EFFECT OF N LEVELS AND SOME PLANT GROWTH REGULATORS ON HYBRID RICE (*ORYZA SATIVA* L.) SEED PRODUCTION

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Abstract. The aim of the present investigation is to identify the suitable N application rates and gibberellic acid to enhance hybrid rice seed production in Egypt. The experimental material comprising of both the parent Giza 178R and CMS line G46A was treated with different N levels and foliar Gibberellic acid (GA_3). Treatments were arranged in a split-plot design with three replications. The main plots were devoted to the four N fertilizer levels (0, 55, 110 and 165 kg N ha^{-1}), while, the doses of foliar GA_3 + boric acid were 0, 150, 150 + 0.5%, 200, 200 + 0.5%, 300 and 300 + 0.5% g ha^{-1} arranged in the sub plots. Application of 165 kg N ha^{-1} produced the highest seed yield in both seasons. The application rates of 300 g GA_3 + 0.5% boric acid ha^{-1} produced the highest seed yield. The interaction between N levels and doses of GA_3 was highly significant for duration of spikelet opening, spikelet opening angle, stigma exsertion, plant height, panicle exsertion, panicle length, number of fertile tillers, panicle weight, seed set, harvest index and seed yield. It is concluded that, the treatment combination of (165 kg N ha^{-1} and 300 g GA_3 ha^{-1} + 0.5% boric acid) gave the best effects for most of the rice characteristics.
Keywords: *hybrid rice, high yield breeding, CMS, nitrogen fertilizer, gibberellic acid, seed yield*

Introduction

Rice is the most important food crop in Egypt, contributing about 21% of the total cereal consumption and utilization about 18% of the annual water consumption (RRTC, 2018). In Egypt, the average national rice yield has to be increased by 25-30% to meet the demands of the rising population. This seems difficult considering to narrow gap between potential and actual yield. However, among available technologies the increase yield, is the exploitation of heterosis of hybrid rice, which appears to be practical approach for Egypt (Bastawisi et al., 2002).

Hybrid rice technology is the innovative breakthrough that can further increase rice production leading to food security and reduction of poverty in Egypt. Hybrid rice varieties can out yield conventional cultivars by at least 15% under the same input levels. Hence, this technology can be used to break the current yield plateau in rice, where yield levels of the conventional released cultivars have stabilized. Hybrid rice seed production technology has increased rice yield potential by 10–20% in Egypt over the past 20 years (Hamad, 2018). Hybrid seed rice production must be produced based on hybrid male sterile (CMS), since, rice is a self-pollinated. Most of the CMS parents developed in Egypt are based on CMS lines having the wild abortive (WA) backgrounds. Incomplete panicle exsertion in almost all the (WA) based CMS lines is one of the major impediments in obtaining higher seed yields as about 20-30% of the panicles are enclosed in the flag leaf, and the enclosed spikelets are not available for

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cross pollination, thus resulting in lower seed yields. To increases the hybrid seed rice production by improving the out-crossing CMS lines (Shi-Hua et al., 2006; Zheng et al., 2018).

Plant hormones play a vital role in coordination of many growth and behavioral processes in the plant life. They regulate the amount, type and direction of plant growth. Remarkable application of Plant Growth Regulators (PGR) such as manipulating plant developments, enhancing yield and quality have been actualized in recent years (Yuan, 2007, 2010). Plant hormones including auxins, gibberellins and cytokinin are involved in controlling developmental of cell division, cell elongation and protein synthesis. Plants have the ability to store excessive amounts of exogenously supplied hormones in the form of reversible conjugates which release active hormone when and where plant needs them during the growth period. Auxins (i.e., NAA) and gibberellins (i.e., GA_3) being well known plant growth promoting hormones has shown to be involved in a variety of plant growth and development processes (Li et al., 2009; Xie et al., 2011). Gibberellic acid (GA_3), plays diverse roles in the stimulation and synchronization of flowering, seed development, seed weight (Zhu et al., 2015; Garcia et al., 2018). In addition, Parihar et al. (2012) found that GA_3 application resulted in a better seed set for seed production of a CMS line of hybrid rice.

Nitrogen (N) fertilizer is more urgent for security hybrid rice production. Applying sufficient N level is essential not only for getting greatest economic return, but also to reducing the environmental impact (Fageria and Baligar, 2003; Gewaily et al., 2018). Modern high-yielding rice cultivars may have differences in accumulation and utilize N from the soil and fertilizer application. The recovery of applied N fertilizer for rice is low and deterrent to get the full potential yield. So, it is necessary to identify what the optimal dose needed for each cultivar as well as its influence on yield and its attributes. Shaiful et al. (2009) reported that, using proper N level led to spare money and maintain our environment sound. Moreover, the abundant application of N fertilizer has an influence on the soil and the environment through the fertilizer residual effect. Apply the most suitable dose of N fertilization is a main interest of economic viability of hybrid rice production (Shaiful et al., 2009; Ghoneim, 2020).

Therefore, the aim of the present instigation is to identify a suitable N levels and GA_3 on some important yield characteristics of the CMS line G46A crossed by the restorer line Giza 178 R which used in producing the hybrid seed in Egypt.

Materials and methods

Field experiment

Two field experiments were conducted at Sakha agricultural experimental farm, Kafr El-Sheikh Governorate, Egypt (31 09° N Latitude and 30 68° longitude) during 2019 and 2020 rice growing seasons. Treatments were arranged in a split-plot design with three replications. The main plots were devoted to the four N fertilizer levels (0, 55, 110 and 165 kg N ha^{-1}), while, the doses of GA_3 + boric acid combinations were (0, 150, 150 + 0.5%, 200, 200 + 0.5%, 300 and 300 + 0.5% g ha^{-1} were arranged in the sub plots with plot size of 12.5 m^2. Rice seeds at the rate of 20 kg ha^{-1} (15 kg of CMS and 5 kg of restorer line) were soaked in fresh water for 24 h and then, incubated for 48 h to hasten germination. The male parent Giza 178 R was sown on May 1st which is sixteen days earlier than the CMS line G46A (as female parent) to get a proper

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synchronization of flowering. Nitrogen fertilizer rates were applied as Urea (46.5% N) in three split applications. The first dose was applied as basal application, while the second dose at 25 days after transplanting (DAT) and the third dose application at 45 DAT. Seedlings were carefully pulled from the nursery after 30 days from seeding and transferred to the permanent field. Seedlings were hand transplanted in hills at the rate of 2-3 seedlings hill^{-1}. 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 were 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 lines to avoid any possibility of cross pollination. The sub plots were isolated by plastic barrier (2.5 m height) to avoid any pollen grain movement from treatment to another.

Foliar application of growth regulators

Application of GA_3 and boric acid was done in two splits. The first split consisted of 40% of the total amount applied when A and R line was at 15-20% heading and the second spray (60%) was applied when A and R line was at 35-40% heading. Rice is basically a self-pollinated crop. Supplementary pollination serves to enhance the outcrossing rate in order to increase seed set. Supplementary pollination was done by shaking the pollen parents (R line) with bamboo sticks. This operation was done 2-3 times in between 9 am to 11.30 am and be continued for 10-12 days during flowering.

Measurements of seed yield and its components

At maturity, 10 hills were sampled diagonally from a 5 m^2 harvest area to determine the yield components. Days to heading, duration of spikelet opening (min), spikelet opening angle (°), stigma exsertion (%), plant height (cm), panicle exsertion (%), panicle length (cm), number of fertile tillers hill $^{-1}$, panicle weight (g), seed set (%), harvest index (%) and seed yield (t ha^{-1}) were recorded. The hybrid rice seed production yield was determined from a 5 m^2 area in each plot and adjusted to 14% moisture content.

Panicle exsertion (%) was estimated from the ten panicles and calculated as follows:

$$\text{Panicle exsertion}(\%) = \frac{\text{Exerted panicle length}}{\text{Panicle length}} \times 100 \qquad \text{(Eq.1)}$$

Fertility (%) was estimated as an average from the ten panicles and calculated as follows:

$$\text{Fertility }\% = \frac{\text{Number of filled grains per panicle}}{\text{Total spikelet's perpanicle}} \times 100 \qquad \text{(Eq.2)}$$

$$\text{Harvest index (H.I }\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100 \qquad \text{(Eq.3)}$$

Statistical analysis

The statistical analysis was done using analysis of variance technique by means of Genes computer software package (Gomez and Gomez, 1984). Means of treatments were compared using the Duncan’s multiple range test with a 5% probability level.

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Results

Nitrogen levels effect

The effect of N levels, doses of GA_3 application and their interaction on days to heading, duration of spikelet opening (min), spikelet opening angle (°) and stigma exsertion (%) are presented in *Table 1*. The highest values for days to heading, duration of spikelet opening, spikelet opening angle and stigma exsertion were obtained with the application rate of 165 kg N ha^{-1} in both seasons. While, the lowest values for days to heading, duration of spikelet opening, spikelet opening angle and stigma exsertion were recorded under control treatment in both seasons.

Table 1. *Effect of N levels and GA_3 + B.A. foliar application and their interaction on floral traits during 2019 and 2020 season*

Main effect and interaction	Days to 50% heading		Duration of spikelet opening (min)		Spikelet opening angle (°)		Stigma exsertion (%)	
	2019	2020	2019	2020	2019	2020	2019	2020
N levels (kg N ha^{-1})								
0	82.90d	83.01d	135.19d	137.43d	23.26d	24.77d	54.89d	56.14d
55	84.63c	85.04c	144.42c	147.09c	25.68c	26.71c	57.48c	59.38c
110	85.65b	86.48b	148.47b	150.38b	27.76b	28.49b	61.77b	63.75b
165	86.90a	87.98a	152.67a	155.47a	29.63a	30.67a	65.44a	67.70a
F-test	**	**	**	**	**	**	**	**
GA_3 + B.A (g ha^{-1}) dosage (D)								
0	84.89	85.78	116.00f	119.83g	20.91g	21.87g	50.85g	52.18g
150	84.86	85.63	130.66e	133.00f	24.32f	24.92f	55.23f	56.52f
150 + 0.5%	84.82	85.65	149.50d	152.25d	26.49d	27.80d	58.93d	60.54d
200	84.81	85.52	149.33d	150.58e	26.12e	27.08e	58.40e	59.95e
200 + 0.5%	85.08	85.53	156.25b	158.08b	28.95b	30.05b	63.49b	66.02b
300	84.94	85.7	154.33c	155.91c	28.52c	29.34c	63.00c	65.47c
300 + 0.5%	85.07	85.06	160.26a	163.50a	31.41a	32.54a	69.37a	71.52a
F-test	NS	NS	**	**	**	**	**	**
Interaction								
(N × D)	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

Growth regulators effect

Otherwise, there were highly significant differences on the effect of GA_3 and boric acid application on duration of spikelet opening, spikelet opening angle and stigma exsertion in both seasons (*Table 1*). The highest values for duration of spikelet opening, spikelet opening angle and stigma exsertion were obtained with the 300 g GA_3 + 0.5% B.A ha^{-1} in both seasons, while, the lowest values for duration of spikelet opening, spikelet opening angle and stigma exsertion were obtained under control treatment in both seasons.

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Interaction effect

The interaction between nitrogen levels and doses of GA_3 application was highly significant for duration of spikelet opening, spikelet opening angle and stigma exsertion in both seasons. While, it is not significantly for days to 50% heading in both seasons. The results in *Table 2* showed that the treatment of 165 kg N ha^{-1} with 300 g GA_3 + 0.5% B.A ha^{-1} combination, recorded significantly highest values of duration of spikelet opening, spikelet opening angle and stigma exsertion in both seasons.

Table 2. *Effect of N levels and GA_3 + B.A. dosage, as well as their interaction on floral traits during 2019 and 2020 seasons*

N levels (kg N ha^{-1})	GA_3 + B.A (g ha^{-1}) (D)	Duration of spikelet opening (min)		Spikelet opening angle (°)		Stigma exsertion (%)	
		2019	2020	2019	2020	2019	2020
0	0	110.00p	115.33t	19.39l	20.27s	49.66q	50.49r
	150	118.67n	121.66q	21.52j	22.09q	52.30n	53.76o
	150 + 0.5%	135.33k	138.33m	23.05hi	24.77m	54.62m	55.72n
	200	139.67j	137.33n	23.01hi	24.08n	54.21m	55.29n
	200 + 0.5%	147.48h	148.33j	25.53g	26.84k	56.73k	57.92k
	300	144.26i	146.66k	25.09g	26.12l	56.17k	57.16lm
	300 + 0.5%	150.30g	154.33h	27.84e	29.20g	60.56h	62.65g
55	0	115.35o	118.33s	20.10k	21.50r	50.20p	51.61q
	150	131.00l	133.33o	23.56h	24.22n	54.35m	55.53n
	150 + 0.5%	150.26g	154.66h	25.72g	26.81k	56.72k	57.68kl
	200	148.33h	152.33i	25.21g	26.15l	56.15k	57.26klm
	200 + 0.5%	154.31f	156.33g	27.58e	28.75h	58.68ij	61.87h
	300	153.33f	154.33h	27.12ef	28.18i	58.52ij	61.06i
	300 + 0.5%	158.30d	160.33e	30.46c	31.31d	67.74e	70.65d
110	0	118.33n	120.33r	21.53i	22.38p	51.37o	52.84p
	150	134.66k	136.66n	25.56g	26.18l	55.41l	56.90m
	150 + 0.5%	154.60f	156.33g	27.47e	28.83h	58.86i	60.72i
	200	153.00f	154.33h	27.10ef	28.09i	58.18j	60.12j
	200 + 0.5%	158.30d	160.33e	30.21c	30.78e	67.90e	70.54d
	300	156.62de	158.33f	29.84cd	30.02f	67.22f	70.29d
	300 + 0.5%	163.67be	166.33c	32.64b	33.18c	73.50b	74.83b
165	0	120.33m	125.33p	22.60i	23.35o	52.16n	53.78o
	150	138.33j	140.33l	26.61f	27.16j	58.86i	59.86j
	150 + 0.5%	157.66de	159.66e	29.75cd	30.80e	65.52g	68.03e
	200	156.33e	158.33f	29.11d	30.02f	65.08g	67.14f
	200 + 0.5%	164.66b	167.33b	32.47b	33.81b	70.64c	73.75c
	300	162.66c	164.33d	32.03b	33.03c	70.11d	73.37c
	300 + 0.5%	168.66a	173.00a	34.78a	36.47a	75.68a	77.94a

* = 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

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Nitrogen levels effect

The effect of N levels, doses of GA_3 application and their interaction on plant height (cm), panicle exsertion (%), panicle length (cm) and number of fertile tillers hill^{-1} are given in *Table 3*. The highest values for plant height, panicle exsertion, panicle length and number of fertile tillers hill^{-1} were obtained with application of 165 kg N ha^{-1} in both seasons while, the lowest one was found under control treatment in both seasons.

Table 3. *Mean performance of various quantitative traits of rice under different N levels and GA3 during 2019 and 2020 seasons*

Main effect and interaction	Plant height (cm)		Panicle exertion (%)		Panicle length (cm)		Number of fertile tillers hill^{-1}	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
N levels (kg N ha^{-1})								
0	83.51d	85.47d	60.00d	59.68d	16.68d	17.69d	12.65d	14.01d
55	85.29c	86.49c	60.89c	61.85c	17.90c	18.48c	14.74c	15.12c
110	88.80b	90.53b	62.68b	63.03b	19.02b	19.70b	16.88b	17.65b
165	95.76a	96.34a	64.18a	64.44a	20.31a	20.73a	18.85a	19.22a
F-test	**	**	**	**	**	**	**	**
GA_3 + B.A (g ha^{-1}) dosage (D)								
0	80.13g	81.71g	34.10g	34.81g	16.59g	17.20g	12.25g	12.84g
150	84.99f	85.35f	57.89f	58.78f	17.47f	17.99f	13.70f	14.25f
150 + 0.5%	88.08d	88.93d	66.39d	65.35d	17.93d	18.86d	15.51d	16.00d
200	87.47e	88.37f	65.05e	64.29e	17.64e	18.44e	15.17e	15.65e
200 + 0.5%	91.24b	91.89c	67.93b	69.12b	19.58b	20.17b	17.00b	17.98b
300	88.08d	93.74b	66.90c	767.90c	19.12c	19.70c	16.54c	17.59c
300 + 0.5%	96.16b	97.96a	75.30a	75.51a	21.00a	21.69a	20.29a	21.18a
F-test	**	**	**	**	**	**	**	**
Interaction								
(N × D)	**	**	**	**	**	**	**	**

* = 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

Growth regulators effect

Otherwise, there were highly significant differences among the doses of GA_3 application for plant height (cm), panicle exsertion (%), panicle length (cm) and number of fertile tillers hill^{-1} in both seasons. The highest values for plant height, panicle exsertion, panicle length and number of fertile tillers hill^{-1} were obtained with the doses of 300 g GA_3 + 0.5% boric acid ha^{-1} in both seasons. The lowest values for plant height, panicle exsertion, panicle length and number of fertile tillers hill^{-1} were found under control treatment in both seasons.

Interaction effect

The interaction between N levels and doses of GA_3 application was highly significant for plant height (cm), panicle exsertion (%), panicle length (cm) and number of fertile tillers hill^{-1} in both seasons. The results in *Table 4* showed that the

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combination between N level at the rate of 165 kg N ha^{-1} with the 300 g GA_3 + 0.5% B.A ha^{-1} produced significantly highest values of plant height, panicle exsertion, panicle length and number of fertile tillers hill^{-1} in both seasons.

Table 4. *Effect of N levels and GA_3 + B. A. foliar application, as well as their interaction on plant characteristics during 2019 and 2020 seasons*

N levels (kg N ha^{-1})	GA_3 + B.A (g ha^{-1}) dosage (D)	Plant height (cm)		Panicle exsertion (%)		Panicle length (cm)		Number of fertile tillers hill^{-1}	
		2019	2020	2019	2020	2019	2020	2019	2020
0	0	74.79x	77.59s	32.29s	33.35t	15.35p	15.35p	10.12q	11.17r
	150	80.38v	82.41q	56.36o	57.14p	16.24o	16.24o	11.59p	12.72o
	150 + 0.5%	84.66r	86.18klm	64.17j	63.35k	16.62n	16.62n	12.62n	14.02n
	200	84.09s	85.75mn	62.38k	62.02k	16.14o	16.14o	12.15o	13.97n
	200 + 0.5%	86.65n	88.38j	68.18f	67.20g	17.12lm	17.12lm	13.95l	15.17k
	300	85.97o	88.02j	67.43g	66.30h	17.01m	17.01m	13.27m	15.02kl
	300 + 0.5%	88.01j	89.98h	69.16e	68.42f	18.29h	18.29h	14.84jk	16.03j
55	0	78.05w	80.20r	34.02r	34.41s	16.20o	16.20o	11.72p	12.31q
	150	83.64t	83.93o	57.38n	58.31o	17.36kl	17.36kl	13.25m	13.28o
	150 + 0.5%	85.45p	86.35kl	65.61i	64.48j	17.64jk	17.64jk	14.96ij	14.81lm
	200	85.07q	86.03lmn	64.01j	63.36k	17.41kl	17.41k	14.69jk	14.16n
	200 + 0.5%	87.60k	88.46j	65.48i	68.20f	18.78g	18.78g	15.76h	16.86i
	300	87.01m	88.11j	64.47j	67.4g	18.42h	18.42h	15.27i	16.16j
	300 + 0.5%	90.22i	92.39g	75.3c	76.83c	19.48e	19.48e	17.53ef	18.21f
110	0	80.84u	83.47p	34.64q	35.28r	17.08lm	17.08lm	12.74n	13.31o
	150	85.65p	86.59k	58.38m	59.28n	17.88ij	17.88ij	14.64jk	14.67m
	150 + 0.5%	88.01j	89.94h	67.21g	66.10h	18.33h	18.33h	16.33g	17.35h
	200	87.35l	89.04i	66.37h	65.38i	18.01i	18.01i	16.03gh	17.23h
	200 + 0.5%	92.37g	94.28e	68.28f	69.47e	20.23d	20.23d	17.66ef	18.56e
	300	91.10h	93.1f	67.48g	68.41f	19.0fg	19.00fg	17.29f	18.17f
	300 + 0.5%	96.27d	97.29c	76.41b	77.30b	22.63b	22.63b	23.51b	24.28b
165	0	86.84mn	85.58n	35.46p	36.20q	17.75ij	17.75ij	14.42k	14.56m
	150	90.28i	88.49j	59.45l	60.39m	18.40h	18.40h	15.32i	16.33j
	150 + 0.5%	94.19e	93.28f	68.59f	67.48g	19.14f	19.14f	18.13d	17.81g
	200	93.38f	92.66g	67.42g	66.42h	19.01fg	19.01fg	17.80e	17.23h
	200 + 0.5%	98.33b	96.44d	69.78d	71.60d	22.20c	22.20c	20.65c	21.32c
	300	97.16c	105.75b	68.24f	69.51e	22.08c	22.08c	20.35c	21.03d
	300 + 0.5%	110.16a	112.19a	80.33a	79.51a	23.59a	23.59a	25.27a	26.22a

* = 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

Nitrogen levels effect

The effect of N levels, doses of GA_3 application and their interaction on panicle weight (g), seed set (%), harvest index (%) and seed yield (t ha^{-1}) are given in *Table 5*. The highest values for panicle weight, seed set, harvest index and seed yield were obtained with application of 165 kg N ha^{-1} in both season, while, the lowest values for

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panicle weight, seed set, harvest index and seed yield were found under control treatment.

Growth regulators effect

There were highly significant differences among the doses of GA_3 application for panicle weight (g), seed set (%), harvest index (%) and seed yield (t ha^{-1}) in both seasons. The highest values for panicle weight, seed set, harvest index and seed yield were obtained with the application of 300 g GA_3 + 0.5% B.A ha^{-1} in both seasons. The lowest values for panicle weight, seed set, harvest index and seed yield were found under control treatment in both seasons.

Table 5. *Effect of N levels and GA_3 + B.A. dosage application and their interactions on panicle weight, seed set, harvest index and seed yield during 2019 and 2020 seasons*

Main effect and interaction	Panicle weight (g)		Seed set (%)		Harvest index (%)		Seed yield (t ha^{-1})	
	2019	2020	2019	2020	2019	2020	2019	2020
N levels (kg N ha^{-1})								
0	1.61d	1.67d	21.62d	23.06d	12.96d	14.03d	0.753d	0.849d
55	1.99c	2.01c	23.25c	24.86c	14.60c	15.72c	0.859c	1.057c
110	2.28b	2.43b	25.44b	26.87b	15.74b	16.95b	1.155b	1.302b
165	2.49a	2.69a	27.94a	28.92a	17.57a	18.77a	1.496a	1.588
F-test	**	**	**	**	**	**	**	**
GA_3 + B.A (g ha^{-1}) dosage (D)								
0	1.62f	1.65g	17.75g	18.92e	11.36g	12.77g	0.735g	0.835f
150	1.82e	1.86f	19.89f	21.18d	13.07f	14.07f	0.850f	0.975e
150 + 0.5%	1.95d	2.07d	23.54d	24.49c	14.84d	16.19d	1.015d	1.083d
200	1.85e	1.97e	23.13e	24.30c	14.49e	15.84e	0.990e	1.065d
200 + 0.5%	2.35b	2.44b	27.91b	29.19b	16.93b	18.03b	1.231b	1.430b
300	2.24c	2.38c	27.49c	29.54b	16.60c	17.61c	1.209c	1.335c
300 + 0.5%	2.84a	3.03a	32.23a	33.67a	19.26a	20.33a	1.433a	1.670a
F-test	**	**	**	**	**	**	**	**
Interaction								
(N × D)	**	**	**	**	**	**	**	**

* = 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

Interaction effect

The interaction between N levels and doses of GA_3 application was highly significant for panicle weight, seed set, harvest index and seed yield in both seasons. The results in *Table 6* showed that the combination of 165 kg N ha^{-1} with the doses 300 g GA_3 + 0.5% B.A ha^{-1} produced significantly highest values of panicle weight, seed set, harvest index and seed yield in both seasons. While the lowest values were recorded in control treatment in both seasons.

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Table 6. *Effect of N levels and GA_3 + B.A. foliar application, as well as their interaction on panicle characteristics and yield during 2019 and 2020 seasons*

N levels (kg N ha^{-1})	GA_3 + B.A ($g\ ha^{-1}$) dosage (D)	Panicle weight (g)		Seed set (%)		Harvest index (%)		Seed yield (t ha^{-1})	
		2019	2020	2019	2020	2019	2020	2019	2020
0	0	1.20p	1.38o	16.22q	17.23o	10.55n	11.22m	0.530n	0.670l
	150	1.24p	1.29p	18.13o	18.48mno	11.25m	12.38l	0.620m	0.720kl
	150+0.5%	1.43o	1.47n	20.11m	22.05klm	12.23k	13.48k	0.716l	0.790i-l
	200	1.31p	1.39o	19.77m	21.87klm	11.79l	13.02k	0.700l	0.776i-l
	200+0.5%	1.98il	1.94k	24.67i	26.33f-i	14.40i	15.73h	0.880hi	0.950hi
	300	1.92jkl	1.90k	23.81k	25.83g-j	14.07i	15.14i	0.850j	0.920hij
	300+0.5%	2.19fg	2.31h	28.64e	29.63cde	16.42g	17.24g	0.980g	1.116fg
55	0	1.63n	1.56m	17.35p	18.44no	10.79m	12.32l	0.610m	0.750jkl
	150	1.83lm	1.70l	19.16n	20.20lmn	12.51k	13.43k	0.710l	0.850ijk
	150+0.5%	1.93jkl	1.95k	22.54l	23.88ijk	14.35i	15.70h	0.843j	0.920hij
	200	1.87kl	1.90k	22.18l	23.18jk	14.03i	15.11i	0.810k	0.903hij
	200+0.5%	2.12f-i	2.18ij	26.18h	28.79c-f	16.21g	17.07g	0.980g	1.410cd
	300	2.01h-k	2.12j	26.02h	28.20d-g	16.09g	16.99g	0.946gh	1.133fg
	300+0.5%	2.01d	2.67e	29.29d	31.29c	18.25d	19.42d	1.116f	1.433cd
110	0	1.73mn	1.68l	18.13n	19.49mno	11.36m	13.34k	0.853j	0.860ijk
	150	2.01h-k	2.15j	20.09m	22.50kl	13.38j	14.27j	0.910hi	1.033gh
	150+0.5%	2.16fgh	2.38h	24.65i	25.40hij	15.41h	16.90g	0.983g	1.213ef
	200	2.07g-j	2.24i	24.18j	25.09hij	15.10h	16.14h	0.95gh	1.190efg
	200+0.5%	2.54d	2.66e	28.40e	30.20cd	17.61e	18.84e	1.363d	1.516c
	300	2.40e	2.58f	28.01f	30.09cd	17.14ef	17.97f	1.340d	1.476c
	300+0.5%	3.04b	3.28b	34.60b	35.32b	20.21b	21.20b	1.690b	1.830b
165	0	1.89kl	1.96k	19.29n	20.50lmn	12.73k	14.21j	0.946gh	1.063fgh
	150	2.17fgh	2.32h	22.20l	23.53jk	15.15h	16.20h	1.160e	1.296de
	150+0.5%	2.26f	2.38h	26.86g	27.43e-h	17.38ef	18.68e	1.516c	1.410cd
	200	2.13f-i	2.36h	26.36h	27.06e-h	17.02f	18.05f	1.500c	1.390cd
	200+0.5%	2.74c	2.97c	32.38c	31.45c	19.50c	20.47c	1.703b	1.846b
	300	2.68c	2.87d	32.12c	34.02b	19.11c	20.34c	1.700b	1.810b
	300+0.5%	3.59a	3.85a	36.41a	38.43a	22.13a	23.49a	1.946a	2.303a

* = 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

Discussion

The improved in rice yield attributes with increasing N levels mostly due to the function of N on improving rice growth, photosynthesis, internodes elongation led to extra panicle formation during the productive stage, produce maximum spikelets per panicle as well as grain filling accordingly, the weight of grain was high. The rice grain yield enhancement could be due to the role of N in increasing grain yield attributes i.e., panicles $hill^{-1}$, panicle length, number of filled grains per panicle and panicle weight (Sorour et al., 2016; Gewaily et al., 2018). Haque et al. (2006) reported that irrespective of rice cultivars, the days requested to heading and maturity significantly increased with the increasing the level of N application. Accelerated vegetative growth could be a reason for delaying heading and crop maturity with the increasing the of N fertilizer rates. Also, Elankavi et al., 2009) reported that the delayed heading with higher N rates may be due to more vegetative growth, which resulted in, delayed maturity. The results are in

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agreements with those obtained by Gharib et al. (2011) and Fu and Yang (2011). Cui et al. (2010) reported that, the suitable N application rate of Japonica super rice in the northern China was 147 kg ha^{-1}, while, Li et al. (2011) found that, N application rate was 270 kg ha^{-1} in order to obtain the yield of 7.5 t ha^{-1} studied the super rice Xinliangyou 6 in the southern China and found a suitable. Zhu et al. (2015) investigated the N application rate on grain yield and quality of Japonic*a* rice Wuyunjing27 and found that, the optimum amount of N fertilizer was 225-300 kg ha^{-1}. The variations in the suitable N application rates in the above studies were due to differences in rice varieties and ecological zones.

Poor panicle exsertion of male sterile lines is a major problem in hybrid rice seed production. Hence, the foliar application of GA_3 at the start of panicle emergence has been widely adopted as an essential technology for improving plant height and panicle exsertion. Godha et al. (2020) reported that applied auxins (i.e., NAA, GA_3 and ascorbic acid) increased the highest value of panicle exsertion and the increases ranged between 87.80% and 88.67% when rice plants of A-line were treated with 200 g GA_3 ha^{-1} of. The results indicated that, the addition of the 0.5% boric acid with 300 g GA_3 ha^{-1}, positively improved the morphological rice traits. GabAllah (2004) reported that, the highest value of leaf angle was ranged between 41.67 to 44.01 when rice plants of A line were treated with 200 g GA_3 ha^{-1}. The results are in agreement with those reported by El-Mowafi et al. (2016). The application of GA_3 influences panicle exsertion, spikelet opening angle and other floral traits which increases outcrossing rate of CMS lines leading higher yield. Rahman et al. (2010) reported that, application of GA_3 at the rate of 150 g ha^{-1} increased panicle exsertion and out crossing rate and seed yield compared with without GA_3. Zhen et al. (2018) found that GA_3 application at the time flowering produced hybrid seeds with a higher seedling vigor index. Additionally, it has been documented that GA_3 stimulates the synthesis and production of hydrolases, resulting in the germination of seeds. Therefore, GA_3 application may affect on seed vigor during hybrid rice seed production. During hybrid rice seed production, the foliar application of GA_3 at the start of panicle emergence improving panicle exsertion of male sterile lines. Moreover, many investigations were conducted in southern China reported that, spraying of GA_3 at 15-30 g for several times after anthesis can act stigma properties, including stigma vigor which ultimately influence the out-crossing rate and seed yield potential. Previous studies have reported the erect of GA_3 application on seed yield during hybrid rice seed production. However, knowledge is limited about the effect of GA_3 application after anthesis on the seed vigor of hybrid rice. We hypothesized that a low concentration of GA_3 application after anthesis can enhance stigma vigor and correspondingly improve seed vigor in hybrid rice seed production. The filament length of the anther determines the degree of versatility of the anthers i.e., higher the filament length greater the degree of versatility of the anther and higher frequency of pollen dispersal and migration from the male parent to female parent. Xiaomin et al. (2019) observed that GA_3 application after anthesis could prolong the duration of seed filling and enhance the sink capacity, correspondingly improving grain weight and out-crossing, and eventually increasing the seed yield. Consequently, the higher seed yield under the GA_3 application with 30 g ha^{-1} was mainly ascribed to the significantly higher 1000-grain weight and out-crossing rate. The increase in yield with the application of GA_3 might be due to increased yield attributes, which in turn resulted from effective translocation of photosynthates. The plant growth hormones also increase mobilization of reserve food materials to the developing sink through increase in hydrolyzing and oxidizing enzyme activities and leads to yield increases (Jayachandran et al., 2000; Muniandi et al., 2018).

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Conclusions

The article aimed to investigate the effects of various N doses and foliar GA_3 application on the seed yield of hybrid and parent rice grown in Egypt, using a split-plot design with three replications. The results indicated that, GA_3 application significantly enhanced the stigma vigor index of the female parent and correspondingly increased the out-crossing rate. Moreover, GA_3 application should be applied at a rate of 300 g GA_3 ha^{-1} to improve seed vigor and increased hybrid rice seed production. Nitrogen application at the level of 165 kg N ha^{-1} produced the highest seed yield in both seasons. The treatment combination of (165 kg N ha^{-1} and 300 g GA_3 ha^{-1} + 0.5% B.A) recorded the best effects for most of the rice characteristics and recommended for achieving higher hybrid rice seed production in Egypt.

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