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Improvement ability of male parent by gibberellic acid application to enhancing the outcrossing of cytoplasmic male sterility rice lines

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Improvement ability of male parent by gibberellic acid application to enhancing the outcrossing of cytoplasmic male sterility rice lines

Abstract: The study quantified the effect of gibberellic acid (GA_3) as a pre-flowering treatment for male parent Giza 178 R and the influence of male to female ratio (2R:10A, 2R:12A, 2R:14A and 2R:16A) between male (R) to female (A) for two Cytoplasmic Male Sterility (CMS) lines ('IR69625' and 'G46') on hybrid rice seed production. The main plots were occupied by CMS lines while; GA3 application for male parent Giza 178R were arranged in the sub plots and male to female ratio was arranged in the sub-sub plots. The results indicated that, the, duration of floret opening, angle of floret opening, filaments exsertion, filaments length**,** anther length, plant height and number of tiller hill^{-1} of male parent Giza 178R were significantly at 300 g GA_3 ha^{-1} concentration. Plant height, panicle exsertion, panicle length, flag leaf angle and 1000-grain mass of CMS were not significantly affected by the GA_3 application for male parent and male to female ratio, while, number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index of CMS lines were highly significantly affected. The highest seed yield (2.880 and 2.950 t ha^{-1}) was obtained by CMS line IR69625A using 300 g GA_3 ha^{-1} of male parent Giza 178R with male to female ratio of 2R:14A during both seasons.

Key words: hybrid rice production; cytoplasmic male sterile lines; gibberellic acid (GA_3); male to female ratio; panicle exsertion

Izboljševanje sposobnosti moških staršev z giberilinsko kislino za pospeševanje navskrižnega križanja citoplazmatsko moško sterilnih linij riža

Izvleček: Preučevan je bil učinek dodajanja giberilinske kisline (GA_3) kot obravnavanja pred cvetenjem na moškega starša 'Giza 178' (R) in vpliv razmerja med moškimi (R) in ženskimi rastlinami (A) (2R:10A, 2R:12A, 2R:14A in 2R:16A) za dve citoplazmatsko moško sterilni liniji (CMS), 'IR69625' in 'G46', na pridelek semena hibridnega riža. Raziskava je potrdila razlike v lastnostih navzkrižnega križanja in pridelku zrnja dveh CMS linij (IR69625A in G46A) pri uporabi štirih koncentracij GA_3 uporabljenih dvakrat, pri 15-20 % in 35-40 % latenju. CMS linije so bile na podploskvah, razmerje med moškimi (R) in ženskimi (A) rastlinami pa na njihovih podploskvah (2R:10A, 2R:12A, 2R:14A in 2R:16A). Rezultati so pokazali, da so se trajanje odpiranja cvetov (min), kot odprtega cveta (^{0}), odstotek podaljšanih filamentov (%), dolžina filamentov (mm)**,** dolžina prašnic (mm), višina rastlin (cm) in število poganjkov na sadilno mesto pri moškem staršu 'Giza 178' značilno povečali pri uporabi 300 g GA_3 ha^{-1}.

Ključne besede: pridelovanje hibridnega riža; citoplazmatsko sterilne moške linije; giberilinska kislina (GA_3); razmerje moških in ženskih rastlin; latenje

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1 INTRODUCTION

Hybrid rice breeding, which was initiated in Egypt has led to great improvement in rice production (Zaman et al., 2002; Hamad, 2018). Breeding high-yielding hybrid rice is one of the promising potential strategies in Egypt for increasing rice production. The hybrid rice technology exploits the phenomenon of heterosis or hybrid vigor. The heterosis can be defined as the superiority of F1 when two genetically dissimilar parents are crossed (Sindhua and Kumar, 2002). The three-line rice breeding system which uses cytoplasmic male sterile (CMS) lines (A), maintainer lines (B) and restorer lines (R) has been proven to be the most useful genetic tool in producing F1 hybrid in rice.

The content of endogenous gibberellic acid (GA_3) in male p lines with pollen abortive wild rice cytoplasm (wild abortive [WA] type male sterile [MS] line) is generally lower than that of fertile plants, therefore, resulting in spikelets unavailable for cross-pollination and producing lower seed yield (Lu, 1994; Pan et al., 2013). Exogenous application of GA_3 was done to cause the panicle base of the CMS line to emerge out of the leaf sheath (Gaballah, 2004; Gaballah et al., 2021). In addition, lower heading characteristics such as small spikelet openings, poor panicle layer carriage and poor stigma exsertion can severely reduce cross-pollination and limit seed yield production. Hence, hybrid rice seed production techniques should be improved to increase seed yields and reduce the cost of seeds (Virmani, 2002; Virmani et al., 2002).

Egypt is currently using a number of CMS lines for the hybrid rice-breeding programs. However, no information is available on how these CMS lines will respond to GA_3 application with reference to their heading characteristics. Such data are very important to generate baseline information whether genotypic variations exist among CMS lines in response to GA_3 pre-flowering treatment and whether such responses follow similar trends. This will also help in identifying CMS lines which are responsive to GA_3 application to maximize their utilization in the development of new hybrid rice varieties with higher seed yield potential.

Therefore, the objective of this investigation was to study the performance of Giza178R male parents as affected by GA_3 application rates and male to female ratio on the growth characteristics and hybrid seed yield production of two CMS lines (IR69625A and G46A).

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE DESCRIPTION AND SOIL SAMPLES

The field experiment was conducted during 2019 and 2020 rice growing seasons in Rice Research and Training Center (RRTC) experimental farm, Sakha, Kafr El-Sheikh, Egypt. Representative soil sample was taken from 0-20 cm depth before the growing season. The soil samples were air-dried, ground and passed through 2mm sieve. Composite soil samples were taken and analyzed for physical and chemical characteristics of the soil namely, electrical conductivity (EC,) pH, organic matter (OM), texture, cations and anions following the standard methods as described by (Page et al., 1982). The physico-chemical characteristics of the soil are presented in Table (1).

2.2 EXPERIMENTAL LAYOUT

The experiment was set up as split split-plot design with three replications. The main plots were devoted to two CMS lines (IR69625A and G46A) for male parent male parent. The GA_3 application rates (0, 150, 200 and 300 g GA_3 ha^{-1}) for male parent Giza 178R was allocated to subplots and male to female ratio (2R:10A, 2R:12A, 2R:14A and 2R:16A) between male (R) to female (A) was arranged in the sub-sub plots.

2.3 PLANT MATERIALS

They were obtained from international rice research institute (IRRI) and China and contain the wild rice with abortive pollen CMS (Table 2).

2.4 CULTURAL PRACTICES

Phosphorus fertilizer was applied @ 36 kg P_2O_5 ha^{-1} as superphosphate (15.5 % P_2O_5) as soil basal application. Nitrogen fertilizer was applied @ 165 kg ha^{-1} as urea. Two thirds of the recommended N fertilizer were added as soil basal application, and the other one third was applied at panicle initiation. Zinc sulphate at the rate of 50 kg ha^{-1} was added during soil preparation.

Rice seeds @ 15 kg of the CMS Lines (IR69625A and G46A) and 5 kg for the male parent (Giza 178 R) were soaked in fresh water for 24 hours, then incubated for 48 hours to hasten early germination. To get a proper synchronization of flowering, the CMS line IR69625A (as female parent) was sown on May 1st which is six

Table 1: The physical and chemical characteristics of the soil during 2019 and 2020 growing seasons

Season	pH	EC (dS m^{-1})	NPK (mg kg^{-1})			Clay (%)	Silt (%)	Sand (%)	OM (%)
2019	7.84	1.50	339	13.7	329	56.4	28.3	15.3	1.35
2020	7.89	1.59	368	14.7	359	58.6	27.1	14.3	1.40

EC; Electrical conductivity, OM; Organic matter

Table 2: Cytoplasmic male sterile (CMS) lines used for evaluation

CMS Lines	Cytoplasmic source	Origin
IR 69625A	Wild abortive (WA) CMS line	IRRI
G46A	Gambiaca CMS line	China

days earlier than the male parent 'Giza 178 R' while, the CMS line G46A (as female parent) was sown on 16 May. Thirty days old seedlings (3-4) per hill of R and A lines were transplanted by 3-4 and 2 seedlings per hill, respectively). Row direction was perpendicular to wind direction. The row spacing maintained for R-R, R-A and A-A lines were 20, 30, and 15 cm, respectively. Hill spacing for both R and A lines was maintained at 15 cm. Isolation space of 100 m was considered for CMS seed production. Moreover, the experimental field was surrounded by an additional 20 rows of R line to avoid any possibility of cross pollination. Every main plot was isolated by plastic barrier (2.5 m height) to avoid any pollen grain movement from treatment to another.

2.5 GIBBERELLIC ACID PREPARATION AND APPLICATION

Gibberellic Acid (GA_3) powder with 90.7 % purity was used. Since GA_3 cannot be completely dissolved in distilled water. In 100 ml of ethanol alcohol (70 %), was used to dissolve the GA_3 powder before it was mixed with water. Application of GA_3 was done in two splits. The first split consisted of 40 % of the total amount of GA_3 applied at 15-20 % heading. The second split in which the remaining 60 % of the total amount of GA_3 was applied at 35-40 % heading. Supplementary pollination was done by shaking the pollen parent (R line) with bamboo sticks. This operation was done 3-4 times between 9.30 am to 12.30 am for a period of 10 days.

2.6 TRAIT EVALUATION

At complete heading, duration of floret opening (min), angle of floret opening (^{0}), filaments exertion (%), filaments length (mm) and anther length (mm) of male parent 'Giza 178' were recorded. Ten panicles of male parent 'Giza 178' from each plot were randomly collected to estimate the panicle length (cm). Also, five hills of male parent 'Giza 178' were randomly identified from each plot to estimate the plant height (cm) and number of tillers hill^{-1}. Data was collected for CMS lines where it was days to heading 50 %, plant height (cm), panicle exsertion (%), flag leaf angle (^{0}), 1000-grain mass (g), panicle length (cm), number of fertile panicles hill^{-1}, panicle mass (g), seed set (%), seed yield (t ha^{-1}), and harvest index (%). After harvesting, rice grain yield was estimated in each plot, and grain yield was adjusted to 14 % moisture content and converted to tons ha^{-1}.

Panicle exsertion % was estimated according to the following equation:

$$\text{Panicle exsertion \%} = \frac{\text{Exserted panicle length (cm)}}{\text{Panicle length (cm)}} \times 100$$

Seed set % was calculated according to the following equation:

$$\text{Seed set \%} = \frac{\text{Number of filled grains/panicle}}{\text{Total Spikelet number/panicle}} \times 100$$

2.7 STATISTICAL ANALYSIS

All data collected were subjected to standard statistical analysis of variance following the method described by Gomez and Gomez (1984). Different means were compared by Duncan's multiple range test (DMRT) with a 5 % probability level.

3 RESULTS AND DISCUSSION

3.1 EFFECT OF GA_3 APPLICATION RATES ON GROWTH TRAITS OF MALE PARENT

The effect of different GA_3 application rates on male parent traits such as duration of floret opening, angle of floret opening, filaments exertion, filaments length, anther length, plant height, number of tiller $hill^{-1}$and panicle length, are presented in (Table 3). The results indicated that, GA_3 applied for male parent up to 300 g GA_3 ha^{-1} recorded a significant increase in duration of floret opening, angle of floret opening, filaments exertion, filaments length, anther length, plant height, number of tiller $hill^{-1}$ and panicle length as compared with GA_3 0 g ha^{-1} treatment in both seasons. Application of 300 g GA_3 ha^{-1} on male parent gave the highest duration of floret opening (130.59 and 129.94 min), the maximum angle of floret opening (41.96 and 44.30 ^{0}), the highest values of filaments exertion (80.81 and 90.15 %), filaments length (9.34 and 9.78 mm), anther length (3.35 and 3.55 mm), the tallest plant (126.49 and 127.36 cm), the highest number of tiller $hill^{-1}$ (24.83 and 25.19) and longest panicle (25.71 and 25.90), during 2019 and 2020 seasons, respectively. A significant increase in panicle exsertion was observed on GA_3 application. The highest value of panicle exsertion was observed at the rate of 300 g GA_3 ha^{-1}, regardless of CMS lines used, indicating that CMS lines were sensitive to exogenous GA_3 application, hence, the problem of the leaf sheath enclosing the panicle could be alleviated by GA_3 application. Panicle exsertion influenced the percentage of exposed spikelets available for pollination, as higher panicle exsertion means a greater number of exposed spikelets. It also tended to scatter the panicle branches providing more space for each spikelet to trap airborne pollen. The increase in panicle exsertion was mainly a function of the elongating topmost internode in response to GA_3 application that consequently pushes the panicle out of the flag leaf sheath. Therefore, poor panicle exsertion of CMS lines was due to the inability of the topmost internodes to elongate during heading stage. The lowest values of above-mentioned traits were obtained with GA_3 0 g ha^{-1} application rate (Table 3). The improved floral traits of male parent were due to increased activity of cell division, enlargement and elongation. Gibberellins are plant hormones that regulate various processes of plant growth and development, which are particularly important in cell elongation (Hedden and Phillips, 2000).

Table 3: Floral traits and growth characters of male parent (Giza 178) as affected by GA_3 application rates during 2019 and 2020 growing seasons

GA_3 application rate (g ha^{-1})	Duration of floret opening (min)		Angle of floret opening (^{0})		Filaments exertion (%)		Filaments length (mm)		Anther length (mm)		Plant height (cm)		Number of tillers $hill^{-1}$		Panicle length (cm)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
0	46.75d	48.09d	24.30d	25.03d	44.31c	43.52d	4.32d	4.55d	1.35d	1.65d	100.2d	98.93d	16.05d	15.43d	19.55d	19.33d
150	68.86c	67.91c	31.56c	32.36c	69.54b	70.07c	6.76c	7.19c	2.28c	2.62c	109.6c	110.47c	19.21c	20.32c	21.87c	20.87c
200	90.37b	90.62b	36.70b	38.40b	80.47a	79.82b	8.02b	8.12b	2.68b	2.97b	120.0b	120.88b	22.17b	22.38b	23.84b	23.82b
300	130.5a	129.9a	41.96a	44.30a	80.81a	90.15a	9.34a	9.78a	3.35a	3.55a	126.4a	127.36a	24.83a	25.19a	25.71a	25.90a
F- Test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

* = Significant at 0.05 level, ** = Significant at 0.01 level and NS = Not significant. Means in the same column designated by the same letter are not significantly different at 5 % level

3.2 F_1 SEEDS OF CMS LINES CHARACTERISTIC AS AFFECTED BY GA_3 APPLICATION FOR MALE PARENT AND MALE TO FEMALE RATIO

Days to 50 % heading, plant height, panicle exsertion, flag leaf angle, panicle length and 1000-grain mass were not significantly affected by GA_3 application rates for male parent and male to female ratio (Table 4). The results showed that there were significant differences between the two CMS lines IR69625A and G46A. Where CMS line IR69625A gave the longest duration to 50 % heading, produced the tallest plants, the longest panicle exsertion, the highest panicle length and the increased flag leaf angle during both seasons. On the other hand, the CMS line G46A recorded the highest 1000-grain mass during the both seasons. The variation between the CMS lines could be attributed to the difference in genetic background. The results are in agreement with those reported by (Hamad et al., 2015). They founded that, the different doses of GA_3 showed highly significantly influence on panicle length and panicle exsertion when 2:4 row ratio. Similar results agreement with those were reported by Ehsan and Robert (2019). Results in Table (4) also showed that, the all of interactions were not significantly affected on days to 50 % heading, plant height, panicle exsertion, panicle length, flag leaf angle and 1000-grain mass in both growing seasons.

Number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index % of two CMS lines as affected by doses of GA_3 application rates for male parent and male to female ratio as well as their interactions are shown in (Table 5). The results indicated that, the CMS line IR 69625A recorded the highest values of number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index % in both seasons. On the other hand, the CMS line G46A recorded the lowest values of number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index % in both seasons (Table 5). The variation between the CMS lines could be attributed to the difference in genetic background. The results are in agreement with those reported by Gaballah, (2004). Results in Table (5) also showed that application GA_3 on the male parent had a high significant effect on the number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index %. The dose of GA_3 application at 300 g ha^{-1} for male parent recorded the highest values of number of fertile panicle hill^{-1}, panicle mass, seed set, seed yield and harvest index % 2019 and 2020 seasons, while the lowest values recoded by control (GA_3 0 g ha^{-1}) in both seasons. The increase in plant height is due to increased activity of cell division, enlargement and elongation. Gibberellins are plant hormones that regulate various processes of plant growth and development, which are particularly important in stem elongation which enhances the cross pollination between both parents. The results are in agreement with those reported by (Hedden and Phillips, 2000; Sakamoto et al., 2004; Sun, 2004; Tiwari et al., 2011). Male to female ratio significantly influenced number of fertile panicle hill^{-1}, panicle mass, seed set, seed yield and harvest index %. The male to female ratio 2R:14A recorded the highest values number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index% during both seasons. This might be due to that the application of GA_3 for male parent led to a noticeable improvement in the characteristics) plant height, panicle exsertion, flag leaf angle, panicle length) of the male parent, which made it able to pollinate the highest number of male lines consequently, increase the number of fertile panicle hill^{-1} and seed yield. On the other hand, the male to female ratio 2R:10A recorded the lowest values of number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index % during the both seasons.

3.3 INTERACTION EFFECT

All types of interactions among CMS lines, doses of GA_3 application rates for male parent and male to female ratio had highly significant effect on number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index during 2019 and 2020 seasons (Table 5).

The results in Table (6) indicated that, the interaction between the CMS lines and GA_3 different application rates for male parent were highly significantly affected on number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index % in both seasons. The CMS line IR69625A, with dose of GA_3 at the rate of 300 g ha^{-1} for male parent recorded the highest values of number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index % in both seasons. On the contrary, the CMS line G46A with 0 g GA_3 ha^{-1} application rates for male parent recoded the lowest values of number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index % in 2019 and 2020 seasons. The results are in agreement with those reported by Sirajul et al. (2005); Gavino et al. (2008).

Table 4: Genotypic variations in panicle exsertion and other morphological traits between CMS lines in response to GA_3 pre-flowering treatment

	Days to 50 % heading		Plant height (cm)		Panicle exsertion (%)		Panicle length (cm)		Flag leaf angle (^{0})		1000-grain mass (g)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
CMS lines(L)												
IR69625A	102.60a	103.46a	117.26a	117.97a	77.25a	78.16a	23.31a	24.25a	38.90a	40.29a	24.30a	24.24a
G46A	85.50b	87.36b	96.38b	97.00b	75.41b	77.32b	22.42b	23.25b	37.21b	39.60b	25.77b	25.45b
F-test	**	**	**	**	**	**	**	**	**	**	**	**
GA_3 doses for male parent(G)												
0	94.15	95.60	106.79	107.47	76.34	78.70	22.76	23.81	37.71	39.35	25.06	24.88
150	94.13	95.36	106.87	107.51	76.28	78.59	22.84	23.76	38.18	39.35	25.02	24.85
200	94.95	95.45	106.79	107.44	76.40	78.33	22.97	23.77	38.19	39.23	25.00	24.84
300	93.72	95.22	106.85	107.49	76.31	78.48	22.88	23.65	38.15	39.62	25.04	24.77
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Male to female ratio (W)												
2R:10A	93.99	95.34	106.93	107.52	76.33	78.71	22.95	23.65	38.16	39.25	25.04	24.83
2R:12A	94.25	95.18	106.84	107.62	76.09	78.52	22.67	23.82	38.71	39.27	25.03	24.87
2R:14A	93.82	95.41	106.89	107.30	76.38	78.33	22.93	23.75	37.75	39.23	25.01	24.80
2R:16A	94.14	95.72	106.64	107.46	76.53	78.58	22.91	23.70	38.27	39.24	25.04	24.84
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
L × G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
L × W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G × W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
L × G × W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* = Significant at 0.05 level, ** = Significant at 0.01 level and NS = Not significant. Means in the same column designated by the same letter are not significantly different at 5% level

Table 5: Effect of CMS lines, doses of GA_3 application for male parent and male to female ratio as well as their interactions on seed yield and other morphological traits

	Number of fertile panicles hill^{-1}		Panicle mass (g)		Seed set (%)		Seed yield (t ha^{1})		Harvest index (%)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
CMS lines (L)										
IR69625A	17.80a	19.65a	2.67a	2.71a	34.00a	34.90a	1.90a	2.08a	19.26a	20.05a
G46A	15.92b	16.94b	2.49b	2.51b	31.14b	33.58b	1.69b	1.84b	17.82b	18.50b
F-test	**	**	**	**	**	**	**	**	**	**
GA_3 doses for male parent (G)										
0	14.29d	15.39d	1.91d	1.89d	25.60d	26.84d	1.19d	1.36d	16.02d	16.75d
150	16.16c	17.06c	2.47c	2.51c	31.28c	32.69c	1.58c	1.72c	17.91c	18.27c
200	17.40d	19.12b	2.83b	2.86b	33.97b	37.91b	2.02b	2.20b	19.30b	20.00b
300	19.58a	21.62a	3.10a	3.15a	35.41a	39.52a	2.32a	2.56a	20.92a	21.96a
F-test	**	**	**	**	**	**	**	**	**	**
Male to female ratio (W)			2.23c			31.87c				
2R:10A	15.66d	17.16d	2.51b	2.25d	28.85d	33.76b	1.57d	1.71c	17.16d	17.79d
2R:12A	16.93c	18.13c	2.84a	2.50c	31.49c	36.30a	1.76c	1.90bc	18.05c	18.90c
2R:14A	17.64a	19.12a	2.73ab	2.96a	33.59a	35.03a	2.03a	2.19a	19.88a	20.62a
2R:16A	17.20b	18.78b		2.74b	32.33b		1.82b	2.03ab	19.07b	19.77b
F-test	**	**	**	**	**	**	**	**	**	**
L × G	**	**	**	**	**	**	**	**	**	**
L × W	*	*	**	**	**	**	**	**	**	**
G × W	**	**	**	**	**	**	*	*	*	*
L × G × W	**	**	**	**	**	**	**	**	**	**

* = Significant at 0.05 level, ** = Significant at 0.01 level and NS = Not significant. Means in the same column designated by the same letter are not significantly different at 5% level

Table 6: Effect of interaction between CMS liens and doses of GA_3 application for male parent on panicle characteristics and yield during 2019 and 2020 seasons

CMS Lines (L)	GA_3 doses for male parent (G)	Number of fertile panicles hill^{-1}		Panicle mass (g)		Seed Set (%)		Seed yield (t ha^{-1})		Harvest Index (%)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
IR6962A	0	15.50d	16.21d	1.95d	1.92d	25.69f	27.19f	1.35e	1.48de	16.48e	17.23de
	150	16.75c	18.14c	2.50c	2.62bc	31.93d	33.4d	1.72d	1.85c	18.43c	19.21c
	200	18.36b	20. 5b	2.90ab	3.03ab	34.5bc	38.7b	2.10bc	2.27b	20.03b	20.68b
	300	20.55a	23.71a	3.22a	3.27a	35.82a	40.2a	2.43a	2.71a	22.11a	22.99a
G46A	0	13.07f	14.57e	1.87d	1.87d	25.51f	26.49i	1.14f	1.24e	15.57e	16.18e
	150	15.57d	15.98d	2.42c	2.46c	30.64e	31.9e	1.45e	1.58d	17.40d	17.54d
	200	16. 4c	17.67c	2.76b	2.70bc	33.40c	37.0c	1.97c	2.12bc	18.58c	19.23c
	300	18.61b	19.54b	2.88ab	3.03ab	34.9ab	38.8b	2.21b	2.41b	19.73b	20.94b

Means in the same column designated by the same letter are not significantly different at 5 % level

The results in Table (7) showed that the interaction between CMS lines and male to female ratio were significantly affected number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index % in both seasons. The male to female ratio of 2R:14A with CMS line IR69625A, recorded the highest values of number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index % in both seasons. This may be due to the optimum availability of pollen that led to the highest effective grain formation. On the other hand, the lowest values of number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index % were obtained by CMS line G46A when male to female ratio of 2R:10A during 2019 and 2020 seasons. The results are in agreement with those reported by Abo-Youssef (2009).

The results in Table (8) showed that the interaction between doses of GA_3 application for male parent and male to female ratio was significantly affected number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index (%) in both seasons. The male to female ratio 2R:14A with applied 300 g GA_3 ha^{-1} re-

Table 7: Effect of interaction between CMS lines and male to female ratio on panicle characteristics and yield during 2019 and 2020 seasons

CMS Lines	Male to Female ratio	Number of fertile panicles hill^{-1}		Panicle mass (g)		Seed Set (%)		Seed yield (t ha^{-1})		Harvest Index (%)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
IR69625A	2R:10A	16.84c	18.18c	2.31d	2.30d	29.17d	32.3cd	1.71cd	1.84c	18.0de	18.84c
	2R:12A	17.79b	19.70b	2.61bc	2.59bc	31.81b	34.23b	1.85bc	2.03b	18.8cd	19.67b
	2R:14A	18.60a	20.62a	2.93a	3.11a	34.17a	37.29a	2.15a	2.32a	20.57a	21.33a
	2R:16A	17.92b	20.12a	2.8ab	2.84ab	32.8ab	35.69b	1.88bc	2.12ab	19.59b	20.3ab
G46A	2R:10A	14.47e	16.14e	2.16d	2.20d	28.54d	31.38d	1.42e	1.59d	16.29f	16.74d
	2R:12A	16.07d	16.5cd	2.41cd	2.41cd	31.17c	33.29c	1.66d	1.76cd	17.26e	18.14c
	2R:14A	16.6cd	17.6cd	2.75ab	2.80ab	33.02a	35.3b	1.92b	2.07ab	19.1bc	19.92b
	2R:16A	16.4cd	17.4d	2.64b	2.64bc	31.8bc	34.36b	1.77cd	1.9bc	18.55c	19.1bc

Means in the same column designated by the same letter are not significantly different at 5 % level

Table 8: Effect of interaction between doses of GA_3 application for male parent and male to female row ratio on panicle characteristics and yield during 2019 and 2020 seasons

GA_3 doses for male parent (g ha^{-1})	Male to female ratio	Number of fertile panicles hill^{-1}		Panicle mass (g)		Seed set (%)		Seed yield (t ha^{-1})		Harvest Index (%)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
0	2R:10A	14.15f	14.61h	1.84d	1.78e	25.50e	26.57d	1.20g	1.28g	15.59g	16.51f
	2R:12A	14.53f	15.29gh	1.92d	1.88e	25.46e	26.92d	1.29fg	1.37f	16.0fg	16.66f
	2R:14A	14.25f	15.92g	1.94d	1.99e	25.7de	27.11d	1.25fg	1.46f	16.2fg	17.14ef
	2R:16A	14.22f	15.74g	1.94d	1.91e	25.6de	26.75d	1.24g	1.34f	16.2fg	16.72f
150	2R:10A	15.57e	16.00g	1.93d	1.98e	28.28d	28.68d	1.39fg	1.48f	16.6fg	16.67f
	2R:12A	16.17de	16.67f	2.27c	2.35d	31.26c	32.01c	1.55ef	1.57f	17.51e	18.19e
	2R:14A	16.60d	17.91e	2.92b	3.00c	33.60b	36.10b	1.78de	1.99d	19.04c	19.67d
	2R:16A	16.30de	17.67e	2.76b	2.86c	32.00c	33.99c	1.59de	1.82e	18.45e	18.98d
200	2R:10A	16.01de	17.62ef	2.48c	2.48d	29.6cd	34.45c	1.70de	1.86d	17.45e	18.10e
	2R:12A	17.27c	19.30d	2.79b	2.74cd	34.31b	37.50b	1.95c	2.09c	18.62e	19.61d
	2R:14A	18.48b	20.00cd	3.11a	3.36ab	37.00a	40.40a	2.33b	2.50b	21.0bc	21.71b
	2R:16A	17.85c	19.56d	2.94b	2.88c	34.97b	39.2ab	2.15c	2.34bc	20.07c	20.59cd
300	2R:10A	16.90d	20.43cd	2.69b	2.77c	32.03c	37.81b	1.92c	2.25c	18.9de	19.90d
	2R:12A	19.77b	21.27bc	3.07ab	3.03bc	34.94b	38.6ab	2.20b	2.57ab	20.0cd	21.17c
	2R:14A	21.23a	22.65a	3.39a	3.49a	38.00a	41.59a	2.78a	2.83a	23.16a	23.99a
	2R:16A	20.43a	22.1ab	3.27a	3.31ab	36.67a	40.09a	2.39b	2.61a	21.53b	22.80a

Means in the same column designated by the same letter are not significantly different at 5 % level

corded the highest values of number of fertile panicles hill^{-1}, panicle mass, seed set (%), seed yield and harvest index (%) in both seasons. On the other hand, the male to female row ratio 2R:10A without GA_3 application gave the lowest values number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index % in both seasons. The results are in agreement with those reported by Rahman et al. (2010) and Abo-Youssef et al. (2017).

The results in Table (9) showed that the interaction among CMS lines, doses of GA_3 application for male parent and male to female ratio was significantly affected number of fertile panicles hill^{-1}, panicle mass, seed set, seed yield and harvest index in both seasons. The highest values of number of fertile panicles hill^{-1}, panicle mass, seed set %, seed yield and harvest index (%) were obtained with the CMS line IR69625A by 300 g GA_3 ha^{-1} for male parent when male to female ratio was 2R:14A during both seasons. While the lowest values of number of fertile panicles hill $^{-1}$, panicle mass, seed set, seed yield and harvest index (%) produced by CMS line G46A when using male to female ratio 2R:10A without GA_3 application in both seasons. The results are in agreement with those reported by Riaz et al. (2019); Ghoneim (2020).

Table 9: Effect of interaction among CMS lines, doses of GA_3 application for male parent and male to female ratio on panicle characteristics and yield during 2019 and 2020 seasons

CMS Lines (L)	GA_3 doses for male parent (G)	Male to female ratio	Number of fertile panicles hill^{-1}		Panicle mass (g)		Seed set (%)		Seed yield (t ha^{-1})		Harvest Index (%)	
			2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
IR69625A	0	2R:10A	15.54ef	15.20e	1.87fg	1.79g	25.60h	26.89hi	1.31fg	1.36g	16.01fg	17.01h
		2R:12A	15.65ef	16.08de	1.98fg	1.90efg	25.50h	27.01hi	1.39fg	1.49g	16.54fg	17.20h
		2R:14A	15.40ef	16.87cde	1.96fg	2.01efg	25.86h	27.70hi	1.32fg	1.62fg	16.72fg	17.96gh
		2R:16A	15.42ef	16.67cde	1.98fg	1.96efg	25.79h	27.15hi	1.36fg	1.45g	16.65fg	17.15h
	150	2R:10A	16.53de	17.00cde	1.89fg	2.00efg	28.76g	29.31gh	1.53f	1.64fg	17.42f	18.04gh
		2R:12A	16.70de	18.13c	2.21f	2.41ef	32.01de	32.80f	1.67ef	1.78ef	18.00ef	19.10fg
		2R:14A	17.02cd	18.91bc	3.03b	3.15bc	34.40b	36.80de	1.95cde	2.12cde	19.40de	20.03ef
		2R:16A	16.76d	18.53c	2.87b	2.97bc	32.54d	34.70ef	1.72def	1.85ef	18.90e	19.65f
	200	2R:10A	16.88d	18.03cd	2.61de	2.55de	30.02ef	35.40e	1.77def	1.97ef	18.20ef	19.01fg
		2R:12A	18.27c	21. 00b	2.90b	2.92bc	34.47cd	38.10cd	2.02d	2.16de	19.25de	20.20ef
		2R:14A	19.66bc	21.98ab	3.16b	3.62a	37.80a	41.50a	2.44bc	2.60bc	21.87b	22.39c
		2R:16A	18.68c	21.24b	2.92bc	3.02bc	35.90b	40.03bc	2.15cd	2.36cd	20.79bc	21.10de
	300	2R:10A	18.50c	22.50a	2.86c	2.87bcd	32.29de	37.88de	2.11cd	2.38bc	20.50bc	21.30d
		2R:12A	20.55a	23.60a	3.35a	3.11b	35.27b	39.02c	2.27bc	2.70ab	21.60bc	22.19c
		2R:14A	22.31a	24.70a	3.57a	3.67a	38.60a	43.15a	2.88a	2.95a	24.30a	24.95a
		2R:16A	20.83ab	24.02a	3.50a	3.42ab	37.13a	40.88ab	2.45bc	2.81a	22.03bc	23.50b
G46A	0	2R:10A	12.76g	14.41e	1.80g	1.77g	25.40h	26.24i	1.08g	1.20g	15.17g	16.00i
		2R:12A	13.40fg	14.50e	1.85g	1.86fg	25.42h	26.83hi	1.19fg	1.24g	15.55fg	16.11hi
		2R:14A	13.10g	14.56e	1.92fg	1.97efg	25.70h	26.52hi	1.17fg	1.30g	15.73fg	16.31hi
		2R:16A	13.02g	14.42e	1.90fg	1.86fg	25.55h	26.35i	1.12fg	1.23g	15.81fg	16.29hi
	150	2R:10A	14.60ef	15.00e	1.96fg	1.95ef	27.80gh	28.04h	1.24fg	1.31g	15.89fg	15.29i
		2R:12A	15.63e	15.20e	2.32ef	2.28ef	30.50ef	31.21g	1.46ef	1.36g	17.02f	17.27h
		2R:14A	16.20d	16.90cde	2.80cd	2.84bc	32.80de	35.40ef	1.61de	1.85ef	18.67ef	19.30fg
		2R:16A	15.84e	16.80cde	2.65de	2.75cd	31.46ef	33.28f	1.47ef	1.78ef	18.00ef	18.30g
	200	2R:10A	15.22e	17.20cd	2.35e	2.40ef	29.20fg	33.50f	1.62de	1.74efg	16.69fg	17.18h
		2R:12A	16.26d	17.60cd	2.67cde	2.56de	34.15c	36.90de	1.88d	2.02ef	17.98ef	19.02fg
		2R:14A	17.30d	18.01c	3.06b	3.10b	36.20a	39.30cd	2.21bc	2.40bc	20.29c	21.03de
		2R:16A	17.02d	17.88c	2.96b	2.74cd	34.03cd	38.51cd	2.15cd	2.32cde	19.35cd	20.07ef
	300	2R:10A	15.30e	18.36c	2.51d	2.66cd	31.76e	37.73de	1.73de	2.11cde	17.39ef	18.50g
		2R:12A	18.98bc	18.94bc	2.79cd	2.95bc	34.60cd	38.20cd	2.12cd	2.43bc	18.47e	20.14ef
		2R:14A	20.14ab	20.59ab	3.20b	3.30ab	37.39a	40.02bc	2.68a	2.71ab	22.02b	23.02b
		2R:16A	20.02b	20.26b	3.03b	3.20b	36.20ab	39.30cd	2.32b	2.40bc	21.02bc	22.09c

* = Significant at 0.05 level, ** = Significant at 0.01 level and NS = Not significant. Means in the same column designated by the same letter are not significantly different at 5 % level

4 CONCLUSION

The study was conducted to assess the optimal GA_3 dose on male parent and row ratio between male to female for two CMS lines. The results indicated that, the foliar application of GA_3 significantly increased panicle exsertion, seed set and seed yield of CMS lines at 300 g ha^{-1} concentration. Increase in seed yield was highly influenced by the increase in of seed set % presumably as a result of higher panicle exsertion, wider flag leaf angle, higher degree of spikelet openings. The application of GA_3 on male parent Giza 178R led to a noticeable improvement in its characteristics such as duration of floret opening, angle of floret opening, filaments exsertion, filaments length, anther length, plant height, number of tillers hill^{-1}, panicle length, plant height and panicle exsertion. The CMS line IR69625A produced the highest seed yield with application of 300 g GA_3 ha^{-1} on male parent when male to female ratio was 2R:14A. The highest values of seed yield (2.880 and 2.950 t ha^{-1}) in 2019 and 2020 seasons were obtained by CMS line IR69625A with the application rate of 300 g GA_3 ha^{-1} on male parent when male to female ratio was 2R:14A.

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