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Temporal deployment of cultivar mixture suppresses weed and enhances rice 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 weed growth and thus enhances crop yield. The objective of this study was to evaluate the potentiality of growing rice cultivars in mixtures in temporal dimension for minimizing weed pressure and increasing rice yield and to determine the best time of introduction of one cultivar in relation to another cultivar. The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during *aman* season (July-December) 2017. Two transplanted *aman* rice cultivars having different plant height and growth duration viz. Binadhan-13 (tall, late- maturing and fine grained aromatic rice cultivar) and BRRI dhan49 (semi-dwarf, mid-maturing and coarse grained rice cultivar) were used in this study. The experiment comprised time of introduction of BRRI dhan49 namely 7 days before Binadhan-13, 7 days after Binadhan-13, same day as Binadhan-13, Binadhan-13 as sole crop, BRRI dhan49 as sole crop and three different weeding regime namely weedy, recommended weeding and weed free. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Both the cultivars showed better growth and higher yield when grown in mixture rather than sole culture. Transplanting of one cultivar before or after another cultivar produced more yield and suppressed weed better than transplanting of two cultivars on the same day. Thus only spatial arrangement produced no advantages over sole culture. Among the weeding regimes, weedy treatment performed the worst, while recommended weeding and weed free treatment performed similarly. Therefore, for better weed suppression and higher production, BRRI dhan49 may be transplanted 7 days before or after Binadhan-13 in 1:1 ratio following recommended weeding.

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Introduction

Weeds are the greatest yield limiting constraint to rice because weeds compete with rice for above and below ground resources like light, water and nutrients (Khan et al. 2017). This competition decreases plant vigor, yield and crop quality. On average, rice yield loss due to weed ranges from 15 to 20%, but in severe cases the yield loss may exceed 50% or even 100% (Anwar et al. 2010). In Bangladesh, rice yield losses due to weeds were estimated as 70-80% in *Aus* rice, 30-40% in transplant *Aman* rice and 22-36% in *Boro* rice (BRRI, 2016).

Cultivar mixtures refer to mixture of cultivated varieties growing simultaneously on the same piece of land with no attempt to breed for phenotype uniformity (Mundt, 2002). They vary for many characteristics, but have sufficient similarity to be grown together. Several reports on this strategy has proved that it helps to control pest, disease, weed and resist lodging. Mixing cultivars can enhance functional diversity and improve yield by providing more chances for positive interactions among cultivars (Castilla et al. 2003). 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. Furthermore, inter-planting cultivars offers a unique opportunity for on-farm conservation of genetic resources by allowing farmers to grow widely adopted traditional rice cultivars.

Temporal deployment of cultivar mixtures refers to the modification of time of transplanting of different cultivars in which seedlings of one cultivar are transplanted on a fixed date and seedlings of another cultivar are transplanted on different dates of transplanting. Modifications in time and temporal deployment of crops grown in association can enhance the compatibility of mixtures and make the system more efficient. Binang et al. (2011) reported that temporal deployment of rice cultivar mixtures affected weed suppressive ability of component mixtures, and both spatial and temporal deployment improved grain yield of rice. Reduction of weed growth due to cultivar mixture is well established. Cultivar mixtures can improve the competitive ability of rice reducing weed biomass production and diminishing rice biomass losses (Jareen et al. 2019; Al-Amin et al. 2019; Sultana et al. 2019). Binang et al. (2011) concluded from their study with lowland rice that cultivars grown in mixture can reduce weed dry matter production by enhancing competitive ability of rice. Rodríguez (2006) also opined that cultivar mixture could improve the competitive ability of crop against weed and he 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 environmental pollution. During the last few decades several studies have been conducted to manage the weed in rice fields considering different chemical, physical, cultural and biological methods. But temporal deployment of cultivar mixture effect on weed growth and rice productivity has not been properly addressed as a sustainable tool. With these end in view, an experiment was undertaken to assess the impact of temporal deployment of rice cultivar mixture on weed growth and rice yield and to determine the best time of introducing interplanted rice cultivar for better weed suppression and higher rice productivity.

Materials and Methods

Experimental Duration and Site

The experiment was conducted during the period from July to December in the *Aman (rainy)* season at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh (24° 75' N latitude and 90° 50' E longitude and at an altitude of 18 meter above the sea level). The experimental area belongs to the non-calcareous dark grey soil under Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9). The land was medium high with silty-loam texture. The soil of the experimental field was more or less neutral in reaction (pH 6.8), low in organic matter content (1.2%) and the general fertility level was moderate. The climate of the experimental site was sub-tropical. 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 33.4°C, 14.5°C, 26.7°C, 84.3%, 174.8 mm, and 168.2 h, respectively.

Experimental Treatments and Design

The experiment comprised two factors namely, temporal deployment of rice cultivar mixture and weeding regime. Temporal deployment (time of transplanting of BRRI dahn49 in relation to Binadhan-13) included i) One week before Binadhan-13 ii) Same day as Binadhan-13, iii) One week after Binadhan-13, iv) Binadhan-13 as sole crop and v) BRRI dhan49 as sole crop; weeding regime included i) weedy ii) recommended weeding (Three hand weeding at 30, 45 and 60 days after transplanting) and iii) weed free. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Thus total number of plot was 45. Each plot size was 4.0 × 2.5 m.

Plant Materials Used

Two high yielding Transplant Aman rice varieties were used as plant materials in this study. A brief description of those has are as follows:

Binadhan-13: The mutant KD5-18-150 was released as Binadhan-13 by Bangladesh Institute of Nuclear Agriculture (BINA). It is a fine grain aromatic rice cultivar suitable for cultivation in transplant *Aman* (T. *Aman*) season in Bangladesh. It has been developed from local fine grain aromatic rice cultivar kalizira with the application of gamma radiation and Datura (*Datura metel*) extract. It is a tall cultivar with average plant height of 160 cm and average thousand grain weight is 13.2 g. It takes about 138-142 days to mature. It produces average grain yield of 3.5 t ha^{-1}.

BRRI dhan49: BRRI dhan49 was developed by Bangladesh Rice Research Institute (BRRI) and was released for cultivation in T. *aman* season. It is a moderate salinity tolerant (8-10ds/m up to 3 weeks) variety. It takes about 110 days to mature. It attains a plant height of 100 cm. Its average thousand grain weight is 23.6 g. The grains are medium bold to medium slender with light golden husks and kernels are white in color. Grain protein content is 8.3%. It gives an average grain yield of 5.5 t ha^{-1}.

Crop husbandry

The experimental field was prepared by a power tiller 15 days before transplanting followed by puddling by a country plough and laddering to make the soil ready for transplanting. The field was fertilized with 200 kg, 60 kg, 100 kg 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 final tillage. Urea was top dressed in three equal splits, at 15, 30 and 45 days after transplanting (DAT). Seedlings of Binadhan-13 were transplanted on 10^{th} August. Seedlings of BRRI dhan49 were transplanted on 3^{rd}, 10^{th} and 17^{th} August as per treatment requirement at the rate of three seedlings $hill^{-1}$ maintaining row and hill distance of 25 cm and l5 cm, respectively. In case of mixed cultivation, Binadhan-13 and BRRI dhan49 were planted in alternate row following mixture ratio of 1:1. Seedling age during transplanting was 30 days. Weeding was done as per treatment. Due to sufficient rainfall during the growing season, crop was grown as rainfed. There were no remarkable infestations by insect pests or diseases during the crop growth period. Therefore, no plant protection measures were taken.

Observations made

Plant height and tillers number per hill for each variety were recorded from randomly selected five hills at 5, 7 and 9 week after transplanting (WAT) and at harvest. Weed species were identified and weed density and dry weight were recorded at 5 and 7 WAT. Dominant weed species were identified based on summed dominance ratio [(relative density + relative dry weight)/2]. The crops were harvested at full maturity. BRRI dhan49 was matured at different times and harvested on 20th, 25th and 30th November. Binadhan-13 was harvested on 7th December. The grains were cleaned, dried and finally the weight was adjusted to a moisture content of 14%. The straw were sun dried. Grain and straw yields of both the cultivars were finally converted to t ha^{-1}.

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 at 5% level of probability.

Results and Discussion

Growth of rice

Rice growth was evaluated in terms of plant height and tillering ability at harvest. Plant height and tillering ability of both the rice cultivars were significantly affected by time of introduction of BRRI dhan49 and weeding regime (Table 1), but not by their interaction (data not shown). Temporal deployment of cultivar mixture showed a positive influence on rice growth. It is evident from the result that plant height and tillering ability of both Binadhan-13 and BRRI dhan49 were higher when the cultivars were grown in mixture in temporal dimension compared to sole cropping or transplanting on the same day (spatial dimension). Weeding regime also exerted significant influence on the growth of rice cultivars. Weedy condition resulted in the shortest plants and lowest tillering ability in both the cultivars. Weed free condition and recommended weeding practice were found statistically similar for plant height. In case of tiller production, on the other hand, weed free condition performed better than recommended weeding (Table 1). In the present study, two contrasting rice cultivars namely Binadhan-13 (>160 cm tall, fine grain and matures by 140 days) and BRRI dhan49 (<120 cm tall, coarse grain and matures by only 110 days) were inter-planted (1:1 row ratio) in different temporal dimension for obtaining the maximum benefit of cultivar mixture in terms of rice growth, yield and weed suppression. It was hypothesized that contrasting traits of both the cultivars will ensure the maximum utilization of the resources which will ultimately be translated into reduced weed growth and increased yield. Advantages of mixed culture of rice cultivars in temporal dimension over sole culture in terms of growth, yield and weed suppression are evident from our study. Growth of both the rice cultivars were monitored in terms of plant stature and tillering ability in the present study. Temporal deployment of rice cultivars enhanced plant height and increased tillering ability of both the cultivars; although transplanting of

BRRI dhan49 before or after Binadhan-13 resulted in similar effect. But, planting of both the cultivars on the same day did not produce any positive effect on plant height and tillering ability as compared with monoculture of either variety, which indicates no advantage of spatial deployment. This was mostly due to the complementary use of resources by the cultivars as mentioned by Jareen et al. (2019) and Al-Amin et al. (2019). When more than one cultivars are grown in mixture, above- and below-ground resources are utilized better than their sole culture because component cultivars differ in their resource use patterns (Fukai and Trenbath, 1993). Complementarity effect works only when component cultivars vary in their plant architectures and growth duration. Here, Binadhan-13 matured by 140 days, BRRI dhan49, on the contrary matured by only 110 days; moreover, Binadhan-13 was much taller than BRRI dhan49 which ensured better utilization of the resources in mixed culture which ultimately translated into increased plant stature and tillering ability.

Table 1. Effect of time of introduction of BRRI dhan49 and weeding regime on plant height and Total tillers hill^{-1} of BRRI dhan49 and Binadhan-13 at harvest.

Time of introduction of BRRI dhan49	BRRI dhan49		Binadhan-13	
	Plant height (cm)	Total tillers hill^{-1}	Plant height (cm)	Total tillers hill^{-1}
7 days before Binadhan-13	115.2 a	9.567 a	165.4 a	12.21 a
7 days after Binadhan-13	115.1 a	9.656 a	165.6 a	12.22 a
Same day as Binadhan-13	110.7 b	8.989 b	160.7 b	11.53 b
Sole	108.0 b	8.933 b	158.1 b	11.46 b
$S\bar{x}$	1.39	0.191	1.47	0.198
Level of significance	**	*	**	**
CV (%)	3.70	6.17	2.71	4.99
Weeding regime				
Weedy	104.1 b	7.117 c	154.4 b	10.43 c
Recommended Weeding	115.8 a	10.02 b	165.8 a	12.23 b
Weed free	116.8 a	10.72 a	167.1 a	12.92 a
$S\bar{x}$	1.20	0.165	1.27	0.171
Level of significance	**	**	**	**
CV (%)	3.70	6.17	2.71	4.99

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,

Yield attributes of rice

Among the yield attributes, number of effective tillers hill^{-1} and 1000-grain weight of both the cultivars were significantly affected by temporal deployment of cultivar mixture, but number of grains panicle^{-1} was found independent (Tables 2 and 3). Interaction effect was insignificant for all the yield attributes of both the cultivars but not by their interaction (data not shown). Introduction of BRRI dhan49 before and after 7 days of Binadhan-13 resulted in statistically similar number of effective tillers hill^{-1} and 1000-grain weight of both the cultivars and those were significantly higher than the respective values recorded in sole culture or transplanting on the same day. Weeding regime significantly affected all the yield parameters of both BRRI dhan49 and Binadhan-13 (Tables 2 and 3). As expected, weed free condition performed the best in terms of yield attributes of rice. Although, weed free condition and recommended weeding resulted in similar number of grains panile^{-1} and 1000-grain weight of either cultivar, but a significant advantage of weed free condition over recommended weeding was evident for number of effective tillers hill^{-1}. Weedy condition, on the other hand, performed the worst for all the yield attributes of BRRI dhan49 and Binadhan-13.

Table 2. Effect of time of introduction of BRRI dhan49 and weeding regime on yield contributing characters of Binadhan-13.

Time of introduction of BRRI dhan49	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	1000-grain weight (g)
7 days before Binadhan-13	9.389 a	122.9	18.39 a
7 days after Binadhan-13	9.511 a	126.0	18.26 a
Same day as Binadhan-13	8.822 b	120.7	17.40 b
Sole Binadhan-13	8.778 b	118.3	17.18 c
$S\bar{x}$	0.185	2.70	0.071
Level of significance	**	NS	**
CV (%)	6.07	6.64	1.20
Weeding regime			
Weedy	8.300 c	114.2 b	16.12 c
Recommended Weeding	9.192 b	122.9 a	18.53 a
Weed free	9.883 a	128.8 a	18.77 a
Sx	0.160	2.34	0.062
Level of significance	**	**	**
CV (%)	6.07	6.64	1.20

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 components, number of panicle bearing tillers hill^{-1} and weight of thousand grains of both the rice cultivars were favored by the temporal deployment of cultivar mixture, but number of grains panicle^{-1} was not. Planting both the cultivars on the same day and sole culture of either cultivar produced similar effect on yield parameters which confirms no advantages of spatial deployment of cultivars on yield attributes of rice. On the other hand, planting of BRRI dhan49 before or after Binadhan-13 performed similarly in terms of yield attributes of rice. When two cultivars are grown in mixture, both the component cultivars enjoy greater capacity to adjust under different limited resources and various biotic and abiotic stresses resulting in better performance than sole culture (Binang et al. 2011). In case of grain weight hill^{-1}, a clear advantage of temporal deployment of rice cultivar mixture is evident, although like yield components, planting of BRRI dhan49 before or after Binadhan-13 resulted in similar grain weight hill^{-1}. Moreover, sole culture of Binadhan-13 or BRRI dhan49 and planting both the cultivars in mixture on the same day performed equally in terms of grain weight hill^{-1}. This confirms that only spatial arrangement is not enough to achieve the benefit of cultivar mixture until and unless temporal deployment is imposed. Similar findings have also been reported by Binang et al. (2011) who opined that spatial arrangement of rice did not influence the productivity of the system.

Table 3. Effect of time of introduction of BRRI dhan49 and weeding regime on yield contributing characters of BRRI dhan49.

Time of introduction of BRRI dhan49	No. of effective tillers hill^{-1}	No. of grains panicle^{-1}	1000-grain weight (g)
7 days before Binadhan-13	8.356 a	132.0	25.56 a
7 days after Binadhan-13	8.478 a	132.3	25.42 a
Same day as Binadhan-13	7.789 b	128.4	24.57 b
Sole BRRI dhan49	7.744 b	127.1	24.34 b
S$\bar{x}$	0.066	2.03	0.264
Level of significance	**	NS	**
CV (%)	2.45	4.69	3.17
Weeding regime			
Weedy	7.267 c	122.2 b	23.28 b
Recommended Weeding	8.158 b	131.4 a	25.70 a
Weed free	8.850 a	136.3 a	25.93 a
Sx	0.057	1.76	0.228
Level of significance	**	**	**
CV (%)	2.45	4.69	3.17

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.

Yield performance of rice

Time of introduction of BRRI dhan49 significantly affected grain weight hill^{-1} of Binadhan-13 and BRRI dhan49. It is evident from the result that grain weight hill^{-1} of Binadhan-13 and BRRI dhan49 were higher when grown in mixture with BRRI dhan49 compared to their respective sole culture. Grain weight hill^{-1} was recorded the maximum when BRRI dhan49 was transplanted 7 days after Binadhan-13, while the minimum grain weight hill^{-1} was found in sole culture (Figures 1 and 2). Like temporal deployment of cultivar mixture, weeding regime also exerted significant influence on grain weight hill^{-1} of both Binadhan-13 and BRRI dhan49 (Figures 3 and 4). Results show that grain weight hill^{-1} was maximum at weed free condition and minimum at weedy condition. Recommended weeding, on the other hand produced intermediate value. Interaction between temporal deployment and weeding regime failed to produce any significant effect on grain weight hill^{-1} of rice (data not shown). As expected, season-long weedy performed the worst in terms of plant height and tillering capacity of both the varieties. In case of plant height, recommended weeding and season-long weed free treatments resulted in statistically similar plant stature. Tilllering ability, on the other hand, was observed higher in case of weed free treatment than in recommended weeding. All the yield components and grain weight hill^{-1} of both Binadhan-13 and

BRRI dhan49 were significantly influenced by weeding regimes. Season-long weedy condition performed the worst as expected. In case of Binadhan-13, weed free regime performed better than recommended weeding for yield components, but for BRRI dhan49, no advantage of season-long weed free condition over recommended weeding was observed. On the other hand, season-long weed free produced higher grain weight hill^{-1} than recommended weeding in case of both the cultivars, which requires further in depth research to reconfirm whether or not the recommended weed management is enough to ensure potential yield of the rice varieties studied.

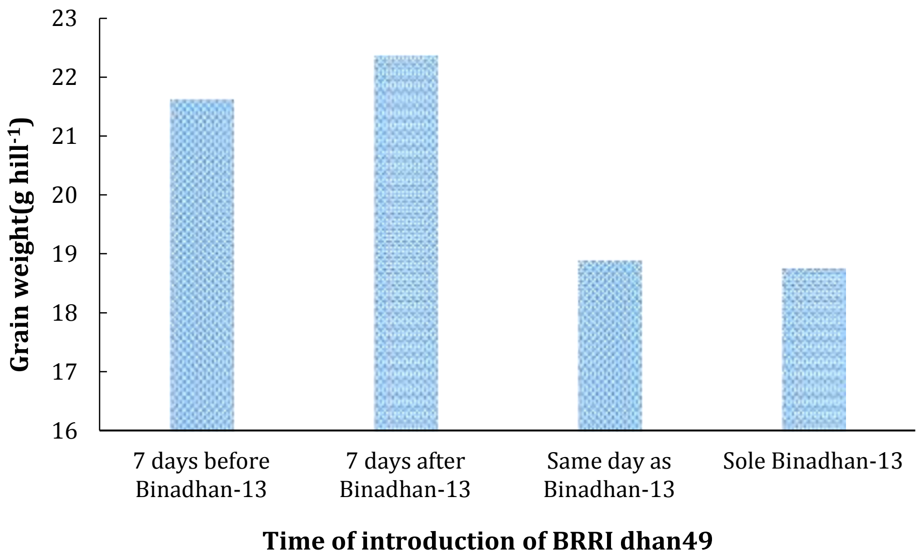

Figure 1. Effect of time of introduction of BRRI dhan49 on grain weight hill^{-1} of Binadhan-13.

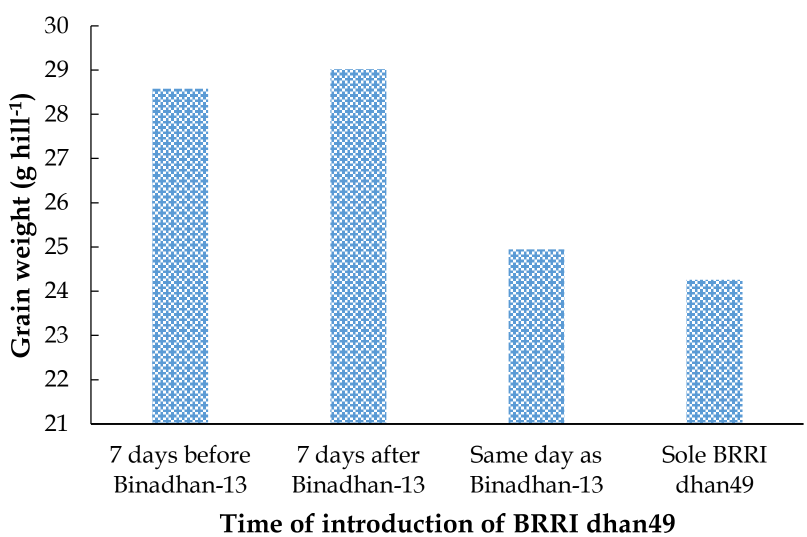

Figure 2. Effect of time of introduction of BRRI dhan49 on grain weight hill^{-1} of BRRI dhan49.

Combined effect of weeding regime and time of introduction of BRRI dhan49 was found significant for total rice yield (Binadhan-13 + BRRI dhan49). Grain yield ranged from 1.73 to 5.23 t ha^{-1}. The highest grain yield was recorded when BRRI dhan49 was grown in sole culture under weed free condition. On the other hand, cultivation of Binadhan-13 as a sole crop in weedy condition produced the lowest grain yield of only 1.73 t ha^{-1}. In general, mixture of cultivars resulted in higher grain yield compared to sole culture. It is evident that temporal deployment of cultivar mixture has a clear advantage over spatial deployment (cultivars transplanted on same day) (Figure 5).

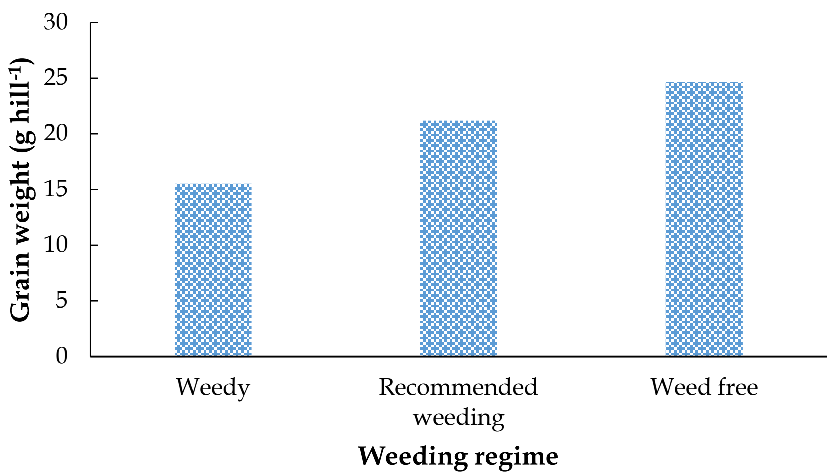

Figure 3. Effect of weeding regime on grain weight hill^{-1} of Binadhan-13.

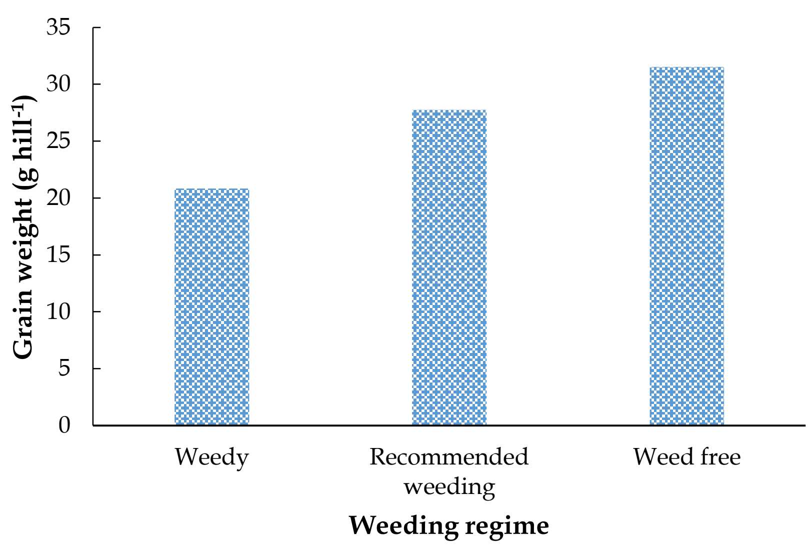

Figure 4. Effect of weeding regime on grain weight hill-1 of BRRI dhan49.

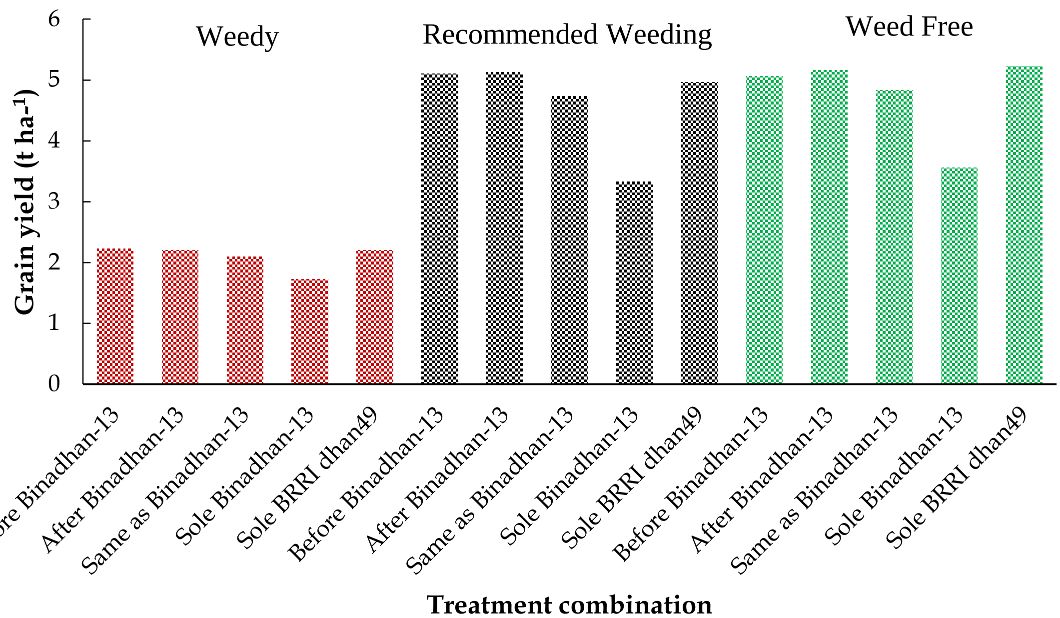

Figure 5. Total rice yield (Binadhan-13 and BRRI dhan49) as influenced by weeding regime and time of introduction of BRRI dhan49.

Weed Community and Weed Growth

Weed floristic composition

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 4. The experimental field was mostly infested with broadleaved weeds followed grass and sedge weeds. Based on the summed dominance ratio (SDR%) values, broadleaved weed species *Monochoria vaginalis* (SDR of 71.45%) was the predominant species in the experimental field and another broadleaved weed *Nymphaea nouchali* emerged as second most dominant weed species (SDR 13.9%) in the experimental plots, and the least dominant weed species was another broadleaved weed *Oxalis corniculata* (SDR 2.55%). Total yield in mixed culture was recorded higher than sole culture of Binadhan-13 but similar to sole culture of BRRI dahn49. This was due to the fact that being a coarse grain cultivar (1000-grain weight = 17 g), yield potential of BRRI dhan 49 was much higher than fine grain cultivar (1000-grain weight = 28 g) Binadhan-13. Although grain weight hill^{-1} for both the cultivars were increased in mixed culture compared to sole culture, but that was not enough to increase total yield because Binadhan-13 occupied 50% space in mixture.

Table 4. Weed species composition and dominance pattern.

Sl. No.	Common name	Scientific name	Family name	Type	Relative density (%)	Relative dry weight (%)	Summed dominance ratio (%)
1	Pani kachu	*Monochoria vaginalis*	Pontederiaceae	Broadleaf	66.2	76.7	71.45
2	Pani shapla	*Nymphaea nouchali*	Nymphaceae	Broadleaf	16.8	11.0	13.9
3	Shama	*Echinochola crusgalli*	Poaceae	Grass	6.1	6.0	6.05
4	Amrul	*Oxalis corniculata*	Oxalidaceae	Broadleaf	4.0	1.1	2.55
5	Sabuj nakful	*Cyperus diformis*	Cyperaceae	Sedge	2.7	4.2	3.45
6	Panilong	*Ludwigia hyssopifolia*	Onagraceae	Broadleaf	4.2	1.0	2.60

Weed density

Effect on time of introduction of BRRI dhan49 was found significant for weed density at 7 week after transplanting (WAT) but not significant at 5 WAT (Table 5). At 7 WAT, weed density was maximum when BRRI dhan49 was planted as sole crop which was statistically followed by sole Binadhan-13 and mixture of BRRI dhan49 and Binadhan-13 transplanted on the same day and minimum when BRRI dhan49 was planted 7 days after Binadhan-13 (Table 5). Yield of both the cultivars were increased when inter-planted with temporal deployment as compared to their respective sole culture. This might be due to the facilitation effect (Garcia and Barrios, 2003) which occurs when one component cultivar benefits another component by preventing lodging, improving microclimate, minimizing different biotic and abiotic stresses (Callaway, 1995). Although neither lodging nor any changes in microclimate due to cultivar mixture was monitored here, but weed growth was measured in terms of weed density and dry matter. Since cultivar mixture reduced weed growth therefore facilitation effect might apply here. Moreover, less lodging of tall cultivar Binadhan-13 due to physical support from short cultivar BRRI dhan49 might also contribute to increased system productivity.

Weed dry weight

Effect on time of introduction of BRRI dhan49 was found significant for weed dry weight at both 5 WAT and 7 WAT (Table 5). At both stages, weed dry weight was maximum when BRRI dhan49 or Binadhan-13 was planted as sole crop while minimum when BRRI dhan49 was planted 7 days after Binadhan-13 statistically followed by 7 days before transplanting or same day. It is therefore evident from this study that cultivar mixture has a clear advantage in terms of weed suppression (Table 5). Temporal deployment of rice cultivar mixture exerted a positive effect on weed suppression by reducing both weed density and dry weight. Inter-planting of Binadhan-13 and BRRI dhan49 on the same day or different days resulted in reduced weed density and dry weight compared sole culture of either cultivar. Present study confirms that inter-planting cultivars suppress weed better than their respective monoculture. This finding is in agreement with those reported by many others (Rodriguez, 2006; Binang et al. 2011; Bahani et al. 2014; Jareen et al. 2019). In this study, Binadhan-13 and BRRI dhan49 produced taller plants when grown in mixture than their respective sole culture which might help reduce weed growth as confirmed by Juskiw et al. (2000). Taller plants have advantages over dwarf plants in suppressing weed growth has been confirmed by many researchers (Juraimi et al. 2013; Arefin et al. 2018; Shabi et al. 2018). Higher tillering ability resulted from temporal deployment of cultivar mixture also contributed to reduced weed growth. As Binang et al. *(*2011) stated, high tillering ability is a good indicator of rice plant competitiveness against weeds. Because, high tillering ensures faster canopy coverage which does not allow sunlight to reach the underlying weeds and thereby smothering the weeds. Fischer et al. (1995) on the other hand opined that enhanced tillering improves competitive ability of rice against weeds through increased leaf area index and faster canopy coverage.

Table 5. Effect of time of introduction of BRRI dhan49 on weed density and weed dry weight at different growth stages of rice.

Time of introduction of BRRI dhan49	Weed density (no. m^{-2})		Weed dry weight (g m^{-2})	
	5 WAT	7 WAT	5 WAT	7 WAT
7days before Binadhan-13	32.07	37.33 b	23.30 b	25.87 b
7 days after Binadhan-13	33.00	36.93 b	21.27 b	24.47 b
Same day as Binadhan-13	34.83	39.60 ab	24.57 b	27.77 b
Binadhan-13 as sole crop	35.23	40.87 a	29.27 a	33.20 a
BRRI dhan49 as sole crop	36.27	41.60 a	29.90 a	34.37 a
$S\bar{x}$	1.19	0.819	1.04	1.01
Level of sig.	NS	**	**	**
CV (%)	6.04	3.61	7.03	6.00

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. WAT = Week after transplanting of Binadhan-13.

Conclusion

Present findings confirm the advantages of inter-planting two rice cultivars in temporal dimension but not in spatial arrangement. Therefore, temporal deployment of cultivar mixture could be practiced for increasing rice productivity in a sustainable way. Transplanting BRRI dhan49 seven days before/after transplanting of Binadhan-13 in 1:1 ratio may be recommended for better weed suppression and higher productivity. However, further in depth research is required with other potential high yielding rice varieties considering agro-climatic conditions, and different agronomic management practices before adoption of this strategy.

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Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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