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Identification of maintainer and restorer lines based on CMS system for developing hybrid wheat in Egypt

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ABSTRACT

The present study was conducted during the 2020/2021 and 2021/2022 wheat growing seasons at Shandaweel Agricultural Research Station, Sohag governorate, Egypt. Three cytoplasmic male sterile (CMS) lines, namely Vorobey A-line, Navojoa A-line and Neloki A-line of wheat having *Triticum Timopheevi* cytoplasmic male sterility source (three- lines system A, B and R) were crossed with twenty-five wheat genotypes as testers in line × tester fashion to identify maintainer and restorer lines for the CMS lines. Based on the evaluation of 75 hybrid combinations for pollen and spikelet fertility percent, results indicated that the identified wheat genotypes as effective maintainers were Shandaweel 1, Misr 3, Misr 4, Giza 168, Gemmeiza 11, Gemmeiza 12, Kutz, Line 1, Line 2, Line 3, Line 4 and Line 5 for all the three CMS lines, Sids 14, Giza 171, Sakha 1001, Nadi and Kenya Sunbird for Vorobey A-line and Navojoa A-line, Misr 1, Kachu #1, Francolin #1 and Baj #1 for Navojoa A-line and Neloki A-line and Sids 12 for Neloki A-line and these genotypes could be converted into new CMS lines through backcross breeding method. On the other side, the identified wheat genotypes as effective restorers were Sakha 95 for Vorobey A-line and Neloki A-line, and Kachu #1, Francolin #1 and Baj #1 for Vorobey A-line, therefore these genotypes could be used to develop promising wheat hybrids. Consequently, the presence of maintainer and restorer lines among the studied wheat genotypes indicates the possibility of developing wheat hybrids using CMS system in Egypt.

Keywords: CMS lines, Restorers, Maintainers, Hybrid wheat

INTRODUCTION

Wheat is most important cereal crop in Egypt, and it is the staple food for all Egyptians. Egypt's wheat cultivation area reached approximately 1.53 million hectares in the 2021/2022 growing season, and production reached about 9.80 million tons of wheat grains, with an average productivity of 6.41-ton hectare^{-1} (USDA, 2023). Despite significant increases in wheat yields, increasing population and shrinking cultivated area are impediments to increase wheat productivity. Thus, the goal is to increase total production by either increasing wheat planted area or increasing productivity per unit area. One of several practical possibilities for improving wheat is hybrid wheat. Hybrid wheat is a desirable choice for attaining hybrid vigour and, consequently, boosting the productivity of wheat to satisfy the expanding demand. Heterosis utilization in wheat is regarded as one of the most effective methods for increasing yield potential and stability (Mühleisen *et al.,* 2014; Murai *et al.,* 2016). Wheat yield could rise by up to 20% due to heterosis, highlighting the advantages of hybrid cultivars. But there are still a few obstacles in the way of fully utilizing wheat heterosis (Gowda et al., 2012; Longin et al., 2012; Singh *et al.,* 2015). Even though a lot of study has been done on how to develop hybrid wheat that exhibits significant yield heterosis, it has proven challenging to economically generate hybrid wheat seeds for commercial usage (Singh *et al.,* 2021; Boeven *et al.,* 2018). Wheat is a crop that self-pollinates with less than 1% cross-pollination. Wheat cannot be produced using mechanical emasculation techniques like detasseling used in the generation of maize hybrids because it is an autogamous plant with flawless blooms. The creation of hybrid seeds and wheat hybridization are both complicated by the biology of wheat. Therefore, altering floral biology to permit cross-fertilization between two parental lines is necessary to make wheat a cross-pollinated species. A variety of techniques have been proposed to limit self-pollination in wheat but the *Triticum timopheevii*-based cytoplasmic male sterility system (CMS), which prevents selfing in female parental lines of wheat, has been widely used (Wilson and Ross, 1962). Incompatibility between the nuclear and cytoplasmic genomes causes cytoplasmic male sterility (CMS), a maternally transmitted condition that is characterized by an inability to produce viable pollen but has no impact on female fertility (Laser and Lersten, 1972). With CMS, the requirement for human anther removal is avoided, enabling a technology that can create an infinite number of hybrid plants. The stable male sterile line (A line), a good agronomic base of maintenance (B line), and the ideal fertility restorer (R line) are the basic and essential elements for a successful development of hybrid wheat via the CMS system. Because *T. timopheevii* lacks functional nuclear-encoded Restorer-of-fertility (Rf) genes and has at least one CMS causing gene in its cytoplasm, the CMS line is employed as the female parent (Schnable and Wise, 1998). The maintainer line, which has the same nuclear genome as the CMS line but a normal fertile *T. aestivum* cytoplasm, serves as the male parent in crosses for the propagation and maintenance of the CMS line. The restorer line, which still carries one or more functioning Rf genes, serves as the male parent in a cross with the CMS line to create F1 hybrid seeds. As a result, it was crucial to find novel restorers and maintainers in order to produce hybrid wheat that could be widely used and provide high yields by using a variety of cytosterile lines from various sources. The objective of this study was to identify the maintainer and restorer lines for F1 hybrids of wheat.

MATERIALS AND METHODS

The present study was conducted during the 2020/2021 and 2021/2022 wheat growing seasons at Shandaweel Agricultural Research Station, Sohag, Egypt. The experimental materials comprised of three cytoplasmic male sterile lines (CMS) received from CIMMYT, Mexico which were developed using *Triticum Timopheevi* cytoplasm in the base varieties Vorobey A-line, Navojoa A-line and Neloki A-line, as well as twenty-five wheat genotypes genetically diverse as shown in Table 1

In the 2020/2021 growing season the three CMS lines were crossed with twenty-five testers following line x tester crossing design (Kempthorne, 1957) in which wheat genotypes were used as male lines and CMS lines were used as female lines to obtain 75 hybrid combinations. Crossing was done by adopting clipping method. Three staggered sowings of both female and male parents were made of at 10 days interval to synchronize flowering. Complete pollen sterility of CMS individual plants were identified before crossing by observing the pollen grains under the microscope using a 1% solution of aceto carmine in 45% acetic acid in which well filled, stained, and round pollen grains were recorded as viable.

In the 2021/2022 growing season a set of 75 hybrids along with their corresponding parents were planted in a randomized complete block design (RCBD) with three replications for the purpose evaluation. Each hybrid was sown in a single row of 1.5-meter length in each replication. The distance between row to row and plant to plant was 30 and 10 cm, respectively. During both seasons of the study, all agronomic practices such as irrigation, fertilization, weed and pest control were practiced as recommended to wheat crop.

Based on the results of the pollen viability test and the spikelet fertility percentage, maintainers and restorers were identified. Five randomly chosen plants from each replication of all the hybrids were used to record the observations. Pollen viability was tested during flowering to determine the fertility / sterility status of F1 plants. Five to ten spikelets from newly emerged spikes of five randomly selected plants were collected in a vial containing 70% ethanol for this purpose. With the aid of forceps, all the anthers from at least five spikelets were removed, and they were then placed on a glass slide with a drop of distilled water. To release the pollen grains, a needle was used to gently break the anthers. The pollen grains were dyed using an aceto carmine 1% solution in a 45% acetic acid solution. After clearing the debris from the slide, a cover slip was added, and the slide was examined under a microscope to determine the pollen fertility percentage. The average proportion of fertile pollen grains to all pollen grains in five randomly selected microscopic fields was estimated as pollen fertility (%). Fertile pollen grains (dark stained round) and sterile pollen grains (unstained withering, unstained spherical, and slightly stained round) were recorded for each microscopic field.

Before flowering, five randomly selected emerging spikes from each F1 hybrid for each replication were bagged (to avoid outcrossing) to estimate spikelet fertility and sterility. All bagged spikes were taken when more than 90% of the plants had reached the waxy ripe stage. Spikelet fertility was measured as a percentage of the ratio of number of grains set in flowers of all of the spikelets to the total number of flowers in all of the spikelets of the spike. Based on the technique suggested by Virmani et al., (1997) the classification of paternal lines Table (2) as restorers and maintainers was carried out.

Table 1. Name, pedigree and selection history of the twenty-five wheat genotypes.

Ent. No.	Genotype	Pedigree and selection history
1	Shandaweel 1	ITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC CMSS93B00567S-72Y-0l0M-010Y-010M-3Y-0M-0HTY-0SH
2	Sids 12	BUC//7C/ALD/5/MAYA74/ON//1160.147/3/BB/GLL/4/CHAT"S"/6/MAYA/VUL//CMH74 A.630/4*SX SD7096-4SD-1SD-1SD-0SD
3	Sids 14	BOW"S"/VEE"S"//BOW"S"/TSI/3/BANI SEWEF 1 SD293-1SD-2SD-4SD-0SD
4	Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S
5	Misr 2	SKAUZ/BAV92 CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S
6	Misr 3	ATTILA*2/PBW65*2/KACHU CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY
7	Misr 4	NS732/HER/3/PRL/ SARA// TSI/VEE 5/6/FRET 2/5/WHEAR/SOKOLL CM SA09Y007125-050Y- 050ZTM-0NJ-099NJ-0B-0EG
8	Giza 168	MRL/BUC//SERI CM93046-8M-0Y-0M-2Y-0B-0SH
9	Giza 171	SAKHA 93/GEMMEIZA 9 S.6-1GZ-4GZ-1GZ-2GZ-0S
10	Gemmeiza 11	BOW"S''/ KVZ // 7C / SERI 82 /3/ GIZA 168 / SAKHA 61 CGM 7892 – 2GM-1GM-2GM-OGM
11	Gemmeiza 12	OTUS/3/SARA/THB//VEE CMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM
12	Sakha 95	PASTOR//SITE/MO/3/CHEN/AEGILOPSSQUARROSA(TAUS)//BCN/4/WBLL1 CMSA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
13	Sakha 1001	SIDS1/ATTILA//GOUMRIA-17 S.16498-042S-013S-21S-0S
14	Kachu #1	Kachu #1 CMSS97M03912T-040Y-020Y-030M-020Y-040M-4Y-2M-0Y
15	Francolin #1	Waxwing*2/Vivitsi CGSS-01-B-00056T-099Y-099M-099M-099Y-099M-14Y-0B
16	Baj #1	Waxing/4/sni/Trap#1/3/Kauz*2/Trap//Kauz CGSS01Y00134S-099Y-099M-099M-13Y-0B
17	Nadi	NACOZARI F 76/TH.ACUTUM//3*PAVON F 76/3/MIRLO/BUCKBUCK/4/ 2*PASTOR/5/KACHU/6/KACHU CMSS06B00734T-099TOPY-099ZTM-099Y-099M-13WGY-0B
18	Kutz	Kutz CMSS06Y00946T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B
19	Kenya Sunbird	ND643/2*WBLL1 gets yr CGSS02B00116T-099B-099Y-099M-099Y-099M-15RGY-0B
20	Sokoll	PASTOR /3/ALTAR 84/AE.SQ(TR.TA)//OPTAM 85 CMSS97M00316S-0P20M-0P20Y-43M-010Y
21	Line 1	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/PARUS/PASTOR PTSA08M00046S-050ZTM-050Y-61ZTM-010Y-0B
22	Line 2	WBLL1//YANGLING SHAANXI/ESDA/3/ROLF07/4/QUAIU*2/KINDE PTSS16Y00040S-0B-099Y-099M-26Y-0Y
23	Line 3	CROC_1/AE.SQUARROSA (224)//OPATA/3/PUB94.15.1.12/WBLL1 PTSS09GHB00054S-0SHB-099Y-099B-4Y-0Y
24	Line 4	WBLL1//YANGLING SHAANXI/ESDA/3/ROLF07/4/QUAIU*2/KINDE PTSS16Y00034S-0B-099Y-099M-21Y-0Y
25	Line 5	FRET22/4/SNI/TRAP#1/3/KAUZ2/TRAP//KAUZ2/5/BOW/URES//2WEAVER/3/CROC_1/A ESQUARROSA (213)//POG CGSS05B00144T-099TOPY-099M-099NJ-099NJ-7GWY-0B-5Y-0B-0NUB

Table 2. Classification of test crosses into maintainers, restorers, partial maintainers and partial restorers.

Category	Pollen fertility %	Spikelet fertility (%)
Maintainer	0 – 1	0
Partial maintainer	1.1 – 50	0.1 – 50
Partial restorer	50.1 – 80	50.1 – 75
Restorer	> 80	> 75

RESULTS

A stable CMS line, along with its suitable maintenance and restorer lines, is required for an effective hybrid development program using the CMS technique Figure (1).

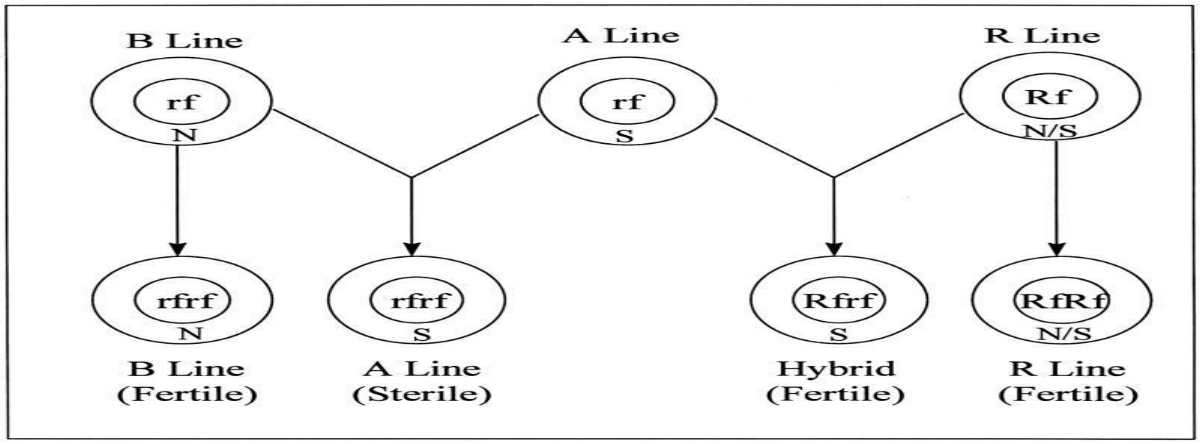

Fig.1 CMS based 3-line hybrid system

Results of the pollen fertility, spikelet fertility percent and fertility reaction for the 75 test crosses are presented in Tables 3 & 4. Data showed that the pollen fertility percent of test hybrids varied from 0.00 % to 86.75 % as well as the spikelet fertility ranged from 0.00 % to 92.46 %. Out of 75 test crosses evaluated, 5 restorers, 1 partial restorer and 14 partial maintainer and 55 maintainer cross combinations were identified on the basis of spikelet sterility and pollen fertility Tables (3 & 4).

Out of 55 maintainer cross combinations, 38 crosses showed zero percent of pollen fertility and spikelet fertility, while 17 maintainer cross combinations showed zero percent of spikelet fertility and pollen fertility ranged from 0.35 to 0.87% percent. The crosses, Sakha 95 × Vorobey A-line, Sakha 95 × Neloki A-line, Kachu #1 × Vorobey A-line, Francolin #1 × Vorobey A-line and Baj #1× Vorobey A-line had pollen fertility and spikelet fertility more than 84.70 and 86.70%, respectively. While, cross Misr 2 × Neloki A-line showed partial restorer (65.00 % pollen fertility and 62.87 % spikelet fertility). On the other hand, out of 75 combinations, 14 crosses showed pollen fertility of 4.54 to 46.00 % and spikelet fertility of 3.56 to 43.25 %. Based on the hybrid evaluation for pollen and spikelet fertility percent, the wheat genotypes identified as effective maintainers were Shandaweel 1, Misr 3, Misr 4, Giza 168, Gemmeiza 11, Gemmeiza 12, Kutz, Line 1, Line 2, Line 3, Line 4 and Line 5 for all the three CMS lines, Sids 14, Giza 171, Sakha 1001, Nadi, Kenya Sunbird for two CMS lines (Vorobey A-line and Navojoa A-line), Misr 1, Kachu #1, Francolin #1 and Baj #1 for two CMS lines (Navojoa A-line and Neloki A-line) and Sids 12 for one CMS line (Neloki A-line). While, Misr 2 and Sakha 95 were not able to maintain male sterility in the three CMS lines, i.e., Vorobey, Navojoa and Neloki A-lines. The wheat genotypes identified as partial maintainers were Sokoll for all three CMS lines, Sids 12 and Misr 2 for two CMS lines (Vorobey A-line and Navojoa A-line), Sids 14, Giza 171, Sakha 1001, Nadi and Kenya Sunbird for Neloki A-line, Misr 1 for Vorobey A-line and Sakha 95 for one CMS line (Navojoa A-line). On the other hand, Sakha 95 wheat cultivar was identified as restorers for Vorobey A-line and Neloki A-line, while Kachu #1, Francolin #1 and Baj #1 wheat genotypes were identified as effective restorers for Vorobey A-line and they gave pollen fertility and spikelet fertility more than 84.70 and 86.70%, respectively.

Misr 2 wheat cultivar showed partial restorer (65.00% pollen fertility and 62.87% spikelet fertility) for Neloki A-line.

Table 3. Pollen fertility percentage of test hybrids.

Testers	**Lines**					
	Vorobey A-line		**Navojoa A-line**		**Neloki A-line**	
	Pollen fertility %	**Fertility reaction**	**Pollen fertility %**	**Fertility reaction**	**Pollen fertility %**	**Fertility reaction**
Shandaweel 1	0.00	M	0.00	M	0.00	M
Sids 12	4.54	PM	6.65	PM	0.35	M
Sids 14	0.00	M	0.00	M	7.40	PM
Misr 1	8.65	PM	0.00	M	0.00	M
Misr 2	13.75	PM	15.32	PM	65.00	PR
Misr 3	0.56	M	0.87	M	0.00	M
Misr 4	0.00	M	0.75	M	0.00	M
Giza 168	0.65	M	0.00	M	0.00	M
Giza 171	0.00	M	0.87	M	9.70	PM
Gemmeiza 11	0.00	M	0.00	M	0.00	M
Gemmeiza 12	0.65	M	0.00	M	0.00	M
Sakha 95	85.43	R	46 .00	PM	85.70	R
Sakha 1001	0.00	M	0.00	M	16.76	PM
Kachu #1	84.70	R	0.00	M	0.00	M
Francolin #1	86.75	R	0.74	M	0.00	M
Baj #1	85.87	R	0.00	M	0.57	M
Nadi	0.00	M	0.65	M	17.56	PM
Kutz	0.65	M	0.00	M	0.00	M
Kenya Sunbird	0.00	M	0.55	M	12.65	PM
Sokoll	23.65	PM	24.56	PM	35.43	PM
Line 1	0.00	M	0.00	M	0.65	M
Line 2	0.75	M	0.00	M	0.00	M
Line 3	0.54	M	0.00	M	0.00	M
Line 4	0.64	M	0.54	M	0.00	M
Line 5	0.00	M	0.00	M	0.00	M

M= Maintainer, PM= Partial maintainer, R = Restorer, PR = Partial restorer

Table 4. Spikelet fertility percentage of test hybrids.

Testers	**Lines**					
	Vorobey A-line		**Navojoa A-line**		**Neloki A-line**	
	Spikelet fertility %	**Fertility reaction**	**Spikelet fertility %**	**Fertility reaction**	**Spikelet fertility %**	**Fertility reaction**
Shandaweel 1	0.00	M	0.00	M	0.00	M
Sids 12	3.56	PM	4.45	PM	0.00	M
Sids 14	0.00	M	0.00	M	5.65	PM
Misr 1	5.87	PM	0.00	M	0.00	M
Misr 2	7.54	PM	9.25	PM	62.87	PR
Misr 3	0.00	M	0.00	M	0.00	M
Misr 4	0.00	M	0.00	M	0.00	M
Giza 168	0.00	M	0.00	M	0.00	M
Giza 171	0.00	M	0.00	M	6.50	PM
Gemmeiza 11	0.00	M	0.00	M	0.00	M
Gemmeiza 12	0.00	M	0.00	M	0.00	M
Sakha 95	92.46	R	44 .00	PM	87.75	R
Sakha 1001	0.00	M	0.00	M	8.85	PM
Kachu #1	90.43	R	0.00	M	0.00	M
Francolin #1	87.75	R	0.00	M	0.00	M
Baj #1	86.70	R	0.00	M	0.00	M
Nadi	0.00	M	0.00	M	10.66	PM
Kutz	0.00	M	0.00	M	0.00	M
Kenya Sunbird	0.00	M	0.00	M	8.25	PM
Sokoll	41.60	PM	32.36	PM	43.25	PM
Line 1	0.00	M	0.00	M	0.00	M
Line 2	0.00	M	0.00	M	0.00	M
Line 3	0.00	M	0.00	M	0.00	M
Line 4	0.00	M	0.00	M	0.00	M
Line 5	0.00	M	0.00	M	0.00	M

M= Maintainer, PM= Partial maintainer, R = Restorer, PR = Partial restorer

DISCUSSION

The CMS hybridization technique, which is based on the sterility caused by *T. timopheevii's* cytoplasm, has been demonstrated to be a potentially effective method for producing hybrid seeds. In wheat, the result of a hybridization event involving *Triticum aestivum* and *T. timopheevii* as the female parent leads to CMS (Bohra et al., 2016). Male sterility is caused using *T. timopheevii* cytoplasm in bread and durum wheat, whereas female fertility is unaffected (Lukaszewski, 2017).

Results of the pollen and spikelet fertility percent showed variable fertility reactions for the 75 test crosses Tables (3 & 4). Similar results were reported by Chen and Wehling (2003) and Ahirwar et al. (2014) who observed a range of complete fertility to complete sterility observed among several hybrid combinations of wheat. The discovery of complete sterility maintainers and complete fertility restorers within wheat genotypes is important in wheat breeding program because it helps in the use of these genotypes in hybrid development. Ahirwar et al. (2014) observed a higher percentage of maintainers and restorers among 130 F1 hybrid wheat. According to these findings, hybrid combinations based on different CMS lines had variable spikelet fertility and pollen fertility. This variation may be caused by the presence of modifier genes, a difference in the penetrance or expressivity of the genes responsible for restoring pollen fertility, or both (Umadevi *et al.,* 2010).

Out of 75 test crosses evaluated, 5 crosses had restorer male parents, 1 cross had partial restorer male parent and 14 crosses had partial maintainer male parents and 55 crosses had maintainer male parents based on spikelet sterility and pollen fertility Tables (3 & 4). Such fertility restoration studies can have a great deal of validity by using various CMS lines in test crosses (Das *et al.,* 2013). The restorer male parents could be employed in a restoration line development effort to create superior hybrids.

The wheat genotypes that were found to be good maintainers of cytoplasmic male sterile (CMS) lines in Tables 3 and 4 could be further backcrossed with their respective F1 progenies to identify backcross progenies that are completely male sterile. These could then be developed into new CMS lines in the genetic background of the corresponding male parents. Singh et al. (2016) evaluated a range of diverse CMS lines, finding 56 lines that showed complete male sterility and thus have potential for use in hybrid wheat development programs. These new CMS lines developed from the male-fertile wheat genotypes identified in this study could be utilized in future hybrid wheat breeding efforts. The procedure would involve backcrossing the identified male-fertile genotypes with their F1 hybrids to select for completely male-sterile offspring, which could then serve as novel CMS sources. The results of the current experiment showed that the genotypes' responses to fertility restoration differ depending on their genetic backgrounds. Through a proper backcross breeding effort, restorer genes uncovered in exotic genotypes can be transferred to elite, high-yielding genotypes to create new restorer lines. To achieve the goal of a superior hybrid with better grain quality, more emphasis should be placed on using popular wheat genotypes as parental lines in hybrid wheat breeding. The identified restorer lines can be utilized as pollen parents to create new commercial hybrid cultivars. Additionally, new restorers can be created by crossing programs that increase the genetic diversity of restorers by pyramiding complementing features from various sources by breeding goals.

CONCLUSION

The investigation concludes that the identified wheat genotypes as effective maintainers were Shandaweel 1, Misr 3, Misr 4, Giza 168, Gemmeiza 11, Gemmeiza 12, KUTZ, Line 1, Line 2, Line 3, Line 4 and Line 5 for all the three CMS lines, Sids 14, Giza 171, Sakha 1001, Nadi and Kenya Sunbird genotypes for two CMS lines (Vorobey A-line and Navojoa A-line), Misr 1, Kachu #1, Francolin #1 and Baj #1 genotypes for two CMS lines (Navojoa A-line and Neloki A-line) and Sids 12 for one CMS line (Neloki A-line). These testers which are identified as effective maintainers can be converted into new potential CMS lines through backcross breeding methods with their respective F1's. While Kachu #1, Francolin #1, and Baj #1 wheat genotypes were found to be efficient restorers for only Vorobey A-line, Sakha 95 cultivar was found to be an excellent fertility restorer for both Vorobey A-line and Neloki A-line. The four parents that showed high fertility with CMS lines after being tested for their combining capacity and heterosis with various CMS lines might be used in the heterosis breeding program.

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تعريف السلالات الحافظة والمعيدة للخصوبة في نظام العقم الذكرى السيتوبلازمى لاستنباط القمح الهجين في مصر

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أجريت هذه الدراسة مصر خلال موسمي الزراعة 2020\2021 و2021\2022 بمحطة البحوث الزراعية بشندويل بمحافظة سوهاج. تم تهجين ثلاثة سلالات قمح ذات عقم ذكرى سيتوبلازمى Vorobey A-line، Navojoa A-line و Neloki A-line تحتوى على مصدر العقم الذكرى السيتوبلازمى *Triticum Timopheevi* (نظام الثلاث سلالات A,B,R) مع خمسة وعشرون تركيب وراثي من القمح مختلفة المنشأ كسلالات كشافة باستخدام نموذج السلالة × الكشاف لتحديد السلالات المعيدة للخصوبة والسلالات الحافظة للسلالات عقيمة الذكر. بناء على تقييم نسبة الخصوبة لكل من حبوب اللقاح والسنيبلات لعدد 75 هجين، أظهرت النتائج أن التراكيب الوراثية التي تم تعريفها كسلالات حافظة هي شندويل 1، مصر 3، مصر 4، جيزة 168، جميزة 11، جميزة 12، Kutz، Line 1، Line 2، Line 3، Line 4، Line 5 للسلالات العقيمة الذكر الثلاثة، التراكيب الوراثية سدس 14، جيزة 171، سخا 1001، Nadi، Kenya Sunbird للسلالات عقيمة الذكر Vorobey A-line و Navojoa A-line، التراكيب الوراثية مصر 1، Kachu #1، Francolin #1، Baj #1 للسلالات عقيمة الذكر Navojoa A-line وNeloki A-line، التركيب الوراثى سدس 12 للسلالة عقيمة الذكر Neloki A-line. وهذه التراكيب يمكن تحويلها إلى سلالات عقيمة باستخدام طريقة التربية بالتهجين الرجعى. من ناحية أخرى، فإن التراكيب الوراثية التي تم تعريفها كسلالات معيدة للخصوبة هي سخا 95 للسلالات عقيمة الذكر Vorobey A-line و Neloki A-line و التراكيب الوراثية Kachu #1، Francolin #1 و Baj #1 للسلالة عقيمة الذكر Vorobey A-line. وهذه التراكيب يمكن استخدامها في إنتاج هجن قمح واعدة. ظهور السلالات معيدة الخصوبة والحافظة للسلالات ذات العقم الذكرى السيتوبلازمى بين هذه التراكيب الوراثية يشير إلى إمكانية تطوير استنباط هجن قمح عالية المحصول واعدة من خلال استخدام نظام العقم الذكرى الستوبلازمى في مصر.

الكلمات المفتاحية: سلالات العقم الذكرى السيتوبلازمى، السلالات المعيدة للخصوبة، السلالات الحافظة، القمح الهجين.