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POLLEN CHARACTERISTICS AND YIELD PERFORMANCES OF RICE AS INFLUENCED BY AIR TEMPERATURE AND RELATIVE HUMIDITY

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Abstract

An experiment was conducted to study the influence of air (low) temperature and relative humidity (RH) on palynological features and rice yield in field condition during the *boro* (winter) season of 2011-2012. Seedlings were transplanted in four different dates to manipulate the temperature ingredients and RH. The earliest transplanted plants suffered from low temperature and RH stresses during vegetative and reproductive phases produced higher percentage of non-viable pollen grains. The viability of pollen grains has no influence on size and exine thickness of pollen. Low temperature and RH, due to early transplanting, induced reduction in plant height, number of total and effective tillers, panicle length, primary and secondary branch number per panicle and hence, the number of spikelets per panicle. The early transplanting promoted spikelet sterility up to 16.80% may be due to higher percentage of non-viable pollen and decreased grain yield up to 51.19% due to both spikelet sterility and lower number of spikelets per panicle. On the bases of comparative responses in spikelet sterility and yield reduction, SL-8H was found to be the most tolerant, Mochi *dhan* and BRRI hybrid *dhan*2 moderately tolerant, BR14 and Lucky *dhan* moderately susceptible and BRRI *dhan*29 was the most susceptible cultivar to low temperature stress.

Introduction

Rice is an essential food item of our daily life. About 79% of the total cropped area is devoted to rice production in three growing seasons *viz*., *aus* (summer-1), *aman* (summer-2) and *boro* (winter), of Bangladesh. About 41.46% of the rice grown area and 58.14% of the total rice production are covered by *boro* rice alone (BBS 2010). The yield of *boro* rice is the highest in the country due to longer growing period with favourable environmental conditions *viz*., marked differences in day and night temperatures, higher active day length, less incidence of insects and diseases, etc. However, rice crops are sometimes affected by low temperature (stress) during flowering while trying to avoid early flash floods (Biswas *et al*. 2008).

Spikelet sterility is a serious problem in *boro* rice as every year the yield loss may occur about 5.54 - 12.89% (BRRI 2007) and this becomes acute particularly in the extended cooler seasons. Spikelet sterility may occur due to both low temperatures and high temperatures prevailing at the reproductive stage, from panicle initiation to flowering (Reddy *et al*. 1987, Nishimura 1990, Gunawardena *et al*. 2003). In Bangladesh condition, a few findings are available involving *boro* rice sterility (Roy *et al*. 2008, Nahar *et al*. 2009). It is not clear as to what proportion of spikelet sterility is caused directly by the effect of low temperature and by what other factors are the determinants to this regard. Therefore, this study was undertaken to study the influence of low temperature and relative humidity on pollen features and grain yield of *boro* rice in field condition.

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Materials and Methods

The field experiment was conducted at the field and Plant Systematics laboratories of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh from October, 2011 to May, 2012. Six, two from each of modern, hybrid and local, cultivars *viz*., BRRI *dhan*29, BR14, BRRI hybrid *dhan*2, SL-8H, Lucky *dhan* and Mochi *dhan*, respectively were used as experimental materials. The field experiment was laid out in a split plot design with three replications. Eighteen treatment combinations (3 × 6) were arranged in 4 blocks according to the planting date to accommodate extra-plant sampling program for studying morphological and other biological features in respect of spikelet sterility, yield and yield components. To manipulate the temperature ingredients and relative humidity (RH) in the field condition, seedlings were transplanted at four different dates *viz*., 21 November, 2011 (1st transplanting), 6 December, 2011 (2nd transplanting), 21 December, 2011 (3rd transplanting; recommended) and 5 January, 2012 (4th transplanting) (Table 1). In first transplanting rice cultivars faced lower average temperature and RH, whereas in later three transplanting they faced higher temperature and RH at the reproductive phase (Table 1). The dates of transplanting were accommodated in the main plot and cultivars in the sub plots. The standard rice cultivation procedure was followed as described by BRRI (2007). The yield and yield contributing characters were studied after ripening (at least 80% spikelets attain to characteristics golden colour) of spikelets.

Table 1. Temperature and relative humidity prevailed at the reproductive phase in different transplanting time.

Treatment		Temperature (ºC)	Relative Humidity (%)
1st transplanting (21 November, 2011)	Maximum	24.0 - 32.5	80.0 - 100.0
	Minimum	9.4 - 22.0	23.0 - 49.0
	Average	18.23	77.67
2nd transplanting (6 December, 2011)	Maximum	27.0 - 34.6	89.0 - 100.0
	Minimum	13.0 - 23.7	23.0 - 65.0
	Average	19.55	73.93
3rd transplanting (21 December, 2011)	Maximum	24.7 - 35.6	86.0 - 100.0
	Minimum	14.5 - 25.0	26.0 - 79.0
	Average	21.79	72.27
4th transplanting (5 January, 2012)	Maximum	24.7 - 35.6	86.0 - 100.0
	Minimum	16.4 - 27.0	28.0 - 49.0
	Average	24.13	73.13

Random selection was done to select 6 spikelets from each panicle two from upper part, two from middle part and the rest from the lower part of the panicle. Anthers from each panicle were placed on 10 separate slides randomly and grinded smoothly. After cleaning of anther wall cells with needle, the glass slides were fixed and stained following standard procedure (Gunawardena *et al*. 2003). Pollen viability was checked under compound (light) microscope with 10x magnification. Stained and evenly round pollen grains were viable but those, don’t get stain and surface of the pollen was somewhat wrinkled, are non-viable (Gunawardena *et al*. 2003). Pollen size (length of longest axis) and exine thickness were measured with ocular micrometer.

The collected data were analyzed following the ANOVA and the mean differences among treatments were adjudged with DMRT using the statistical computer package program MSTAT-C.

Results and Discussion

Rice pollen grains are dispersed as monad, 1-porate, annulate (Fig. 1). Pollen size (length of longest axis) and exine thickness varied among the cultivar studied. However, these variations were insignificant in pollen size and exine thickness due to temperature and/or relative humidity effect (Table 2). Irrespective of temperature and relative humidity ingredient, the longest pollen grain was found in BR14 (46.42 µm) and the shortest in Mochi *dhan* (36.50 µm). These variations in pollen size and exine thickness might be genetically controlled characters. Small (< 40 µm) pollen grains were found in local, large (> 45 µm) were in modern cultivars, and the medium (40 - 45 µm) pollen grains characterizes the hybrid cultivars (Table 2). This pollen feature may possess systematic significance and to be used as an identifying character of local, modern and hybrid rice cultivars. The thickest exine was found in BR14 in all transplanting times. Similar variation in pollen size and exine thickness was reported by Chaturvedi *et al.* (1998) and Jian-Hua *et al.* (2001). Chaturvedi *et al.* (1998) reported that pollen size and exine sculpture could be used as identification tools for species and cultivar as well (Datta and Chaturvedi 2004).

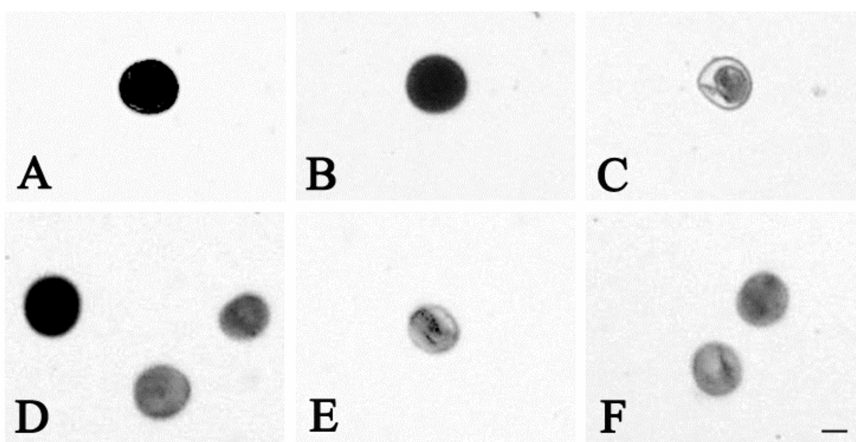

Fig. 1. Light micrographs of rice pollen grains. A-B. Normal (viable) pollen; C, E-F. Non-viable pollen; D. Both viable and non-viable. Scale bars = 20 µm.

Non-viable pollen varied significantly among different rice cultivars under different transplanting time i.e. in different temperature levels and RH (%) (Table 2). Temperature decreased gradually when the 1st transplanted seedlings were moved towards the reproductive phase. Despite this, all the cultivars showed reducing trends in viable pollen towards the lower temperatures but rate of reduction was different. Among cultivars and transplanting times, the highest amount of non-viable pollen was found in BRRI hybrid *dhan*2 (39.43%) at 1st transplanting and the lowest in SL-8H (4.86%) at third transplanting. In case of pollen viability, hybrid cultivars showed greater sensitivity to low temperature (Table 2). All the cultivars produced higher number of non-viable pollen when transplanted at 21 November (third transplanting). This may be associated with lower RH (%) with low temperature during growing period especially at the reproductive phase (Table 1). This type effect of low temperature on pollen viability was also observed by Gunawardena *et al*. (2003). During the development of male gametophyte, low temperature causes disruption of meiosis, tapetal hypertrophy, stunted development of pollen grain, anther protein degradation, pollen sterility, pollen tube deformation which ultimately leads to spikelet sterility in rice (Nishiyama 1995).

Table 2. Pollen characteristics of rice cultivars as affected by planting times (temperature and RH).

Temperature (ºC) /Cultivar		Length (μm) Mean ± SE (Range)	Exine thickness (μm) Mean ± SE (Range)	Non-viable pollen (%)
9.4-22.0 (1st transplanting)	BRRI *dhan*29	45.86±1.67 (42.75-49.50)	1.12±0.074 (0.90-1.17)	30.62 c
	BR14	46.41±1.68 (42.75-49.50)	1.16±0.069 (0.95-1.22)	16.34 h
	BRRI hybrid *dhan*2	41.20±3.86 (31.50-42.75)	1.14±0.081 (0.90-1.22)	39.43 a
	SL-8H	42.40±2.84 (38.25-49.50)	1.15±0.072 (0.86-1.17)	32.78 b
	Lucky *dhan*	38.67±4.21 (28.25-45.00)	1.00±0.093 (0.78-1.13)	20.45 f
	Mochi *dhan*	36.50±3.85 (25.50-40.00)	1.00±0.093 (0.78-1.11)	22.25 e
13.0-23.7 (2nd transplanting)	BRRI *dhan*29	45.87±1.65 (42.75-49.50)	1.12±0.074 (0.90-1.17)	22.95 de
	BR14	46.42±0.65 (42.75-49.50)	1.16±0.069 (0.95-1.22)	12.64 i
	BRRI hybrid *dhan*2	41.21±3.84 (31.50-42.75)	1.14±0.081 (0.90-1.22)	24.19 d
	SL-8H	42.40±2.81 (38.25-49.50)	1.15±0.072 (0.86-1.17)	23.35 de
	Lucky *dhan*	38.67±4.20 (28.25-45.00)	1.00±0.093 (0.78-1.13)	17.56 gh
	Mochi *dhan*	36.51±3.83 (25.50-40.00)	1.00±0.093 (0.78-1.11)	18.07 g
14.5-25.0 (3rd transplanting)	BRRI *dhan*29	45.87±1.62 (42.75-49.50)	1.12±0.074 (0.90-1.17)	7.45 k
	BR14	46.42±1.63 (42.75-49.50)	1.16±0.069 (0.95-1.22)	6.37 k-m
	BRRI hybrid *dhan*2	41.21±3.80 (31.50-42.75)	1.14±0.081 (0.90-1.22)	6.79 kl
	SL-8H	42.40±2.78 (38.25-49.50)	1.15±0.072 (0.86-1.17)	4.86 m
	Lucky *dhan*	38.67±4.19 (28.25-45.00)	1.00±0.093 (0.78-1.13)	7.48 k
	Mochi *dhan*	36.51±3.80 (25.50-40.00)	1.00±0.093 (0.78-1.11)	9.12 j
16.4-27.0 (4th transplanting)	BRRI *dhan*29	45.86±1.62 (42.75-49.50)	1.12±0.074 (0.90-1.17)	6.78 kl
	BR14	46.41±1.62 (42.75-49.50)	1.16±0.069 (0.95-1.22)	5.23 lm
	BRRI hybrid *dhan*2	41.20±3.81 (31.50-42.75)	1.14±0.081 (0.90-1.22)	6.24 k-m
	SL-8H	42.40±2.77 (38.25-49.50)	1.15±0.072 (0.86-1.17)	5.77 k-m
	Lucky *dhan*	38.67±4.20 (28.25-45.00)	1.00±0.093 (0.78-1.13)	6.37 k-m
	Mochi *dhan*	36.50±3.82 (25.50-40.00)	1.00±0.093 (0.78-1.11)	6.54 k-m
$LSD_{0.05}$		ns	ns	1.56

In a column, figures having different letter(s) differ significantly ($p \leq 0.05$) according to DMRT.

Plant height of all the cultivars decreased due to low temperature and RH conditions and the decreased values were significantly different (Table 3). Among all treatments, Mochi *dhan* showed the highest plant height (138.3 cm) and BRRI *dhan*29 was the shortest (84.33 cm, Table 3) at 1st transplanting. Modern cultivars were the most susceptive and local cultivars were the least susceptive to low temperature in respect of plant height at all the planting times. Plant height was statistically similar to two hybrids *viz*., BRRI hybrid *dhan*2 and SL-8H cultivars at all the planting times. Local cultivars *viz*., Lucky *dhan* and Mochi *dhan* showed similar trend from 2nd transplanting to 4th transplanting. But modern cultivars BRRI *dhan*29 and BR14 showed significant differences in different transplanting time due to different temperature levels. This irregular trend in plant height may be due to the difference in growth

Table 3. Effect of cultivar and (low) temperature at the entire growing period on different growth and yield attributing characters. HI - Harvest Index.

Minimum temperature (^{0}C)/cultivar		Plant height (cm)	Total no. of tillers	No. of effective tillers	Panicle length (cm)	No. of primary branches/ panicle	No. of secondary branches/ panicle	No. of spikelets/ panicle	No. of grains/ panicle	Spikelets sterility (%)	1000-grain weight (g)	Grain yield (t/ha)	HI
9.4-25.0	BRRI *dhan*29	84.33 f	15.30c-f	12.43 d-g	23.30 c-f	8.17 d	16.47 g-i	153.7 fg	128.2 i-k	16.80 a	20.18 b	3.67 jk	28.64 cd
(1st trans-	BR14	95.33 d	10.83 kl	9.83 ij	22.00 g-j	6.30 e	20.80 de	156.2 f	138.9 hi	10.85 b	23.08 a	3.52 k	29.34 c
planting)	BRRI hybrid *dhan*2	86.43 ef	13.50 f-i	12.97 d-f	22.53 f-i	8.60 cd	21.60 c-e	158.4 ef	140.5 h	11.22 b	23.03 a	5.25 f-h	32.61 ab
	SL-8H	84.37 f	10.37 l	9.10 j	21.07 j	8.73 cd	20.57 d-f	194.2 bc	173.4 de	10.58 bc	22.41 ab	5.70 d-g	32.72 ab
	Lucky *dhan*	126.2 c	13.90 e-h	10.93 g-j	22.50 f-i	6.30 e	13.37 i	109.9 l	104.1 n	5.42 f	21.41 b	4.02 jk	29.33 c
	Mochi *dhan*	134.5 ab	15.93 b-d	13.83 cd	22.40 f-i	6.53 e	15.20 hi	120.3 j-l	111.4 mn	7.67 e	22.11 ab	3.35 k	26.78 d
13.0-26.5	BRRI *dhan*29	85.80 ef	17.23 ab	16.57 ab	23.37 c-f	9.67 a-c	23.57 b-d	165.2 ef	153.2 fg	7.24 e	20.17 b	5.81 d-g	29.06 c
(2nd trans-	BR14	95.63 d	12.93 h-j	11.27 f-i	23.27 c-g	6.43 e	20.50 d-f	158.6 f	143.0 gh	9.83 c	23.11 a	4.29 i-k	30.09 b
planting)	BRRI hybrid *dhan*2	86.47 ef	14.27 d-h	13.23 c-f	22.67 e-i	8.73 cd	22.63 b-e	181.4 cd	163.3 ef	10.32 bc	23.02 a	6.24 b-e	33.27 ab
	SL-8H	84.63 f	11.30 j-l	9.83 ij	21.70 ij	8.80 cd	21.40 c-e	199.6 b	182.0 cd	8.77 d	22.42 ab	6.35 b-d	33.36 ab
	Lucky *dhan*	130.3 bc	14.90 c-g	13.30 c-f	22.70 e-i	6.83 e	19.23 e-g	125.0 i-k	120.0 k-m	4.01 g	21.42 b	4.58 h-j	31.22 b
	Mochi *dhan*	135.2 a	16.23 bc	15.17 bc	23.17 c-h	6.77 e	15.37 hi	127.8 ij	121.1 k-m	5.36 f	22.10 ab	4.3 i-k	29.15 c
14.5-27.0	BRRI *dhan*29	85.87 ef	17.30 ab	15.17 bc	24.17 a-c	10.03 a	25.00 bc	191.1 bc	186.4 bc	2.38 hi	20.17 b	7.17 b	30.26 bc
(3rd trans-	BR14	97.07 d	14.73 c-g	13.33 c-f	24.97 ab	8.93 a-d	22.90 b-e	189.7 bc	181.8 cd	4.02 g	23.12 a	6.17 c-f	31.06 bc
planting)	BRRI hybrid *dhan*2	90.73 e	14.70 c-g	13.33 c-f	23.33 c-f	10.00 ab	25.50 b	200.4 b	196.9 b	1.77 h-k	23.03 a	8.08 a	34.14 a
	SL-8H	86.70 ef	13.17 g-i	11.40 e-i	21.97 h-j	9.63 a-c	30.63 a	213.9 a	209.9 a	1.87 h-k	22.41 ab	8.33 a	34.25 a
	Lucky *dhan*	128.3 c	15.60 b-e	15.20 bc	23.93 b-e	8.77 cd	23.93 b-d	143.9 gh	140.7 h	2.25 h-j	21.41 b	6.78 bc	32.16 ab
	Mochi *dhan*	138.3 a	18.17 a	17.30 a	25.17 a	8.90 b-d	16.33 g-i	136.8 hi	133.1 h-j	2.68 h	22.11 ab	5.08 g-i	30.00 bc
16.4-28.0	BRRI *dhan*29	85.73 ef	15.57 b-e	14.30 cd	24.07 a-d	10.00 ab	24.70 bc	190.7 bc	186.9 bc	2.08 h-k	20.17 b	6.56 b-d	28.02 cd
(4th trans-	BR14	98.87 d	14.37 d-h	12.30 d-h	23.07 c-h	8.83 cd	21.43 c-e	171.0 de	168.8 e	1.31 jk	23.12 a	5.34 e-h	28.65 cd
planting)	BRRI hybrid *dhan*2	99.27 d	12.13 i-k	9.93 ij	22.57 f-i	9.07 a-d	22.73 b-e	190.4 bc	187.9 bc	1.34 jk	23.04 a	5.40 e-h	31.83 b
	SL-8H	86.90 ef	11.33 j-l	10.37 h-j	21.93 h-j	8.67 cd	23.63 b-d	193.4 bc	191.1 bc	1.17 k	22.42 ab	7.00 bc	30.96 bc
	Lucky *dhan*	128.0 c	14.97 c-g	13.77 cd	22.90 d-i	6.13 e	19.60 e-g	114.3 kl	112.6 l-n	1.45 i-k	21.42 b	5.04 g-i	29.28 c
	Mochi *dhan*	137.3 a	15.37 c-e	13.43 c-e	22.23 f-j	9.40 a-c	17.23 f-h	125.3 i-k	123.4 j-l	1.54 i-k	22.11 ab	3.59 k	25.00 d
$LSD_{0.05}$		4.33	1.54	1.80	1.08	0.96	3.13	11.63	10.38	0.86	1.38	0.84	2.14

In a column, figures having different letter(s) differ significantly ($p \leq 0.05$) according to DMRT.

pattern in different stages which is completely associated with the genetic makeup of the plants (Nahar *et al*. 2009). The results regarding plant height were in confirmatory with the earlier findings (Sarwar and Ali 1998, BRRI 2007).

Low temperature (earlier transplanting) decreased the number of tillers per hill in all the cultivars studied compared to higher temperature (later transplanting) (Table 3). From the above mentioned results, it can be inferred that the tillering ability in all cultivars decreased with the decreasing temperature (Nahar *et al*. 2009). At the maturity, the highest number of tillers was found in Mochi *dhan* (18.17) at 3rd transplanting and the lowest was obtained from hybrid cultivar SL-8H (10.37) under 1st transplanting (Table 3). The number of effective tillers per hill also followed the similar trend *i.e.,* the highest number in Mochi *dhan* (17.30) and the lowest in SL-8H (9.10) (Table 3). This may be due to genetic makeup of respective cultivars.

Among all the cultivars, the longest panicle was recorded in Mochi *dhan* (25.17 cm) at 3rd transplanting and the smallest was found in SL-8H (21.07 cm) at 1st transplanting (Table 3). It confirms that the low temperature has adverse effect on panicle length (Geng *et al*. 2009). But there are differences in level of low temperature effects. The highest number of primary branches/panicle (PBN) was obtained in BRRI *dhan*29 (10.03) at 3rd transplanting and the lowest was found in BR14 (6.30) at 1st transplanting with no significant difference in some instances (Table 3). This irregular trend may be associated with the genetic variations and different responses of cultivars to temperature (Sarwar and Ali 1998). Similar trend was found among the transplanting times in case of secondary branch number per panicle (SBN) *i.e.,* the highest was found at the 3rd transplanting and the lowest was found at the 1st transplanting (Table 3). Hybrid cultivar SL-8H produced the highest number of secondary branch per panicle (30.63). This character was found strong to contribute to number of spikelets per panicle (Mo *et al*. 2012). Genetic variations attribute such kind of variation in cultivars. Similar differences in panicle length, number of primary and secondary branches per panicle were also observed by Sarwar and Ali (1998) and Mo *et al*. (2012). This indicates that the low temperature might cause reduction in PBN and SBN. This reveals the secret of hybrids behind the high yield potential; because there is a direct relation between SBN and spikelets per panicle (Mo *et al*. 2012).

All the cultivars produced lower number of spikelets per panicle with lower temperature and RH at the reproductive stage (Table 3). The highest number of spikelets was found in hybrid cultivar SL-8H (213.9) followed by BRRI hybrid *dhan*2 (200.4) in the 3rd transplanting and the lowest was found in Lucky *dhan* (109.9) in the 1st transplanting. This result showed that the hybrid cultivars produced higher number of spikelets/panicle which may be the secret of high yield potential in hybrids. Such type of variation is probably associated with the genetic makeup the cultivars. Sarwar and Ali (1998) expressed similar views in respect of number of spikelets per panicle. The sudden unfavourable environmental conditions e.g., low temperature (up to 8^0C), lower RH (up to 23%), etc. at the vegetative stage may trigger the reduction in number of spikelets per panicle at later period (transplanted at 4th transplanting) which was pronounced only in the local cultivars. However, the modern and hybrid cultivars were less or not affected (Table 3).

Grain number per panicle varied significantly among the cultivars under different temperature and RH ingredients (Table 3). The highest number of grains per panicle was found in hybrid cultivar SL-8H (209.9) followed by BRRI hybrid *dhan*2 (196.9) at the 3rd transplanting. The lowest was found in Lucky *dhan* (104.1) at 1st transplanting. Grains per panicle in all the cultivars reduced when relatively lower temperature and RH (%) prevailed in reproductive phase. It can be assumed that cultivars having higher number of spikelets per panicle produced higher number of grains per panicle.

There were significant differences in spikelet sterility (%) among the cultivars. The highest percentage of spikelet sterility (16.8) was found in BRRI *dhan*29 at the 1st transplanting and the lowest (1.17) in SL-8H when transplanted at the 4th transplanting (Table 3). The differences in spikelet sterility might be due to genetic makeup of the respective cultivar. Cold temperature increased the spikelet sterility (%) in rice was reported by BRRI (2007). Perhaps this sterility may have attributed with the non-viable pollen which ultimately led to spikelet sterility (Nizigiyimana 1990). Moreover, the malformation of gynoecium/ovary, small stigmatic surface, drying-up of stigma, etc. due to low temperature and RH at the reproductive stage might be causes spikelet sterility in rice cultivars (Sarwar and Islam 2013).

The 1000-grain weight, although varied relatively in small scale and differed significantly among the cultivars (Table 3). The highest 1000-grain weight was recorded from BR14 (23.11 g) with no significant difference in BRRI hybrid *dhan*2 (23.03 g) followed by Mochi *dhan* (22.11 g). The lowest weight was obtained from BRRI *dhan*29 (20.17 g) (Table 3). This grain weight indicates that BRRI *dhan*29 was smallest in size in all respects. Such variations in 1000-grains weight were also reported by Bhowmick and Nayak (2000). Thousand-grain weight of the same cultivar did not differ significantly at different temperature levels (Table 3). This result indicates that the 1000-grain weight is strongly controlled by the genetic makeup of the cultivars.

Grain yield gradually reduced with the decrease of temperatures in all cultivars (Table 3). This happened due to higher sterility in association with lower number of spikelets per panicle. The lowest grain yield was found at the 1st transplanting and the highest was at the 3rd transplanting in all the cultivars. Irrespective of temperature, highest grain yield was obtained from SL-8H (8.33 t/ha) with no significant difference in BRRI hybrid *dhan*2 (8.08 t/ha) and the lowest was found in Mochi *dhan* (3.35 t/ha) with no significant difference in BR14 (3.52 t/ha). Yield reduction was the maximum in transplanting at 1st transplanting (Table 3). When transplanted at 5th January, 2012, grain yield of hybrid cultivars reduced drastically probably because of the lower number of spikelets formation on the panicle due to low average minimum temperature along with lower RH (%) as discussed above (Nahar *et al*. 2009). Low temperature often causes flower abortion, pollen and ovule infertility, breakdown of fertilization, poor seed filling, decreases in seed setting which ultimately reduce the grain yield (Thakur *et al*. 2010).

Significant variation in harvest index (HI) was observed among the cultivars at different temperature ingredients (Table 3). The highest HI value was observed in SL-8H (34.25) at 3rd transplanting which was followed by BRRI hybrid *dhan*2 (34.14) and the lowest in Mochi *dhan* (25.00) at 4th transplanting. In the earliest transplanting date, seedlings passed relative the longer establishment and vegetative period may be produced more straw (vegetative) biomass resulting low HI values (Table 3). However, the HI seems to be a genetically controlled character (BRRI 2007). The earlier transplanting, resulting relatively lower temperature and RH, caused increment of crop duration period in all the cultivars studied (data not shown). This happened probably due to the longer establishment period after transplanting under low temperature and/or due to adverse effect of low temperature on growth and development.

On the basis of comparative response in spikelet sterility and yield reduction, SL-8H was found to be tolerant, Mochi *dhan* and BRRI hybrid *dhan*2 moderately tolerant, BR14 and Lucky *dhan* moderately susceptible, and BRRI *dhan*29 was susceptible to low temperature stress in Bangladesh condition.

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