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# DOSE OPTIMIZATION OF FOLIAR APPLIED GIBBERELIC ACID FOR NEWLY DEVELOPED OF HYBRID RICE LINES IN EGYPT

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## ABSTRACT

Gibberellic acid (GA<sub>3</sub>) plays a vital role in boosting hybrid rice yield, however, fresh research needs to be done for its dose optimization especially for newly developed hybrid rice lines. To fill this research gap, an investigation was conducted at the experimental farm of Sakha Agricultural Research Station, Kafrelsheikh, Egypt during two growing seasons of 2017 and 2018. The main objective of this study was to evaluate the impact of GA<sub>3</sub> application on hybrid rice lines for boosting seed production. Egyptian hybrid No.1 and G46 A/Giza 178 R were the hybrid rice lines, while GA<sub>3</sub> in four doses viz. 0, 250, 300 and 350 g/ha were applied. The experimental design was split plot with three replications, where the main plot was devoted to hybrid rice lines, while the sub-plots had different doses of GA<sub>3</sub>. The results showed that the best desirable values for the studied characteristics especially for hybrid seed yield (2.5 t/ha) were recorded of the hybrid combination IR69625/Giza 178 followed by G46A/Giza178 with the highest dose of GA<sub>3</sub>. It is concluded that foliage application of GA<sub>3</sub>@ 350 g/ha has the potential to enhance hybrid rice seed production, while hybrid rice line Giza 178 can be recommended for general adoption in the irrigated regions of Egypt.

## KEYWORDS:

Gibberellic acid, morphology, yield, hybrid rice

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple crops in the global food system providing energy, protein and vitamins for about half of the world population [1,2]. Rice requirement increases dramatically which necessitates boosting

rice productivity for ensuring food and nutritional security [3]. Thus, improved technologies are required to bridge the gap for feeding the increasing population. Therefore, enhancing productivity of rice through novel genetic approaches like hybrid rice was felt necessary [4]. Globally, rice is considered as one of the most important cereal crops [5,6].

Rice crop plays an important role in Egypt for strengthen self-sufficiency of food and for maximizing the export of rice as strategic crop. Rice cultivation is one of the main activity and source of income for millions peoples in Egypt, which depend heavily on rice as a source of foreign exchange earnings [6,7]. Furthermore, rice crop plays a significant role in Egypt, as strategic crop for sustaining the food self-sufficiency and to the increase the export [8, 9].

Keeping in view declining land area under plough and rapidly increasing population, all options including new hybrid lines must be evaluated to increase paddy yield. Cultivation of hybrid rice instead of inbred rice can satisfy this problem. Therefore, hybrid rice seed production is an important task to produce more food in the world. Accordingly, the main focus of rice investigation in the next decade must be the development of high-yielding and early maturing varieties for ensure food scarcity and efficient use of natural resources [10]. To face the challenge of providing extra rice from proper lands, the rice varieties/hybrids with preferable yield potential and maximal yield stability is needed [2].

Currently, the most popular male sterility system for commercial exploitation of hybrid rice technology is the CMS, popularly known as the three-line system. Seed production technology is a key to the success of hybrid rice [4]. To enhance the efficiency of hybrid seed production, it is necessary to increase the yield of hybrid seed by improving the out crossing capacity of CMS lines [11]. Hybrid rice seed production is a systematic

complex and demanding approach compared with inbred seed production. The most important step from research for commercialization of hybrid rice is hybrid seed production [12].

Presently, interest in optimizing agronomic management practices is revitalizing and application of GA<sub>3</sub> holds the potential to increase paddy productivity. However, optimization of its dose is critical as sub-optimized doses drastically decreased the germination, viability and seed vigor index of field crops [13]. In contrast, application of GA<sub>3</sub> at the optimum concentration increased the hybrid rice seed yield by providing the highest values of panicle length, seed setting percentage as well as panicle exertion percentage [4,14,15]. GA<sub>3</sub> application helps to complete exertion of the panicle out of the flag leaf sheath in CMS lines and increased the grain yield [15]. So, the optimum dose of GA<sub>3</sub> is very important to produce high quality hybrid seed. Considering the above facts, the present study was, therefore, undertaken to determine the suitable dose of GA<sub>3</sub> for each of the two CMS lines for increasing productivity of hybrid rice seed.

## MATERIALS AND METHODS

**Experimental design, treatment, parental lines used and Cultural practices.** This study was conducted at the experimental farm of Sakha Agriculture Research Station (SARS), KafrElsheikh, Egypt, during the successive summer seasons 2017 and 2018. Two CMS lines IR69625A (WA) and G46A (Gambica) as female parents with their restorer line Giza 178 were used in this study to produce F1 hybrid seed for two promising hybrid combinations, IR 69625A/Giza 178R (Sakha 2034H) and G4A/Giza 178R (Sakha 2003), respectively. Four levels of GA<sub>3</sub> concentration viz., 0, 250, 300 and 350 g/ha were applied on the hybrid rice lines.

The experiment was laid out in split plot design with three replications. The main plot was reserved for CMS lines and the sub-plot contained GA<sub>3</sub> concentrations. The seed sowing was done on

20 April for IR69625A as female parent, 27 April for first restorer line Giza178, 30 April for second restorer line Giza178, 3 May for third restorer line Giza178, and 5 May for G46A line as female earlier parent. The row ratio was maintained as 2 rows for male parent and 10 rows for female parent.

**Data collection.** It was harvested and grains were sun-dried and adjusted at 14% moisture for measuring the yield. The data were noted per plot randomly chosen hills excluding border rows. The studied characteristics were the number of panicles/hill, percentage of panicle exertion and seed set, 1000-grains weight, grain yield and harvest index. The general reference for data collection according to [16].

**Statistics analyses.** The recorded data were determined by Standard Evaluation System (SES) as recommended by [17], and mean values were used for statistical analysis. All collected data were subjected to standard statistical analysis following the proceeding described by [18] using the computer program (Genstat) with significance at 5% level of probability.

## RESULTS AND DISCUSSION

Based on the data that referred to the maximum (max), minimum (min) temperature, relative humidity (RH), and wind velocity from April to August during 2017 and 2018 seasons were presented in Table (1). It was observed that the monthwise max temperatures were lower in 2017 season than in 2018. On the other hand, min temperatures were higher in 2017 season. The values of RH at 1<sup>st</sup> season were higher than the 2<sup>nd</sup> season. The wind velocity was also in 2017 season than in 2018 except only in the months of July and August. According to data, the weather condition at SARS was stable during the two seasons. Consequently, it could be used the total duration as a method to adjust the synchronization of flowering for these parental lines.

**TABLE 1**  
**Month-wise maximum and minimum temperature (°C), relative humidity (%) and wind velocity (Km/h) at RRTC SARS, KafrELsSkeikh province during 2017 and 2018 seasons**

Months	2017 season			2018 season						
	Temperature (°C)	Relative humidity (%)		Wind velocity (Km/h)	Temperature (°C)	Relative humidity (%)		Wind velocity (Km/h)		
		Max	Min			7.30	13.00		Max	Min
April	26.5	21.6	79.4	50.8	89.3	27.8	20.0	80.9	43.9	74.0
May	30.6	25.8	77.7	45.6	106.5	31.2	23.8	75.6	43.9	95.8
June	32.5	28.1	80.1	51.4	102.6	33.6	25.3	75.5	48.0	98.6
July	34.2	29.0	84.4	57.6	80.9	35.2	25.4	82.6	51.0	89.5
August	33.9	28.3	85.9	55.3	70.2	34.9	25.2	82.4	51.4	76.0
Sept.	32.5	25.9	86.3	50.3	85.7	32.8	23.5	83.1	48.3	68.7
Oct.	28.7	24.0	81.1	54.7	73.2	29.5	20.6	82.5	49.6	57.9

**TABLE 2**  
**Sowing data, heading data and total duration for parental lines during two seasons**

Entries	Sowing date	Transplanting date	Heading date	Total date	Remarkable
IR69625	20/04/2017	20/05/2017	30/07/2017	101±3	Spray 1% K <sub>2</sub> PO <sub>4</sub>
GIZA178R1	27/04/2017	27/05/2017	01/08/2017	98+2	
GIZA178R2	30/04/2017	30/05/2017	04/08/2017	96+3	Urea 2 %
GIZA178R3	03/05/2017	03/06/2017	07/08/2017	96+3	
G46A	05/05/2017	05/06/2017	21/08/2017	88+2	
IR69625A	24/04/2018	24/05/2017	04/08/2018	102±2	
GIZA178R1	01/05/2018	01/06/2018	06/08/2018	98±3	
GIZA178R2	03/05/2018	05/06/2018	08/08/2018	95±3	
GIZA178R3	06/05/2018	07/06/2018	10/08/2018	94±3	
G46A	08/05/2018	10/06/2018	05/08/2018	89±2	

**TABLE 3**  
**Effect of GA<sub>3</sub> application on panicle characteristics of two CMS lines during two seasons**

Main effect and interaction	Number of effective panicles/hill		Panicle weight (g)		Panicle exertion (%)		Number of spikelets/panicle	
	2017	2018	2017	2018	2017	2018	2017	2018
Lines (L)								
IR69625A	16.29	16.67	2.15	2.21	70.95	64.43	157.31	159.45
G46A	14.79	15.2	2.27	2.28	69.35	63.25	161.26	163.16
LSD 0.05	0.71	1.01	0.06	0.02	0.99	0.96	2.54	1.56
GA <sub>3</sub> doses (G)								
Control	12.15	13.43	1.95	2.02	57.63	55.76	155.68	158.06
250	14.2	16.51	2.2	2.36	68.93	63.23	159.98	161.41
300	16.92	18.58	2.31	2.42	71.1	66.07	162.11	162.11
350	18.87	20.21	2.38	2.5	72.91	69.66	165.37	163.63
LSD 0.05	0.58	0.82	0.05	0.02	0.8	0.78	2.77	1.27
Interaction	**	*	*	**	*	*	*	**
L x G								

In the present research, the data in (Table 2) revealed that the date of sowing and heading for the three parental lines where the IR69625A line was later than the restorer line Giza 178R line, while the G46A line was earlier than the restorer line Giza 178 R line. Therefore, to get good synchronization of flowering on the bases of the total duration, IR 69625A as female line should be sown earlier than the restorer line Giza 178 from 8-10 days at least, while the G46A should be sown later than the restorer line Giza 178 from 5-8 days for the second sowing date for Giza 178. Moreover, the restorer lines should be sown three times with 3-4 days intervals. It was suggested that increasing the amount of GA<sub>3</sub> is an effective measure to improve the heading characteristics [19].

The performance of seed parent of the two hybrid combinations regarding the number of effective panicles/hill, panicle weight, panicle exertion percentage, and number of spikelets/panicle are represented in Table 3. The highest value of the number of panicles/plant was recorded for G46A compared to IR69625A, and application of GA<sub>3</sub> with the highest dose (350 g/ha) recorded the highest value of panicles/hill. The seed parent G46A line recorded the highest values for the panicle weight, and the number of spikelets/panicle, while the seed parent IR 69625A recorded the highest value for the panicle exertion percentage. The highest concentration of GA<sub>3</sub> (350 g/ha) recorded

the highest values of panicle weight, panicle exertion percentage, and number of spikelets/panicle compared to the control. The results revealed that GA<sub>3</sub> has the important role for plant growth and development, and this is might be due to application of GA<sub>3</sub> extended of cell membrane and cell multiplication then elongation of internode and increase panicle exerted from flag leaf which increase the seed setting percentage and panicle characteristics. The results are in line with the finding of [15], who reported that application of GA<sub>3</sub> @400 g/ha produced the highest panicle length (cm), seed setting percentage, panicle weight (g), panicle exertion percentage, and seed yield. [5] reported that the panicle number and weight had direct impact on paddy yield, and slight decline in their weight resulted insignificant reduction of rice yield. [20] found that application of 200 g NAA/ha resulted in the highest percentage of panicle exertion (88%), seed set (23.52-27.39%) and seed yield (1660-1795Kg/ha).

The data in Table 4 showed the interaction between the CMS lines and different GA<sub>3</sub> concentrations for the number of panicles/hill, where the IR69625A line recorded the highest values for the number of effective panicles/hill with using 350 g/ha of GA<sub>3</sub>, while the CMS G46A line recorded the lowest values for the number of effective panicles/hill, that meaning the IR69625A line was highly responsive to GA<sub>3</sub> application. The

application of different concentrations of GA<sub>3</sub> significantly affected the number of fertile panicles/hill, and spraying of GA<sub>3</sub> at appropriate times with fitting dosages was a valuable measure to enhance the number of fertile panicles/hill [15]. The progressive improvement in the formation of better number of fertile panicles/hill could be due to availability of GA<sub>3</sub>, which improved more tillering and led to improve the number of effective tillers/hill [12].

The interaction effects between the CMS lines and different GA<sub>3</sub> concentrations for panicle weight are presented in Table 5, where the G46A line recorded the highest value for panicle weight with the application of GA<sub>3</sub> @ 350 g/ha, while the CMS IR69625A line recorded the lowest values of panicle weight in both seasons, that means the G46A line responded highly to GA<sub>3</sub>. Application of 300 g/ha

of GA<sub>3</sub> also produced the same number of effective panicles/hill for the G46A CMS line. [21] reported that GA<sub>3</sub> application @ 200 g/ha remained instrumental in recording the highest panicle weight (2.13g) which was 50% higher than control.

The data in Table (6) showed the interaction between the CMS lines and different GA<sub>3</sub> concentrations regarding the panicle exertion, where the IR69625A line recorded the highest values for panicle exertion percentage with using 350 g of GA<sub>3</sub>, while the CMS G46A line recorded the lowest values, indicating the IR69625A line was highly responsive to GA<sub>3</sub> application. The data were agreement with those obtained by [13], who found that GA<sub>3</sub> application increased the panicle exertion percentage. [22] found that application of GA<sub>3</sub> increased the panicle exertion when GA<sub>3</sub>

**TABLE 4**  
**Number of effective panicles/hall as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Main effect and interaction	GA <sub>3</sub> doses	Number of effective panicles/hill	
		2017	2018
IR69625A	Control	13.48	12.83
	250	14.81	15.23
	300	17.93	18.00
	350	18.91	19.07
G46A	Control	10.83	11.04
	250	13.59	14.91
	300	15.90	16.16
	350	17.83	18.73
LSD 0.05		0.90	0.98

**TABLE 5**  
**Panicle weight (g) as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Main effect and interaction	GA <sub>3</sub> doses (g/ha)	Panicle weight (g)	
		2017	2018
IR69625A	Control	1.85	1.90
	250	2.15	2.29
	300	2.25	2.31
	350	2.36	2.38
G46A	Control	2.05	2.11
	250	2.25	2.24
	300	2.37	2.34
	350	2.39	2.42
LSD 0.05		0.06	0.04

**TABLE 6**  
**Panicle exertion percentage as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Main effect and interaction	GA <sub>3</sub> doses (g/ha)	Panicle exertion (%)	
		2017	2018
IR69625A	Control	69.15	56.93
	250	69.56	63.00
	300	71.53	68.02
	350	73.52	69.06
G46A	Control	66.11	54.06
	250	68.30	63.46
	300	70.68	65.02
	350	72.30	69.73
LSD 0.05		1.13	0.074

TABLE 7

**Number of spikelets/panicle as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Main effect and interaction	GA <sub>3</sub> doses (g/ha)	Number of spikelets/panicle	
		2017	2018
IR69625A	Control	143.66	146.46
	250	156.08	158.5
	300	158.73	160.73
	350	160.07	162.10
G46A	Control	147.07	149.66
	250	163.16	164.33
	300	161.5	163.50
	350	162.68	165.16
LSD 0.05		0.61	1.61

TABLE 8

**Effect of GA<sub>3</sub> application for two CMS lines on seed set and yield components during two seasons**

Main effect and interaction	Seed set (%)		1000 grain weight (g)		Seed yield (t/ha)		Harvest index (%)	
	2017	2018	2017	2018	2017	2018	2017	2018
Lines (L)								
IR69625A	32.38	32.65	23.21	23.66	0.878.2	3.032	20.69	21.42
G46A	33.63	33.60	24.13	24.22	3.206	3.302	21.50	23.23
LSD 0.05	0.70	0.72	0.38	0.18	0.92	0.96	0.59	1.91
GA <sub>3</sub> doses (G)								
Control	30.23	29.78	24.66	24.68	2.534	2.625	17.66	17.99
250	31.15	32.38	23.98	24.49	2.949	2.955	19.76	21.76
300	35.04	34.80	23.60	23.65	3.190	3.449	23.18	23.73
350	35.60	35.56	22.44	22.95	3.642	3.56	23.78	25.81
LSD 0.05	0.57	0.59	0.31	0.15	0.35	0.38	0.48	1.56
Interaction	*	*	**	**	**	**	*	*
L x G								

was applied at the rate of 125 g/ha during 15-20% of heading stage. Moreover, [23] found that GA<sub>3</sub> application increased the panicle exertion value with 90 g GA<sub>3</sub>/ha.

The data in Table (7) showed the interaction between the CMS lines and different GA<sub>3</sub> concentrations for the number of spikelets/panicle where the G46A line produced the highest number of spikelets/panicle in response to application of 350 g/ha of GA<sub>3</sub>, while the CMS IR69625A line recorded the lowest values of spikelets/panicle. The G46A line was highly responsive to GA<sub>3</sub> application, as evident through significantly higher panicle exertion, spikelet opening angle and other floral traits which contributed to higher paddy yield [4].

The results in Table (8) showed the performance of seed parent of two hybrid combination for seed set percentage, 1000 grain-weight (g), grain yield/plant (g) and harvest index (%). However, the highest values of seed set percentage, grain yield/plant and harvest index were recorded with the high dose of GA<sub>3</sub> (350 g/ha), while G46A remained superior to IR69625A. Moderate doses of GA<sub>3</sub> (300 g/ha) produced the highest value of 1000-grain weight. Application GA<sub>3</sub> has been reported to extend the cell membrane and to multiply the cells which elongated the internode, and finally increased the panicle exertion from flag leaf, seed set resulting increased grain yield/plant. Applica-

tion of 200 g NAA/ha showed the highest percentage of the panicle exertion (88%), seed set (23.52-27.39%) and seed yield (1660-1795 kg/ha) [20]. [21] reported that the spraying of GA<sub>3</sub> @ 200g/ha gave the highest values of panicle exertion, panicle weight and seed set of 85.55%, 2013 gm and 32.95%, respectively. The results were in agreement with those obtained by [12], who reported that application of GA<sub>3</sub> at the rate of 0-45, 75-120 and 180-220 g/ha produced seed yield 0.54, 1.80 and 2.5 t/ha, respectively. [24] reported that application of GA<sub>3</sub> at the rate of 200 g/ha with 500 liter of water produced the grain yield of 3.0-3.5 t/ha which was significantly higher than control treatment.

The interaction effects between the CMS lines and different GA<sub>3</sub> levels for seed set (%) were presented in Table 9. However, the lower values for seed set percentage was recorded in the CMS IR69625A line as compare to G46A which indicates that the G46A line was comparatively more responsive to GA<sub>3</sub> than the CMS IR69625A line. The data were in agreement with [21], who reported that the application of GA<sub>3</sub> at the higher dose (200 g/ha) gave the highest value of the seed set percentage (32.95%) comparing without GA<sub>3</sub> (control) which gave lowest one 17.34%. [12] found that application of GA<sub>3</sub> @ 180-220g/ha increased seed set of 45-50%. The result was reported by [15] indicated that GA<sub>3</sub> increased the panicle exertion encouragingly enhanced seed set. Additionally,

**TABLE 9**  
**Seed set (%) as affected by GA<sub>3</sub> application for the tow CMS lines during the two seasons**

Lines	GA <sub>3</sub> doses (g/ha)	Seed set (%)	
		2017	2018
IR69625A	Control	29.30	29.92
	250	29.82	31.78
	300	34.16	34.11
	350	35.60	34.79
G46A	Control	30.54	29.64
	250	32.48	32.98
	300	35.10	35.47
	350	35.60	36.32
LSD 0.05		1.25	0.90

**TABLE 10**  
**1000-grain weight (g) as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Lines	GA <sub>3</sub> doses (g/ha)	1000-grain weight (g)	
		2017	2018
IR69625A	Control	24.10	24.26
	250	23.68	24.10
	300	23.33	23.63
	350	21.73	22.63
G46A	Control	25.22	25.10
	250	24.27	24.88
	300	23.86	23.66
	350	23.15	23.26
LSD 0.05		0.46	0.34

**TABLE 11**  
**Grain yield (t/ha) as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Lines	GA <sub>3</sub> doses (g/ha)	Seed yield (t/ha)	
		2017	2018
IR69625A	Control	2.335	2.457
	250	2.702	2.785
	300	3.007	3.248
	350	3.414	3.642
G46A	Control	2.733	2.795
	250	3.140	3.123
	300	3.372	3.650
	350	3.577	36.32
LSD 0.05		0.57	0.90

panicles exertion enhanced the chances of seed set because part of the panicle covered with flag leaf could be allowed the cross breeding [25].

The data in Table 10 showed that G46A line recorded the highest values for 1000-grain weight at GA<sub>3</sub> dose of 350 g/ha, while the CMS IR69625A line recorded the lowest values for 1000-grain weight, that meaning the G46A line highly responded to GA<sub>3</sub> application. [13] found that the application of 100g GA<sub>3</sub>/ha gave the highest 1000-seed weight, while control plants produced the lowest 1000-seed weight. On the other hand, 1000-grain weight was reduced by the increment of GA<sub>3</sub> concentrations, and the maximum 1000-grain weight was noticed under control condition [15], which contradicts in our study.

The interaction effects between the CMS lines and different concentrations of GA<sub>3</sub> regarding the grain yield are presented in Table 11. Application of GA<sub>3</sub> significantly influenced the grain yield of two rice lines in both years, and GA<sub>3</sub> @ 350 g/ha produced the highest grain yield in both lines.

Nevertheless, the G46A line recorded the maximum grain yield per plant compared to CMS IR69625A line. The data are in agreement with those obtained by [26], who mentioned that, the hybrid grain yield was significantly influenced by the application different doses of GA<sub>3</sub>. The improving in panicle exertion and enhanced morphological traits correlated with outcrossing rates of the female parent which are some of the strategies to enhance seed yield [27]. The application of GA<sub>3</sub> concentrations was significant for grain yield, and the increase could be due to the higher outcrossing rate and panicle exertion [15].

The data in Table (12) show the interaction between the CMS lines and different GA<sub>3</sub> concentration for harvest index, where the G46A line recorded the highest harvest index by using 350 g of GA<sub>3</sub>, while the CMS IR69625A line recorded the lowest values for harvest index. The G46A line was higher response to GA<sub>3</sub> than CMS IR69625A line. This increase in harvest index could be due to the high grain yield [15]. The greater harvest index

**TABLE 12**  
**Harvest index (%) as affected by GA<sub>3</sub> application for the two CMS lines during the two seasons**

Lines	GA <sub>3</sub> doses	Harvest index (%)	
		2017	2018
IR69625A	Control	16.97	16.83
	250	19.35	19.59
	300	23.11	23.01
	350	23.34	24.08
G46A	Control	18.36	21.44
	250	20.17	22.03
	300	23.25	24.46
	350	24.22	26.83
LSD 0.05		0.57	0.84

revealed that GA<sub>3</sub> treatment enhanced to supply assimilates to the sink for obtaining the highest values of seed yield for better harvest index [28].

## CONCLUSION

Application of GA<sub>3</sub> significantly influenced agronomical, morphological and physiological traits of hybrid rice lines. The best desirable values for the studied characteristics especially for hybrid seed yield (2.5 t/ha) were recorded of the hybrid combination IR69625/Giza 178 with high dose of GA<sub>3</sub> (350 g/ha) followed by G46A/Giza178. Application of GA<sub>3</sub> influenced the growth, yield traits and yield of both lines, and GA<sub>3</sub> @ 350 g/ha performed the best results in most of the cases. Hence, it is recommended to apply GA<sub>3</sub> as a potential source for triggering rice growth and producing higher paddy yield.

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