

## Effect of Planting Dates, Gibberellic and Boric Acid on Morphological Characters and Seed Yield in Rice Hybrid Pusa RH-10

MURLIDHAR J SADAWARTI\*, ALICE K VARI AND S K CHAKRABARTY

Division of Seed Science and Technology, ICAR-Indian Agricultural Research Institute, New Delhi 110 012  
\*murlidharsada@gmail.com

**ABSTRACT:** Pusa Rice Hybrid-10 (Pusa RH-10) is world's first fine grain aromatic rice hybrid. Therefore, an attempt was made to maximize seed yield. The study was conducted during *kharif* 2004 and 2005 at ICAR-IARI, New Delhi, involving three planting dates in twelve days interval, from first week of June. The seeds of A and R lines were sown in the nursery for three dates and proper staggered sowing was done to obtain synchrony of flowering. Transplanting of both the parents was done on same day when the seedlings were four weeks old for each date of sowing. Gibberellic acid was applied in three doses viz., 50 g/ha, 100 g/ha and 150 g/ha in split application in the ratio (40:60) in two consecutive days and in three (25: 50: 25) ratios, in three consecutive days. One per cent boric acid was also applied along with gibberellic acid. There was considerable effect of climatic conditions like rainfall, temperature, relative humidity and wind velocity on flowering and morphological parameters. There was a decreasing trend in flowering and morphological parameters with delayed sowing. Sowing during 1<sup>st</sup> week of June was found most favorable for hybrid seed production of Pusa RH-10. GA<sub>3</sub> had profound effect on flowering and morphological parameters. GA<sub>3</sub> @ 150 g/ha + 1% boric acid sprayed in a ratio of 25: 50: 25, on consecutive days, during panicle emergence provided maximum seed yield.

**Key words:** Hybrid rice, seed production, planting dates, gibberellic acid

Success of hybrid seed production programme in rice mainly depends on synchronized flowering of male sterile (A) and restorer (R) lines, proper planting time of the parental lines, local climatic conditions during crop growth particularly during flowering, characteristics of parental lines and cultural practices [1]. Among different improved techniques for increasing seed yield, GA<sub>3</sub> application has been widely adopted as an essential input. Panicle exertion could be increased from 74-77% in control to 84-89% with the application of 135-180 g GA<sub>3</sub>/ha [2]. Besides enhancing panicle exertion, GA<sub>3</sub> application also improves other morphological and floral characters, viz., plant height, flag leaf angle, spikelet opening angle, duration of spikelet opening, stigma exertion percentage, seed set percentage and yield [3, 4, 5 & 6]. Boric Acid and urea were found to

be cheap substitute for GA<sub>3</sub>, but have lesser effect when applied separately [7]. However, boric acid has significant effect when applied with GA<sub>3</sub> [6].

As per recommended practice, 40% dose of GA<sub>3</sub> is applied at 5% panicle emergence and remaining 60% is sprayed the next day. A single spaced plant of rice takes 5-7 days for panicles of all tillers to emerge. The panicles on the late tillers remain unexserted because two applications of GA<sub>3</sub> on consecutive days are not available to those late order panicles. Hence in order to improve the panicle emergence and thereby more effective pollination, it would be desirable to increase the frequency of spray of gibberellic acid. It also has very positive effect on morphological and floral character, which leads to higher seed set and yield when GA<sub>3</sub> was applied @ 90 and 180 g/ha in

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split doses on 1<sup>st</sup> and 3<sup>rd</sup> day (40:60) and 1<sup>st</sup>, 3<sup>rd</sup> and 5<sup>th</sup> (25:50:25) day of heading [8] and also spraying in consecutive days with 25:50:25 ratio [1 & 8].

The present study was undertaken to generate precise information on the effect of date of planting and GA<sub>3</sub> spray schedule on floral, plant morphological characters and seed yield in newly developed fine grained aromatic rice hybrid, Pusa RH-10.

## MATERIAL AND METHODS

The experiment was conducted with parents of Pusa RH-10 - Pusa 6A as a CMS line (seed parent) and Pusa Rice Restorer (PRR) 78 as male parent. The seed materials were obtained from ICAR-IARI Regional Station, Karnal and MAHYCO. Sowing of seeds was done with the available information on synchronization of flowering. In *kharif* 2004, R line was sown in nursery on 2<sup>nd</sup>, 14<sup>th</sup> and 26<sup>th</sup> June for 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> date of sowing (DOS) and respective combination of A line was sown on 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July for 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> date of sowing respectively. In *kharif* 2005, R line was sown in nursery on 7<sup>th</sup>, 19<sup>th</sup> June and 4<sup>th</sup> July for 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> date of sowing and respective combination of A line was sown on 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July for 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> date of sowing respectively. Transplanting of both the parents was done on same day when the seedlings were four weeks old for each date of sowing. The planting ratio between parental lines was 2:8 (R: A line). The spacing was 30 cm (between 'R' and 'R' line), 20 cm (between 'R' and 'A' line) and 15 cm (between 'A' and 'A' line). The experiment was laid out in Randomized Block Design in four replications for each date of sowing. The plot size was 3.75 x 1.55 M<sup>2</sup> with one set of CMS and restorer line/plot.

Seven treatments used were: T<sub>1</sub>-control; T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>-50, 100, 150 gm GA<sub>3</sub>/ha in 40: 60 ratio along with 1% boric acid, respectively; T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub>-50, 100, 150 gm GA<sub>3</sub>/ha in 25:50:25 ratio along with 1% boric acid, respectively. Spraying of the chemicals was done at 5% panicle emergence. GA<sub>3</sub> was dissolved in 70 per cent ethanol @ 10 ml ethanol/g of GA<sub>3</sub> and required quantity of water was added for each spray application. Split

application of GA<sub>3</sub> was given for treatment T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> where, 40% of total GA<sub>3</sub> was sprayed on first day and remaining 60% on the next day. For treatment T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub>, 25% of GA<sub>3</sub> was sprayed on 1<sup>st</sup> day, 50% on 2<sup>nd</sup> day and 25% on third day of 5% panicle emergence. All the quantity of boric acid was sprayed on the first day for each treatment. Observations were recorded on floral and morphological characters and seed parameters. For spikelet opening angle, fully opened individual spikelets from CMS line were collected randomly for each treatment and kept on a paper. With the help of pointed needle, the points of the opened spikelet were marked. Later these points were joined and angle was measured with protractor in degrees. For measuring the flag leaf angle, the protractor was kept in straight line to the main culm and the angle made by flag leaf with main culm was recorded. For panicle exertion, the number of spikelets of each panicle which emerged out of the leaf sheath, was cut with the help of scissors and were counted and reported on percentage basis over total number of spikelets.

The data from field experiment was analyzed statistically by adopting Randomized Block Design (RBD). The data in percentage form were transformed to the respective angular (arc sin) values before subjecting them to statistical analysis.

## RESULT AND DISCUSSION

### *Spikelet opening angle*

Higher spikelet opening angle is the most important parameter for pollen catching by stigma and thereby higher seed set and seed yield. GA<sub>3</sub> plays important role for increasing floret opening angle. In the present study, the overall value for spikelet opening angle ranged from 21.1 to 24.1° in *kharif* 2004 and 22.6 to 24.0° in *kharif* 2005, for different DOS. GA<sub>3</sub> spraying improved the angle of opening significantly and it increased from 19.2° and 18.0° in control to 26.2° and 25.9° respectively for *kharif* 2004 and 2005 when GA<sub>3</sub> @ 150 g/ha (25:50:25) and GA<sub>3</sub> @ 150 g/ha (40:60) + 1% Boric acid was applied (Table 1). With delayed planting, the spikelet opening angle decreased, which may be due to the milder temperature and high RH that prevailed during blooming time. GA<sub>3</sub> spray has been earlier also reported to increase spikelet

**Table 1. Effect of planting dates and chemicals on spikelet opening angle (°) in Pusa 6A**

Treatment/DOS	2004				2005			
	1 <sup>st</sup> *	2 <sup>nd</sup> *	3 <sup>rd</sup> *	Mean	1 <sup>st</sup> @	2 <sup>nd</sup> @	3 <sup>rd</sup> @	Mean
Control	19.8	19.6	18.2	18.2	19.8	18.6	15.6	18.0
GA <sub>3</sub> @ 50 g/ha (40:60) + 1% Boric Acid	20.6	21.8	18.8	22.0	20.6	21.4	20.8	19.2
GA <sub>3</sub> @ 100 g/ha (40:60) +1% Boric Acid	25.6	21.8	22.4	23.9	25.6	22.2	23.8	23.8
GA <sub>3</sub> @ 150 g/ha (40:60) +1% Boric Acid	27.2	23.0	22.6	24.4	27.2	24.8	26.2	26.1
GA <sub>3</sub> @ 50 g/ha (25:50:25) +1% Boric Acid	22.8	21.6	19.2	21.2	23.8	22.6	22.6	23.0
GA <sub>3</sub> @ 100 g/ha (25:50:25) +1% Boric Acid	24.8	24.6	22.8	24.0	24.4	24.4	24.0	24.3
GA <sub>3</sub> @ 150 g/ha (25:50:25) +1% Boric Acid	28.0	26.4	24.2	26.2	26.8	25.6	25.2	25.9
Mean	24.1	22.7	21.1	23.0	24.0	22.7	22.6	23.1
C.D. (p=0.05) DOS =	3.53				1.32			
Treatment =	1.24				2.02			
Treatment x DOS =	N.S.				N.S.			

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>; 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004 ; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July in 2005

opening angle in CMS parent of rice [9, 5, 6, 2 & 10].

#### Flag leaf angle

Flag leaf angle and its orientation is an important morphological trait for effective pollen availability and hybrid seed set. In the present study, there was non-significant difference in widening of flag leaf with different DOS and GA<sub>3</sub> doses. There was decreasing trend in flag leaf angle with delay of planting in both the years (35.5 to 30.9° in *kharif* 2004 and 34.6 to 31.6° in *kharif* 2005), which may be due to higher temperature conditions in 1<sup>st</sup> DOS and milder conditions during later DOS (Table 2).

There was increase (though non-significant) in flag leaf angle during both the years due to GA<sub>3</sub> treatment. It increased from 28.0° and 25.5° in control to 37.0° and 38.8° in *kharif* 2004 and *kharif* 2005 when GA<sub>3</sub> @150 g/ha (25:50:25) + 1% Boric acid was applied (Table 2). Flag leaf angle widened upto 38 and 44° with two applications of GA<sub>3</sub> @ 135 g/ha (40:60) in two seasons respectively [2]. Elongation of the cells of the leaf at the collar region by the application of GA<sub>3</sub> has facilitated flattening of flag leaf, thereby allowing better pollen

flow. Increased dose of GA<sub>3</sub> favorably affected flag leaf angle in the present study. GA<sub>3</sub> along with Boric acid had favorable effect on flag leaf angle [6]. This effect of GA<sub>3</sub> on flag leaf has been reported in earlier studies as well [6, 11 & 12].

#### Plant height

Plant height of the parental lines has significant effect on hybrid seed production. Increased plant height in A and R lines by GA<sub>3</sub> application can help in enhancing the pollen dispersal by wind and gravity thereby favoring out crossing. There was non-significant difference in plant height between different DOS in both the years. There was linear decrease in plant height as date of sowing advanced. Similar non-significant decrease was found in PRR-78 (R line) also (Table 4). The variation in plant height was from 110 cm to 94 cm during 1<sup>st</sup> DOS and 3<sup>rd</sup> DOS in A line and 123 cm to 117 cm in R line. This might be due to the shrinking photoperiod available at active growth phases [13]. Spray of GA<sub>3</sub> increased the plant height significantly in both female and male parents in all DOS. It increased from 94.6 cm in control to 107.6 cm when GA<sub>3</sub> @ 150 g/ha (25:50:25) + 1% Boric acid was applied (Table 3).

Table 2. Effect of planting dates and chemicals on Flag leaf angle (°) in Pusa 6A

Treatment/DOS	2004				2005			
	1 <sup>st</sup> *	2 <sup>nd</sup> *	3 <sup>rd</sup> *	Mean	1 <sup>st</sup> @	2 <sup>nd</sup> @	3 <sup>rd</sup> @	Mean
Control	27.6	27.6	28.8	28.0	27.6 (09.30)	23.6 (07.95)	25.4 (8.51)	25.5 (8.78)
GA <sub>3</sub> @ 50 g/ha (40:60) + 1% Boric Acid	34.2	30.2	30.2	29.2	34.2 (11.53)	29.4 (10.00)	27.0 (09.10)	30.2 (10.18)
GA <sub>3</sub> @ 100 g/ha (40:60) +1% Boric Acid	38.0	32.4	31.6	34.0	37.0 (13.01)	34.6 (11.08)	29.8 (10.04)	33.8 (11.51)
GA <sub>3</sub> @ 150 g/ha (40:60) +1% Boric Acid	38.6	38.8	32.6	36.7	38.0 (12.81)	39.0 (13.15)	34.2 (11.54)	37.0 (13.01)
GA <sub>3</sub> @ 50 g/ha (25:50:25) +1% Boric Acid	34.2	31.8	30.2	32.1	32.5 (10.86)	32.0 (10.50)	32.6 (10.99)	32.4 (10.71)
GA <sub>3</sub> @ 100 g/ha (25:50:25) +1% Boric Acid	37.0	33.6	31.4	34.0	35.4 (12.10)	37.1 (13.01)	33.4 (11.26)	35.3 (12.01)
GA <sub>3</sub> @ 150 g/ha (25:50:25) +1% Boric Acid	39.0	39.4	32.8	37.0	37.8 (12.51)	40.0 (13.48)	38.6 (13.01)	38.8 (13.09)
Mean	35.5	33.4	30.9	33.3	34.6 (11.87)	33.7 (11.44)	31.6 (10.65)	33.3 (11.22)
C.D. (p=0.05)	DOS =		3.53				0.73	
	Treatment =		1.24				1.12	
	Treatment x DOS =		N.S.				N.S.	

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>; 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July in 2005

Pusa 6A is dwarfier than the restorer line, PRR-78, on an average by 20 cm. Application of GA<sub>3</sub> increases the plant height of 6A by 9-13 cm and in PRR 78 by 18-20 cm (Table 4). GA<sub>3</sub> application has been established to cause increase in plant height by previous workers [14 & 15].

#### Panicle length

Panicle length is important as it determines the number of spikelets in a panicle. GA<sub>3</sub> has profound effect on panicle length due to increase in collar length. In the present study the delay in sowing had negative effect on panicle length as in the case of plant height. The panicle length ranged from 22.6 cm (control) to 25.2 cm in *Kharif* 2004 and 22.8 cm to 25.2 cm in *Kharif*, 2005 when GA<sub>3</sub> @ 150 g/ha (25:50:25) + 1% Boric acid was applied (Table 5). GA<sub>3</sub> application improves the panicle

length, panicle exertion and higher seed set in rice. Increase in panicle length by 8 cm over control was reported when GA<sub>3</sub> @ 60 ppm was applied in rice [4]. GA<sub>3</sub> application directly influences the internode length and is responsible for increase in plant height as well as panicle length [16].

#### Panicle exertion

Panicle exertion is one of the most important factors that determine higher seed set and ultimately seed yield in hybrid rice seed production. In the present study, there was significant difference in panicle exertion for different DOS. It ranged from 80.0% in 3<sup>rd</sup> DOS to 89.8% in 1<sup>st</sup> DOS in *Kharif* 2004 and 78.1 in 3<sup>rd</sup> DOS to 83.9% in 2<sup>nd</sup> DOS in *Kharif* 2005 (Table 6). This indicates that panicle exertion was influenced by climatic condition and proper expression of

**Table 3. Effect of planting dates and chemicals on plant height (cm) of Pusa 6A**

Treatment/DOS	2004				2005			
	1 <sup>st*</sup>	2 <sup>nd*</sup>	3 <sup>rd*</sup>	Mean	1 <sup>st@</sup>	2 <sup>nd@</sup>	3 <sup>rd@</sup>	Mean
Control	102.0	93.4	85.6	94.6	105.4 (48.49)	108.6 (49.95)	91.4 (42.05)	101.8 (46.08)
GA <sub>3</sub> @ 50 g/ha (40:60) + 1% Boric Acid	108.6	94.2	87.6	96.8	109.5 (50.43)	112.8 (51.80)	93.6 (42.61)	105.1 (48.10)
GA <sub>3</sub> @ 100 g/ha (40:60) +1% Boric Acid	109.0	96.8	90.2	98.7	112.4 (51.72)	113.8 (52.36)	95.6 (43.99)	107.3 (49.41)
GA <sub>3</sub> @ 150 g/ha (40:60) +1% Boric Acid	112.2	102.6	96.2	103.7	113.6 (52.27)	115.7 (53.18)	95.8 (44.12)	108.4 (49.64)
GA <sub>3</sub> @ 50 g/ha (25:50:25) +1% Boric Acid	110.0	95.6	98.2	101.2	113.2 (52.08)	113.4 (52.17)	93.4 (42.97)	106.7 (49.1)
GA <sub>3</sub> @ 100 g/ha (25:50:25) +1% Boric Acid	112.0	102.0	101.4	105.1	114.8 (52.82)	115.8 (52.78)	94.6 (43.53)	108.4 (49.64)
GA <sub>3</sub> @ 150 g/ha (25:50:25) +1% Boric Acid	113.8	105.8	103.2	107.6	116.8 (53.74)	117.4 (54.02)	96.0 (45.22)	110.3 (50.04)
Mean	109.6	98.6	94.6	100.9	112.3 (51.64)	113.7 (52.29)	94.2 (43.32)	106.7 (49.01)

C.D. (p=0.05)	DOS =	2.93	0.72
	Treatment =	1.92	2.88
	Treatment x DOS =	N.S.	N.S.

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>; 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004 ; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July in 2005

**Table 4. Effect of planting dates and chemicals on plant height (cm) of R line**

Treatment/DOS	2004				2005			
	1 <sup>st*</sup>	2 <sup>nd*</sup>	3 <sup>rd*</sup>	Mean	1 <sup>st@</sup>	2 <sup>nd@</sup>	3 <sup>rd@</sup>	Mean
Control	108.0	108.0	104.0	106.7	123.8	113.0	108.4	115.1
GA <sub>3</sub> @ 50 g/ha (40:60) + 1% Boric Acid	115.2	113.4	114.0	114.1	130.4	123.6	117.2	123.6
GA <sub>3</sub> @ 100 g/ha (40:60) +1% Boric Acid	119.8	115.4	126.0	117.0	132.2	133.6	116.4	127.4
GA <sub>3</sub> @ 150 g/ha (40:60) +1% Boric Acid	127.2	127.4	118.6	124.3	134.4	135.0	122.8	130.7
GA <sub>3</sub> @ 50 g/ha (25:50:25) +1% Boric Acid	118.6	120.4	117.6	118.8	130.8	130.2	117.4	126.2
GA <sub>3</sub> @ 100 g/ha (25:50:25) +1% Boric Acid	124.6	121.2	119.8	121.8	131.2	134.8	122.0	129.3
GA <sub>3</sub> @ 150 g/ha (25:50:25) +1% Boric Acid	127.8	127.8	125.8	127.1	135.0	140.0	1125.4	133.5
Mean	120.2	119.1	116.6	118.6	131.	130.0	118.5	126.5

C.D. (p=0.05)	DOS =	3.53	1.86
	Treatment =	5.39	2.66
	Treatment x DOS =	N.S.	N.S.

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>; 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004 ; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July

Table 5. Effect of planting dates and chemicals on panicle length (cm) of Pusa 6A

Treatment/DOS	2004				2005			
	1 <sup>st</sup> *	2 <sup>nd</sup> *	3 <sup>rd</sup> *	Mean	1 <sup>st</sup> @	2 <sup>nd</sup> @	3 <sup>rd</sup> @	Mean
Control	23.9	21.9	22.1	22.6	23.6	23.2	21.7	22.8
GA <sub>3</sub> @ 50 g/ha (40:60) + 1% Boric Acid	25.1	23.8	22.9	23.9	24.2	24.1	22.1	23.5
GA <sub>3</sub> @ 100 g/ha (40:60) + 1% Boric Acid	25.3	24.1	23.0	24.1	24.7	24.6	22.7	24.0
GA <sub>3</sub> @ 150 g/ha (40:60) + 1% Boric Acid	26.0	24.2	23.2	24.5	27.5	24.8	23.2	25.2
GA <sub>3</sub> @ 50 g/ha (25:50:25) + 1% Boric Acid	25.1	23.4	22.6	24.0	24.6	22.1	22.3	23.0
GA <sub>3</sub> @ 100 g/ha (25:50:25) + 1% Boric Acid	25.4	24.0	23.6	24.3	25.3	22.4	22.8	23.5
GA <sub>3</sub> @ 150 g/ha (25:50:25) + 1% Boric Acid	26.3	25.4	23.9	25.2	26.4	25.2	23.9	25.2
Mean	25.3	23.8	23.2	24.1	25.2	23.8	22.7	23.9
C.D. (p=0.05)	DOS =		0.62		0.60			
	Treatment =		0.41		0.40			
	Treatment x DOS =		0.70		0.67			

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>; 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July in 2005

Table 6. Effect of planting dates and chemicals on factors favoring outcrossing (panicle exertion %) of Pusa 6A

Treatment/DOS	2004				2005			
	1 <sup>st</sup> *	2 <sup>nd</sup> *	3 <sup>rd</sup> *	Mean	1 <sup>st</sup> @	2 <sup>nd</sup> @	3 <sup>rd</sup> @	Mean
Control	87.0	86.3	75.7	83.0	74.3	78.0	70.3	75.7
GA <sub>3</sub> @ 50 g/ha (40:60) +1% Boric Acid	90.3	88.3	81.3	86.7	79.3	82.3	76.0	79.2
GA <sub>3</sub> @ 100 g/ha (40:60) + 1% Boric Acid	89.6	88.0	81.7	86.4	81.7	84.3	80.3	82.1
GA <sub>3</sub> @ 150 g/ha (40:60) + 1% Boric Acid	91.3	88.0	81.3	86.9	84.0	85.3	80.7	83.3
GA <sub>3</sub> @ 50 g/ha (25:50:25) + 1% Boric Acid	89.6	87.3	78.7	85.2	77.7	83.0	77.7	79.5
GA <sub>3</sub> @ 100 g/ha (25:50:25) + 1% Boric Acid	90.0	87.7	80.3	86.0	79.7	80.3	79.7	81.9
GA <sub>3</sub> @ 150 g/ha (25:50:25) + 1% Boric Acid	90.7	88.7	81.3	86.9	84.6	88.0	82.0	84.9
Mean	89.8	88.7	80.0	85.9	80.2	83.9	78.1	80.7
C.D. (p=0.05)	DOS =		0.63		1.63			
	Treatment =		0.97		2.49			
	Treatment x DOS =		1.67		0.67			

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>; 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July in 2005

morphological characters is correlated with better panicle exertion in rice (Table 8). In late planting, the panicle exertion was very poor even after GA<sub>3</sub> application resulting in poor seed set. Therefore,

in hybrid rice seed production date of sowing and planting is very crucial.

There was significant increase in panicle

exsertion due to  $GA_3$  treatment and it was 83.0% in control to 86.9% when  $GA_3$  @ 150 g/ha (25:50:25) + 1% Boric acid was applied in *Kharif* 2004. In *Kharif* 2005, there was linear but non-significant increase in panicle exsertion and it ranged from 75.7% in control to 84.9% when  $GA_3$  150 g/ha (25:50:25) + 1% Boric acid was applied. A maximum of 80% panicle exsertion at  $GA_3$  150 g/ha concentration was reported by previous worker [17]. Significant increase in the panicle exsertion over control was recorded when  $GA_3$  along with 1% Boric acid was applied in 40:60 and 25:50:25 ratios and also split application (three to four times) of a higher dose of  $GA_3$  yielded better than a single application [8].

#### Hybrid seed yield

Hybrid seed yield mainly depends upon the weather conditions prevailing during crop growth phases especially during flowering and subsequently up to maturity. The weather parameters like temperature, RH, photoperiod and sunshine are the major factors determining seed yield. The effect of temperature on enhancing floral behavior for better pollination and seed set has been well established [17]. Duration of sunshine hours in combination with temperature is also known to affect the photosynthetic ability of plant since photosynthesis helps in assimilation, mobilization of reserves and seed yield [18].

The delayed planting can reduce the expression of various floral and morphological characters *viz* spikelet opening duration, spikelet opening angle, duration of blooming, number of spikelet, flag leaf angle, panicle length, plant height, panicle exsertion, number of tillers and seed set [13] as validated in the present study.

Further, the maximum seed yield (3.17t/ha) in 1<sup>st</sup> DOS, in *Kharif* 2004 was obtained when there was optimum environmental conditions in terms of max/min temperature (38/24°C), mean relative humidity (RH) (47-71%), absence of rainfall, sunshine hours (2.8-9.8), average wind velocity (2.3-8.9 km/h), which was available during peak pollination period and they contributed positively for higher seed yield. Similar yield (1.64-2.84 t/ha) was observed when favorable climatic conditions prevailed during flowering in *Kharif* 2005 in the

seed production plot (Table 7, 8). Higher yield in such range of climatic conditions were earlier also reported [2].

The lower seed yield in subsequent date of sowing in *Kharif* 2004 and 2005 (except 1<sup>st</sup> DOS in 2005 which had aberrant weather conditions during flowering) is due to higher RH, low temperature, low sunshine hours during flowering, leading to poor expression of floral and morphological characters and also due to low photosynthetic ability as compared to 1<sup>st</sup> DOS. Similar results were reported earlier [13 & 21].

$GA_3$  plays important role in rice for better expression of floral and morphological characters like longer spikelet opening duration, wider spikelet opening angle, more panicle length, plant height, wider flag leaf angle and panicle exsertion, through cell elongation, leading to higher seed set and yield [3, 6 & 19].

In the present study, seed yield increased during all dates of sowing with the incremental dose of  $GA_3$  but varied with the climatic conditions that prevailed during crop growth, especially during flowering. In the present study, the mean seed yield for the three planting dates increased from 1.89 to 2.41 t/ha in *Kharif* 2004, 1.18 to 1.70 t/ha in *Kharif* 2005 when  $GA_3$  @ 150 g/ha (40:60) + 1% Boric acid was applied. There was lower but non significant difference when  $GA_3$  was applied in 40:60 ratio (Table 7). This is due to better effect of  $GA_3$  sprayed in split doses [8 & 19]. Seed set and seed yield had significant correlation with plant height, panicle exsertion, flag leaf angle and spikelet opening angle [20]. The above observations support the present study since during later dates of planting, all the above characters had reduced values along with the seed yield.

Thus profitable hybrid seed production can be possible if the planting of parental lines are taken in the first week of June under north Indian conditions, as the chances of getting favorable weather conditions during flowering period is higher leading to higher out crossing rate which contributed towards higher seed production in Pusa RH-10, than delayed date of sowing.

Table 7. Effect of planting dates and chemicals on hybrid seed yield (t/ha)

Treatment/DOS	2004				2005			
	1 <sup>st</sup> *	2 <sup>nd</sup> *	3 <sup>rd</sup> *	Mean	1 <sup>st</sup> @	2 <sup>nd</sup> @	3 <sup>rd</sup> @	Mean
Control	2.56	2.09	1.03	1.89	0.98	1.61	0.95	1.18
GA <sub>3</sub> @ 50 g/ha (40:60) +1% Boric Acid	3.20	2.23	1.23	2.22	1.17	1.86	1.19	1.41
GA <sub>3</sub> @ 100 g/ha (40:60) +1% Boric Acid	3.33	3.20	1.23	2.25	1.29	2.11	1.31	1.57
GA <sub>3</sub> @ 150 g/ha (40:60) +1% Boric Acid	3.42	2.26	1.30	2.33	1.40	2.26	1.32	1.61
GA <sub>3</sub> @ 50 g/ha (25:50:25) +1% Boric Acid	3.02	2.21	1.32	2.16	1.18	1.64	1.10	1.31
GA <sub>3</sub> @ 100 g/ha (25:50:25) +1% Boric Acid	3.21	2.30	1.34	2.28	1.2	2.31	1.25	1.60
GA <sub>3</sub> @ 150 g/ha (25:50:25) +1% Boric Acid	3.51	2.33	1.40	2.41	1.31	2.33	1.46	1.70
Mean	3.17	2.23	1.26	2.22	1.22	2.02	1.22	1.48

C.D. (p=0.05) DOS = 0.145  
 Treatment = 0.121  
 Treatment x DOS = 0.100

DOS: date of sowing: \* 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 7<sup>th</sup>, 19<sup>th</sup> June and 1<sup>st</sup> July in 2004 ; @ 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>: 12<sup>th</sup> and 24<sup>th</sup> June and 9<sup>th</sup> July in 2005

Table 8. Meteorological observation during flowering period

Parameters/DOS	2004			2005		
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>
Date of transplanting	7.7.2004	24.7.2004	3.8.2004	14.7.2005	25.7.2005	5.8.2005
Date of initiation of flowering	5.9.2004	10.9.2004	27.9.2004	10.9.2005	21.9.2005	5.10.2005
Max. Temperature (°C) range	24.3-38.0	29.6-36.8	33.0-36.0	25.7-35.0	26.9-35.0	32.7-34.9
Min. Temperature (°C) range	24.0-27.0	23.5-28.0	20.5-23.0	20.6-25.2	21.8-26.0	18.2-20.8
Mean Temperature (°C) range	29.7-32.5	27.0-32.4	27.5-29.0	23.5-29.9	24.4-30.5	25.0-27.4
Temperature range (°C)	24.0-38.0	23.5-36.8	20.5-36.0	20.6-35.0	21.8-35.0	18.2-34.9
Mean Relative Humidity (%) range	47-71	57-76	51-63	67-93	69-96	55-65
Relative Humidity range (%)	32-86	43-86	18-84	50-100	51-95	28-96
Total rainfall range (mm)	0.0-0.0	0.0-5.4	0.0-0.0	0.0-48.8	0.0-45.6	0.0-0.0
Sunshine hr/day range	2.8-9.8	1.2-8.0	5.6-9.3	0.0-9.0	0.1-9.5	8.5-9.9
Wind speed range (km/hr)	2.3-8.9	0.8-4.4	0.8-4.3	0.7-19.5	0.1-5.0	1.9-5.1

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## REFERENCES

1. BASTASA DB, RR SURATTA, RF IRANG, TS VELASQUER, EV SANTIAGO, ED REDONA AND ED GASPAR (2002). Development of improved hybrid rice seed production technologies. *Philippine Journal of Crop Science*, **27**(1): 62.
2. JAGADEESWARI P, SP SHARMA AND M DADLANI (2004). Effect of different chemicals on traits favouring outcrossing and optimization of GA<sub>3</sub> for seed production of cytoplasmic male sterile line in hybrid rice. *Seed Science and Technol.*, **32**: 473-483.
3. DUAN XM AND MA HS (1992). Effects of gibberellic acid application on seed yield and quality of hybrid rice. *Seed Science and Technol.*, **20**: 209-214.
4. THIRTHALINGAPPA B, RS KULKARNI AND TG PRASAD (1999). Effect of GA<sub>3</sub> and homobrassinosteroid in rice hybrid production. *Mysore Journal of Agri. Sciences*, **33**(2): 210-213.
5. MURLIDHAR JS (2002) Studies on maximization of seed production in female line of rice hybrid. M.Sc. thesis submitted to Division of Sees Science and Technology, Indian Agricultural Research Institute, New Delhi, India.
6. PANDEY S, SP SHARMA AND M DADLANI (2003). Effect of gibberellic acid application on floral and morphological traits, seed yield and storability of parental lines in hybrid rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences*, **73**(7): 376-386
7. SIDDIQ EA, PJ JACHUCK, M MAHADEVAPPA, FU ZAMAN, VIJAY KUMAR, B VIDYACHANDRA, GS SINDHU, I KUMAR, MN PRASAD, RM RANGASWAMI, MP PANDEY AND A ILLYAS (1994). *Hybrid Rice Research in India*. In: Hybrid Rice Technology: new Developments and Future Prospects. Virmani, S.S. (Ed), IRRI, Manila, Philippines. pp. 157-171
8. JOSE S, SK CHAKRABARTY, SP SHARMA AND M DADLANI (2006). Management of GA<sub>3</sub> application to enhance seed production in the CMS parent of rice (*Oryza sativa*) hybrids. *Indian Journal of Agricultural Sciences*, **76**(2): 122-124.
9. SINGH R AND SK SAHOO (1998). Evaluating hybrid seed production technology along with the new growth hormone mangiferin. *IRRN*, **23**(1): 23.
10. THU BUI VIET, SK CHAKRABARTY, SP SHARMA AND M DADLANI (2008). Studies on environmental conditions and pollination management in hybrid rice seed production. *Indian J. Genet.*, **68**(4): 426-434.
11. PONNUSWARMY AS, MI RANGSWAMY, P RANGASWAMY AND K THIYAGARAJAN (1998). Adopting hybrid rice seed production technology. *IRRN*, **23**(2): 26.
12. SURATTA RR AND RP ROBLES (2003). Gibberellic acid (GA<sub>3</sub>) improves heading characteristics of cytoplasmic male sterile (CMS) lines and seed yield of hybrid rice seed production. *Philippine Journal of Crop Science*, **28**(1): 22.
13. RAI HK AND HS KHUSHAVAHA (2005). Performnce of upland rice (*Oryza sativa*) under different transplanting dates and soil water regimes in tarai conditions. *Indian Journal of Agricultural Sciences*, **75**(12): 817-19.
14. PANDEY S (2000). Studies on synchronization of flowering, seed production and storability of parental lines of hybrid rice. Ph.D. thesis submitted to Division of Seed Science and Technology, Indian Agriculture Research Institute, New Delhi, India.
15. LIANG MANZHONG AND FU ZAMAN (1999). Optimization of hybrid rice seed production. *Seed Research*, **27**(1): 7-10.
16. YUAN LP (1977). The execution and theory of developing hybrid rice. *Zhejiong Nongye Kexue (Chinese Agricultural Science)*, **1**: 27-31.
17. YOSHIDA S AND T HARA (1977). Effect of air temperature and light on grain filling of indica and japonica rice (*Oryza sativa* L.) under controlled environmental conditions. *Soil science and Plant Nutrition*, **23**: 93-107.
18. CHOPRA NK AND N CHOPRA (2004). Influence of transplanting dates on heat unit-treatment requirement of different phonological stages and subsequently yield and quality of scented rice seed. *Indian Journal of Agricultural Sciences*, **78**(8): 414-419.
19. SURATTA RR AND RP ROBELES (2004). Gibberellic acid (GA<sub>3</sub>) effects on heading characteristics of ten cytoplasmic male sterile (CMS) lines and on hybrid rice seed production using IR58025A CMS line. *Philipp. Agric. Scientist*, **87**: 285-297.
20. JAGADEESWARI P (2001). Studies on the effect of chemicals on flowering, pollination and seed yield in the parental lines of hybrid rice. Ph.D. Thesis, Division of Seed Science and Technology, Indian Agricultural Research Institute, New Delhi.
21. SINGH AK (2003) Performance of rice (*Oryza sativa*) in response to transplanting time and varieties. *Journal of Agrometeorology*, **5**(1): 105-111.