J Bangladesh Agril Univ 18(2): 354–361, 2020 https://doi.org/10.5455/JBAU.76259

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau, www.banglajol.info/index.php/JBAU

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

Suvonkar Sarker[1], Md. Atikur Rahman[1], Md. Parvez Anwar[2], Muhammed Ali Hossain[1]✉

[1]Plant Microbe Interaction Laboratory, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

[2]Agro Innovation Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

ARTICLE INFO

Article history:
Received: 03 December 2019
Accepted: 03 April 2020
Published: 30 June 2020

Keywords:
Rice,
Varietal mixtures,
Bacterial blight,
Disease incidence,
Disease severity

Correspondence:
Muhammed Ali Hossain
✉: 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.

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

Cite this article

Sarker, S., Rahman, M.A., Anwar, M.P., Hossain, M.A. 2020. Varietal mixture effect on the disease incidence and severity of bacterial blight in rice. *Journal of Bangladesh Agricultural University*, 18(2): 354–361. https://doi.org/10.5455/JBAU.76259

different rice-growing regions of the globe (Xu *et al.*, 2010). This disease is a seed borne in nature (Srivastavaand Rao, 1963) and was first recognized in Japan in 1884 (Tagamiand 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 (Tabeiand 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.

Effect of variety mixture on BB disease of rice

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

Alternate Rows	Ratio	Alternate Hills
Only Binadhan-13as a sole crop	1:0=T_1	Only Binadhan-13as a sole crop
One row Binadhan-13: two rows BRRI Dhan49	1:2=T_2	One hill Binadhan-13: two hills BRRI dhan49
Two rows Binadhan-13: one row BRRI Dhan49	2:1=T_3	Two hills Binadhan-13: one hill BRRI dhan49
Two rows Binadhan-13: three rows BRRI Dhan49	2:3=T_4	Two hills Binadhan-13: three hills BRRI dhan49
Three rows Binadhan-13: two rows BRRI Dhan49	3:2=T_5	Three hills Binadhan-13: two hills BRRI dhan49
Two rows Binadhan-13: four rows BRRI Dhan49	2:4=T_6	Two hills Binadhan-13: four hills BRRI dhan49
Four rows Binadhan-13: two rows BRRI Dhan49	4:2=T_7	Four hills Binadhan-13: two hills BRRI dhan49
One row Binadhan-13: one row BRRI Dhan49	1:1=T_8	One hill Binadhan-13 : one hill BRRI dhan49
only BRRI dhan49 as a sole crop	0:1=T_9	only BRRI 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-

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

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^{-1} 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_3 (2 rows Binadhan-13: 1 row BRRI dhan49) and the disease incidence was 44.50% for Binadhan-13and 48.29% for BRRI dhan49 followed by treatment T_2 (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_8 (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_2 (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_1	68.07a	0.00g	83.92a	0.00f
T_2	45.51d	51.49f	70.94c	72.76d
T_3	44.50d	48.29f	69.05c	79.91bc
T_4	56.09c	62.39cd	69.87c	79.28bc
T_5	58.54bc	57.37de	76.60b	79.06c
T_6	43.58d	69.44b	68.27d	83.54ab
T_7	61.72b	51.89ef	76.15b	78.46c
T_8	59.23bc	63.84bc	64.31d	68.00e
T_9	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_1= 1:0 (Only Binadhan-13 as sole crop: no BRRI dhan49), T_2= 1:2 (One hill Binadhan-13: two hills BRRI dhan49), T_3= 2:1 (Two hills Binadhan-13: one hill BRRI dhan49), T_4= 2:3 (Two hills Binadhan-13: three hills BRRI dhan49), T_5= 3:2 (Three hills Binadhan-13: two hills BRRI dhan49), T_6= 2:4 (Two hills Binadhan-13: four hills BRRI dhan49), T_7= 4:2 (Four hills Binadhan-13: two hills BRRI dhan49), T_8= 1:1 (One hill Binadhan-13: one hill BRRI dhan49), T_9= 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_3 (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_2 (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_3 (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_2 (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_1	69.63a	0.00f	83.92a	0.00g
T_2	54.44cde	55.88de	74.81bc	73.14de
T_3	48.33e	53.22de	69.07de	74.83de
T_4	53.03de	72.00ab	72.12cd	81.33bc
T_5	66.46ab	58.00d	72.33cd	81.78bc
T_6	46.67e	63.96bcd	68.00e	77.50cd
T_7	64.35abc	57.17e	78.37ab	73.08f
T_8	63.15abc	67.11abc	78.86ab	83.70ab
T_9	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_1= 1:0 (Only Binadhan-13 as sole crop: no BRRI dhan49), T_2= 1:2 (One hill Binadhan-13: two hills BRRI dhan49), T_3= 2:1 (Two hills Binadhan-13: one hill BRRI dhan49), T_4= 2:3 (Two hills Binadhan-13: three hills BRRI dhan49), T_5= 3:2 (Three hills Binadhan-13: two hills BRRI dhan49), T_6= 2:4 (Two hills Binadhan-13: four hills BRRI dhan49), T_7= 4:2 (Four hills Binadhan-13: two hills BRRI dhan49), T_8= 1:1 (One hill Binadhan-13: one hill BRRI dhan49), T_9= 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_3),T2 (1:2) and 1:1 (T_8) 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_3 (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_2 (1 row Binadhan-13: 2 rows BRRI dhan49) at 60 DAT (Table 3). On the other hand, lowest disease severity was recorded at 90 DAT for the treatment T_3 (2 rows Binadhan-13: 1 row BRRI dhan49) and the severity was observed for both the BINA and BRRI rice varieties 40.74% and 54.07% respectively followed by treatment T_2 (1 row Binadhan-13: 2 rows BRRI dhan49) 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, BRRI dhan49 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_1	42.22ab	0.00e	76.30a	0.00e
T_2	25.92cd	33.33cd	49.63bc	57.04bcd
T_3	25.92cd	28.89d	40.74d	54.07d
T_4	24.44d	45.18b	60.00ab	77.78ab
T_5	43.70ab	39.26bc	61.48ab	58.52bcd
T_6	39.26abc	58.52a	34.81e	83.70a
T_7	25.92cd	51.11a	49.63bc	61.48cd
T_8	30.37cd	43.70b	52.59bc	70.37abc
T_9	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_1= 1:0 (Only Binadhan-13 as sole crop: no BRRI dhan49), T_2= 1:2 (One hill Binadhan-13: two hills BRRI dhan49), T_3= 2:1 (Two hills Binadhan-13: one hill BRRI dhan49), T_4= 2:3 (Two hills Binadhan-13: three hills BRRI dhan49), T_5= 3:2 (Three hills Binadhan-13: two hills BRRI dhan49), T_6= 2:4 (Two hills Binadhan-13: four hills BRRI dhan49), T_7= 4:2 (Four hills Binadhan-13: two hills BRRI dhan49), T_8= 1:1 (One hill Binadhan-13: one hill BRRI dhan49), T_9= 0:1 (No Binadhan-13: only BRRI dhan49 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_3 (2 hills Binadhan-13: 1 hill BRRI dhan49) and the disease severity was 28.88% for Binadhan-13 and 30.37% for BRRI dhan49 followed by treatment T_4 (2 hills Binadhan-13: 3 hills BRRI dhan49) at 60 DAT (Table 4), whereas the sole cultivation of Binadhan-13 (T_1) showed 40.74% and sole cultivation BRRI dhan49 showed 67.41% disease severity. On the other hand, lowest disease severity was recorded at 90 DAT for the treatment T_3 (2 hills Binadhan-13: 1 hill BRRI dhan49) and the disease severity was recorded as 37.78% for Binadhan-13 and 48.15% for BRRI dhan49 followed by treatment T_2 (1 hill Binadhan-13: 2 hills BRRI dhan49) shown in Table 4. But the sole cultivation of Binadhan-13 and BRRI dhan49 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 BRRI dhan49 compared to the sole cultivation of those cultivars. The varietal mixture ratios 2:1 (T_3) and 1:2 (T_2) 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_1	40.74a	0.00d	58.52cd	0.00f
T_2	37.03ab	41.48bc	42.22e	65.93cd
T_3	28.88d	30.37c	37.78de	48.15e
T_4	28.88d	42.22bc	62.96bc	85.19ab
T_5	39.26ab	42.22bc	60bc	80.74c
T_6	33.33c	55.56ab	54.08cd	86.67ab
T_7	37.77ab	48.14bc	67.41a	62.96cd
T_8	35.55c	40.74bc	62.96bc	71.85c
T_9	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_1= 1:0 (Only Binadhan-13 as sole crop: no BRRI dhan49), T_2= 1:2 (One hill Binadhan-13: two hills BRRI dhan49), T_3= 2:1 (Two hills Binadhan-13: one hill BRRI dhan49), T_4= 2:3 (Two hills Binadhan-13: three hills BRRI dhan49), T_5= 3:2 (Three hills Binadhan-13: two hills BRRI dhan49), T_6= 2:4 (Two hills Binadhan-13: four hills BRRI dhan49), T_7= 4:2 (Four hills Binadhan-13: two hills BRRI dhan49), T_8= 1:1 (One hill Binadhan-13: one hill BRRI dhan49), T_9= 0:1 (No Binadhan-13: only BRRI dhan49 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 recoded 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.

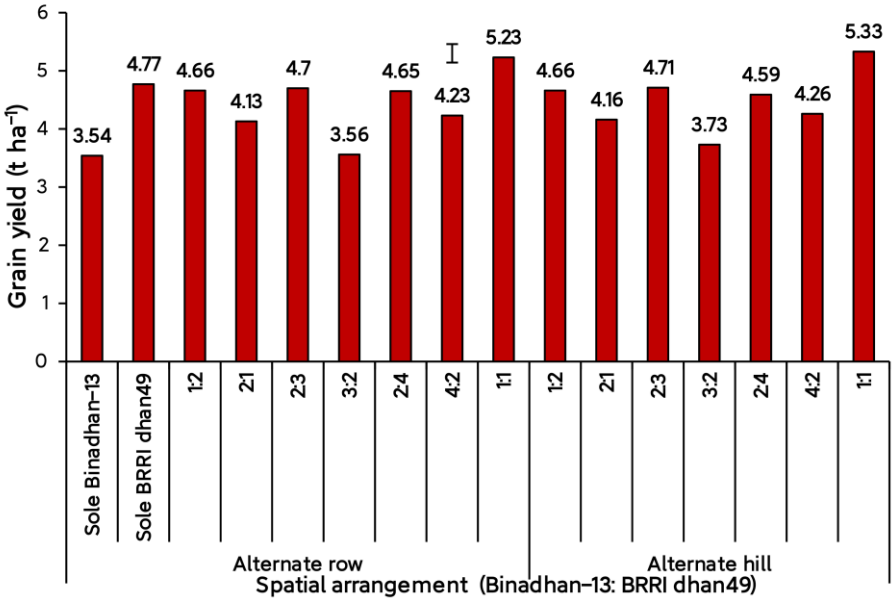

Fig. 1. Effect of spatial arrangement and varietal mixture ratios on the yield of rice over sole culture

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. J*iet 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 sued 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-13and BRRI dhan49 were planted in 1: 1 ratio in alternate hill orientation which was higher than sole culture yield of Binadhan-13and 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 recoded 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.

References

Ahmed, M. ,Hossain, M. , Hasan, K. and Dash, C. K. 2013. Efficiency of different plant extract on reducing seed borne infection and increasing germination of collected rice seed sample.*Universal Journal of Plant Science*,1(3): 66-73.https://doi.org/10.13189/ujps.2013.010302

Ashrafuzzaman, H. 1992. ShasyerRog (disease of crop). Forth reprint, Bangla Academy, Dhaka, Bangladesh. pp. 203 -207.

Bangladesh Economic Review (BER), 2010.Department of Finance, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

BARC, 2012.Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

Binang WB, Okapara DO, Nita JD, Shiyam JO, 2010: Spatial and temporal deployment of cultivar effects on rice cultivar

mixtures. *Research Journal of Agriculture and Biological Science*, 6: 1099-1102.

Browning J A. and Frey K J. 1981. The multiline concept in theory and practice. In: Jenkyn J F, Plumb R T, eds., Strategies for the Control of Cereal Disease. *Blackwell Scientific*,pp. 36-37.

BRRI, 2018.AdhunicDhaner Chas (Bengali Bulletin), Bangladesh Rice Research Institute, Gazipur.

Castro, A. 2001.Cultivar Mixtures. The Plant Health Instructor. *The American Phytopathological Society (APS)*. https://doi.org/10.1094/PHI-A-2001-1230-01

Department of Agricultural Extension DAE, 2017. Government of the People's Republic of Bangladesh, Dhaka

Dordas C. 2008. Role of nutrients in controlling plant diseases in sustainable agriculture: A review. *Agronomy for Sustainable Development*, 28: 33-46. https://doi.org/10.1051/agro:2007051

Fakir, G. A. 1982.An annotated list of seed borne diseases in Bangladesh Agricultural Information Service, Dhaka, Bangladesh. pp. 15-22.

FAOSTAT, 2017. Worldwide rice area harvest and production. FAO Statistical Yearbook 2018.Finance, Government of the People's Republic of Bangladesh, Dhaka.

Finckh, M.R., Gacek, E.S., Goyeau, H., Lannou, C., Merz, U., Mundt, C.C., Munk, L., Nadziak, J., Newton, A.C., de Vallavieille-Pope, C., Wolfe, M.S. 2000. Cereal cultivar and species mixtures in practice. *Agronomie: Plant Genetics and Breeding*, 20: 813-837. https://doi.org/10.1051/agro:2000177

Fukai, S. and Trenbath, B. R. 1993. Processes determining intercrop productivity and yields of component crops. *Field Crops Research*, 34: pp. 247-271. https://doi.org/10.1016/0378-4290(93)90117-6

Garcia-Barrios L. 2003. Plant-plant interactions in tropical agriculture, *Tropical Agroecosystems*, *CRC Press*, pp. 11-58.https://doi.org/10.1201/9781420039887.ch2

Gomez, K.A. and A.A. Gomez, (1984).*Statistical procedures for agricultural research* (*2nd edition.*).John wiley and sons, NewYork, 680p.

Guang-yu, H., Lang, J., Sun, Y., Wang, Y.,,Zhu, Y., Lu., B. 2016. Intercropping of rice varieties increases the efficiency of blast control through reduced disease occurrence and variability. *Journal of Integrative Agriculture*, 15(4): 795-802. https://doi.org/10.1016/S2095-3119(15)61055-3

IRRI, 1980.Standard Evaluation System for Rice. International Rice Testing Program.Losbanos, Philippines. pp. 7-20.

Jensen, N. F. 1988.Plant breeding methodology. John Wiley & Sons, Inc. pp. 676.

Jeung, J.U., Heu, S.G. Shin, M.S., Ruz, C.M.V. and Jena, K.K. 2006.Dynamics of *Xanthomonas oryzae* pv. *oryzae* populations in Korea and their relationship to known bacterial blight resistance genes. *The American Phytopathological Society*, 96: 867-875. https://doi.org/10.1094/PHYTO-96-0867

Ji, G., We, L. F., He, Y. ,Zang, S. G. and Li, Y. 2007. "Proceeding of the 2"d international conference on bacterial blight of rice", Nanjing, China, pp 105-106.

Leung H, Zhu Y, Revilla M I, Fan J X, Chen H, Pangga I, Cruz C V, Mew T W. 2003. Using genetic diversity to achieve sustainable rice disease management. *Plant Disease*, 87: 1156-1169. https://doi.org/10.1094/PDIS.2003.87.10.1156

Mew, T.W., Alvarez, A.M., Leach, J.E. and Swings, J. 1993. Focus on bacterial blight of rice. *Plant Disease*, 77:5-12. https://doi.org/10.1094/PD-77-0005

Mikkelsen.D.S., Jayaweera, G.R. and Rolston, D.E. 1995. Nitrogen fertilization practices of low land rice culture. Nitrogen Fertilization in the Environment, 171-223.

Mundt, C.C. 2002.Use of multiline cultivars and cultivar mixtures for disease management. *Annual Review of Phytopathology*, 40:1, 381-410. https://doi.org/10.1146/annurev.phyto.40.011402.113723

Ou, S. H. 1985. Rice Diseases.2nd ed. Commonwealth Mycological Institute, Kew, Surrey, England. pp. 61-96.

Palti J. 1981. Cultural Practices and Infectious Crop Diseases. *Advanced Series in Agricultural Sciences*.https://doi.org/10.1007/978-3-642-68266-7

Rajput, R. L. and Bartaria, A. M. 1995.Reaction of rice cultivars to brown spot. *Agricultural Science Digest Journal*, 15 (4): 205-206.

Risch S J, Andow D, Altieri M A. 1983. Agro-ecosystem diversity and pest control: Data, tentative conclusions, and new research directions. *Environmental Entomology*, 12:625-629. https://doi.org/10.1093/ee/12.3.625

Salim, M., Akram,M., Akhtar, M.H. and Ashraf, M. 2003. Rice - a production hand book. Pakistan Agriculture Research Council, Islamabad. p70.

Sheehy., J.E. and Mitchell, P.L. 2013. Designing rice for the 21st century: the three laws of maximum yield.Discussion Paper Series 48. Los Banos, International Rice Research Institute, p19.

Smithson, J. B., and Lenne, J. M. 1996. Varietal mixtures: a viable strategy for sustainable productivity in subsistence agriculture. *Annals of applied biology*, 128:127-158. https://doi.org/10.1111/j.1744-7348.1996.tb07096.x

Srivastava, D.N. and Rao, Y.P.1963. Epidemic of bacterial leaf blight of rice in North India. *Indian Phytopathology*, 16: 393-394.

Swings J, Mooter M van den, Vauterin L, Hoste B, Gillis M, Mew TW, Kersters K, 1990. Reclassification of the causal agents of bacterial blight (*Xanthomonas campestris* pv. *oryzae*) and bacterial leaf streak (*Xanthomonas campestris* pv. *oryzicola*) of rice as pathovars of *Xanthomonas oryzae* (ex Ishiyama 1922) sp. nov., nom. rev. *International Journal of Systematic Bacteriology*, 40(3):309-311. https://doi.org/10.1099/00207713-40-3-309

Tabei, H. and Mukoo, H. 1960. Anatomical studies of rice plant leaves affected with bacterial leaf blight, in particular reference to the structure of water exudation system. *Bulletin National Institute of Agricultural Science, Japan*,11: 37-43.

Tagami, Y. and Mizukami, T. 1962. Historical review of the researches on bacterial leaf blight of rice caused by *Xanthomonas oryzae* (Uyeda and Ishiyama) Dow son. Species report of the plant disease and insect pests forecasting service, 10: p112.

Tilman, D, Reich, P. B., Knops, J., Wedin, D., Mielke, T., Lehman, C. 2001. Diversity and productivity in a long-term grassland experiment. *Science*, 294: 843-845. https://doi.org/10.1126/science.1060391

Wolfe, M. S. 1985. The Current Status and Prospects of Multiline Cultivars and Variety Mixtures for Disease Resistance. *Annual Review of Phytopathology*, 23(1), 251–273. https://doi.org/10.1146/annurev.py.23.090185.001343

Zhu, Y., Chen,H., Fan, J., Wang,Y.,, Li,Y., Chen,J., Fan,J.X., Yang,S., Hu,L., Leung, H., Mew,T.W. Teng,P., Wang, Z and Mundt, C.C. 2000. Genetic diversity and disease control in rice. *Nature*, 406(6797): 718-722. https://doi.org/10.1038/35021046