



## Varietal mixture effect on the disease incidence and severity of bacterial blight in rice

Suvonkar Sarker<sup>1</sup>, Md. Atikur Rahman<sup>1</sup>, Md. Parvez Anwar<sup>2</sup>, Muhammed Ali Hossain<sup>1</sup>✉

<sup>1</sup>Plant Microbe Interaction Laboratory, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

<sup>2</sup>Agro Innovation Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

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#### Correspondence:

Muhammed Ali Hossain

✉: [alihossain.ppath@bau.edu.bd](mailto:alihossain.ppath@bau.edu.bd)



### ABSTRACT

Bacterial blight (BB) caused by *Xanthomonas oryzae* pv. *oryzae* is an important disease of rice in Bangladesh. The experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh during the period from July to December 2017. Two T. Aman (monsoon) rice varieties viz. Binadhan-13 and BRRI dhan49 were used in this study. The main objective of the study was to evaluate the disease incidence and severity of BB during the growing period considering spatial arrangement of alternate rows and hills with nine different ratios (1:0, 1:2, 2:1, 2:3, 3:2, 2:4, 4:2, 1:1, 0:1). The effect of varietal mixtures on combined grain yield was also observed in this experiment. Rice cultivation with the varietal mixture ratios of 2:1 (2 rows Binadhan-13 : 1 row BRRI dhan49) and 1:1 (1 row Binadhan-13 : 1 row BRRI dhan49) considering the spatial arrangement of alternate rows showed minimum disease incidence at 60 and 90 days after transplanting (DAT) respectively, whereas 2:1 mixture ratio was also reduced disease severity at 60 and 90 DAT compared to all other varietal mixtures ratios including sole cultivation of both the varieties. Disease incidence and severity of BB was also reduced by the spatial arrangement of alternate hills and the best mixture ratio was 2:1 (2 rows Binadhan-13: 1 row BRRI dhan49) for low disease incidence and severity at 60 and 90 DAT, whereas 1:1 ratio (1 row Binadhan-13 : 1 row BRRI dhan49) of hill orientation reduced disease incidence and severity at 60 and 90 DAT compared to some other treatments including sole cultivation. All the mixed culture, irrespective of mixture ratio and spatial arrangement, resulted in higher grain yield than sole culture yield. In case of alternate hill, the highest grain yield of 5.32 t/ha was recorded when Binadhan-13 and BRRI dhan49 were planted in 1:1 ratio, which was respectively 1.79 t/ha (50.56%) and 0.56 t/ha (11.74%) higher than sole culture yield of Binadhan-13 and BRRI dhan49. In case of alternate row arrangement, cultivation of Binadhan-13 and BRRI dhan49 in 1:1 ratio resulted in the maximum grain yield of 5.22 t/ha which was respectively 1.69 t/ha (47.7%) and 0.46 t/ha (9.6%) higher than Binadhan-13 and BRRI dhan49 sole culture yields. Thus cultivar mixture confirms reduced incidence and severity of BB and rice yield advantage over sole culture.

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### Introduction

Rice (*Oryza sativa* L.), a cereal crop of the grass family Gramineae is principally grown in tropical and sub-tropical zones and is the staple food for about 9.3 billion by the year 2050 around the world (Salim *et al.*, 2003; Sheehy and Mitchell, 2013). It is a cereal crop of the grass family Gramineae. In Bangladesh, rice is grown in three distinct seasons, namely Aus/summer (April to August), Aman/monsoon (August to December) and Boro/winter (January to June) covering almost 11.8 million hectares of land (DAE, 2017). About 95 % of the total food requirements are fulfilled by producing rice in three different seasons, but there is still need to be increased production to feed the growing population which increases at the rate of 1.32 % per annum (BER, 2010). The average world yield of rice is 3.84 tons/ha

(Ahmed *et al.*, 2013). There are so many constraints to increase the production of rice in Bangladesh of which disease and pest play a major role (Fakir, 1982). A total of 68 microorganisms of which 36 fungal, 6 bacterial, 21 viral and 5 nematode diseases are recorded in rice (Ou, 1985) where about 32 diseases are found to be occurred in Bangladesh (BRRI, 2018). Asia's hot and humid climate during the long and heavy monsoon season provides the most favorable agro-ecological environment for rice cultivation as well as disease development. So far in Bangladesh, about 32 diseases are recorded to occur in rice including 10 major diseases (BRRI, 2018). Among these diseases in Bangladesh, bacterial blight (BB) is the major one that was regarded as the oldest rice disease of Asia (Jeung *et al.*, 2006) and exerts severe losses in different rice-growing regions of

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the globe (Xu *et al.*, 2010). This disease is a seed borne in nature (Srivastava and Rao, 1963) and was first recognized in Japan in 1884 (Tagami and Mizukami, 1962). Bacterial blight (BB) caused by *Xanthomonas oryzae* pv. *oryzae*, occurs at all the growth stages of rice and is manifested by leaf blight symptoms. *Xanthomonas oryzae* pv. *oryzae* consists of straight rods, with a single polar flagellum and exists in singular form, in pairs and sometime in chains (Swings *et al.*, 1990). The causal organism invades plants through water pores and wounds (Tabei and Mukoo, 1960). Since the water pores are located at the margins of upper parts of the leaf, the lesion usually starts from the leaf margin near its tip. The incidence of BB was found to be aggravated by high dosages of nitrogen. Yield reduction upto 50% were recorded in case of severe infection by the disease (Mew *et al.*, 1993) whereas 10-12% yield reduction has been found in case of mild infection (Ou, 1985). In Bangladesh, 10-30% yield loss has been estimated in rice due to bacterial blight (Ashrafuzzaman, 1992).

Control of crop disease is one of the key activities of agricultural to maintain high crop yields (Dordas, 2008). Till to date, there are several methods have been practiced for controlling crop diseases, namely application of chemical, use of biological control agents, physical and cultural approaches (Palti, 1981). Varietal mixture, a ecological approaches is one of the effective and eco-friendly ways to control crop diseases in modern agricultural systems (Risch *et al.*, 1983; Tilman *et al.*, 2001), in which crop heterogeneity is created to provide considerable disease suppression (Zhu *et al.*, 2000; Leung *et al.*, 2003). Mixed-cultivation of traditional and modern rice varieties has been found to be the effective control measure for blast disease (Zhu *et al.*, 2000). The lower level of exposure to the pathogen population of the resistance gene in a mixture compared with monoculture will reduce selection pressure on the pathogen population and therefore increase the gene's durability and mixtures support more diverse pathogen populations than do pure stands, and that diversity is positively related to the degree of disease control provided by the mixture (Mundt, 2002).

Varietal mixtures can provide functional diversity that limits pathogen and pest expansion, and that makes use of knowledge about interactions between hosts and their pests and pathogens to direct pathogen evolution. Indeed, one of the most powerful ways both to reduce the risk of resistance break-down and to still make use of defeated resistance genes is to use cereal variety and species mixtures. Wolfe (1985) defined cultivar mixtures as "mixtures of cultivars that vary for many characters including disease resistance but have sufficient similarity to be grown together." Cultivar mixtures do not cause major changes to the agricultural system, generally increase yield stability, and in some cases can

reduce pesticide use. They are also quicker and cheaper to formulate and modify than "multilines," which are defined as mixtures of genetically uniform lines of a crop species (near-isogenic lines) that differ only in a specific disease or pest resistance (Browning and Frey, 1981). Cultivars used in the mixture must possess good agronomic characteristics and may be phenotypically similar for important traits including maturity, height, quality and grain type, depending on the agronomic practices and intended use (Castro, A., 2007). Varietal mixtures provide an ecological approach for effective disease control, maintaining high yields with the minimum fungicide applications. Whether such an approach is universally applicable for random rice variety combinations and what is the variation pattern of the diseases under intercropping still remains unclear (Han Guang-yu *et al.*, 2016). Creating a crop-heterogeneous system by intraspecific mixtures of different rice varieties can substantially reduce blast diseases (Zhu *et al.*, 2000). The monoculture included either traditional or modern rice varieties grown in separate plots. The intercropping included both traditional and modern rice varieties planted together in the same plots. Results from the field experiments under natural disease conditions demonstrated a significant reduction for blast disease in intercropping plots, compared with that in monoculture plots (Han Guang-yu *et al.*, 2016). In view of the above facts, the present research work was undertaken to evaluate the effect of different arrangements of varietal mixture ratios on the disease incidence and severity of BB and grain yield of rice.

## Materials and Methods

### *Experimental site and period*

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh from July to December 2017 during the Aman season. Two popular rice varieties viz. Binadhan-13 and BRRI dhan 49 were used for this study. However, Binadhan-13 was developed from local fine grain aromatic rice cultivar kalizira with the application of gamma radiation and *Datura* (*Datura metel*) extract. This variety is moderately tolerant to BB disease. BRRI dhan49 is a medium drought tolerant variety and susceptible to bacterial blight disease (BB).

### *Experimental treatments*

Two individual experiments were carried out to know the effect of varietal mixtures on the disease incidence and severity of BB of rice. In this experiment, 9 ratios considering the spatial arrangement of alternate rows and alternate hills were used in the experimental plots.

The following experimental treatments were used in case of the spatial arrangement as follows:

Alternate Rows	Ratio	Alternate Hills
Only Binadhan-13 as a sole crop	1:0=T <sub>1</sub>	Only Binadhan-13 as a sole crop
One row Binadhan-13: two rows BRR1 Dhan49	1:2=T <sub>2</sub>	One hill Binadhan-13: two hills BRR1 dhan49
Two rows Binadhan-13: one row BRR1 Dhan49	2:1=T <sub>3</sub>	Two hills Binadhan-13: one hill BRR1 dhan49
Two rows Binadhan-13: three rows BRR1 Dhan49	2:3=T <sub>4</sub>	Two hills Binadhan-13: three hills BRR1 dhan49
Three rows Binadhan-13: two rows BRR1 Dhan49	3:2=T <sub>5</sub>	Three hills Binadhan-13: two hills BRR1 dhan49
Two rows Binadhan-13: four rows BRR1 Dhan49	2:4=T <sub>6</sub>	Two hills Binadhan-13: four hills BRR1 dhan49
Four rows Binadhan-13: two rows BRR1 Dhan49	4:2=T <sub>7</sub>	Four hills Binadhan-13: two hills BRR1 dhan49
One row Binadhan-13: one row BRR1 Dhan49	1:1=T <sub>8</sub>	One hill Binadhan-13 : one hill BRR1 dhan49
only BRR1 dhan49 as a sole crop	0:1=T <sub>9</sub>	only BRR1 dhan49 as a sole crop

#### Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. For each of the experiment, 27 plots were used for experiment with alternate rows and 27 plots were used for experiment with alternate hills. Each of the plot size was 4 m × 2.5 m for both the row and hill arrangements.

#### Preparation of nursery bed and seed sowing

A piece of high land was selected in the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh for raising seedlings. The land was puddled well with country plough followed by cleaning and leveling with ladder. Sprouted seeds of both the cultivars were sown in the wet nursery bed on 11 July 2017.

#### Seedling transplanting

Seedlings were uprooted carefully with soil at the base of the seedling from the nursery beds to avoid root injury and kept under shade to avoid root injury until they were transplanted after wetting of soil by applying water. Thirty days old seedlings were transplanted in the well prepared puddled field with maintaining proper ratio.

#### Assessment of the disease incidence and disease severity in the field conditions

Each of the plots was investigated for recording the incidence and severity of BB diseases. Data were recorded visually by observing the typical symptoms. Affected plants from each unit plot were selected for assessing the disease incidence and severity. Data were recorded in two time points at an interval of 30 days such as 60 DAT and 90 DAT. Ten hills were randomly selected from each plot to evaluate the disease incidence and severity under different treatments.

#### Disease incidence

Data were recorded number of infected hill/total no. of hill in each plot for disease incidence estimation. Percent disease incidence was estimated by using the following formula (Rajput and Bartaria, 1995)-

$$\% \text{ disease incidence} = \frac{\text{No. of infected hill}}{\text{Total no. of hill assessed}} \times 100$$

#### Disease severity

Disease severity is the percentage of relevant host tissues or organ covered by symptoms or lesion or damaged by the disease. Severity results from the number size of the lesions. Percent disease severity was estimated by using the following formula-

$$\% \text{ disease severity} = \frac{\text{Sum of all diseaserating}}{\text{Total number of rating} \times \text{maximum disease grade}} \times 100$$

IRRI recommended grading scale for BB of rice (0-9 scale of Standard Evaluation System (SES) for Rice, 1980), was used to calculate the percent disease severity, where, 0 = no lesion, 1 = 1-5% lesion area, 3 = 6-12% lesion area, 5 = 13-25% lesion area, 7 = 26-50% lesion area, 9 = 51-100% lesion area.

#### Harvesting and combined yield determination

The crops were harvested at full maturity stage. Maturity of crops was determined when 90% of the grains became matured. The harvested crops were threshed, cleaned and sun dried. Combined rice yield was calculated by adding the yields of both (where applicable) rice cultivars and finally converted to t ha<sup>-1</sup> at the moisture content of 14%.

#### Data analysis

The experiment was conducted in RCBD with three replications. The recorded data on different parameters were statistically analyzed using Analysis of Variance (ANOVA) technique to find out the level of significance (Gomez and Gomez, 1984). The treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance. The collected data were analyzed using SAS (University Edition version 3.71 basic edition) statistical package.

## Results

#### Effect of spatial arrangement and varietal mixture ratios of rice on disease incidence and severity of BB

In this experiment, two rice varieties were used in nine different ratios in two spatial arrangements namely alternate rows and alternate hills to know the effect of varietal mixture on the disease incidence and severity of BB of rice. The combined grain yield also considered for both the rice varieties in this experiment.

*Effect of varietal mixtures of rice in alternate rows on disease incidence of BB*

In case of varietal mixtures of rice in alternate rows, the minimum percentage of disease incidence was recorded in the treatment T<sub>3</sub> (2 rows Binadhan-13: 1 row BRRI dhan49) and the disease incidence was 44.50% for Binadhan-13 and 48.29% for BRRI dhan49 followed by treatment T<sub>2</sub> (1 rows Binadhan-13: 2 rows BRRI

dhan49) at 60 DAT (Table 1). On the other hand, lowest disease incidence was recorded at 90 DAT for the treatment T<sub>8</sub> (1 row Binadhan-13: 1 row BRRI dhan49) for both the BINA and BRRI rice varieties (64.31% and 68.00%, respectively) followed by the treatment T<sub>2</sub> (1 row Binadhan-13: 2 rows BRRI dhan49) shown in (Table 1).

Table 1. Effect of varietal mixtures of rice in alternate rows on disease incidence of BB

Treatments	% Disease incidence (60 DAT)		% Disease incidence (90 DAT)	
	Binadhan-13	BRRIdhan49	Binadhan-13	BRRIdhan49
T <sub>1</sub>	68.07a	0.00g	83.92a	0.00f
T <sub>2</sub>	45.51d	51.49f	70.94c	72.76d
T <sub>3</sub>	44.50d	48.29f	69.05c	79.91bc
T <sub>4</sub>	56.09c	62.39cd	69.87c	79.28bc
T <sub>5</sub>	58.54bc	57.37de	76.60b	79.06c
T <sub>6</sub>	43.58d	69.44b	68.27d	83.54ab
T <sub>7</sub>	61.72b	51.89ef	76.15b	78.46c
T <sub>8</sub>	59.23bc	63.84bc	64.31d	68.00e
T <sub>9</sub>	0.00e	75.81a	0.00e	85.77a
*LSD (0.05)	4.879	5.617	3.681	5.164

\*LSD (0.05):Least Significant Difference at 5% level of significance. In a column, means followed by same letter(s)are statistically similar at 5% level by DMRT. T<sub>1</sub>= 1:0 (Only Binadhan-13 as sole crop: no BRRI dhan49), T<sub>2</sub>= 1:2 (One hill Binadhan-13: two hills BRRI dhan49), T<sub>3</sub>= 2:1 (Two hills Binadhan-13: one hill BRRI dhan49), T<sub>4</sub>= 2:3 (Two hills Binadhan-13: three hills BRRI dhan49), T<sub>5</sub>= 3:2 (Three hills Binadhan-13: two hills BRRI dhan49), T<sub>6</sub>= 2:4 (Two hills Binadhan-13: four hills BRRI dhan49), T<sub>7</sub>= 4:2 (Four hills Binadhan-13: two hills BRRI dhan49), T<sub>8</sub>= 1:1 (One hill Binadhan-13: one hill BRRI dhan49), T<sub>9</sub>= 0:1 (No Binadhan-13: only BRRI dhan49 as sole crop).

*Effect of varietal mixtures of rice in alternate hills on disease incidence of BB*

In case of varietal mixtures of rice in alternate hills, the result showed that the minimum percentage of disease incidence was recorded in the treatment T<sub>3</sub> (2 hills Binadhan-13 : 1 hill BRRI dhan49) and the disease incidence was 48.33% for Binadhan-13 and 53.22% for BRRI dhan49 followed by treatment T<sub>2</sub> (1 hill

Binadhan-13 : 2 hills BRRI dhan49) at 60 DAT (Table 2). On the other hand, lowest disease incidence was also recorded at 90 DAT for the treatment T<sub>3</sub> (2 hills Binadhan-13 : 1 hill BRRI dhan49) for both the BINA and BRRI rice varieties (69.07% and 74.83%, respectively) followed by treatment T<sub>2</sub> (1 hill Binadhan-13 : 2 hills BRRI dhan49) shown in Table 2.

Table 2. Effect of varietal mixtures of rice in alternate hills on disease incidence of BB

Treatments	60 DAT		90 DAT	
	Binadhan-13	BRRIdhan49	Binadhan-13	BRRIdhan49
T <sub>1</sub>	69.63a	0.00f	83.92a	0.00g
T <sub>2</sub>	54.44cde	55.88de	74.81bc	73.14de
T <sub>3</sub>	48.33e	53.22de	69.07de	74.83de
T <sub>4</sub>	53.03de	72.00ab	72.12cd	81.33bc
T <sub>5</sub>	66.46ab	58.00d	72.33cd	81.78bc
T <sub>6</sub>	46.67e	63.96bcd	68.00e	77.50cd
T <sub>7</sub>	64.35abc	57.17e	78.37ab	73.08f
T <sub>8</sub>	63.15abc	67.11abc	78.86ab	83.70ab
T <sub>9</sub>	0.00f	73.66a	0.00f	88.26a
*LSD(0.05)	9.963	9.509	4.117	4.679

\*LSD (0.05):Least Significant Difference at 5% level of significance. In a column, means followed by same letter(s)are statistically similar at 5% level by DMRT. T<sub>1</sub>= 1:0 (Only Binadhan-13 as sole crop: no BRRI dhan49), T<sub>2</sub>= 1:2 (One hill Binadhan-13: two hills BRRI dhan49), T<sub>3</sub>= 2:1 (Two hills Binadhan-13: one hill BRRI dhan49), T<sub>4</sub>= 2:3 (Two hills Binadhan-13: three hills BRRI dhan49), T<sub>5</sub>= 3:2 (Three hills Binadhan-13: two hills BRRI dhan49), T<sub>6</sub>= 2:4 (Two hills Binadhan-13: four hills BRRI dhan49), T<sub>7</sub>= 4:2 (Four hills Binadhan-13: two hills BRRI dhan49), T<sub>8</sub>= 1:1 (One hill Binadhan-13: one hill BRRI dhan49), T<sub>9</sub>= 0:1 (No Binadhan-13: only BRRI dhan49 as sole crop).

The above results are indicating that the varietal mixtures have reduced the BB incidence of Binadhan-13 and BRRI dhan49 compared to sole cultivation of those cultivars. The varietal mixture ratios 2:1 (T<sub>3</sub>),T<sub>2</sub> (1:2) and 1:1 (T<sub>8</sub>) showed better performance at 60 and 90 DAT respectively compared to other treatments including sole rice cultivation.

*Effect of varietal mixtures of rice in alternate rows on disease severity of BB*

The effect of varietal mixtures of rice in alternate rows on disease severity was also observed in this experiment. However, the minimum percentage of disease severity was recorded in the treatment T<sub>3</sub> (2 rows Binadhan-13: 1 row BRRI dhan49) and the disease severity was 25.92% for Binadhan-13 and 28.89% for BRRI dhan49 followed by treatment T<sub>2</sub> (1 row Binadhan-13: 2 rows BRRI

*Effect of variety mixture on BB disease of rice*

dhan49) at 60 DAT (Table 3). On the other hand, lowest disease severity was recorded at 90 DAT for the treatment T<sub>3</sub> (2 rows Binadhan-13: 1 row BRRIdhan49) and the severity was observed for both the BINA and BRRIdhan49 rice varieties 40.74% and 54.07% respectively followed by treatment T<sub>2</sub> (1 row Binadhan-13: 2 rows

BRRIdhan49) and shown in Table 3. In case of sole cultivation, Binadhan-13 showed 42.22% and 76.30% disease severity at 60 DAT and 90 DAT respectively. Whereas, BRRIdhan49 showed 61.48% and 83.70% disease severity at 60 DAT and 90 DAT respectively in case of sole cultivation (Table 3).

Table 3. Effect of varietal mixtures of rice in alternate rows on disease severity of BB

Treatments	60 DAT		90 DAT	
	Binadhan-13	BRRIdhan49	Binadhan-13	BRRIdhan49
T <sub>1</sub>	42.22ab	0.00e	76.30a	0.00e
T <sub>2</sub>	25.92cd	33.33cd	49.63bc	57.04bcd
T <sub>3</sub>	25.92cd	28.89d	40.74d	54.07d
T <sub>4</sub>	24.44d	45.18b	60.00ab	77.78ab
T <sub>5</sub>	43.70ab	39.26bc	61.48ab	58.52bcd
T <sub>6</sub>	39.26abc	58.52a	34.81e	83.70a
T <sub>7</sub>	25.92cd	51.11a	49.63bc	61.48cd
T <sub>8</sub>	30.37cd	43.70b	52.59bc	70.37abc
T <sub>9</sub>	0.00e	61.48a	0.00f	83.70a
*LSD (0.05)	13.131	12.232	22.963	22.844

\*LSD (0.05): Least Significant Difference at 5% level of significance. In a column, means followed by the same letter(s) are statistically similar at 5% level by DMRT. T<sub>1</sub>= 1:0 (Only Binadhan-13 as sole crop: no BRRIdhan49), T<sub>2</sub>= 1:2 (One hill Binadhan-13: two hills BRRIdhan49), T<sub>3</sub>= 2:1 (Two hills Binadhan-13: one hill BRRIdhan49), T<sub>4</sub>= 2:3 (Two hills Binadhan-13: three hills BRRIdhan49), T<sub>5</sub>= 3:2 (Three hills Binadhan-13: two hills BRRIdhan49), T<sub>6</sub>= 2:4 (Two hills Binadhan-13: four hills BRRIdhan49), T<sub>7</sub>= 4:2 (Four hills Binadhan-13: two hills BRRIdhan49), T<sub>8</sub>= 1:1 (One hill Binadhan-13: one hill BRRIdhan49), T<sub>9</sub>= 0:1 (No Binadhan-13: only BRRIdhan49 as sole crop).

*Effect of varietal mixtures of rice in alternate hills on disease severity of BB*

In the present experiment, two rice varieties were mixed with nine ratios and sown in the spatial arrangement of alternate hills to know the effect of varietal mixtures on the disease severity of BB of rice. In this varietal mixture study, the minimum percentage of disease severity was recorded in the treatment T<sub>3</sub> (2 hills Binadhan-13: 1 hill BRRIdhan49) and the disease severity was 28.88% for Binadhan-13 and 30.37% for BRRIdhan49 followed by treatment T<sub>4</sub> (2 hills Binadhan-13: 3 hills BRRIdhan49) at 60 DAT (Table 4), whereas the sole cultivation of Binadhan-13 (T<sub>1</sub>) showed 40.74% and sole cultivation BRRIdhan49 showed 67.41% disease severity. On the other hand, lowest disease severity was recorded at 90 DAT for the

treatment T<sub>3</sub> (2 hills Binadhan-13: 1 hill BRRIdhan49) and the disease severity was recorded as 37.78% for Binadhan-13 and 48.15% for BRRIdhan49 followed by treatment T<sub>2</sub> (1 hill Binadhan-13: 2 hills BRRIdhan49) shown in Table 4. But the sole cultivation of Binadhan-13 and BRRIdhan49 showed 58.52 % and 91.11% disease severity, respectively at 90 DAT. The above results are indicating that the varietal mixtures have reduced the BB severity for both the Binadhan-13 and BRRIdhan49 compared to the sole cultivation of those cultivars. The varietal mixture ratios 2:1 (T<sub>3</sub>) and 1:2 (T<sub>2</sub>) showed better performance at 60 and 90 DAT respectively compared to other treatments including sole rice cultivation.

Table 4. Effect of varietal mixtures of rice in alternate hills on disease severity of BB

Treatments	60 DAT		90 DAT	
	Binadhan-13	BRRIdhan49	Binadhan-13	BRRIdhan49
T <sub>1</sub>	40.74a	0.00d	58.52cd	0.00f
T <sub>2</sub>	37.03ab	41.48bc	42.22e	65.93cd
T <sub>3</sub>	28.88d	30.37c	37.78de	48.15e
T <sub>4</sub>	28.88d	42.22bc	62.96bc	85.19ab
T <sub>5</sub>	39.26ab	42.22bc	60bc	80.74c
T <sub>6</sub>	33.33c	55.56ab	54.08cd	86.67ab
T <sub>7</sub>	37.77ab	48.14bc	67.41a	62.96cd
T <sub>8</sub>	35.55c	40.74bc	62.96bc	71.85c
T <sub>9</sub>	0.00e	67.41a	0.00f	91.11a
*LSD (0.05)	16.357	21.332	11.202	15.377

\*LSD (0.05): Least Significant Difference at 5% level of significance. In a column, means followed by same letter(s) are statistically similar at 5% level by DMRT. T<sub>1</sub>= 1:0 (Only Binadhan-13 as sole crop: no BRRIdhan49), T<sub>2</sub>= 1:2 (One hill Binadhan-13: two hills BRRIdhan49), T<sub>3</sub>= 2:1 (Two hills Binadhan-13: one hill BRRIdhan49), T<sub>4</sub>= 2:3 (Two hills Binadhan-13: three hills BRRIdhan49), T<sub>5</sub>= 3:2 (Three hills Binadhan-13: two hills BRRIdhan49), T<sub>6</sub>= 2:4 (Two hills Binadhan-13: four hills BRRIdhan49), T<sub>7</sub>= 4:2 (Four hills Binadhan-13: two hills BRRIdhan49), T<sub>8</sub>= 1:1 (One hill Binadhan-13: one hill BRRIdhan49), T<sub>9</sub>= 0:1 (No Binadhan-13: only BRRIdhan49 as sole crop).

*Effect of spatial arrangement and varietal mixture ratios of rice on combined rice yield*

In this experiment, two rice varieties were used in nine different ratios in two spatial arrangements namely alternate rows and alternate hills to know the effect of varietal mixture on the disease pressure as well as combined yield for both the rice varieties. The combined yield of Binadhan-13 and BRRI dhan49 was significantly affected due to the mixture ratio under both alternate hill and alternate row arrangements compared to sole culture. Sole BRRI dhan49 and sole Binadhan-13 respectively produced 4.76 and 3.53 t/ha of grain yield. All the mixed culture resulted in higher grain yield than sole culture yield irrespective of mixture ratio and spatial arrangement. In case of alternate hill, the highest grain yield of 5.32 t/ha was recorded when Binadhan-13 and BRRI dhan49 were planted in 1: 1 ratio, which was

respectively 1.79 t/ha (50.56%) and 0.56 t/ha (11.74%) higher than sole culture yield of Binadhan-13 and BRRI dhan49. The lowest combined yield under alternate hill arrangement was 4.15 t/ha recorded with 2:1 ratio which was even 17 % higher than the sole culture of fine grain rice Binadhan-13 (Fig. 1). In case of alternate row arrangement, on the other hand, cultivation of Binadhan-13 and BRRI dhan49 in 1:1 ratio resulted in the maximum grain yield of 5.22 t/ha which was respectively 1.69 t/ha (47.7%) and 0.46 t/ha (9.6%) higher than Binadhan-13 and BRRI dhan49 sole yields. The lowest combined yield under alternate row arrangement was 3.55 t/ha recorded with 3:2 ratio which was even 0.5 % higher than the sole culture of fine grain rice cultivar Binadhan-13 (Fig. 1). Thus cultivar mixture confirms rice yield advantage over sole culture.

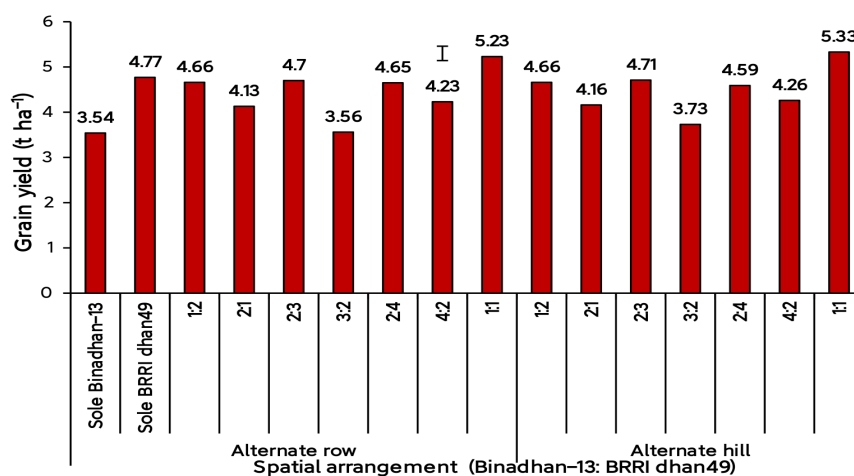


Fig. 1. Effect of spatial arrangement and varietal mixture ratios on the yield of rice over sole culture

## Discussion

The present investigation was conducted to evaluate the effect of different arrangement of varietal mixture ratios on the disease incidence and severity of BB of rice and to determine the effect of different arrangement of varietal mixture ratios on the yield of rice. The experiment was conducted under field condition in Aman season during the period from July to December 2017. For this study, two varieties Binadhan-13 and BRRI dhan49 were selected that are widely cultivated in Bangladesh during Aman rice season in Bangladesh. From the results it was observed that, all the selected varieties were infected with BB disease and developed the typical symptom under the field conditions. The cultivars Binadhan-13 and BRRI dhan49 were transplanted in different spatial arrangement with 9 mixture ratios Advantages of mixed culture of rice cultivars over sole culture in terms of incidence, severity and yield are evident from our study and these findings are corroborate with the finding of previous experiments. Mundt (2002) found that the monoculture of a genetically uniform crop is a major feature of

modern agricultural systems. However, this genetic uniformity favours the rapid development of plant diseases and renders these agricultural systems dependent on high pesticide input. One strategy proposed for increasing the spatial diversification of host resistance is the use of multiline cultivars or cultivar mixtures.

Many studies have shown the efficiency of cultivar mixtures for reducing epidemics of aerial pathogens, mainly in cereal crops. Jiet *et al.* (2007) stated that rice cultivar mixtures have been used recently to control rice BB with great success. Cultivar mixtures have been shown to impact a spectrum of plant diseases, and their commercial use is increasing. The BB management was more effective in combinations of resistant Indica rice cultivars, inter-planting with susceptible cultivars, than mixtures of two susceptible rice lines, compared with their pure stand.

In this study, based on the varietal mixtures on disease incidence for alternate rows of Binadhan-13 and BRRI dhan49, the best row mixture ratios was found in the

mixture ratio 2:1 (2 rows Binadhan-13: 1 row BRRI dhan49) at 60 DAT, whereas at 90 DAT the best mixture ratio for low disease incidence was of 1:1 (1 row Binadhan-13: 1 row BRRI dhan49). In case of hill orientation, the best mixture ratio was 2:1 (2 rows Binadhan-13: 1 row BRRI dhan49) for low disease incidence at 60 and 90 DAT, whereas 1:1 ratio (1 row Binadhan-13: 1 row BRRI dhan49) of hill orientation showed low disease incidence at the same time points compared to some other treatments including sole cultivation.

On the other hand, minimum disease severity was observed in the varietal mixtures ratio 2:1 (2 rows Binadhan-13: 1 row BRRI dhan49) at 60 and 90 DAT compared to other treatments used in this study. The above findings are in agreement with the previous findings. Han Guang-yu *et al.* (2016) found that in case of modern rice varieties, the average incidence of rice blast was reduced from 18.5 and 19.6%, respectively for the two-year experiments in the monoculture plots, to 10.2 and 10.3% in the intercropping plots. The average severity index of rice blast was also reduced from 7.4 and 8.4%, respectively for the two-year experiments in the monoculture plots, to 4.1 and 4.3% in the intercropping plots. Han Guang-yu *et al.* (2016) reported that creating a crop-heterogeneous system by intraspecific mixtures of different rice varieties can substantially reduce blast disease incidence. Such variety mixtures provide an ecological approach for effective disease control, maintaining high yields with the minimum fungicide applications. Such an approach is universally applicable for random rice variety combinations.

The combined rice yield also influenced by the varietal mixtures ratios used in this study. Irrespective of mixture ratio and spatial arrangement, all the mixed culture resulted in higher grain yield compared to sole culture yield. The highest grain yield of 5.32 t/ha was recorded when Binadhan-13 and BRRI dhan49 were planted in 1:1 ratio in alternate hill orientation which was higher than sole culture yield of Binadhan-13 and BRRI dhan49. On the other hand, the lowest combined yield was recorded as 4.15 t/ha with 2:1 ratio under alternate hill arrangement which was even 17 % higher than the sole culture of fine grain rice Binadhan-13. In addition, the maximum grain yield of 5.22 t/ha was recorded under alternate row arrangement with 1:1 ratio of Binadhan-13 and BRRI dhan49 which was respectively 48% and 10 % higher than Binadhan-13 and BRRI dhan49 sole yields. The lowest combined yield under alternate row arrangement was 3.55 t/ha recorded with 3:2 ratio which was even 0.5 % higher than the sole culture of fine grain rice cultivar Binadhan-13. This might be due to the facilitation effect as mentioned by Garcia-Barrios (2003). Our findings are corroborated with the previous findings of Smithson and Lenne (1996) who reported that the mixed cultivation of different rice varieties mixtures represents a low-tech method for increasing

and stabilizing grain yields and also to reduce the dependence on pesticides. Mikkelsen *et al.* (1995) observed that the potential for increased rice production strongly depends on the ability to integrate a better crop management for the different varieties mixture into the existing cultivation systems. Jensen (1988) stated that mixture yields of rice usually lie above the mean of their components in monoculture and that mixture yields better than the yield of the best component or worse than that of the poorest component are comparatively rare. In cultivar mixture, overall use of above and below ground resources are better than sole culture. This happens only when component cultivars differ in their resource use patterns (Fukai & Trenbath, 1993). Complementarity occurs when component cultivars vary in their architectures and growth duration. In the present study, Binadhan-13 took 135 days to mature while BRRI dhan49 matured only in 110 days. The cultivars also differed in their plant height; Binadhan-13 was a tall variety (>160 cm) while BRRI dhan49 was a semi-dwarf one (< 110 cm). This difference in both plant height and growth duration ensured the maximum utilization of the resources which ultimately resulted in increased combined yield. Here, yield performances of different cultivar mixture ratios were variable. This might happen due to the differences in their spatial pattern resulted from inter-planting ratios of both cultivars (Binang *et al.*, 2010).

## Conclusion

Based on the findings of the present study it may be concluded that rice cultivation considering varietal mixtures can reduce the disease incidence and severity of BB. Two different varietal mixture ratios such as 2:1 (2 rows Binadhan-13: 1 row BRRI dhan49) and 1:1 (1 row Binadhan-13: 1 row BRRI dhan49) were found to be the effective varietal mixture combination for cultivation of both the T. Aman rice cultivars which can reduce disease pressure of BB and influenced combined yield positively compared to other mixture combinations especially sole cultivation.

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