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

## Abstract

Lemongrass (*Cymbopogon* spp.) is an important perennial aromatic plant and natural source of citral that is used in preparations of various perfumes.In the present study, eight lemongrass cultivars were evaluated for growth, herbage and essential oil yield during 2018-2019 at Southern region of Karnataka, India.Results revealed that significant differences was noticed in growth and yield parameters of eight lemongrass cultivars studied. The plant height varies and number of tillers ranged from 108.47-136.75cm and 38.13-47.60, respectively.Significantly higher herb yield (t/ha/year) was recorded in CIM-Shikar (24.25) followed by Krishna (22.50) and CKP-25 (20.72). The lowest herb yield recorded in 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 future. Overall, cultivar CIM-Shikar was superior compared 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 oilyield;Lemongrasscultivars.

## Introduction

Lemongrass (*Cymbopogon,include species name* family: poaceae) is an important perennial aromatic grass having 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 preparation of herbal teas and also have wide applications in food preparations. The essential oil has wide application in flavour 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, flavours and perfume, for vitamin ‘A’ synthesis β-iononeis used(Thappa *et al.,* 1981).

There aremore than 140 species in genus *Cymbopogon* (Kumari *et al.* 2007), out of which 45 are grown in India and lemongrass is commercially important for production of essential oil (Hassan *et al.,* 2007). The *Cymbopogon spp*. are having special 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 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 demand for lemongrass oil in world raising and its about 500 tonnes. However, its production is only about 300 tonnes, India is one of the major producer of lemongrass oil to an 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 industries for lemongrass oil, these leads to a research and development activities for selection of superior cultivars.There is an immediate need for development of high yielding essential oil bearing cultivars and pressure on arable lands for its commercial cultivation to meet out the world demand in coming days.For profitable cultivation aspects of lemongrass, assortment procedure is depends upon the breeding plant traits like plant height, tiller numbers, leaf area, herbage yield oil yield and citral content of the cultivar(Nair, 1982).Taking consideration of these points eight lemongrass cultivars were evaluated in the Southern region of Karnataka, India.

## Materials and Methods

### ***Experimental location***

The field experiment was conducted at CSIR-Central Institute of Medicinal and Aromatic Plants, Research Centre, Bengaluru with eight lemongrass cultivars which 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 which received an annual rainfall of about925 mm during2018 (Figure 1). The soil characteristics of the experimental site is presented in Table 1.

### ***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 3.6m x 3.6m with 45cm spacing between row-to-row and plant-to-plant. RDF (Recommended dose of fertilizers)150:40:40 kg/ha N, P2O5, K2O, respectively were applied to the soil on the day of planting.Top dressing was done with 75% N with four equal splits. The crop was irrigated wheneverthere 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 meter scale. Number of tillers per clump and 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 admixtures of the other cultivars. Whereas, CIM-Atal geraniol rich lemongrass cultivar was recently releasedbyCSIR-CIMAP during 2019which was developed from Bengaluru, Research Centre. The source and year of release of cultivars and other information were provided Table2 and their visual physical identical and morphological characteristics were provided in Table 3.

### ***Analytical methods***

### ***Extraction of the essential oil:***

The fresh leaves (100 g) of each cultivars of lemongrass (*Cymbopogon spp*.) were collected and subjected to hydro distillation for 3 hours in a Clevenger-type apparatus for the extraction of essential oil. The oils samples were dehydrated with anhydrous Na2SO4 and kept in a cool, dark place until further analysis.

### ***GC Method:***

Gas chromatographic analysis was performed on an Agilent 7890B gas chromatograph equipped with flame ionisation detector. An Agilent HP-5 column of 30 m length, 320 µm intermal diameter and 0.25µm film thickness was used for separation. 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. 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 ionisation source of MS was at 250ºC and the compounds were ionized with ionization potential of 70eV. The mass spectrometer was programmed to scan in the range of 40 to 450 amu with scan time of 0.8 sec and interscan delay of 0.01 sec.Compounds were identified by matching the relative retention index calculated using *n*-alkanes, (C7-C30 hydrocarbons) and confirmed by comparing the mass spectrum of the compounds with mass spectral library.

## Results and Discussion

The growth and yield parameter of different cultivars of lemongrass were presented in Table 4. Growth traits of lemongrass varied significantly due to 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. The higher number of tillers per clump was noticed in CIM-Shikar (47.60) followed by Krishna (47.53) and CKP-25 (42.13). The 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, our results are agreement with findings of Lal *et al*. (2006), who reported plant height in the range of 100-160cm and 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 that incidence of variation in plantsoccur due to hereditary differences in the plant and environmental conditions where plants are grown or sometimes combination of both.

The herbage and oil yield was differed significantly due to different cultivars and yield attributing characters of lemongrass. The herb yield ranges from 17.85-24.24t/ha. The higher herbage yield was recorded in cultivar CIM-Shikar (24.25t/ha), followed by Krishna (22.50t/ha) and CKP-25 (20.72t/ha); conversely, cultivar Cauvery showed the lowest herbage yield (17.85t/ha) among all the cultivars evaluated in the present study. The recovery of essential oil ranges from 0.70% to 1.35%.The highest recovery recorded in CIM-Atal (1.35%) followed by CIM-Shikar (1.25%) and 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 the essential oil yield was recorded in cultivar CIM-Shikar(302.40kg/ha/year), followed by CIM-Atal (275.44 kg/ha/year) and Krishna (269.98 kg/ha/year), whereas cultivar OD-19 (133.56kg/ha/year) 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, 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 m2) with 80.70% of citral among eight lemongrass evaluated under the Himalayan region of India.

With concern to 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 lowest amount was found in CIM-Atal (1.47 ± 0.02%) cultivar (Table 5, Figure2-9). Similarly, 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 decides 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 cultivar bear low citral content compared to all other cultivars in the present study. CIM-Atal cultivar was mainly breed for high geraniol content purpose rather than citral content. Though, palmarosa (*C. martini*) crop yield comparatively less oil recovery of about (0.56%) with an average oil yield of 139.7 kg/ha comprising geraniol content of about 82.26%and geranyl acetate approximately 13.05% under Himalayan region as reported by Chauhan *et al.,* (2017) whereas CIM-Atal stands superior in comparison with palmarosa crop for geraniol source. Thereby this cultivar can be a substitute for geraniol rich essential oil bearing plant in future. Further studies are needed address its geraniol content and performance in different season and location for the stability.

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 1.32-1.84among the eight lemongrass cultivars examined. There was not 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 have more than 45% of citral, however, the variation in citral contentis observed in different species. Whereas, *C. citrates* are 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 yield 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, similar trend of results were noticed for oil yield except geranyl acetate (0.550\*\*). The herbage and oil yield of lemongrass was 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 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 under Himalayan region varied from 1.17 to 1.76 in different seasons.

## Conclusion

In conclusion, performance of lemongrass cultivars in the southern region of Bengaluru, Karnataka, India have similar to that lemongrass grown in different parts of India in comparisation to herbage, oil yield and quality. The cultivar CIM-Shikar recorded significantly higher amounts of essential oil (302.40 kg/ha/year) with 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 future.Cultivation of lemongrass in subtropical and similar climatic areas can offeran alternate cash crop to the farmers, which is not menaced by animals and less maintenance cost void of pest and diseases. This crop can be planted in marginal fertility soils and also appropriate for waste land development programmes where agricultural crops establishment and maintenance is difficult.

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## Compliance with ethical standards

## Conflict of interest

The authors declare that they have no conflict of interest.

## References

Allard, R.W., 1960. Principles of Plant Breeding. John Wiley and Sonc Inc., New York, USA.

Anonymous, 1997. Improved clonal variety Krishna of lemongrass developed. Central Institute of Medicinal and Aromatic Plants (CIMAP). Newsletter, **24:** 2-3.

Anonymous, 2003. Citral rich and high yielding lemongrass variety ‘Nima’ released for commercialization. Central Institute of Medicinal and Aromatic Plants (CIMAP). *Newsletter.*, **1:** 4–6.

Anonymous, 2016. New medicinal and aromatic crop varieties. *In: MAPs News, CSIR-CIMAP*, Lucknow.

Antonioli, G., Fontanella, G., Echeverrigaray, S., Longaray Delamare, A.P., FernandesPauletti, G. and T. Barcellos, 2020. Poly (lactic acid) nano capsules containing lemongrass essential oil for postharvest decay control: Invitro and in vivo evaluation against phytopathogenic fungi.*Food Chem.,***1:**326:126997.<https://doi.org/10.1016/j.foodchem.(2020).126997>.

Avoseh, O., Oyedeji, O., Rungqu, P., [Chungag](https://www.ncbi.nlm.nih.gov/pubmed/?term=Nkeh-Chungag%20B%5BAuthor%5D&cauthor=true&cauthor_uid=25915460),B.N. and A.[Oyedeji](https://www.ncbi.nlm.nih.gov/pubmed/?term=Oyedeji%20A%5BAuthor%5D&cauthor=true&cauthor_uid=25915460).2015. *Cymbopogon species*; Ethnopharmacology, phytochemistry and pharmacological importance. *Molecules.,***20:** 7438-7453.

Chauhan, N.K., Semwal, M.P., Singh, D., Singh B. and S. Rauthan. 2017. Influence of various plant spacing on growth, herbage yield, essential oil yield and aroma content of palmarosa (*Cymbopogonmartinii*Roxb.) at different harvest under agro-climatic condition of Doon valley. *J. Essen. Oil Bearing Plants*.,**20(6):** 1587-1593. <https://doi.org/10.1080/0972060X.2017.1421103>.

Francisco, V., Figueirinha, A., Neves, B.M., García-Rodríguez, C., Lopes, M.C., Cruz, M.T., and M.T. Batista. 2011. *Cymbopogoncitratus* as source of new and safe anti-inflammatory drugs: bio-guided assay using lipopolysaccharide-stimulated macrophages. *J. Ethno-pharmacology*.,**133:** 818–827.

Ganjewala, D., Kumari, A. and K.H. Khan. 2008. Ontogenic and developmental changes in essential oil content and compositions in *Cymbopogon flexuous* cultivars. In: Prasad BN, Lazer Mathew, editor. Recent Advance in Biotechnology. New Delhi, India: ExcelIndia Publishers. 82–92.

Gupta, B.K. and N.Jain. 1978. Cultivation and utilization of genus aromatic *Cymbopogon* in India. *Indian Perfumer*., **22:** 55–68.

Hassan, V.U., Saleem, M., Shaffi, N., Din, K.U. and M.Qasuer. 2007. Lemongrass: Botany, Ethnobotany and chemistry. *Pak. J. Weed Sci. Res.,***13(1-2):** 129-134.

Husain, A., 1994. Essential oil-bearing plants and their cultivation. Central Institute of Medicinal and Aromatic Plants (CIMAP) Publication, Lucknow.

Ibrahim, M.M. and K.A. Khalid. 2013. Phenotypic recurrent selection on herb growth yield of citronella grass (*Cymbopogonnardus*) grown in Egypt, *Nusantara bioscience.*,**5(2):** 70- 74.

Joy, P.P., Baby, P.S., Samuel, M., Gracy, M. and J. Ancy. 2006. Lemongrass: The fame of Cochin. *Indian J. Arecanut Spices Med. Plants.,***8(2):** 55-64.

Kumar, S.S., Dwivedi, A.K., Kukreja, J.R. and G.D. Sharma. 2000. Bagchi, Cymbopogon: The aromatic grass monograph. *Central Institute of Medicinal and Aromatic Plants (CIMAP) Publication, Lucknow*.

Kumari, J., Verma, V., Goyal, A., Shahi, A.K., Sparoo, R., Sangwan, R.S. and G.N.Qazi. 2009. Genetic diversity analysis in *Cymbopogon* species using DNA markers. *Plant Omics J.,***2(1):** 20-29.

Kumari, J., Verma, V., Shahi, A.K., Qazi, G.N. and H.S. Balyan. 2007. Development of simple sequence repeat markers in *Cymbopogon* species. *Planta Medica*.,**73(3):** 262.<https://doi.org/10.1055/s-2007-967121>.

Kumar, S., Dwivedi, S., Kukreja, A.K., Sharma J.R. and G.D.Bagchi.*Cymbopogon*: The aromatic grass monograph. *Central Institute of Medicinal and Aromatic Plants (CIMAP) Publication, Lucknow* (2000).

Kulkarni, R.N., Baskaran, K., Sundaresan, V., ChannayyaHiremath,Yogendra, N.D., Manoj,K.Y., Srinivas, KVN., Kumar, J.K., Kumar, N., Padalia, R.C., Kumar, A., Kalra, A. and A.K. Tripathi.2020. A geraniol rich variety of lemongrass (*Cymbopogonflexuosus* (Steud.) Wats.): CIM-Atal. *J. Med. Arom. Pl. Sci.,* **42**(1-2): 64-67.

Lal, R.K., Sharma, J.R., Misra, H.O., Sharma, S. and A.A. Naqvi. 2001. Changes in monoterpene content accompanying development of *Cymbopogonwinterianusjowitt*leaves. *J. Essent. Oil Res.,***13:**58–162.<https://doi.org/10.1080/10412905.1991.9697955>.

Lal, R.K., Misra, H.O., Sharma, J.R., Singh, N., Shasany, A.K., Naqvi, A.A., Bahl, J.R., Prasad, A. and S.P.S.Khanuja. 2006. Citral Rich High Yielding Lemongrass Plant ‘Nima’ of *Cymbopogonflexuosus*.United States Plants Patent (PP16712).*Council of Scientific and Industrial Research, New Delhi, India*, 1-14.

Lal, R.K., Chandra, R., Chauhan, H.S., Misra, H.O., Singh, A., Srikrishna, Shankar, H., Singh, H., Singh, S., Kumar. B., Yadav, A., Shasany, A. K., Dhawan, S. and A. Gupta. 2010. A high yielding variety of lemongrass (*Cymbopogonkhasianus*) 'CIM-SUWARNA' suitable for water stress/rainfed/marginal land conditions. *J. Med. Arom. Pl. Sci.,***32:** 61-63.

Nair, E.V.G., 1982. Promotional aspect of lemongrass, cultivation and utilization of aromatic plants. CUMAP. Ed. C.K.Atal and B.M. Kapoor, Published by RRL Jammu- Tawi India.

Negrelle, R.R.B. and E.C. Gomes. 2007. *Cymbopogoncitratus* (DC) Stapf: Chemical composition and biological activities. Brazilian *J. Med. Biol. Res.,***9:**80-92.

Padalia, R.C., Verma, R.S., Chanotiya C.S. and A.Yadav. 2011. Chemical fingerprinting of the fragrant volatiles of nineteen Indian cultivars of *CymbopogonSpreng*. (Poaceae). *Rec. Nat. Prod.,***5:** 290–29.

Patra, N.K., and B. Kumar. 2005. Improved varieties and genetic research in medicinal and aromatic plants (MAPs). In: Proceedings of Second National Interactive Meet (NIM) on Medicinal and Aromatic Plants, p. 53, *Central Institute of Medicinal and AromaticPlants (CIMAP), Lucknow*.

Poehlman, J.M. and D.A. Sleper. 1995. Field Crops. Iowa State University Press, United States of America.

Rao, B.L., 1997. Scope for development of new cultivars of *Cymbopogon* as a source of terpene chemicals. In: Supplement to Cultivation and Utilization of Aromatic Plants. Edits., S.S. Handa and M.K. Kaul, p. 71, National Institute of Science and Communication, New Delhi.

Rao, B.L. and S.N. Sobti. 1991. CKP/25, a hybrid lemongrass. *Indian Perfumer*. **35:** 148–149.

Ravinder, K., Pawan, K., Gaurav, S., Paramjot, K., Gagan, S. and K. Appramdeep. 2010. Pharmacognostical investigation of *Cymbopogoncitratus* (DC) Stapf, *Der Pharmacia Letter*., **2(2):** 181-189.

Sarma, A. and T.C. Sarma. 2005. Studies on the morphological characters and yields of oil and citral of certain lemongrass [*Cymbopogonflexuosus* (Steud) Wats.] accessions grown under agroclimatic conditions of northeast India. *J. Essent. Oil Bearing Plants*. **8:**250–257.<https://doi.org/10.1080/0972060X.2005.10643454>.

Shioda, S. 2014. Recent advances in aromatherapy for dementia. *Aroma Research*, **15(2):** 103–107. <https://www.cabdirect.org/cabdirect/abstract/20143204405>

Sharma, S.N., Baleshwar and S.C. Taneja. 2005. Growth studies on an elemicin containing grass: *Cymbopoganpendulus* (Nees ex. Steud) Wats in Jammu, *Indian Perfumer*. **46(2):**105-108.

Sidibe, L., Chalchat, J. C. and R.P. Garry. 2011. Aromatic plants of Mali (IV): Chemical composition of essential oils of *Cymbopogoncitratus* (DC) Stapf and C. giganteus (Hochst.) Chiov. *J. Essent. Oil Res*.,**13(2)**: 110-112.

Singh, A.L., Rahman, R.S., Verma, R.K., Verma, U.B., Singh, S.K., Singh, A., Chauhanand A.K. Kukreja. 2009. Effect of plant geometry on growth and yield of lemongrass (*Cymbopogonflexuosus* Ness ex. Stued.) cultivars from Uttarakhand hills. J. Med. Arom. Pl. Sci.,**31:** 10–12.

Singh, O.P. and T.P. Singh. 1999. Genetic variability among some genotype for morphological characters in lemongrass (*Cymbopoganflexuosus* L. Stapf), *Indian Perfumer*,**43(1):** 35-36.

Soares, M.O., Vinha, A.V., Barreira, S.V.P., Coutinho, F., Gonçalves, S.A., Oliveira, M.B.P.P., Pires, P.C. and A. Castro.2013. *Cymbopogoncitratus* EO antimicrobial activity against multi-drug resistant Gram-positive strains and non-albicans-Candida species. In: Méndez-Vilas A (ed.). Microbial Pathogens and Strategies for Combating them: Science, Technology and Education. Formatex Research Center, Spain.

Thappa, R.K., Agrawal, S.G., Dhar, K.C. and C.K.Atal. 1981. Citral containing *Cymbopogonspecies*. *Indian Perfumer*. 25(1), 15-18.

Verma, R.K., Verma, R.S., Chauhan, A. and A.Bisht. 2015. Evaluation of essential oil yield and chemical composition of eight lemongrass (*Cymbopogon spp*.) cultivars under Himalayan region.<https://doi.org/10.1080/10412905.2015.1014936>.

Zhang, C., Liu, R., He, J., Ma, Z. and X.Zhang. 2016. Chemical compositions of ligusticum chuanxiong oil and lemongrass oil and their joint action against aphis citricola van der goot (Hemiptera:Aphididae). *Molecules,***21(10):**1359. <https://doi.org/10.3390/molecules21101359>.

**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 P2O5 (kg ha-1 ) | 21.75 |
| Available K2O (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 |

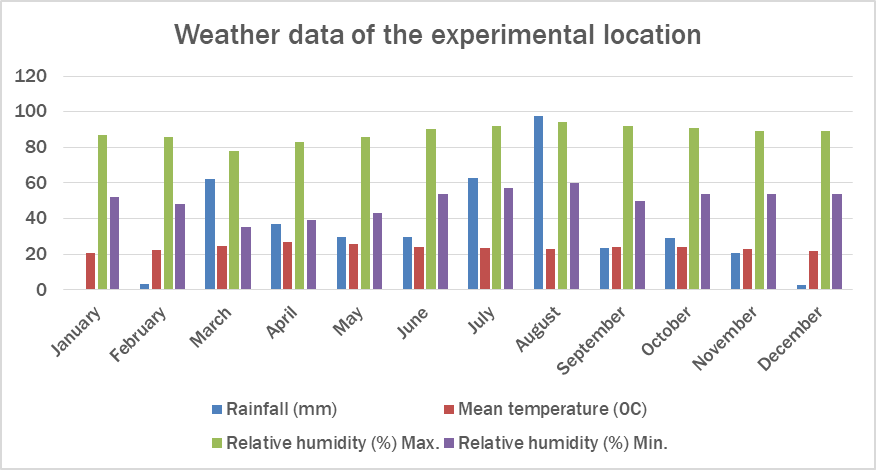
****

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

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sl.**  **No.** | **Cultivars** | **Plant species** | **Variety Development** | **Adaptability** | **Cultivar details references** |
| 1. | Krishna | *Cymbopogon. flexuosus* | Clonal selection | Indian Plains and hills | Anonymous (1997) |
| 2. | Cauvery | *Cymbopogon. flexuosus* | Phenotypic recurrent selection | Requires high soil moisture and is evolved for river valley tracts of Indian Plains | Patra *et al.,* (2005) |
| 3. | Nima | *Cymbopogon. flexuosus* | Half-sib seed followed by clonal selection | Indian Plains | Anonymous (2003) |
| 4. | 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) |
| 5. | CIM-Suwarna | *Cymbopogon. flexuosus* | Clonal selection | Drought prone areas and marginal lands | Lal *et al.,* (2010) |
| 6. | CIM Shikar | *Cymbopogon. flexuosus* | Recurrent selection | High yielding cultivar (>20% Krishna) | Anonymous, (2016) |
| 7. | CKP-25 | *C. khasianus × C. pendulus* | Hybridization | Grows well in northern plains | Rao and Sobti, (1991) |
| 8. | CIM-Atal | *Cymbopogon. flexuosus* | Selection | Geraniol rich (80-85%) grows well in tropical and subtropical region | Kulkarni *et al.,* (2020) |

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

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cultivars** | | **Krishna** | **Suwarna** | **OD-19** | **Neema** | **Kaveri** | **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 |

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cultivar** | **Plant height(cm)** | **Number tillers/clump** | **Number of leavess per tiller** | **Herbage yield**  **(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 taken into account*

**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

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Plant height** | **Number tillers/**  **clump** | **Number of leafs per tiller** | **Oil**  **recovery**  **(%)** | **Herb**  **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 |  |  |  |  |  |  |  |  |
| Herb 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



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