sustainability

MDPI

Article

Flowering Synchronization in Hybrid Rice Parental Lines at Different Sowing Dates

Mahmoud Gaballah [1], Hassan Hamad [1], Atif Bamagoos [2], Hesham Alharby [2], Sharif Ahmed [3], Ismail A. Ismail [4], Md Sohidul Islam [5] and Ayman EL Sabagh [6,*]

[1] Agricultural Research Center, Field Crops Research Institute, Rice Research and Training Center, Kafr El–sheikh 33511, Egypt; mahmoudgab@yahoo.com (M.G.); hassanshehata28@yahoo.com (H.H.)
[2] Department of Biological Sciences, Faculty of Science, King Abdulaziz University, Jeddah 21577, Saudi Arabia; abamagoos@kau.edu.sa (A.B.); halharby@kau.edu.sa (H.A.)
[3] International Rice Research Institute, Bangladesh Office, Dhaka 1213, Bangladesh; s.ahmed@irri.org
[4] Department of Biology, College of Science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia; i.ismail@tu.edu.sa
[5] Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200 Bangladesh; shahid_sohana@yahoo.com
[6] Department of Agronomy, Kafrelsheikh University, Kafrelsheikh 33511, Egypt
* Correspondence: ayman.elsabagh@agr.kfs.edu.eg

check for updates

Citation: Gaballah, M.; Hamad, H.; Bamagoos, A.; Alharby, H.; Ahmed, S.; Ismail, I.A.; Sohidul Islam, M.; EL Sabagh, A. Flowering Synchronization in Hybrid Rice Parental Lines at Different Sowing Dates. *Sustainability* **2021**, *13*, 3229. https://doi.org/10.3390/su13063229

Academic Editor: José Manuel Mirás-Avalos

Received: 6 February 2021
Accepted: 10 March 2021
Published: 15 March 2021

Abstract: Hybrid seed set on the female line depends primarily on its flowering synchronization with the restorer line (R), therefore, the sowing of male and female lines must be planned properly to achieve this. Field experiments on different sowing dates (May 1st, May 15th, and May 30th) of R lines (Giza 178R, Giza 179R, and Giza 181R) and cytoplasmic male sterile (CMS) lines (IR69625A, IR70368A, IR58025A, K17A, and G46A) were carried out at the farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during 2019 and 2020 to study the effect of sowing dates on flowering synchronization in hybrid rice. The results indicated that the synchronization of flowering between CMS lines and R lines has highly significant effects on the days to 50% heading, number of leaves, effective accumulated temperature (EAT), plant height, panicle exertion percentage, panicle length, number of fertile panicles, panicle weight, seed set percentage, harvest index and seed yield of hybrid rice. The highest seed yield (1.72 and 1.41 t ha^{-1}, respectively in 2019 and 2020) was recorded from the sowing date May 1st and the hybrid combination of Giza 178R × IR58025A (2.06 and 2.12 t ha^{-1} in 2019 and 2020, respectively). The grain yield had a significant and highly significant positive correlation with the plant height (cm), panicle exertion percentage, panicle length, number of panicles plant^{-1}, panicle weight, seed set percentage, and harvest index. In Egypt, May 1st is the best time for the synchronization of hybrid rice lines and a combination of Giza 178R × IR58025A may be recommended for better performance.

Keywords: hybrid rice; sowing date; CMS lines; restorer lines; grain yield

1. Introduction

Rice is an important food crop and the main food source for more than half of the global population. Rice is cultivated in Egypt over an area of about 660 thousand hectares, with an annual production of about 4.6 million tons of paddy, with average productivity of 10 tons per hectare [1]. Hybrid rice production is an innovative technology to increase further rice productivity, leading to food security and the reduction of poverty in Egypt. This technology can be used to increase the current yield in rice, where the yield levels of the conventional cultivars have stabilized and reported yield advantage of 15–20% over conventional varieties [2]. The heterosis advantage of hybrids may be expressed by superiority over inbred varieties in vigor, number of productive tillers, panicle size, number of spikelets/panicle, and grain yield.

Hybrid varieties are generally developed by the three lines and the two lines breeding method. Meanwhile, in the three line method, the cytoplasmic genetic male sterility system is a three lines system that is involved and needed a cytoplasmic male sterile (CMS) source, a maintainer, and restorer (R) line is extensively being used in rice hybrids production [3]. Several factors influence the hybrid seed production, such as seeding time, field condition, planting pattern, weather conditions at flowering, synchronization of flowering in the parental lines, supplementary pollination techniques, and application GA3, etc. [4]. Synchronization of flowering between the parental lines of hybrid is one of the most important considerations in hybrid seed production. Seed production on female parents depends on the pollen supplied from the male parent during the flowering period and if failure to obtain proper synchronization resulting in very poor or no seed set, the most commonly experienced problem in hybrid seed production. By synchronization of flowering, female parents and the pollinator parents flower at the same time, even though they may have different growth durations. Pollen grains from the R line should be available to the CMS line throughout its flowering period, so synchronization of flowering is very important. Adjusting the sowing dates of the parents' line in the seedbed is one of the strategies to obtain flowers in both lines at the same time in the field [5]. Synchronization of flowering between the R lines and cytoplasmic male sterility lines assumes greater importance, as the seed set on the female parent depends on the amount of pollen supplied from the male parent during the flowering period. Failure in earning proper synchronization is the most faced problem in hybrid rice seed production, resulting in poor or no seed set at all. The knowledge on flowering behavior of the parental lines which varies with the sowing date is very much essential to know the exact difference in days to flowering between the parental lines. If there is a flowering gap, the problem of non-synchronization could be overcome by staggered sowing of the male parent based on the information on days to flowering [6]. Despite adjusting the sowing date, even sometimes the parents do not flower at the same time because of the differential response of the parents to stress conditions [7]. Therefore, it is essential to adjust the flowering of parental lines after observing the difference at the primordial development stage [8].

The difference in flowering can be manipulated to some extent by the application of urea and potassium as a foliar spray. In case of adverse conditions, nonflowering synchronization among parental lines could be predicted. In such conditions, some techniques should be adapted to adjust flowering synchronization as possible. Spraying 2% urea at panicle initiation delayed about four days to flowering or spraying 1% potassium sulphate at panicle initiation enhanced three days earlier flowering [9]. Since the parents of each hybrid behave differently in diverse locations and dissimilar situations to flowering at different sowing dates, there is a need to take up studies to find out the effectiveness of different techniques to achieve the synchronization of flowering. The methods used for determining seeding intervals were growth duration differences (GDD), based on the difference between the CMS and R lines in terms of days from seeding to initial heading (10%), the number of leaves differences (LND) based on the difference between the parental lines in terms of leaf growth, emergence rate and effective accumulative temperature (EAT) depends on the difference between the CMS and R lines, in terms of biologically effective and accumulative temperature required from seeding to heading (50%) [5]. Therefore, the present study aimed to test some CMS lines and R lines under different sowing dates, to identify the perfect seeding time to optimize synchronization of flowering between parental lines and determine the correlation coefficient for all pairs of traits.

2. Materials and Methods

2.1. Experimental Site and Soil Characteristics

Two field experiments were carried out at the Experimental Farm of Rice Research and Training Center, Sakha Agriculture Research Station, Kafr EL-Sheikh, Egypt, during 2019 and 2020, to study the effect of sowing dates on the synchronization of flowering between parental lines of some promising hybrid combinations.

The climate of the area is tropical and the average maximum and minimum temperatures during the study period given in Figure 1. The topsoil (0–15 cm) of the experimental field was a sandy loam with a bulk density of 1.75 Mg m^{-3}, a pH of 7.7, organic carbon—%. The physical and chemical properties of the soil in trial sites were shown in Table 1, while the average air temperature and relative humidity percentage were given in Figure 1.

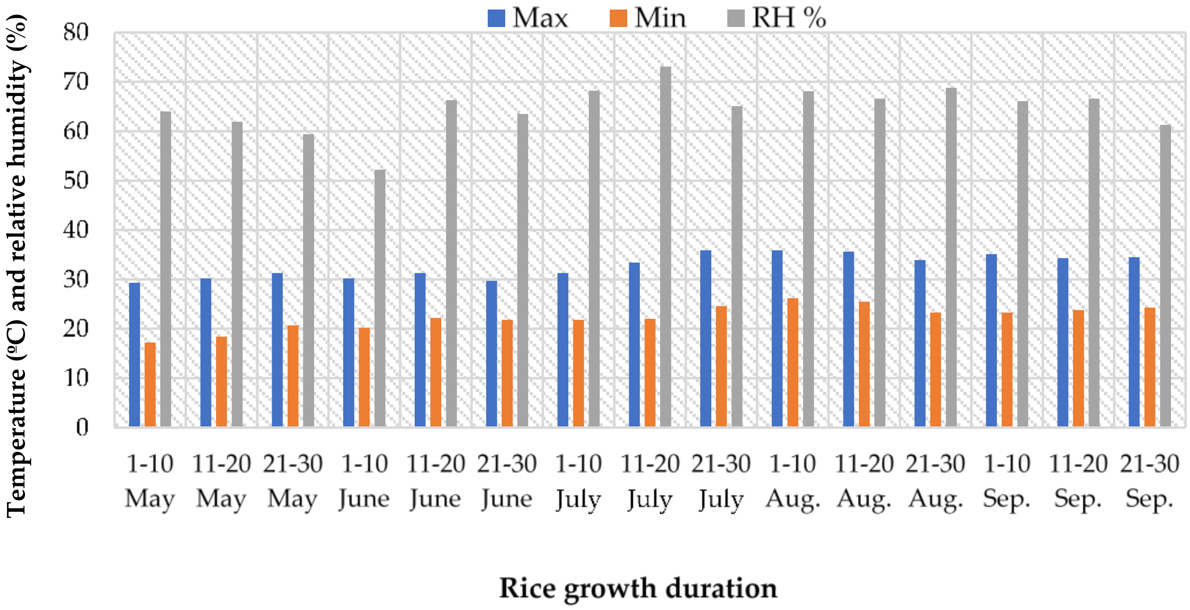

Figure 1. Maximum and minimum air temperatures (°C) and relative humidity (%) in 2019 and 2020 rice growing seasons.

Table 1. Physical and chemical properties of the topsoil (0–15 cm) at Sakha Research Station in 2019 and 2020.

Properties	**2019**	**2020**
Clay (%)	55	55
Silt (%)	32.4	32.4
Sand (%)	12.6	12.6
Texture	Clayey	Clayey
Organic Matter	1.39	1.39
pH	8.1	8.2
Electrical Conductivity(Ec) (dS/m)	3.30	3.33
Total N (ppm)	512	518
Available P(ppm)	15.09	16.03
CO_3^{2-}	-	-
HCO^{3-}	5.55	5.56
Mg^{2+}	4.3	5
Na^{+}	1.88	1.69
K^{+}	16	16
Fe^{3+}	4.55	4.55
Mn^{2+}	3.1	3.5

2.2. Study Design and Treatment

The materials included the parental lines of Giza 178, Giza 179 and Giza 181 as R lines, and IR69625A, IR70368A, IR58025A, K17A and G46A as female (cytoplasmic male sterile or CMS lines) to produce the F1 hybrid seeds. The experiments were performed in a split-plot design with three replications. The main plots were devoted to three sowing dates, and the subplots were located to eighteen genotypes or combinations of rice. The row ratio for each combination was 2 R: 10 CMS. The different seeding dates were done as illustrated in Table 2 for each R line and CMS lines in their combination.

Table 2. First and second sowing dates of R lines in three sowing dates of CMS lines at the same time in 2019 and 2020 seasons.

Combinations	R		CMS	R		CMS	R		CMS
	First	Second		First	Second		First	Second	
IR69625A × Giza178R	−4	−6	May 1st	−4	−6	May 15th	−4	−6	May 30th
IR70368A × Giza178R	−3	−5	May 1st	+1	−1	May 15th	−1	−3	May 30th
IR58025A × Giza178R	−7	−9	May 1st	−7	−9	May 15th	−5	−7	May 30th
K17A × Giza178R	+14	+17	May 1st	+14	+17	May 15th	+14	+17	May 30th
G46A × Giza178R	+13	16	May 1st	+14	+17	May 15th	+12	+15	May 30th
IR69625A × Giza179R	−10	−12	May 1st	−12	−14	May 15th	−13	−15	May 30th
IR70368A × Giza179R	−9	−11	May 1st	−8	−10	May 15th	−10	−12	May 30th
IR58025A × Giza179R	−13	−15	May 1st	−15	−17	May 15th	−14	−16	May 30th
K17A × Giza179R	+8	+11	May 1st	+6	+9	May 15th	+4	+7	May 30th
G46A × Giza179R	+7	+10	May 1st	+5	+8	May 15th	+2	+5	May 30th
IR69625A × Giza181R	+11	+14	May 1st	+9	+12	May 15th	+7	+10	May 30th
IR70368A × Giza181R	+12	+15	May 1st	+13	+16	May 15th	+10	+13	May 30th
IR58025A × Giza181R	+8	+11	May 1st	+6	+9	May 15th	+6	+9	May 30th
K17A × Giza181R	+28	+31	May 1st	+27	+30	May 15th	+24	+27	May 30th
G46A × Giza181R	+28	+31	May 1st	+26	+29	May 15th	+22	+25	May 30th

The minus (−) and plus (+) refer to the seeded date of the R line after or before the respected CMS line in its combination, respectively.

2.3. Experimentation

Rice seeds at the rate of 20 kg ha^{-1} (15 kg from the CMS lines and 5 Kg from the R lines) were soaked in fresh water for 24 h and then drained water and incubated for 48 h to hasten germination. The pre-germinated seeds were uniformly broadcasted in the plastic trays according to the three target sowing dates (May 1st, May 15th, May 30th in 2019 and 2020). The pre-germinated seeds were uniformly broadcasted in the plastic trays according to the three target sowing dates. The field was well ploughed and dry leveled and then irrigated the field to make the soil puddled condition. Phosphorous fertilizer as a form of mono-super phosphate (15.5% P_2O_5) at the rate of 100 kg/ha and Zinc fertilizer as a form of zinc sulphate (24% Zn So_4) at the rate of 20 kg/ha was added before seedling transplanting. Nitrogen as a form of urea (46% N) was applied in two splits, the first split at the rate of 20 kg/ha as a basal and the second split at the rate of 40 kg/ha as a top dress at the panicle initiation stage. Seedlings were carefully pulled from the nursery (plastic trays) after 30 days from sowing and seedlings of each parent for each date of sowing were individually transplanted to the main field in two rows in three replications. Each row measured five meters long and 25 cm apart between plants while the distance between two rows was 30 cm. Irrigation and pest management were followed on a need basis.

2.4. The Synchronization of Flowering Characteristics

Days to heading (day): It was determined from seeding to initial heading or 50% flowering.

Number of leaves: The number of leaves on the main culms of parental lines were recorded as leaf just emerge (0.2), leaf half-opened (0.5) and leaf almost opened (0.8) according to [10].

Effective accumulated temperature (EAT): The EAT [11] was calculated from the equation as follows,

$$EAT = (T - H - L)$$

where, T = mean daily temperature, H = temperature over upper limit (T-27 °C), and L = temperature of lower limit (12 °C).

Through the days to heading, the number of leaves on the main culm and effective accumulation temperature could determine accurately the sowing date to synchronization flowering between parental lines.

2.5. Agronomic Characteristics

Plant height (cm) was measured from soil surface to the tip of the tallest panicle of each plant and 10 of plants for each treatment were used for plant height measurement. Panicle exertion percentage was estimated as an average from the 10 panicles and calculated as follows:

$$Panicle\ exertion\ (\%) = \frac{Exerted\ panicle\ length}{Panicle\ length} \times 100$$

Panicle length was measured from the panicle base up to a piculus of the upper most spikelet of the panicle and 10 of panicles were used to measure this. The number of panicles plant^{-1} was estimated at harvest by counting the number of panicles from 10 hills. Individual panicle weight was recorded by the weighting of the main panicle per hill and 10 of hills were used to measure this. Seed set percentage or fertility percentage was estimated as an average from the 10 panicles and calculated as follows:

$$Fertility\ (\%) = \frac{Number\ of\ filled\ grains\ per\ panicle}{Total\ spikelets\ per\ panicle} \times 100$$

Rice grain and straw yields (t ha^{-1}) were determined by harvesting m^2 in the center of each subplot, and determined the fresh weight of the grain after manual threshing. At the same time, grain moisture was determined using a grain moisture meter and yield was converted to t ha^{-1} at 14% moisture content.

Harvest index (HI%) was calculated using the formula as suggested by [12]:

$$HI\ (\%) = \frac{Grain\ yield/Economic\ yield}{Total\ dry\ matter} \times 100$$

2.6. Statistical Analysis

All data collected were subjected to a two-way analysis of variance according to Gomez and Gomez [13]. Means of treatment were compared by Duncan's multiple range test [14]. The correlation coefficient estimates were carried out using the formula given by Kown and Torrie [15].

3. Results

The ordinary analysis of variance results indicated in both years highly significant differences among sowing dates (S) for all traits studied in both years (Table 3). The genotypes (G) variances were highly significant for all characteristics through two rice growing seasons. Meanwhile, the interaction of genotypes and sowing dates (S × G) was significant and highly significant for all traits, except harvest index in the first year and leaf number and panicle length in the second year.

3.1. Effect of Sowing Dates

Across genotypes, there was a significant effect of sowing dates on different traits (Table 4). The first sowing date (May 1st) produced the maximum number of leaves (18 and 19), the longest duration to heading days (101 and 100), effective accumulated temperature (1304 and 1334 °C), plant height (105 and 106 cm) and panicle exertion percentage (66.8 and 66.4%), in 2019 and 2020, respectively. Meanwhile, the third sowing date (May 30th) recorded the lowest number of leaves, days to heading, EAT, plant height and panicle exertion percentage (Table 4). Considering the panicle length, the highest length was recorded from the first sowing date followed by the second sowing, and the lowest panicle length was obtained from the third sowing date. The highest number of fertile panicles were found from the sowing date May 1st, and fertility decreased when sowing was delayed from May 1st to May 30th. Considering the panicle weight, seed set percentage, harvest index, and grain yield, superior results were found from the sowing date May 1st and their performance was decreased when the sowing date was delayed from May 1st to May 30th.

Table 3. Mean sum of squares for traits studied in 2019 and 2020 rice growing seasons.

Source	Df	Number of Leaves		Days to Heading		EAT		Plant Height (cm)		Panicle Exertion (%)		Panicle Length (cm)
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019
Blocks	2	0.12 ns	2.47 ns	3.70 **	3.02 ns	9.932 ns	10.021 ns	0.31 ns	1.01 ns	0.399 ns	2.35 ns	7.56 *
Sowing dates (S)	2	29.98 **	37.87 **	837.36 **	786.2 **	67247.1 **	67918.01 **	625.07 **	389.53 **	1691. **	1216.9 **	111.54 **
Error	4	0.11	0.56	0.16	0.60	28.978	29.25	1.40	0.38	0.726	4.081	0.52
Genotypes (G)	17	13.92 **	14.93 **	718.34 **	715.10 **	268317 **	2710022 **	321.95 **	241.92 **	2976. **	2880.1 **	17.56 **
Error b	34	0.08	0.59	0.61	0.35	21.115105	21.325481	0.70	0.96	0.713	0.936	0.42
G × S	34	0.36 **	0.95 ns	2.24 **	5.36 **	596.2785 **	602.26 ***	4.47 **	4.42 **	34.80 **	32.089 **	0.76 *
Error	68	0.08	0.75	0.32	0.19	9.2496369	9.34	0.73	0.78	0.591	0.829	0.46
Total	161											

Source	Df	Panicle Length (cm)	No. of Fertile Panicle		Panicle Weight (g)		Seed Set (%)		Harvest Index (%)		Grain Yield t ha^{-1}	
		2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Blocks	2	7.79 **	1.31 ns	0.01 ns	0.01 ns	0.03 ns	0.73 ns	1.72 ns	11.07 ns	18.98 **	0.009 ns	0.023 *
Sowing dates (S)	2	81.28 **	336.1 **	418.90 **	5.44 **	4.86 **	554.38 **	567.47 **	146.73 **	126.18 **	7.88 **	6.458 **
Error	4	0.26	0.44	1.85	0.03	0.03	1.04	0.51	2.53	0.28	0.0031	0.002
Genotypes (G)	17	11.06 **	32.22 **	36.46 **	7.60 **	9.06 **	4314.4 **	4222.2 **	518.47 **	505.35 **	98.407 **	100.400 **
Error b	34	0.61	0.82	1.05	0.04	0.04	1.50	0.91	0.98	0.62	0.011	0.016
G × S	34	0.95 ns	3.72 **	2.00 **	0.10 **	0.11 **	5.50 **	5.66 **	0.71 ns	1.50 **	0.334 **	0.37 **
Error	68	0.74	0.95	0.63	0.03	0.01	0.61	0.96	0.66	0.62	0.006	0.012
Total	161											

* and ** = significant and highly significant at probability 0.05 and 0.01, respectively; ns = not significant; EAT = effective accumulated temperature.

Table 4. Across genotypes performance of different traits as affected by sowing dates in the 2019 and 2020 seasons.

Traits	May 1st		May 15th		May 30th	
	2019	2020	2019	2020	2019	2020
Number of leaves	18.32 a	18.54 a	17.26 b	17.44 b	16.83 c	16.89 c
Days to heading (day)	100.60 a	100.49 a	96.30 b	96.67 b	92.74 c	92.85 c
Effective accumulated temperature	1303.59 a	1334.00 a	126183 b	1271.17 b	1233.35 c	1228.83 c
Plant height (cm)	105.40 a	105.55 a	102.87 b	103.16 b	98.66 c	100.19 c
Panicle exertion (%)	66.84 a	66.41 a	59.22 b	60.07 b	55.22 c	56.40 c
Panicle length	22.09 a	22.62 a	20.21 b	20.10 b	19.27 c	20.19 c
Number of fertile panicles	21.76 a	22.93 a	18.42 b	19.28 b	16.88 c	17.46 c
Panicle weight (g)	3.00 a	3.02 a	2.69 b	2.68 b	2.36 c	2.42 c
Seed set (%)	50.65 a	51.74 a	46.60 b	47.62 b	44.32 c	45.34 c
Harvest index (%)	23.10 a	23.65 a	21.38 b	21.90 b	19.79 c	20.60 c
Grain yield t ha^{-1}	1.720 a	1.710 a	1.580 b	1.590 b	1.250 c	1.320 c

Within a column, means followed by the different letter are statistically different according to the DMRT test at 0.05 probability.

3.2. Genotype Effect

Across sowing date, the R line Giza 181 produced the highest number of leaves, days to heading (day), effective accumulated temperature, panicle exertion percentage, panicle length, panicle weight, seed set percentage and harvest index in both seasons (Table 5). Meanwhile, the restorer line Giza 179 exhibited the highest panicle exertion percentage, number of fertile panicles and grain yield. Considering the CMS line, IR70368A showed the highest number of leaves and panicle exertion percentage, and line IR58025A produced the highest plant height, panicle length, number of panicles, panicle weight, seed set percentage, harvest index and grain yield t/ha (Table 4). In both seasons, the highest EAT and days to heading (day) was found from the line IR69625A. The lowest number of leaves, days to heading (day), EAT, plant height, panicle exertion percentage, panicle length, number of panicle/plant, panicle weight, harvest index and grain yield t ha^{-1} in both seasons were recorded from the CMS line K17A. On the other hand, the least values for the seed set were found from the line G46A (Tables 6 and 7).

Table 5. Across sowing date performance of different traits, such as numbers of leaves, days to heading, effective accumulated temperature (EAT), plant height, and panicle exertion affected by genotypes in 2019 and 2020 seasons.

Genotypes	Number of Leaves		Days to Heading (day)		EAT		Plant Height (cm)		Panicle Exertion	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Giza178R	17.15 d	17.19 b	98.50 e	99.05 e	1329.11 e	1335.76 e	106.89 c	108.28 bc	100 a	100 a
Giza179R	15.16 f	15.35 c	90.61 f	91.49 f	1269.33 f	1275.68 f	104.20 e	105.58 d	100 a	100 a
Giza181R	19.22 a	19.27 a	112.17 a	111.56 a	1491.33 a	1498.79 a	107.80 bc	108.56 b	100 a	100 a
IR69625A × Giza178R	18.49 bc	18.60 a	105.25 b	104.94 b	1429.78 b	1436.93 b	103.01 f	103.36 e	56.33 d	55.52 cd
IR70368A × Giza178R	18.65 b	18.59 a	99.59 d	100.12 d	1336.44 d	1343.13 d	105.88 d	107.72 bc	58.35 b	57.26 b
IR58025A × Giza178R	18.17 c	18.12 a	102.46 c	102.76 c	1393 c	1399.97 c	110.23 a	110.51 a	52.14 g	52 f
K17A × Giza178R	16.26 e	16.41 b	84.81 h	85.01 h	1035.56 h	1040.74 h	91.62 k	93.08 i	54.2 e	54.07 e
G46A × Giza178R	16.24 e	16.52 b	86.18 g	85.95 g	1043.33 g	1048.55 g	95.25 i	96.95 h	46.28 h	46.68 h
IR69625A × Giza179R	18.48 bc	18.75 a	104.98 b	104.94 b	1429.78 b	1436.93 b	104.19 e	103.46 e	57.6 bc	58 b
IR70368A × Giza179R	18.95 a	18.82 a	99.70 d	100.33 d	1336.33 d	1343.02 d	108.01 b	107.24 c	58.03 bc	57.47 b
IR58025A × Giza179R	18.21 c	18.28 a	102.25 c	102.64 c	1392.22 c	1399.19 c	108.26 b	104.84 d	53.27 ef	54.3 de
K17A × Giza179R	16.53 e	16.61 b	84.98 h	85.12 h	1035.78 h	1040.96 h	93.61 j	93.69 i	54.07 e	55.3 cde
G46A × Giza179R	16.26 e	16.44 b	86.33 g	85.90 g	1043.44 g	1048.66 g	96.48 h	98.88 g	46.97 h	48.3 g
IR69625A × Giza181R	18.44 bc	18.88 a	105.34 b	105.20 b	1429.44 b	1436.59 b	102.12 g	102.04 f	55.75 d	57.45 b
IR70368A × Giza181R	19.01 a	18.93 a	99.87 d	100.54 d	1337.67 d	1344.36 d	105.60 d	103.78 e	57.27 c	56.02 c
IR58025A × Giza181R	18.13 c	18.31 a	102.95 c	102.88 c	1393.67 c	1400.64 c	107.37 bc	105.42 d	52.95 fg	55.08 cde
K17A × Giza181R	16.48 e	16.86 b	85.15 h	85.56 gh	1035.44 h	1040.62 h	94.14 j	96.34 h	53.4 ef	56.14 c
G46A × Giza181R	16.39 e	15.30 c	86.68 g	86.09 g	1042.56 g	1047.77 g	96.93 h	103.65 e	46.82 h	48.59 g

Within a column, means followed by the different letter are statistically different according to the DMRT test at 0.05 probability.

3.3. Interaction Effects of Sowing Date and Genotypes Effect

Number of leaves, days to heading, EAT, plant height, panicle exertion percentage, panicle length, number of panicle/plant, panicle weight, seed set percentage, harvest index and grain yield (t ha^{-1}) were affected by the interaction of sowing date and genotypes (Table 7). The highest leaves number, EAT, panicle exertion percentage, number of panicles/plants, seed set, and grain yield were found from the interaction of the first sowing date (May 1st) and genotype restorer line Giza181. Considering the CMS lines, the maximum leaf number, EAT, and panicle exertion percentage were found from the interaction of the first sowing date (May 1st) and genotype IR69625A. Interaction of genotype K17 sown on May 30th recorded the earliness days to heading (Table 7). The shortest stature of plant height was recorded from the interaction of sowing date May 30th and genotype G46A in both seasons. The highest panicle length, number of panicles/plant, panicle weight, seed set percentage, harvest index and grain yield were recorded from the interaction of the first sowing date (May 1st) and genotype IR58025A.

The LND, GGD and EAT differences over two growing seasons (Table 8) found that the leaf number differences ranged between −3.18 to 4.49 means that should be planting R line Giza179 after IR58025A by formatted 3.18 leaves or by 12.94 days according to growth duration differences or after 144 °C EAT.

Meanwhile, 4.49 leaf number differences mean that planting CMS lines before its R line (Giza181 × G46A) by 4.49 formatted leaves or by 26.32 days or EAT about 415.50 °C. In addition to the GDD ranged between −15.27 to 28.39 for hybrid seed production combination IR58025A × Giza179R and K17A × Giza181R at the second sowing date and first sowing date, respectively. Regarding the EAT, the temperature ranged between −144.00 to 456.67 for combinations IR58025A × Giza179R, and K17A × Giza181R in planted date May 1st, respectively. From the data in Table 8 could be designed a chart (Figure 2) for every two combinations as an example for other combinations to determine seed sequence between R line and CMS line to optimizing the synchronization of flowering.

3.4. Correlation Coefficient

The data in Table 9 show the correlation coefficient among all traits studied in the present investigation. Meanwhile, a highly significant and positive correlation was found among the number of leaves and days to heading (day), EAT, plant height (cm), panicle length and the number of panicles/plant. The days to heading were highly significant and positive correlation with EAT, plant height, panicle exertion percentage, panicle length, number of panicles/plants, panicle weight, seed set percentage and harvest index. The EAT had a highly significant and positive correlation with plant height, panicle exertion percentage, panicle length (cm), number of panicles/plants, panicle weight, seed set percentage, and harvest index. The plant height, panicle length, and the number of panicles/plants had a highly significant correlation with all traits studied. Panicle exertion percentage had a positive significant and highly significant correlation with all studied traits except the number of leaves. Panicle weight, seed set percentage, and harvest index had a positive, significant and highly significant correlation with all traits except the number of leaves. The grain yield had a significant and highly significant positive correlation with plant height (cm), panicle exertion percentage, panicle length, number of panicles/plants, panicle weight, seed set percentage, and harvest index.

Table 6. Across sowing date performance of different traits such as panicle length, the number of panicles plant^{-1}, panicle weight, seed set percentage, harvesting index, and grain yield affected by genotypes in 2019 and 2020 seasons.

Genotypes	Panicle Length (cm)		No of Panicle/Plant		Panicle Weight (g)		Seed Set (%)		Harvest Index (%)		Grain Yield t ha^{-1}	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Giza178R	22.86 ab	22.97 ab	20.92 bc	21.65 b	4.24 b	4.53 c	93.69 a	93.71 b	42.81 b	42.82 b	9.96 b	10.06 b
Giza179R	22.35 b	22.41 bc	22.97 a	23.87 a	4.72 a	4.74 b	94.16 a	95.11 a	46.45 a	46.95 a	11.03 a	11.14 a
Giza181R	23.32 a	23.43 a	20.68 c	20.40 bcd	4.77 a	5.07 a	93.89 a	94.81 a	40.05 c	40.37 c	9.9 b	10 b
IR69625A × Giza178R	20.11 efg	21.10 def	18.92 def	20.74 bc	2.58 de	2.50 e	42.22 d	44.44 d	18.27 e	20.14 d	1.86 d	1.94 d
IR70368A × Giza178R	20.03 efg	21.23 c–f	18.69 ef	19.11 def	2.27 fgh	1.78 i	40.22 e	41.08 f	17.76 ef	17.25 fg	1.72 de	1.7 ef
IR58025A × Giza178R	21.40 c	22.18 bcd	21.77 b	23.41 a	2.94 c	2.97 d	46.56 b	48.20 c	19.44 d	20.49 d	2.06 c	2.12 c
K17A × Giza178R	18.76 hi	19.76 gh	16.31 h	16.59 g	2.03 hij	2.13 h	37.88 f	38.16 gh	16.75 f	17.19 fg	1.68 e	1.68 f
G46A × Giza178R	19.44 gh	20.71 efg	18.15 fg	19.64 c–f	2.22 f–i	2.23 fgh	35.73 g	37.37 hi	17.83 ef	18.81 e	1.72 de	1.7 ef
IR69625A × Giza179R	20.45 def	21.44 c–f	18.54 fg	19.53 c–f	2.48 def	2.45 ef	38.81 f	38.90 g	18.19 e	18.72 e	1.75 de	1.83 def
IR70368A × Giza179R	19.59 fgh	21.35 c–f	18.79 ef	20.26 b–e	2.44 efg	2.41 efg	36.07 g	37.47 hi	17.18 ef	16.84 gh	1.76 de	1.73 ef
IR58025A × Giza179R	21.25 cd	21.76 cde	20.12 cd	21.58 b	2.73 d	2.82 d	45.13 c	43.76 de	17.77 ef	18.19 ef	1.98 c	1.87 de
K17A × Giza179R	18.20 i	19.47 h	16.43 h	16.84 g	2.04 hij	1.98 hi	33.48 h	35.07 j	15.52 g	16.14 h	1.62 e	1.67 f
G46A × Giza179R	19.48 gh	20.54 fg	17.52 gh	18.49 f	2.18 ghi	2.12 h	33.18 hi	34.75 jk	17.09 ef	18.57 e	1.61 e	1.66 f
IR69625A × Giza181R	20.61 cde	22.00 bcd	19.83 cde	18.83 ef	2.22 f–i	2.20 gh	36.07 g	37.13 hi	16.52 f	17.85 efg	1.69 e	1.68 f
IR70368A × Giza181R	20.77 cde	21.02 def	19.13 def	20.25 b–e	2.10 hij	2.15 h	36.11 g	36.80 i	15.25 g	15.16 i	1.6 e	1.64 f
IR58025A × Giza181R	21.47 c	22.05 bcd	20.12 cd	20.84 bc	2.54 de	2.63 e	41.88 d	43.15 e	16.8 f	17.14 fg	1.68 e	1.7 ef
K17A × Giza181R	19.06 h	19.67 gh	16.39 h	17.18 g	1.86 j	1.97 hi	32.45 hi	34.46 jk	15.19 g	16.09 h	1.35 f	1.37 g
G46A × Giza181R	20.21 efg	20.39 fgh	17.06 h	18.81 ef	1.95 ij	2.07 h	31.85 i	33.79 k	16.73 f	18.18 ef	1.44 f	1.46 g

Within a column, means followed by the different letter are statistically different according to the DMRT test at 0.05 probability.

Table 7. Interaction effects of sowing dates and genotypes on different traits in 2019 and 2020 seasons.

a. Interaction Effects of Sowing Dates and Genotypes on Number of Leaves, Days to Heading (day), EAT, Plant Height (cm) and Panicle Exertion (%) Different Traits in 2019 and 2020 Seasons											
Sowing Date	**Genotype**	**Number of Leaves**		**Days to Heading (day)**		**EAT**		**Plant Height (cm)**		**Panicle Exertion (%)**	
		2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
May 1st	Giza178R	17.71 i–l	17.77 a–k	101.69 hi	102.54 g	1381.67 g	1388.58 g	108.65 c–f	110.46 bc	100 a	100 a
	Giza179R	15.70 nop	15.79 h–l	95.49 k	96.73 i	1305.33 l	1311.86 l	105.45 hjk	107.63 e–h	100 a	100 a
	Giza181R	19.89 a	19.92 ab	117.18 a	117.53 a	1526.67 a	1534.3 a	110.55 bc	111.87 ab	100 a	100 a
	IR69625A × Giza178R	19.82 a	19.89 ab	105.47 def	105.87 ef	1477.33 b	1484.72 b	106.75 f–j	105.38 h–l	65.53 bc	62.61 c
	IR70368A × Giza178R	19.09 b cd	19.21 a–d	104.39 f	105.14 f	1362.33 h	1369.15 h	109.8 bcd	111.13 ab	64.54 bcd	60.12 d
	IR58025A × Giza178R	18.87 b–f	18.916 a–f	109.19 c	109.05 c	1443 d	1450.22 d	114.26 a	112.79 a	60.8 e	58.62 d–g
	K17A × Giza178R	17.45 jkl	17.58 a–k	88.49 m	88.17 l	1065.33 p	1070.66 p	95.4 tu	96.43 q–t	58.18 fg	56.07 g–j
	G46A × Giza178R	17.17 l	17.34 a–l	89.89 lm	88.76 l	1075.67 o	1081.05 o	97.8 rs	99.63 p	56.75 ghi	57.18 e–h
	IR69625A × Giza179R	19.28 abc	19.92 ab	105.76 def	106.01 ef	1477.67 b	1485.06 b	107.36 e–i	106.26 f–j	65.93 b	65.6 b
	IR70368A × Giza179R	19.38 ab	19.44 abc	104.60 f	105.21 f	1361 h	1367.81 h	110.44 bc	109.94 bcd	64.15 cd	63.03 c
	IR58025A × Giza179R	18.90 b–e	18.94 a–f	109.49 c	108.62 c	1439.33 d	1446.53 d	113.29 a	108.23 d–g	60.53 e	58.24 d–h
	K17A × Giza179R	17.66 i–l	17.72 a–k	88.67 m	88.23 l	1065.33 p	1070.66 p	96.95 st	95.36 rst	57.35 gh	58.28 d–h
	G46A × Giza179R	17.44 jkl	17.22 b–l	89.92 lm	88.39 l	1076 o	1081.38 o	99.63 pqr	102.4 mno	57.99 fg	58.94 def
	IR69625A × Giza181R	18.71 b–g	19.96 a	106.37 de	106.17 ef	1477.33 b	1484.72 b	105.6 h–k	103.74 j–n	63.81 d	63.9 bc
	IR70368A × Giza181R	19.31 abc	19.67 ab	105.05 ef	105.49 ef	1363 h	1369.82 h	108.82 c–f	106.09 f–j	62.98 d	64.13 bc
	IR58025A × Giza181R	18.50 c–h	19.03 a–e	109.00 c	108.95 c	1442 d	1449.21 d	110.98 b	108.33 def	59.55 ef	60.07 d
	K17A × Giza181R	17.30 kl	17.72 b–j	88.97 m	88.95 l	1065.33 p	1070.66 p	95.64 tu	97.27 qr	57.5 gh	59.2 de
	G46A × Giza181R	17.47 jkl	17.56 b–j	90.34 l	88.92 l	1072.3 op	1077.7 op	99.8 pq	106.87 e–i	58.06 fg	58.89 def
May 15th	Giza178R	17.29 kl	17.26 b–j	98.94 j	99.00 h	1323.3 jk	1329.95 jk	107.59 eh	108.96 cde	100 a	100 a
	Giza179R	15.02 pq	15.36 kl	90.56 l	91.07 k	1282.6 m	1289.08 m	104.7 j–m	105.57 h–k	100 a	100 a
	Giza181R	19.05 b–e	19.16 a–e	112.64 b	111.51 b	1482 b	1489.41 b	108.42 c–f	109.09 cde	100 a	100 a
	IR69625A × Giza178R	18.33 d–i	18.54 a–g	102.58 gh	102.81 g	1423.67 e	1430.79 e	102.8 mno	103.97 j–n	54.27 jk	53.61 jkl
	IR70368A × Giza178R	18.63 b–g	18.53 a–g	98.23 j	98.70 h	1317.67 k	1324.26 k	105.71 h–k	107.83 d–h	58.32 fg	57.46 e–h
	IR58025A × Giza178R	18.07 f–k	18.08 a–i	105.20 def	106.38 ef	1395 f	1401.98 f	111.29 b	112.55 a	50.52 mn	52.56 k–n
	K17A × Giza178R	16.30 mn	16.32 f–l	84.59 np	85.09 n	1031.33 r	1036.49 r	94.22 u	95.49 rst	55.26 ij	56.11 g–j
	G46A × Giza178R	16.19 mno	16.49 e–l	85.32 n	85.18 n	1042.67 q	1047.88 q	95.84 tu	96.94 qrs	41.08 q	41.54 s
	IR69625A × Giza179R	18.58 b–g	18.70 a–g	102.83 gh	103.02 g	1423.33 e	1430.45 e	105.11 jkl	102.97 l–o	55.7 hij	56.54 f–i
	IR70368A × Giza179R	18.96 b–e	18.70 a–g	98.27 j	98.96 h	1318 k	1324.59 k	108.5 c–f	105.89 g–k	57.8 fg	56.07 g–j
	IR58025A × Giza179R	18.03 g–k	18.36 a–h	105.46 def	106.72 de	1395 f	1401.98 f	109.37 b–e	105.55 h–k	53.2 kl	54.54 ijk
	K17A × Giza179R	16.55 m	16.55 d–l	84.74 nop	85.16 n	1032 r	1037.16 r	93.75 uv	94.66 st	54.21 jk	56.53 f–i
	G46A × Giza179R	16.12 mno	16.28 f–l	85.55 n	85.25 n	1042 q	1047.21 q	95.65 tu	98.04 q	41.92 q	45.2 q
	IR69625A × Giza181R	18.81 b–g	18.85 a–f	103.33 g	103.52 g	1422.67 e	1429.78 e	102.63 no	101.7 nop	54.29 jk	56.41 f–i
	IR70368A × Giza181R	18.96 b–e	18.85 a–f	98.3 j	99.10 h	1319 k	1325.6 k	106.14 g–k	103.51 k–n	56.79 ghi	54.44 ijk
	IR58025A × Giza181R	18.07 f–k	18.38 a–h	105.79 def	107.37 d	1396.67 f	1403.65 f	108.05 d–g	104.91 i–l	51.3 m	54.09 i–l
	K17A × Giza181R	16.55 m	16.78 c–l	85.07 no	85.60 n	1031 r	1036.16 r	94.65 u	95.87 q–t	54.5 jk	55.83 hij
	G46A × Giza181R	16.46 m	12.77 c	85.88 n	85.62 n	1043.67 q	1048.89 q	97.15 st	103.41 k–n	41.4 q	44.08 qr

Table 7. *Cont.*

a. Interaction Effects of Sowing Dates and Genotypes on Number of Leaves, Days to Heading (day), EAT, Plant Height (cm) and Panicle Exertion (%) Different Traits in 2019 and 2020 Seasons

Sowing Date	Genotype	Number of Leaves		Days to Heading (day)		EAT		Plant Height (cm)		Panicle Exertion (%)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
	Giza178R	16.43 m	16.52 e–l	94.86 k	95.61 j	1282.3 m	1288.75 m	104.42 k–n	105.42 h–l	100 a	100 a
	Giza179R	14.74 q	14.9 l	85.77 n	86.66 m	1220 n	1226.1 n	102.42 no	103.53 k–n	100 a	100 a
	Giza181R	18.71 b–g	18.74 a–f	106.69 d	105.61 ef	1465.33 c	1472.66 c	104.42 k–n	104.73 i–m	100 a	100 a
	IR69625A × Giza178R	17.32 kl	17.37 b–j	98.70 j	99.20 h	1388.3 fg	1395.28 fg	99.45 pqr	100.73 op	49.18 no	50.33 nop
	IR70368A × Giza178R	18.24 e–j	18.02 a–i	96.14 k	96.51 i	1329.33 j	1335.98 j	102.15 o	104.2 j–m	52.2 lm	54.2 i–l
	IR58025A × Giza178R	17.55 i–l	17.35 b–j	100.50 i	99.38 h	1341 i	1347.71 i	105.12 jkl	106.2 f–j	45.1 p	44.82 q
	K17A × Giza178R	15.02 pq	15.31 kl	81.34 q	81.76 p	1010 s	1015.05 s	85.23×	87.3 v	49.17 no	50.04 op
	G46A × Giza178R	15.35 pq	15.73 i–l	83.32 p	83.92 o	1011.67 s	1016.73 s	92.1 v	94.27 t	41 q	41.33 s
May 30th	IR69625A × Giza179R	17.58 i–l	17.64 b–j	98.80 j	99.25 h	1388.3 fg	1395.28 fg	100.1 p	101.16 op	51.17 m	51.87 l–p
	IR70368A × Giza179R	18.50 c–h	18.32 a–h	96.22 k	96.81 i	1330 j	1336.65 j	105.08 jkl	105.89 g–k	52.14 lm	53.3 klm
	IR58025A × Giza179R	17.68 i–l	17.52 b–j	100.80 i	99.48 h	1342.33 i	1349.05 i	102.12 o	100.75 op	46.08 p	50.13 nop
	K17A × Giza179R	15.36 pq	15.55 jkl	81.53 q	81.97 p	1010 s	1015.05 s	90.12 w	91.03 u	50.63 mn	51.09 m–p
	G46A × Giza179R	15.20 pq	15.82	83.52 p	84.05 o	1012.33 s	1017.4 s	94.17 u	96.2 q–t	41 q	40.75 s
	IR69625A × Giza181R	17.78 h–l	17.83 b–j	99.14 j	98.95 h	1388.3 fg	1395.28 fg	98.13 qrs	100.64 op	49.16 no	52.05 k–o
	IR70368A × Giza181R	18.75 b–g	18.26 a–h	96.27 k	97.04 i	1331 j	1337.66 j	101.85 o	101.7 nop	52.05 lm	49.47 p
	IR58025A × Giza181R	17.81 h–l	17.52 b–j	100.39 i	99.27 h	1342.33 i	1349.05 i	103.08 l–o	103 l–o	48 o	51.07 m–p
	K17A × Giza181R	15.57 op	16.07 g–l	81.40 q	82.14 p	1010 s	1015.05 s	92.12 v	95.87 q–t	48.2 o	53.38 klm
	G46A × Giza181R	15.21 pq	15.57 jkl	83.81 op	83.73 o	1011.67 s	1016.73 s	93.85 uv	100.67 op	41 q	42.79 rs

b. Interaction effects of sowing dates and genotypes on Panicle Length (cm), No of Panicle/Plant, Panicle Weight (g), Seed Set (%), Harvest Index (%) and Grain Yield t ha^{-1} in 2019 and 2020 seasons.

Sowing Date	Genotype	Panicle Length (cm)		No of Panicle/Plant		Panicle Weight (g)		Seed Set (%)		Harvest Index (%)		Grain Yield t ha^{-1}	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
	Giza178R	24.24 b	24.39 ab	23.52 bc	24.26 bcd	4.87 b	5.01 b	94.54 a	94.68 ab	44.5 c	46.57 b	11.13 c	11.24 c
	Giza179R	23.51 bc	23.48 a–e	25.60 a	26.93 a	5.10 ab	4.99 b	94.90 a	95.94 a	48.66 a	49.16 a	11.78 a	11.9 a
	Giza181R	25.34 a	24.79 a	21.63 c–g	21.96 d–g	5.29 a	5.42 a	94.68 a	96.02 a	42.51 d	42.97 d	11.37 b	11.48 b
	IR69625A × Giza178R	21.12 e–j	22.1 b–g	23.21 bcd	24.08 bcd	2.90 fg	2.86 gh	45.35 c	47.17 d	20.1 gh	22.01 g	2.1 hi	2.21 gh
	IR70368A × Giza178R	22.02 c–i	22.33 b–f	20.08 f–j	22.03 d–g	2.53 g–k	2.79 g–j	43.31 de	44.05 e	19.11 ghi	18.23 hij	1.97 i–m	1.89 i–m
	IR58025A × Giza178R	23.03 b–e	23.31 a–e	24.21 ab	26.13 ab	3.49 e	3.35 f	50.13 b	52.01 c	21.02 g	22.08 g	2.32 g	2.38 g
	K17A × Giza178R	20.13 i–n	21.11 e–h	18.12 j–m	19.61 g–j	2.19 k–p	2.21 l–r	40.12 fgh	42.05 efg	18.12 hij	19.04 hi	1.85 j–n	1.8 j–n
	G46A × Giza178R	22.08 c–i	23.09 a–e	22.09 b–f	23.50 cde	2.43 h–n	2.51 h–m	39.04 gh	41.02 fgh	19.22 ghi	20.13 h	1.98 i–l	1.9 i–m
May 1st	IR69625A × Giza179R	22.06 c–i	22.25 b–f	21.23 c–h	22.09 d–g	2.82 f–i	2.73 g–k	43.08 de	42.32 efg	19.29 ghi	20 h	2.02 hij	2.1 hij
	IR70368A × Giza179R	20.4 i–m	22.02 b–g	21.00 c–i	23.04 cde	2.75 f–g	2.68 g–k	41.04 efg	42.06 efg	19.01 ghi	18.19 hij	1.91 i–n	1.88 i–m
	IR58025A × Giza179R	22.05 c–i	23.17 a–e	23.20 bcd	24.66 bc	3.18 f	3.25 f	49.12 b	48.25 d	20 gh	19.28 hi	2.21 gh	1.84 i–n
	K17A × Giza179R	20.07 i–n	21.06 e–h	20.06 f–j	19.07 hij	2.12 k–p	2.19 l–r	38.32 hi	39.13 hij	17.26 ijk	17.08 ijk	1.78 j–o	1.8 j–n
	G46A × Giza179R	21.32 d–j	21.83 c–g	21.27 c–h	21.18 e–h	2.25 j–p	2.36 k–p	38.24 hi	40.05 ghi	19.01 ghi	20.04 h	1.81 j–n	1.84 i–n
	IR69625A × Giza181R	22.4 c–h	23.17 a–e	22.17 b–f	22.15 def	2.55 g–k	2.49 h–n	41.07 efg	42.09 efg	18.25 hij	19.21 hi	1.92 i–n	1.9 i–m
	IR70368A × Giza181R	22.03 c–i	22.07 b–g	23.05 b–e	24.13 bcd	2.36 i–o	2.41 j–p	40.05 fgh	39.13 hij	17.3 ijk	16.32 jk	1.81 j–n	1.83 i–n
	IR58025A × Giza181R	22.85 b–f	24.02 abc	22.09 b–f	24.08 bcd	2.9 fg	2.78 g–j	46.30 c	47.02 d	18.1 hij	19.08 hi	1.91 i–n	1.91 i–m
	K17A × Giza181R	20.93 f–l	21.00 e–h	20.00 f–j	21 e–h	2.02 k–p	2.15 l–r	36.01 ij	39.00 hij	16.25 jkl	17.08 ijk	1.56 opq	1.6 m–q
	G46A × Giza181R	22.02 c–i	22 b–g	19.12 g–k	22.75 c–f	2.13 k–p	2.21 l–r	36.33 ij	39.27 hij	18.04 hij	19.23 hi	1.73 l–o	1.69 k–q

Table 7. *Cont.*

Sowing Date	Genotype	Panicle Length (cm)		No of Panicle/Plant		Panicle Weight (g)		Seed Set (%)		Harvest Index (%)		Grain Yield t ha^{-1}	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
b. Interaction effects of sowing dates and genotypes on Panicle Length (cm), No of Panicle/Plant, Panicle Weight (g), Seed Set (%), Harvest Index (%) and Grain Yield t ha^{-1} in 2019 and 2020 seasons.													
May 15th	Giza178R	22.82 b–f	22.58 b–f	20.63 d–j	21.79 d–g	4.02 cd	4.55 cd	93.80 a	93.60 ab	42.75 cd	42.11 d	9.7 e	9.79 e
	Giza179R	22.73 b–g	22.29 b–f	22.80 b–e	24.28 bcd	4.84 b	4.80 bc	94.28 a	95.09 ab	46.34 b	46.72 b	11.06 c	11.17 c
	Giza181R	23.14 bcd	23.69 a–d	21.34 c–h	20.39 f–i	5.00 ab	4.99 b	93.89 a	94.60 ab	39.58 e	40.35 e	9.13 f	9.22 f
	IR69625A × Giza178R	20.12 i–n	21.19 d–h	17.28 k–n	19.06 hij	2.49 h–l	2.51 h–m	42.10 ef	44.08 e	17.75 h–k	20.1 h	1.99 i–l	1.97 h–l
	IR70368A × Giza178R	19.08 k–q	22.07 b–g	18.00 j–m	18.17 i–l	2.25 j–p	1.32 s	39.20 gh	40.10 ghi	18.09 hij	17.31 ijk	1.85 j–n	1.8 j–n
	IR58025A × Giza178R	21.01 f–k	22.09 b–g	21.08 c–h	23.08 cde	2.87 fgh	2.99 g	46.33 c	48.30 d	20.23 gh	20.33 h	2.1 hi	2.15 hi
	K17A × Giza178R	18.08 opq	19.08 hi	15.80 mno	15.06 mn	2.012 k–p	2.20 l–r	38.23 hi	36.31 kl	16.13 jkl	17.33 ijk	1.76 j–o	1.7 k–q
	G46A × Giza178R	18.24 n–q	20.02 f–i	16.08 l–o	18.34 i–l	2.19 k–p	2.13 l–r	36.08 ij	37.04 jk	18.13 hij	19 hi	1.82 j–n	1.78 j–n
	IR69625A × Giza179R	20.27 i–m	21.04 e–h	18.08 j–m	19.22 h–j	2.43 h–n	2.50 h–m	38.17 hi	38.27 ijk	18.01 hij	18.12 hij	1.89 i–n	1.9 h–m
	IR70368A × Giza179R	19.66 j–p	21 e–h	17.01 k–n	19.00 hij	2.35 i–o	2.44 i–o	34.13 jkl	36.16 kl	17.32 ijk	16.33 jk	1.9 i–n	1.81 j–n
	IR58025A × Giza179R	21.63 d–j	22.12 b–g	19.08 g–k	21.06 e–h	2.79 f–i	2.85 ghi	45.07 cd	43.00 ef	17.21 ijk	18.2 hij	2 ijk	2.02 h–k
	K17A × Giza179R	17.34 q	18.32 i	15.23 no	16.29 k–n	2.25 j–p	1.81 qr	32.03 lm	34.00 lm	15.23 klm	16.14 jk	1.69 nop	1.7 k–q
	G46A × Giza179R	19.11 k–q	20.25 f–i	17.1 k–n	18.29 i–l	2.25 j–p	2.00 o–r	32.01 lm	34.12 lm	17.19 ijk	18.63 hi	1.71 mno	1.74 k–p
	IR69625A × Giza181R	20.35 i–m	21.95 b–g	20.08 f–j	18.32 i–l	2.17 k–p	2.10 m–r	35.07 jk	36.05 kl	16.25 jkl	18.1 hij	1.82 j–n	1.75 k–o
	IR70368A × Giza181R	20.65 h–m	21.00 e–h	20.00 f–j	20.33 f–i	2.09 k–p	2.18 l–r	35.19 jk	37.10 jk	15.23 klm	15.08 kl	1.69 nop	1.7 k–q
	IR58025A × Giza181R	21.55 d–j	22.08 b–g	20.05 f–j	21.00 e–h	2.57 g–k	2.78 g–j	41.07 efg	43.17 ef	17.1 ijk	16.32 jk	1.71 mno	1.8 j–n
	K17A × Giza181R	18.23 n–q	19.02 hi	14.93 no	16.00 lmn	1.85 op	1.96 pqr	32.07 lm	34.09 lm	15.3 klm	16 jkl	1.46 qr	1.42 pqr
	G46A × Giza181R	19.69 j–p	20.04 f–i	17.06 k–n	17.33 jm	1.91 m–p	2.02 o–r	30.08 mn	32.01 mn	17.08 ijk	18.01 hij	1.45 qr	1.51 n–q
May 30th	Giza178R	21.54 d–j	21.93 b–g	18.62 h–l	18.89 hij	3.82 d	4.04 e	92.72 a	92.84 b	41.17 d	39.79 e	9.05 f	9.14 f
	Giza179R	20.82 g–l	21.45 d–h	20.50 e–j	20.383 f–i	4.21 c	4.42 d	93.30 a	94.30 ab	44.35 c	44.97 c	10.24 d	10.34 d
	Giza181R	21.47 d–j	21.83 c–g	19.06 g–k	18.85 hij	4.02 cd	4.80 bc	93.08 a	93.79 ab	38.05 f	37.78 f	9.21 f	9.3 f
	IR69625A × Giza178R	19.08 k–q	20.01 f–i	16.28 l–o	19.06 hig	2.27 j–p	2.20 m–r	39.21 gh	42.08 efg	16.97 ijk	18.32 hij	1.5 pqr	1.63 l–q
	IR70368A × Giza178R	19 k–q	19.29 hi	18.00 j–m	17.12 j–m	2.03 k–p	1.24 s	38.15 hi	39.08 hij	16.08 jkl	16.2 jk	1.35 qr	1.42 pqr
	IR58025A × Giza178R	20.17 i–n	21.14 e–h	20.04 f–j	21.00 e–h	2.45 h–m	2.57 h–l	43.23 de	44.30 e	17.08 ijk	19.07 hi	1.75 k–o	1.84 i–n
	K17A × Giza178R	18.08 opq	19.08 hi	15.00 no	15.07 mn	1.88 nop	1.97 pqr	35.30 jk	36.10 kl	16.01 jkl	15.2 kl	1.44 qr	1.53 n–q
	G46A × Giza178R	18.00 pq	19.02 hi	16.28 l–o	17.08 j–m	2.04 k–p	2.05 n–r	32.09 lm	34.05 lm	16.13 jkl	17.3 ijk	1.38 qr	1.41 pqr
	IR69625A × Giza179R	19.01 k–q	21.05 e–h	16.3 l–o	17.28 j–m	2.19 k–p	2.12 m–r	35.19 jk	36.12 kl	17.28 ijk	18.03 hij	1.35 qr	1.45 o–r
	IR70368A × Giza179R	18.72 m–q	21.04 e–h	18.37 i–m	18.74 h–k	2.21 k–p	2.11 m–r	33.04 kl	34.20 lm	15.2 klm	16 jkl	1.48 qr	1.51 n–q
	IR58025A × Giza179R	20.06 i–n	20 f–i	18.07 j–m	19.00 hij	2.21 k–p	2.36 k–p	41.20 efg	40.03 ghi	16.08 jkl	17.1 ijk	1.74 k–o	1.76 j–o
	K17A × Giza179R	17.18 q	19.03 hi	14.00 o	15.16 mn	1.75 p	1.84 r	30.09 mn	32.08 mn	14.08 lm	15.21 kl	1.4 qr	1.51 n–q
	G46A × Giza179R	18.01 pq	19.55 ghi	14.20 o	16.00 lmn	2.06 k–p	1.99 o–r	29.30 n	30.09 n	15.07 klm	17.04 ijk	1.32 qr	1.41 pqr
	IR69625A × Giza181R	19.10 k–q	20.87 e–h	17.23 k–n	16.00 lmn	1.90 l–p	2.00 o–r	32.08 lm	33.27 m	15.07 klm	16.23 jk	1.34 qr	1.39 qr
	IR70368A × Giza181R	19.63 j–p	20 f–i	14.34 o	16.28 k–n	1.85 op	1.88 qr	33.10 kl	34.17 lm	13.23 m	14.08 l	1.3 r	1.4 qr
	IR58025A × Giza181R	20.00 j–o	20.07 f–i	18.23 j–m	17.43 j–m	2.09 k–p	2.32 k–q	38.26 hi	39.26 hij	15.2 klm	16.03 jkl	1.4 qr	1.41 pqr
	K17A × Giza181R	18.02 pq	19.00 hi	14.23 o	14.52 n	1.71 p	1.80 r	29.27 n	30.30 n	14.04 lm	15.2 kl	1.02 s	1.1 s
	G46A × Giza181R	18.91 l–q	19.12 hi	15.00 no	16.33 k–n	1.82 op	1.99 o–r	29.13 n	30.08 n	15.07 klm	17.3 ijk	1.13 s	1.19 rs

Within a column, means followed by the different letters are statistically different according to the DMRT test at 0.05 probability.

Table 8. Differences between Restore/CMS lines combinations for LND, GDD and EAT over two seasons.

Combinations	LND			GDD			EAT		
	May 1st	May 15th	May 30th	May 1st	May 15th	May 30th	May 1st	May 15th	May 30th
IR69625A × Giza178R	−2.12	−1.16	−0.87	−3.55	−3.74	−3.72	−77.17	−58.83	−74.17
IR70368A × Giza178R	−1.41	−1.31	−1.65	−2.65	0.51	−1.10	21.00	36.00	−15.00
IR58025A × Giza178R	−1.15	−0.80	−0.97	−7.01	−6.82	−4.72	−60.00	−63.00	−63.50
K17A × Giza178R	+0.23	+0.97	+1.31	+13.78	+14.13	+13.69	+318.83	+309.00	+282.00
G46A × Giza178R	+0.48	+0.94	+0.94	+12.79	+13.72	+11.62	+296.50	+283.50	+279.00
IR69625A × Giza179R	−3.86	−3.45	−2.79	−9.77	−12.11	−12.81	−161.17	−119.83	−137.67
IR70368A × Giza179R	−3.67	−3.64	−3.59	−8.79	−7.80	−10.30	−63.00	−25.00	−78.50
IR58025A × Giza179R	−3.18	−3.01	−2.78	−12.94	−15.27	−13.93	−144.00	−124.00	−127.00
K17A × Giza179R	−1.95	−1.36	−0.64	+7.66	+5.87	+4.46	+234.83	+248.00	+218.50
G46A × Giza179R	−1.59	−1.01	−0.69	+6.95	+5.42	+2.43	+212.50	+222.50	+215.50
IR69625A × Giza181R	+0.57	+0.27	+0.92	+11.08	+8.65	+7.12	+60.67	+73.17	+82.00
IR70368A × Giza181R	+0.42	+0.20	+0.22	+12.08	+13.38	+9.51	+158.83	+168.00	+141.17
IR58025A × Giza181R	+1.14	+0.88	+1.05	+7.97	+5.50	+6.33	+77.83	+69.00	+92.67
K17A × Giza181R	+2.39	+2.44	+2.90	+28.39	+26.74	+24.40	+456.67	+441.00	+438.17
G46A × Giza181R	+2.38	+4.49	+3.33	+27.73	+26.32	+22.40	+434.33	+415.50	+435.17

− and + means seeding date of R line after and before its CMS line in combination, respectively.

CMS line has 3 days longer growth duration than R line such as in combination IR69625A × Giza178R on May 1st

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
seeding CMS line		First seeding R line		second seeding R line										

CMS line has 14 days shorter growth duration than R line such as in combination K17A × Giza178R on May 1st

18	19	20	21	22	23	24	25	24	25	26	27	28	1	2
First seeding R line		second seeding R line										seeding CMS line		

Figure 2. R line and CMS line seeded sequences to optimizing synchronization of flowering between two combinations.

Table 9. Correlation coefficient for grain yield and related traits in 2019 growing season.

	Number of Leaves	Days to Heading (day)	EAT	Plant Height (cm)	Panicle Exertion (%)	Panicle Length (cm)	No of Panicle/ Plant	Panicle Weight (g)	Seed Set (%)	Harvest Index (%)	Grain Yield t ha^{-1}
Number of leaves	1.00										
Days to heading (day)	0.74 **	1.00									
EAT	0.68 **	0.95 **	1.00								
Plant height (cm)	0.49 **	0.79 **	0.75 **	1.00							
Panicle exertion (%)	0.10	0.33 *	0.37 *	0.46 **	1.00						
Panicle length (cm)	0.44 **	0.66 **	0.60 **	0.71 **	0.55 **	1.00					
No of panicle/plant	0.38 *	0.56 **	0.50 **	0.71 **	0.44 **	0.74 **	1.00				
Panicle weight (g)	0.10	0.44 **	0.44 **	0.54 **	0.90 **	0.62 **	0.56 **	1.00			
Seed set (%)	0.02	0.34 *	0.38 *	0.48 **	0.96 **	0.55 **	0.45 **	0.95 **	1.00		
Harvest index (%)	0.01	0.31 *	0.34 *	0.46 **	0.92 **	0.56 **	0.44 **	0.94 **	0.96 **	1.00	
Grain yield t ha−1	−0.07	0.23	0.28	0.40 *	0.95 **	0.48 **	0.38 *	0.93 **	0.98 **	0.96 **	1.00

* and ** significant and highly significant at probability 5 and 1%, respectively.

4. Discussion

The synchronization of flowering between female and pollen parents is the key determinant to an efficient and higher seed yield in a hybrid seed production program [16]. Seed set percentage on the female parent highly depends on the pollen supplemented by the male parent at the time of flowering in the production plot. The determination of suitable seeding dates is the primary and foremost step in the successful synchronization of the parental lines. However, the seasonal and weather fluctuations greatly influenced the flowering of female and male lines, as well as seed setting, therefore, the seeding interval may not be the same for all environments [5]. Actual practices for synchronization of flowering would have to be standardized for each hybrid and the location selected for hybrid seed production. The interval sowing of male parents can be determined by EAT, leaf age and growth duration. Usually, the duration from initial to complete heading of a CMS line is 4–6 days longer than R lines [17]. The mean of sum squares of sowing dates were found to be highly significant for all studied traits, indicating the vital role of seeding date in grain yield and related traits, and the suitable seeding time enhancement the seed setting percentage and adjusted synchronization between hybrid parental lines CMS/R. Different seeding time of genotypes to achieve good synchronization between them depends on many factors *viz.*, temperature degree, humidity percentage, soil fertility (weather and soil conditions). The diversity between genotypes was shown to be highly significant for all studied traits, implying that this difference is due to the genetic background for each genotype and its effect on the seeding date to increase grain yield for CMS lines and its components. The diversification of CMS lines in hybrid rice technology has a pivotal role in the development of superior hybrids [18]. Despite the application, CMS systems face some challenges, such as the narrow germplasm resources of R lines, the low genetic diversity between the CMS lines and R lines, the instability of male sterility under weather conditions, the negative effect of aberrant mitochondrial genes on hybrid performance, and the difficulty to improve new traits into the parental lines [19]. Utilizing CMS-HL hybrid rice could increase the CMS source variety, and reduce the hazard of using single CMS [20]. To multiply CMS lines and produce hybrid seeds, we should be planting maintainers and R lines, staggered to achieve optimized synchronization between CMS/B and CMS/R. Meanwhile, the key point to increase seed production for CMS/B and CMS/R is to optimize synchronization at the differences of sowing dates. Moreover, the sowing date on May 1st increased all the traits remarkably compared to other sowing dates, indicating that the first seeding date is more suitable for the genotypes to achieve maximum seed production.

It has been reported that the days to 50% flowering ranges from 120 to 135 days for 5 CMS lines, and 127 to 139 days for 12 R lines [21]. In our study, the leaf number diverged from 15.07 to 18.63 and from 17.05 to 19.89 for the CMS and R lines, respectively. The EAT ranged from 1069 to 12910C for the CMS line, and 1174 to 13,510C for the R lines. The growth duration differences between CMS and R lines ranged from 1 to 19 days. Similarly, the leaf number differences between CMS and R lines were from 0 to 4.82. The seeding differences between CMS and R lines in terms of EAT were from 13.50 to 282.20 °C. Yin Crop development to flowering can be influenced to some extent by factors such as energy supply, humidity, nutrients and water stress; it is principally controlled by temperature and photoperiod [6]. Varma et al. [5] indicated that to achieve the synchronization of Pant Sankar Dhan 1 multiplication of CMS line and hybrid seed production should be seeding of B and R lines when the CMS line reaches LND of 1.45 and 1.07, EAT of seed parent (CMS line) gets 90.55 and 62.26, and 5 and 4 days after seeding of CMS line for CMS/B and CMS/R seed production, respectively.

For the optimal synchronization of flowering, the CMS parent should flower two to three days earlier than the R parent. CMS and R lines have the same growth duration; the CMS line would flower one to two days earlier than the R line in all panicle developmental stages. Therefore, the CMS line has a shorter duration compared with R line; in this case, the R line should behave one stage earlier than the CMS line through the primary three panicle development stages. Once the CMS line is longer than the R line at growth duration, the CMS line should have two to three days earlier than the R line through the first three panicle development stages [4]. The mean squares for genotypes found to be highly significant for all studied traits might be due to the genetic background differences for each one. The data in Table 5 explained that the IR58025A × Giza178R had a higher number of panicles/plants, panicle weight, seed set, harvest index and grain yield over three sowing dates. Thus, the combinations IR69625A × Giza178R, and IR69625A × Giza179R were found to be desirable characters for grain yield and its components. Arasakesary et al. [22] observed that the cross combinations Tnau18S/IET21508 and TS29-150-GY/DRR 3306 had perfect synchronization with acceptable hybrid seed yield. Agronomic methods that involved varying the sowing depth, seeding rate and phosphate fertilization affect the time of flowering in line L106R, a potential R line for the production of hybrid rice [7].

The interaction between sowing dates and genotypes is highly significant for all studied traits, thus the sowing date on 1st May gave good agronomic traits with all genotypes followed by the second sowing date, and the third sowing date showed the lowest values for performance to all traits. The choice of the genotype desire with suitable sowing date achieved the highest performance regarding agronomic traits which reflected the grain yield for seed production. Likewise, by accounting for the differences in LND, GDD and EAT between combinations were used for A/R lines could determine and optimizing synchronization to get the highest seed set percentage and grain yield for every sowing date, such as the first combination IR69625A × Giza178R in the first sowing date having −2.12, −3.55 and −77.17 means that should be planted Giza178R after IR69625A by 2.12 leaves formatted, or 3.55 days or 77.17 EAT. A justified synchronization can be highly accurate according to the present data by following the LND > EAT and GDD methods to achieve high seed setting and seed yield. Varma et al. [5] revealed that higher consistency in flowering days in CMS line was with LND method, as compared to other two methods, and advised LND method to be more reliable through the planting dates followed by EAT and GDD to predict synchronization between CMS and R lines of hybrids. The influence of different techniques on flowering synchronization and seed yield in Karnataka Rice Hybrid-2 indicated that the location of seed production influenced the flowering and seed yield significantly hence, seeding R parent by eight and four days earlier has attained better synchronization of flowering and improved seed yield by 115 and 129%, respectively [8]. The successful and efficient hybridization program dependent on the information of parental lines, the reproductive biology and development of rice, the conditions required to promote flowering and seed development, and the methods to synchronize flowering of various parents [23]. For sterile lines' traits by low stigma feature, the synchronization of flowering time with R lines is acute for seed production [3]. The flower synchronization between two parental lines of different GD can be achieved by seeding them on different dates, which are termed as seeding intervals [24]. The synchronization of flowering between the parental lines in hybrid seed production is needed to obtain a higher seed yield, because this is based on the amount of pollen supplied from the male parent at the flowering period [16].

Evaluations of coefficient correlations between traits, or between the same trait measured in diverse environments, are useful in determining the fatal power of a screen or selection environment and beneficial in deciding whether to select right for a target trait or indirectly for a secondary or correlated trait. The correlation between the goal trait and the secondary trait is significantly less than 1; direct selection is more effective than indirect selection. The important statistical parameter correlation coefficient determined the degree of linked pair characteristics through the correlation coefficient in Table 9, which showed that they were highly positive and correlated among grain yield and plant height, panicle exertion percentage, panicle length, number of panicles/plants, panicle weight, seed set percentage and harvest index. There is no significant correlation between grain yield and number of leaves, days to heading (day) and EAT means that these three parameters are not associated with grain yield but important to determine synchronization between flowering genotypes. Gramaje et al. [25] observed Pearson's correlation and revealed that all of the yield component traits were positively correlated with grain yield. Genetic distance was correlated positively with grain length, panicle number and length: width ratio and correlated negatively with grain width, grain yield and seed setting rate [26,27]. Highly positive and significant phenotypic correlations were observed between yield index and leaf rolling, sterility percentage [28].

5. Conclusions

Synchronization of flowering between CMS lines and R lines has highly significant effects on flowering and agronomic characteristics of hybrid seed production. The sowing date on May 1st provided the highest seed yield 1.72 and 1.41 t ha^{-1}, and the hybrid combination of Giza 178R × IR58025A produced the highest seed yield of 2.06 and 2.12 t ha^{-1} in the 2019 and 2020 seasons, respectively. The grain yield had a significant and highly significant positive correlation with the plant height (cm), panicle exertion percentage, panicle length, number of panicles/plants, panicle weight, seed set percentage, and harvest index.

Author Contributions: Conceptualization, M.G., and H.H.; methodology, M.G. and H.H. software, A.E.S.; validation, A.E.S., M.G.; formal analysis, M.G., A.E.S.; investigation, M.G.; resources, M.G. and H.H.; data curation, H.H., M.G.; writing—original draft preparation, M.G., H.H., and A.E.S.; writing—review and editing, H.A., A.B., S.A., M.S.I., I.A.I.; visualization, H.H.; supervision, M.G.; funding acquisition, H.A., A.B., I.A.I., A.E.S. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by Taif University Researchers Supporting Project number (TURSP-2020/120), Taif University, Taif, Saudi Arabia.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is not publicly available, though the data may be made available on request from the corresponding author.

Acknowledgments: This publication was made possible through support provided by Rice Research and Training Center in Egypt. The author's also express sincere appreciation to Field Crops Research Institute, Agricultural Research Center (ARC) for conducting this study. The authors extend their appreciation to Taif University for funding APC by Taif University Researchers Supporting Project number (TURSP-2020/120), Taif University, Taif, Saudi Arabia.

Conflicts of Interest: The authors have not declared any conflict of interest.

References

1. Hagrus, A.M.; AboYoussef, M.I.; Zaazaa, E.I.; El-Sehely, A.B. Effect of seeding rates and plant spacing on hybrid rice seed production in egypt. *J. Plant Prod.* **2013**, *4*, 591–604. [CrossRef]
2. El-Mowafi, H.; Bastawisi, A.O.; Attia, K.A.; Abdelkhalik, A.F.; Abdallah, R.M.; Reda, A.M. EHR3 (Egyptian Hybrid Rice 3): A new high yielding hybrid variety EHR3 (Egyptian hybrid rice 3). *Egypt. J. Plant Breed.* **2019**, *23*, 11–23.
3. Zheng, W.; Ma, Z.; Zhao, M.; Xiao, M.; Zhao, J.; Wang, C.; Gao, H.; Bai, Y.; Wang, H.; Sui, G. Research and Development Strategies for Hybrid Japonica Rice. *Rice* **2020**, *13*, 1–22. [CrossRef]
4. Akhter, M.; Riaz, M.; Sabar, M.; Haider, Z.; Latif, T. FAO Regional office for Asia and Pacific and Asia-Pacific seed association. Hybrid rice development in Asia: Assessment of limitations and potential. In Proceedings of the Regional Expert Consultation on Hybrid Rice Development in Asia: Assessment of limitation and Potential, Bangkok, Thailand, 2–3 July 2014; p. 209.
5. Varma, R.L.; Singh, S.; Kumar, M.; Bal, D.; Rout, D.; Samantaray, S.; Singh, O.N. Method optimization for parental line synchronization in hybrid rice seed production. *Plant Arch.* **2018**, *18*, 200–204.
6. Yin, X. Quantifying the Effects of Temperature and Photoperiod on Phenological Development to Flowering in Rice. Ph.D. Thesis, Wageningen University, Wageningen, The Netherlands, 1996. [CrossRef]
7. Mondo, V.H.V.; Nascente, A.S.; Neves, P.C.F.; Taillebois, J.E.; Neto, M.O.A.C. Flowering synchronization in hybrid rice parental lines. *Aust. J. Crop Sci.* **2016**, *10*, 1213–1221. [CrossRef]
8. Biradarpatil, N.K.; Shekhagouda, M. Synchronization Studies in Hybrid Rice. *J. Agric. Sci.* **2006**, *19*, 298–303.
9. Sorour, S.G.R.; AboYoussef, M.I.; Mohamed, A.A.A.; Tawfik, M.A. Effect of application time of NK fertilizers and foliar spraying with ascobien compound on production of hybrid rice seed. *J. Plant Prod.* **2015**, *6*, 41–56. [CrossRef]

10. Viraktamath, B.C.; Ramesha, T. Synchronization of parental lines in staggered sowing in rice hybrid. *Rice Genet. News* **2000**, *5*, 103–107.
11. Virmani, S.S.; Mao, C.X.; Toledo, R.S.; Hossain, M.; Janaiah, A. Hybrid rice seed production technology and its impact on seed industries and rural employment opportunities in Asia. *Int. Rice Res. Newsl.* **1998**, 1–13.
12. Yoshida, S. *Fundamentals of Rice Crop Science*; The International Rice Research Institute: Los Banos, Philippines, 1981.
13. Gomez, K.A.; Gomez, A.A. *Statistical Procedures for Agricultural Research*, 2nd ed.; John Wiley and Sons: New York, NY, USA, 1984. Available online: http://www.sciepub.com/reference/51715 (accessed on 20 November 2020).
14. Duncan, D.B. Multiple Range And Multiple F Tests. *Biometerics* **1955**, 1–42. [CrossRef]
15. Kown, S.H.; Torrie, J.H. Heritability and interrelationship among traits of two soybean populations. *J. Crop Sci.* **1964**, *4*, 196–198. [CrossRef]
16. Anis, G.; Hamada Hassan, A.E.-S.; Saneoka, H.; EL Sabagh, A. Evaluation of New Promising Rice Hybrid and Its Parental Lines for Floral, Agronomic Traits and Genetic Purity Assessment. *Pak. J. Agri. Sci.* **2019**, *56*, 567–576. [CrossRef]
17. Singh, R.; Ram, L. Ideal Hybrid Rice Seed Production Package: An Overview. *Indian Res. J. Ext. Educ.* **2012**, *II*, 244–251.
18. Das, P.; Santra, C.K.; Mukhopadhyay, S.; Mukherjee, B.; Dasgupta, T. Genetic variability in cytoplasmic male sterile lines in rice (Oryza sativa L.). *IOSR J. Agric. Vet. Sci.* **2013**, *3*, 95–100.
19. Chang, Z.; Chen, Z.; Wang, N.; Xie, G.; Lu, J.; Yan, W.; Zhou, J.; Tang, X.; Deng, X. Construction of a male sterility system for hybrid rice breeding and seed production using a nuclear male sterility gene. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 14145–141501. [CrossRef] [PubMed]
20. Li, S.; Yang, D.; Zhu, Y. Characterization and Use of Male Sterility in Hybrid Rice Breeding. *J. Integr. Plant Biol.* **2007**, *49*, 791–804. [CrossRef]
21. Kader, A.; Patwary, A.K.; Hossain, M.M.; Hore, T.K.; Haque, M. Determination of seeding interval of most promising parental lines of hybrid rice (Oryza sativa L.). *Haya Saudi J. Life Sci.* **2017**, *2*, 1–5.
22. Arasakesary, S.J.; Manonmani, S.; Pushpam, R.; Rbin, S. New Temperature Sensitive Genic Male Sterile Lines with Better Outcrossing Ability for Production of Two-Line Hybrid Rice. *Rice Sci.* **2015**, *22*, 49–52. [CrossRef]
23. Sha, X. Rice Artificial Hybridization for Genetic Analysis. *Methods Mol. Biol.* **2013**, *956*, 1–12. [CrossRef]
24. Pal, R.; Tah, J. Strategy of F1 Hybrid Rice Seed Production through CMS Breeding Technology. *J. Env. Treat.Tech.* **2013**, *1*, 8–12.
25. Gramaje, L.V.; Caguiat, J.D.; Enriquez, J.O.S.; dela Cruz, Q.D.; Millas, R.A.; Carampatana, J.E.; Tabanao, D.A.A. Heterosis and combining ability analysis in CMS hybrid rice. *Euphytica* **2020**, *216*, 1–22. [CrossRef]
26. Wang, Y.; Cai, Q.; Xie, H.; Wu, F.; Lian, L.; He, W.; Chen, L.; Xie, H.; Zhang, J. Determination of Heterotic Groups and Heterosis Analysis of Yield Performance in Indica Rice. *Rice Sci.* **2018**, *25*, 261–269.
27. Gaballah, M.M.; Metwally, A.M.; Skalicky, M.; Hassan, M.M.; Brestic, M.; EL Sabagh, A.; Fayed, A.M. Genetic Diversity of Selected Rice Genotypes under Water Stress Conditions. *Plants* **2021**, *10*, 27. [CrossRef] [PubMed]
28. Gaballah, M.M.; Abu El-Ezz, A.F. Genetic Behavior of Some Rice Genotypes under Normal and High Temperature Stress. *Alex. Sci. Exch. J.* **2019**, *40*, 370–384. [CrossRef]