Physiological Behaviour and Yield Performances of Hybrid Rice at Different Planting Dates in *Aus* Season

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ABSTRACT

Two field experiments were conducted in 2009 and 2010 to evaluate some physiological traits and yield of three hybrid rice varieties (BRRI hybrid dhan2, Heera2, and Tia) in comparison to BRRI dhan48 in *Aus* season. The experiments involved four planting dates (1 April, 16 April, 1 May and 16 May). Compared to BRRI dhan48, hybrid varieties accumulated greater shoot dry matter at anthesis, higher flag leaf chlorophyll at 2, 9, 16 and 23 days after flowering (DAF), flag leaf photosynthetic rate at 2 DAF and longer panicles. However, hybrid varieties demonstrated smaller remobilization of shoot reserve to grain and photosynthetic rate of its flag leaf at 9 and 16 DAF than BRRI dhan48. Heera2 and BRRI hybrid dhan2 maintained significantly higher chlorophyll a:b ratio over Tia and BRRI dhan48 at 2, 9, 16 and 23 DAF in their flag leaf. Shoot reserve remobilization to grain exhibited higher degree of sensitivity to rising of minimum temperature in the studied hybrids compared to the inbred. Inefficient photosynthetic activities of flag leaf and poor shoot reserve translocation to grain resulted poor grain filling percentage in the test hybrids. Consequently the studied hybrids showed significantly lower grain yield (*ca*. 36.7%) as compared to inbred BRRI dhan48, irrespective of planting date in Aus season.

Key Words: BRRI hybrid dahn2, flag leaf, grain filling, translocation.

INTRODUCTION

Yearly increment of rice production in Bangladesh needs to be sustained to feed her ever increasing population. But there is population Yearly increment of rice production in Bangladesh needs to be sustained to feed her ever a little scope to increase rice area (Sarker *et al*., 2008) rather agricultural land is declining @1% per annum (BBS, 2011). However, the recent yield level of modern rice varieties has been reached to plateau **(**Bhuiyan, 2002**)**. For breaking the yield ceiling of conventional varieties, hybrid rice is a viable option and appropriate strategy (Kumar *et al*., 1998). It can produce 15 - 20% higher yield over the conventional semi-dwarf inbred variety (Longping, 2004 and Julfiquar, 2009). Hybrid rice has been introduced in Bangladesh during the last eight years (Masum, 2009). It has already gained positive experience in *Boro* season and drawn much attention of the stakeholders. Recently, a few hybrid varieties are also recommended and cultivated in T. *Aman* season. But report on hybrid rice cultivation in *Aus* season is scanty. So, it is needed to generate information on agronomic and physiological performance of hybrid rice varieties for extending its cultivation in *Aus* season. A non-monetary input, planting date is one of the most important factor influencing the growth and yield of rice. Planting date determines the flowering time and it greatly influences dry-matter accumulation. It is possible to increase the grain yield of hybrid rice by planting at early or optimum time of the season (Pan, *et al,* 1998 and Om, *et al.,* 1996). Under these circumstances, the present study was undertaken to evaluate some physiological characteristics and yield of hybrid rice varieties at different planting dates in *Aus* season.

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MATERIALS AND METHODS

Two experiments were carried out at the research farm of Sher-e-Bangla Agricultural University, Dhaka and BRRI, Gazipur during (April to July) *Aus* season 2009 and 2010, respectively including three hybrids (BRRI hybrid dhan2, Heera2 and Tia) and one inbred (BRRI dhan48) varieties. Four planting dates (1 April, 16 April, 1 May, 16 and 16 May) were selected for each experiment. Both the experiments were laid out in split-plot design with three replications and assigned planting date to the main plot and variety to the sub-plot. The unit plot size was 4 m × 5 m (20 m^2). Twenty-five-day-old seedlings were transplanted maintaining 25 cm x15 cm spacing and one seedling $hill^{-1}$ (for both hybrid and inbred varieties).

Cowdung was applied in unit plot @ 5 t ha^{-1} and chemical fertilizers such as urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate were applied @ 160, 100, 110, 40, and 10 kg ha^{-1}, respectively (BRRI, 2008). Cowdung was applied 15 days before land preparation. All the fertilizers was applied as basal dose except urea, which was applied as top dressing in three equal installments at five days after transplanting (DAT), mid-tillering stage and panicle initiation stage. Standard intercultural operation and plant protection measures were taken as and when required. Flag leaf chlorophyll content was estimated according to Witham (1986) and flag leaf photosynthetic rate was measured with a portable photosynthesis system (Model: LI-6400, Li-COR Inc. USA) at 2, 9, 16 and 23 DAF only from the second experiment. Pre-anthesis shoot stem +(leaf) reserve translocation was calculated by net loss in dry weight of vegetative organs between pre-anthesis and maturity (Bonnett and Incoll, 1992). Data were recorded on yield and yield components at maturity. Daily maximum and minimum temperature of the experimental field was also recorded. The collected data were analyzed using the statistical computer package programme MSTAT-C (Russell, 1986) and the difference between the pairs of treatment mean was adjudged by DMRT.

RESULTS AND DISCUSSION

Flag leaf chlorophyll content and chlorophyll a:b

All the test hybrid varieties synthesized and retained significantly higher amount of chlorophyll in their flag leaf at different DAF compared to inbred BRRI dhan48 (Table 1). Heera2 accumulated the highest amount of chlorophyll (2.43 mg g^{-1}) in its flag leaf at 2 DAF while it was the lowest in BRRI dhan48 (1.88). These results were in consistent to Tang *et al.,* (2010) who reported that hybrid rice content higher amount of chlorophyll (SPAD) in their leaves. While Islam *et al.,* (2006) found slightly higher chlorophyll content in the leaf of hybrids compared to inbred BRRI dhan31. Heera2 and BRRI hybrid dhan2 maintained significantly higher chlorophyll a:b in their flag leaf compared to the rest two. Tia exhibited significantly lowest chlorophyll a:b at 2 DAF (2.32) and at 9 DAF (2.07). Flag leaf chlorophyll content and chlorophyll a t b gradually decreased up to 23 DAF, irrespective of variety. The chlorophyll a t b in flag leaf declined by about 27 % in hybrids and 41 % in inbred BRRI dhan48 at 23 DAF as compared to 2 DAF. That is, BRRI hybrid dhan2 and Heera2 had higher amount of chlorophyll 'a' in their flag leaf compared to inbred BRRI dhan48 till 23 DAF. These results suggested the higher source used (flag leaf photosynthetic) by Heera2 and BRRI hybrid dhan2 over BRRI dhan48 at post heading stage in *Aus* season.

Flag leaf photosynthetic rate

Flag leaf photosynthetic rate significantly varied among the varieties at different DAF (Table 2). Maximum photosynthetic rate (33.37 μ mol CO_2 m^{-2} s^{-1}) was recorded in BRRI hybrid dhan2 at 2 DAF followed by hybrid Heera2 (32.25 µmol CO_2 m^{-2} s^{-1}). The inbred BRRI dhan48 exhibited the lowest photosynthesis rate (28.15 µmol CO_2 m^{-2} s^{-1}) in 2 DAF, which was statistically different from Tia (29.87 µmol CO_2 m^{-2} s^{-1}). This finding is partially consistent with Tang *et al.,* (2010) also reported that photosynthetic capability of flag leaf in hybrid rice was higher. Flag leaf photosynthetic rate was the highest at 2 DAF and gradually decreased with the advancement of grain filling period, regardless of variety and planting date. Reduction of photosynthetic rate at the day 9 and 16 after flowering were 21.51% and 34.20% in BRRI dhan48 whereas average 37.70% and 45.52% in hybrids respectively compared to 2 DAT. Lower reduction of flag leaf photosynthetic rate in BRRI dhan48 probably associated with its efficient sink activities. However, at 23 DAF the rate was significantly higher in BRRI hybrid dhan2 and Heera2 indicating extended grain filling and delayed senescence compared to tia and BRRI dhan48.

Table 1. Flag leaf chlorophyll content and chlorophyll a t b in hybrid and inbred rice varieties at different planting dates in *Aus* season 2010

Variety	Total chlorophyll (mg g^{-1}fresh wt.)				Chlorophyll a t b			
	2DAF	9DAF	16DAF	23DAF	2DAF	9DAF	16DAF	23DAF
BRRI hybrid dhan2	2.37a	2.31a	2.04a	1.86a	3.12a	3.04a	2..85a	2.30a
Heera2	2.43a	2.33a	2.08a	1.78ab	3.12a	3.12a	2.89a	2.29a
Tia	2.34a	2.10b	1.86b	1.75b	2.32c	2.07c	2.07?	1.67b
BRRI dhan48	1.88b	1.80c	1.51c	1.24c	2.76b	2.55b	1.73?	1.62b
CV(%)	6.50	7.59	6.61	7.17	5.67	5.33	5.47	4.89

Within a column, values followed by different letters differ at the 5% level of significance as per DMRT. (Variety x planting date^{NS}

Table 2. Flag leaf photosynthetic rate in hybrid and inbred rice varieties at different planting dates in *Aus* 2010

Variety/ planting date	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})			
	2DAF	9DAF	16DAF	23DAF
Variety				
BRRI hybrid dhan2	33.37a	19.62bc	18.38b	14.23a
Heera2	32.25a	20.79b	17.63b	14.28a
Tia	29.87b	19.09c	16.09c	12.99b
BRRI dhan48	28.15c	22.88a	19.18a	12.82b
Planting date				
01April	31.61	24.38a	19.46a	14.17
16 April	32.28	22.62a	18.75ab	14.18
01 May	29.93	18.49b	17.09b	13.58
16 May	29.82	16.92b	14.98c	12.41
CV(%)	5.80	8.67	7.44	10.77

Within a column, values followed by different letters differ at the 5% level of significance as per DMRT. (Variety x planting date^{NS})

Shoot dry matter accumulation and its remobilization to grain

Pre-anthesis shoot DM accumulation became maximum in Heera2 (24.20 g $hill^{-2}$) and minimum in Tia (19.94 g $hill^{-2}$) in 2009. Hybrid varieties tended to accumulated significantly higher amount of dry matter compared to inbred BRRI dhan48 (Table 3). Shoot DM retention at maturity showed almost similar pattern as DM accumulation was noticed in hybrid and inbreed varieties at pre-anthesis time. This result indicates that normal growth of these hybrids was not affected up to flowering stage in *Aus* season. The highest shoot reserve translocation was found in inbred BRRI dhan48 (7.70% and 8.56%), which was significantly different from all three hybrid varieties (ranged from 4.83% to.2%) in the 1st and 2nd *Aus* season, irrespective of transplanting date. Shoot dry matter significantly declined with delayed transplanting regardless of variety. The maximum reduction of shoot reserve translocation was observed in Heera2 (160.23%) followed by BRRI hybrid dhan2 (136.78%), Tia (65.29%) due to delayed transplanting (16 May) in comparison to 1 April transplanted crop. This value was the lowest in inbred BRRI dhan48 (15.92%). Almost similar result was obtained in second *Aus* season. The result indicated that the studied hybrids were more sensitive to delayed transplanting in terms of shoot reserve translocation to grain compared to inbred BRRI dhan48.

Table 3. Pre-anthesis dry matter accumulation in shoot and its translocation to the grain of hybrid and inbred rice varieties at different planting dates in *Aus* 2009 and 2010

Variety/ Planting date	Shoot dry matter at pre-anthesis (g hill^{-2})		Shoot dry matter at maturity (g hill^{-2})		Changes in shoot dry matter (g hill^{-2})		Shoot reserve translocation (%)	
	2009	2010	2009	2010	2009	2010	2009	2010
Variety								
BRRI hybrid dhan2	21.49b	19.38a	21.00b	18.78a	0.50c	0.59c	2.28c	2.97c
Heera2	24.20a	19.65a	23.88a	18.75a	0.31c	0.90b	1.21d	4.52b
Tia	19.94c	19.48a	18.96c	18.66a	0.97b	0.34bc	4.83b	3.73bc
BRRI dhan48	21.16b	16.82b	19.52c	15.12b	1.64a	1.46a	7.70a	8.56a
LSD(0.05)	0.92	0.99	1.01	0.81	0.23	0.23	1.00	0.98
Interaction	BRRI hybrid dhan2 X							
01April	22.76	20.05	21.77	19.17	0.99def	0.84	4.35def	4.21f
16 April	21.32	20.00	20.58	18.85	0.75efg	1.14	3.52efg	5.67c-f
01 May	21.14	18.43	20.55	18.04	0.60fg	0.38	2.83fg	2.04gh
16 May	20.75	19.03	21.09	19.04	-0.33h	-0.10	-1.60hi	-0.05i
	Heera2 X							
01April	24.82	19.13	23.94	17.75	0.88def	1.38	3.52efg	7.16bcd
16 April	24.75	20.72	23.52	19.39	1.23bcd	1.33	4.98cde	6.39b-e
01 May	24.46	19.86	24.83	19.09	-0.37h	0.76	-1.54h	3.82fg
16 May	22.76	18.90	23.24	18.77	-0.48h	0.13	-2.12h	0.71hi
	Tia X							
01April	21.08	21.08	20.02	20.25	1.06cde	0.83	5.07cde	3.95fg
16 April	20.21	19.48	18.97	18.43	1.24bcd	1.04	6.14bcd	5.34def
01 May	19.47	19.09	18.21	18.21	1.24bcd	0.88	6.37bc	4.58ef
16 May	18.99	18.26	18.65	17.73	0.34g	0.19	1.76g	1.05hi
	BRRI dhan48 X							
01April	22.49	17.55	20.54	15.91	1.94a	1.84	8.67a	10.27a
16 April	21.71	17.26	19.55	15.81	1.61ab	1.45	7.60ab	8.33ab
01 May	20.47	16.39	18.98	15.04	1.49abc	1.35	7.26ab	8.23b
16 May	20.52	15.89	19.02	14.70	1.50abc	1.19	7.29ab	7.41bc
CV(%)	5.01	6.22	5.74	5.35	31.71	29.06	29.54	23.47

Within a column values followed by different letters differ at the 5% level of significance as per DMRT.

Relationship between shoot reserve remobilization percent and temperature

A strongly negative relation exists between minimum temperature (flowering to maturity) and shoot reserve translocation to grain (%) in all the tested rice varieties (Fig. 1). Shoot reserve remobilization to grain in all the hybrid varieties was more sensitive than the BRRI dhan48 for the minimum temperature. This finding is partially in agreement with Kanno and Makino (2010) who reported that cool night temperature favoured the carbon allocation to panicles.

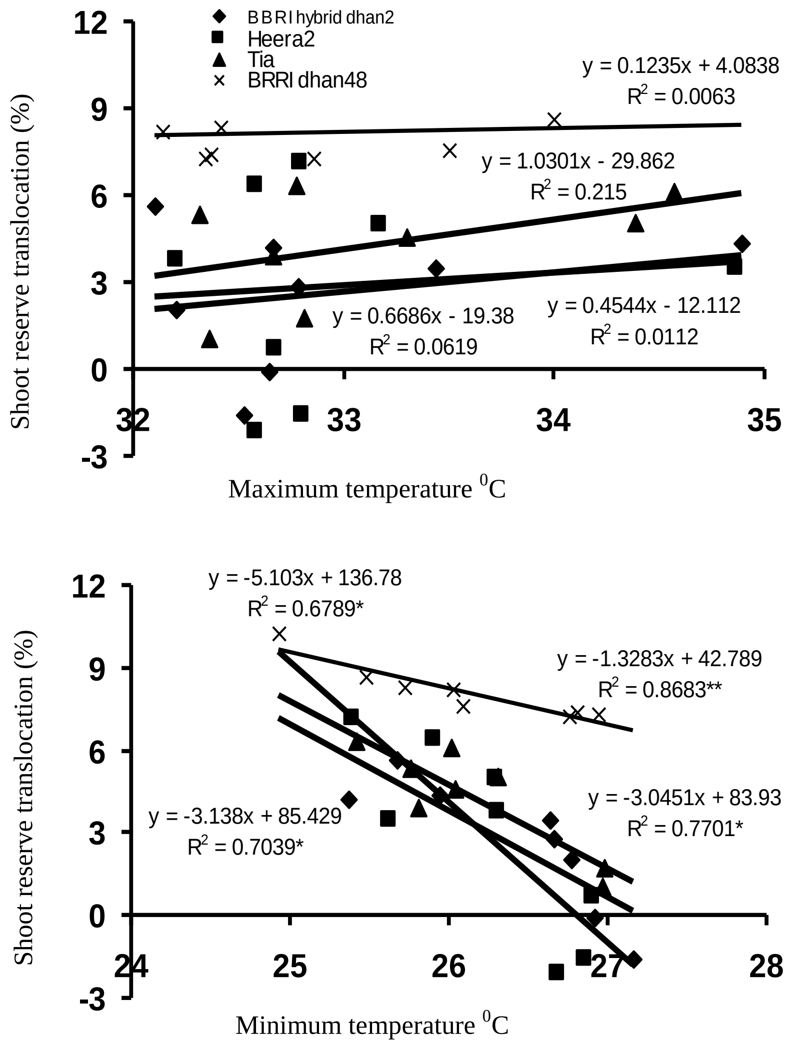

Fig. 1. Relationship between shoot reserve translocation to grain (%) of the hybrid and inbred rice varieties and air temperature (flowering to maturity) in *Aus* season. (data of two *Aus* seasons, 2009 and 2010)

Yield components

The hybrid varieties produced significantly longer panicle and higher number of spikelets panicle^{-1} compared to elite inbred BRRI dhan48 in both *Aus* seasons (Table 4). The variety Heera2 and BRRI hybrid dhan2 had the highest thousand grain weight in the same statistical rank and the lowest grain weight was recorded in BRRI dhan48. Planting date had no significant effect on grain size 1000-grain weight is a genotypic character controlled by genetic makeup (Yoshida, 1981). Individual grain weight remained unchanged in the hybrids at delayed planting indicating physiological activity of sink was for temperature rise

Table 4. Yield components of hybrid and inbred rice varieties grown in *Aus* season 2009 and 2010

Variety	Panicle length (cm)		Spikelets panicle^{-1} (no.)		1000- Grain weight (g)	
	2009	2010	2009	2010	2009	2010
BRRI hybrid dhan2	24.91b	25.03b	133.8a	130.4a	25.74a	26.17a
Heera2	25.28b	24.92b	137.1a	137.2a	25.87a	25.68a
Tia	27.52a	27.64a	135.3a	140.3a	23.60b	23.66b
BRRI dhan48	23.77c	23.45c	110.9b	110.5b	22.13c	22.18c
CV(%)	2.76	3.24	6.60	5.74	3.11	2.69

Within a column, values followed by different letters differ at the 5% level of significance as per DMRT. (variety x planting date^{NS})

Table 5. Yield and components of the hybrid and inbred rice varieties grown in *Aus* season 2009 and 2010

Variety/ Planting date	Panicles m^{-2}		Filled spikelets m^{-2}		Spikelet filling (%)		Grain yield (t ha^{-1})	
	2009	2010	2009	2010	2009	2010	2009	2010
Variety								
BRRI hybrid dhan2	173.3c	200.7b	7105d	12012b	30.17c	44.61b	1.56d	2.27c
Heera2	187.0b	201.0b	10856b	12166b	40.62b	43.99b	2.51b	2.56b
Tia	164.7c	168.4c	8982c	9286c	37.38b	37.85c	1.92c	1.87d
BRRI dhan48	219.8a	244.1a	17103a	17916a	69.48a	65.47a	3.56a	3.34a
Interaction				BRRI hybrid dhan2				
01April	188.2cde	218.7cd	12412de	13523cd	48.43d	46.97c	2.77de	2.49fg
16 April	177.9e	213.8d	6515g	14038bcd	28.12f	49,26c	1.40g	2.57efg
01 May	177.3e	204.3d	5879g	10280cf	25.36fg	38.10de	1.31g	2.11gh
16 May	150.7f	166.0fgh	3613h	10203f	18.76gh	44.11cd	0.74h	1.93h
				Heera2				
01April	206.3bcd	215.8cd	18637b	14741bcd	65.69b	50.14c	4.5ab	3.31abc
16 April	186.8de	206.4d	12105de	14539bcd	46.68d	51.71c	2.95cd	2.88cdef
01 May	201.8bcd	213.4d	9881f	10403ef	37.03e	35.67ef	2.08f	2.12gh
16 May	153.0f	168.2fg	2799h	8961f	13.11h	38.44de	0.51h	1.90h
				Tia				
01April	209.9bc	198.3de	15821c	13882cd	53.81cd	49.90c	3.40c	3.05bcd
16 April	176.5e	178.3ef	11715ef	12797de	48.05d	50.89c	2.62de	2.66def
01 May	140.1f	151.9gh	4679gh	6218g	25.27fg	29.36f	0.95gh	1.10i
16 May	132.2f	145.3h	3712h	4247g	22.37fg	21.24g	0.69h	0.65i
				BRRI dhan48				
01April	245.0a	246.7ab	22750a	20100a	81.58a	70.41a	4.88a	3.76a
16 April	220.0b	258.7a	18755b	19530a	78.46a	66.87ab	4.05b	3.51ab
01 May	212.5b	235.1bc	14160cd	15601bc	60.83bc	61.82b	2.94cd	3.11bcd
16 May	201.6bcd	235.8bc	12747de	16433b	57.04c	62.79ab	2.36ef	2.99cde
CV(%)	6.99	6.15	11.36	11.24	10.14	9.52	13.02	11.19

Within a column, values followed by different letters differ at the 5% level of significance as per DMRT in late *Aus* season. Panicles m^{-2} (219.8 and 244.1) and filled spikelets m^{-2} (17103 and 17916) were markedly higher in inbred BRRI dhan48 compared to all the test hybrid varieties. These two yield contributing characters were rapidly deceased in hybrid varieties compared to inbred BRRI dhan48 in delayed transplanting. Maximum number of panicles m^{-2} was recorded from BRRI dhan48 at 1 April transplanting (245.0) in first *Aus* season and at 16 April transplanting (258.7) in second *Aus* season. Reduction in number of spikelets m^{-2} at delayed transplanting associated with poor spikelets filling percent. Yang *et al.* (2002), Ao *et al.*, (2008) and Yang and Zhang (2010) reported that poor spikelet filling is a problem in hybrid rice varieties. The maximum spikelets filling (69.48% and 65.47%) was found in 2009 and 2010 of inbred variety BRRI dhan48, irrespective of transplanting date, which was statistically higher than that of all the three hybrid varieties. The extent of reduction of grain filling percentage was higher in all the tested hybrid rice varieties (49.82%) compared to inbred BRRI dhan48 (21.12%) when transplanting date shifted from 1 April to 16 May. This might be due to the poor adaptability of test hybrid rice varieties to climate of late *Aus* season.

Grain yield

Irrespective of transplanting dates, inbred BRRI dhan48 (3.56 t ha^{-1} and 3.34 t ha^{-1}) out yielded the studied hybrid rice varieties by producing 36.7% (average) higher grain yield in each *Aus* season (Table 5) attributed by higher number of panicles m^{-2} and higher spikelets filling percent. This result is consistent with findings of Horie *et al.*, (1997) and Ying *et al.*, (1998) who mentioned that yields of hybrid rice varieties are very much unstable across environment. It is apparent form the table that grain yield gradually decreased in delayed transplanting. The highest grain yield (4.88 t ha^{-1} and 3.76 t ha^{-1}) was achieved from BRRI dhan48 at 1 April transplanting, which was statistically at par with Heera2 (4.50 t ha^{-1} and 3.31 t ha^{-1}) at same transplanting date in both *Aus* seasons. On average, the grain yield reduction was the maximum (79.22%) in Tia at 16 May transplanting compared to 1 April transplanting while it was 49.23%, 68.89% and 38.08% in BRRI dhan2, Heera2 and BRRI dhan48 respectively i.e. grain yield of inbred BRRI dhan48 was relatively stable at different planting dates in *Aus* season.

CONCLUSION

In *Aus* season, all the studied hybrids had better vegetative growth up to heading stage but failed to provide desirable grain yield due to poor shoot reserve remobilization to the grain and inefficient photosynthetic activity of flag leaf. This poor shoots reserve remobilization in the test hybrids was associated with their higher sensitivity to rising of minimum temperature at grain filling period.

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