Plant Archives Vol. 26, No. 1, 2026 pp. 333-339 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.046

IDENTIFICATION OF RESTORER LINES FOR COMPLETE RESTORATION ON CMS LINES IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

Divya K.[1*], Vikas V. K.[2], B. V. Tembhurne[3], Rajannna B.[4], M. R. Umesh[2] and Vijaykumar Ghante[2]

[1]Department of Genetics and Plant Breeding, College of Agriculture, Raichur, Karnataka, India.
[2]AICRP on Sunflower, MARS, University of Agricultural Sciences, Raichur - 584 104, Karnataka, India.
[3]Associate Director of Research, College of Agriculture, Kalaburagi, Karnataka, India.
[4]AICRP on Groundnut, MARS, University of Agricultural Sciences, Raichur - 584 104, Karnataka, India.
*Corresponding author E-mail : divyakoripalli509@gmail.com

(Date of Receiving- 08-12-2025; Date of Revision-13-01-2026; Date of Acceptance-17-02-2026)

ABSTRACT

A comprehensive study evaluated fertility restoration by crossing 86 restorer lines (PM and RCR series) with 12 CMS lines of PET 1 cytoplasm (CMS 1A, 8A, 9A, 34A, 38A, 76A, 96A, 98A, 103A, 104A, 105A and 107A), generating 336 F1's. Of these, 70 hybrids (20.8%) were restorers (R), 206 (61.3%) were partial restorers (PR), and 60 (17.9%) were maintainers (M). out of these, the PM series exhibited superior fertility restoration, with PM-66 and PM-8 achieving complete restoration with five CMS lines each. Conversely, the RCR series showed limited restoration ability, with only RCR-71 and RCR-41 demonstrating complete restoration with CMS 98A and CMS 9A, respectively. Differential restoration patterns indicated the influence of modifier genes, maternal nuclear background, and complex cytoplasmic-nuclear interactions on fertility expression. The study identified valuable restorer and maintainer lines essential for developing new CMS lines and advancing hybrid breeding programs.

***Key words*:** Restorer Lines, CMS Lines, Sunflower (*Helianthus annuus* L.)

Introduction

The highly cross-pollinating nature of sunflower, combined with the availability of cytoplasmic male sterile (CMS) and fertility restoring sources, has enabled commercial-scale exploitation of heterosis. Commercial sunflower hybrid development became possible after Leclercq's (1969) discovery of cytoplasmic male sterility and the subsequent identification of pollen fertility restorer sources by Kinman (1970). These discoveries shifted breeding efforts from population improvement to heterosis breeding. Farmers prefer sunflower hybrids over varieties due to their uniformity, early maturity, improved seed setting from high autogamy, and enhanced resistance to major diseases and insect pests (Hernández *et al*., 2017). The development of heterosis lead to the recognition of pollination control system like cytoplasmic- nuclear genetic male sterility system (CGMS). First ever CGMS system was obtained from an interspecific cross among *Helianthus petiolaris* and cultivated sunflower *H. annuus* (Leclercq, 1969) which is now generally known as PET 1 CGMS system. In India the first CGMS-based sunflower hybrid *viz.*, BSH-1 was developed by AICRP on sunflower, Bangalore and released for the commercial production during 1980 (Seetharam, 1980).

Success in heterosis breeding programme is largely dependents upon the development of inbreds with broad genetic base (Giriraj, 1998) with high combining ability and *per se* performance. The best inbreds identified have to be converted into CMS lines before being used in hybrid development. Those inbreds from maintainer gene pool are used for new CMS lines development and those from restorer gene pools are used as male lines in hybrid breeding programme. Hence, the superior inbreds must be evaluated for maintainer or restorer. The present investigation was taken up to explore the possibilities of finding out good restorers and maintainers based on sterility and fertility reactions in the twelve CMS of PET-1 back ground.

Keeping these points in the view, an effort was undertaken, to identify efficient restorers for various CMS lines. Before incorporating the best maintainer inbreds into hybrid development programs, they must be converted to CMS lines through backcrossing. Inbreds from the restorer gene pool can then serve as male lines in hybrid programs.

Material and Methods

A total 86 restorer lines (PM series and RCR series lines) were crossed randomly with 12 different CMS lines belonging to PET 1 cytoplasm *viz.*, CMS 1A, CMS 8A, CMS 9A, CMS 34A, CMS 38A, CMS 76A, CMS 96A, CMS 98A, CMS 103A, CMS 104A, CMS 105A and CMS 107A to generate 336 hybrids during *rabi*, 2022. Before flowering (star bud stage) all the heads in the lines (CMS lines) and testers (restorer lines) were covered with cloth bags to prevent open pollination. The pollen from the male lines was collected separately in petri-dishes with the help of camel hair brush, during morning hours (9:00 to 11:00 AM) and pollinated to the female lines separately and cloth bags were replaced immediately after pollination. The crossing was repeated (alternate day) till all the disc florets completed their opening. Each test hybrid was grown in a row of 3.0 m with 60 × 30 cm row to row and plant to plant distances during the *Kharif*-2023 at the AICRP on Sunflower, MARS, UAS, Raichur.

At the time of flowering, individual plants in each cross were observed for anther exertion and pollen shedding at anthesis stage and the crosses were categorised into male fertile, male sterile and partially fertile which correspond to restorer, sterile and partially fertile behaviours of restorer lines. All the F_1s were visually screened for male fertility or sterility reaction based on the presence or absence of pollen, anther dehiscence and pollen shedding at the anthesis stage, to know the fertility restoration or sterility maintenance behaviour of inbred lines (Table 1). Percentage of fertile and sterile plants was calculated for each cross by counting respective plants. Based on their fertility restoration ability, restorer lines were classified as fertility restorers, when all the F_1s plants were fertile and as sterility maintainers, when all the plants were sterile and those which were segregating for fertility and sterility were considered as partial restorers (Narkhede *et al.*, 2025 and Mohan *et al.*, 2022). Based on this data, F_1s were grouped as male sterile or male fertile or partially restorers. All the sterile hybrids were also allowed for open pollination to set seeds for evaluation.

Table 1: Classification of F_1 population based on frequency of fertility restoration in sunflower.

Class	Frequency Fertility Restoration (%)
Complete Restorer (R)	>90 %
Partial Restorer (PR)	5-90 %
Complete Maintainer (M)	<5 or 0 %

Results and Discussion

Eighty-six restorer lines (PM series and RCR series lines) were crossed with 12 different CMS lines belonging to PET 1 cytoplasm *viz.*, CMS 1A, CMS 8A, CMS 9A, CMS 34A, CMS 38A, CMS 76A, CMS 96A, CMS 98A, CMS 103A, CMS 104A, CMS 105A and CMS 107A to generated 336 hybrids. These 336 crosses thus obtained were evaluated for fertility restoration and sterility maintenance reaction by counting the number of sterile / fertile plants in the respective crosses. The restorer lines which resulted in hybrids with complete fertility (>90%) were classified as fertility restorers, with completely sterile plants as sterility maintainers and those which segregated for both fertility and sterility were considered as partial restorers or heterozygous lines for fertility restoration (Table 1). Fertility restoration reactions of 12 CMS lines with different restorer lines are presented in Table 2. Frequencies of restoration behaviour of restorer lines on twelve CMS lines are mentioned in Table 3.

The analysis of 336 hybrid crosses across 12 different CMS (Cytoplasmic Male Sterile) lines reveals significant variations in fertility restoration capabilities and breeding utility. Across the 336 hybrids set, 70 hybrids (20.8%) were classified as restorers (R), 206 hybrids (61.3%) were partial restorers (PR), and 60 hybrids (17.9%) acted as maintainers (M). The evaluation of 336 hybrids derived from 12 CMS lines, CMS-38A demonstrated the highest restoration efficiency with R lines. Of twenty-one CMS-38A derived hybrids, 16 R lines of 21 (76.2%) restored fertility in F_1's of CMS 38A, and none were maintainers, and this line consistently delivered high-frequency hybrids, with nine crosses showed 100 per cent restoration frequency, while seven crosses showed frequency range of 90.9 to 96 per cent. Second best restoration behaviour of R lines were seen on CMS 34A with 40 per cent (16 R lines) restoration frequency across 40 crosses, followed by CMS 98A with 36.1 per cent (13 R lines) restoration frequency across 36 crosses. CMS 107A and CMS 9A carried moderate frequencies of restorers (6/21 with 28.6% and 15/59 with 25.4%), respectively. Similar results of differential expression of fertility restoration of restorers for different CMS lines have been reported by Rukminidevi *et al.*, (2006), Keshavamurthi (2018) and Manohara (2019).

Table 2: Fertility restoration behaviour of different restorer lines in 336 experimental crosses.

S. No	F_1 hybrids	Frequency	Status of cross
1	CMS 1A × RCR 3	31.3	PR
2	CMS 1A × RCR 6	50	PR
3	CMS 1A × RCR 12	41.2	PR
4	CMS 1A × RCR 31	35.3	PR
5	CMS 1A × RCR 35	0	M
6	CMS 1A × RCR 41	11.8	PR
7	CMS 1A × RCR 44	61.5	PR
8	CMS 1A × RCR 46	11.1	PR
9	CMS 1A × RCR 48	17.6	PR
10	CMS 8A × RCR-3	15.4	PR
11	CMS 8A × RCR-16	52.6	PR
12	CMS 8A × RCR-18	35.7	PR
13	CMS 8A × RCR-21	6.3	M
14	CMS 8A × RCR-44	30.8	PR
15	CMS 8A × RGM 49	16.7	PR
16	CMS 8A × PM 82	44.4	PR
17	CMS 8A × PM 81	33.3	PR
18	CMS 9A × RCR-1	38.5	PR
19	CMS 9A × RCR-2	65	PR
20	CMS 9A × RCR-3	14.3	PR
21	CMS 9A × RCR-4	68.4	PR
22	CMS 9A × RCR-5	38.9	PR
23	CMS 9A × RCR-6	12.5	PR
24	CMS 9A × RCR-7	22.2	PR
25	CMS 9A × RCR-9	21.4	PR
26	CMS 9A × RCR-11	38.5	PR
27	CMS 9A × RCR-12	37.5	PR
28	CMS 9A × RCR-13	12.5	PR
29	CMS 9A × RCR-15	41.2	PR
30	CMS 9A × RCR-16	23.8	PR
31	CMS 9A × RCR-18	35.7	PR
32	CMS 9A × RCR-19	47.1	PR
33	CMS 9A × RCR-20	41.2	PR
34	CMS 9A × RCR-21	11.8	PR
35	CMS 9A × RCR-22	37.5	PR
36	CMS 9A × RCR-23	18.8	PR
37	CMS 9A × RCR-24	43.8	PR
38	CMS 9A × RCR-30	50	PR
39	CMS 9A × RCR-31	46.2	PR
40	CMS 9A × RCR-32	33.3	PR
41	CMS 9A × RCR-33	47.1	PR
42	CMS 9A × RCR-35	52.9	PR
43	CMS 9A × RCR-36	56.3	PR
44	CMS 9A × RCR-39	37.5	PR
45	CMS 9A × RCR-41	100	R
46	CMS 9A × RCR-44	5.6	M
47	CMS 9A × RCR-46	18.8	PR

Continue 2...

48	CMS 9A × RCR-48	36.8	PR
49	CMS 9A × RCR-49	33.3	PR
50	CMS 9A × RCR-70	14.3	PR
51	CMS 9A × RCR-72	5.3	M
52	CMS 9A × RCR-74	41.2	PR
53	CMS 9A × RCR-76	76.5	PR
54	CMS 9A × RCR-81	0	M
55	CMS 9A × RGM-49	35.3	PR
56	CMS 9A × PM-1	90.9	R
57	CMS 9A × PM-2	94.4	R
58	CMS 9A × PM-4	65	PR
59	CMS 9A × PM-8	92.9	R
60	CMS 9A × PM-34	94.7	R
61	CMS 9A × PM-33	71.4	PR
62	CMS 9A × PM-49	58.3	PR
63	CMS 9A × PM-41	94.4	R
64	CMS 9A × PM-63	100	R
65	CMS 9A × PM-108	47.4	PR
66	CMS 9A × PM-118	60	PR
67	CMS 9A × PM-123	94.1	R
68	CMS 9A × PM-126	92.3	R
69	CMS 9A × PM-130	90.5	R
70	CMS 9A × PM-135	93.8	R
71	CMS 9A × PM-155	66.7	PR
72	CMS 9A × PM-160	31.3	PR
73	CMS 9A × PM-81	94.7	R
74	CMS 9A × PM-82	90	R
75	CMS 9A × PM-83	92.9	R
76	CMS 9A × PM-66	93.8	R
77	CMS 34A × RCR-3	30.8	PR
78	CMS 34A × RCR-4	12.5	PR
79	CMS 34A × RCR-5	16.7	PR
80	CMS 34A × RCR-13	12.5	PR
81	CMS 34A × RCR-21	40	PR
82	CMS 34A × RCR-22	44.4	PR
83	CMS 34A × RCR-23	31.8	PR
84	CMS 34A × RCR-24	29.4	PR
85	CMS 34A × RCR-31	86.7	PR
86	CMS 34A × RCR-36	60	PR
87	CMS 34A × RCR-37	77.8	PR
88	CMS 34A × RCR-41	5.3	M
89	CMS 34A × RCR-44	13.6	PR
90	CMS 34A × RCR-46	86.7	PR
91	CMS 34A × RCR-61	56.3	PR
92	CMS 34A × RCR-67	18.8	PR
93	CMS 34A × RCR-74	68.4	PR
94	CMS 34A × RCR-127-1	66.7	PR
95	CMS 34A × RGM-49	61.5	PR
96	CMS 34A × PM-1	93.3	R
97	CMS 34A × PM-2	94.4	R
98	CMS 34A × PM-4	94.4	R

Continue 2...

99	CMS 34A × PM-8	94.4	R
100	CMS 34A × PM-33	90.5	R
101	CMS 34A × PM-34	93.8	R
102	CMS 34A × PM-41	90.5	R
103	CMS 34A × PM-49	94.1	R
104	CMS 34A × PM-63	94.1	R
105	CMS 34A × PM-108	95.7	R
106	CMS 34A × PM-118	90	R
107	CMS 34A × PM-123	92.3	R
108	CMS 34A × PM-126	73.7	PR
109	CMS 34A × PM-130	94.4	R
110	CMS 34A × PM-135	71.1	PR
111	CMS 34A × PM-155	90.9	R
112	CMS 34A × PM-160	70	PR
113	CMS 34A × PM-81	94.4	R
114	CMS 34A × PM-82	91.3	R
115	CMS 34A × PM-83	13.6	PR
116	CMS 34A × PM-66	63.6	PR
117	CMS 38A × PM-1	100	R
118	CMS 38A × PM-2	100	R
119	CMS 38A × PM-4	96	R
120	CMS 38A × PM-8	100	R
121	CMS 38A × PM-33	100	R
122	CMS 38A × PM-34	86.4	PR
123	CMS 38A × PM-41	87.5	PR
124	CMS 38A × PM-49	94.4	R
125	CMS 38A × PM-63	100	R
126	CMS 38A × PM-108	95.5	R
127	CMS 38A × PM-118	45	PR
128	CMS 38A × PM-123	100	R
129	CMS 38A × PM-126	95.5	R
130	CMS 38A × PM-130	73.9	PR
131	CMS 38A × PM-135	100	R
132	CMS 38A × PM-155	95.5	R
133	CMS 38A × PM-160	100	R
134	CMS 38A × PM-81	44.4	PR
135	CMS 38A × PM-82	100	R
136	CMS 38A × PM-83	91.7	R
137	CMS 38A × PM-66	90.9	R
138	CMS 76A × RCR-1	0	M
139	CMS 76A × RCR-4	21.4	PR
140	CMS 76A × RCR-5	38.5	PR
141	CMS 76A × RCR-9	7.7	M
142	CMS 76A × RCR-16	64.3	PR
143	CMS 76A × RCR-21	15.4	PR
144	CMS 76A × RCR-2-1	7.7	M
145	CMS 76A × RCR-22	22.2	PR
146	CMS 76A × RCR-24	20	PR
147	CMS 76A × RCR-26	7.1	M
148	CMS 76A × RCR-29	0	M
149	CMS 76A × RCR-31	5.3	M

Continue 2...

150	CMS 76A × RCR-33	7.7	M
151	CMS 76A × RCR-37	30	PR
152	CMS 76A × RCR-44	33.3	PR
153	CMS 76A × RCR-47	7.1	M
154	CMS 76A × RCR-48	20	PR
155	CMS 76A × RCR-49	18.8	PR
156	CMS 76A × RCR-62	50	PR
157	CMS 76A × RCR-64	0	M
158	CMS 76A × RCR-65	15.4	PR
159	CMS 76A × RCR-67	23.1	PR
160	CMS 76A × RCR-71	0	M
161	CMS 76A × RCR-74	5.6	M
162	CMS 76A × RCR-75	7.1	M
163	CMS 76A × RCR-80	17.6	PR
164	CMS 76A × RCR-85	13.3	PR
165	CMS 76A × RCR-86	6.7	M
166	CMS 76A × RCR-88	7.7	M
167	CMS 76A × RCR-91	6.3	M
168	CMS 76A × RCR-93	7.1	M
169	CMS 76A × RCR-98	21.4	PR
170	CMS 76A × RCR-101	7.1	M
171	CMS 76A × RCR-103	16.7	PR
172	CMS 76A × RCR-104	0	M
173	CMS 76A × RCR-105	26.7	PR
174	CMS 76A × RCR-109	5	M
175	CMS 76A × RCR-133	7.1	M
176	CMS 76A × RCR-143	14.3	PR
177	CMS 76A × RGM-49	50	PR
178	CMS 76A × PM-81	21.4	PR
179	CMS 76A × PM-82	53.8	PR
180	CMS 96A × RCR-37	0	M
181	CMS 96A × RCR-39	43.8	PR
182	CMS 96A × RCR-46	23.1	PR
183	CMS 96A × RCR-61	0	M
184	CMS 96A × RCR-67	5.6	M
185	CMS 96A × RCR-91	0	M
186	CMS 96A × RCR-103	0	M
187	CMS 96A × RCR-143	20	PR
188	CMS 96A × RGM-49	15	PR
189	CMS 96A × PM-81	35.3	PR
190	CMS 96A × PM-82	7.1	M
191	CMS 98A × RGM-49	33.3	PR
192	CMS 98A × RCR-93	18.8	PR
193	CMS 98A × RCR-9	13.3	PR
194	CMS 98A × RCR-88	0	M
195	CMS 98A × RCR-86	6.3	M
196	CMS 98A × RCR-74	5.9	M
197	CMS 98A × RCR-72	81.3	PR
198	CMS 98A × RCR-71	100	R
199	CMS 98A × RCR-44	20	PR
200	CMS 98A × RCR-37	0	M

Continue 2...

201	CMS 98A × RCR-31	11.1	PR
202	CMS 98A × RCR-143	17.6	PR
203	CMS 98A × RCR-121	17.6	PR
204	CMS 98A × RCR-103	12.5	PR
205	CMS 98A × R-127-1	22.2	PR
206	CMS 98A × PM-1	91.3	R
207	CMS 98A × PM-2	94.4	R
208	CMS 98A × PM-4	94.1	R
209	CMS 98A × PM-8	90	R
210	CMS 98A × PM-33	72.7	PR
211	CMS 98A × PM-34	63	PR
212	CMS 98A × PM-41	52.4	PR
213	CMS 98A × PM-49	93.3	R
214	CMS 98A × PM-63	36.4	PR
215	CMS 98A × PM-108	90.9	R
216	CMS 98A × PM-118	50	PR
217	CMS 98A × PM-123	63.2	PR
218	CMS 98A × PM-126	100	R
219	CMS 98A × PM-130	94.4	R
220	CMS 98A × PM-135	42.1	PR
221	CMS 98A × PM-155	94.7	R
222	CMS 98A × PM-160	72.2	PR
223	CMS 98A × PM-81	94.7	R
224	CMS 98A × PM-82	61.9	PR
225	CMS 98A × PM-83	94.7	R
226	CMS 98A × PM-66	90	R
227	CMS 103A × RCR-1	6.7	M
228	CMS 103A × RCR-2	50	PR
229	CMS 103A × RCR-3	12.5	PR
230	CMS 103A × RCR-9	11.8	PR
231	CMS 103A × RCR-15	5.9	M
232	CMS 103A × RCR-19	6.7	M
233	CMS 103A × RCR-22	6.7	M
234	CMS 103A × RCR-24	7.1	M
235	CMS 103A × RCR-32	37.5	PR
236	CMS 103A × RCR-33	11.8	PR
237	CMS 103A × RCR-35	73.7	PR
238	CMS 103A × RCR-36	68.8	PR
239	CMS 103A × RCR-37	38.9	PR
240	CMS 103A × RCR-41	29.4	PR
241	CMS 103A × RCR-46	62.5	PR
242	CMS 103A × RCR-48	5.3	M
243	CMS 103A × RCR-5-1	31.3	PR
244	CMS 103A × RCR-67	5.9	M
245	CMS 103A × RCR-71	11.8	PR
246	CMS 103A × RCR-72	6.3	M
247	CMS 103A × RCR-74	5.9	M
248	CMS 103A × RCR-75	15	PR
249	CMS 103A × RCR-76	11.8	PR
250	CMS 103A × RCR-91	11.8	PR
251	CMS 103A × RCR-90	5.9	M

Continue 2...

252	CMS 103A × RCR-101	0	M
253	CMS 103A × PM-1	23.8	PR
254	CMS 103A × PM-2	70	PR
255	CMS 103A × PM-4	54.5	PR
256	CMS 103A × PM-8	50	PR
257	CMS 103A × PM-33	72.2	PR
258	CMS 103A × PM-34	79.2	PR
259	CMS 103A × PM-41	75	PR
260	CMS 103A × PM-49	82.4	PR
261	CMS 103A × PM-63	76.2	PR
262	CMS 103A × PM-108	56	PR
263	CMS 103A × PM-118	90.9	R
264	CMS 103A × PM-123	69.6	PR
265	CMS 103A × PM-126	80	PR
266	CMS 103A × PM-130	78.9	PR
267	CMS 103A × PM-135	80	PR
268	CMS 103A × PM-155	0	M
269	CMS 103A × PM-160	9.5	PR
270	CMS 103A × PM-81	64.7	PR
271	CMS 103A × PM-82	60	PR
272	CMS 103A × PM-83	69.2	PR
273	CMS 103A × PM-66	90	R
274	CMS 104A × PM-1	7.1	PR
275	CMS 104A × PM-2	6.7	PR
276	CMS 104A × PM-4	22.2	PR
277	CMS 104A × PM-8	23.8	PR
278	CMS 104A × PM-33	11.8	PR
279	CMS 104A × PM-34	20	PR
280	CMS 104A × PM-41	33.3	PR
281	CMS 104A × PM-49	7.7	PR
282	CMS 104A × PM-63	90	R
283	CMS 104A × PM-108	31.3	PR
284	CMS 104A × PM-118	7.1	PR
285	CMS 104A × PM-123	17.6	PR
286	CMS 104A × PM-126	45	PR
287	CMS 104A × PM-130	19	PR
288	CMS 104A × PM-135	15.8	PR
289	CMS 104A × PM-155	33.3	PR
290	CMS 104A × PM-160	6.7	PR
291	CMS 104A × PM-81	10	PR
292	CMS 104A × PM-82	11.1	PR
293	CMS 104A × PM-83	10	PR
294	CMS 104A × PM-66	0	M
295	CMS 105A × PM-1	23.1	PR
296	CMS 105A × PM-2	21.4	PR
297	CMS 105A × PM-4	10.5	PR
298	CMS 105A × PM-8	4.5	M
299	CMS 105A × PM-33	6.7	PR
300	CMS 105A × PM-34	4.3	M
301	CMS 105A × PM-41	4.3	M
302	CMS 105A × PM-49	0	M

Continue 2...

303	CMS 105A × PM-63	0	M
304	CMS 105A × PM-108	15	PR
305	CMS 105A × PM-118	100	R
306	CMS 105A × PM-123	15.8	PR
307	CMS 105A × PM-126	15	PR
308	CMS 105A × PM-130	0	M
309	CMS 105A × PM-135	9.5	PR
310	CMS 105A × PM-155	0	M
311	CMS 105A × PM-160	5	M
312	CMS 105A × PM-81	5.9	PR
313	CMS 105A × PM-82	0	M
314	CMS 105A × PM-83	0	M
315	CMS 105A × PM-66	20	PR
316	CMS 107A × PM-1	0	M
317	CMS 107A × PM-2	12.5	PR
318	CMS 107A × PM-4	94.4	R
319	CMS 107A × PM-8	95.7	R
320	CMS 107A × PM-33	89.5	PR
321	CMS 107A × PM-34	68.4	PR
322	CMS 107A × PM-41	75	PR
323	CMS 107A × PM-49	66.7	PR
324	CMS 107A × PM-63	85	PR
325	CMS 107A × PM-108	68.4	PR
326	CMS 107A × PM-118	77.3	PR
327	CMS 107A × PM-123	100	R
328	CMS 107A × PM-126	81.3	PR
329	CMS 107A × PM-130	90.9	R
330	CMS 107A × PM-135	81.8	PR
331	CMS 107A × PM-155	100	R
332	CMS 107A × PM-160	85.7	PR
333	CMS 107A × PM-81	82.4	PR
334	CMS 107A × PM-82	38.9	PR
335	CMS 107A × PM-83	78.9	PR
336	CMS 107A × PM-66	92.3	R

Restorers (R); Partial Restorers (PR); Maintainers (M)

In contrast, several lines were dominated by partial restoration, CMS 104A (19/21 with 90.5% PR), CMS 1A (8/9 with 88.9% PR), and CMS 8A (7/8 with 87.5% PR). Some CMS lines tended towards maintenance, CMS 76A (20/42 with 47.6% M) and CMS 96A (6/11 with 54.5% M) showed the highest proportion of maintainers, indicating weak or absent restoration in those crosses. CMS 103A was largely partial restorer type (33/47 with 70.2% PR) with a moderate number of maintainers (25.5%) and two restorers (4.2%). However, crosses that exhibited a sterility reaction (maintainers) are highly valuable in breeding programs, since they serve as maintainers for perpetuating CMS lines, facilitate the development of new CMS sources through backcrossing, and provide insights into the inheritance of fertility restoration genes. Similar results were supported by Sujatha and Vishnuvardhan Reddy (2008) and Yogesh *et al.*, (2007).

Table 3: Frequencies of restoration behaviour of different restorer lines on twelve CMS lines of sunflower.

CMS Line	TH	Frequency			Percentage		
		R	PR	M	R	PR	M
CMS 98A	36	13	19	04	36.1	52.8	11.1
CMS 9A	59	15	41	03	25.4	69.5	5.1
CMS 34A	40	16	23	01	40.0	57.5	2.5
CMS 103A	47	02	33	12	4.2	70.2	25.5
CMS 38A	21	16	05	00	76.2	23.8	0
CMS 104A	21	01	19	01	4.8	90.5	4.8
CMS 105A	21	01	10	10	4.8	47.6	47.6
CMS 107A	21	06	14	01	28.6	66.7	4.8
CMS 76A	42	00	22	20	0	52.4	47.6
CMS 96A	11	00	05	06	0	45.5	54.5
CMS 1A	09	00	08	01	0	88.9	11.1
CMS 8A	08	00	07	01	0	87.5	12.5
TOTAL	**336**	**70**	**206**	**60**	**20.8**	**61.3**	**17.9**

TH: Total Hybrids; R: Restorers; PR: Partial Restorers; M: Maintainers

The PM series demonstrated superior fertility restoration across CMS lines, with PM-66 and PM-8 emerging as top performers, each achieving complete restoration (R) with five CMS lines, PM-66 with CMS 9A, CMS 38A, CMS 98A, CMS 103A, CMS 107A and PM-8 with CMS 9A, CMS 34A, CMS 38A, CMS 98A, CMS 107A. The next best performers were PM-1, PM-2, PM-4, PM-49, PM-63, PM-123, PM-130 and PM-155 achieved complete restoration with 4 CMS lines each, particularly excelling with CMS 9A, 34A, 38A, 98A or 107A. Moderate performers including PM-33, PM-108, PM-118, PM-126, PM-81, PM-82 and PM-83 showed mixed restoration patterns with 3 complete restorations each. Weak performers PM-34, PM-41 and PM-160 consistently exhibited high partial restoration at 87.5%, indicating they function exclusively as partial restorers, only one achieving complete fertility restoration with CMS-34A or CMS-38A respectively.

Whereas, the RCR series showed limited restoration ability, with only RCR-71 and RCR-41 demonstrating complete restoration capability with CMS 98A and CMS 9A respectively. However, the series offers value through partial restoration lines useful for gene introgression in breeding programs, and many maintainer lines. The predominant partial restoration behaviour indicates weak restoration alleles requiring genetic enhancement for commercial use. Overall, the predominance of partial restorers (61.3%) across CMS lines indicates that intermediate restoration is most common in these parental combinations, whereas complete restorers are concentrated in a few CMS lines (notably CMS 38A, CMS 34A, CMS 98A and CMS 9A).

Conclusion

CMS-38A derived hybrids showed strongest restoration efficiency with different restorer lines of 76.2% followed by CMS-34A derived hybrids at 40% and CMS-98A at 36.1%. Several lines including CMS-104A, CMS-1A, and CMS-8A based hybrids were dominated by partial restoration, while CMS-76A and CMS-96A derived hybrids showed highest maintainer proportions. Complete restorers are vital for producing fully fertile hybrids that achieve maximum seed set and commercial yields. Maintainers are equally important for preserving CMS lines by ensuring complete male sterility, which enables consistent production of sterile seeds required for ongoing hybrid breeding programs. Partial restorers constituting the majority, reveal the involvement of weak restoring alleles that could be exploited through selective breeding.

References

Giriraj, K. (1998). Development of A, B and R lines for use in Heterosis breeding in sunflower. In: *Hybrid Sunflower Seed Production Technology*, Directorate of Oilseeds Research, Rajendranagar, Hyderabad-500030, India, 9-12.

Hernandez, F., Lindstrom L.I., Parodi E., Poverene M. and Presotto A. (2017). The role of domestication and maternal effects on seed traits of crop-wild sunflower hybrids (*Helianthus annuus* L.). *Ann. Appl. Biol.,* **171**, 237–251.

Kinman, M.L. (1970). New developments in USDA and state experiment station sunflower breeding programmes. Proc. 4th *Int. Sunflower Conf., Memphis, Tennessee*, 181-183.

Keshavamurthi, S.K. (2018). Identification of fertility restorer lines in newly derived inbred lines of sunflower (*Helianthus annuus* L.) *M.Sc.* (*Agri*) *Thesis,* Univ. Agric. Sci., Raichur.

Leclercqe, P. (1969). Line sterile cytoplasmique chez le tournesol. *Ann. Amelior Planta*, **12**, 99-106.

Manohara, S.N. (2019). identification of fertility restorers / sterility maintainers and assessment of combining ability and heterosis of untested inbred lines in sunflower (*Helianthus annuus* L.). *M.Sc. (Agri.) Thesis,* Univ. Agric. Sci., Bangalore, Karnataka, India.

Mohan, D., Meena H.P., Sandhya G. and Payasi S.K. (2022). Restoration ability of newly developed restorer gene pool inbreds on two different CMS sources in sunflower (*Helianthus annuus* L.). *Electron. J. Pl. Breed*., **13(2)**, 419-424.

Narkhede, T.A., Pole S.P., Dhuppe M.V., Zade P.S. and Singh G. (2025). Identification of sterility maintenance or fertility restoration behaviour for different CMS lines in Sunflower (*Helianthus annuus* L.) using inbreds. *IJAFS*., **7(9)**, 439-442.

Rukminidevi, K., Ganesh M. and Ranganatha A.R.G. (2006). Identification of fertility restorers for new CMS sources in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res*., **23**, 46-48.

Seetharam, A. (1980). Hybrid sunflowers. *Indian Farming*, **24**, 15-16.

Sujatha, M. and Vishnuvardhan R.A. (2008). Identification of fertility restorers/ maintainers in sunflower (*Helianthus annuus* L.). *J. Oilseeds Res.,* **25(2)**, 181-182.

Yogesh, L.N., Gangappa E., Shadakshari Y.G. and Manjunath Y.S. (2007). Maintainer and restorer reaction of new sunflower inbred lines on PET 1 system with three nuclear backgrounds. National Seminar on Changing Global Vegetable Oils Scenario: Issues and Challenges before India, Jan. 29-31, 136-139.