

Variations in the Composition of Oil in Citronella

E. E. IRUTHAYATHAS,* H.M.W. HERATH,* R. O. B. WIJESKERA AND A. L. JAYEWARDENE
*Natural Products Section, Ceylon Institute of Scientific and Industrial Research (CISIR),
 P. O. Box 787, Colombo 7, Sri Lanka.*

(Paper accepted : 9 September 1977).

Abstract : Commercial oil of citronella in Sri Lanka is distilled mainly from 'lenabatu' grass. In citronella plantations some mixed populations of 'lenabatu' and 'mahapengiri' types are found. Selections among these enabled eleven strains to be located. The propagation of these strains and the investigation of the essential oils distilled from them using gas liquid chromatography revealed differences among thirty-one of the chemical constituents. In addition to the oil from the vegetative parts of the plants, the flowering parts also yielded essential oils which again showed differences from the leaf oils of the same plant and variations among the strains. Correlation studies provided values which have helped to explain the factors influencing the production of one group of components more than another. The variability of the chemical composition of oils that are reported have been observed to be in accord with the genetic difference of the strains.

1. Introduction

Sri Lanka is one of the principal citronella oil producing countries, and citronella has been cultivated in Sri Lanka for over a century. The two types of citronella oil sold in world market are the Java type and the Ceylon type, the former being produced from the Java variety called 'Mahapengiri' and the latter from the Ceylon variety called 'Lenabatu'. Botanically the two types, 'Mahapengiri' and 'Lenabatu' are derived from *Cymbopogon winterianus* Jowitt and *Cymbopogon nardus* (L) Rendel respectively.¹ It is believed that both types originated in Sri Lanka.³ 'Mahapengiri' is now being grown in Java, Formosa, People's Republic of China, Haiti, Honduras, Taiwan, Guatemala and India. 'Lenabatu' is grown only in Sri Lanka. Although the bulk of the Sri Lanka oil is distilled from 'Lenabatu', 'Mahapengiri' type is also grown in certain areas. These two main types of grass could be distinguished morphologically, anatomically and chemically ; morphologically by the shape of leaves, length and width of leaves, length of sheath, colour of sheath and size of auricles ; anatomically by the nature of vascular bundles of leaf tissues, sclerenchyma arrangements, stomatal distribution their density and shape, type of epidermal appendages and their size (trichomes) ;⁴ chemically by the composition of oil present in them.^{6,14} It was believed that the main chemical differences between the oil from the two varieties were in the relative amounts of total acetylisables (total geraniol content) and the occurrence of compounds related to eugenol. GLC studies

*and Faculty of Agriculture, University of Sri Lanka, Peradeniya Campus, Peradeniya

by Rogers and Toth showed that the two types of oil differ more markedly in their citronellol content than in the geraniol content.¹⁰ Furthermore, a higher percentage of monoterpene hydrocarbons was observed in Lenabatu reported by Wijesekera and others.¹⁴ The work on the composition of citronella oil conducted by the earlier workers was based on the analysis of commercially available citronella oil. Wijesekera *et al.* attempted to analyse the freshly distilled oil from Mahapengiri grown in plantations of Sri Lanka. Commercial Ceylon oil is distilled mainly from Lenabatu type, but there are areas where both Mahapengiri and Lenabatu are grown in mixtures and the oil from these plantations enters the oil of commerce. From earlier work it was observed that even in the oil of selected Mahapengiri types grown in Sri Lanka, a high percentage of terpene hydrocarbons occurred though not as high as in Lenabatu. Thus, it is likely that the Sri Lanka Mahapengiri is a hybrid of both types. In other words, among the present cultivars of citronella grown in Sri Lanka there may be hybrids, mutants and polyploids yielding oil with different compositions. Some of these oils may be of better quality than the bulk oil exported from Sri Lanka which represents mostly Lenabatu oil.

Therefore with a view to selecting commercially desirable strains of citronella grass, a field survey was carried out in citronella growing areas. Preliminary selection of strains was based upon the morphological differences and these selections were subsequently tested for some of their morphological, anatomical, physiological and chemical features. In addition, a true Java variety was introduced from India and field experiments were conducted on both these selections and the Java variety. From the results of these experiments it was possible to isolate ten different selections of "strains".⁴ Some of these strains possessed Lenabatu character, some Mahapengiri character, while others showed characteristics that were intermediate to the two types.^{4,5} Morphological, anatomical and physiological character differences among the ten strains and the Java variety were recorded. Their yielding capacity of grass and oil also showed variation. Further investigations suggest the possibility of existence of polyploidy among some of these strains.⁵ As such, a detailed study of constituents of oil extracted from different strains was undertaken in order to ascertain genetic influence on the composition of citronella oil.

2. Experimental

The selected ten strains (1—10), and the Java variety introduced from India (designated strain 11), were used for this investigation at the University Farm, Meewatura, Peradeniya. A completely randomized block design with ten treatments (strains) and three replicates was used for this experiment. Cross plot size was 4.5 × 4.5 metres. Planting was done at a spacing of 90 × 90 cm, with two tillers per hill. Fertilizer was applied with a basal dressing of 56 kg, 44.8 kg and 56 kg/ha followed by top dressings of 56 kg/ha of nitrogen at four monthly intervals.

The soil of the experimental site was a sandy loam, low in available nitrogen (515 kg/ha) and moderate in available phosphate (326 kg/P₂O₅/ha) and the pH was 6.1.

Harvests of grass and flower heads were taken at four monthly intervals and oil extraction was carried out after two days of drying under shade. Distillation of oil was carried out using a laboratory type water-steam still of glass. Leaf oil samples from 11 strains and flower oil samples from 8 strains were separately extracted and stored under refrigeration prior to GLC analysis.

Oil composition of first harvest were studied using Varian 1700 GLC equipment at the Ceylon Institute of Scientific and Industrial Research, Colombo. Analysis was carried out on samples of 0.3 μ l. The column was held at 60° C for 4 minutes and then programmed at 4° C per minute to 200° C and held. Injector and detector temperatures were 200° C. Samples of oil from all three replicates of the trials were analysed separately for each strain. Identification of constituents was accomplished according to the method adopted by Wijesekera *et al.* Tentative peak identification was assigned by comparing the corrected retention volumes with those of authentic compounds. Chromatogram peak assignments of earlier workers, viz ; Wijesekera, Jayewardene and Fonseka, as well as the technique of peak enrichment were employed to confirm the identifications.

3. Results

Thirty-one peaks indicated the existence of a minimum of thirty-one different components in the oil of each strain. All three replicates gave identical chromatograms, indicating the consistency of composition of oil from the replicates of the trial. Between them the strains showed differences in composition of oil with quantitative variations among the thirty-one constituents of the leaf oil (Table 1). The magnitude of the differences varied widely between strains and the variability was highly prominent in the content of monoterpene alcohols, phenolics and in some of the terpene hydrocarbons namely camphene and limonene.

Flower oil also showed variations in composition between the eight strains (Table 2). The magnitude of differences in the percentage of constituents between the strains was less compared to that of the leaf oil. In all the strains, the percentages of monoterpene hydrocarbon compounds of flower oil were lower than those of leaf oil while the relative amount of monoterpene alcohols was higher in the flower oil. The citronellal content of flower oil was less than that of leaf oil except in strain one where it showed a higher value (9.90 and 0.97, respectively). Methyl isoeugenol was higher in the flower oil than in the leaf oil in five strains while it was low in three strains.

TABLE 1. Comparison of Constituents of Leaf Oil from Citronella Strains

Peak No.	Compound	Leaf Oil Composition in %					Strain					
		1	2	3	4	5	6	7	8	9	10	11
1	-- Pinene Tricyclene	2.06	1.47	4.95	2.83	2.64	1.95	1.43	2.70	1.15	2.05	1.52
2	Camphene	4.19	5.39	3.93	8.62	11.55	3.31	2.79	6.95	3.25	4.42	1.55
3	-- Myrcene	0.10	0.92	0.50	0.30	0.20	0.25	0.18	0.97	0.11	1.31	0.19
4	-- Phellandrene Terpinene	0.71	1.13	1.20	0.95	1.14	0.70	0.50	0.67	0.47	0.80	0.99
5	Limonene	7.52	5.78	10.36	8.76	9.29	3.91	5.66	4.66	5.20	5.11	4.96
6	Cis Ocimene	1.33	2.29	5.50	3.40	3.39	3.12	0.90	2.14	1.26	2.19	2.77
7	-- Terpinene	1.05	1.15	2.41	1.84	2.07	2.71	0.50	1.19	0.78	1.62	0.25
8	-- Cymene Terpinolene	0.78	0.65	1.05	0.79	1.00	0.54	0.57	0.62	0.47	0.57	0.05
9	Unknown	0.06	0.09	0.39	0.00	0.17	0.25	0.13	0.26	0.21	0.04	0.46
10	Unknown	0.00	0.08	0.20	0.12	0.11	0.23	0.14	0.25	0.07	0.06	0.11
11	Unknown	0.16	0.21	0.33	0.00	0.25	0.34	0.18	0.18	0.07	0.04	0.17
12	Citronellal	0.97	3.91	5.65	4.80	0.98	0.37	0.66	8.44	33.96	8.22	1.85
13	Unknown	0.42	1.09	2.06	1.10	2.11	0.92	1.17	1.21	0.45	0.50	0.42
14	Linalool	1.01	1.63	2.20	1.25	2.52	2.85	1.27	1.44	0.82	0.88	2.10
15	-- Caryophyllene	1.89	1.20	2.15	1.36	1.70	2.04	1.98	3.19	0.81	0.53	0.89
16	Unknown	0.93	0.37	1.21	0.85	0.94	0.57	1.17	0.83	0.39	0.57	0.39
17	Unknown	0.58	0.93	1.61	1.65	0.39	1.18	1.09	1.74	1.05	1.29	2.57
18	Unknown	2.80	2.30	3.72	2.16	1.84	3.69	2.33	2.37	0.78	2.40	3.19
19	Borneol	5.97	4.90	7.86	6.64	9.82	6.23	5.22	4.10	3.87	3.31	2.62
20	Citronellyl Acetate	0.96	1.55	2.69	2.21	1.34	1.25	1.21	1.67	0.93	2.32	4.43
21	Sesquiterpene	1.06	9.35	2.12	3.54	1.84	0.90	9.26	7.19	2.37	6.17	12.64
22	Citronellol	0.52	2.20	5.60	3.14	0.61	0.69	2.50	3.52	7.38	3.24	4.90
23	Nerol	0.92	0.67	1.49	1.03	0.00	0.00	1.62	0.78	0.29	1.03	1.11
24	Geraniol	0.13	33.12	9.26	18.56	1.95	2.08	36.82	29.76	23.78	37.83	44.24
25	Geranyl Butyrate	0.20	0.39	0.68	0.44	0.12	0.00	1.00	1.17	0.35	0.10	1.94
26 ¹	Methyl Eugenol	0.00	0.00	0.53	0.00	0.52	0.95	0.53	0.00	0.00	3.28	0.00
26 ²	Nerolidol	0.61	0.53	2.81	1.05	0.52	13.02	3.52	0.45	0.10	1.62	3.43
27	Elemol	5.29	1.55	2.36	2.73	1.88	6.99	7.29	2.45	3.10	2.30	2.72
28	Unknown	34.41	0.75	2.09	1.30	5.47	12.89	7.78	0.97	1.33	2.41	1.19
29	Methyl Iso Eugenol	10.36	16.49	12.92	13.87	32.29	25.36	7.83	7.96	4.89	6.20	15.89
30	Unknown	1.07	1.98	1.68	3.79	1.05	0.70	1.00	0.28	0.08	0.89	1.29

TABLE 2. Comparison of Constituents of Flower Oil from Citronella Strains

Peak No.	Compound	1	2	3	4	5	6	7	8	9	10
1	α -Pinene & Tricyclene	0.00	0.77	2.31	1.84		1.13		1.68	1.11	0.86
2	Camphene	0.00	3.45	5.74	4.94		4.07		4.91	3.31	2.84
3	α -Myrcene	0.00	0.00	0.56	0.17		0.15		0.61	0.00	0.85
4	α -Phellandrene	0.00	0.00	1.05	0.53		0.54		0.51	0.84	0.40
5	Limonene	0.00	6.90	8.90	6.16		5.11		6.28	4.96	5.73
6	Ocimene	0.00	0.86	2.45	2.24		2.32		1.23	1.06	0.92
7	α -Terpinene	0.00	0.48	1.90	1.21		1.78		0.45	0.93	0.64
8	α -Cymene & Terpinolene	0.00	0.00	0.84	0.73		0.56		0.70	0.61	0.41
9	Unknown	0.77	0.00	0.00	1.05		0.00		0.00	0.00	0.00
10	Unknown	0.26	0.00	0.00	0.00		0.00		0.00	0.00	0.00
11	Unknown	0.99	0.00	0.00	0.00		0.22		0.00	0.00	0.00
12	Citronellal	9.90	1.68	5.68	1.05		0.45		2.41	14.04	2.87
13	Unknown	2.29	0.00	1.10	0.40		0.87		0.73	0.00	0.34
14	Linalool	2.70	0.96	2.10	0.66		4.46		1.52	1.52	1.10
15	β -Caryophyllene	1.76	1.68	1.54	1.59		4.86		3.62	1.77	3.27
16	Unknown	0.94	0.00	0.59	1.78		0.72		0.87	0.00	0.43
17	Unknown	1.59	0.00	1.26	0.62		0.95		1.21	1.54	1.00
18	Unknown	2.24	3.59	1.60	3.00		2.39		3.21	2.43	2.51
19	Borneol	7.15	4.79	6.25	7.13		4.87		4.78	4.39	4.15
20	Citronellyl Acetate	7.52	3.45	1.77	2.54		4.94		2.48	2.02	2.16
21	Sesquiterpene	3.49	10.78	2.88	3.35		1.34		6.88	2.70	4.56
22	Citronellol	8.71	3.16	3.77	1.54		1.11		2.52	10.39	3.31
23	Nerol	1.26	3.45	0.74	0.66		0.56		1.47	0.61	1.10
24	Geraniol	34.43	35.78	11.56	24.35		3.42		12.32	25.51	28.08
25	Geranyl Butyrate	1.49	0.00	1.12	0.25		0.17		1.49	0.00	2.29
26 ¹	Methyl Eugenol	0.62	0.00	1.58	0.74		1.72		0.61	1.21	3.91
26 ²	Nerolidol	3.09	0.00	5.76	1.99		21.56		3.27	0.00	2.87
27	Elemol	1.38	2.68	3.86	3.82		12.69		11.60	6.41	4.74
28	Unknown	1.22	0.00	0.00	3.82		10.16		9.34	4.05	3.44
29	Methyl Isoeugenol	2.81	15.71	18.22	20.88		4.91		11.28	8.60	13.32
30	Unknown	1.39	0.00	5.47	0.95		1.94		2.03	0.00	1.94

For the convenience of comparison the constituents were grouped into seven groups :—

	GROUP	COMPOUNDS	PEAK NO.
G 1.	Total Monoterpene Hydrocarbons	α — Pinene and Tricyclene	1
		Camphene	2
		Myrcene	3
		α — Phellandrene and α Terpinene	4
		Limonene	5
		Ocimene	6
		γ — Terpinene	7
		ρ — Cymene and Terpinolene	8
G 2.	Monoterpene Oxygenated compounds	Citronellal	12
		Citronellol	22
		Geraniol	24
		Linalool	14
		Borneol	19
G 3.	Camphene-Bornane Compounds	Camphene	2
		Borneol	19
		α — Pinene and Tricyclene	1
G 4.	Sesquiterpenes	β — Caryophyllene	15
		Unknown sesquiterpene	21
		Unknown sesquiterpene	16
		Unknown sesquiterpene	17
		Unknown sesquiterpene	18
G 5.	Sesquiterpene alcohols	Nerolidol	26 ³
		Elemol	27
G 6.	Phenolics and derivatives	Methyleugenol	26 ¹
		Methyl isoeugenol	29
G 7.	Total acetylisables and esters	Citronellal	12
		Linalool	14
		Citronellyl acetate	20
		Borneol	19
		Citronellol	22
		Nerol	23
		Geraniol	24
		Geranyl butyrate	25
		Nerolidol	26 ³
Elemol	27		

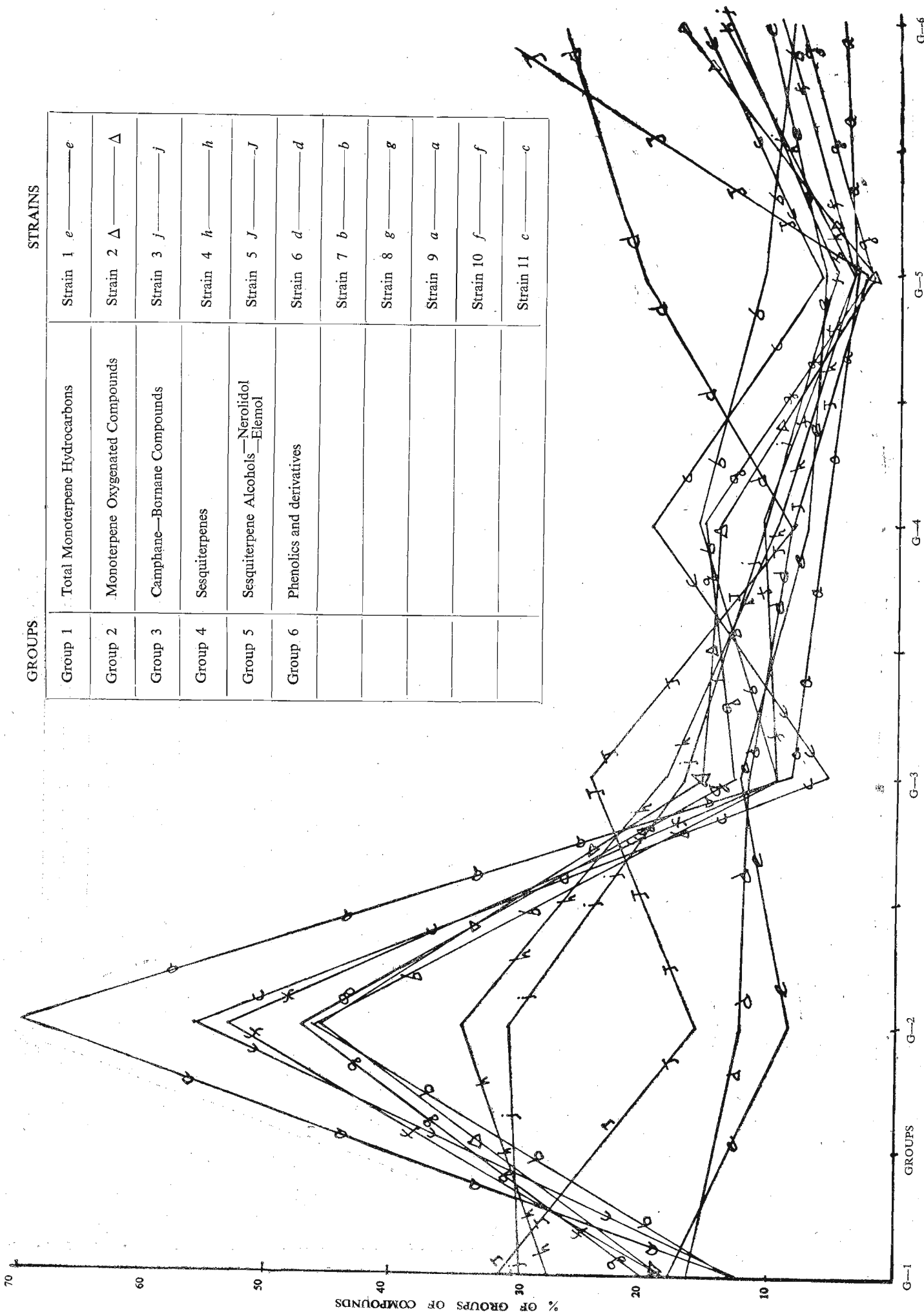


Figure 1. Percentage of groups of compounds in different citronella strains.

The percentage of these groups of compounds varied greatly within the strains for leaf oil and flower oil (Table 3 and Figure 1). A correlation network was found which illustrates the relationship between the contents of total terpene hydrocarbons, monoterpene alcohols, camphene bornane compounds, phenolics and total acetylisables (Table 4). In other words, these correlation values explained the influence of production of one particular group of compounds over the others.

TABLE 3. Comparison of Groups of Compounds of Oil from Citronella Strains

Group %	Strain										
	S ₁	Leaf S ₂	Oil S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	S ₉	S ₁₀	S ₁₁
1	17.76	18.10	29.90	27.49	31.22	16.49	12.53	19.90	12.69	18.07	12.28
2	8.59	45.24	30.57	34.39	15.88	12.22	46.47	47.26	69.81	53.48	55.71
3	12.22	15.24	16.74	13.91	24.01	11.49	9.44	13.75	8.27	9.78	5.69
4	7.26	14.15	10.81	10.34	8.41	8.38	15.83	15.32	5.36	10.96	19.62
5	5.90	2.08	5.17	5.81	2.40	20.01	10.81	2.90	3.20	3.92	6.15
6	10.36	17.02	13.45	21.62	32.81	26.31	8.36	7.96	4.89	9.28	15.89
7	16.56	48.82	40.60	41.85	19.74	33.48	61.31	53.78	74.58	60.85	69.40
Flower Oil											
1	0.00	12.46	23.75	17.83		15.66		16.37	12.82	12.65	
2	62.89	46.37	29.36	34.73		14.31		23.55	55.85	37.87	
3	7.15	9.01	14.30	13.91		10.07		11.37	8.81	6.21	
4	10.02	16.05	7.87	10.34		10.26		15.79	8.44	7.96	
5	4.47	2.68	9.56	5.81		34.25		14.87	6.41	7.61	
6	3.43	15.71	19.80	21.62		6.63		11.89	9.81	17.23	
7	78.97	55.95	42.55	43.89		54.69		43.86	64.86	52.64	

TABLE 4. Correlation values of the Constituents of Citronella Leaf Oil Between the 11 Strains

Compound	Nature of Correlation	Coefficient of Correlation (r)
Group 1 Vs Group 7	Negative	0.6136*
Group 1 Vs Group 2	Negative	0.5117 (N.S.)
Linalool Vs Group 2	Negative	0.5200 (N.S.)
Group 3 Vs Group 2	Negative	0.5745 (N.S.)
Group 3 Vs Group 7	Negative	0.7110**
Group 6 Vs Group 7	Negative	0.6079*

* Significant at 5%

** Significant at 1%

- Group 1 — Total terpene hydrocarbons
- Group 2 — Monoterpene alcohols
- Group 3 — Camphene-bornane compounds
- Group 6 — Phenolics
- Group 7 — Total acetylisables

Total terpene hydrocarbons had a negative correlation significant at 5% level over the contents of total acetylisable while it did not have any significant correlation over the content of monoterpene alcohols. Similarly, the camphene-bornane compound group had a negative correlation significant at 1% level with total acetylisable and esters while it did not have significant correlation with total monoterpene alcohols. Linalool had no significant correlation with total monoterpene alcohols. Phenolics showed a negative correlation significant at 1% with total acetylisable.

4. Discussion

Most of the constituents of citronella oil were terpenes and their oxygenated compounds. Within a given genus of a number of plant families studied, the terpene appear to be distributed rather selectively within certain species. If the environmental factors such as soil and climate are kept constant, this distribution is probably under specific genetic control. For instance, in the genus *Monarda*, Fujita² found that one species *M. didyma* contained large quantities of linalool and little or no phenolic or aromatic constituents such as p-cymene or thymol, whereas in other species of this genus the reverse was found.² Fujita developed from these observations a biogenetic scheme envisioning linalool as the parent material of the cyclic intermediates. Further, the influence of specific genetic factors is markedly apparent in the studies of Penfold and Morrison⁸ on the eucalyptus genus. Their study showed that 230 species of eucalyptus could be grouped into four types—those producing largely (1) cineole (2) piperitone (3) phellandrene or (4) acyclic terpenes like geraniol. In a group of such trees growing a few feet apart some contained essential oil consisting predominantly of cineole, others contained predominantly piperitone.⁷ Similarly, Mirov⁷ in a study of the genus *Pinus* gives examples where individual species could not be differentiated morphologically, but differed in terpene content. With regard to citronella the eleven strains originated from two species namely *Cymbopogon nardus* and *Cymbopogon winterianus* and they were proved to be different morphologically, anatomically and cytologically.⁴

Thus their variability in terpene content of oil could be expected and variability of the oil composition could be attributed to their genetic differences. Examination of the essential oil content of various *Mentha* species suggested that a genetic factor was responsible for high menthol content, where genes from two species were found essential.⁹ Reitsema⁹ has shown evidence for the presence or absence of a particular enzyme system which is genetically controlled and which may influence the terpene content of certain mint plant species. Similar views could also be envisaged in citronella strains, as the pattern of terpene distribution in different strains showed consistency. One may expect the feasibility of the existence of a pair of genes or more or even an entire chromosome responsible for the production of the enzyme that controls the biogenesis of these compounds in citronella species.

A general similarity could be observed in the composition of oil in strains 9, 10, 11 and 8 as against strains 3, 4, 5, 6 while strains 2 and 7 behave intermediate to those two groups. Strain 1 forms a separate group by itself in this respect. Therefore one could expect that the genes responsible for the production of terpenes are distributed in a regular, but unknown pattern in these strains of citronella. This is further supported by the fact that these strains exhibit polyploidy.⁵

The study of correlation coefficient of group of constituents show interesting predictions over the biogenesis of these compounds. According to Wijesekera *et al.*,¹³ the possible pathways in the formation of monoterpenoids in citronella too follow the usual sequence ; leading to the formation of camphene bornane group (group 3) compounds in bigger quantities which will deplete the formation of mono-(erpene alcohols (group 2). Our correlation values (Table 4) showed no significant linear correlation between these two groups. At the same time camphene bornane compounds showed a highly significant negative correlation with total acetylisable which is the value of monoterpene alcohols plus other oxygenated compounds. Thus one could arrive at the fact that in citronella the production of camphene bornane compounds might have influence over the pathways where the other oxygenated compounds are produced from the monoterpene alcohols. This may suggest that, at the expense of latter the former is synthesized.

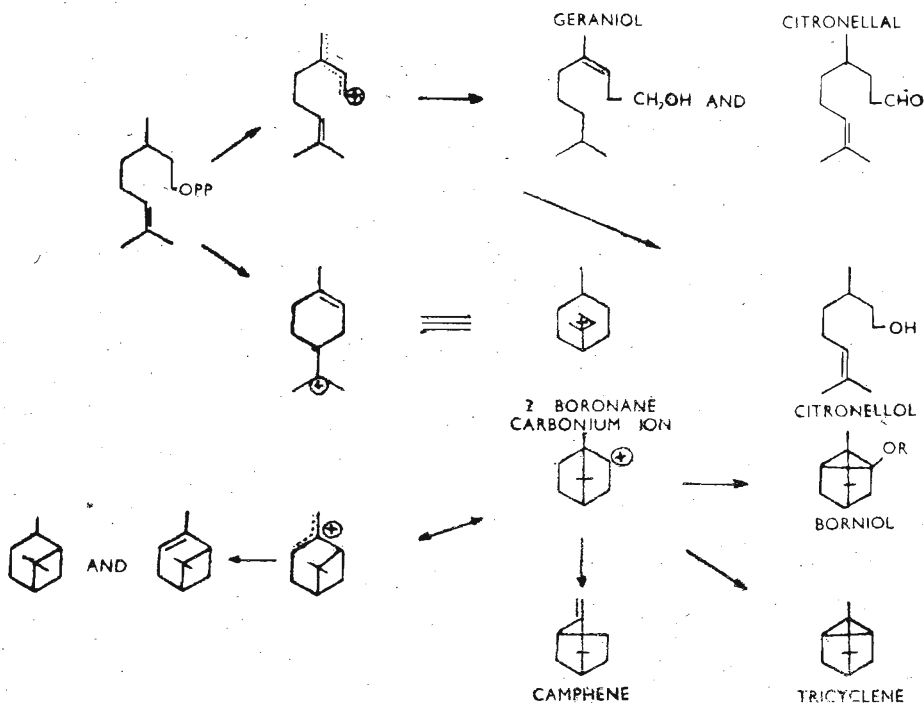


Figure 2. Possible pathways in the performance of monoterpenoids of Citronella.

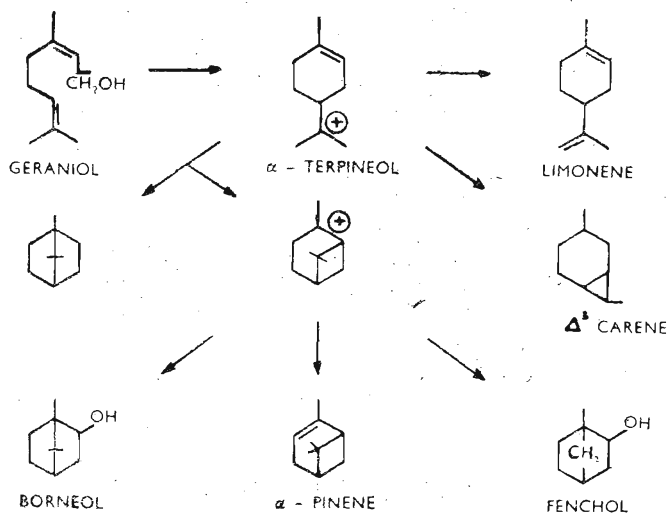


Figure 3. Ionic mechanisms in the biogenesis of monoterpenes (Ruzicka)

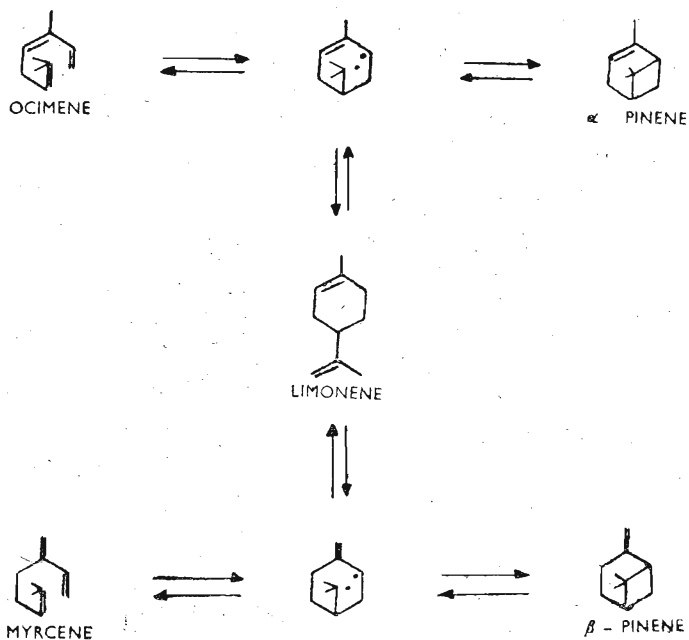


Figure 4. Radical mechanisms in the biogenesis of monoterpenes (Ruzicka).

Similarly the content of total monoterpene hydrocarbons (Group I), which again includes the camphane-bornane compounds except borneol had significant negative correlation with total acetylisables whereas total hydrocarbons had no linear correlation with total monoterpene alcohols. In other words, production of total hydrocarbons might have control over the production of total acetylisable but not when considered individually for terpene alcohols and oxygenated compounds. This prediction is in accord with the earlier experiments of Charabot¹² who indicated that terpene alcohols are the first condensation products that arise in higher plants and that esters and terpene hydrocarbons are derived from them by acylation and dehydration, respectively. This is in accord with the classical concepts of Ruzicka,¹¹ in developing the "biogenetic isoprene rule". Tracer studies would throw considerable light on the biosynthetic mechanisms.

In commercial cultivation of citronella, usually the harvests of grass are taken before flowering and about six inches above the ground level. The high total acetylisable content and low hydrocarbon content in flower oil as against the leaf oil suggests that flower head contains oil of better utility. In fact, in strain 1, flower oil showed only a trace amount of hydrocarbons while the total acetylisables was increased almost five-fold as compared with the leaf oil. Another interesting finding was the occurrence of a very high nerolidol content in flower oil of strain 6. All the strains (only 8 strains flowered) except strain 1, showed increased nerolidol content in flower oil. Strain 6 had a high content of nerolidol even in leaf oil (13% in strain 6 as against 0.1% in strain 9) whereas in flower oil it had 21.56% of nerolidol as against traces in strain 9 and 2. Production of this sesquiterpene alcohol seems to have a correlation with flowering habit. Among all the citronella strains, strain 6 had a high tendency to flower throughout its growth period whereas the other strains varied in their time of flowering. Strain 6 also flowers first during the flowering season common to the citronella varieties. This suggests that the biogenesis and storage after the biogenesis of sesquiterpene alcohol nerolidol are closely connected in some way or other to the flowering habit of citronella.

When morphological and anatomical characters are considered to be the important criteria to classify the citronella strains into Lenabatu and Mahapengiri types, the strains 3, 4, 5 and 6 fall into Lenabatu type, strain 9, 8 and 10 fall into Mahapengiri type while strain 1, 2 and 7 fall into the intermediate type.⁴ Strain 11 was typical Java Mahapengiri introduced from India. Earlier workers in this field observed that the main chemical differences between the two types were in the relative amounts of total acetylisable and the occurrence or absence of compounds related to eugenol. The distribution pattern of total acetylisable in the eleven strains confirmed the earlier work but the content of phenolics (compounds related to eugenol) did seem to agree with their findings only in respect to the introduced Java pengiri strain 11. In fact, the Ceylon Mahapengiri strains followed the pattern (Table 1) reported by the earlier workers whereas the strain 11 had fairly high phenolic contents (15.8%)

which was equivalent to that of some of Lenabatu strains. Similar problems arose in the citronellal and total hydrocarbon content. According to Wijesekera,¹⁴ and Rogers and Toth,¹⁰ the Java variety contains a high proportion of citronellal, citronellol and lower proportions of terpene hydrocarbons, but strain 11 had lower content of citronellal and the total hydrocarbon content was found to be equivalent to the typical Ceylon Mahapengiri in our investigations. Wijesekera *et al.*¹⁴ indicated that even the Ceylon Mahapengiri contains higher proportion of terpene hydrocarbons than that found in the Java oil available in the world market. They suspected that the sample of oil used may have been previously deterpinated,¹⁴ since these samples were obtained from the commercial sources abroad. Another possibility for such a situation may be that the Java pengiri plant introduced for our investigations also might be one of the chemotypes that might be present in countries where Java pengiri citronella type are cultivated continuously. In other words, the commercial plantations in those countries may have mixed populations of several Java strains similar to our local conditions for Lenabatu.

The borneol content was low in strain 11, Ceylon Mahapengiri strain 8, 9 and 10 which agree with these findings of earlier workers.

The above chemical differences attributed to the differences in their genetic nature will be useful in plant improvement programmes and the establishment of commercial plantations. The consistently wide variation of chemical composition of oil between strains of citronella might be useful also in the chemical industry especially for perfumery and cosmetic manufacture.

References

1. ABYEWICKREMA, B. A. (1959). *Ceylon J. Sci. biol. Sci.* 2: (2) : 132.
2. FUJITA, J. (1951). In *Fundamental Studies of Essential Oils* (in Japanese). *The Ogawa Perfumery Times*, Ogawa and Co. Ltd., Osaka and Tokyo, No. 202, September 1951, p. 502.
3. GUENTHER, E. (1950). *The Essential Oils*, 4: 67, Van Nostrand, New York.
4. IRUTHAYATHAS, E. D. & HERATH, H. M. W. (1975). *Investigations on Lemongrass and Citronella*, *Proc. Agric. Research Seminar Series*, Faculty of Agriculture, University of Sri Lanka, Peradeniya, Sri Lanka.
5. IRUTHAYATHAS, E. D. & HERATH, H. M. W. (1976). *Characterization and Identification of Citronella Cultivars*, (paper under preparation).
6. JOWITT, J. F. (1908). *The Volatile Oils*. GILDMEISTER, A. & HOFFMAN, A. eds. KREMERE, E. Trans., 2nd Edn. 2: 217-243, *Ann. R. bot. Gdns. Peradeniya*, 41: 185.
7. NICHOLAS, H. J. (1963). *The Biogenesis of Terpenes in Plants*, BERNFELD, P. (1963). *Biogenesis of Natural Compounds*, Pergamon Press Ltd., United Kingdom Edn. 640-687.
8. PENFOLD, A. R. & MORRISON, F. R. J. (1927). *Proc. R. Soc. N.S.W.* 61: 54.
9. REITSEMA, R. H. (1958). *J. Am. pharm. Ass.* Edn. 47: 267.
10. ROGERS, J. A. & TOTH, Z. E. (1961). *Proc. Sci. Sect. Toilet Goods Association* 35: 29.
11. RUZICKA, L. (1953). *Experientia* 9: 257.
12. SINGLETON, F. (1931). *Chem. Ind. London*, 50: 989.
13. WIJESKERA, R. O. B. (1973). *A Second Look at Citronella*, *Proc. Inst. Chem. Cey. 2nd Ann. Sess.* 17-20.
14. WIJESKERA, R. O. B., JAYEWARDENE, A. L. & FONSEKA, B. D. (1973). *Varietal Differences in the Constituents of Citronella Oil*, *Phyt-chemistry*, 1973, 12: 2697-2704.