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Growing tall and dwarf rice cultivars in mixture for better weed management and higher yield

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Abstract

Growing two or more cultivars of same crop species in mixture reduces intra-specific competition for natural resources and increases competitive ability of crops against weeds and thus enhances crop yield. The objective of this study was to evaluate the potentiality of growing rice cultivars in mixtures for minimizing weed pressure and increasing rice yield. The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during *Aman* season (July-December) 2017. Two transplant *Aman* rice cultivars viz. Binadhan-13 (tall, late- maturing and fine grain aromatic cultivar) and BRRI dhan49 (semi-dwarf, mid-maturing and coarse grain cultivar) were grown following two spatial arrangements viz., alternate row and alternate hill, and nine different cultivar mixture (Binadhan-13:BRRI dhan49) row ratios viz., 1:0, 1:2, 2:1, 2:3, 3:2, 2:4, 4:2,1:1 and 0:1. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Results confirmed the positive influence of spatial arrangement and cultivar mixture ratio on rice productivity. Both the cultivars showed better growth and higher yield when grown in mixture irrespective of ratios compared to their sole culture performances. But cultivar mixture ratio showed no advantages over sole culture in suppressing weeds. Based on the total yield Binadhan-13 and BRRI dhan49 inter-planted in 1:1 row ratio following alternate hill performed the best resulting in 50% and 12% yield advantages over sole culture of Binadhan-13 and BRRI dhan49, respectively. Therefore, growing tall and dwarf rice cultivars in mixture can be adopted as a tool for increasing rice productivity.

Introduction

Cultivar mixture refers to growing more than one cultivars simultaneously on the same piece of land with no attempt to breed (Mundt, 2002). The component cultivars may vary in some features, but must have enough similarity to be grown together. Cultivar mixture may be "intra specific mixtures", composed of cultivars of the same species or "multi-lines", which are mixtures of genetically uniform lines of a crop species differing only in a specific character. Inter-planting cultivars provides each of the component cultivars a greater capacity to utilize resources more efficiently, and helps them adjust under different stress conditions that ultimately leading to higher yields compared with monoculture of component crop.

Modifications in temporal and spatial deployment of crops grown in association can enhance the compatibility of mixtures and make the system more efficient. Several reports on this strategy have confirmed that it helps in controlling pest, disease, lodging and weed. Mixing cultivars can enhance functional diversity and improve yield by providing more chances for positive interactions among cultivars (Castilla *et al.*, 2003). The cultivar mixture strategy is practical, and can easily be practiced by resource poor farmers who only need to mix existing cultivars with variable agronomic traits and performance. It also provides scope for on-farm conservation of genetic resources by allowing farmers to grow widely adopted local cultivars. Although the benefits of growing cultivars mixtures for disease controlare well documented in world literature, they have also been used for some other purposes. Bowden *et al.* (2001) listed three advantages of cultivar mixtures; stabilization of yield, compensation effects (a strong variety compensates for a weak or injured variety) and disease control. Reduction of weed growth due to cultivar mixture has also been reported. Cultivar mixtures can improve the competitive ability of rice reducing weed biomass production and diminishing rice biomass losses by enhancing competitive ability of rice (Binang *et al.*, 2011). Estavan (2006) also opined that cultivar mixture could improve the competitive ability of crop against weed and the author emphasized on devising a formula to design correct mixture ratio for effective weed suppression. The use of cultivar mixtures thus be a potent supplement to weed management practices and could reduce production costs and

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environmental pollution by minimizing herbicide use for weed control.

During the last few decades several attempts have been made to manage rice field weeds in different ways. But cultivar mixture strategy has not been properly addressed by the researchers as an alternative tool for weed management. Moreover, this strategy is yet to be explored for increasing rice productivity. Present study was, therefore, undertaken to evaluate the effect of spatial deployment of rice cultivar mixture (in terms of spatial arrangement and mixture row ratio) on weed suppression and yield performance of rice.

Materials and Methods

Experimental site

The experimental field was located at 90º 50' E and 24º 75' N and at an altitude of 18 meter above the sea level. The experimental area was located under the subtropical climate, which is specialized by moderately high temperature and heavy rainfall during April to September and low rainfall with moderately low temperature during October to March. The monthly values of maximum, minimum and average temperature (°C), relative humidity (%), monthly total rainfall (mm) and sunshine (hour) received at the experimental site during the study period were 33.2°C, 14.6°C, 26.8°C, 83.6%, 176.9 mm, and 165.5 h, respectively.

Experimental treatments and design

The experiment comprised two factors namely, spatial arrangement and cultivar mixture row ratio. Spatial arrangement included planting between row (alternate rows) and planting within row (alternate hills); while cultivar mixture row ratio [Binadhan-13 (tall variety): BRRI dhan49 (dwarf variety)] included 1:0, 1:2, 2:1, 2:3, 3:2, 2:4, 4:2,1:1 and 0:1. The experiment was laid out in randomized complete block design (RCBD) with three replications. Thus, total number of plot was 54.

Crop husbandry

The experimental land was prepared by a power tiller 10 days before transplanting. It was then puddled well with the help of a country plough to make the soil nearly ready for transplanting. Weeds and stubbles were removed and the field was then leveled by laddering. The field was fertilized with 200, 60, 100, and 70 kg ha^{-1} of urea, triple superphosphate (TSP), muriate of potash (MoP) and gypsum, respectively. The full doses of TSP, MoP and gypsum were applied before transplanting. Urea was top dressed in three equal splits, at 15, 30 and 45 days after transplanting (DAT). Thirty days old seedlings of both cultivars were transplanted in the well-prepared puddled field on 12 August 2017 at the rate of three seedlings $hill^{-1}$ maintaining row and hill distance of 25 cm and l5 cm, respectively. During transplanting, cultivar mixture row ratio was maintained as per experimental treatments. Three manual weeding was done at 4, 7 and 9 week after transplanting (WAT), 7 WAT and 9 WAT. Due to frequent rainfall during crop growth period no irrigation was needed and water was drained out before maturity. There were no remarkable infestations of insect pests or diseases during the crop growth period. Therefore, no plant protection measures were taken.

Data Collection

Data on plant height, tillering ability, yield contributing parameters and yield of rice were collected at harvest. All data, except rice yield, were collected from five randomly selected hills of each plot, while rice yield data were collected from the whole plot after harvest. Rice yield was calculated after harvesting the whole plot. Grain weight obtained from the five sample hills were added to the grain weight of respective plot for calculating grain yield. Data on weed population were collected at 4 WAT and 7 WAT from each plot by using a 0.25 m × 0.25 m quadrate placed randomly at two places of each plot. The weeds within the quadrate were counted and converted to number m^{-2}(weed density). After counting, weeds inside each quadrate were uprooted, cleaned, separated species-wise and dried first in the sun and then in an electric oven for 72 hours at a temperature of 80°C. The dry weight of each species was taken by an electric balance. Dominant weed species were identified using the summed dominance ratio (SDR) computed as follows:

$$\text{SDR} = \frac{\text{Relative density (RD)} + \text{Relative dry weight (RDW)}}{2}$$

$$\text{Where, RD (\%)} = \frac{\text{Density of a given weed species}}{\text{Total weed density}} \times 100$$

$$\text{RDW (\%)} = \frac{\text{Dry weight of a given weed species}}{\text{Total weed dry weight}} \times 100$$

Harvesting

The crops were harvested at full maturity. Maturity of crops was determined when 90% of the grains became matured. BRRI dhan49 and Binadhan-13 were harvested on 27 November and 7 December 2017, respectively. The harvested crops were threshed and sun dried. The grains were cleaned and finally converted to t ha^{-1} at the moisture content of 14%.

Statistical analysis

The collected data were compiled and tabulated in the proper form and analyzed statistically. Analysis of variance was done following the randomized complete block design(RCBD) with the help of computer package MSTAT and the mean differences among the treatments were adjudged by Duncan's Multiple Range Test.

Results

Growth and yield of Binadhan-13

Effect of spatial arrangement on plant height of Binadhan-13 was not significant but that of cultivar mixture ratio was significant (Table 1). It is evident from the results that plant height of Binadhan-13 was increased when grown in mixture with BRRI dhan49 compared to sole cropping. Interaction between spatial arrangement and cultivar mixture ratio failed to produce

any significant effect on the plant height of Binadhan-13 (Table 2). Spatial arrangement did not significantly affect the tillering ability of Binadhan-13 but cultivar mixture ratio did (Table 1). Binadhan-13 showed the lowest tillering ability when grown as sole culture compared to grown in mixture with BRRI dhan49. Spatial arrangement and cultivar mixture ratio interacted significantly to produce tillers of Binadhan-13 (Table 2). Binadhan-13 exhibited the maximum tillering potentiality when grown with BRRI dhan49 in 1:1 ratio planted in alternate hill at harvest and showed the lowest tillering ability when grown as sole crop.

Table 1. Effect of spatial arrangement and cultivar mixture ratio on plant height and tillering ability of Binadhan-13 and BRRI dhan49 at harvest

Treatments	Plant height (cm) and tillering ability hill^{-1}			
	Binadhan-13		BRRI dhan49	
	Plant height	Tillering ability	Plant height	Tillering ability
Spatial arrangement				
Alternate row	160.92	11.95	105.21	9.75b
Alternate hill	161.48	12.20	106.13	10.00a
$S\overline{x}$	0.459	0.091	0.458	0.080
Level of significance	NS	NS	NS	*
Cultivar mixture ratio (Binadhan-13:BRRI dhan49)				
Sole Binadhan-13	157.9b	10.87d	101.4d	8.667d
1:2	161.8a	11.90c	106.7abc	9.700c
2:1	161.5a	11.63c	105.9bc	9.433c
2:3	160.9a	12.97a	106.1bc	10.77a
3:2	162.4a	12.00bc	107.3ab	9.800c
2:4	160.9a	11.87c	103.9cd	9.667c
4:2	161.1a	12.47ab	105.2bc	10.27b
1:1	163.1a	12.90a	108.9a	10.70ab
$S\overline{x}$	0.919	0.183	0.917	0.161
Level of significance	*	**	**	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).
NS = Not significant.
** =Significant at 1% level of probability, * =Significant at 5% level of probability.

Table 2. Interaction effect of spatial arrangement and cultivar mixture ratio on plant height and tillering ability of Binadhan-13 and BRRI dhan49

Interaction		Plant height (cm) and Tillering ability hill^{-1} at harvest			
		Binadhan-13		BRRI dhan49	
Spatial arrangement	Binadhan-13: BRRIdhan49	Plant height	Tillering ability	Plant height	Tillering ability
Alternate row	Sole	157.9	10.87e	101.4	8.667g
	1:2	161.5	12.13cd	106.4	9.933def
	2:1	161.7	11.53de	107.5	9.333efg
	2:3	160.8	12.80bc	105.1	10.60bcd
	3:2	163.2	11.73d	105.8	9.533ef
	2:4	161.2	12.20cd	103.3	10.00cdef
	4:2	160.5	12.87bc	105.4	10.67bc
	1:1	160.7	11.47de	106.7	9.267fg
Alternate hill	Sole	157.9	10.87e	101.4	8.667g
	1:2	162.1	11.67de	106.9	9.467ef
	2:1	161.3	11.73d	104.3	9.533ef
	2:3	160.9	13.13b	107.0	10.93b
	3:2	161.7	12.27cd	108.8	10.07cde
	2:4	160.6	11.53de	104.6	9.333efg
	4:2	161.8	12.07cd	104.9	9.867ef
	1:1	165.6	14.33a	111.2	12.13a
$S\overline{x}$		1.30	0.258	1.30	0.227
Level of sig.		NS	**	NS	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).
** =Significant at 1% level of probability, NS = Not significant.

Among the yield contributing characters, only number of effective tillers hill^{-1} and grain weight hill^{-1} were significantly affected by spatial arrangement while grains panicle^{-1} and 1000-grain weight were not (Table 3). Alternate hill resulted in higher number of effective tillers hill^{-1} compared to alternate row. Grain weight hill^{-1} was also found higher in case of alternate hill than alternate row because of higher number of effective tillers hill^{-1}. It is evident from this study that planting in alternate hill produced 0.69g more grains hill^{-1} than alternate row. All the yield contributing characters except 1000-grain weight and grain weight hill^{-1} were significant for cultivar mixture ratio at different growth stages as shown in Table 3. It is evident from the result that cultivar mixture produced a positive effect on number of effective tillers hill^{-1} and grains panicle^{-1} of Binadhan-13. Both the yield contributing characters were found the lowest when Binadhan-13 was planted as sole crop but the highest was when grown in mixture with BRRI dhan49 following 1:1 ratio. Although some other mixture ratios also resulted in statistically similar values. All the mixture ratios produced statistically higher grain weight hill^{-1} than sole culture which confirms a positive influence of cultivar mixture strategy on the productivity of Binadhan-13.

Growth and yield of BRRI dhan49

Effect of spatial arrangement on plant height of BRRI dhan49 was not significant but effect of cultivar mixture ratio was significant (Table 1). Results show that plant height of BRRI dhan49 was higher when grown in mixture with Binadhan-13 compared to sole cropping. Interaction between spatial arrangement and cultivar mixture ratio failed to produce any significant effect on the plant height of BRRI dhan49 (Table 2). Spatial arrangement and cultivar mixture ratio significantly affected tillering ability of BRRI dhan49. Alternate hill gave higher number of tillers than alternate row. BRRI dhan49 showed the lowest tillering ability when grown as sole culture compared to grown in mixture with Binadhan-13, and the highest tillering ability was when grown with Binadhan-13 in 1:1 ratio. Spatial arrangement and cultivar mixture ratio interacted significantly to produce tillers of BRRI dhan49 (Table 2). BRRI dhan49 exhibited the maximum tillering potentiality when grown with Binadhan-13 in 1:1 ratio planted in alternate hill and the lowest tillering ability was when grown as sole crop.

Among the yield contributing characters, only number of effective tillers hill^{-1} was significantly affected by spatial arrangement while grains panicle^{-1}, 1000-grain weight and grain weight hill^{-1} were not (Table 4). Alternate hill resulted in higher number of effective tillers hill^{-1} compared to alternate row. All the yield contributing characters except thousand grain weight and grain weight hill^{-1} were significant for cultivar mixture ratio at different growth stages as shown in Table 4. It is evident from the result that cultivar mixture produced a positive effect on number of effective tillers hill^{-1} and grains panicle^{-1}of BRRI dhan49. Both the yield contributing characters were found the lowest when BRRI dhan49 was grown as sole crop but they were recorded the highest when grown in mixture with Binadhan-13 following 1:1 ratio. Although some other mixture ratios also resulted in statistically similar values. All the mixture ratios produced statistically higher grain weight hill^{-1} than sole culture which confirms a positive influence of cultivar mixture strategy on the productivity of BRRI dhan49.

Total Yield

Combined effect of spatial arrangement and cultivar mixture ratio was found significant for total grain yield of rice. Grain yield ranged from 3.54 to 5.33 t ha^{-1} among different treatment combinations. The highest grain yield was recorded when Binadhan-13 and BRRI dhan49 were grown in 1:1 ratio following either alternate row or alternate hill arrangements. On the other hand, cultivation of Binadhan-13 as a sole crop produced the lowest grain yield of only 3.54 t ha^{-1} statistically followed by that obtained from the mixed culture of Binadhan-13 and BRRI dhan49 grown in 3:2 ratio in either of the spatial arrangements (Fig. 1).

Weed composition and pressure

Six weed species belonging to six families infested the experimental field. Based on their morphology, the following groups were distinguished: broadleaved, grass and sedges. Among the six weed species, four were broadleaved, one grass and one sedge. Common name, scientific name, family name, morphological type and summed dominance ratio (SDR%) of the weeds found in plots are presented in Table 5. Based on the summed dominance ratio (SDR%) values, broadleaved weed species *Monochoria vaginalis* (SDR of 71.30%) was the predominant species in the experimental field, and another broadleaved weed *Nymphaea nouchali* emerged as second most dominant weed species (SDR 13.05%), while the least dominant species was *Ludwigia hyssopifolia* (SDR 2.70%).

Weed density was not significantly affected by the spatial arrangement but affected by cultivar mixture ratios at both 4 and 7 weeks after transplanting (WAT) (Table 6). At 4 WAT, weed density ranged from 52.5 to 56.5 m^{-2}. Weed density was recorded the highest when Binadhan-13 and BRRI dhan49 were planted in 1:2 ratio statistically followed by 2:4 ratio and sole Binadhan-13. The lowest weed density, on the other hand was observed when Binadhan-13 and BRRI dhan49 were planted in 3:2 ratio statistically followed by many other ratios. Weed density at 7 WAT also followed the similar trend. Interaction between spatial arrangement and cultivar mixture ratio interacted significantly for weed density only at 7 WAT (Table 7). At 7 WAT, weed density ranged from 40.33 to 46.33 m^{-2}. The maximum

weed density was recorded when Binadhan-13 and BRRI dhan49 were grown in 2:1 ratio following alternate hill which was statistically similar to those produced by many other interactions. On the other hand, the maximum weed density at 7 WAT was recorded when Binadhan-13 and BRRI dhan49 were planted in 2:4 ratio following alternate hill arrangement.

Only cultivar mixture ratio significantly affected weed dry weight at both the observation dates while spatial arrangement and interaction effect were non- significant (Table 6). At 4 WAT, weed dry weight ranged from 33.67 to 45.33 g m^{-2}. Binadhan-13 and BRRI dhan49 planted in 1:1 ratio allowed the lowest weed growth which was statistically similar to that produced by 2:4 ratio. At 7 WAT, weed dry weight ranged from 29.17 to 32.67 g m^{-2}. Maximum weed growth was recorded when Binadhan-13 and BRRI dhan49 were grown in 1:2 ratio followed by 2:1, 2:4 ratios and sole Binadhan-13. The least weed dry weight was observed when Binadhan-13 and BRRI dhan49 were grown in 3:2 ratio statistically followed by 4:2, 1:1 and 2:3 ratios.

Table 3. Effect of spatial arrangement and cultivar mixture ratio on yield contributing characters and yield of Binadhan-13

Treatments	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	1000-grain weight (g)	Grain weight hill^{-1} (g)
Spatial arrangement				
Alternate row	9.74b	131.27	19.15	24.51b
Alternate hill	10.21a	130.96	19.18	25.20a
$S\bar{x}$	0.082	0.438	0.041	0.191
Level of significance	**	NS	NS	**
Cultivar mixture ratio (Binadhan-13:BRRI dhan49)				
Sole Binadhan-13	9.533c	128.0b	19.00	23.17b
1:2	10.13ab	130.5ab	19.22	25.17a
2:1	9.817bc	130.3ab	19.22	24.64a
2:3	10.17ab	132.6a	19.17	25.46a
3:2	9.783bc	132.3a	19.10	24.73a
2:4	9.950abc	130.8a	19.22	25.03a
4:2	10.00abc	132.7a	19.20	25.12a
1:1	10.45a	131.7a	19.23	25.55a
$S\bar{x}$	0.164	0.876	0.082	0.381
Level of significance	**	**	NS	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).
** =Significant at 1% level of probability,* =Significant at 5% level of probability, NS = Not significant.

Table 4. Effect of spatial arrangement and cultivar mixture ratio yield contributing characters and yield of BRRI dhan49

Treatments	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	1000-grain weight (g)	Grain weight hill^{-1} (g)
Spatial arrangement				
Alternate row	7.57b	135.04	22.23	26.73
Alternate hill	7.79a	135.44	22.32	27.14
$S\bar{x}$	0.042	0.349	0.045	0.225
Level of significance	**	NS	NS	NS
Cultivar mixture ratio (Binadhan-13:BRRI dhan49)				
Sole BRRI dhan49	7.067d	131.3b	22.40	25.48b
1:2	7.550c	136.1a	22.32	26.90a
2:1	7.533c	134.5a	22.33	26.37ab
2:3	7.917ab	136.3a	22.32	27.69a
3:2	7.750bc	136.5a	22.13	27.25a
2:4	7.617c	136.0a	22.10	26.85a
4:2	7.917ab	135.3a	22.25	27.83a
1:1	8.117a	135.8a	22.38	27.13a
$S\bar{x}$	0.085	0.699	0.089	0.449
Level of significance	**	**	NS	*

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).
** =Significant at 1% level of probability,* =Significant at 5% level of probability, NS = Not significant.

Table 5. Weed species composition and dominance pattern

Sl. No.	Common name	Scientific name	Family name	Type	Relative density (%)	Relative dry weight (%)	Summed dominance ratio (%)
1	Panikachu	*Monochoria vaginalis*	Pontederiaceae	Broadleaf	68.2	74.4	71.30
2	Panishapla	*Nymphaea nouchali*	Nymphaceae	Broadleaf	14.8	11.3	13.05
3	Shama	*Echinochloa crusgalli*	Poaceae	Grass	5.8	6.5	6.15
4	Amrul	*Oxalis corniculata*	Oxalidaceae	Broadleaf	4.3	2.6	3.45
5	Sabuj nakful	*Cyperus diformis*	Cyperaceae	Sedge	2.9	3.8	3.35
6	Panilong	*Ludwigia hyssopifolia*	Onagraceae	Broadleaf	4.0	1.4	2.70

Table 6. Effect of spatial arrangement and cultivar mixture ratio on weed density and weed dry weight at different growth stages of rice

Treatments	Weed density (no. m^{-2})		Weed dry weight (g m^{-2})	
	4 WAT	7 WAT	4 WAT	7 WAT
Spatial arrangement				
Alternate row	53.96	43.25	37.37	30.59
Alternate hill	54.51	43.85	37.44	31.11
$S\bar{x}$	0.351	0.274	0.304	0.264
Level of significance	NS	NS	NS	NS
Cultivar mixture ratio (Binadhan-13:BRRI dhan49)				
Sole Binadhan-13	55.33ab	44.67ab	39.67b	32.00a
Sole BRRI dhan49	54.00bc	43.67bc	37.50c	31.33ab
1:2	56.50a	45.67a	35.83c	32.67a
2:1	54.83abc	44.67ab	37.83bc	32.00a
2:3	53.00bc	42.17c	33.67d	29.83bc
3:2	52.50c	41.83c	36.83c	29.17c
2:4	55.17ab	44.50ab	33.83d	31.50ab
4:2	53.50bc	42.50c	36.17c	29.83bc
1:1	53.33bc	42.33c	45.33a	29.33c
$S\bar{x}$	0.743	0.580	0.644	0.558
Level of significance	**	**	**	**

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).
NS = Not significant; ** =Significant at 1% level of probability.
WAT= weeks after transplanting of rice.

Table 7. Interaction effect of spatial arrangement and cultivar mixture ratio on weed density and weed dry weight at different growth stages of rice

Interaction		Weed density (no. m^{-2})		Weed dry weight (g m^{-2})	
Spatial arrangement	Binadhan-13: BRRIdhan49	4 WAT	7 WAT	4 WAT	7 WAT
Alternate row	Sole Binadhan-13	55.33	44.67abcd	39.67	32.00
	1:2	53.67	43.33bcde	36.67	31.00
	2:1	55.67	45.00abc	35.33	32.00
	2:3	54.33	44.33abcd	38.33	32.00
	3:2	53.33	42.00def	33.67	29.67
	2:4	53.67	43.33bcde	37.33	30.33
	4:2	54.67	43.67abcd	34.33	30.67
	1:1	51.67	40.67ef	35.67	28.33
	Sole BRRI dhan49	53.33	42.33cdef	45.33	29.33
Alternate hill	Sole Binadhan-13	55.33	44.67abcd	39.67	32.00
	1:2	54.33	44.00abcd	38.33	31.67
	2:1	57.33	46.33a	36.33	33.33
	2:3	55.33	45.00abc	37.33	32.00
	3:2	52.67	42.33cdef	33.67	30.00
	2:4	51.33	40.33f	36.33	28.00
	4:2	55.67	45.33ab	33.33	32.33
	1:1	55.33	44.33abcd	36.67	31.33
	Sole BRRI dhan49	53.33	42.33cdef	45.33	29.33
$S\bar{x}$		1.05	0.821	0.911	0.789
Level of sig.		NS	*	NS	NS

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).
* =Significant at 5% level of probability, NS = Not significant.

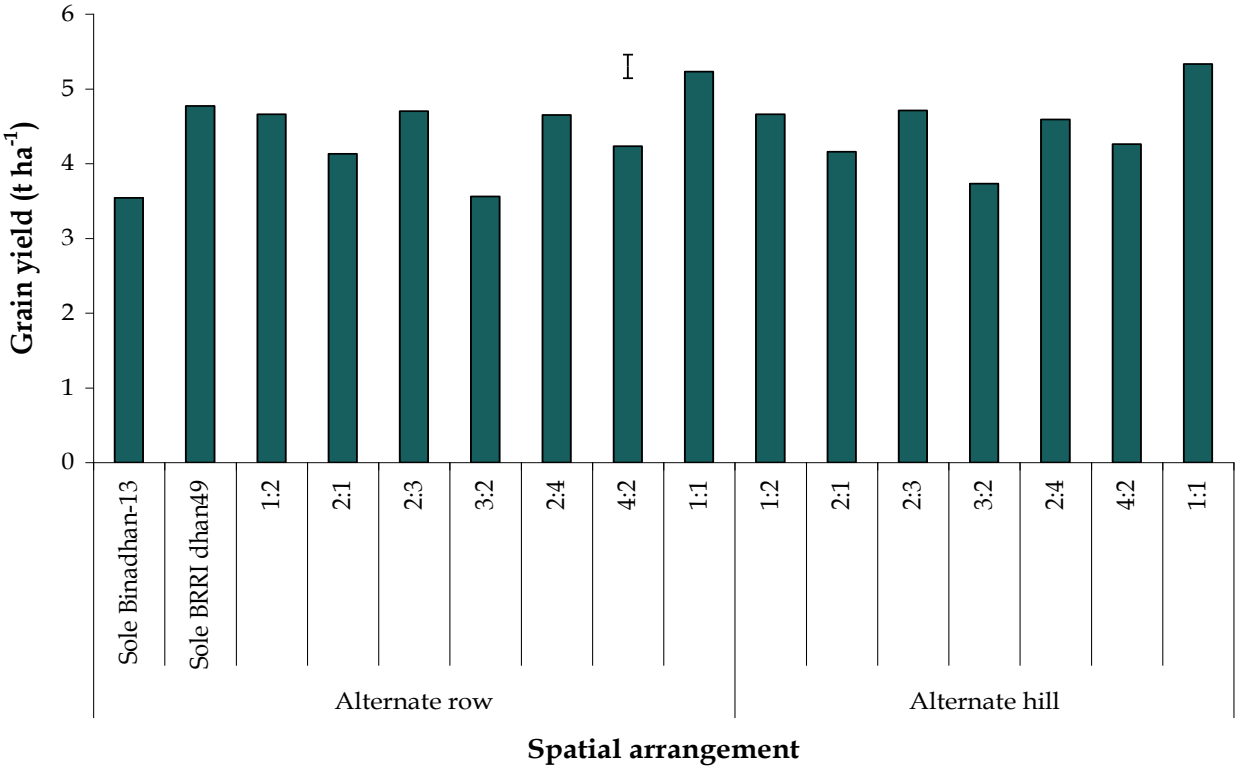

Fig. 1. Effect of spatial arrangement and cultivar mixture ratio on grain yield of rice

Discussion

In this study Binadhan-13 and BRRI dhan49 were transplanted in different spatial arrangement and cultivar mixture ratios to study their growth and yield performance and weed suppressive ability. Due to wide variation in agronomic traits between the cultivars, it was hypothesized that the demand for resources would occur in different times and one cultivar will provide physical support to other to prevent lodging. Advantages of mixed culture of rice cultivars over sole culture in terms of growth and yield are evident from the study. Based on the combined rice grain yield, the best row mixture ratios were in the order 1:1, 1:2 and 2:4 Binadhan-13 to BRRI dhan49. Cultivar mixture also suppressed weed growth better than sole culture of either cultivar. These findings are in conformity with those of many researchers (Rodriguez, 2006; Bahani *et al.*, 2014; Jareen, 2018) who confirmed that growing rice cultivars in mixture improves rice yield.

In this study, yield of both Binadhan-13 and BRRI dhan49 were increased when inter-planted compared to their mono-culture. This might be due to the facilitation effect as mentioned by Garcia and Barrios (2003). Facilitation occurs when one component cultivar benefits another component by providing physical support (like by preventing lodging), improving microclimate, ameliorating abiotic stresses and minimizing different biotic stresses (Callaway, 1995). Although lodging of the rice cultivars and any changes in microclimate due to cultivar mixture were not monitored in this study, but weed growth was studied. As weed biomass was reduced in cultivar mixture than in sole culture of either cultivar, therefore, facilitation effect applies here. Moreover, higher resistance to lodging of tall cultivar Binadhan-13 in mixture due to physical support provided by short cultivar BRRI dhan49 might also contribute to increased combined yield of mixture.

The mechanism which is mostly applicable here is complementary use of resources by the cultivars as mentioned by Willey (1979). 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 and Trenbath, 1993). Complementarity occurs when component cultivars vary in their architectures and growth duration. In this study, Binadhan-13 took 145 days to mature while BRRI dhan49 matured only in 135 days. They 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. As stated by many

researchers (Binang *et al*., 2010; Jareen, 2018) mixture ratio influences competitiveness of component cultivars and ultimately the yield. Kalu *et al*. (1998) on the contrary, opined that varying spatial arrangements determined plant population of each component cultivar that ultimately affected the combined yield of the mixture. As stated by Binang *et al*. (2011), in mixture all the component cultivars enjoy greater capacity to adjust under different limited resources and various stresses resulting higher yield than sole culture.

Findings of the present study also confirm that cultivars grown in mixtures suppress weed better than sole culture of respective cultivar. Similar findings have been reported by many researchers (Estavan, 2006; Binang *et al.*, 2010, 2011; Jareen, 2018). As reported by Jedel *et al*. (1988), cultivar mixture resulted in taller plants compared to sole culture due to intra-specific competition for resources especially for solar radiation. Taller plants suppress weeds better than dwarf plants as reported by many researchers (Anwar *et al.*, 2010; Juraimi *et al.*, 2013; Rahman *et al*., 2017; Arefin *et al*., 2018; Shabi *et al*., 2018). In our study, plant height of Binadhan-13 and BRRI dhan49 were recorded higher in different mixtures than in sole culture which might help reduce weed growth.

Higher number of tillers in cultivar mixture compared with respective sole culture might also contribute to reduce weed growth. Apart from taller plants, high tillering ability also is a good measure of plant vigor which enhances plant competitiveness against weeds as mentioned by Binang *et al. (*2011). Fischer *et al.* (1995) also opined that tillering affects competitive ability of rice against weeds through changes in leaf area index and canopy coverage. Although, contrasting findings have also been reported (Anwar *et al*., 2010). High tillering resulted in faster canopy coverage which prevent sunlight from reaching the underlying weeds and thereby smothering the weeds (Binang *et al*., 2011). However, the competitive effect of cultivar mixtures against weeds depends on several factors including plant architecture, growth behavior, weed species composition, botanical characteristics of weeds, agronomic management and agro-ecological conditions among others (Jareen, 2018).

Thus, findings of the present study confirms the advantages of inter-planting Binadhan-13 and BRRI dhan49 over their sole culture and therefore cultivar mixture could be considered as a sustainable option for increasing rice productivity. Binadhan-13 and BRRI dhan49 inter-planted in 1:1 ratio appeared as the best mixture ratio which resulted in 50% and 12% yield advantages over sole culture of Binadhan-13 and BRRI dhan49, respectively. However, further site specific research is required by including potential rice varieties other agronomic management factors before adoption of this strategy.

Conclusion

Based on the combined rice grain yield, spatial arrangement and different cultivar mixture ratios performed in Binadhan-13 to BRRI dhan49, Binadhan-13 and BRRI dhan49 inter-planted in 1:1 ratio appeared as the best mixture ratio which resulted in 50% and 12% yield advantages over sole culture of Binadhan-13 and BRRI dhan49 respectively. Weed density and dry weight were significantly affected by the rice cultivar mixture ratio and spatial arrangement. The highest weed density and dry weight were found in Binadhan-13+BRRI dhan49 transplanted in 1:2, 2:4 and sole Binadhan-13 and the lowest values were found in Binadhan-13+BRRI dhan49 transplanted in 3:2 row ratio. Thus, no clear advantages of growing cultivars in mixture over monoculture of a single cultivar in suppressing weeds was evident. It may therefore be concluded that spatial arrangement and cultivar mixture ratio strategy can be practiced as a tool for increased yield of rice. Based on the findings of this experiment, it is recommended to grow Binadhan-13 and BRRI dhan49 in 1:1 ratio following alternate hill planting for better yield of T. *aman* rice.

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