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Morphological characterization, seed production, and oil content of several lemongrass (*Cymbopogon citratus* (D.C.) Stapf.) line

Abstract. *Cymbopogon citratus*, commonly known as lemongrass, is a perennial herb widely cultivated for its culinary, medicinal, and aromatic industries. This research investigates the morphological characterization and potential yield of different lemongrass lines. The study involved the collection of diverse lemongrass genotypes from various geographic regions in Indonesia. The research was conducted using a randomized block design with three replications. Morphological character observations encompass both quantitative and qualitative characters of plants. Morphological characteristics such as plant height, leaf length and width, stem diameter, and number of tillers were measured to assess the variations among the genotypes. The results revealed considerable variability in the morphological traits among the lemongrass. Plant height ranged from 102.28 to 158.96 cm, while stem length and diameter varied between 26.11 to 42.61 cm and 8.99 to 19.68 cm, respectively. The number of tillers per plant ranged from 7.59 to 49.41. Moreover, the essential oil content varied from 0.07% to 0.26% (v/w). According to correlation analysis, the stem's diameter and the leaf's width positively correlate with the essential oil content. As a result, we can continue to develop the Sukabumi local line to maximize biomass and essential oil yields.

Keywords: Crop improvement · Essential oil · Genotypes · Lemongrass · Morphological characterization

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Introduction

Lemongrass (*Cymbopogon citratus* (D.C.) Stapf.) is one of the most widely grown essential oil plants in the tropical and subtropic family Poaceae (Owolabi et al., 2008). Lemongrass originates from India or Sri Lanka and is cultivated in Asia, especially the Indian subcontinent, North and South America, Europe, North Africa, and Australia (Silva & Bárbara, 2022). Lemongrass is a perennial crop that may be cultivated in either irrigated or non-irrigated settings. However, a considerable area is taken from wild natural ecosystems, such as mixed woods, canals, and river banks (Lawal et al., 2017).

The plant's delightful citrus fragrance has validated its use in perfume production and cosmetics. Oil from lemongrass, known as lemongrass oil, contains the main components of acyclic terpenoids such as myrcene, neral, and geranial (Cortes-Torres et al., 2023; Shamsheer et al., 2022). It is the same as the citral type, and the chemical composition is almost identical in some tropical countries (Magotra et al., 2021). Lemongrass stems and leaves have been used in Asian, Latin American, and African cuisine to season curries, soups, shellfish, and chicken (Husain & Wahidah, 2018). It has recently been explored as a food (Djati & Christina, 2019). Lemongrass leaves are widely utilized as a lemon-flavoring element in herbal teas and other popular beverages and aromatic fragrances (Ariska & Utomo, 2020). The most critical portions of the plant for medicinal uses are the leaves, which can be used fresh or dried. However, the stems and rhizomes have also been studied and are traditionally used as antimalaria (Evbuomwan et al., 2023; Sucitra et al., 2022). Lemongrass biomass is steam distilled to obtain essential oil, a natural product used in the food and pharmaceutical sectors, fragrance and cosmetics, and environmentally friendly herbicides (Távora et al., 2023). Lemongrass oil has a pleasant and refreshing aroma and anti-fungal (Sahal et al., 2020), antibacterial (Naik et al., 2010), antidiabetic (Dewanti et al., 2023), anti-cholesterol (Siagian et al., 2022), and an antioxidant (Nambiar & Matela, 2022).

The area of lemongrass cultivation reached 7,600,196 m², with stem production of 3.75 tons in 2022 (Badan Pusat Statistika, 2022). Along with the increasing demand for lemongrass, high-yielding varieties of lemongrass plants are needed. Currently, there are no superior varieties of lemongrass plants, necessitating plant cultivation to produce these superior varieties. Plant breeding begins with collecting genetic resources and observing morphological characters, yielding potential results (Cicevan et al., 2022). Characterizing plant characters/idiotypes is the initial capital in assembling superior plant varieties (Usman & Fatima, 2018). The study aimed to provide valuable insights into the lemongrass line's morphological characterization, seed production, and yield.

Materials and Methods

The experiment was conducted at the Sukamulya experimental field (6°56'35.02" S, 106°46'21.30" E), Sukabumi Regency, West Java Province, Indonesia (332 meters above sea level). The plant materials used in this study were plants selected from genetic resource collections, namely the Purbalingga (PUR01), Yogyakarta (YOG02), Majalengka (MAJ08), Sumedang (SUM11), Cianjur (CIA18), Kutai Timur (KUT20), and Papua (PAP19) as well as local lemongrass plants in Sukabumi (LSU), Bogor (LBOG), and Cikampek (LCIK). The experiment was laid out in Randomized Block Design (RBD) with three replications and 20 plants per experimental plot. The plant seeds used are lemongrass seeds collected at the age of 6 months after planting. Manure derived from cow dung as much as 20 tons/ha, urea 150 kg/ha, SP-36 60 kg/ha, and KCl 90 tons/ha were applied during the experiment. Irrigation, weeding, mulching, staking, and pesticide application were appropriately done when required.

Observation of morphological characters. Qualitative and quantitative morphological features were evaluated five months after planting (MAP). Qualitative traits include habitus, stem color, stem surface, leaf color, leaf surface, and margin. The Royal Horticultural Society (RHS) color chart was used to determine the color sample. Quantitative traits include plant height, canopy, stem number, stem length and diameter, leaf width, leaf length, number of saplings per clump, number per clump, and stem diameter. Number of tillers/clumps used to determine the seed potential of lemongrass.

Harvesting and refining lemongrass oil. Lemongrass plants were harvested at six MAPs

and weighed to determine the yield/initial biomass weight (wo). Lemongrass biomass was held for three days to minimize moisture content before distillation for eight hours using a steaming system (hydrodistillation). The boiler is filled with 40 liters of pure water and 10-15 kg lemongrass. Natural gas is ignited to increase the temperature of the water and generate heat and pressure within the vessel. After 15 minutes, the medium heat mode is resumed, and the water reaches 100°C, causing the steam to vaporize and condense while the cooling water continues to circulate. 500 mL of condensed water and essential oil compounds are drawn from the glass capacitor and added to the funnel to facilitate oil separation every hour. The crude oil volume is determined after the essential oil is extracted (v1). The lemongrass oil content is calculated using the formula v1/wo x 100% (w/v). The lemongrass oil content is calculated using the formula v1/wo x 100% (w/v).

Data analysis. Analysis of variance was used to compare the morphological characteristics of each line's plants. Tukey analysis is used if the results are significantly different. Correlation analysis is used with the Spearman method to determine the relationship between phenotype characters. R program software is used throughout the study.

Results and Discussion

The quantitative character of the lemongrass line. Based on the conducted quantitative character, KUT20 has the maximum plant height and stem length, 158.96 cm, and 42.61 cm, respectively (Table 1). The PAP19 line has the most extended canopy of 128.33 cm (N-S) and 120 cm (W-E), in addition to having the highest leaf length and width of 92.67 cm and 1.47 cm, respectively. However, this line has a shorter stem length than other lines. PAP19 has a lusher header character and quickly touches the ground surface when viewed from these characters. The lowest steam diameter and leaf width are owned by the CIA18 line, which is 8.99 mm and 1.03 cm, respectively. LSUK line has the lowest canopy of 78.33 cm and 75.00 cm but has the largest stem diameter of 19.68 mm. From these characters, no line is found that dominates the same highest character.

Qualitative character of lemongrass plants. Qualitative characters can be seen in Table 2. Additionally, qualitative characteristics revealed genetic diversity amongst lemongrass accessions. There are two habitus of lemongrass plants, namely erect, which we can find in the PUR01, CIA18, KUT20, and LSUK lines. In contrast, the other line has a semi-erect habitus. The round bar type is found in the KUT20 and LSUK lines, while other lines have a flat stem type. Lemongrass stems are generally green with different intensities of purple anthocyanin colors. The color of the stem varies types in various kinds of colors, including yellowish green (yellow-green group/YGG) and green (green group/GG). Research from Susilowati & Syukur (2022) shows the same result that lemongrass leaves were green in color and pointed in shape with fine hairs on the surface. Similarly, the leaf color of lemongrass is green but with different intensities (Figure 1).

Table 1. The quantitative character lemongrass line.

Line	Plant Height (cm)	Canopy		Stem length (cm)	Stem diameter (mm)	Leaf length (cm)	Leaf width (cm)
		North-South	West-East				
PUR01	105.37ab	116.67a	113.33ab	27.06b	9.38c	60.67b	1.13b
YOG02	102.28c	113.33a	102.67ab	26.30b	10.27c	55.67b	1.17b
MAJ08	109.85ab	106.67a	103.33ab	26.76b	10.42c	57.67b	1.10b
SUM11	114.74ab	108.33a	101.67ab	28.15b	9.22c	52.33b	1.13b
CIA18	112.26ab	108.33a	107.67ab	27.41b	8.99c	58.50b	1.03b
KUT20	158.96a	110.00a	103.67ab	42.61a	14.23b	66.67ab	1.10b
PAP19	108.56ab	128.33a	120.00a	26.11b	10.51c	92.67a	2.47a
LBOG	116.56ab	105.67a	109.33ab	26.70b	10.07c	72.00ab	1.35b
LCIK	115.80ab	100.67a	98.33b	26.85b	9.38c	59.33b	1.10b
LSUK	125.24b	78.33b	25.00c	32.43ab	19.68a	66.33b	1.30b

Note: Mean followed by the same lowercase alphabet in the same column is not significantly different based on Tukey's test at 5 %.

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Table 2. Qualitative character of lemongrass line.

Line	Habitus	Stem type	Stem color	Stem surface and anthocyanins	Leaf color	Leaf surface and margin
PUR01	Erect	Flat	Green (YGG144D)	Smooth with anthocyanins	Green (GG137D	Acute, hairy
YOG02	Semi-erect	Flat	Green (YGG145C)	Smooth with anthocyanins	Green (GG138B)	Acute, hairy
MAJ08	Semi-erect	Flat	Green (YGG145B)	Smooth with anthocyanins	Green (GG139C)	Acute, hairy
SUM11	Semi erect	Flat	Green (YGG145B)	Smooth with anthocyanins	Green (GG138A)	Acute, hairy
CIA18	Erect	Flat	Green (YGG145B)	Smooth with anthocyanins	Green (GG137B)	Acute, hairy
KUT20	Erect	Round	Green (YGG144B)	Smooth with anthocyanins	Green (GG137A)	Acute, hairy
PAP19	Semi erect	Flat	Green (YGG145A)	Smooth with anthocyanins	Green (GG138A)	Acute, hairy
LBOG	Semi-erect	Flat	Green (GG138B)	Smooth with anthocyanins	Green (GG138A)	Acute, hairy
LCIK	Semi-erect	Flat	Green (GG139D)	Smooth with anthocyanins	Green (GG138A)	Acute, hairy
LSUK	Erect	Round	Green (GG139B)	Smooth with anthocyanins	Green (GG137A)	Acute, hairy

Figure 1. Lemongrass plants on many lines showed, PUR01 (a), YOG02(b), MAJ08(c), CIA18 (d), PAP19 (e), LBOG (f), LSUK(g), LCIKA(h)

Table 3. Seed production, yield, and oil content of lemongrass line

Line	Number of tiller/clump	Seed Potential (seed/Ha)	Number of stem (stem/clump)	Yield (kg/plot)	Yield (kg/clump)	Oil content (%)
PUR01	37.07ab	370,700ab	129.15a	19.50ab	2.39ab	0.22ab
YOG02	41.93ab	419,300ab	150.89a	13.20b	3.00a	0.17abc
MAJ08	39.59ab	395,900ab	118.11a	17.93b	2.85a	0.16abc
SUM11	49.41a	494,100a	153.41a	19.25ab	2.61ab	0.15abc
CIA18	46.30a	463,000a	155.48a	17.50ab	2.92a	0.19ab
KUT20	23.67bc	236,700b	63.04b	22.20a	3.10a	0.07c
PAP19	38.78ab	387,800ab	138.33a	18.50ab	1.44b	0.19ab
LBOG	36.85ab	368,500ab	113.37a	11.25c	3.03a	0.13bc
LCIK	34.59ab	345,900ab	123.59a	23.23a	2.23ab	0.16abc
LSUK	7.59c	57,900b	13.11c	11.00c	2.39ab	0.26a

Note : Mean followed by the same lowercase alphabet in the same column is not significantly different based on Tukey's multiple range test at 5 %.

Table 4. Phenotypic correlations between the pairs of traits analyzed (below the diagonal) and the p-value of the correlation (above the diagonal).

Correlated trait	1	2	3	4	5	6	7	8	9	10
1. Plant Height (cm)	1	0.454	0.639	0.000	0.044	0.106	0.805	0.621	0.391	0.565
2. Canopy (U-S)	-0.268	1	0.008	0.502	0.021	0.026	0.321	0.463	0.388	0.475
3. Canopy (B-T)	-0.170	**0.781****	1	0.853	0.054	0.095	0.887	0.729	0.634	0.720
4. Stem lenght (cm)	**0.967****	-0.241	-0.068	1	0.036	0.067	0.939	0.564	0.366	0.904
5. Number of stems	**-0.646***	**0.710***	0.623	**-0.660***	1	0.000	0.639	0.864	0.894	0.455
6. Stem diameter (mm)	0.541	**-0.693***	-0.556	0.600	**-0.946****	1	0.624	0.929	0.973	0.029
7. Leaf length (cm)	0.090	0.350	-0.052	0.028	-0.170	0.177	1	0.000	0.052	0.947
8. Leaf width (cm)	-0.179	0.463	0.126	-0.208	0.063	0.033	**0.917****	1	0.965	0.008
9. Yield (kg/clump)	0.305	-0.250	-0.172	0.321	-0.048	-0.012	-0.628	**-0.776****	1	0.181
10. Oil content (%)	-0.207	-0.256	0.130	-0.044	-0.268	**0.427***	-0.024	**0.094***	**-0.460**	1

Correlation is significant at the 0.01 level (**), 0.05 level (*) (2-tailed).

Seed production, biomass yield, and lemongrass oil. In plant development activities, the provision of seeds is essential. Seed potential is known by calculating the number of saplings per clump. The highest number of saplings in the SUM 11 line so the SUM11 line also owns the highest seed potential with a value of 494,100 seeds/ha. The highest number of lemongrass stems are owned by CIA18 and SUM 11, with 155.48 stems/clumps and 494,100 stems/clumps, respectively (Table 3). The amount of biomass harvested determines the oil content to be processed, although certain varieties with low biomass/yield have high oil content. The LBOG line has the highest biomass of 3.03 kg/clump, while the lowest is the PAP19 line of 1.44 kg/ clump. The content of essential oils in some lines indicates that the oil content ranges from 0.07% to 0.26%. most significantThe largest oil content is owned by the LSUK branch, and the lowest is the Kut20 line. According to research Sawadogo, et al. (2022), the oil content of lemongrass varies between 0.13-1.33% of the dry weight of the sample. The same result was obtained Shamsheer, et al. (2022), the oil yield ranged from 1.32 ± 0.42 ml/g.

Of all the growth characteristics among lemongrass negatively correlated with yield (Table 4), even leaf width is highly negatively correlated. At the same time, plant height is negatively correlated, although statistically, it is not significantly different. Not all growth characters were markedly correlated with oil content; the positive correlation was stem diameter and leaf width. In contrast to the results of research by Yogendra et al. (2021), the character of plant height and number of leaves positively correlate with the results and content of essential oils. This hypothesis is based on the observations, which show nearly identical plant

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heights. As a result, this investigation does not consider the number of lemongrass leaves but rather the diameter of the stem.

Conclusion

The results revealed considerable variability in the morphological traits among the lemongrass genotypes. Based on the morphological character, plant height ranged from 102.28 to 158,96 cm, while stem length and diameter varied between 26.11 to 42.61 cm and 8.99 to 19.68 cm, respectively. Moreover, the essential oil content ranged from 0.07% to 0.26% (v/w). Based on the correlation analysis, select genotypes exhibited desirable morphological traits and higher essential oil content, indicating their potential for increased yield. Therefore, the Sukabumi Local line (LSUK) with high diameters and leaf width is considered for commercial cultivation to maximize biomass production and essential oil yield.

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