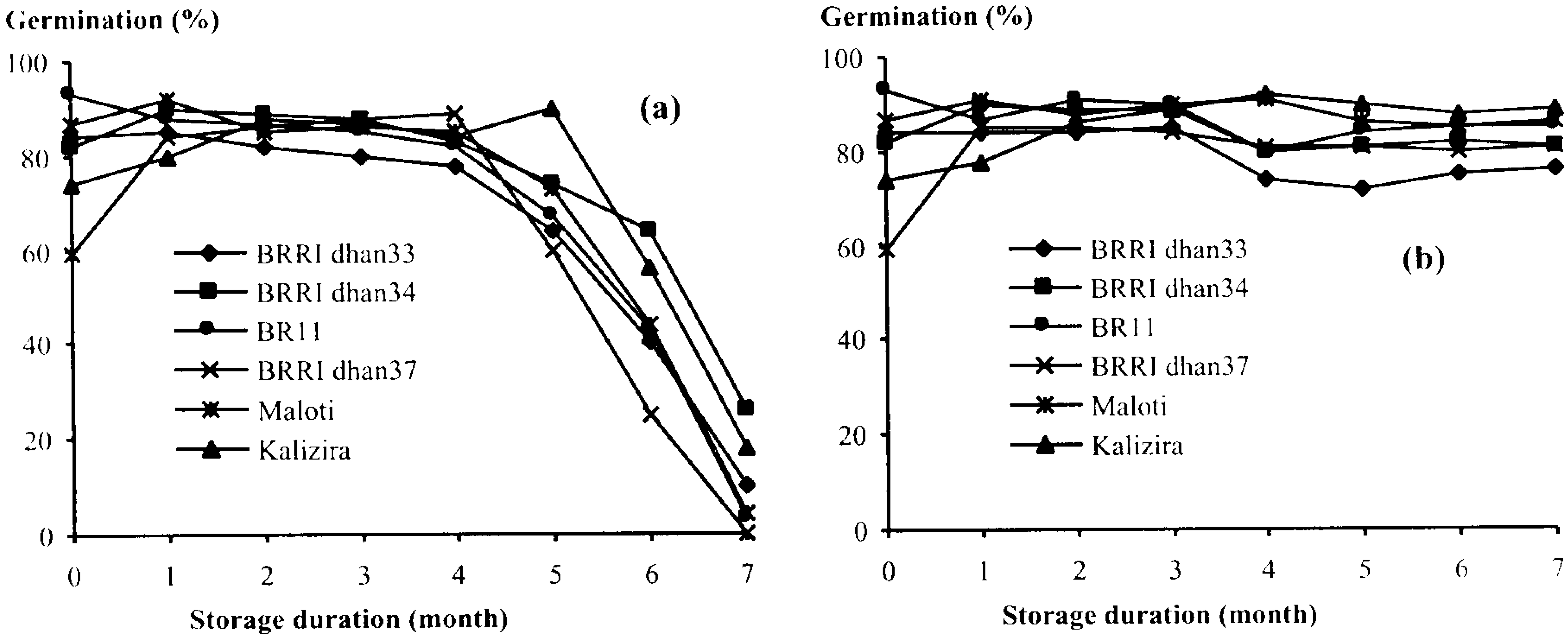

Fig. 2. Germination percentage of six rice varieties stored in (a) ambient and (b) controlled conditions at 3-day ageing.

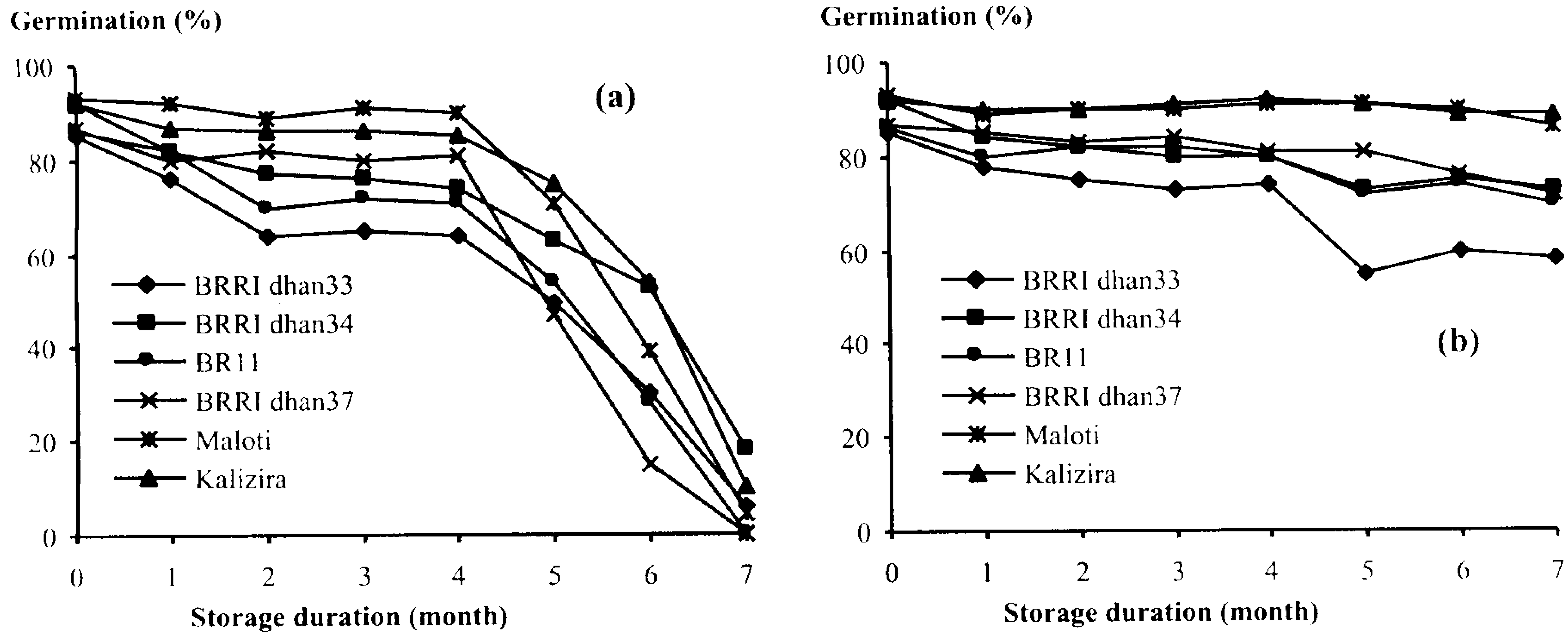

Fig. 3. Germination percentage of six rice varieties stored in (a) ambient and (b) controlled conditions at 6-day ageing.

dhan33 produced the lowest percent germination (Fig. 4a). However, storage in controlled temperature, Kalizira and Maloti produced the highest percent germination (around 85%) throughout the whole storage period, whereas other varieties maintained around 60-70% germination (Fig. 4b).

Germination percentage of rice varieties with 12-day ageing. In ambient storage condition and 12-day ageing, Maloti and Kalizira showed similar and the highest percent germination (around 80%) up to four month storage and then declined sharply (Fig. 5a). The rest of the varieties gave significantly the lowest percent germination at that storage condition (around 60%) and declined at elevated storage period (Fig. 5a). In controlled temperature storage, Kalizira and Maloti maintained the highest germination (around 85%) throughout the whole storage period whereas other varieties showed significantly lower germination percentage up to seven months storage (around 60%) (Fig. 5b).

Vigour indices of rice varieties as influenced by storage conditions and duration (on average of six ageing levels)

When data were averaged over six levels of ageing, vigour indices differed significantly within the

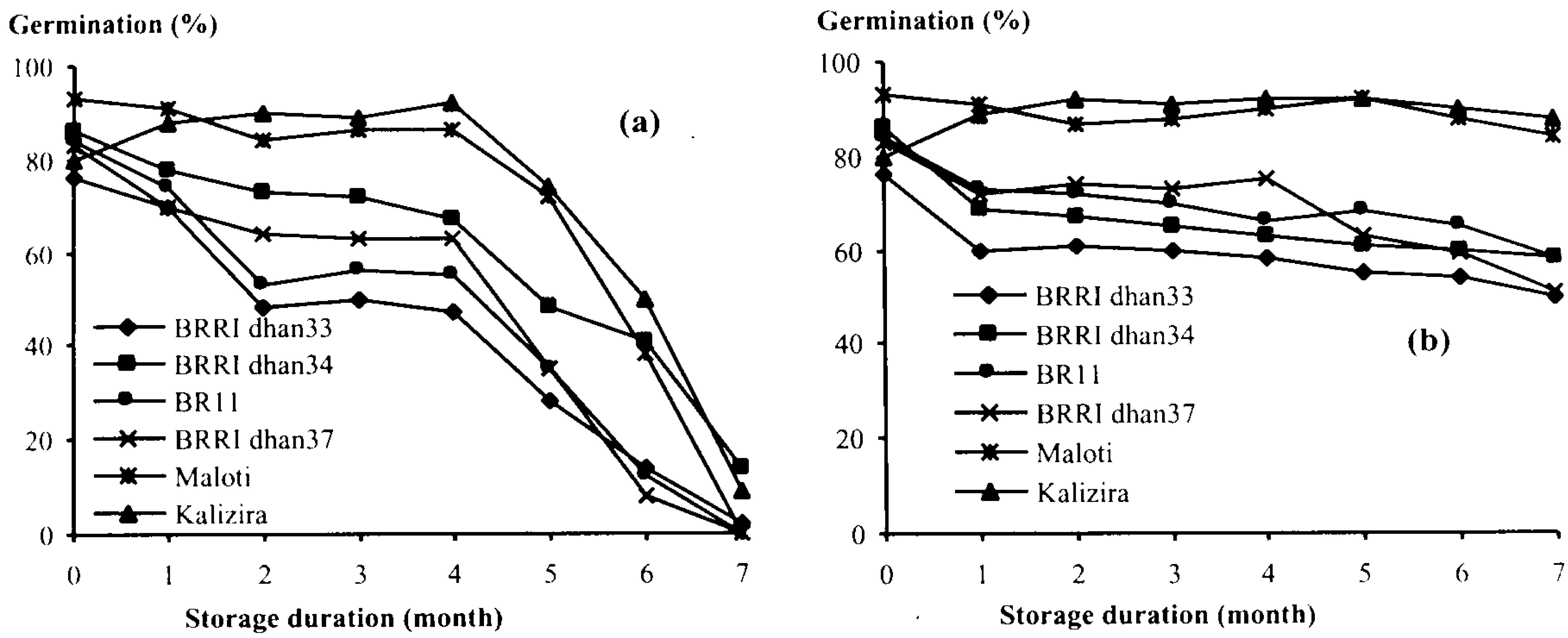

Fig. 4. Germination percentage of six rice varieties stored in (a) ambient and (b) controlled conditions at 9-day ageing.

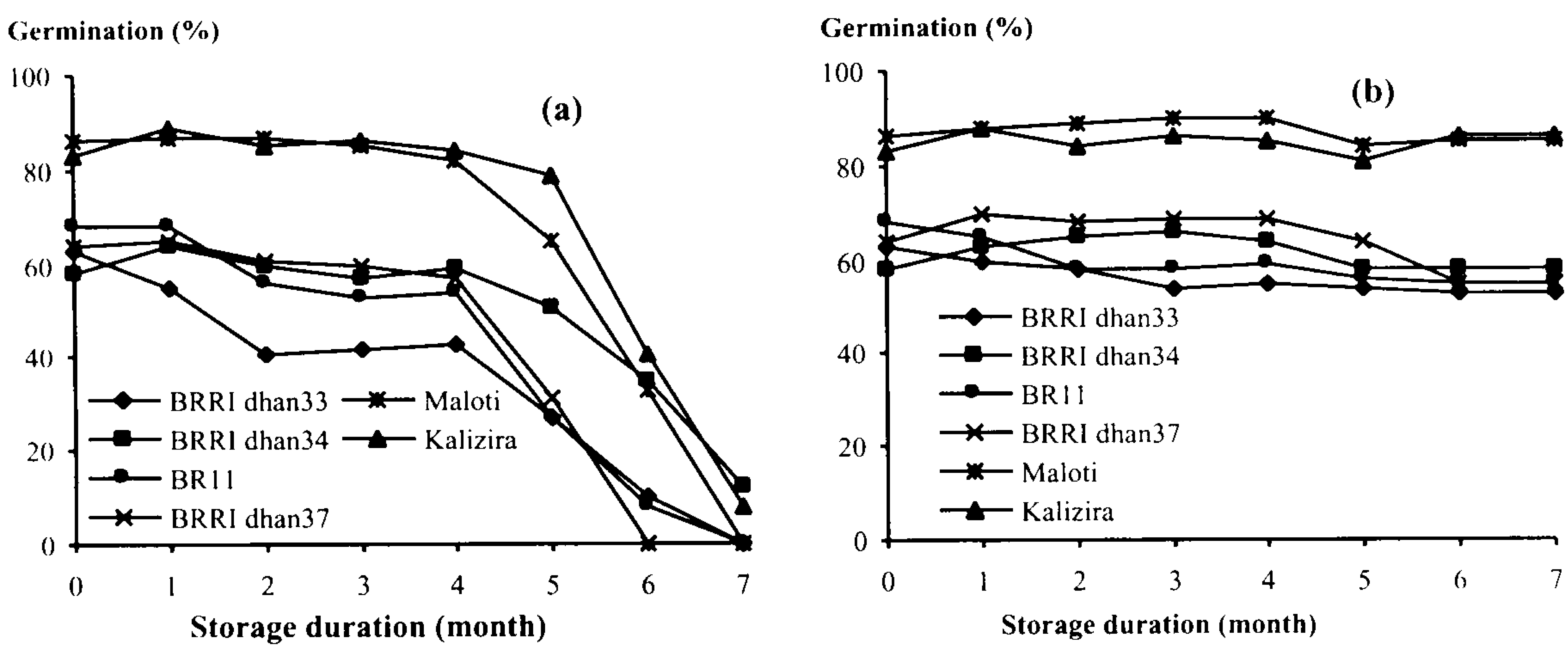

Fig. 5. Germination percentage of six rice varieties stored in (a) ambient and (b) controlled conditions at 12-day ageing.

varieties. From initial to last month of storage, the vigour indices differed significantly (Table 2). Up to four months of storage a little difference was observed within two storage conditions. From fifth month the differences in vigour indices within two storage conditions became clear. The varieties, which were stored in controlled condition, gave the highest vigour indices than that of ambient storage condition and this trend was found up to last month of observation, whereas at seven months storage, vigour indices greatly reduced in ambient temperature storage condition (Table 2). Among the varieties, Maloti showed the highest vigour indices throughout the storage period in both the storage conditions, which was followed by BRRI dhan33 and Kalizira and the lowest of that was observed with BRRI dhan34 (Table 2).

Seedling dry matter of rice varieties as influenced by storage conditions and duration, and levels of accelerated ageing

Seedling dry matter of rice varieties with no ageing. Without ageing treatment, varietal differences were observed with seedling dry matter, irrespective of storage conditions and duration. Maloti produced the highest dry matter, which was followed by BR11

Table 2. Vigour indices of rice varieties under two storage conditions and at varying storage duration (on average of six ageing levels).

Variety	Storage condition	Storage duration (month)							
		1	2	3	4	5	6	7	Mean
BRRI dhan33	S_1	1106	959	936	949	670	441	62	732
	S_2	1021	1053	988	1035	893	1019	957	995
BRRIdhan34	S_1	805	876	777	779	664	561	217	668
	S_2	760	849	807	793	731	769	849	794
BR11	S_1	922	879	861	834	604	327	15	635
	S_2	925	944	914	964	850	905	878	911
BRRI dhan37	S_1	833	871	838	860	551	178	0	590
	S_2	803	877	884	912	810	782	899	852
Maloti	S_1	1535	1487	1510	1403	1115	682	46	1111
	S_2	1439	1549	1614	1528	1525	1356	1399	1487
Kalizira	S_1	945	929	965	928	819	566	152	758
	S_2	922	993	992	980	946	949	887	953

S_1 = Ambient storage condition. S_2 = Controlled storage condition.

and BRRI dhan33 in both the storage conditions (ambient and controlled temperature storage). Seedling dry matter was increased at 4 and 5 months storage and then deceased (Fig. 6a, b). Similar results were observed at 3-day and 6-day ageing (Fig. 7a, b and 8a, b).

Seedling dry matter of rice varieties with 9-day ageing. At 9-day ageing, similar trend was found as with no ageing but only the exception that no increased dry matter productions at 4 and 5 months storage were observed in both storage conditions (Fig. 9a, b).

Seedling dry matter of rice varieties with 12-day ageing. At 12-day ageing, similar trend was observed as with 9-day ageing. However, Maloti performed better than other varieties in almost all the storage period and storage conditions (Fig. 10a, b).

Electrical conductivity of rice varieties as influenced by storage conditions and duration (on average of six ageing levels)

Recently, an electronic instrument, the Automatic Seed Analyzer has been developed to detect the

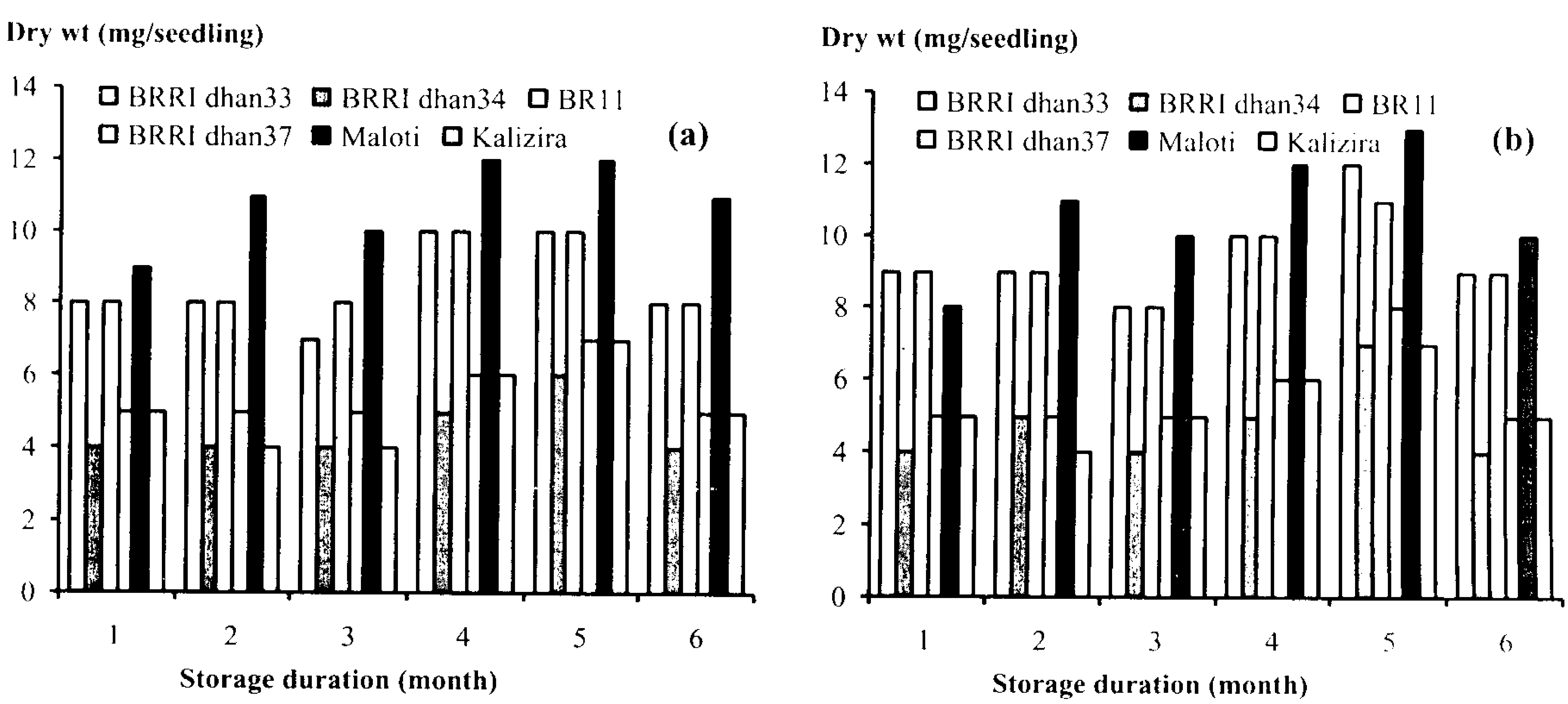

Fig. 6. Seedling dry weight (mg/seedling) of six rice varieties stored in (a) ambient and (b) controlled conditions at 0-day ageing (without ageing).

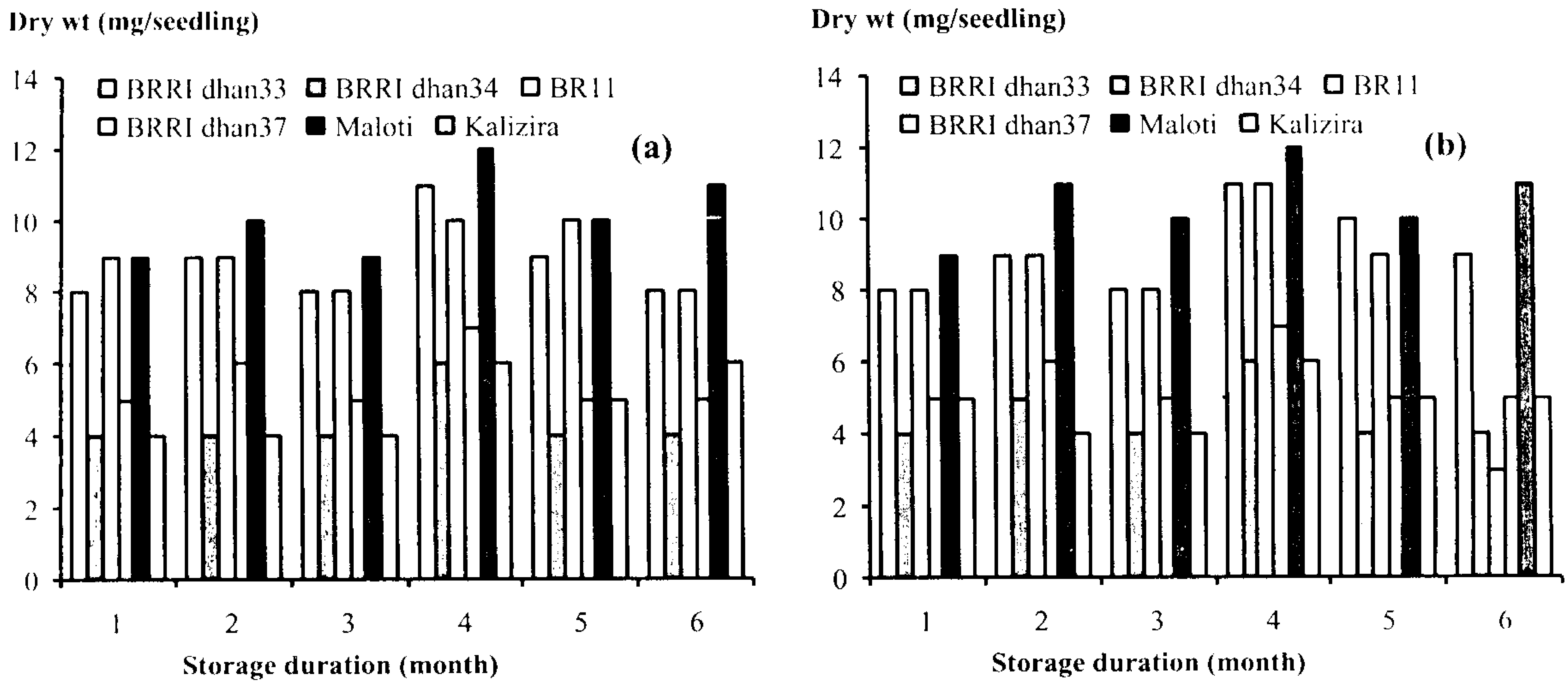

Fig. 7. Seedling dry weight (mg/seedling) of six rice varieties stored in (a) ambient and (b) controlled conditions at 3-day ageing.

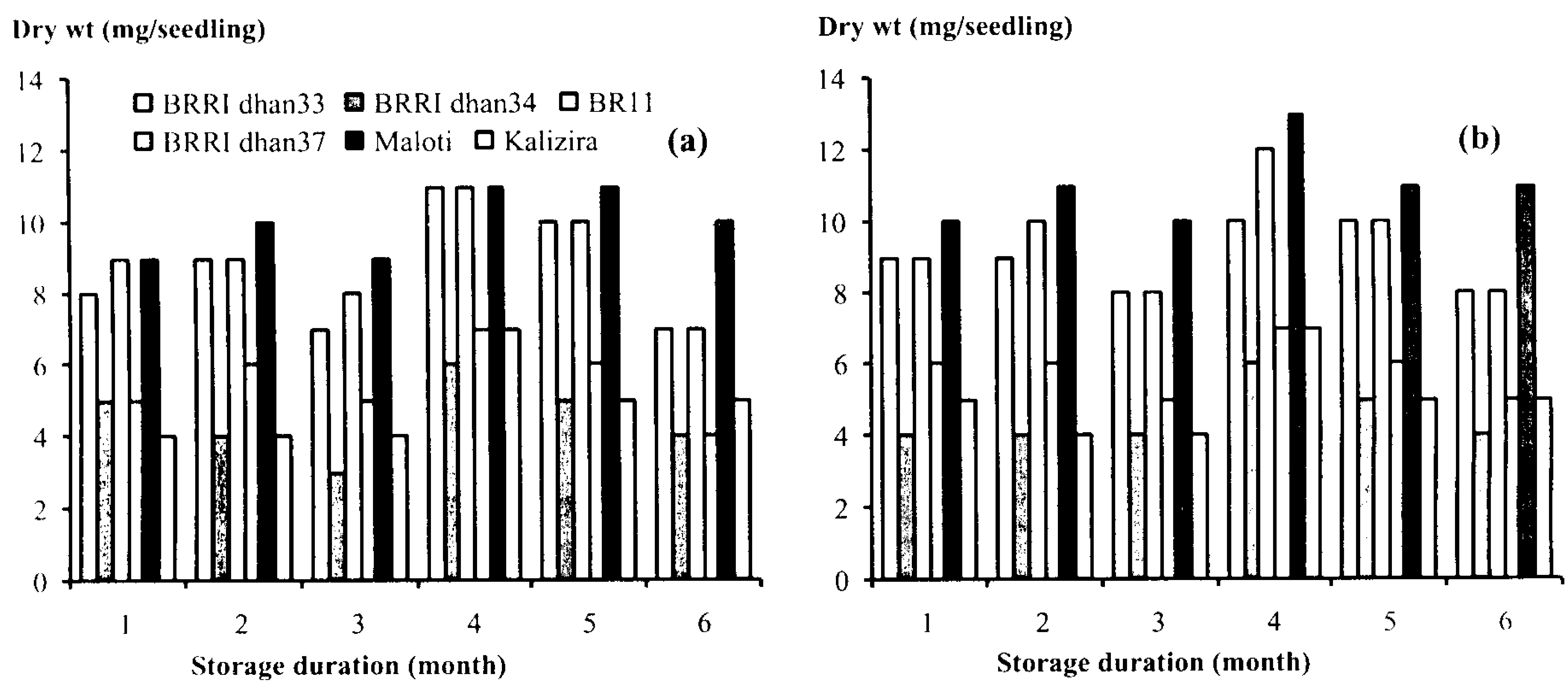

Fig. 8. Seedling dry weight (mg/seedling) of six rice varieties stored in (a) ambient and (b) controlled conditions at 6-day ageing.

viability level of seed. This device is equipped with a multi-electrode head that measures the electrical conductivity of the seed leachates in a specially designed seed soaking tray. The soaked seeds emit electrolytes, the quantity of which is inversely related to the quality of seed. From initial to last month of storage, electrical conductivity of seed leachates differed significantly within the varieties (Table 3). In initial observation (ie before storage) the highest electrical conductivity was obtained by BRRI dhan34 ($40.73\mu scm^{-1}g^{-1}$) and the lowest of that was with Maloti ($24.93\mu scm^{-1}g^{-1}$). Significant and negative correlation between seed weight and electrical conductivity was reported by Yadav and Dhankhar (2001), which was similar to this finding. Up to four-month storage, no significant difference was observed within two storage conditions. From fifth month, the difference in electrical conductivity within two storage conditions became clear and significant. Seeds that were stored in ambient condition, obtained the highest electrical conductivity than that of controlled temperature storage. Similar trend in

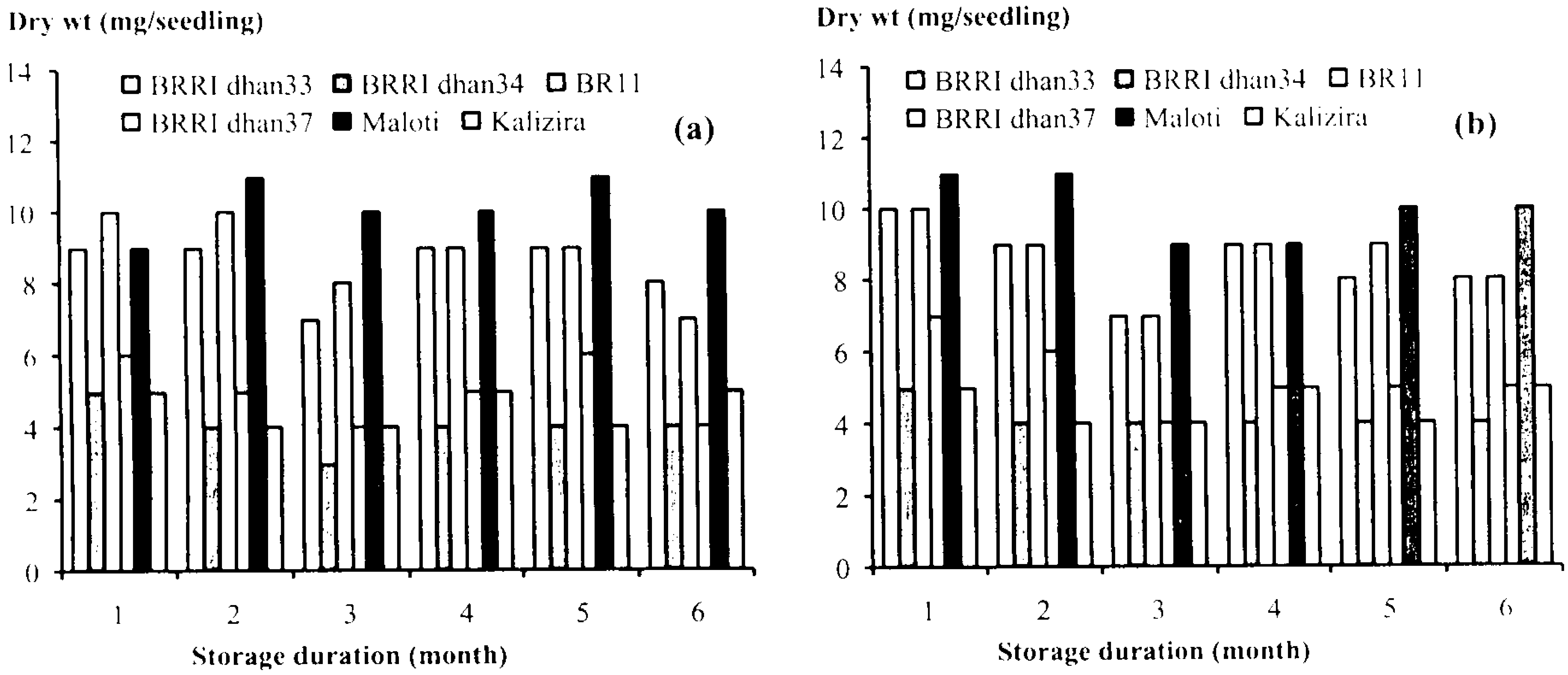

Fig. 9. Seedling dry weight (mg/seedling) of six rice varieties stored in (a) ambient and (b) controlled conditions at 9-day ageing.

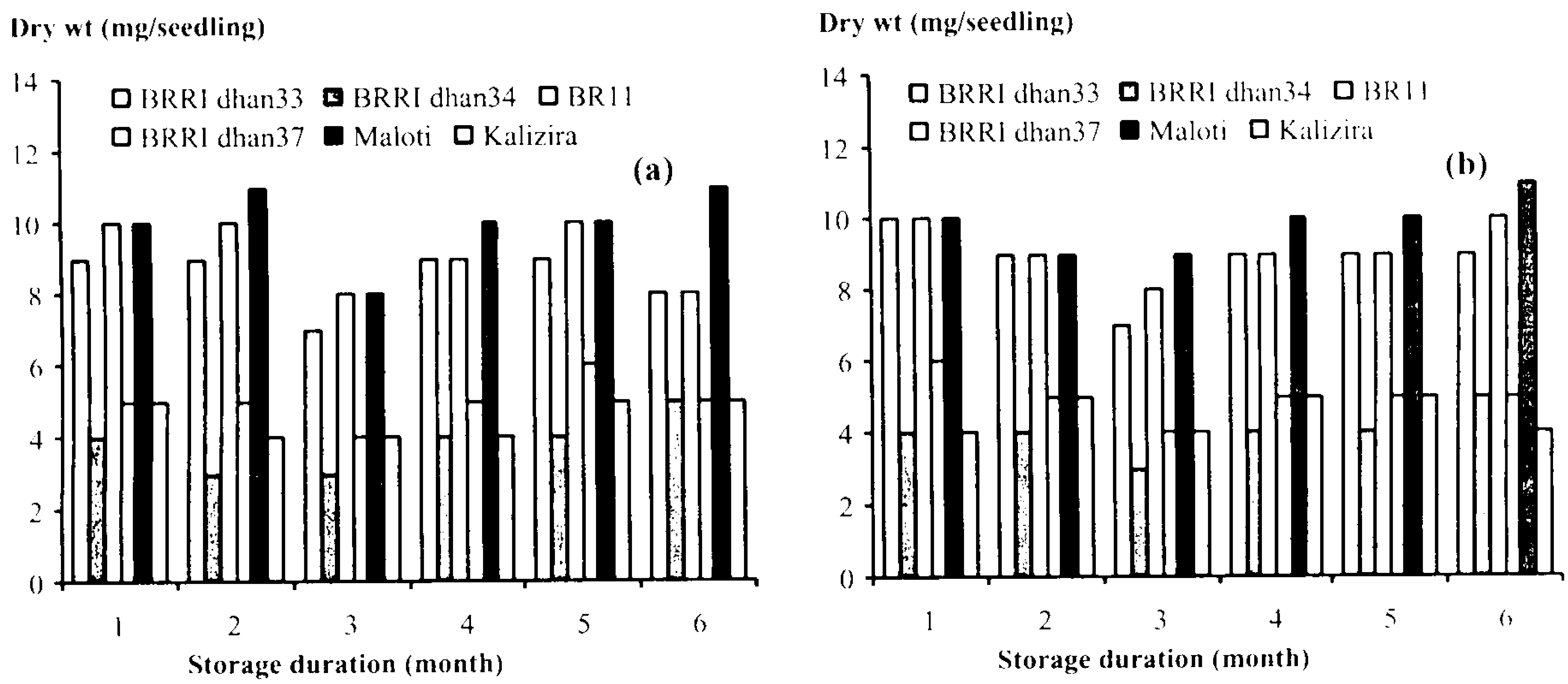

Fig. 10. Seedling dry weight (mg/seedling) of six rice varieties stored in (a) ambient and (b) controlled conditions at 12-day ageing.

electrical conductivity in respect to variety was found up to last month of observation. The electrical conductivity gradually increased as the period of storage increased (Table 3). The increase was greater in case of ambient storage condition than controlled temperature storage. In ambient condition, BRRI dhan37 achieved the highest electrical conductivity (47.67μscm^{-1}g^{-1}) and the lowest of that was with Maloti (32.72μscm^{-1}g^{-1}) whereas, in controlled temperature storage, BRRI dhan34 showed the highest (47.33μscm^{-1}g^{-1}) electrical conductivity and the lowest of that with BR33 (29.02μscm^{-1}g^{-1}), which was closely followed by Maloti (30.16μscm^{-1}g^{-1}) (Table 3).

Some of the physiological and biochemical factors associated with the adverse effects of accelerated ageing on germination and seedling growth were reported by earlier workers. During the ageing process, proteins with higher mobility are denatured (Nautiyal *et al.*, 1985). When seeds age,

Table 3. Varietal difference and storage condition effects on vigour as determined by electrical conductivity ($\mu scm^{-1}g^{-1}$) for six rice varieties (on average of six ageing levels).

Variety	Storage condition	Storage during (month)								
		Initial	1	2	3	4	5	6	7	Mean
BRRI dhan33	S_1	25.30	25.33	27.53	29.35	34.68	39.50	37.55	46.48	33.22
	S_2		26.73	26.78	25.95	29.88	29.35	35.80	32.35	29.02
BRRIdhan34	S_1	40.73	41.30	51.88	41.60	49.73	52.83	58.43	61.93	44.71
	S_2		41.00	52.55	43.18	46.88	51.60	50.90	51.83	47.33
BR11	S_1	30.83	31.15	30.23	29.95	37.58	42.75	41.25	44.65	36.05
	S_2		35.60	35.10	32.73	37.00	37.93	34.50	35.40	34.89
BRRI dhan37	S_1	35.15	34.68	46.33	39.00	45.40	56.03	57.18	67.55	47.67
	S_2		33.90	43.48	37.73	45.43	42.20	49.50	48.08	41.93
Maloti	S_1	24.93	25.10	27.60	29.48	34.93	37.50	38.05	44.13	32.72
	S_2		28.93	28.43	28.88	31.30	32.93	32.53	33.33	30.16
Kalizira	S_1	34.63	36.60	40.90	55.33	51.80	49.10	47.88	55.60	42.15
	S_2		33.90	36.53	41.00	44.10	48.45	47.68	48.40	37.51
$LSD_{(0.05)}$	1.72	3.50	5.15	3.83	3.94	1.48	4.75	2.78		
CV	3.7	7.4	9.6	7.4	6.7	2.4	7.5	4.1		

S_1 = Ambient storage condition. S_2 = Controlled storage condition.

respiration rate, phosphates activity and sugar content declined and severely aged seeds show complete decline of α-amylase activity that may hinder germination (Mitr *et al.,* 1974). Although accelerated ageing caused a general decline in germination and seedling growth, varietal differences were noticed in related traits and the degree of depression.

CONCLUSION

Studies on varietal differences in tolerance to accelerated ageing of seeds with two storage environments indicated that some varieties maintained significantly higher viability through all treatments. These should offer potential germplasm for rice breeding programmes to improve the seed longevity of future varieties.

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Genotyping of Some Local and Exotic Wild Rice Germplasm

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ABSTRACT

The genetic diversity of 19 local and exotic wild rice accessions was investigated using four SSR primers distributed on chromosome numbers 3-12. The primers showed distinct polymorphism among the test materials indicating robust nature of microsatellites in revealing polymorphism. The number of alleles per locus ranged from three (RM231) to seven (RM17), with an average of 4.5 alleles across the 18 loci in the study. The polymorphism information content (PIC) values ranged from 0.54 (RM231) to 0.80 (RM17) in all 18 loci. RM17 was observed as the best marker for the identification of 19 genotypes as revealed by PIC values followed by RM219 with PIC value 0.66. The frequency of the major allele at each locus ranged from 26.3% (RM17) to 52.6% (RM231). The UPGMA clustering system generated two clusters with 20% similarity co-efficient. Acc # 105881 and 103404, 105993 and 105190, 100161,100888, and 100967 showed strong genetic relationship. No difference was recognized between acc # 106218 and 103623. This is possibly due to use of a fewer number of marker in this study. Pair-wise comparisons of genetic distance among wild genotypes for the four primers, ranged from 0.00 (0%) to 0.90 (90%). The principal co-ordinate analysis (PCoA) showed that the genotypes with acc # 105881, 103404, 105890, 100161,101395 and 100888 were distantly placed from the centroid. Exotic wild genotypes showed wider genetic variability than local wild species. To create high genetic variability or transgressive segregrants exotic wild germplasms may be employed in crossing programme. It is evident from the study that microsatellite marker based molecular fingerprinting could serve as a potential tool for diversity study as well as sorting duplicate accessions.

Key words: Genotyping, microsatellite markers, wild rice

INTRODUCTION

Rice, *Oryza sativa* (2n=24) is the staple food for one-third of the world's population and occupies almost one-fifth of the total land area covered under cereals. The world's rice production has doubled during the last 25 years, largely due to the use of improved technology such as high yielding varieties and better crop management practices (Byerlee, 1996). Further scope of crop improvement depends on the conserved use of genetic variability and diversity in plant breeding programmes and the use of new biotechnological tools. Bangladesh is the fourth largest rice producer in the world and situated within the center regions of origin of cultivated rice. Hundreds of local cultivars are still grown here. Some wild rice and related grass species are also prevalent in the country. Although wild species are valued as a unique source of genetic variation, they have been rarely used for the genetic improvement of rice.

Rice is also a model plant for the study of grass genetics and genome organization due to its diploid genetics with relatively small genome size of 430 Mb, significant level of genetic polymorphism (McCouch *et al.*, 1998), large amount of well conserved genetically diverse material (approximately 100,000 accessions of rice germplasm worldwide) and the availability of widely collected compatible wild species.

The wild relatives of cultivated rice constitute a major gene pool for genetic improvement. Recently, interests in wild rice germplasm have intensified as a

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source of new genes such as resistance to biotic and abiotic stresses that can be used for the genetic improvement of rice.

Characterization and quantification of genetic diversity has long been a major goal in evolutionary biology. Information on the genetic diversity within and among closely related crop varieties is essential for a rational use of genetic resources. The analysis of genetic variation both within and among elite breeding materials is of fundamental interest to plant breeders. It contributes to monitoring germplasm and can also be used to predict potential genetic gains. The wild rice species have donated genes of high yield potential in rice, which indicates the usefulness of wild rice germplasm in breaking the present ceiling of yield enhancement in rice breeding. Information regarding genetic variability at molecular level could help to identify and develop genetically unique germplasm.

Molecular marker technologies can assist conventional breeding efforts and are valuable tools for the analysis of genetic relatedness and the identification and selection of desirable genotypes for crosses as well as for germplasm conservation in gene banks. Single sequence repeats markers (microsatellites) are co-dominant, hyper variable, abundant and well distributed throughout the rice genome (Temnykh *et al.*, 2001).

Limited information available on the diversity of some local and exotic wild genotypes of Bangladesh. The morphological data are influenced highly by environments and evaluation of these traits requires growing the plants to full maturity prior to identification. Molecular markers can reveal differences among accessions at the DNA level and provide a more direct, reliable and efficient tool for crop improvement in plant breeding.

The information of genetic diversity of the wild rice genotypes of Bangladesh by molecular markers is very much fragmentary. Microsatellite markers based on the variation in the number of simple sequence DNA repeats (SSRs) have become the markers of choice for a wide spectrum of genetic population and evolutionary studies because they can detect a significantly higher degree of polymorphism in rice and both technically efficient and cost-effective in use.

Our study was involved with the nineteen local and exotic wild rice germplasm. Among them eight were local and eleven were exotic. Thus, four microsatellite markers were used against nineteen local and exotic wild rice germplasm to assess the extent of molecular diversity in the local and exotic wild rice genotype, to establish their genetic relationships and to evaluate their potential utility in the breeding programme.

MATERIALS AND METHODS

Plant materials

The nineteen local and exotic wild rice genotypes (Table 1) were selected from the rice germplasm collection at the International Rice Research Institute (IRRI) genebank. The whole experiment was conducted at the Biotechnology Division of Bangladesh Rice Research Institute (BRRI). The germinated seeds from each genotype were sown in the pot.

Genotyping protocol

DNA was extracted from young leaves of three-week-old plants following a simple and modified protocol to isolate total genomic DNA for PCR analysis, which did not require liquid nitrogen and required only a very small amount of tissue samples as described by Zheng *et al.* (1995).

Each PCR was carried out in a 10 μL reaction volume containing 1 μL of $MgCl_2$ free 10X PCR buffer, 1.2 μL of 25 mM $MgCl_2$, 0.2 μL of 10 mM dNTPs, 0.2 μL of 5 U/μL Taq DNA polymerase, 0.5 μL of 10 μM forward and reverse primers and 10ng of DNA using a 96 well thermal cycler. The mixture was overlaid with one drop of mineral oil to prevent evaporation.

The temperature profile used for PCR amplification comprised 94°C for 5 minutes (initial denaturation) followed by 35 cycles of 94°C for 1 minute (denaturation), 55°C for 1 minute (annealing), 72°C for 2 minutes (extension) with a final extension for 7 minutes at 72°C at the end of 35 cycles. The annealing temperature was adjusted based on the specific requirements of each primer combination. The PCR products were mixed with gel loading dye (bromophenol blue, xylene cyanol and sucrose) and

Table 1. List of nineteen local and exotic wild rice genotypes.

Sl No.	Genotypes	IRGC Acc #	Source Country	Sl No.	Genotypes	IRGC Acc #	Source Country
1	*Oryza alata*	100161	Brazil	11	*Oryza rufipogon*	105890	Bangladesh
2	*Oryza alata*	101395	-	12	*Oryza rufipogon*	105891	Bangladesh
3	*Oryza latofolia*	100888	-	13	*Oryza rufipogon*	105901	Bangladesh
4	*Oryza latifolia*	100967	Suriname	14	*Oryza rufipogon*	105902	Bangladesh
5	*Oryza nivera*	105837	Thailand	15	*Oryza rufipogon*	106029	Bangladesh
6	*Oryza punctata*	104975	Kenya	16	*Oryza glaberrima*	103229	Senegal
7	*Oryza rufipogon*	103404	Bangladesh	17	*Oryza glaberrima*	103623	Mali
8	*Oryza rufipogon*	105881	Bangladesh	18	*Oryza glaberrima*	105190	Togo
9	*Oryza rufipogon*	105887	Bangladesh	19	*Oryza barthii*	105993	Mali
10	*Oryza barthii*	106218	Mali				

electrophoresed in 8% polyacrylamide gel using mini vertical polyacrylamide gels for high throughput manual genotyping. Four μL of amplification products were resolved by running gel in 1X TBE buffer for 1.5hrs to 2.5hrs depending upon the allele size at around 70 volts. The gels were stained in 1 μg/ml ethidium bromide and were documented using UVPRO (Uvipro Platinum, EU) gel documentation unit. Microsatellite or simple sequence repeat (SSR) markers were used for selection (Temnykh *et al.*, 2001; McCouch *et al.*, 2002). Four SSR markers with clear amplifications were selected for genetic diversity analysis of nineteen genotypes (Table 2).

Data analysis

Each amplified allele was measured in base pair using Alpha-EaseFC 5.0 software. The summary statistics including the number of alleles per locus, major allele frequency, gene diversity, polymorphism information content (PIC) values were determined using PowerMarker version 3.25 (Liu and Muse 2005). The allele frequency data from PowerMarker was used to export the data in binary format (allele presence = 1 and allele absence = 0) for analysis with NTSYS-pc version 2.1 (Rohlf, 2002). The pair-wise genetic dissimilarity coefficients were calculated using "C S Chord 1967" distance as implemented in Power Marker 3.25. A similarity matrix was calculated with the Simqual subprogram using the Dice coefficient, followed by cluster analysis with the SAHN subprogram using the UPGMA clustering method as implemented in NTSYS-pc. The similarity matrix was also used for principal coordinate analysis (PCoA) with the DCenter, Eigen, Output and MXPlot subprograms in NTSYS-pc.

RESULTS AND DISCUSSION

SSR diversity

Eighteen alleles were detected at the loci with four microsatellite markers across 19 wild rice genotypes. Similar number of microsatellite markers was previously used as subset for genetic diversity analysis of *Oryza sativa* (Chakrabarthia and Naravaneni, 2006, Thomson *et al.*, 2007, Hossain *et al.*, 2007). The number of alleles per locus ranged from three (RM231) to seven (RM17), with an average of 4.5 alleles across the eighteen loci (Table 2). This value is comparable to 2-7 alleles per locus as reported by Chakrabarthi and Naravaneni (2006) and also

Table 2. Particulars of test alleles used for the genotyping of 19 wild rice species.

Marker	Chr. no.	Allele no.	Size range (bp)	Maj. all.	Maj. all. fr. (%)	Diversity index PIC = $1-\Sigma X_{ij}^2$
RM231	3	3	178-198	174	52.6	0.54
RM219	9	4	161-200	210	36.8	0.66
RM206	11	4	125-168	133,145	36.8	0.63
RM17	12	7	170-193	165	26.3	0.80
Mean		4.5			38.16	0.66

comparable to three alleles to nine alleles, with an average of 4.53 alleles per locus for 30 microsatellite markers as per Hossain *et al.* (2007).

The frequency of the major allele at each locus ranged from 26.3% (RM17) to 52.6% (RM231) (Table 2), which is comparable to Thomson *et al.* (2007). On average, 38.16% of the 19 rice genotypes shared a common major allele at any given locus (Table 2). polymorphism information content (PIC) values ranged from 0.54 to 0.80 with an average of 0.66. The PIC values observed, are comparable to two previous estimates of microsatellite analysis in rice viz 0.67-0.88 (Gohain *et al.*, 2006), 0.34-0.88 (Thomson *et al.*, 2007), and 0.30-0.84 with an average of 0.58 (Hossain *et al.*, 2007). The highest PIC value was obtained for RM17 (0.80) followed by RM219 (0.66), RM206 (0.63) and RM 231 (0.54), respectively (Table 2). PIC value revealed that RM17 was considered as the best marker for 19 genotypes and this was reported to be linked to the gene for fragrance (*fgr*) (Gohain *et al.*, 2006). Figure 1 Shows a gel picture of the microsatellite marker RM17 and Figure 2 for RM231 for all genotypes.

Genetic distance based analysis

The values of pair-wise comparisons of genetic distance between varieties were computed from combined data for the four primers, ranged from 0.00 to 0.90 (Table 3). Pair-wise genetic dissimilarity coefficients indicated that the higher genetic distance was found to be 0.90 and observed in 59 pairs (Table 3). As the pairs were genetically apart, can be source of new genes used in breeding programme for improving the desired traits such as resistance to abiotic and biotic stresses. The lowest genetic distance (0.00) was observed between acc # 106218 and 103623. Considering this, we conclude that acc # 106218 and 103623 were originated from same parents or closely related parents or they could be the same genotype. Cluster analysis was used to group the varieties and to construct a dendogram. The UPGMA based dendogram obtained from the binary data deduced from the DNA profiles of the samples analysed adds a new dimension to the genetic similarity perspectives. This dendrogram revealed that the genotypes that are derivatives of genetically similar type clustered more together.

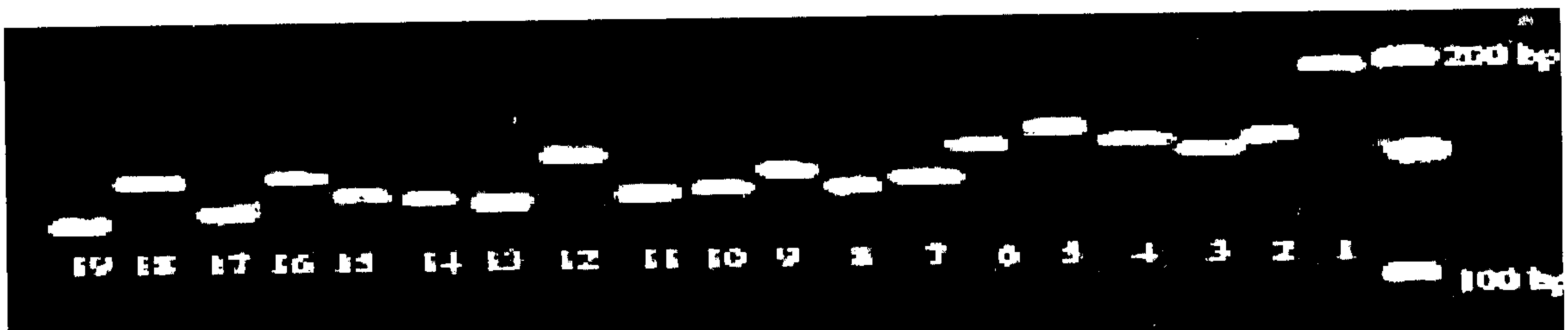

Fig. 1. Microsatellite profiles of 19 rice germplasms at loci RM17.

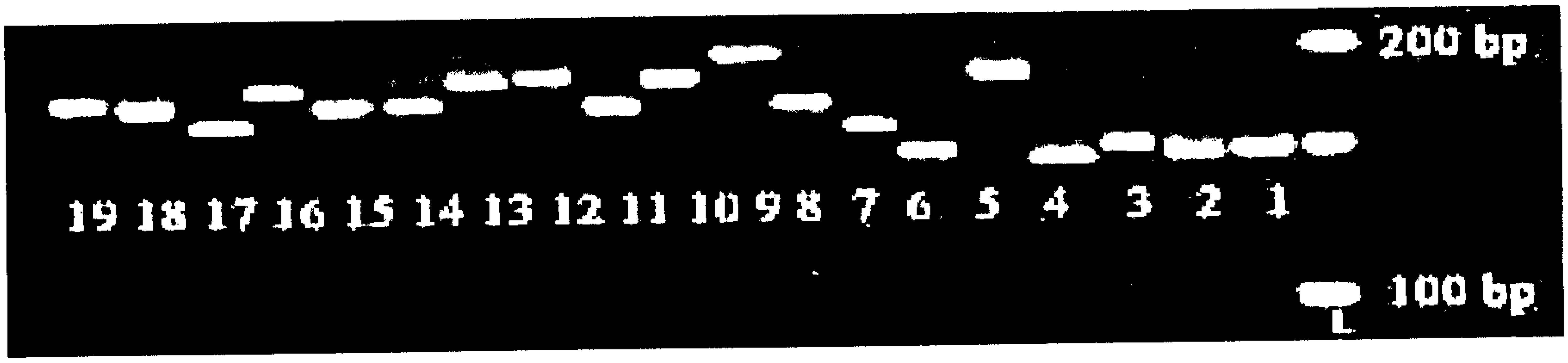

Fig. 2. Microsatellite profiles of 19 rice germplasms at loci RM231.

Legend: L = kb' ladder ; Lane -1 = *Oryza alata* (Acc #100161); L-2 = *O. alata* (Acc #101395); L-3 = *O. latifolia* (Acc #100888); L-4 = *O. latifolia* (Acc #100967); L-5 = *O. nivera* (Acc.no.105837); L-6 = *O. puntata* (Acc #104975); L-7 = *O. rufipogon* (Acc #103404); L-8 = *O. rufipogon* (Acc #105881); L-9 = *O. rufipogon* (Acc #105887); L-10 = *O. rufipogon* (Acc #105890); L-11 = *O. rufipogon* (Acc #105891); L-12 = *O. rufipogon* (Acc #105901); L-13 = *O. rufipogon* (Acc #105902); L-14 = *O. rufipogon* (Acc #106029); L-15 = *O. glaberrima* (Acc #103229); L-16 = *O. glaberrima* (Acc #103623); L-17 = *O. glaberrima* (Acc #105190); L-18 = *O. barthii* (Acc #105993); L-19 = *O. barthii* (Acc #106218).

Table 3. Genetic dissimilarity index among the wild rice genotypes.

OTU	ACC100161	ACC100888	ACC100967	ACC101395	ACC103229	ACC103404	ACC103623	ACC104975	ACC105190	ACC105837	ACC105881	ACC105887	ACC105890	ACC105891	ACC105901	ACC105902	ACC105993	ACC106029	ACC106218
ACC100161	0.00																		
ACC100888	0.25	0.00																	
ACC100967	0.22	0.22	0.00																
ACC101395	0.45	0.45	0.45	0.00															
ACC103229	0.90	0.90	0.90	0.90	0.00														
ACC103404	0.90	0.90	0.90	0.90	0.45	0.00													
ACC103623	0.90	0.90	0.90	0.90	0.22	0.67	0.00												
ACC104975	0.45	0.45	0.45	0.67	0.67	0.67	0.67	0.00											
ACC105190	0.90	0.90	0.90	0.90	0.45	0.45	0.22	0.67	0.00										
ACC105837	0. 67	0. 67	0.67	0.45	0.90	0.90	0.90	0.45	0.90	0.00									
ACC105881	0.90	0.67	0.90	0.90	0.45	0.22	0.67	0.67	0.45	0 90	0.00								
ACC105887	0.90	0.90	0.90	0.90	0.45	0.67	0.67	0.67	0.90	0 45	0.67	0.00							
ACC105890	0.90	0.90	0.67	0.90	0.67	0.90	0.45	0 90	0.67	0.67	0.90	0.45	0.00						
ACC105891	0.90	0.90	0.65	0.90	0.45	0.67	0.45	0.67	0.67	0.90	0.67	0.67	0.45	0.00					
ACC105901	0. 67	0.67	0.67	0.90	0.90	0.67	0.67	0.67	0.67	0.67	0.90	0.67	0.45	0.90	0 00				
ACC105902	0.67	0.67	0.67	0.67	0 90	0.90	0.90	0.67	0.90	0.67	0.90	0.67	0.67	0.67	0.45	0.00			
ACC105993	0.67	0.67	0.67	0.90	0.45	0.67	0.22	0.45	0.22	0.90	0.67	0.90	0.67	0.67	0.45	0.67	0.00		
ACC 106029	0.90	0.90	0.90	0.67	0.45	0.67	0.22	067	0.45	0.90	0.67	0.67	0.45	0.45	0.67	0.67	0.45	0.00	
ACC 106218	0.90	0.90	0.90	0.90	0.22	0.67	0.00	0.67	0.22	0.90	0.67	0.67	0.45	0.45	0.67	0.90	0.22	0.22	0.00

The genetic similarity analysis using UPGMA clustering system also generated two genetic clusters with similarity co-efficient of 20% (Fig. 3). The wild genotype acc # 100161, 100888 and 100967 showed close relationship among them. The local species acc # 103404 and 105881 possesses similar genetic background. Close similarity was observed between exotic genotype acc # 105190 and 105993. No dissimilarity was observed in two genotypes *Oryza glaberrima* (Acc # 103623) and *Oryza barthii* (Acc #106218) and they were cluster with *Oryza glaberrima* (Acc # 103229). The results indicate that the genotypes viz acc # 103623 and acc # 106218 might be the same genotype, which could be verified by other markers.

The two dimensional graphical view of principal co-ordinate analysis (PCoA) showed the spatial distribution of the genotypes along the two principal axes (Fig. 4). Acc # 100888, 100161, 101395, 105890,103404 and 105881 were found distantly placed from the centroid of the cluster and rest of the genotypes were placed more or less around the centroid . Here, the local wild germplasm acc # 105890 and 105902 were placed distantly from the centroid

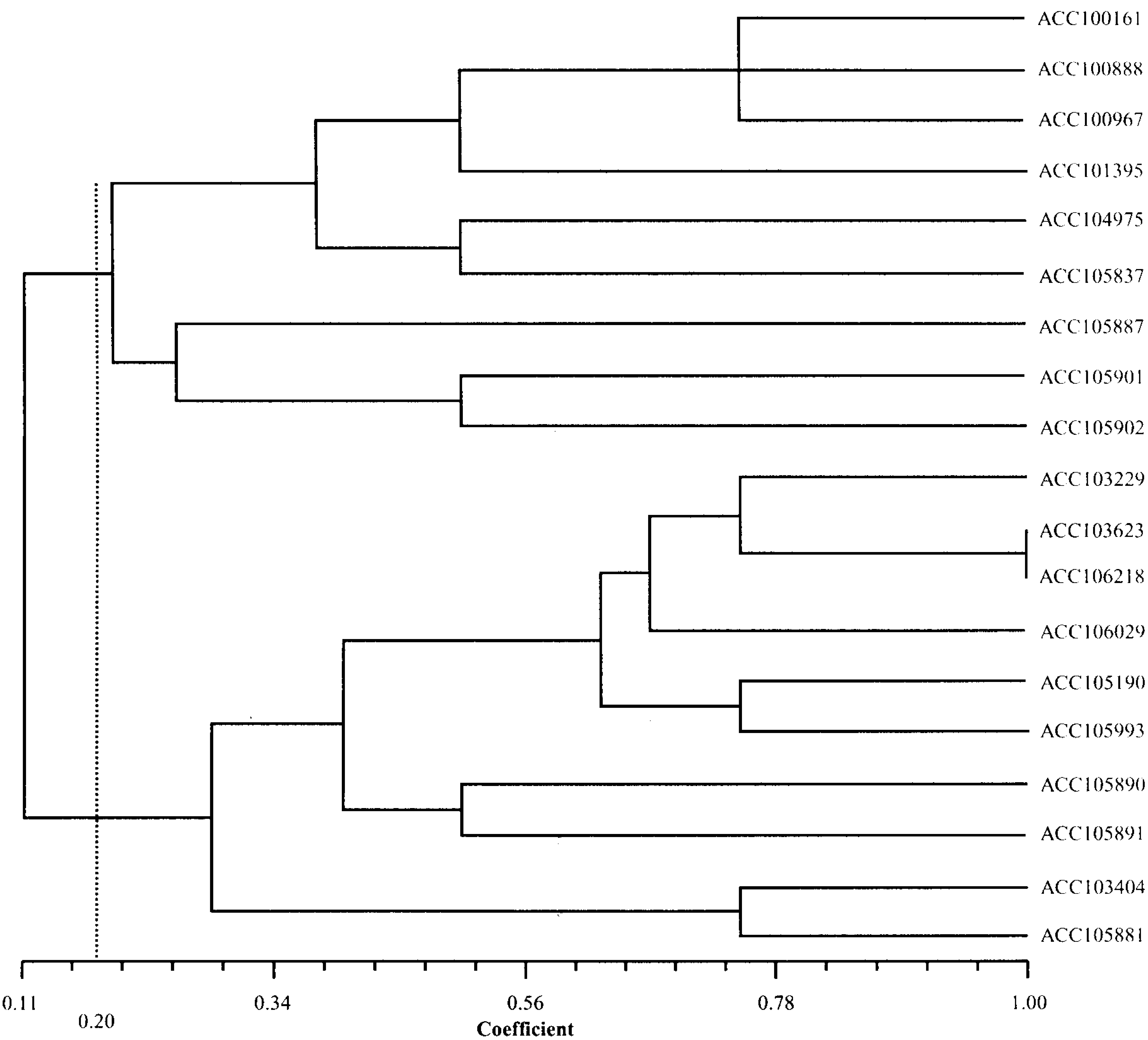

Fig. 3. A UPGMA dendogram showing the genetic relationships among test wild rice genotypes.

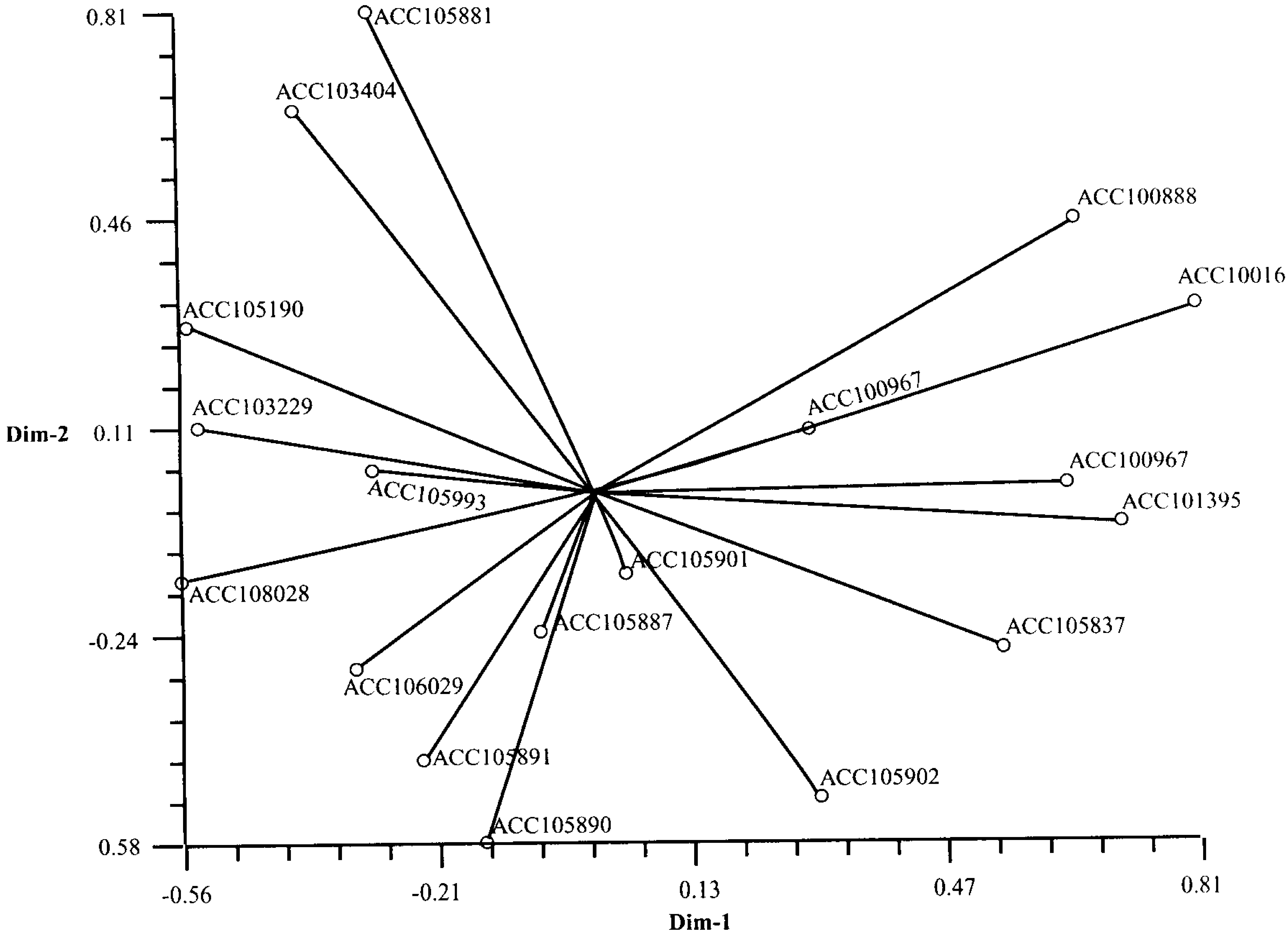

Fig. 4. Two dimensional view of principal co-ordinate analysis (PCoA) among the wild rice genotypes.

of the cluster and they were also different from other exotic wild germplasm. In crop improvement programme these genotypes could be chosen as parents in the crossing programme to create genetic variability. The wild species acc # 100967 and 100161 presented the same line showing similar genetic background.

The results indicate that the genotypes placed far away from the centroid were more genetically diverse while the genotypes placed near around the centroid possessed more or less similar genetic background. The connecting line between the each genotype and the centroid represented eigen vectors for the respective genotypes. However, centroid may be defined as the vector representing the middle point of the cluster, which contained at least one number for each variable. However, the distant genotypes should be selected in breeding to broaden the genetic base and for wider adaptability.

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