Journal of Medicinal and Aromatic Plant Sciences 44(3-4), 2022, 127-134

NEW VARIETY RELEASE

Registration of CIM-Vrinda: A citral (Neral and Geranial) rich high essential oil yielding variety of *Ocimum basilicum* L.

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Article History

Received: August 24, 2022
Revised: September 18, 2022
Accepted: September 20, 2022

Key Words

CIM-Vrinda
Citral
Essential oil
Geraniol
Neral
Ocimum Basilicum

ABSTRACT

*Citral oil holds a 41.5% market share in the booming global essential oil industry (CAGR of 9.57%). Citral (3,7, dimethyl-2,6-Octadienal), is a chemical compound made up of the aldehydes citral A (Geranial) and citral B (Neral). Ocimum basilicum, which can produce a short duration, quick bumper supply with minimal resources and fits in the crop cycle of important cereals and pulses, could satisfy a requirement for early growth, high biomass of "citral," within 3–4 months. To cater to the pacing demand, CSIR-CIMAP developed releases "***CIM-Vrinda***", a citral-rich high essential oil yielding variety of Ocimum basilicum L. with an average citral content of 77-80%, potential fresh herb yield of 450-460q/h, and essential oil yield of 140-150Kg/ha in a single harvest of 3-4 months. CIM-Vrinda can be identifiable through glossy dark green (RHS 144A), undulated lamina margin, long leaf, and inflorescence with the pink corolla, with 77-81% citral content in essential oil obtained from the fresh herb, fetching a net income of more than Rs 83,500-1,00,000 Lakhs per ha. Culturing in agroclimatic zones IV, V, VIII & X is recommended.*

INTRODUCTION

The global essential oil market is expected to grow from $9.62 billion in 2021 to $18.25 billion in 2028, and citral oil constitutes a 41.48% share of this market. Citral($C_{10}H_{16}O$) is a pale yellow liquid with a strong lemon odor that naturally occurs in the essential oils of plants. Chemically it is a mixture of two aldehydes Citral A (Geranial) and Citral B (Neral) that have the same molecular weight (152.2334) but different stereoisomeric structures. It is insoluble in water but soluble in ethanol, diethyl ether, and mineral oil. It has a high demand for perfumes and flavoring, lemon essence and hygiene products, sanitizers, personal care, food and beverages, and in the manufacture of other chemicals.

There are limited ISO-certified natural sources of citral oil, primarily catered by lemongrass (*Cymbopogon flexuous*). Lemongrass starts yielding essential oil in six to eight months of cultivation. It holds the farmer's field for a longer time which opens the demand for a quick supply, low resource intensive, majorly rainfed and could sustain high moisture stress, fitting in the crop cycle of major cereals and pulses. Citral is biosynthesised in *Ocimum* species like *Ocimum africanum* Lour (upto 75%), *Ocimumpilosum* (35%) *Ocimum americanum* (65.6%), *Ocimum citriodorum* (79%), *Ocimum canum* (71.9%), (Pandey *et al*., 2014), *Ocimum basilicum* green (46.1%), Limoncino (*O. basilicum* (50%) (Souse *et al*., 2021).

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Doi: https://doi.org/10.62029/jmaps.v44i4.Jhang

Though the other species of *Ocimum* biosynthesizing citral are low in biomass, *Ocimum basilicum* has high branching, and canopy area, accounting for its high biomass and, therefore, high essential oil yield. Authors have carried out ten years of citral-targeted half-sib selections for essential oil content combined with high essential oil yield to make *Ocimum baslilicum* the most suitable, viable option to breed for Citral(Neral and Geranial). This variety will now serve as a sustainable, low-cost citral resource at par with lemongrass (citral content up to 65-85%) and a quantum-fold yield over all existing natural citral resources from other *Ocimum* species. In India, only one citral-rich *Ocimum* variety CIM-Jyoti (Lal *et al*., 2014) is used as a check here. Since the proposed variety is significantly greater in total essential oil yield and high biomass over the check, this applies to registration for the commercial release.

MATERIALS AND METHODS

The citral oil yield improvement in *Ocimum basilicum* was initiated in 2012 with extensive screening of a large germplasm of *Ocimum basilicum* with 150 accessions, for its essential oil diversity for two years, i.e., 2012 and 2013. The large population size under the initial evaluation trial further led to isolating distinct breeding lines regarding their morphotype and citral content. Advance evaluation trial (AVT) in two phases, AVT I was carried out for 2018 & 2019 with three entries with their sub-populations along with check CIM Jyoti (Lal *et al*., 2014) with seven replicates. AVT II was carried out for 2020 & 2021 with three entries with their subpopulations and check CIM Jyoti with eleven replicates evaluated for essential oil yield and citral content with defined selection thresholds (Allard, 1960).

Parameters and their abbreviations used

The parameters used for evaluation were days to 50% flowering (DTF) and days to maturity (DTM). Citral content (%) in the essential oil, essential oil content (EOC) (%), fresh herb yield (FHY) (gm, Kg, q), essential oil yield (EOY), plant height (P.H.) (cm), plant canopy (CAN) (cm square), inflorescence length (SPKL) (cm), number of whorls in the inflorescences (NWS), leaf length (L.L.)(cm) leaf width (L.W.) (cm), leaf shape (L.S.), leaf area (L.A.) (cm square) and leaf stem ratio (LSR), which were assessed at the essential oil analysis. Essential oil analysis was carried out at full bloom stages, and agronomic performance was recorded twice at full bloom stage and maturity. The fresh herb yield observation presented here is at the full bloom stage.

Essential oil extraction and gas chromatography-mass spectrometry

The sampling was carried out at the full bloom stage for essential oil profiling. Fresh Inflorescence and leaves of 10 plants from each replication for all entries (200gm each) were hydro distilled for 4 hrs. using a Clevenger's type apparatus, and essential oils collected were dried over anhydrous Na_2SO_4 and stored at 4^oC until further analysis. Gas chromatography was conducted on Perkin Elmer Autosystem XL GC equipped with Equity-5 column (Length 30m x I.D. 0.25um, film thickness 250 um) and flame-ionization detector to quantify the components present in oils. Hydrogen was used as carrier gas at a constant flow rate of 1ml/min, 10psi and injection volume was 0.2ul(dilute in DCM) worked in split mode with a split ratio of 1:100. The oven temperature was programmed from 60 ^oC to 240 ^oC at the ramp rate of 3 ^oC/min. Injector, and detector (FID) temperatures were maintained at 290 ^oC each.

Identification of components was carried out using GCMS on a Perkin Elmer Clarus 680 GC interfaced with a Clarus SQ8C Quadrupole mass spectrometer. Programmed Split/Splitless(PSS) injector temperatures were 250 ^oC with a Split ratio of 1:50 Column oven was programmed from 270 ^oC at 5 ^oC/min. Helium was used as carrier gas at a constant flow of 1ml/min, interface and source temperatures were 280 ^oC; electron impact ionization mode (EI+) was used with ionization energy of 70eV; scan duration comprised of scan time (0.39s) inter scan delay (0.01s) and mass scan range50-600 amu. Characterization was based on relative retention index using homologous series of n-alkane (C6-C28 hydrocarbons, Polyscience Corp. Nile IL), retention time, order of elution, and simultaneous injection with standards in GC-FID and GCMS & comparisons of M.S. libraries (Turbo Mass NIST 2011 ver 2.3.0 Wiley registry of mass spectral data (9 edition) and comparing with mass spectral literature data (Adam RP,1995).

Statistical analysis

Statistical analysis was performed using software R with different packages like 'variability'.

Variation among lines was compared using the least significant difference (LSD at 1%level of probability. Multivariate principal component analysis was performed using package 'pca'.

RESULTS AND DISCUSSION

Pedigree and genetic development of the variety

The citral oil yield improvement in *Ocimum basilicum* was initiated in 2012 with 150 accessions belonging to *O. sanctum, O. africanum, O. klimandcharicum, O. gratissimum* and *O. basilicum* which were extensively screened for their essential oil diversity for two years, i.e., 2012 and 2013. A few natural hybrids with mild to moderate citral content odor were found in the tall, high-biomass French basil base populations with low essential oil content. They were further subjected to paired row preliminary yield trial (PYT). Selections were carried out further in a preliminary yield trial (2014-2015) within individual plant progenies (population size=80-100 plants per entry) of these selected entries along with check CIM Jyoti, which was released in 2014 and had very high citral content but limited biomass and hence low essential oil yield. To overcome this essential oil yield (EOY) gap in *Ocimum*, the selected six entries' stabilized breeding lines were subjected to initial evaluation trials in 2016 and 2017 with a large population size with five replications each (4.5mx3.5m plot size and 30cmx30cm row-to-plant spacing). At least 150 plants screened per replication. All entries with citral content less than 60% were rejected. The large population size under the initial evaluation trial further led to the isolation of distinct breeding lines regarding their morphotype and citral content. Advance evaluation trial (AVT) was performed in two phases. AVT I was carried out for 2018 & 2019 with three entries, their subpopulations along with check CIM Jyoti with its seven replicates, and AVT II was carried out for 2020 & 2021 with three entries, their subpopulations along with check CIM Jyoti in eleven replicates. Essential oil yield and citral content were evaluated with defined selection thresholds.

Preliminary yield trial (2014 & 2015)

Nine lines were selected from the gene pool of selected *O. basilicum* germplasm for citral content and herb weight based on initial essential oil screening in 2012 and 2013. They were subjected to preliminary yield trial (2014 & 2015) with individual plant progenies (population size=150-165 plants per entry) of these selected entries along with

Table 1: Performance means of nine entries along with check CIM Jyoti in the preliminary yield trial (PYT: 2014 & 2015)

ENTRY	DTM	PH	EOC	Citral Content %	FHY/plot (Kg)	EOY/plot (g)
G-10	108.00	76.33	0.18	38.53	77.25	136.6
G-28	106.50	120.67	0.52	64.38	86.75	445.5
G-38	115.00	121.00	0.30	37.00	71.25	213.8
G-43	101.00	116.00	0.21	54.33	72.00	154.2
G-63	109.50	121.00	0.22	52.50	81.00	179.2
G-87	105.75	119.83	0.11	53.33	124.75	137.4
G-132	110.00	108.00	0.26	61.43	78.00	200.2
G-138	104.50	117.00	0.21	55.38	50.50	264.5
G-147	122.00	109.67	0.44	58.67	70.50	312.9
CIM-Jyoti	**96.67**	**75.67**	**0.67**	**66.00**	**19.20**	**128.7**
S.Em	2.89	3.04	0.03	1.07	19.803	35.23
C.D(5%)	8.21	8.66	0.09	3.05	56.3083	100.23
C.D(1%)	10.95	11.54	0.12	4.07	75.1155	133.71
MSS_Rep,df=2	12.754	46.72	0.001	3.69	1594	569
MSS, entry,df=9	298.76***	1887.87***	0.21***	574.43***	395.4***	57094***
MSS_Residual,df=48	25.01	27.8	0.01	3.46	1176	3728

Rep=3, Net Plot Size 4.5x3.5m^2; Test area/entry =15.75m^2 , spacing30x30cm; Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

check CIM Jyoti which was by that time released in 2014 and had very high citral content but limited biomass and hence low essential oil yield. Three replicates/entries, each with the row-to-plant spacing of 30x30cm in randomized block design as per standard agronomic and agricultural practices, were evaluated in PYT (Table 1). Subsequently, entries with citral content > 50% and essential oil content >0.2% were selected.

Initial evaluation trial (2016 & 2017)

Six entries from PYT were evaluated at the IET station trial with check CIM Jyoti in RCBD with plot size 4.5 x 3.5m^2 with five replications as per standard agronomic and agricultural practices (Table 2). Entries with citral content> 55% or essential oil content >0.2% were selected.

Advance variety yield trial phase I (2018 & 2019)

Three entries G147, G132, and G28, qualified for initial evaluation trial. Promising intra-populations variations for essential oil and citral content and slight phenotypic variations were observed. Phenotypically distinct four half-sib lines were extracted from entry G132, hereby termed G132-1, G132-1, G132-3, G132-4, and similarly, three phenotypic distinct half-sib lines were extracted from G28, hereby termed G28-1, G28-2, G28-3. Thus eight entries (main entry along with their extracted half-sib lines) were evaluated for 23 quantitative agronomic traits and DUS characters, leaf colour, and flower color as per RHS chart in seven replication in RCBD along with check CIM Jyoti in plot size 4.5 x 3.5 m^2. Half sib selection for citral content > 60%, EOC>0.3%, and uniformity in large population size under the initial evaluation trial further led to the isolation of homozygous distinct breeding lines and higher citral content (Table 3).

Advance variety yield trial phase II (2020 & 2021)

Five half-sib entries were carried forward in the final advance variety trial phase II, and pilot scale data were scrutinized for two years for all the parameters discussed in AVT I besides essential oil yield parameters in 50 Kg CIM-Asvika distillation units as presented (Table 4).

Statement of distinction

CIM-Vrinda variety has been generated through half-sib selection for high neral (35.779%) and geranial (44.764%), with total citral content reaching 77-81% and a minor note from 6-methyl-5 heptene-2-one (0.6%), nerol (3.752%) and geraniol (1.130%). The essential oil content is 0.65%-0.70%, and fresh herb yield is 450-480q/ha, essential oil yield 140-150 kg/ha. The comparison with check CIM-Jyoti, along

Table 2: Performance means of six entries along with check CIM-Jyoti in the initial evaluation trial (IET:2016 & 2017)

ENTRY	DTM	PH	EOC	Citral Content%	FHY/plot (Kg)	EOY/plot (g)
G-28	117.00	121.70	0.61	65.31	84.90	519.4
G-43	111.00	111.60	0.23	53.77	65.55	151.6
G-63	110.00	119.70	0.21	53.53	81.16	171.0
G-132	108.00	107.40	0.24	60.75	80.03	193.7
G-138	103.78	119.17	0.20	50.36	98.90	196.0
G-147	127.00	122.17	0.39	62.74	69.19	271.9
CIM-Jyoti	**101.40**	**75.40**	**0.65**	**67.42**	**25.50**	**165.9**
S.Em	1.27	1.13	0.01	0.61	1.03	9.09
C.D(5%)	3.60	3.19	0.04	1.73	2.93	25.73
C.D(1%)	4.78	4.24	0.05	2.31	3.89	34.24
MSS_Rep,df=4	17.75	4.56	0.00	3.76	11.20	799
MSS, entry,df=6	712.24***	2753.36***	0.367***	356.32***	5420.2***	167823***
MSS_Residual,df=59	8.07	6.34	0.00	1.87	5.30	414

Rep=3, Net Plot Size 4.5x3.5m^2; Test area/entry =15.75m^2, spacing30x30cm; Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

Table 3: Performance means of entries in advance variety trial (AVT I) during 2018 & 2019

Entry	Year	DTF	LSR	PH	Citral-Cont %	EOC	FHY/ Plot (Kg)	EOY/ plot (g)	^FHY/ha (q)	^EOY/ha (Kg)
G147	**2018**	129.71	2.25	103.33	61.13	0.37	73.19	273.45	406.18	151.83
G132-1	**2018**	120.98	2.26	108.33	63.50	0.34	78.97	267.30	438.28	148.39
G132-2	**2018**	122.43	2.24	116.83	63.29	0.35	74.74	265.66	414.83	146.59
G132-3	**2018**	106.71	2.07	100.83	53.47	0.22	72.68	159.83	403.39	88.84
G132-4	**2018**	122.66	2.13	102.08	55.17	0.22	88.91	199.41	493.46	110.79
G28-1	**2018**	117.93	2.42	120.60	75.43	0.66	83.15	551.66	461.51	306.6
G28-2	**2018**	111.86	2.46	106.67	58.16	0.24	70.92	172.00	393.59	95.31
G28-3	**2018**	111.40	2.40	109.80	65.86	0.42	83.75	349.63	464.80	193.35
CIM-Jyoti	**2018**	**87.43**	**1.50**	**86.75**	**71.12**	**0.65**	**33.18**	214.92	184.15	119.26
G147	**2019**	129.86	2.39	112.66	62.29	0.43	83.55	360.71	463.71	200.02
G13/*=2-1	**2019**	121.98	2.43	102.00	66.16	0.42	83.79	348.60	465.01	193.44
G132-2	**2019**	122.43	2.40	114.82	61.86	0.42	70.24	293.73	389.85	163.03
G132-3	**2019**	106.00	2.16	103.80	48.83	0.24	73.97	179.15	410.53	99.51
G132-4	**2019**	112.29	2.28	105.81	62.43	0.24	77.38	181.83	429.45	101.25
G28-1	**2019**	106.71	2.66	117.71	76.77	0.68	86.55	536.07	469.23	297.53
G28-2	**2019**	127.12	2.49	104.60	57.95	0.24	85.05	204.03	472.05	113.15
G28-3	**2019**	127.12	2.49	107.74	62.18	0.43	85.05	362.59	472.05	201.25
CIM-Jyoti	**2019**	**91.29**	**1.54**	**89.56**	**70.84**	**0.64**	**33.75**	217.43	187.31	120.67
SEm		2.6420	0.09	3.61	1.15	0.01	39.51	11.08	15.4	8.20
CD 5%		7.41	0.24	10.11	3.21	0.03	2870.5	31.06	43.17	22.98
CD 1%		9.80	0.32	13.38	4.25	0.04	30.32	41.08	57.10	30.41
MSS_Rep, df=6		43.30	0.256	71.42	6.44	0.000	2.08	910	2163	498
MSS, entry, df=10		1544.14***	1.04	1049.99***	542.38***	0.29***	5.583***	156727***	125189***	85823***
MSS, Residual,df=109		48.86	0.05	91.14	9.19	0.00	7.72	860	1660	471

Rep=11, Net Plot Size 4.5 x 3.5m^2; Test area/entry =173.25m^2, 30x30cm, Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' ^ Estimated Yields

with distinguishing unique features, is presented in Table 5. The CIM-Vrinda can be identifiable through glossy, dark green (RHS 144A) undulated lamina margin, long leaf length and Inflorescence with the pink corolla, with 77-80% citral content in essential oil obtained from fresh herb (Table 6.).

Table 4: Performance means of entries in advance variety trial (AVT II) during 2020 & 2021

Entry	Year	EOC	EOC pilot	Citral%	FHY/plot (Kg)	EOY/ plot (g)	EOY/ pilot (g)	^FHY/ha (q)	^EOY/ha (Kg) pilot
G147	2020	0.42	0.16	61.80	72.19	302.7	11.24	400.64	62.53
G132-1	2020	0.45	0.22	65.15	82.00	37.28	18.02	455.09	100.15
G132-2	2020	0.40	0.18	65.00	74.15	29.39	13.34	411.56	74.05
G28-1	2020	0.72	0.32	78.13	86.22	78.92	27.99	479.41	152.67
G28-3	2020	0.42	0.20	71.00	96.15	40.43	18.96	533.62	105.21
CIM-Jyoti	**2020**	**0.65**	**0.32**	**71.86**	**29.88**	**19.28**	**9.44**	**165.82**	**52.41**
G147-1	2021	0.44	0.16	61.80	71.54	31.58	11.14	472.18	80.32
G132-1	2021	0.41	0.22	65.15	87.55	36.06	19.23	485.88	86.15
G132-2	2021	0.41	0.18	65.00	87.55	35.82	15.75	397.03	71.13
G28-1	2021	0.70	0.34	79.03	85.77	71.02	28.03	474.49	148.95
G28-3	2021	0.44	0.22	72.39	87.05	38.01	18.04	482.91	93.78
CIM-Jyoti	**2021**	**0.64**	**0.32**	**71.86**	**34.53**	**21.99**	**10.89**	**191.63**	**59.89**
SEm		0.02	0.005	0.473	1.77	17.61	4.94	13.18	3.87
CD 5%		0.05	0.014	1.32	4.97	49.33	13.83	36.94	10.82
CD 1%		0.070.003	0.018	1.752	6.57	65.24	18.30	48.84	14.31
MSS_Rep, df=10		0.37***	0.001	8.59	10.4	3005	158	574	159
MSS, entry, df=6		0.004	0.11***	837.78	10355***	408736***	88539***	564416***	48194***
MSS_Residual, df=114			0.001	2.46	34.6	3412	268	1913	164

Rep=11, Net Plot Size 4.5x3.5m^2; Test area/entry =173.25m^2, 30x30cm Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' ^ Estimated Yields

Table 5: Distinguishing features of CIM-Vrinda

Characteristics	CIM-Vrinda	CIM-Jyoti (Check)
Plant Growth Habit	Rounded	Intermediate
Plant height	Medium	Short
Plant Density	Dense	Loose
Stem Hairiness	Present	Present
Leaf Blade: Shape	Elliptic	Ovate
Leaf Blade: Length	Long	Short
Leaf Blade: Breadth	Narrow	Medium
Leaf Color Green	Dark green	Light
Leaf Blade Glossiness	Strong	Medium
Leaf blade serration of margin	Medium	Shallow
Leaf Blade: depth of serration	Medium	Shallow
Leaf Blade: Undulation of margin	Strong	Weak
Petiole length	Medium	Short
Inflorescence lengths	Medium	Short
Flowering stem: Hairiness of bracts	High	Moderate/Low
Flower: Color of corolla	Very Light Pink	White
Flower: Color of style	Purple	White
Time of Flower	medium	Early

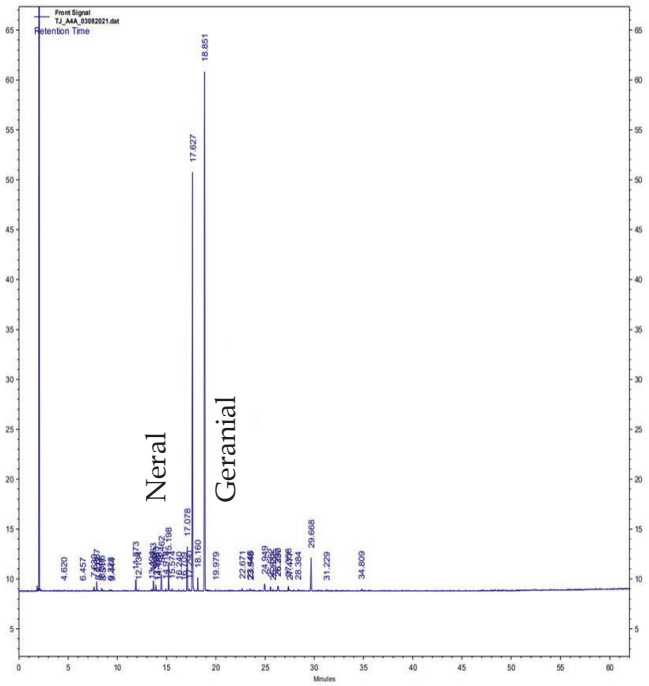

Figure 1: Signature peaks of Neral and Geranial in the chromatogram of the essential oil of variety CIM-Vrinda

Table 6: Identifying DUS traits for the CIM-Vrinda and the check CIM-Jyoti

DUS Characteristics	CIM-Vrinda	CIM-Jyoti (Check)
Plant height	Medium	Short
Plant Density	Dense	Loose
Leaf Blade: Shape	Elliptic	Ovate
Leaf Blade: Length	Long	Short
Leaf Blade: Breadth	Narrow	Medium
Leaf Margin	Undulated	Normal
Leaf Apex	Acute	Acuminate
Time of Flower	Medium	Early

Table 7: GCMS base major constituent in the essential oil of CIM-Vrinda and its comparison with CIM-Jyoti (Check) and BIS Standards for lemon grass variety

Compound	RI obs	R.I. lit	CIM- Vrinda G28-1 / (FSA4A)	CIM-Jyoti	*C. flexuosus* (BIS 327: 1991)
β-Pinene	982	976	0.25	0.9	
6-methyl-5-hepten-2-one	990	985	0.59	0.1	0.1-2.0%
β-Myrcene	994	991	0.10	0.05	
α-Phallendrene	1006	1002	0.22	-	
ä-3-carene	1010	1006	0.08	0.14	
Linalool	1103	1095	0.87	3.62	
Nerol oxide	1157	1154	0.49	0.49	
Nerol	1240	1227	0.20	0.18	
Neral	1249	1244	35.78	34.13	25-35%
Geraniol	1261	1249	1.13	1.68	1.5-7.0%
Geranial	1278	1264	44.77	42.13	35-47%
Neryl Acetate	1364	1359	0.18	0.13	
Geranyl Acetate	1390	1379	0.08	0.24	0.5-6%
trans-Caryophyllene	1426	1417	0.80	1.09	
trans α Bergamotene	1442	1432	0.40	0.53	
(Z, β) Farnasene	1449	1477	0.09	0.07	
α-Humulene	1461	1455	0.39	0.997	
Bicyclogermacrene	1487	1478	0.44	0.95	
Germacrene D	1490	1484	0.11	0.094	
trans-Muurola-4(14)-5-diene	1499	1491		0.09	
Cis α-Bisabolene	1549	1537	2.96	2.54	
Caryophyllene oxide	1589	1581	0.08	0.07	
Total Identified			90.0	90.0	

Figure 2: Field view of variety CIM-Vrinda

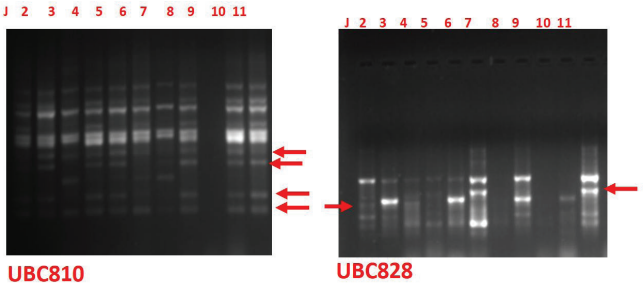

Figure 3: DNA fingerprints using UBC810 and UBC828 on CIM-Jyoti (J) and G28-1 derived HS lines (2-10) and CIM-Vrinda(11)

The team did not observe any major incidence of pests or diseases-causing significant damage to the crop of more than 5% as the exit to excess water in monsoon was well maintained.

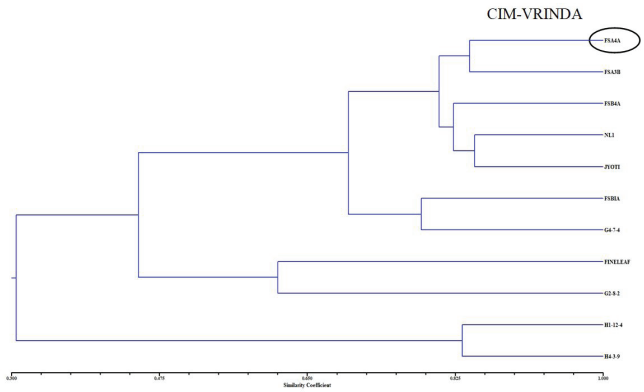

Figure 4: DNA fingerprints using UBC ISSR markers based on phylogenetic clustering of CIM-Vrinda, other half-sib progenies and the check CIM-Jyoti

Conflict of Interest: The authors declare that they have no conflict of interest

ACKNOWLEDGMENTS

The encouragement and institutional facility received from Director CSIR-CIMAP, Lucknow and the funding support received over the years under CSIR-funded Supra Institutional Project BSC 0203 (2013-15), and CSIR-AROMA MISSION (Phase I) is duly acknowledged. "**CIM-Vrinda"** is released under the aegis of the CSIR-AROMA Mission.

Note: CIM-Vrinda, developed by CSIR-CIMAP, was released for commercial cultivation on the occasion of CSIR-CIMAP 44 the Annual Day on 22nd August 2022.

Table 8: Recommended agro-cultivation practices and schedule

Agro-operation	Recommendations &Crop schedule
Climate	Subtropical to Tropical under 26-35 C temperatures,100-350mm rainfall regions
Soil	Sandy Loam to loam soil with neutral reaction (pH 8.5-7.5), Well-drained
Nursery	April-end-May first week
Transplanting	40 days to sowing
Weeding	Needed once in 20-25 days of transplanting
Manures and Fertilizers	Apply FYM@ 8-10t/ha along with 80(N):40(P):40(K) Kg where 80N is divided into 3 equal parts one at field bed preparation and the rest two at crop establishment and pre-flowering stage while complete phosphorous and potash is applied in the basal dose.
Irrigation	Light irrigation just after transplant and thereafter may be raised with monsoon rains or as and when required. Suitable for rainfed and irrigated conditions, it can tolerate submergence conditions for two days.
Harvesting	For herbage and oil at full bloom stage. Multicut may be taken. Seeds at harvested at complete maturity
Agroclimatic Zones	Suitable for cultivation in agroclimatic zones IV, V, VIII & X
Seed Production	For seed production may be a quarter of the crop may be left for seed maturity for five months till all the spikes turn brown and mature.

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