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Variety Registration Report

Registration of developed resilient somaclonal variant of geranium 'CIM-SANGAM' with high oil yield and low citronellol: Geraniol ratio for cultivation in the North Indian plains

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Abstract

Geranium (*Pelargonium graveolens*), a perennial, multi-harvest aromatic herb belonging to the Geraniaceae family, is renowned for its erect and branched growth habit. Its essential oil, prized for its therapeutic and commercial value, primarily contains citronellol and geraniol as major constituents, alongside several important minor compounds. Existing commercial varieties are inadequate in oil yield, stress resilience, and adaptation to the northern Indian plains, especially due to fungal susceptibility and post-rainy season propagule scarcity. To address these limitations, the somaclonal variation method was initiated in 2020 using the CIMAP-24 (Chinese) line to develop genetically improved clone, which was registered as the new variety 'CIM-Sangam' of *P. graveolens* for commercial application. The developed clone has superior agronomic traits, including strong stems, a high Leaf: Stem ratio of 2.46, oil content of 0.12%, abundant branching, and substantial biomass. The distinctive feature of the clone is enhanced tolerance to fungal infections and biotic stress, particularly during the rainy season, which leads to adaptation in the agro-climatic conditions of northern Indian plains. The developed variety has two main essential oil chemical constituents, Citronellol: Geraniol (C: G) ratio (<2) to meet high oil quality for improved Indian economy. The minor constituents 6, 9-guaiadiene and 10-epi-ɣ-eudesmol are present in a concentration of 3.36 and 0.19%, respectively. Altogether, clone can produce impressive oil yields of 65.0 kg/ha in the first harvest and 32.64 kg/ha in the second harvest. These features make CIM-Sangam a promising variety for sustainable geranium cultivation and essential oil production in the northern plains of India.

Keyword: Biotic stress, CIM-Sangam, Geranium, Somaclonal variation, Tolerance.

Introduction

Geranium (*Pelargonium graveolens*) is an erect, branched, perennial, and multi-harvest aromatic herb belonging to the family Geraniaceae. The plant originates from South Africa, Madagascar, Egypt, and Morocco. This plant is highly valued for its essential oil, which has extensive applications in pharmacology, fragrance, aromatherapy, cosmetics, and the food industry. The essential oil is rich in secondary metabolites, imparting anti-microbial and insecticidal properties. In India, geranium is cultivated as a rain-fed perennial crop in the Nilgiri and Palni hills of Tamil Nadu, while in the northern plains, it is grown as an annual crop. However, the national demand for geranium essential oil is around 200 tonnes per year, while domestic production is limited to just 20 tonnes, necessitating significant imports (Kahkashan *et al*., 2024). Moreover, the agriculture of the crop gives 70 to 80 kg/ha potential oil yield to get a net profit of ~ Rs. 2 to 2.5 lacs/year. Subsequently, limited commercial variety is insufficient to fulfil the demand of the market and supply (Singh *et al*., 2021; Lothe and Verma, 2023). The commercial sector primarily values geranium oil based on its major constituents—citronellol and geraniol—along with minor but significant components such as rose oxide. Various commercial types of geranium essential oils, including Bourbon, Chinese, Algerian, Egyptian, and Moroccan, differ significantly in their chemical composition (Saxena *et al*., 2008). Despite its commercial importance, geranium production in India faces critical challenges due to biotic and abiotic stresses,

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particularly fungal infections that lead to yield losses. A major issue in the northern plains is the unavailability of healthy propagules after the rainy season. Additionally, existing cultivars lack fungal resistance, making them unsuitable for year-round cultivation. The market now demands high-yielding, low C:G ratio, and fungal-resistant geranium varieties to bridge the gap between supply and demand. To address these challenges, an improved geranium cultivar with superior yield and stress resilience was developed through a systematic breeding program.

Materials and Methods

The breeding process commenced in 2020 with the establishment of the CIMAP-24 (Chinese) line *in-vitro*, using petiole explants to induce callus formation and subsequent indirect regeneration. A total of 75 somaclonal variants were acclimatized in a greenhouse, followed by rigorous morphological and yield screenings. In 2021, six promising plant populations were identified and tested in an initial evaluation trial (IET) following a randomized complete block design (RCBD) to evaluate herb yield, oil yield, and fungal resistance, as illustrated in Figure 1

Table 1: Growth attributes of six selected individual plant populations/clones in IET (2020-21)

Population	*Plant height (cm)*	*Canopy (cm)*	*Leaf length (cm)*	*Leaf width (cm)*	*Internode length (cm)*	*Petiole length (cm)*	*Branches Plant^{-1}*
CIMAP-K14	54.3	157	7.5	11.46	**6.9**	**10.9**	38.33
CIMAP-K19	58.1	166	7.3	11.30	10.8	11.7	**29.66**
CIMAP-K24	**61.3**	**193**	7.2	10.70	7.8	12.1	**51.00**
CIMAP-K28	57.1	**121**	**6.7**	**10.33**	**13.2**	13.1	38.66
CIMAP-K30	**50.5**	137	**7.8**	**11.60**	9.6	**14.6**	29.67
CIMAP-K36	57.2	158	6.9	10.66	10.7	12.1	42.34
SDE ±	1.52	1.83	0.12	0.15	0.28	0.22	1.38
CD @ 1%	4.66	5.60	0.38	0.47	0.85	0.69	4.21
CD @ 5%	3.32	4.00	0.27	0.33	0.61	0.49	3.00

Table 2: Yield attributes of six selected individual plant populations/clones in IET (2020-21)

Population	*Leaf stem ratio*	*Herb yield (g plant^{-1})*	*Essential oil content (%)*	*Essential oil yield (ml plant^{1})*	*Expected essential oil yield (kg ha^{-1})*
CIMAP-K14	1.8	1430	0.163	2.33	93.42
CIMAP-K19	2.2	**1546**	0.166	2.57	103.11
CIMAP-K24	2.6	1538	**0.246**	**3.79**	**151.78**
CIMAP-K28	**3.3**	1479	0.193	2.85	114.37
CIMAP-K30	2.5	1461	0.183	2.67	107.14
CIMAP-K36	3.0	1441	0.200	2.88	115.30
SDE ±	0.12	24.83	0.01		6.63
CD @ 1%	0.36	75.85	0.03		20.28
CD @ 5%	0.26	54.10	0.02		14.46

Table 3: Growth attributes of 4 promising plant populations/clones under BST-I (2021-22)

Cultivars	*Plant height (cm)*				*Canopy (cm)*				*Total no. of branches/plant*			
	R_1	*R_2*	*R_3*	*Mean*	*R1*	*R2*	*R3*	*Mean*	*R1*	*R2*	*R3*	*Mean*
CIMAP-K14	52.49	49.47	53.11	**51.69**	191.3	184.93	196.93	**191.07**	43.3	36.3	40.6	**40.11**
CIMAP-K24	56.72	61.83	59.30	**59.28**	182.88	189.26	183.36	**185.16**	58.4	53.7	50.7	**54.23**
CIMAP-K28	51.78	53.21	51.35	**52.11**	177.80	173.78	183.11	**178.23**	38.6	39.6	43.3	**40.56**
CIMAP-K30	49.14	49.19	48.80	**49.04**	171.87	168.05	172.12	**170.67**	29.3	36.6	35.6	**33.89**
CIMAP-24	52.50	57.58	46.73	**52.26**	178.64	172.76	183.15	**178.18**	51.7	53.7	52.8	**52.67**
SDE ±	1.39				3.23				1.32			
CD @ 1%	3.76				8.75				3.57			
CD @ 5%	2.81				6.54				2.67			

Table 4: Yield attributes of 4 promising plant populations/clones under BST-I (2021-22)

Cultivars	*Leaf:Stem ratio*				*Fresh biomass (q ha^{-1})*				*Essential oil content (%)*				*Essential oil yield (kg ha^{-1})*			
	R_1	*R_2*	*R_3*	*Mean*	*R1*	*R2*	*R3*	***Mean***	***R1***	***R2***	***R3***	***Mean***	***R1***	***R2***	***R3***	***Mean***
CIMAP-K14	1.96	1.86	2.03	**1.95**	572.0	579.6	571.0	**574.23**	0.17	0.15	0.16	**0.16**	97.2	88.8	91.3	**92.49**
CIMAP-K24	2.63	2.53	2.43	**2.53**	603.3	601.3	614.4	**606.35**	0.19	0.20	0.18	**0.19**	118.6	120.2	112.6	**117.10**
CIMAP-K28	3.03	3.52	3.23	**3.26**	601.8	592.0	584.6	**592.84**	0.20	0.20	0.20	**0.20**	122.3	120.3	116.9	**119.89**
CIMAP-K30	2.43	2.36	2.56	**2.45**	584.5	582.2	577.7	**581.51**	0.18	0.17	0.19	**0.18**	109.1	100.9	111.6	**107.24**
CIMAP-24	2.13	1.96	2.33	**2.14**	559.4	548.1	552.2	**553.28**	0.16	0.17	0.16	**0.16**	89.5	93.1	92.04	**91.58**
SDE.±	0.09				4.22				0.00				3.48			
CD @ 1%	0.26				11.43				0.01				9.40			
CD @ 5%	0.19				8.54				0.01				7.03			

Table 5: Growth attributes of 4 promising plant populations/clones under BST-II (2023-24)

Cultivars	*Plant height (cm)*				*Canopy (cm)*				*Total no. of branches/plants*			
	R_1	*R_2*	*R_3*	*Mean*	*R_1*	*R_2*	*R_3*	*Mean*	*R_1*	*R_2*	*R_3*	*Mean*
CIMAP-K14	51.54	49.48	52.86	**51.29**	195.3	185.3	195.1	**191.9**	44.00	41.66	43.00	**42.8**
CIMAP-K24	56.09	60.87	61.26	**59.40**	194.1	197.3	185.3	**192.2**	59.00	56.00	52.66	**55.8**
CIMAP-K28	51.43	52.85	52.53	**52.27**	178.3	172.5	182.3	**177.7**	41.00	38.66	42.00	**40.5**
CIMAP-K30	50.37	49.92	50.56	**50.28**	172.9	172.6	174.1	**173.2**	31.00	38.00	39.00	**36.0**
CIM-BHARAT	50.62	59.04	49.40	**53.02**	177.5	174.7	182.6	**178.2**	51.66	53.00	51.66	**52.1**
SDE. ±	0.877				1.859				0.917			
CD @ 1%	2.371				5.027				2.480			
CD @ 5%	1.772				3.757				1.853			

Table 6: Yield attributes of 4 promising plant populations/clones under BST-II (2023-24)

Cultivars	*Leaf:Stem ratio*				*Fresh biomass (q ha^{-1})*				*Essential oil content (%)*				*Essential oil yield (kg ha^{-1})*			
	R_1	*R_2*	*R_3*	*Mean*	*R1*	*R2*	*R3*	*Mean*	*R1*	*R2*	*R3*	*Mean*	*R1*	*R2*	*R3*	*Mean*
CIMAP-K14	1.96	1.8	2.0	**1.95**	599.8	577.8	570.0	**582.5**	0.157	0.150	0.157	**0.154**	93.9	86.6	89.3	**89.9**
CIMAP-K24	2.7	2.6	2.6	**2.65**	605.0	603.8	609.7	**606.2**	0.200	0.197	0.193	**0.197**	121.0	118.7	117.8	**119.2**
CIMAP-K28	3.1	3.5	3.5	**3.36**	598.5	591.8	594.5	**594.9**	0.183	0.183	0.187	**0.184**	109.7	108.5	110.9	**109.7**
CIMAP-K30	2.4	2.4	2.6	**2.47**	586.8	581.2	586.6	**584.8**	0.183	0.190	0.183	**0.186**	107.5	110.4	107.5	**108.5**
CIM-BHARAT	2.1	2.1	2.4	**2.2**	581.6	561.3	557.0	**566.6**	0.163	0.167	0.167	**0.166**	94.9	93.5	92.8	**93.7**
SDE.±	0.056				2.877				0.002				1.334			
CD @ 1%	0.151				7.779				0.005				3.607			
CD @ 5%	0.113				5.814				0.004				2.696			

Table 7: Comparative studies on performance and yield potential of 'CIMAP-K24' and 'CIM-Bharat' at multi-harvesting in northern regions of India

Harvest	*Leaf:Stem ratio*		*Fresh biomass (q ha^{-1})*		*Essential oil content (%)*	
	CIM-BHARAT	*CIMAP-K24*	*CIM-BHARAT*	*CIMAP-K24*	*CIM-BHARAT*	*CIMAP-K24*
H_1	1.84	2.58	425.4	541.3	0.11	0.12
H_2	1.54	2.34	274.6	288.0	0.11	0.11

Harvest	*Essential oil yield (kg ha^{-1})*		*Total oil yield (kg ha^{-1}) [H_1+H_2]*	
	CIM-Bharat	*CIMAP-K24*	*CIM-Bharat*	*CIMAP-K24*
H_1	49.62	64.96	81.7	97.6
H_2	32.04	49.62		

Location: CSIR-CIMAP, Lucknow district (UP). [b] H_1: First harvesting; H_2: Second harvesting.
[*]Planting time: First fortnights of December 2022; First harvesting time: Second fortnights of April 2023 (130-140 Days after planting); Second harvesting time: First fortnights of August 2023 (90-100 Days after first harvest).

Figure 1: Close-up view of 5 potential candidate clones

Figure 2: Field view of candidate clone CIM-Sangam at CSIR-CIMAP, Lucknow, U.P.

Table 8: Agronomic features of proposed clone CIMAP-K24

S. No.	*Agronomic features*	*Comments*
1.	Resistance to abiotic and biotic stresses	Resilient
2.	Fertilizer application	180:60:60 kg ha^{-1}
3.	Planting time	Mid Nov-Jan
6.	Transplanting	30-45 DAS
7.	Ist Harvesting	130–140 Days after transplanting
	IInd Harvesting	90–100 Days after the first harvest

Table 9: Distinct morphological and other features of clone CIMAP-K24

S. No.	*Plant characteristics*	*CIM-sangam*
1	Leaf:Stem ratio	2.00–3.00
2	Propagation	Vegetative propagation (Stem cutting)
3	Herb yield (q ha^{-1})	600–615
4	Oil yield (kg ha^{-1})	70–80 (in each harvesting)
5	Establishment after planting (%)	95–98%
6	Geraniol (%)	15.08%
7	Citronellol (%)	29.48%
8	6,9-Guaidiene (%)	3.36%
9	10-epi-γ-eudesmol	0.19%
10	C:G ratio	1.95

and detailed in Tables 1 and 2. Four top-performing clones were evaluated from 2021 to 2024 in bench scale trials (BST-I and BST-II), using CIMAP-24 as the reference variety, with results shown in Tables 3–6. Among them, a high-yielding and fungal-resistant clone, CIMAP-K24, demonstrated significant superiority over other strains. Subsequently, this lead strain underwent pilot scale trials (PST) at CSIR-CIMAP, Lucknow, in 100 m^2 plots alongside CIM-Bharat as presented in Table 7. After consistently maintaining its superior performance, this strain was officially released as the variety CIM-Sangam, (Figure 2), designed for large-scale cultivation in the northern plains. The proposed “CIMAP-K24” clone has a strong stem and is stable in the Northern plains of India.

Historically, CSIR-CIMAP has released geranium varieties such as CIM-Pawan (2003) and CIMAP-BIO171 (2013), which were preferred for their favourable C: G ratio (~1) and high 10-epi-γ-eudesmol content. However, their oil yield remained insufficient to meet industrial demands. Later, the market demand shifted towards Chinese-type cultivars with a C:G ratio of more than 3.0 and a high concentration of 6, 9-guaiadiene, leading to the release of CIM-Bharat in 2022. Despite these advancements, existing varieties struggled to adapt to fluctuating environmental conditions and fungal infections. The development of CIM-Sangam fills this critical gap by combining high oil yield, desirable chemical composition, and enhanced resilience to fungal infections, making it the most suitable variety for large-scale cultivation in the northern Indian plains.

Results

The proposed clone oil yield in the first harvest was 65.0 and 32.64 kg ha^{-1} in the second harvest. The clone leaves

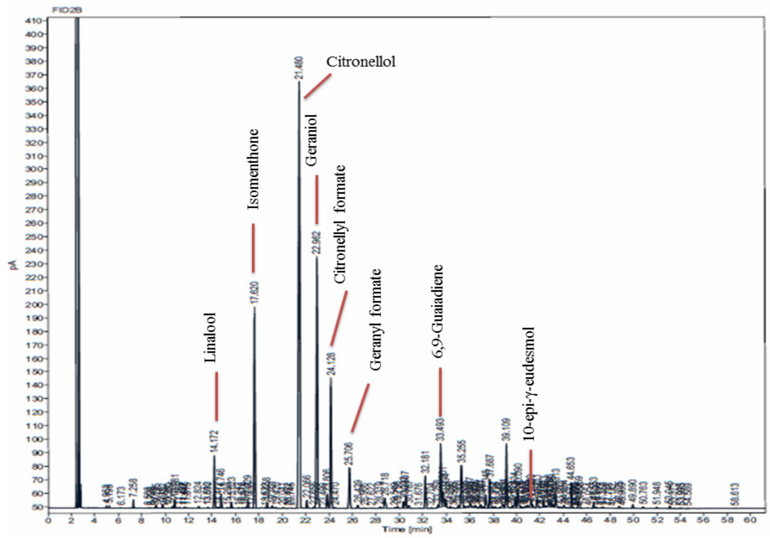

Figure 3: Chromatographic profile (GC: total ion chromatogram) of rose-scented geranium clone proposed for release

Table 10: Aromatic essential oil composition of *Pelargonium graveolens* clone proposed for release

Compound	*RI[a]*	*RI[b]*	*Content (%)*			
			Clone	*ISO-2012*		
			CIM-Sangam	*China*	*Bourbon*	*North africa*
Linalool	1101	1095	2.27	2.0–4.5	8.0–11.0	4.0–8.5
(*Z*)-Rose oxide	1111	1106	0.64	1.3–3.5	0.3–1.1	0.7–1.5
(*E*)-Rose oxide	1127	1122	0.31	0.5–1.5	0.1–0.5	0.3–0.6
Menthone	1152	1148	0.40	n.d.-2.5	n.d.-2.0	n.d.-2.1
Isomenthone	1163	1158	9.61	4.0–7.0	5.0–10.0	4.0–8.0
α-Terpineol	1190	1186	0.14	0.1–0.5	0.3–1.2	0.3–0.6
Citronellol	1233	1223	29.48	32.0–43.0	18.0–26.0	25.0–36.0
Geraniol	1256	1249	15.08	5.0–12.0	12.0–20.0	10.0–18.0
Citronellyl formate	1277	1271	6.99	7.0–12.0	6.5–11.0	4.0–8.0
Geranyl formate	1303	1298	2.47	1.0–3.0	4.0–8.0	2.0–7.0
6,9-Guaiadiene	1443	1442	3.36	4.0–7.0	5.0–8.5	n.d.–0.5
Geranyl butyrate	1563	1562	3.12	0.4–1.0	0.7–2.0	0.7–2.0
2-Phenylethyl tiglate	1586	1584	1.16	0.4–1.0	0.4–1.0	0.5–1.2
10-epi-γ-eudesmol	1618	1622	0.19	n.d.	4.0–7.0	3.0–6.2
Geranyl tiglate	1703	1696	1.25	1.0–1.6	0.7–2.0	0.9–2.0

[a]RI: retention index determined on HP-5 column; [b]RI: retention index from literature; nd: not detectable

are dark green with vigorous upright growth like CIM-Bharat and are more tolerant to major fungal pathogens of *P. graveolens*. Leaf:Stem ratio 2.46 and oil content of 0.12%. The two main essential oil constituents are citronellol and geraniol content with 29.48 and 15.08%, respectively, as shown in Figure 3. The minor constituent 6, 9-guaiadiene, is present in a concentration of 3.36%.

Initial evaluation trial (IET)

Layout: Randomized complete block design (RCBD), Replications: 3, Plot size: 6.25 m^2.

Bench scale trials-I (BST-I): 2021-2022

Location: CIMAP, Lucknow, India) (Layout: RCBD, Replications: 3, Plotsize: 6.25 m^2.

Bench scale trials-II (BST-II): 2023-2024

Location: CIMAP, Lucknow, India) (Layout: RCBD, Replications: 3, Plotsize:6.25 sqm.

Pilot scale trial

Year (2022-2023) (Layout: Plotsize: 100 m^2, 50 kg steam distillation unit.

Agronomic features (e.g., resistance to lodging, shattering, fertilizer responsiveness, suitability to early or late sown conditions, seed rate, etc.)

The agronomic characteristics of CIMAP-K24, including its growth performance, yield potential, and other key traits, are presented in Table 8, providing a comprehensive overview of the variety's field performance and adaptability.

Statement of distinction

The proposed clone CIMAP-K24 is a fast-growing, upright, robust herb with a dark green stem. CIM-Sangam is distinguished by its superior fungal tolerance, elevated leaf-to-stem ratio, substantial biomass production, high essential oil yield, and greater branch proliferation compared to the reference variety CIM-Bharat, as detailed in Table 9. The proposed clone shows tolerance to biotic stress during the rainy season in the northern region of India, thereby increasing survivability. The C: G ratio of the proposed clone is lower (< 2) than the existing check variety, CIM-Bharat.

The development and release of the geranium variety *CIMAP-K24* address a critical gap in the commercial cultivation of rose-scented geranium in India, particularly in sub-tropical and temperate regions. Existing commercial varieties exhibit limited adaptability to diverse agro-climatic conditions, lack structural robustness, and are highly susceptible to harvest shock (>80%) when cultivated as annual crops. Furthermore, these varieties suffer from low oil yield and heightened vulnerability to biotic stress, significantly reducing their commercial viability. Given the increasing demand from farmers, growers, and the perfumery industry, *CIMAP-K24* has been selectively developed to integrate key desirable traits, including high herb and oil yield, enhanced fungal tolerance, and a balanced Citronellol:Geraniol (C:G) ratio of <2. Additionally, the variety demonstrates the presence of essential secondary metabolites, such as 6, 9-Guaiadiene and 10-epi-γ-eudesmol, which are critical for superior oil quality. Notably, *CIMAP-K24* exhibits strong resistance to major diseases and insect infestations, making it a highly sustainable choice for large-scale cultivation. With its distinctive dark green foliage, sturdy stems, superior oil yield, and resilience to both biotic and abiotic stress, this variety is well-suited for commercial cultivation in sub-tropical and temperate regions, offering a reliable and high-value alternative for the perfumery and aroma industries.

Author Contribution

ZIW: performed plant tissue culture, molecular characterization, genetic improvement, field data recording, data preparation, and statistical analysis. KK: contributed to the development and analysis of somaclonal variants, molecular work, and field data collection. AS and KS: conducted pathological analyses, including both *in-vivo* and *in-vitro* evaluations. SKV: supported experimental design, plant tissue culture, field preparation, and data interpretation. RKV: managed germplasm collection, agro-technology, and field trials. GP and TS: were involved in field evaluation and data collection. ZH: contributed to data interpretation. RSV and MS: performed chemical profiling. ST: handled commercial-scale steam distillation. LUR: conceptualized the study, designed the experiments, prepared the proposal, and contributed to agro-technology development, variant selection, data preparation, and interpretation.

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Conflict of Interest

The authors declare no conflict of interest.

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