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Fragrant grass and essential oil industry development program in Cagayan Valley

Nenette T. Columna*, Zarina Kate C. Laggui, Lauro J. Julian, Roje Marie Clemente

Cagayan State University, Lal-lo, Philippines

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Abstract

Cymbopogon grasses such as lemongrass and citronella are widely known as source of indigenous medicine and essential oils of various uses. At present, the cultivation of these species is still at an early stage, and the intensive processing and manufacturing industry of its products are yet to be established in the region. Hence, this research was conducted with the goal to provide vital scientific information and research-based technology geared toward the development of the fragrant grass industry in Region 2. The study made use of a Randomized Complete Block Design for its nutrient management trial. Steam distillation is the primary method used for essential oil extraction. Results revealed that among the three fragrant grass varieties, citronella recorded the highest in terms of plant height, number of tillers, and plant weight. Except for a number of tillers for the white lemon grass variety at 4 months, the level of fertilizer application does not substantially affect the fragrant grasses' agronomic characteristics, which implies that the recommended nutrient and fertilizer requirement is already sufficient. The highest oil recovery and yield is recorded for citronella, followed by the red and white lemongrass cultivar, respectively. In lemongrass, oil yield is higher when the leaves are extracted fresh rather than air-dried, but the opposite is observed in citronella where air-dried leaves give higher oil yield.

* **Corresponding Author:** Nenette T. Columna ✉ nettecolumna123@gmail.com

Introduction

Growing grasses for fragrance is very rare. The fragrance comes mostly from flowers of ornamental plants and trees. Today, grasses with fragrant leaves add a big dimension in the world of fragrance and pharmaceutical industry. Fragrant grasses of the genus *Cymbopogon* is very much well – known for its aromatic fragrance and high – content of essential oil.

Cymbopogon is a genus that belongs to the family *Poaceae*, and is widely distributed in tropical and subtropical regions such as Asia, Australia, Africa, and America (Kamari 2018, Muttalib 2018). In Asia, *Cymbopogon species* originated from Sri Lanka and found its way to Indonesia and the rest of the continent. Now some of these *Cymbopogon species* are being widely cultivated in the Philippines. The genus *Cymbopogon* is a perennial grass with long, thin leaves, and well – known for its aromatic fragrance. Common species of this genus here in the Philippines include *Cymbopogon nardus*, commonly known as Citronella grass or Java citronella, *Cymbopogon winterianus* (Java Citronella), and *Cymbopogon citratus* or best known as lemongrass. The citronella varieties are frequently used for their mosquito-repellent activity, while lemon grasses are most often utilized as spices and flavorings (Mu`azu *et al.*, 2019).

Essential oil, which is one of the important phytochemicals, is a concentrated hydrophilic and lipophilic liquid of plants having high volatile aroma compounds carrying a distinctive scent, flavor, or essence of plant (Abdurahman *et al.*, 2013). Famous for being a rich source of essential oils, *Cymbopogon species* are highly regarded and are being used extensively in cosmetics, perfumery, and food industries, and most recently in the pharmaceutical industry (Kamari 2018, Muttalib 2018, Mu`azu, 2019). Essential oil of these plants is generally extracted through steam distillation, and as a by–product of the process, hydrosol is also produced. Hydrosol is a liquid that contains most of water and about 3% of essential oil, and also carries a scent fainter than its essential oil.

At present, cultivation of these species is still at an early stage, and the intensive processing and manufacturing industry of its products are yet to be established in the region. Moreover, although small – scale oil extraction of fragrant grass (citronella), as well as processing of its products, has been an emerging practice in the locality, literature however reveals that these are not supported by systematic and comprehensive studies establishing the mainstay of this emerging enterprise.

The aim of this project is to improve citronella and lemongrass production and management, with an end goal of making fragrant grass a major industry in the region through providing quality planting materials to growers and beneficiaries, and extending capacity-building trainings for partner communities such as the RIC-Lal-lo members and citronella growers in Lal-lo and neighboring municipalities on research-based technology on cultivation, nutrient management, and extraction of fragrant grasses.

This present project includes nutrient management and extraction of cultivated Cymbopogon species at Cagayan State University Lal-lo. The study sought to provide scientific information about the most adaptable cultivar, as well as the most effective management practices, and oil extraction methodology for fragrant grass production and processing.

Materials and methods

Plant Specimen, Cultivation and Nutrient Management

The study was conducted at the production site and experimental areas of Cagayan State University at Lal-lo from March 2021 to August 2022.

Varietal characterization of collected fragrant grasses within the province resulted in the identification of three fragrant grass varieties under the genus *Cymbopogon*, namely Citronella, Lemongrass White cultivar, and Lemongrass Red cultivar. Authentication and verification of these three plant specimens was done by sending plant samples to the DA-Bureau of Plant Industry, Region 2.

The establishment of the production area of citronella and lemongrass started with the selection of suitable sites for planting. Selected sites are open spaces where

grasses would receive full sunlight throughout the day. The site has a sandy loam texture for good drainage.

Soil samples were collected and submitted for soil analysis at the DA CVIAL Laboratory at Tuguegarao City, where results served as the basis on the formulation of fertilizer and amount of application for the experimental phase.

Nutrient management of *Cymbopogon* grasses employed the Randomized Complete Block Design using the factorial method, involving three replications and five levels of fertilizer treatment, including the control. Three blocks were established, each consisting of 15 plots. Each plot has a measurement of 13m x 13m.

Healthy slips of Citronella and Lemongrass were collected and planted in the experimental field in December 2021. A respective spacing of 2 ft x 2 ft is maintained between hills. Each of the 13m x 13m plots is planted with 49 hills of plants. Inter-row cultivation was carried out uniformly whenever required to maintain faster growth of the grasses, as well as to control weed growth. Agronomic characteristics, including a number of tillers per plant, plant height, and plant weight of each fragrant grass were recorded. Data such as fresh biomass yield and essential oil yield per hectare were also provided.

Harvesting and Extraction

Steam distillation is the primary essential oil extraction method used. Mature leaves were collected fresh by cutting the plant 6-8 inches from its base. Sieving follows after the collection to separate the dried and withered leaves from the heap. Leaves were then weighed, then soaked in purified water dissolved with a handful of baking soda to remove dirt and eliminate contaminants. Rewashing the leaves with tap water was done after soaking. One hundred kilograms (100kg) of either fresh or air-dried plant material was used. For fresh plant material, leaves were chopped using a stainless cutter into cutlets of 2 inches for better essential oil recovery. As for dried leaves, an additional step of air drying of leaves is done for 3-4 days. Right after rewashing, the leaves were spread out on a clean steel top or laid on the floor in a clean canvas or tarpaulin, and left to dry under a shade. Withered leaves were then chopped into cutlets. Purified water was used for the distillation to prevent microbial contamination and to ensure the quality of essential oil. Hydrosol and essential oil start to come out of the separator tube after two hours of boiling. The essential oil and hydrosol were separately collected using beakers. Essential oil and hydrosol continuously come out up to 2 hours from the first drip. A maximum of 3 hours was allotted until all the oil was extracted. Essential oil yield and hydrosol and percentage of oil recovery of each fragrant grass variety were recorded and compared.

Results and discussion

Plant Specimens

The genus Cymbopogon is aromatic grasses known for their citrus fragrance and high essential oil content. These tufted perennial herbs grow in thick clumps, with leaves narrow and linear, growing to a height of up to 1.5 – 2m. For this research, three *Cymbopogon* species are identified based morphological differences. Of the three fragrant grasses, two are lemongrass and the other is citronella. Fig. 1 shows the photo of fragrant grasses cultivated at CSU Lal-lo. The Lemongrass white cultivar and red cultivar were named by virtue of the plants' stem color. Aside from the color of their stalk, the two cultivars can be identified by their height and leaf form. The white lemongrass is taller with erect leaves, while the red cultivar is shorter with leaves drooping off at the tip. The citronella, on the other hand, has a magenta base, longer stems and broader leaves. Citronella leaves are bright green in color, with sharper leaf blades, and tapering off at the middle. Citronella plants are the tallest of the three species.

Authentication and verification by the DA - Bureau of Plant Industry revealed the common name and scientific name of each fragrant grass species as follows:

Cultivated Plant	Common Name	Scientific Name
Lemongrass White variant	West-Indian Lemongrass	*Cymbopogon citratus*
Lemongrass Red variant	East-Indian Lemongrass	*Cymbopogon flexuosus*
Citronella	Citronella grass	*Cymbopogon winterianus*

Table 1 presents the soil analysis of the production and experimental site of the fragrant grasses. The analysis reveals that the soil pH is 4.97 which is slightly acidic. Organic matter (N) of 2.32% and phosphorus (P) of 4.0ppm suggests the minimal amount of said macronutrient in the site. Potassium (K) is 76ppm denoting high availability of the nutrient. Available Zinc (0.18ppm), Copper (1.32ppm), and Iron (17.4) are present in minimal quantity, while Manganese (52.6ppm) content of the soil is high.

From L to R: Cymbopogon citratus, Cymbopogon flexuosus, Cymbopogon winterianus

Fig. 1. Cymbopogon species cultivated at CSU Lal-lo.

Table 1. Soil Analysis of Fragrant grass production and experimental area.

Lab # RSL 2021	Sample Code	Macronutrient				Micronutrient			
		pH	O.M% (N)	Available P,ppm	Available K,ppm	Available Zn,ppm	Available Cu,ppm	Available Mn,ppm	Available Fe,ppm
HVC 489	2	4.97	2.32	4.00	76	0.18	1.32	52.6	17.4

Nutrient Requirement

The recommended nutrient and fertilizer requirement for lemongrass and citronella is presented in Table 2. From the result of soil analysis, the Nitrogen and Phosphorus content of the site is low, while Potassium content is high, thus the recommended nutrient is 60-60-0.

The recommended fertilizer has the ratio 0-18-0 of 6.5 bags per hectare on the first application. Succeeding applications require only 1.3 bags per hectare of fertilizer with a high nitrogen content of 46-0-0. Shaikh *et al.* (2019) suggested that fertilizer application may influence the increase of citral content in lemongrass.

Table 2. Recommended Nutrient and Fertilizer Requirement of Lemongrass/Citronella.

Lab # RSL 2021	Sample Code	CROP Variety	Nutrient Requirement (kg/ha)			Fertilizer Recommendation		
			N	P	K	1st application	2nd application	3rd application
HVC 489	2	Lemongrass/Citronella	60	60	0	6.5 bags/ ha 0-18-0	1.3 bags/ ha 46-0-0	1.3 bags/ ha 46-0-0

Nutrient Management of Fragrant Grasses

Nutrient Management of Cymbopogon citratus

The agronomical characteristics of *Cymbopogon citratus* (Lemongrass White) at 4 months and 8 months is presented in Table 3. Height of the plants at 4 months revealed that plants applied with the least rate of fertilizer in T1 were the tallest with a mean of 113.4cm. It was followed by plants in T3, T5, T4, and T2 with means of 113.13, 86.93, 85, 77.07, and 74.83cm respectively. The analysis of variance on the height at 4 months showed significant differences. T1 is significantly different to T2, T3 T4, and T5 however, T2 is not significantly different from T3, T4 and T5. On the other hand, the mean plant height at 8 months old showed almost the same height. This manifests that white lemon grass variety have variations on their growth on their first 4 months, as they mature, they reach their peak attainable height

and almost have the same height, thus the analysis of variance at 8 months, as presented in Table 4, revealed no significant differences.

Table 3. Summary of Agronomical characteristics of *Cymbopogon citratus* (Lemongrass White) at 4 months and 8 months.

Treatment	At 4 months		At 8 months		
	Plant Height (cm)	Number of Tillers	Plant Height (cm)	Number of Tillers	Ave. weight per Plant (kg)
	Mean	Mean	Mean	Mean	Mean
T1-(40-40-0)	113.13 [a]	40.47	166.25	44.60	1.91
T2-(50-50-0)	74.83 [b]	33.03	162.24	40.16	1.64
T3-(60-60-0) RR	86.93 [b]	31.93	159.95	45.60	2.14
T4(70-70-0)	77.07 [b]	36.66	165.73	47.37	2.07
T5-(80-80-0)	85.00 [b]	33.17	158.63	42.70	1.76
Grand Mean	87.39	35.05	162.56	44.70	1.9

As to the number of tillers produced at 4 and 8 months, the table reveals that the lowest rate of fertilization garnered the most number of tillers at 4 months with a mean of 40.47 tillers. It was followed by plants in T4 with 36.66 tillers. However, at 8 months old, T4 overcome T1 and ranked first with 47.47 tillers. Nevertheless, the analysis of variance reveals no significant difference as far as the number of tillers at 4 and 8 months in concerned.

As to the average weight per plant, plants in T3 that ranked 2nd in the production of tillers and ranked 4th in height, produced the heaviest weight per plant. Although T4 produced the most number of tillers and T1 were the tallest, they only ranked 2nd and 3rd as far as weight per plant is concerned. This is so because they were observed to produce thinner plants as compared to plants in T3. Nevertheless, the analysis of variance reveals no significant differences.

Table 4. Analysis of variance on the Agronomic characteristics of *Cymbopogon citratus* (Lemongrass White).

Source of Variation	Df	Plant Height				Number of Tillers				Plant Weight	
		At 4 months		At 8 months		At 4 months		At 8 months		At 8 months	
		F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
Block	2	4.68	0.0451	0.41	0.6774	0.98	0.4157	0.54	0.6003	0.07	0.9316
Treatment	4	5.88	0.0165 **	0.62	0.6633	0.24	0.9074	0.75	0.5868	1.21	0.3795
Error	8										
Total	14										
CV (%)		12.48		4.60		35.35		12.58		17.25	
Statistical Inference		Significant		Not significant		Not significant		Not significant		Not significant	

Nutrient Management of Cymbopogon flexuosus

The agronomical characteristics of *Cymbopogon flexuosus* (Lemongrass Red) at 4 months and 8 months is presented in Table 5. As in the case of Lemon grass white, plants that were fertilized with the least rate of fertilizer were the tallest at 4 and 8 months, while plants that were fertilized with higher rates were the shortest.

T6 attained a mean height of 95.67cm at 4 months, while 142.33cm at 8 months. It can be observed that plants fertilized with 50-50-0, 60-60-0, 70-70-0 and 80-80-0 NPK per hectare have almost the same height at 4 months except for plants that were fertilized with the least rate in T1 (40-40-0 NPK). However, during their 8 months, the different treatments produced almost the same height. It is a common knowledge that the more fertilizer applied to plants, the taller the plants should be. However, for the case of Lemon grass red variety, this generalization does not really apply, since the lower the rate of fertilization, the taller is the plants. However, the analysis of variance reveals no significant differences as to the height at 4 and 8 months is concerned.

The result of the mean number of tillers at 4 and 8 months of lemon grass white variety as affected by different rates of fertilizer is also presented in Table 6. The same trend was again observed as in the case of the lemon grass white variety in which the lower the rates of fertilization, the greater number of tillers was produced at 4 months. T6 (40-40-0) garnered a mean

tiller of 43.13 and outranked the other treatment. However, T9 (70-70-70 NPK) which ranked 4th in tillers at 4 months overcome the other treatments at 8 months and produced a mean tiller of 62.47. Nevertheless, the analysis of variance reveals no significant differences.

As to the average weight per plant, treatment that produced the most number of tillers, produced the heaviest weight per plant. T9 garnered a mean weight of 2.03kg and outranked the other treatment. Although T6 (40-40-0) were the tallest plants, the additional height did not compensate for the weight produced. Nevertheless, the analysis of variance reveals no significant differences, thus the level of fertilization did not influence the weight of Lemon grass red variety.

Table 5. Summary of Agronomical characteristics of *Cymbopogon flexuosus* (Lemongrass Red) at 4 months and 8 months.

Treatment	At 4 months		At 8 months		
	Plant Height (cm)	Number of Tillers	Plant Height (cm)	Number of Tillers	Plant weight (kg)
	Mean	Mean	Mean	Mean	Mean
T6-(40-40-0)	95.67	43.13	142.33	52.27	1.70
T7-(50-50-0)	75.77	28.99	138.40	30.48	1.85
T8-(60-60-0) RR	71.20	29.87	134.40	55.27	1.86
T9(70-70-0)	72.20	29.07	131.97	62.47	2.03
T510 (80-80-0)	67.57	30.70	135.60	54.60	1.86
Grand Mean	76.48	32.35	136.54	54.70	1.86

Table 6. Analysis of variance on the Agronomic characteristics of *Cymbopogon flexuosus* (Lemongrass Red).

Source of Variation	Df	Plant Height				Number of Tillers				Plant Weight	
		At 4 months		At 8 months		At 4 months		At 8 months		At 8 months	
		F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
Block	2	1.20	0.3503	0.40	0.6828	4.23	0.0557	19.69	0.0008	11.58	0.0043
Treatment	4	1.25	0.3654	0.54	0.7129	2.33	0.1431	1.80	0.2228	0.74	0.5896
Error	8										
Total	14										
CV (%)		22.55		6.89		21.26		11.82		12.35	
Statistical Inference		Not significant		Not significant		Not significant		Not significant		Not significant	

Nutrient Management of Cymbopogon winterianus

The agronomical characteristics of *Cymbopogon winterianus* (Citronella grass) at 4 months and 8 months are presented in Table 7. The same trend was observed on the height at 4 and 8 months as in the case of Lemon grass white and red variety. Plants fertilized with the lesser rate of fertilizer in T11 and T12 (40-40-0 and 50-50-0) tend to produce taller plants while plants fertilized with higher rates tend to be smaller. T15 (80-80-0 NPK) produced the shortest plants while T12 (50-50-0) produced the tallest at 8 months. However, as in the case of the other parameters, the analysis of variance showed no significant differences as far as the height at 4 and 8 months is concerned. The number of tillers at 4 and 8 months is also presented in the same table. Citronella variety fertilized with higher rates of fertilizer in T15 (80-80-0) produced the most number of tillers at 4 and 8 months. However, the table reveals that not all tillers at 4 months developed up to 8 months as the number of tillers at 8 months decreased in number. Nevertheless, the analysis of variance again reveals no significant differences as presented in Table 8.

As to the mean weight per plant, plants that ranked second in the production of tillers T14 (70-70-0), produced the heaviest weight per plant, while plants in T15 that produced the most number of tillers only ranked 4th. This simply explains that number of tillers produced is not only a contributory to weight, but also the quality of tillers as plants in T14 were observed to have better and bigger diameter tillers. However, as in the case of the other parameters measured, the analysis of variance reveals no significant differences.

Table 7. Summary of Agronomical characteristics of *Cymbopogon winterianus* (Citronella) at 4 months and 8 months.

Treatment	At 4 months		At 8 months		
	Plant Height (cm)	Number of Tillers	Plant Height (cm)	Number of Tillers	Plant weight (kg)
	Mean	Mean	Mean	Mean	Mean
T11-(40-40-0)	129.73	64.77	217.20	52.77	2.31
T12-(50-50-0)	136.43	62.47	223.77	52.13	2.39
T13-(60-60-0) RR	93.53	44.90	205.30	60.03	2.47
T14(70-70-0)	113.47	60.03	216.70	62.00	2.73
T15 (80-80-0)	114.20	74.60	188.77	65.70	2.34
Grand Mean	117.47	61.35	210.35	58.53	

Table 8. Analysis of variance on the *Agronomic characteristics* of Cymbopogon winterianus (Citronella).

Source of Variation	Df	Plant Height				Number of Tillers				Plant Weight	
		At 4 months		At 8 months		At 4 months		At 8 months		At 8 months	
		F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
Block	2	0.03	0.9663	2.66	0.1304	0.51	0.6205	7.38	0.0153	9.08	0.0088
Treatment	4	0.60	0.6755	1.05	0.4413	0.49	0.7435	1.94	0.1972	0.57	0.6894
Error	8										
Total	14										
CV (%)		31.80		11.09		43.26		12.57		15.66	
Statistical Inference		Not significant		Not significant		Not significant		Not significant		Not significant	

Comparison of Cymbopogon species as to their agronomic characteristics

Height of Plants

A comparison of the height of three fragrant grasses at four months and eight months after planting is shown in Table 9. Maximum plant height is recorded on citronella during the 4th and 8th months of growth, while the lemongrass white cultivar comes second, and the minimum plant height is recorded for the red lemongrass cultivar. This result is consistent with the observed height of the fragrant grasses in the non-experimental production site in the campus. This result also suggests that fragrant grasses' growing season reaches up to 8 months and beyond. As a reference, citronella plants grow from 1.5 to over 2 meters while lemongrasses grow from 1m to over 1.5 meters.

It is important to note, however, that citronella and lemongrass are best harvested between 6-9 months after planting the slips. Subsequent harvests can be done thereafter every 3 months interval for citronella, and 1-3 months interval for lemongrass, to ensure better oil yield. Harvesting too soon and too late affects the quality of oil adversely. The delay also causes the leaves to dry up resulting in decrease in yield of oil.

Table 9. The summary of results on the comparison of plants' heights at 4 months and 8 months.

Variety	At 4 months	At 8 months	
	Mean (cm)	Group	Mean (cm) Group
1-Lemongrass (W)	87.39	15b	162.56 15b
2-Lemongrass (R)	76.48	15b	136.54 15c
3-Citronella	117.47	15a	210.35 15a
Grand Mean	93.78		169.82

* Means with the same letter are not significantly different

Table 10. The analysis of variance on the heights of plants at 4 months and 8 months.

Source of Variation	Df	At 4 months		At 8 months	
		F-value	P-value	F-value	P-value
Block	2	0.10	0.9044	2.88	0.0729
Fertilizer	4	2.04	0.1164	1.30	0.2944
Variety	2	11.61	0.0002 **	83.33	0.0000 **
Fertilizer: Variety	8	0.62	0.7571	0.64	0.7369
Error	28				
Total	44				
CV (%)		25.73		9.35	

*Significant ** Highly Significant

As shown in Table 10, the plants' height is significantly different in terms of variety, with citronella plants as the tallest and lemongrass red cultivar as the shortest, which coincides with the grasses' natural growth potential. There was no significant difference between the three plants' height across blocks and the level of fertilizer application. This only implies that increasing the fertilizer application or modifying the formulation from the recommended

amount and ratio has no significant effect on the height of the three cultivars. No interaction between the levels of fertilizer and the variety of the grasses is revealed, implying that fertilization and nutrient management is applied as recommended based on the soil analysis of the site of cultivation.

Number of Tillers

Table 11 shows the number of tillers of each fragrant grass variety at 4 months interval. At 4 months, highest number of tillers is recorded for citronella plant with an average of 61 tillers per hill, followed by lemongrass white cultivar with a mean of 35 tillers per hill, while the red cultivar recorded an average of 32 tillers per hill. It is interesting to note that the average number of tillers of each variety changes in the course of time, suggesting an active growing season, especially for the red lemongrass variety, which recorded the highest increase in tillers (average of 23 additional tillers) in the succeeding 4 months. The white lemongrass cultivar has a slight increase with an average of 9 additional tillers. Although still the highest in terms of the number of tillers, citronella has decreased from having 61 tillers to 58 tillers in the 8th month. This may be due to the fact that citronella tends to become highly robust, inducing intra-nutrient competition. Moreover, this observation suggests that harvesting of citronella plants within 3-4 months interval is recommended.

Analysis of variance on the plants' number of tillers in Table 12 reveals that there is a very high variation of samples across blocks and among varieties. It was noted that citronella has greatest number of tillers among the fragrant grasses, and the lemongrass cultivars are statistically similar in the first 4 months. Moreover, the red lemongrass has remarkable increase in tillers in the next growing season, recording a statistically similar average tillers with that of citronella. However, there was no significant interaction between the level of fertilizer application and the variety of fragrant grasses, implying that increasing the amount of fertilizer application does not significantly affect the number of tillers of either the citronella and lemongrass cultivars, and hence, nutrient management of the fragrant grasses will proceed as proposed by the recommended nutrient and fertilizer requirement of the plants as based from the results of the soil analysis of the planting area.

Table 11. The summary of results on the comparison of plants' number of tillers at 4 months and 8 months.

Variety	At 4 months		At 8 months	
	Mean/ Group		Mean/ Group	
1 – Lemongrass (W)	35.05	15b	44.09	15b
2 – Lemongrass (R)	32.35	15b	54.70	15a
3 – Citronella	61.35	15a	58.53	15a
Grand Mean	42.92		52.44	

* Means with the same letter are not significantly different.

Table 12. The analysis of variance on the plants' number of tillers at 4 months and 8 months.

Source of Variation	Df	At 4 months		At 8 months	
		F-value	P-value	F-value	P-value
Block	2	1.01	0. 3769	12.57	0.0001 **
Fertilizer	4	0.86	0.4998	2.19	0.0964
Variety	2	13.35	0.0001 **	12.77	0.0001 **
Fertilizer: Variety	8	0.42	0.8964	0.45	0.8794
Error	28				
Total	44				
CV (%)		39.57		15.46	

*Significant

** Highly Significant

Weight of Plants (First Harvest)

Comparison on the three fragrant grasses' weight is presented in Table 13, in which Citronella plant recorded the highest average weight of 2.45kg per hill. Meanwhile, the lemongrass white and red cultivar does not vary significantly with an average weight per hill of 1.90kg and 1.86kg, respectively. The weight difference may be due to the fact that citronella plants are by far taller and with thicker stalks than their lemongrass counterparts.

Statistical data presented in Table 14 reveals that there is a significant weight differences among samples taken from across the three blocks, and among varieties of fragrant grasses. Nonetheless, no significant interaction is exhibited by the levels of fertilizer and weight of the fragrant grass varieties. The inference assumes that increasing the amount and modifying the ratio of fertilizer applied to the crops does not have a considerable effect on the weight of the herbage.

Table 13. The summary of results on the comparison of plants' weights at 8 months.

Variety	Mean/ Group
1 – Lemon Grass (White)	1.90 15 b
2 – Lemon Grass (Red)	1.86 15 b
3 – Citronella grass	2.45 15 a
Grand Mean = 2.07	

* Means with the same letter are not significantly different.

Table 14. The analysis of variance on the weights of plants at 8 months.

Source of Variation	Df	Sum of Squares	Mean Square	F-value	P-value
Block	2	2.6777	1.3389	0.16	0.0005
Fertilizer	4	0.6931	0.1733	1.32	0.2886
Variety	2	3.2084	1.6042	12.18	0.0002
Fertilizer: Variety	8	0.3215	0.0402	0.31	0.9578
Error	28	3.6892	0.1318		
Total	44	10.5899			
CV (%)		17.53			
Statistical Inference		Highly Significant			

Essential Oil Yield and Hydrosol

At present, the most popular and widely used extraction method of lemongrass and citronella essential oil is steam distillation (Fernandes, *et al.*, 2019), because of the simplicity of the method and the low cost of the extractor machine. This method works by passing the steam through the fresh or dried plant material. The steam softens the cells enabling the essential oil to escape in vapor form, which will be subsequently cooled in a condenser and collected.

Fig. 2 presents the data on the essential oil yield of the three varieties of fragrant grasses in their fresh and air-dried state. A 100kg of plant material is prepared for each variety, and a total of 6 batches of extraction is done. The highest oil yield is recorded in citronella plant in both fresh and air-dried states with 249mL and 315mL of extracted oil, respectively. For lemongrass varieties, the red variety has a higher oil yield than the white cultivar. It is observed that in lemongrass, the greater oil yield is recorded when plants are distilled in their fresh state compared when they are air-dried prior to extraction. This result is in consonance with the study of Nair *et al.* (1980) on factors of processing of essential oils, which revealed that field drying of cut grass reduced the oil yield and active chemical content in the oil. The opposite is observed in citronella where air-dried plant material has a higher oil yield than in its fresh state. The observed value is consistent with other studies that citronella has a higher oil yield than lemongrass.

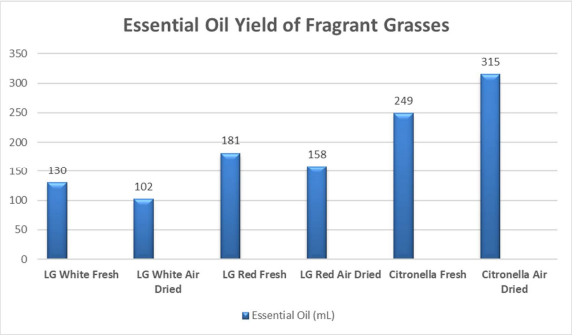

Fig. 2. Comparison of Essential Oil Yield of Fragrant Grasses in their Fresh and Air-dried Condition.

The amount of hydrosol collected for each variety is presented in Fig. 3. Hydrosol is the watery by-product of the steam distillation of aromatic grasses, formed together with the oil by cooling of condensate. It is commonly used as an insect-repellent spray. The highest amount of 30 liters of hydrosol is collected from the distillation of fresh plant material of citronella, while 20 liters of hydrosol is recovered from the air-dried state. The same amount of 20 liters of hydrosol is collected from the fresh and air-dried red lemon grass, while the white lemongrass variety recorded, 16 liters and 18 liters of hydrosol from the fresh and air-dried state, respectively.

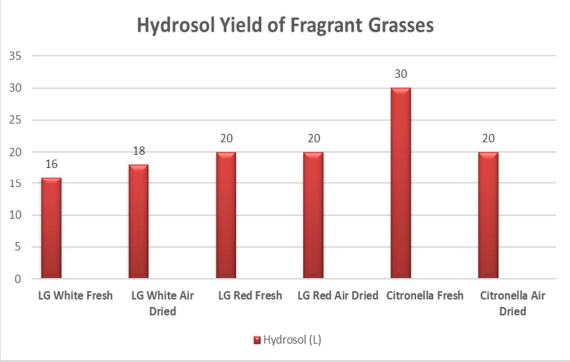

Fig. 3. Comparison of Hydrosol Yield of Fragrant Grasses in their Fresh and Air-dried Condition.

Percent Essential Oil Recovery

Fig. 4 displays the percent of essential oil recovery of all 6 batches of extraction of the three fragrant grass varieties. Extraction time per batch includes the induction time until the boiler reaches boiling point

and the actual extraction time where the first oil droplet is seen. Actual extraction time lasts approximately two hours. Most of the essential oil, which amounts to 50-66 percent of the total oil volume is recovered in the first 30 minutes of actual extraction, starting from the time the first drop of oil comes out. 18-30 percent of oil is recovered in the next 30 minutes, and around 5-20 percent in the last 1 hour. There is a reduction of more than half the volume of oil recovered in each 30-minute interval, which implies that distilling beyond two hours may result to very low oil quantity. This finding is consistent with the study of Mu'azu *et al.* (2019) where the yield of lemongrass oil increases with an increase in extraction time until it reached about 30 minutes before declining. Moreover, darker oil is extracted at later stage of extraction.

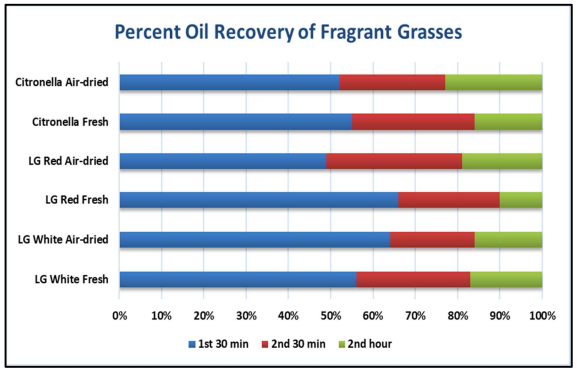

Fig. 4. Percent Oil Recovery of Fragrant Grasses.

Conclusion

1. Citronella grass, *Cymbopogon winterianus* recorded highest in terms of plant height, number of tillers and plant weight.
2. Level of fertilizer application does not substantially affect the fragrant grasses' agronomic characteristics.
3. Highest oil recovery and yield is within the first 30 minutes; yield starts to decline to about 50-60% in the succeeding time intervals.
4. Citronella grass, *Cymbopogon winterianus* has the highest oil yield, followed by the red lemon grass, *Cymbopogon flexuosus* and white lemon grass, *Cymbopogon citratus* cultivars respectively.
5. In lemon grass, oil yield is higher when the leaves are extracted fresh, while in citronella grass, air-dried leaves give higher oil yield.

Recommendations

1. Continue the establishment of experimental and mass production areas of Cymbopogon grass species as a source of quality planting materials for expansion and distribution to target beneficiaries.
2. Subject the citronella and lemon grass essential oil and hydrosol in phenol coefficient, organoleptic properties, chemical component, repellency, shelf life, antifungal, and microbiological analysis.

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