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RESEARCH ARTICLE

Comparative Morphological Assessment of Lemongrass (*Cymbopogon* spp.) Cultivars for Oil yield, Chemical Composition and Quality Parameters under Southern region of India

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ABSTRACT

Lemongrass (*Cymbopogon flexuosus*) is an important perennial aromatic plant and natural source of citral that is used in the preparations of variousperfumes.In the present study, eight lemongrass cultivars were evaluated for growth, herbage, and essential oil yield during 2018-2019 inthe southern region of Karnataka, India. Results revealed that significant differences were noticed in the growth and yield parameters of eight lemongrass cultivars studied. The plant height and the number of tillers varies, ranging from 108.47-136.75cm and 38.13-47.60, respectively. Significantly higher herbage yield (t/ha/year) was recorded in CIM-Shikar (24.25), followed by Krishna (22.50) and CKP-25 (20.72). The lowest herbage yield wasrecorded in the Cauvery cultivar. Essential oil content varied from 0.70-1.35% (v/w) and essential oil yield varies from 133.56- 302.40 kg/ha/year in different cultivars. The amount of citral varied from 2.20% to 88.14% among eight lemongrass cultivars. The varieties arranged according to the citral content as follows, Cauvery (88.84 ± 0.99) >Nima (88.57 ± 0.70) >CIM-Shikar (84.97 ± 4.08) >OD-19 (85.90 ± 0.59) >CIM-Suvarna (82.53 ± 1.10) >CKP-25 (81.84 ± 0.30) >Krishna (79.26 ± 0.44) >CIM-Atal (2.15 ± 0.07). CIM-Atal was superior in geraniol (88.92 ± 1.00%) compared to citral (geranial and neral) content among lemongrass cultivars studied; this cultivar may be a partial replacement/ substitute for geraniol rich essential oil-bearing plant in the future. Overall, cultivar CIM-Shikar was superior to other cultivars in terms of essential oil yield (302.40 kg/ha/year) and superior in citral content (84.97 ± 4.08).

Keywords:*Citral content; Essential oil content; Herbage and oil yield; Lemongrass cultivars*

INTRODUCTION

Lemongrass (*Cymbopogon flexosus*, Family: Poaceae) is an important perennial aromatic grass with enormous pharmaceuticaland industrial demand, broadly distributed throughout the world and particularly in tropical and subtropical nations (Francisco *et al.,* 2011). Leaves of lemongrass plants are commonly used in thepreparation of herbal teas and also have wide applications in food preparations. The essential oil has wide application in flavor and fragrance, pharmaceutical, aromatherapy (Shioda, 2014) and pesticide industries (Zhang *et al.,*2016; Antonioli *et al.,*2020). Lemongrass essential oil ranks in the top ten among the essential oil-bearing crops in the world mainly because of its commercial value and wide applications (Ravinder *et al.,* 2010). The main chemical constituent of lemongrass is citral (geranial and neral) comprises more than 70-80% and it is one of the very important molecules involved in several chemical syntheses (Negrelle and Gomes, 2007). For synthesis of α-and β-ionones, citral is a base material, α-ionone is used in cosmetic, flavors and perfume, for vitamin 'A' synthesis β-iononeis used (Thappa *et al.,* 1981).

There aremore than 140 species in the genus *Cymbopogon* (Kumari *et al.,* 2007), out of which 45 are grown in India, and lemongrass is commercially important for the production of essential oil (Hassan *et al.,* 2007). The *Cymbopogon* spp. have a unique character, that they can be cultivated in different types of soils even with less fertile status of the land and have good adaptability to diverse agro-climatic conditions. The most commonly cultivated and

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economic species of *Cymbopogon* are *C. nardus, C. flexuosus*, *C. pendulus*, *C. citratus*, *C. khasianus*, *C. martini, C. winterianus,* and *C. jwarancusa*, yields essential oils which are having commercial value *viz.,*lemongrass oil, citronella oil, palmarosa oil, ginger grass (Gupta and Jain, 1978; Rao 1997; Kumar *et al.,* 2000). More than 60000 hectares area is under cultivation of aromatic grasses in India distributed in different states *viz.,* Madhya Pradesh, Gujarat, Karnataka, Assam, Kerala, Maharashtra, Uttar Pradesh and Andhra Pradesh (Husain, 1994; Padalia *et al.,* 2011).

The total demandfor lemongrass oil in the world is rising, and it's about 500 tonnes. However, its production is only about 300 tonnes; India is one of the major producers of lemongrass oil to the extent of about 200 tonnes, about 90 tonnes is exported (Singh *et al.,* 2009). Therefore, the crop was gaining popularity due to the enormous scope and demand arising from lemongrass oil industries, leading to research and development activities for the selection of superior cultivars. There is an immediate need for the developmentof high-yielding essential oil-bearing cultivars and pressure on arable lands for its commercial cultivation to meet the world demand in the coming days. For profitable cultivation aspects of lemongrass, the assortment procedure depends upon the breeding plant with traits like plant height, tiller numbers, leaf area, herbage yield oil yield and citral content of the cultivar(Nair, 1982). Considering these points, eight lemongrass cultivars were evaluated in the southern region of Karnataka, India.

MATERIALS AND METHODS

Experimental location

The field experiment was conductedat CSIR-Central Institute of Medicinal, and Aromatic Plants, Research Centre, Bengaluru with eight lemongrass cultivars that were released by CIMAP. The location comes under southern region of Karnataka, with an altitude of 930m above the MSL. The latitude and longitude of the zone N:13.085 and longitude of E: 77.592, respectively, received an annual rainfall of about 925 mm during2018 (Figure 1). The soil characteristics of the experimental site are presented in Table 1.

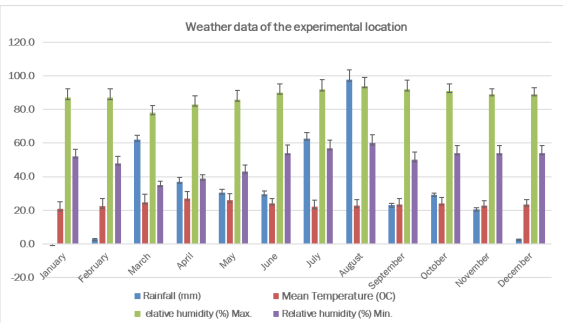

Figure 1. Monthly average temperature and rainfall condition of the experimental area during 2018-2019

Table 1. Initial soil characteristics of lemongrass experimental site

Particulars	Values
A. Physical properties	
Particle size distribution	
Sand (%)	66.65
Silt (%)	22.89
Clay (%)	9.65
Textural class	**Sandy loam**
B. Chemical properties	
pH (1:2.5)	7.25
EC (dSm^{-1})	0.65
OC (%)	0.65
CEC (C mol (P^{+}) kg^{-1}	11.75
Available N (kg ha^{-1})	292.50
Available P_2O_5 (kg ha^{-1})	21.75
Available K_2O (kg ha^{-1})	90.53
Available S (ppm)	9.55
Exchangeable Ca (C mol $P^{(+)}$ kg^{-1})	1.45
Exchangeable Mg (C mol $P^{(+)}$ kg^{-1})	1.30
Available Fe (ppm)	16.58
Available Zn (ppm)	1.75
Available Cu (ppm)	1.76
Available Mn (ppm)	16.85

Experimental details

A Randomized Complete Block Design (RCBD) was adopted to carry out the experiment in the field with eight lemongrass cultivars which were replicated thrice. The experimental plot size was 3.6mx3.6m with 45cm spacing between row-to-row and plant-to-plant. RDF (Recommended dose of fertilizers) 150:40:40 kg/ha N, P_2O_5, K_2O, respectively, were applied to the soil on the planting day. The top dressing was done with 75% N with four equal splits. The crop was irrigated whenever there was a need.

Observations

Five randomly selected healthy plants were selected and tagged for observations. The plant height was measuredduring the time of harvest with a meter scale.The number of tillers per clump and the number of leaves per tillers, were recorded by counting manually. Yield parameters *viz.,* herbage yield, and essential oil yield was calculated based on the net plot yield and converted to tone per hectare.

Source of different lemongrass cultivars

Different *Cymbopogon* spp. (*viz.,* OD-19, CKP-25, Cauvery, Nima, CIM-Suvarna, Krishna and CIM-Shikar) evaluated in the present study were collected from CSIR-CIMAP, Research Centre, Bengaluru, lemongrass gene bank. The gene bank was properly maintained from its initiation in the same piece of land with proper isolation distance and proper care was taken to avoid add mixtures of the other cultivars. Whereas, CIM-Atal geraniol rich lemongrass cultivar was recently released by CSIR-CIMAP in 2019, which was developed from Bengaluru Research Centre. The source and year of release of cultivars and other information are provided in Table 2, and their visual physical identical and morphological characteristics are provided in Table 3.

Table 2. General information of different cultivars of lemongrass (*Cymbopogon* spp.).

Cultivars	Plant species	Variety Development	Adaptability	Cultivar details references
Krishna	*Cymbopogon. flexuosus*	Clonal selection	Indian Plains and hills	Anonymous (1997)
Cauvery	*Cymbopogon. flexuosus*	Phenotypic recurrent selection	Requires high soil moisture and is evolved for river valley tracts of Indian Plains	Patra *et al* (2005)
Nima	*Cymbopogon. flexuosus*	Half-sib seed followed by clonal selection	Indian Plains	Anonymous (2003)
OD-19	*Cymbopogon. flexuosus*	Clonal selection	Adapted to a wide range of soil and climatic condition. much suited for rained cultivation	Kumar *et al* (2000)
CIM-Suwarna	*Cymbopogon. khasianus*	Clonal selection	Drought prone areas and marginal lands	Lal *et al* (2010)
CIM Shikar	*Cymbopogon. flexuosus*	Recurrent selection	High yielding cultivar (>20% Krishna)	Anonymous, (2016)
CKP-25	*C. khasianus* × *C. pendulus*	Hybridization	Grows well in northern plains	Rao and Sobti, (1991)
CIM-Atal	*Cymbopogon. flexuosus*	Selection	Geraniol rich (80-85%) grows well in tropical and subtropical region	Kulkarni *et al* (2020)

ANALYTICAL METHODS

Extraction of the essential oil:

The fresh leaves (100 g) of each cultivar of lemongrass (*Cymbopogon* spp.) were collected and subjected to hydrodistillation for 3 hours in a Clevenger-type apparatus to extract essential oil. The oils samples were dehydrated with anhydrous Na_2SO_4 and kept in a cool, dark place until further analysis.

Table 3. Comparative analysis of physical parameters of different lemongrass*flexuosus*

Cultivars		Krishna	Suwarna	OD-19	Neema	Cauvery	CKP-25	CIM-Shikar	CIM-Atal
Characteristics									
Habit		Semi pendent	Erect straight	Erect straight	Erect straight	Semi pendent	Erect straight	Erect straight	Erect straight
Height(cms)	1)Vegetative	75	81	80	73	72	77	73	79
	2)Matured	128	132	127	115	126	109	130	125
Colour	1)Stalk/Culm	Light brown	Light yellow	Dark brown	Reddish brown	Reddish brown	Light purple	Reddish brown	Reddish brown
	2)Leaf sheath	Reddish brown	Light purple	Reddish brown	Light purple	Light purple	Light yellow	Light purple	Light purple
Supressed internodes	1)Number	8	7	7	7	7	6	6	6
Length(cms)	1)Ligule	0.4	0.3	0.2	0.4	0.2	0.3	0.3	0.2
	2)Auricle	0.3	0.2	0.3	0.3	0.4	0.2	0.3	0.4
Leaf area(cm2)	Avg. of 5 leaves	1.54	1.2	1.42	2.3	1.38	1.2	1.38	1.3
Tiller Number		55	53	46	45	38	48	58	55
Inter nodal distance		1.6	1.4	2.3	1.3	3.2	0.9	2.5	2.1
Shoot initiation Point(cms)		20	15	14.8	13	20	11	21	23
Number of Leaves		5	5	5	4	3	3-4	5	5
Midrib(cms)	1)Right side region	0.6	0.5	0.7	0.9	0.6	0.5	0.7	0.5
	2)Left side region	0.5	0.4	0.6	1.0	0.4	0.5	0.7	0.5

GC Method:

Gas chromatographic analysis was performed on an Agilent 7890B gas chromatograph equipped with a flame ionization detector. For separation, an Agilent HP-5 column of 30 m length, 320 µm internal diameter, and 0.25 µm film thickness was used. Samples were injected into a split/splitless inlet maintained at a temperature of 250ºC with a split ratio of 1:35. Nitrogen was used as a carrier gas with 2 mL/min constant flow rate. The column oven temperature, was programmed from 60ºC and increased at the rate of 3ºC/min till 240ºC and held at 240ºC for 2 min. The FID detector temperature was kept at 280ºC.

GC-MS Method:

Gas chromatography-mass spectrometry analysis was performed on a PerkinElmer Clarus 680 model GC and a SQ 8C MS using an Elite-5MS column of dimensions, 30 m x 0.25 mm with film thickness of 0.25 µm. Injector temperature of GC was kept at 290ºC and Helium as carrier gas with 1 mL/min constant flow rate with a split ratio of 1:100. The column oven was programmed from 60ºC to 240ºC at the rate of 3ºC/min. Samples were transferred from GC to MS through an inter line which was maintained at a temperature of 250ºC. The ionization source of MS was at 250ºC and the compounds were ionized with an ionization potential of 70eV. The mass spectrometer was programmed to scan in the range of 40 to 450 amu with a scan time of 0.8 sec and an interscan delay of 0.01 sec. Compounds were identified by matching the relative retention index calculated using *n*-alkanes, (C_7-C_{30} hydrocarbons) and confirmed by comparing the mass spectrum of the compounds with themass spectral library.

RESULTS AND DISCUSSION

The growth and yield parameters of different cultivars of lemongrass are presented in Table 4. Growth traits of lemongrass varied significantly due to the different cultivars studied. The significantly higher plant height was noticed in CIM-Shikar (136.75cm), followed by CIM-Suwarna (131cm), and the lowest plant height was noticed in Cauvery. A higher number of tillers per clump was noticed in CIM-Shikar (47.60) followed by Krishna (47.53) and CKP-25 (42.13). A lesser number of tiller per clump was noticed in Nima (38.13) cultivar. This difference in the number of tillers is mainly due to dissimilarity in the inherited characters of the genotypes and variations in the environmental conditions (Singh and Singh, 1999, Sharma *et al.,*2005, Ibrahim and Khalidh, 2013). Similarly, results are in agreement with the findings of Lal *et al*. (2006), who reported plant height in the range of 100-160cm and the number of tillers/plant in the range of 45-65 for four elite clones of lemongrass. However, there was no significant difference in the number of leaves per tillers among the cultivars studied.Allard (1960) and Poehlman and Sleper (1995) reported thatincidence of variation in plants occurs due to hereditary differences in the plant and environmental conditions where plants are grown or sometimes combination of both.

Table 4. Growth and yield parameters of eight different lemongrass cultivars

Cultivar	Plant height (cm)	Number tillers/ clump	Number of leaves per tiller	Herbageyield (t/ ha/year)*	Oil recovery (%)	Oil yield (kg/ha/ year)
Krishna	128.87	47.53	5.08	22.50	1.20	269.98
Cauvery	108.47	39.53	5.08	17.85	0.85	151.44
Nima	111.73	38.13	5.25	18.35	0.90	164.90
OD-19	123.85	41.20	4.85	19.05	0.70	133.56
CIM-Suvarna	131.00	39.20	5.17	19.35	1.15	223.17
CIM-Shikar	136.75	47.60	5.65	24.25	1.25	302.40
CKP-25	115.87	42.13	4.93	20.72	1.20	247.82
CIM-Atal	122.87	40.67	5.45	20.35	1.35	275.44
SEm ±	1.28	1.59	0.37	1.28	0.04	18.07
CD at 5%	3.89	4.83	NS	3.88	0.13	54.80

*Harvest at 8months and 20 days second harvest was takeninto account

The herbage and oil yield differed significantly due to different cultivars and yield attributing characters of lemongrass. The herbage yield ranges from 17.85-24.24 tha^{-1}. The higher herbage yield was recorded in cultivar CIM-Shikar (24.25 tha^{-1}), followed by Krishna (22.50 tha^{-1}) and CKP-25 (20.72 tha^{-1}); conversely, cultivar Cauvery showed the lowest herbage yield (17.85 tha^{-1}) among all the cultivars evaluated in the present study. The recovery of essential oil ranges from 0.70% to 1.35% .The highest recovery was recorded in CIM-Atal (1.35%) followed by CIM-Shikar (1.25%) and the lowest was noticed in OD-19 (0.70%). Sarma and Sarma,(2005) reported that oil recovery range from 0.55 –1.03% for lemongrass collections cultivated in Northeast Indian climatic circumstances. Similarly, the higher essential oil yield was recorded in cultivar CIM-Shikar(302.40 kg/ha/year), followed by CIM-Atal

(275.44 kgha^{-1}year^{-1}) and Krishna (269.98 kg ha^{-1} year^{-1}), whereas cultivar OD-19 (133.56 kg ha^{-1} year^{-1}) recorded lower essential oil yield. The increase in the herbage yield and essential oil yield maybe due to the production of more tillers per plant, the number of leaves/tillers, plant height had a positive and strong correlation/association with yield parameters (Table 6). Verma *et al.* (2015) reported that cultivar Krishna recorded higher amounts of essential oil (2.35 L per 100 m^2) with 80.70% of citral among eight lemongrasses evaluated under the Himalayan region of India.

Table 5. Chemical composition of lemongrass cultivars

Cultivar	Geranial	Neral	Citral*	Geraniol	Geranyl acetate	G/N ratio
Krishna	47.38 ± 0.42	31.88 ± 0.01	79.26 ± 0.44	6.43 ± 0.18	1.98 ± 0.13	1.49 ± 0.01
Cauvery	51.47 ± 0.58	37.37 ± 0.41	88.84 ± 0.99	0.61 ± 0.04	0.12 ± 0.01	1.38 ± 0.00
Nima	51.94 ± 0.49	36.63 ± 0.21	88.57 ± 0.70	0.76 ± 0.21	0.31 ± 0.08	1.42 ± 0.01
OD-19	52.78 ± 1.52	33.12 ± 2.11	85.90 ± 0.59	1.22 ± 0.10	0.51 ± 0.22	1.60 ± 0.15
CIM-Suvarna	46.94 ± 0.71	35.59 ± 0.40	82.53 ± 1.10	2.78 ± 0.01	3.02 ± 0.13	1.32 ± 0.00
CIM-Shikar	50.79 ± 1.48	34.18 ± 2.60	84.97 ± 4.08	3.76 ± 3.30	2.14 ± 2.28	1.49 ± 0.07
CKP-25	48.84 ± 0.18	33.00 ± 0.13	81.84 ± 0.30	3.15 ± 0.30	2.13 ± 0.06	1.48 ± 0.00
CIM-Atal	1.47 ± 0.02	0.80 ± 0.07	2.15 ± 0.07	88.92 ± 1.00	2.50 ± 0.03	1.84 ± 0.13

*Citral = geranial + neral, G/N ratio : geranial/neral

With concern to the chemical composition of lemongrass cultivars studied in the present study, geranial was recorded highest (52.78 ± 1.52%) in OD-19, followed by Nima (51.94 ± 0.49), and the lowest amount was found in CIM-Atal (1.47 ± 0.02%) cultivar (Table 5, Figure2-9). Similarly, the highest neral content was recorded in cultivar Cauvery (37.37 ± 0.41%) followed by Nima (36.63 ± 0.218%) cultivar. The market acceptability of lemongrass essential oil is determined by the amount of citral which is a combination of two stereo-isomeric monoterpenoid aldehyde compounds namely, geranial (trans isomer) and neral (cis isomer). The amount of geranial and neral constitute the total amount of citral, which is the main compound thatdecides the marketability of lemongrass essential oil. The citral content varies from 2.15-88.84%.The verities arranged according to the citral content as, Cauvery (88.84 ± 0.99) >Nima (88.57 ± 0.70) > CIM-Shikar (84.97 ± 4.08) > OD-19(85.90 ± 0.59)> CIM-Suvarna (82.53 ± 1.10) > CKP-25(81.84 ± 0.30) > Krishna (79.26 ± 0.44) > CIM-Atal (2.15 ± 0.07).The citral content range between 72-75% was reported for Indian lemongrass collections by Kumari *et al.* (2009). A comparatively higher amount of citral (89%) was stated by Lal *et al.* (2001) for SEG 49 lemongrass clone; similarly, Ganjewala (2008) reported citral range of 82-88% for West Indian lemongrass. CIM-Atal cultivars bear low citral content compared to all other cultivars in the present study.

Table 6. Correlation of growth, yield and chemical parameters of different lemongrass cultivars

Parameters	Plant height	Number tillers / clump	Number of leaves per tiller	Oil recovery (%)	Herbage yield	Oil yield	Geranial	Neral	Citral	Geraniol	Geranyl acetate	G/N ratio
Plant height(cm)	1.000											
Number tillers/clump	0.656***	1.000										
Number of leafs per tiller	0.437*	0.283 ns	1.000									
Oil recovery (%)	0.493*	0.453*	0.582**	1.000								
Herbage yield	0.760***	0.928***	0.517**	0.670***	1.000							
Oil yield	0.639***	0.682***	0.621***	0.955***	0.860***	1.000						
Geranial	-0.055 ns	0.132 ns	-0.377 ns	-0.544 ns	-0.025 ns	-0.389 ns	1.000					
Neral	-0.060 ns	0.070 ns	-0.346 ns	-0.536 ns	-0.071 ns	-0.401 ns	0.993***	1.000				
Citral	-0.057 ns	0.106 ns	-0.365 ns	-0.542 ns	-0.044 ns	-0.395 ns	0.999***	0.998***	1.000			
Geraniol	0.044 ns	-0.110 ns	0.397 ns	0.517**	0.039 ns	0.378 ns	-0.996 ns	-0.995 ns	-0.998 ns	1.000		
Geranyl acetate	0.342 ns	0.008 ns	0.019 ns	0.714***	0.177 ns	0.550**	-0.518 ns	-0.488 ns	-0.507 ns	0.451*	1.000	
G/N ratio	0.032 ns	0.029 ns	0.306 ns	0.455*	0.136 ns	0.372 ns	-0.933 ns	-0.968 ns	-0.949 ns	0.954***	0.331 ns	1.000

***significance at P<0.001, **significance at P<0.01, *significance at P<0.5; ns=non-significant; P<0.05 probability level

CIM-Atal cultivar was mainly bred for high geraniol content purposes rather than citral content. Though, palmarosa (*C. martini*) crop yields comparatively less oil recovery of about (0.56%) with an average oil yield of 139.7 kgha^{-1} comprising geraniol content of about 82.26% and geranyl acetate approximately 13.05% under the Himalayan region as reported by Chauhan *et al.* (2017) whereas CIM-Atal stands superior in comparison with palmarosa crop for geraniol source. This cultivar can be a substitute for geraniol-rich essential oil bearing plant in the future. Further studies are needed address its geraniol content and performance in different seasons and locations for stability.

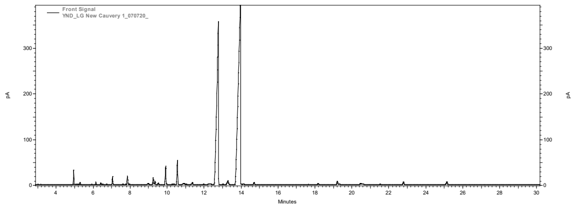

Figure 2. Gas chromatographic profile of the essential oil of cultivar Cauvery

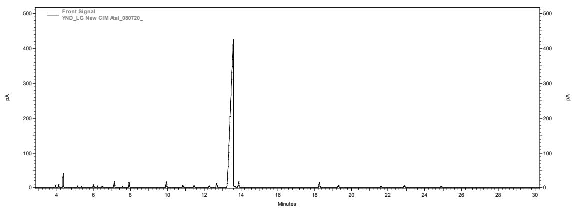

Figure 3. Gas chromatographic profile of the essential oil of cultivar CIM-Atal

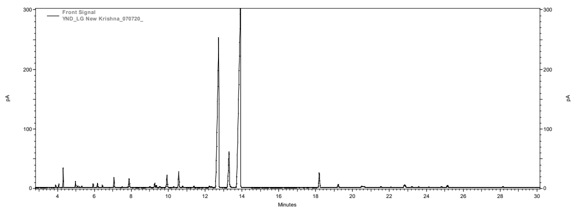

Figure 4. Gas chromatographic profile of the essential oil of cultivar Krishna

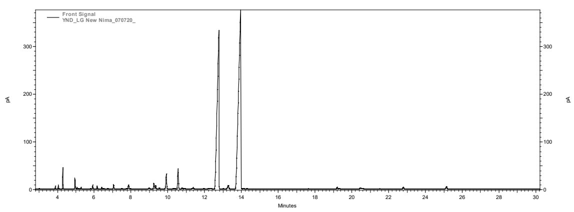

Figure 5. Gas chromatographic profile of the essential oil of cultivar Nima

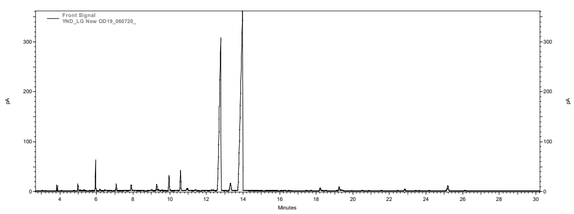

Figure 6. Gas chromatographic profile of the essential oil of cultivar OD-19

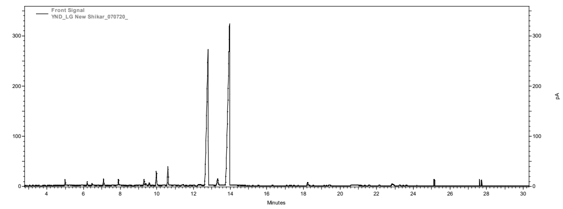

Figure 7. Gas chromatographic profile of the essential oil of cultivar CIM-Shikar

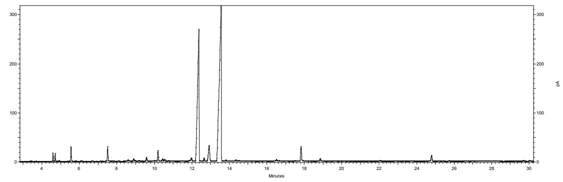

Figure 8. Gas chromatographic profile of the essential oil of cultivar CKP-25

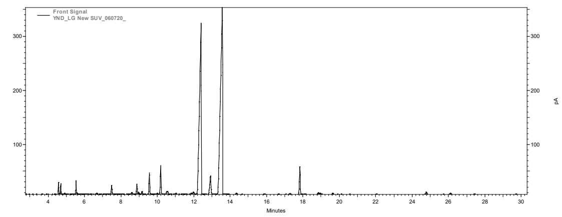

Fig.9. Gas chromatographic profile of the essential oil of cultivar CIM-Suwarna

In the present study, all cultivars met market standards of citral content, but they differ in the level of other essential oil constituents; these variations could be due to the different ratios of geranial and neral (G/N ratio) present in different cultivars of lemongrass (Table 5). G/N ratio varies from 1.32-1.84 among the eight lemongrass cultivars examined. There were no notable observations with G/N ratio of lemongrass. The G/N ratio of *C. citratus* from Angola is 1.43% (Soares *et al.,* 2013), in Iran 1.26% (Avoseh *et al.,* 2015) and whereas in Ivory Coast, it is reported about 1.33% (Sidibé *et al.,* 2011). The essential oil of lemongrass constitutes generally has more than 45% of citral. However, the variation in citral content is observed in different species. Whereas *C. citrates* were reported with citral content of 30-94% being geranial as the major compound (Avoseh *et al.,* 2015).

Correlation of different lemongrass varieties with growth, yield and chemical parameters

All the growth parameters of lemongrass were positively correlated with theyield of lemongrass (Table 6). Plant height (0.760***), number of leaves per tillers (0.517***) and number of tillers/clump was highly significantly correlated with herbage yield (0.928***). The chemical parameters of lemongrass *viz.,* geranial, neral, geraniol, geranyl acetate and G/N ratios were not- significantly correlated with herbage yield of lemongrass. Whereas, a similar trend of results was noticed for oil yield except geranyl acetate (0.550**). The herbage and oil yield of lemongrass were negatively non-significant with geranial (-0.025&-0.389), neral (-0.071&-0.401), and citral (-0.044&-0.395) respectively. Among the chemical parameter of lemongrass, geranial was highly significantly correlated with neral (0.993***) and citral (0.999*). G/N ratio was non-significant with all the parameters of the study except with oil recovery (0.455*) and geraniol (0.957***). The results of the present study are in agreement with the findings of Joy *et al*. (2006) reported a significant positive association of morphological characters with herbage and essential oil yield of lemongrass. Verma *et al.*(2015) reported that G/N ratio of eight lemongrass cultivars grown in the Himalayan region varied from 1.17 to 1.76 in different seasons.

CONCLUSION

The performance of lemongrass cultivars in the southern region of Bengaluru, Karnataka, India was similar to that of lemongrass grown in different parts of India in comparison to herbage, oil yield, and quality. The cultivar CIM-Shikar recorded significantly higher amount of essential oil (302.40 kg/ha/year) with a superior market citral percentage of 84.97 ± 4.08%. CIM-Atal was superior in geraniol (88.92 ± 1.00%) compared to citral content among all the cultivars studied; this cultivar may be a partial replacement/substitute for geraniol rich essential oil-bearing plant in the future. Cultivating lemongrass in subtropical and similar climatic areas can offer an alternate cash crop to the farmers, which is not menaced by animals and less maintenance cost void of pests and diseases. This crop can be planted in marginal fertility soils and is also appropriate for wasteland development programmes where, crops establishment and maintenance are difficult.

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COMPLIANCE WITH ETHICAL STANDARDS

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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