CHAPTER IV

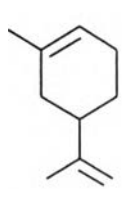
RESULTS

1 Essential Oil Composition of *Aegle marmelos* Correa

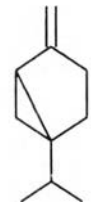
By hydrodistillation, the yield of the essential oil from *Aegle marmelos* leaves was found to be 1.8% (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that 14 peaks were well separated from each other (Fig. 2) These peaks were identified as 5 monoterpenes, 3 oxygenated monoterpenes, 4 sesquiterpenes and 2 oxygenated sesquiterpenes (Table 2). Among these, sylvestrene (82.49%) was found to be the major component, followed by sabinene (8.93%) and germacrene D (3.54%).

In terms of relative amount, the monoterpenes appeared to be the major terpenoid group, accounting for 93% of the essential oil. Sesquiterpenes and oxygenated monoterpenes were present in lesser amount, with 6% and 1%, respectively.

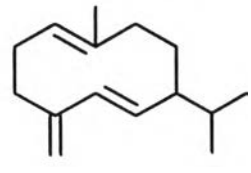
In terms of structure type, the major components of sylvestrene and sabinene belong to the monoterpenoid groups of menthane and thujane, respectively (Fig. 3).



sylvestrene
(*menthane*)



sabinene
(*thujane*)



germacrene D
(*germacrane*)

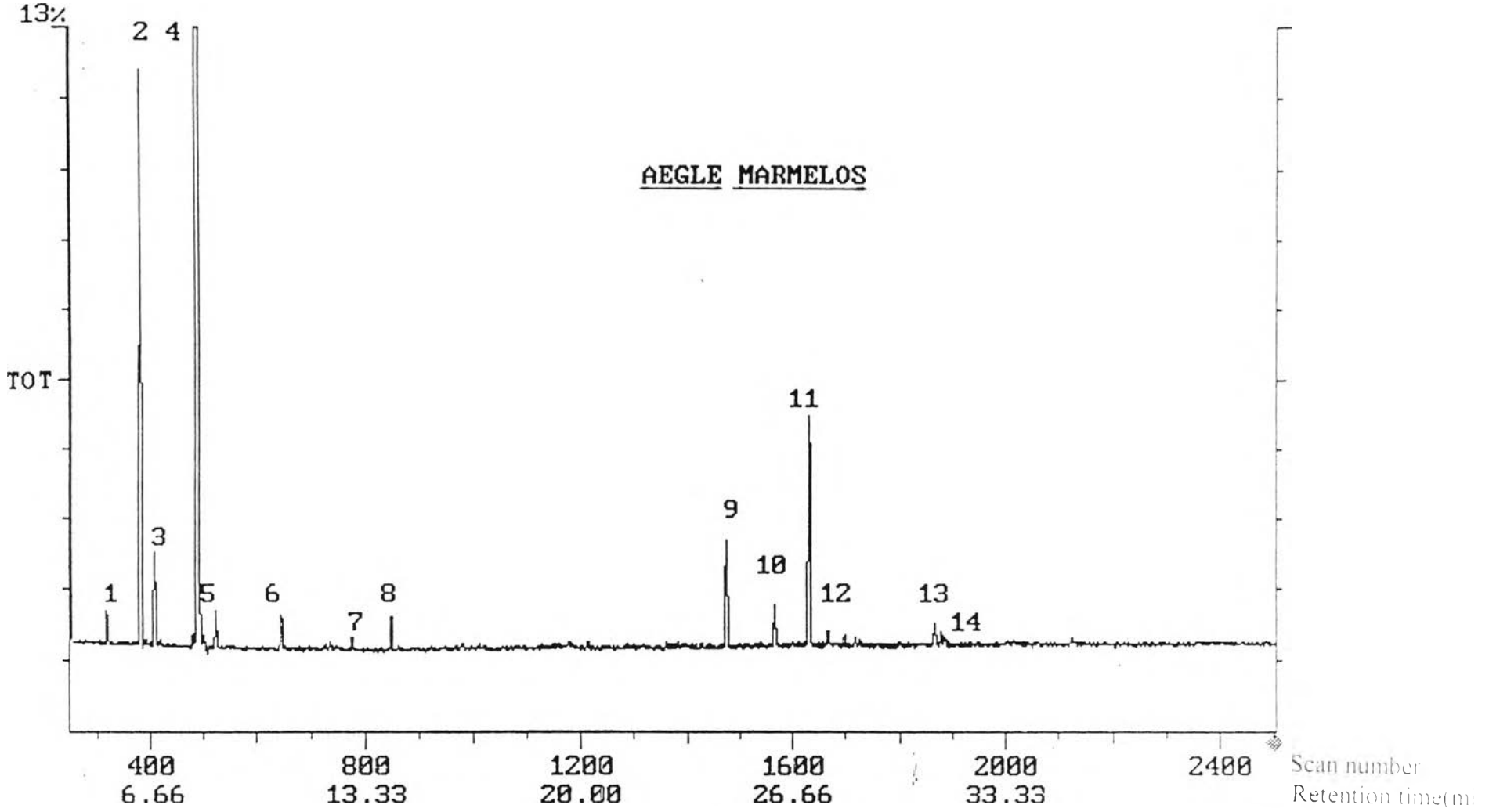


Figure 2 GC chromatogram of the essential oil from *Aegle marmelos* Corr. leaves

Table 2 Essential oil composition of *Aegle marmelos* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.31	t
2	sabinene	6.35	8.93
3	myrcene	6.79	1.33
4	sylvestrene	8.16	82.49
5	*(E)*-β-ocimene	8.71	0.59
	Oxygenated monoterpenes		
6	linalool	10.74	0.39
7	citronellal	12.94	t
8	terpin-4-ol	14.11	0.47
	Sesquiterpene hydrocarbons		
9	*9-epi-(E)*-Caryophyllene	24.56	1.65
10	α-humulene	26.08	0.60
11	germacrene D	27.18	3.54
12	bicyclogermacrene	27.78	t
	Oxygenated sesquiterpenes		
13	spathulenol	31.09	t
14	caryophyllene oxides	31.30	t

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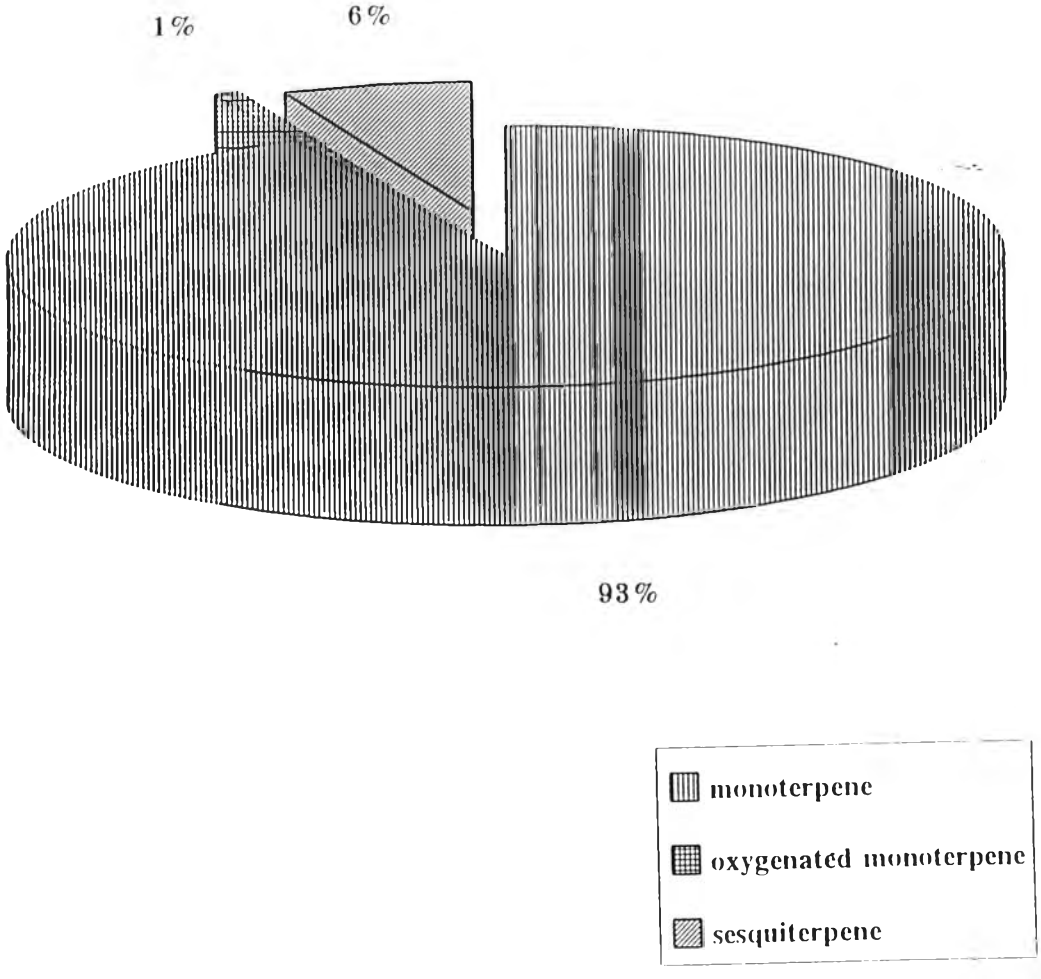


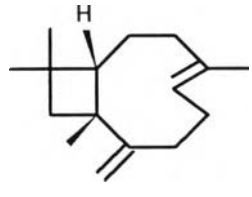
Figure 3 The percentage composition of various terpenoid groups present in the essential oil of *Aegle marmelos* leaves

2 Essential Oil Composition of *Atalantia monophylla* Correa

The essential oil isolated from *Atalantia monophylla* leaves was found to be 0.2 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that it contained at least 34 components (Fig. 4). These components were identified as 10 monoterpenes, 4 oxygenated monoterpenes, 10 sesquiterpenes and 3 non-terpenoid compounds (Table 3). Among these, 9-epi-β-caryophyllene (35.67%) appeared to be the major component, followed by germacrene D (13.88%) and *(Z)*-nerolidol (10.70%).

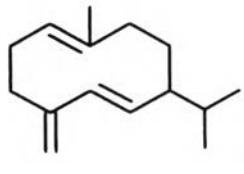
In contrast to the species of *Aegle marmelos*, the total sesquiterpenoid content in *Atalantia monophylla* appeared to be the major terpenoid group, accounting for 64% of the essential oil. Oxygenated sesquiterpenes, sesquiterpenes and oxygenated monoterpenes were present in lesser amount, with 16%, 4% and 2%, respectively (Fig. 5).

Structurally, the major components of 9-epi-β-caryophyllene and germacrene D belong to the sesquiterpenoid group of caryophilane and simple germacrane, respectively.



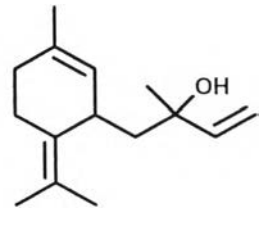
9-epi-β-caryophyllene

(*caryophylane*)



germacrene D

(*germacrene*)



(Z)-nerolidol

(*simple farnesane sesquiterpenoid*)

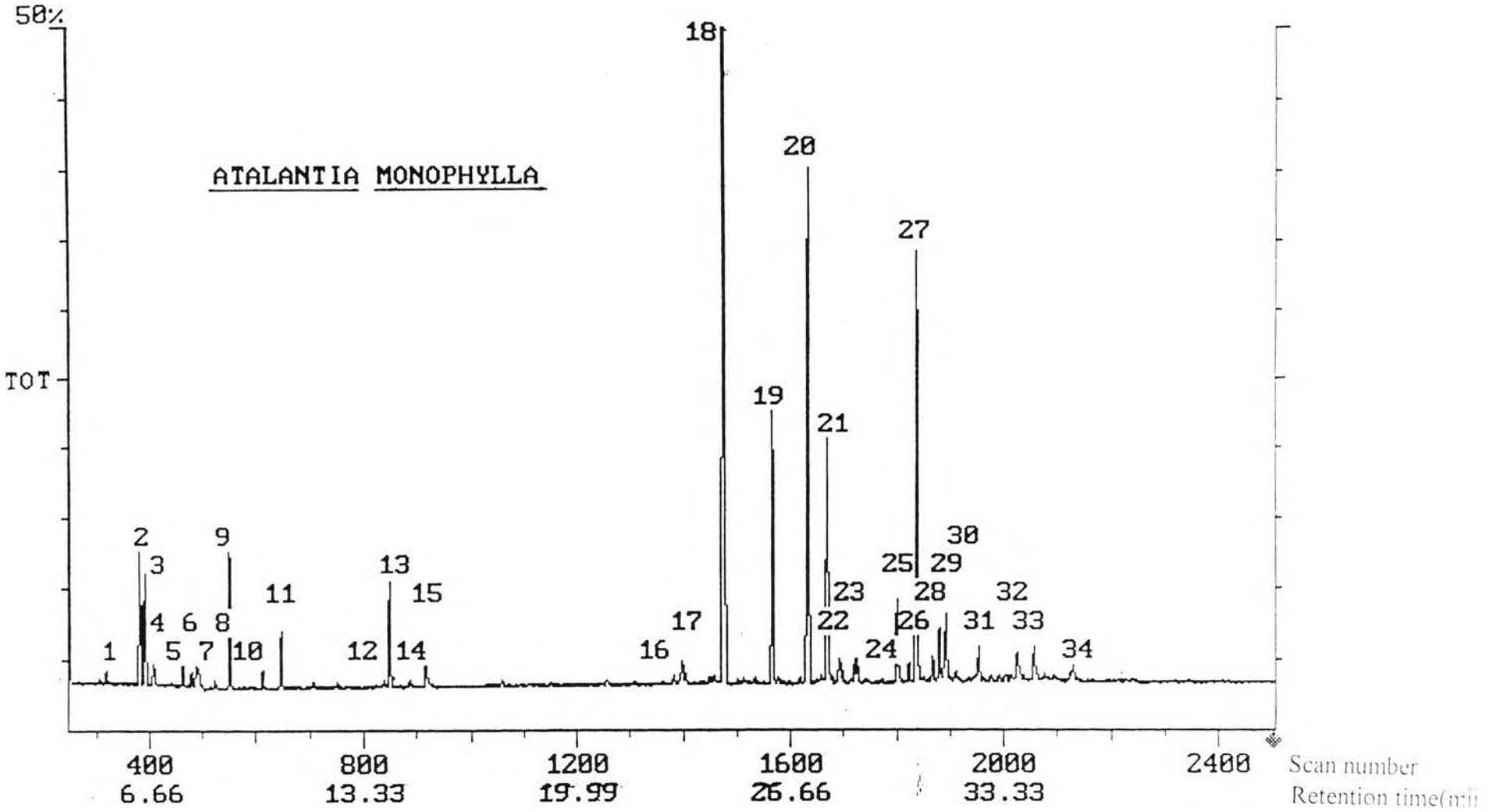


Figure 4 GC chromatogram of the essential oil from *Atalantia monophylla* Correa leaves

Table 3 Essential oil composition of *Atalantia monophylla* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.31	t
2	sabinene	6.35	3.39
3	*β*-pinene	6.53	2.68
4	myrcene	6.81	0.54
5	δ-2-carene	7.73	0.48
6	*o*-cymene	7.98	t
7	limonene	8.13	t
8	*(E)*-*β*-ocimene	8.71	t
9	*γ*-terpinene	9.16	3.02
10	terpinolene	10.20	0.42
	Oxygenated monoterpenes		
11	linalool	10.76	1.24
12	geijerene	13.69	t
13	terpin-4-ol	14.13	2.36
14	*α*-terpineol	14.78	t
	Sesquiterpene hydrocarbons		
16	*β*-bourbonene	23.03	t
17	*β*-elemene	23.29	t
18	*9-epi-(E)*-caryophyllene	24.60	35.67
19	*α*-humulene	26.11	6.66
20	germacrene D	27.19	13.88
21	bicyclogermacrene	27.80	6.34
22	*trans*-*β*-guaiene	28.19	0.75

Table 3 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
24	δ-cadinene	28.76	0.60
26	germacrene B	30.38	0.47
	Oxygenated sesquiterpenes		
27	*(Z)*-nerolidol	30.61	10.70
28	spathulenol	31.11	0.70
29	caryophyllene oxide	31.33	1.46
32	*epi*-α-cadinol	33.74	0.96
33	α-cadinol	34.26	1.06
34	*epi*-α-bisabolol	35.46	t
	Phenylpropanoid		
25	elemicin	30.00	2.26
	Long chain hydrocarbons		
15	*n*-decanol	15.29	1.16
30	n-hexyl-n-hexanoate	31.53	1.87
	Miscellaneous		
23	unknown	28.68	0.62
31	unknown	32.54	0.70

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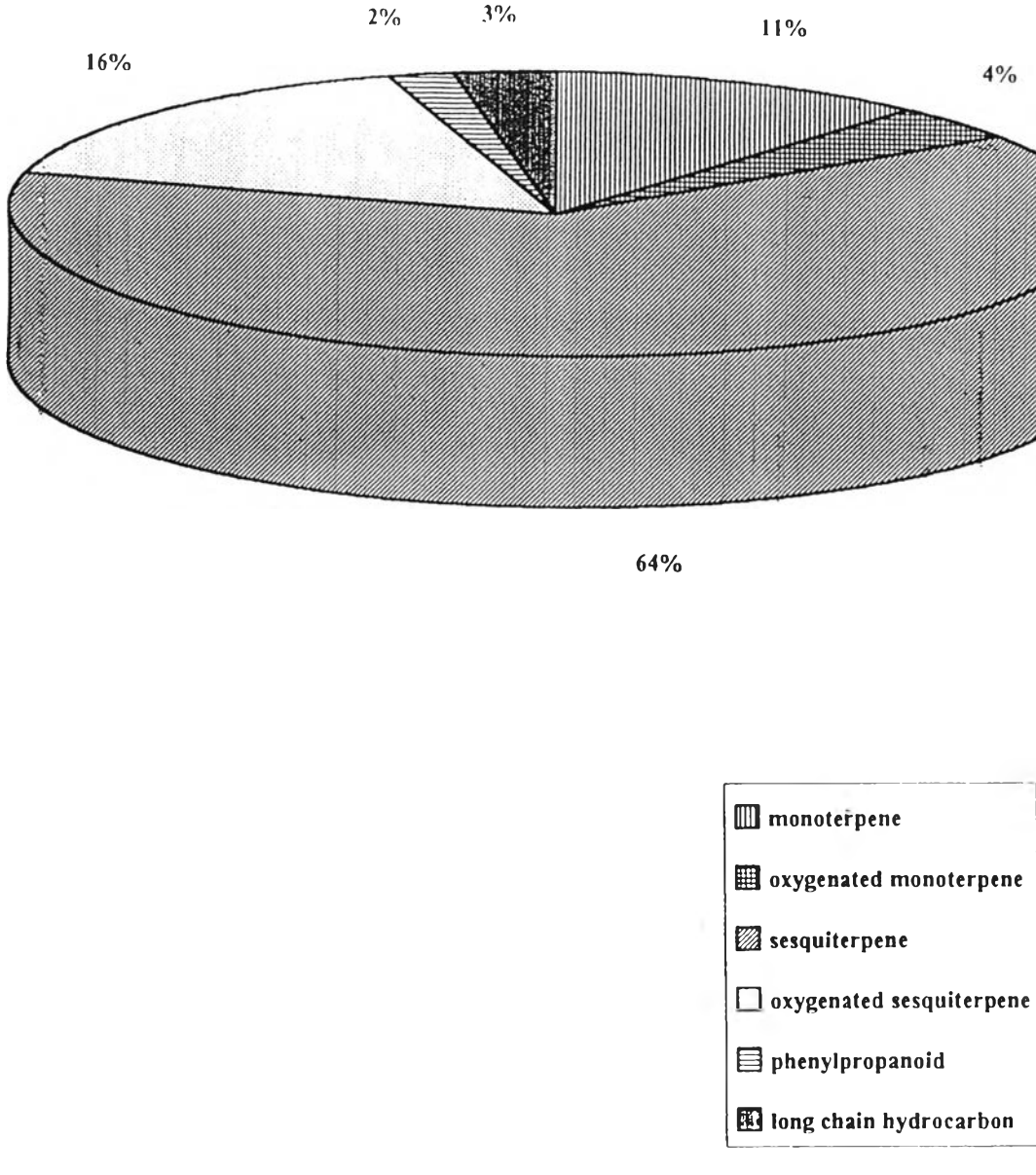


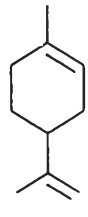
Figure 5 The percentage composition of various terpenoid groups present in the essential oil of *Atalantia monophylla* leaves

3 Essential Oil composition of *Citrus aurantifolia* Swing.

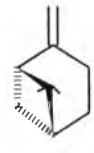
The yield of the essential oil from *Citrus aurantifolia* leaves was found to be 0.5% (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that the oil was composed of at least 28 components (Fig. 6). These components were identified as 8 monoterpenes, 13 oxygenated monoterpenes, 5 sesquiterpenes and 2 oxygenated sesquiterpenes (Table 4). Among these, limonene (33.88%) appeared to be the major component followed by β-pinene (19.64%) and 1,8-cineol (8.75%).

In terms of relative amount, the monoterpenes were found to be the major terpenoid group, accounting for 74% of the essential oil. Oxygenated monoterpenes and sesquiterpenes were present in lesser amount, with 23% and 3%, respectively (Fig. 7).

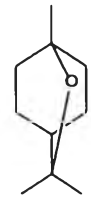
In terms of structure type, the major components of limonene and β–pinene belong to the monoterpenoid group of menthane and pinane, respectivly.



limonene (*menthane*)



β-pinene (*pinane*)



1,8-cineol (*menthane*)

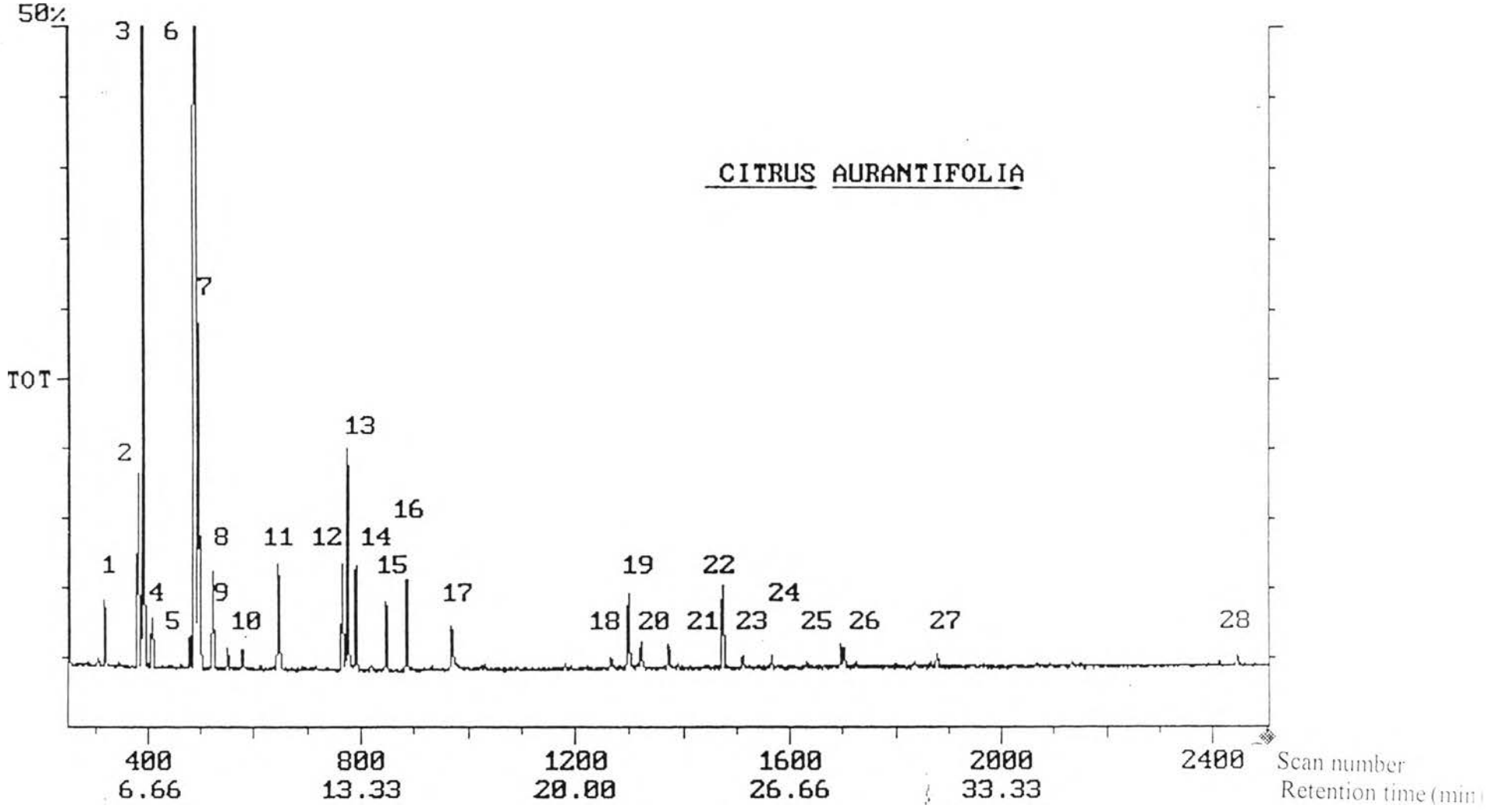


Figure 6 GC chromatogram of the essential oil from *Citrus aurantifolia* Swingle leaves

Table 4 Essential oil composition of *Citrus aurantifolia* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.30	1.59
2	sabinene	6.34	5.07
3	*β*-pinene	6.51	19.64
4	myrcene	6.79	1.29
5	*o*-cymene	7.98	0.90
6	limonene	8.13	33.88
8	*(E)*-*β*-ocimene	8.71	2.37
9	*γ*-terpinene	9.16	0.52
	Oxygenated monoterpenes		
7	*1,8*-cineol	8.26	8.75
10	*cis*-sabinene hydrate	9.61	0.47
11	linalool	10.74	2.68
12	isopulegol	12.74	2.69
13	citronellal	12.91	5.42
14	*iso*-isopulegol	13.18	2.53
15	terpin-4-ol	14.11	1.64
16	*α*-terpineol	14.74	2.62
17	citronellyl formate	16.14	1.31
18	hydroxyl citronellal	21.13	t
19	citronellyl acetate	21.61	1.88
20	lavandulyl acetate	21.99	0.71
21	geranyl acetate	22.88	0.67

Table 4 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
22	*9-epi-(E)-caryophyllene*	24.56	2.22
23	*α-trans*-bergamotene	25.18	t
24	α-humulene\	26.08	t
25	*(E,E)*-α-farnescene	28.26	0.62
26	β-bisabolene	28.36	0.51
	Oxygenated sesquiterpenes		
27	caryophyllene oxide	31.31	t
28	*(E,E)*-farnesol	40.74	t

t = trace

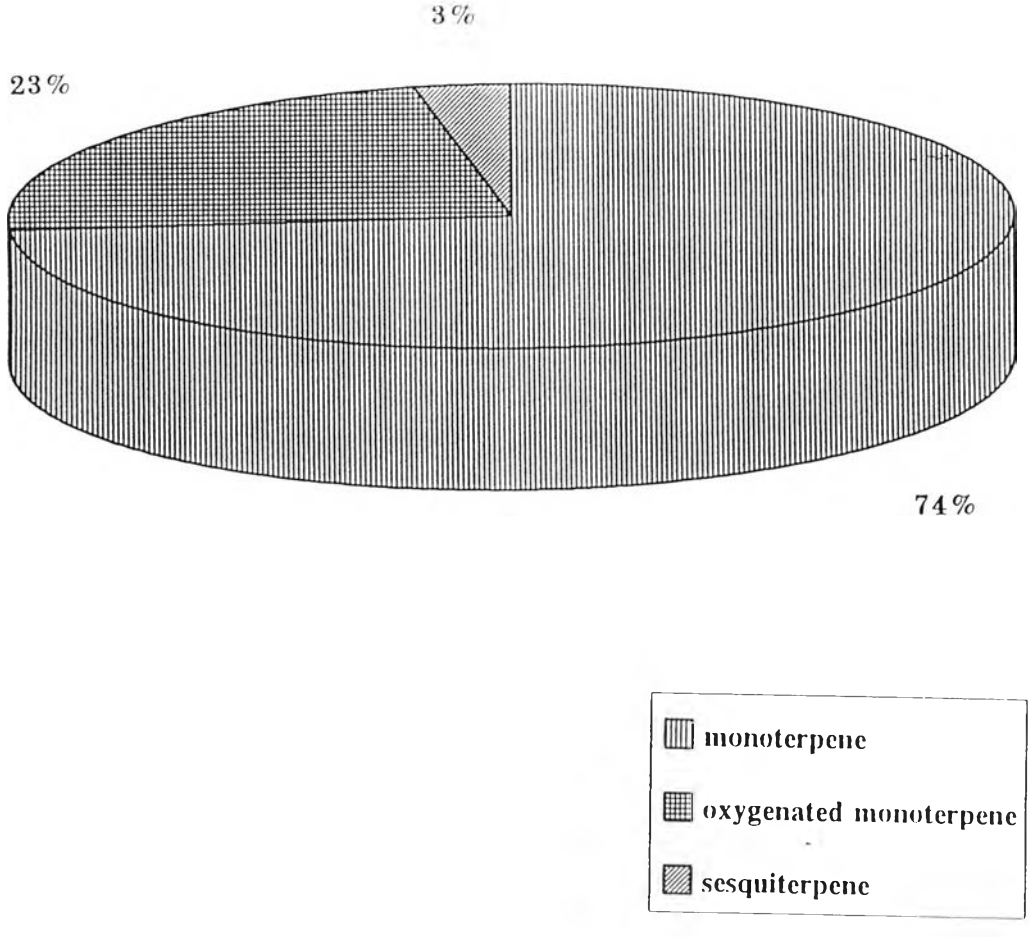
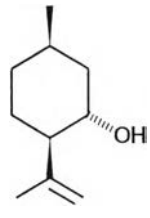


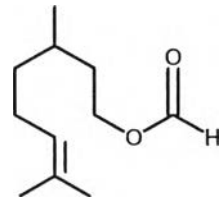
Figure 7 The percentage composition of various terpenoid groups present in the essential oil of *Citrus aurantifolia* leaves

4 Essential Oil Composition of *Citrus hystrix* DC.

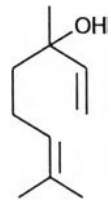
The yield of the essential oil obtained by hydrodistillation of *Citrus hystrix* leaves was found to be 0.8% (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that there were only 5 peaks were separated from each other (Fig. 8). These peaks were all identified as oxygenated monoterpenes (Table 5). Among these, *iso*-isopulegol (83.82%) appeared to be the major component, followed by citronellyl formate (8.78%) and linalool (8.75%). Isopulegol belongs to the structure type of menthane whereas the latter two belong to the acyclic monoterpenoid type (Fig. 9).



iso-isopulegol
(*menthane*)



citronellyl formate
(*acyclic monoterpenoid*)



linalool
(*acyclic monoterpenoid*)

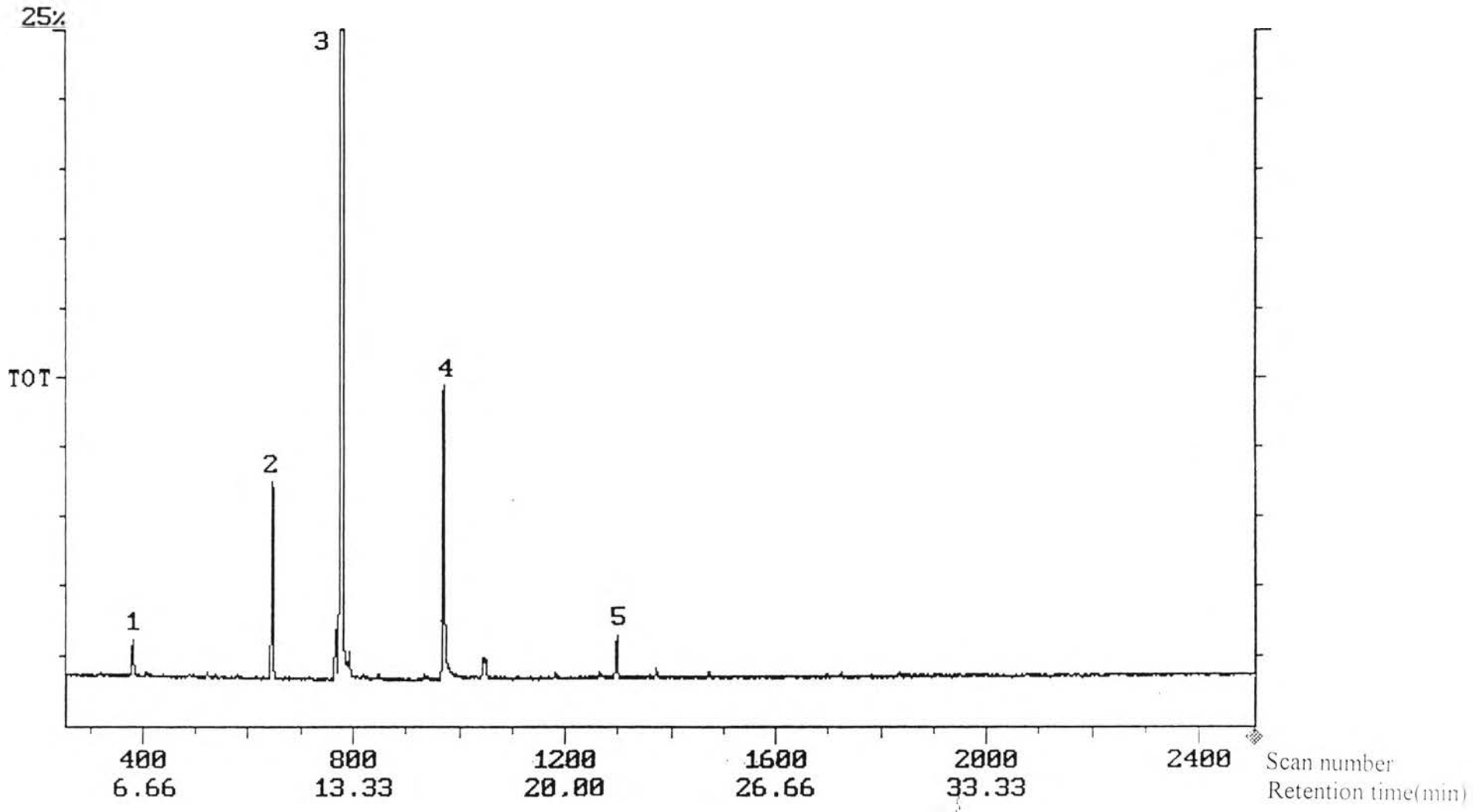
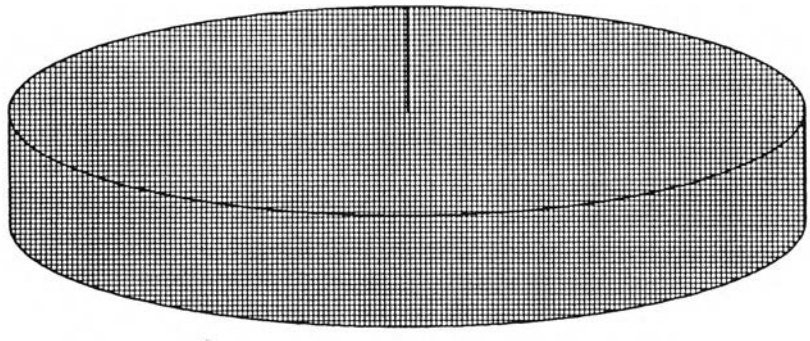


Figure 8 GC chromatogram of the essential oil from *Citrus hystrix* DC. leaves

Table 5 Essential oil composition of *Citrus hystrix* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated monoterpenes		
1	linalool	10.74	4.95
2	isopulegol	12.74	1.39
3	*iso*-isopulegol	12.98	83.82
4	citronellyl formate	16.16	8.78
5	citronellyl acetate	21.61	1.05



100%

oxygenated monoterpene

Figure 9 The percentage composition of various terpenoid groups present in the essential oil of Citrus hystrix leaves

5 Essential Oil Composition of *Citrus maxima* Merr.

The essential oil isolated from *Citrus maxima* leaves was found to have the yield of 0.4% (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that the oil were composed of at least 36 components (Fig. 10). These components were identified as 9 monoterpenes, 16 oxygenated monoterpenes, 7 sesquiterpenes and 3 oxygenated sesquiterpenes and 1 non-terpenoid compounds (Table 6). Among these, β-phellandrene (24.84%) appeared to be the major component, followed by β-pinene (8.93%) , nerol (6.42%) and citronellol (6.32%). The high content of these components contributed greatly to the overall monoterpenoid content which appeared to be the major terpenoid group, accounting for 51% of the essential oil. This was followed closely by the oxygenated monoterpenes (43%), Sesquiterpenes and oxygenated sesquiterpenes were present in much lesser amount, with 4% and 2%, respectively (Fig. 11).

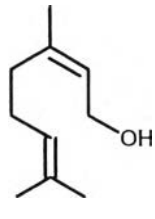
In terms of structure type , the major components of β–phellandrene, β–pinene and nerol belong to the monoterpenoid group of menthane and pinane and acyclic monoterpenoid, respectively.

β–Phellandrene

(*menthane*)

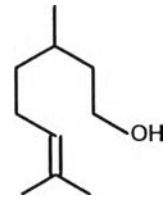
β-Pinene

(*pinane*)



Nerol

(*acyclic monoterpenoid*)



citronellol

(*acyclic monoterpenoid*)

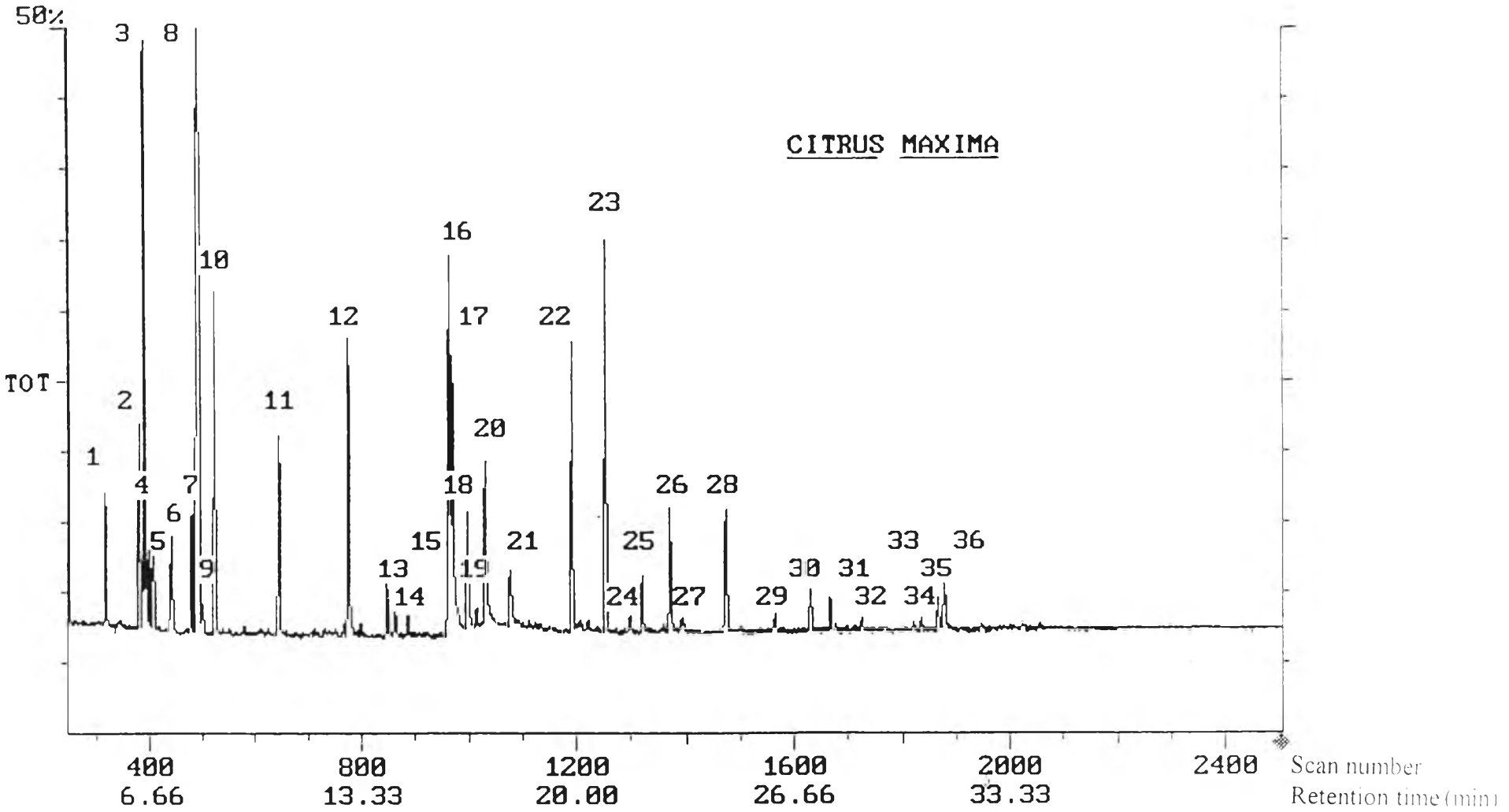


Figure 10 GC chromatogram of the essential oil from *Citrus maxima* Merr. leaves

Table 6 Essential oil composition of *Citrus maxima* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.30	2.20
2	sabinene	6.34	3.46
3	*β*-pinene	6.51	9.90
5	myrcene	6.78	1.36
6	*α*-phellandrene	7.36	1.77
7	*o*-cymene	7.98	1.98
8	*β*-phellandrene	8.19	24.84
9	*(Z)*-*β*-ocimene	8.33	0.47
10	(E)-*β*-ocimene	8.71	5.35
	Oxygenated monoterpenes		
11	linalool	10.74	2.71
12	citronellal	12.91	5.10
13	terpin-4-ol	14.11	0.78
15	*α*-terpineol	14.74	0.36
16	nerol	16.03	6.42
17	citronellol	16.14	6.32
18	neral	16.63	2.11
20	geraniol	17.18	3.28
21	geranial	17.94	1.13
22	*(E)*-citral dimethoxy	19.86	4.30
24	citronellyl acetate	21.63	t
25	lavandulyl acetate	21.99	0.94
26	geranyl acetate	22.86	2.00

Table 6 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
27	*β*-cubebene	23.19	t
28	*9-epi-(E)*-caryophyllene	24.54	2.08
29	*α*-humulene	26.08	0.35
30	germacrene D	27.16	0.74
31	bicyclogermacrene	27.76	0.59
32	*γ*-cadinene	28.78	t
33	germacrene B	30.34	t
	Oxygenated sesquiterpenes		
34	*(E)*-nerolidol	30.56	t
35	spathulenol	31.09	0.59
36	caryophyllene oxide	31.31	1.03
	Long chains hydrocarbons		
4	*6-methyl-5*-hepten-2-one	6.64	1.19
	Miscellaneous		
14	sabina ketone	14.36	0.37
19	unknown	16.93	0.25
23	unknown	20.88	6.00

t =trace

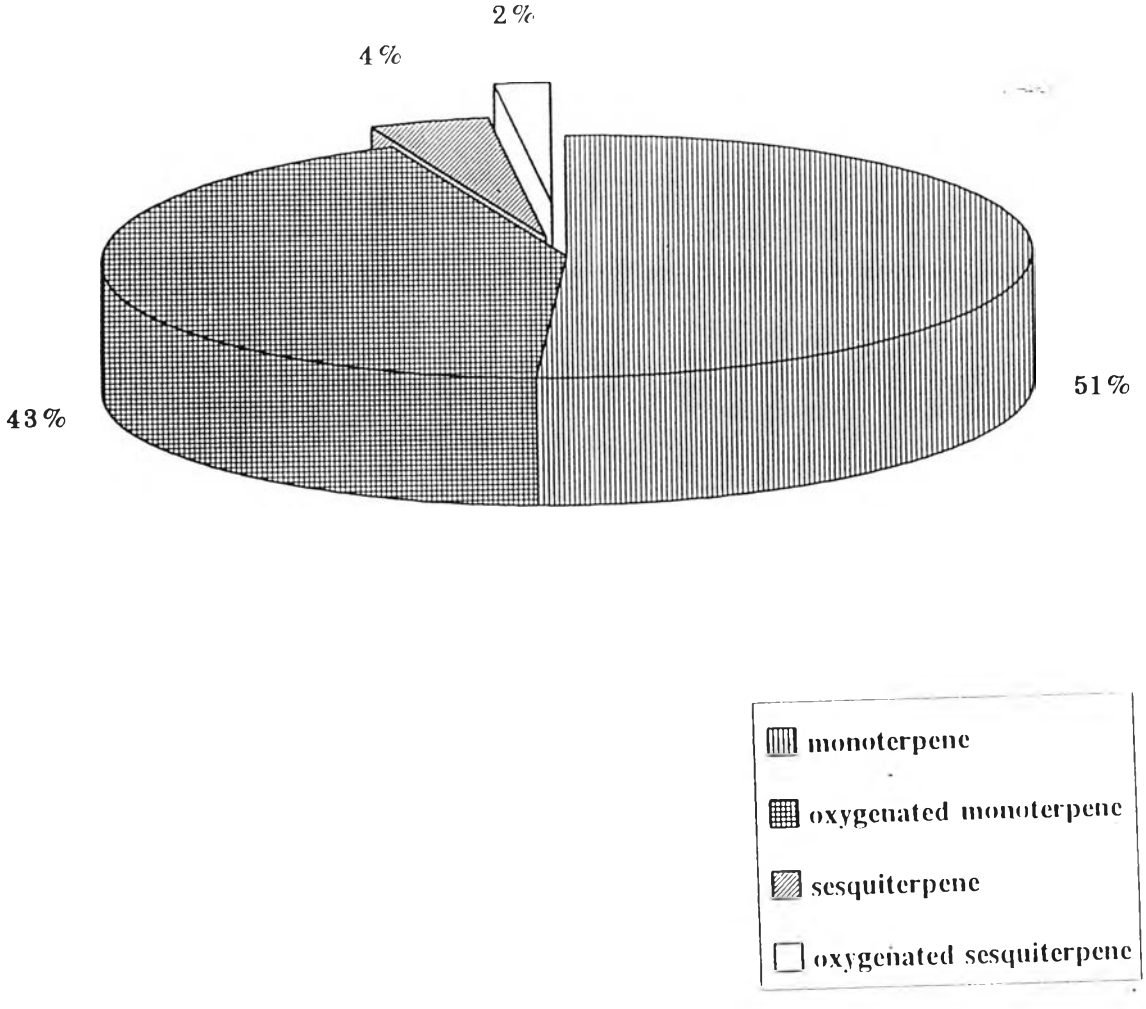
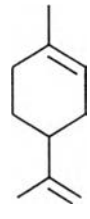


Figure 11 The percentage composition of various terpenoid groups present in the essential oil of *Citrus maxima* leaves.

6 Essential Oil Composition of *Citus medica* Linn.

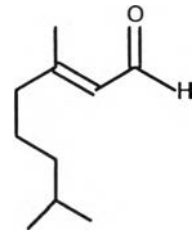
The essential oil hydrodistillated from *Citrus medica* leaves was found to have the yield of 1.5% (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that 23 peaks were well separated from each other (Fig. 12) These peaks were identified as 5 monoterpenes, 14 oxygenated monoterpenes, 2 sesquiterpenes and 1 oxygenated sesquiterpenes (Table 7). Among these, limonene (27.05%) was found to be the major component, followed by geranial (19.88%) and methyl eugenol (11.47%).

In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 59% of the essential oil. Monoterpenoids, phenylpropanoids and sesquiterpenoids were present in lesser amount, with 29%,11% and 1%, respectively (Fig. 13). Structurally, limonene belongs to the group of menthane whereas geranial and neral belong to the monoterpenoid group of acyclic monoterpenoid. Methyl eugenol is a phenylpropanoid compound.



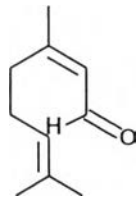
limonene

(*menthane*)



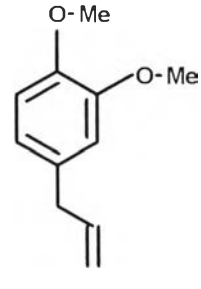
geranial

(*acyclic monoterpenoid*)



neral

(*acyclic monoterpenoid*)



methyl eugenol

(*phenylpropanoid*)

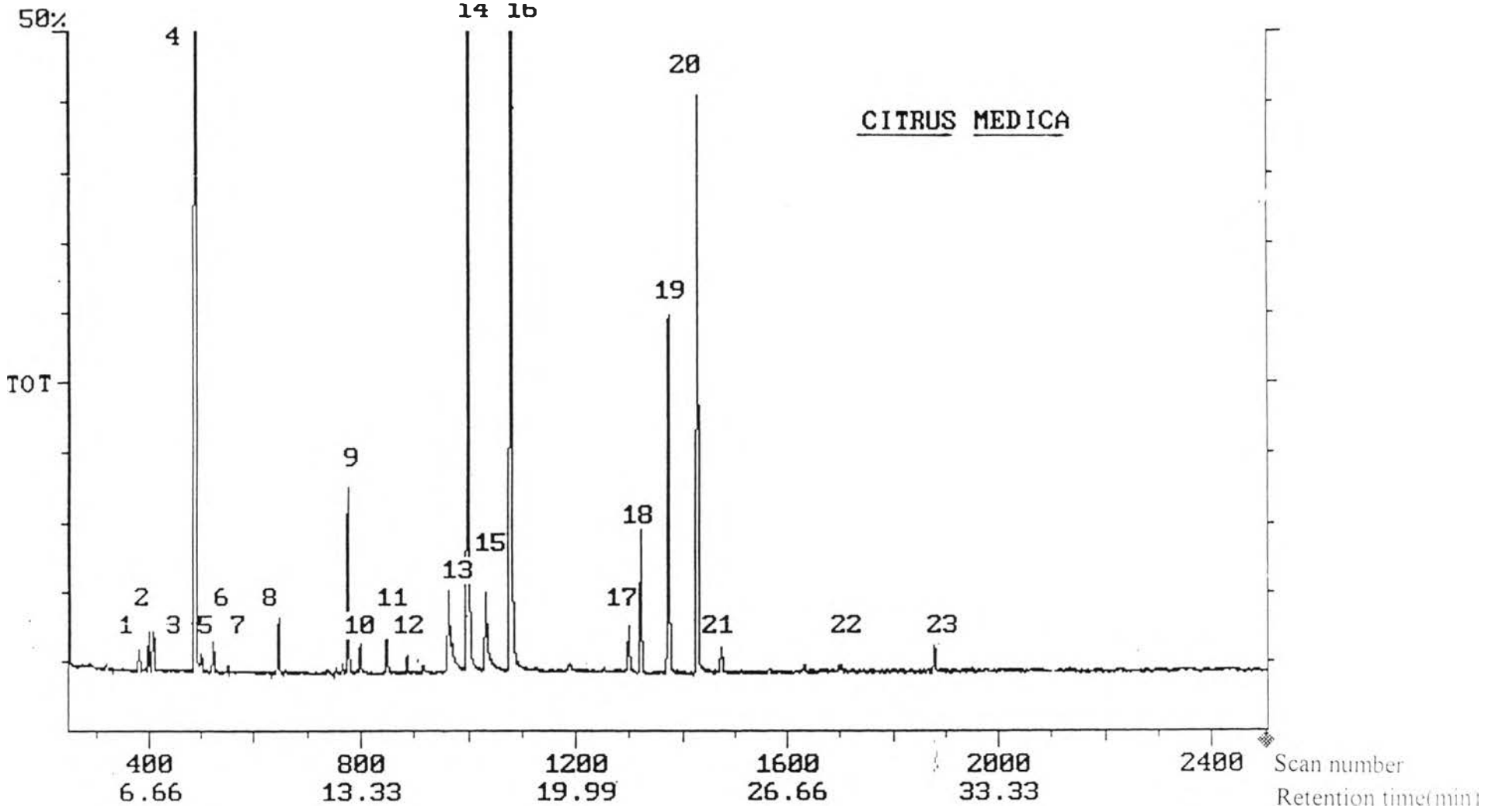


Figure 12 GC chromatogram of the essential oil from *Citrus medica* Linn. leaves

Table 7 Essential oil composition of *Citrus medica* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	sabinene	6.34	0.28
3	myrcene	6.81	0.81
4	limonene	8.14	27.05
6	*(E)*-β-ocimene	8.71	0.63
7	γ-terpinene	9.18	t
	Oxygenated monoterpenes		
5	*1,8*-cineol	8.33	t
8	linalool	10.76	0.95
9	citronellal	12.93	3.28
10	*cis*-verbenol	13.31	0.53
11	*trans*-verbenol	14.13	0.94
12	α-terpineol	14.76	0.33
13	nerol	16.05	2.48
14	neral	16.66	16.39
15	geraniol	17.19	2.33
16	geranial	18.00	19.88
17	citronellyl acetate	21.63	1.08
18	lavandulyl acetate	22.01	2.78
19	geranyl acetate	22.90	7.02
	Sesquiterpene hydrocarbons		
21	*9-epi-(E)*-caryophyllene	24.56	0.48
22	*(E,E)*-α-farnescene	28.25	t
	Oxygenated sesquiterpenes		
23	caryophyllene oxide	31.31	0.57

Table 7 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Long chain hydrocarbons		
2	*6-methyl-5*-hepten-2-one	6.66	0.70
	Phenylpropanoids		
20	methyl Eugenol	23.81	11.47

t = trace

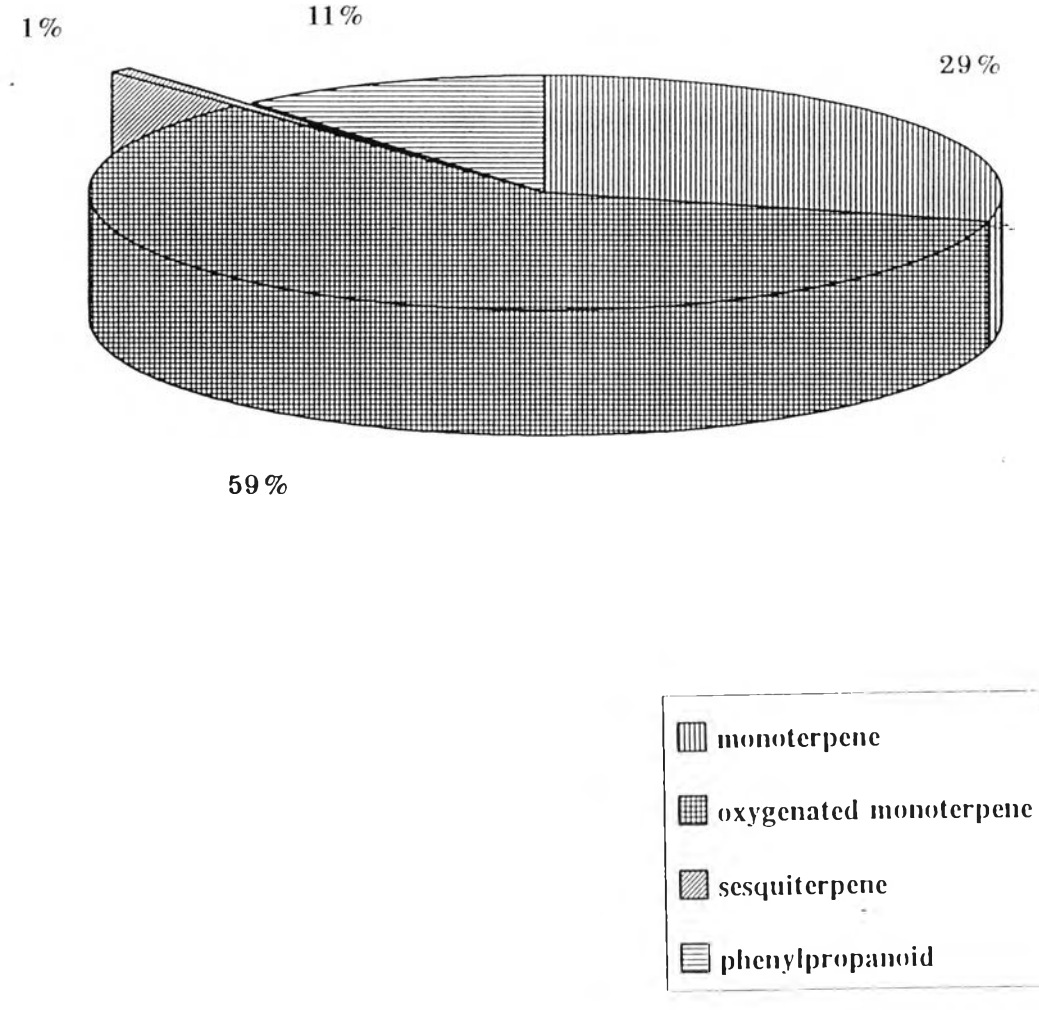


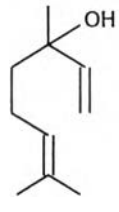
Figure 13 The percentage composition of various terpenoid groups present in the essential oil of *Citrus medica* leaves

7 Essential Oil Composition of *Citrus reticulata* Blanco.

The leaves of *Citrus reticulata.* was found to contain essential oil with the content of 1.5% (v/w) of fresh weight. By GC/MS analysis, the oil showed at least 20 peaks in its GC chromatogram (Fig. 14). These peaks were identified as 9 monoterpenes, 4 oxygenated monoterpenes, 7 sesquiterpenes and 1 oxygenated sesquiterpenes (Table 8). Among these, the major components were found to be linalool (47.77%), sabinene (22.25%) and *(E)*-β-ocimene (5.36%).

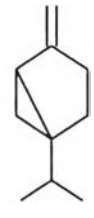
In terms of relative amount, the oxygenated monoterpenes appeared to be the major terpenoid group, accounting for 48% of the essential oil. Monoterpenes, and sesquiterpenes were present in lesser amount, with 41% and 11% , respectively (Fig. 15).

In terms of structure, the major components of linalool and sabinene belong to the monoterpenoid group of acyclic monoterpenoid and thujane group, while (E)-b-ocimene belongs to the group of acyclic monoterpenoid, respectively



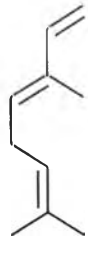
linalool

(*acyclic monoterpenoid*)



sabinene

(*thujane*)



(E)-*β*-ocimene

(*acyclic monoterpenoid*)

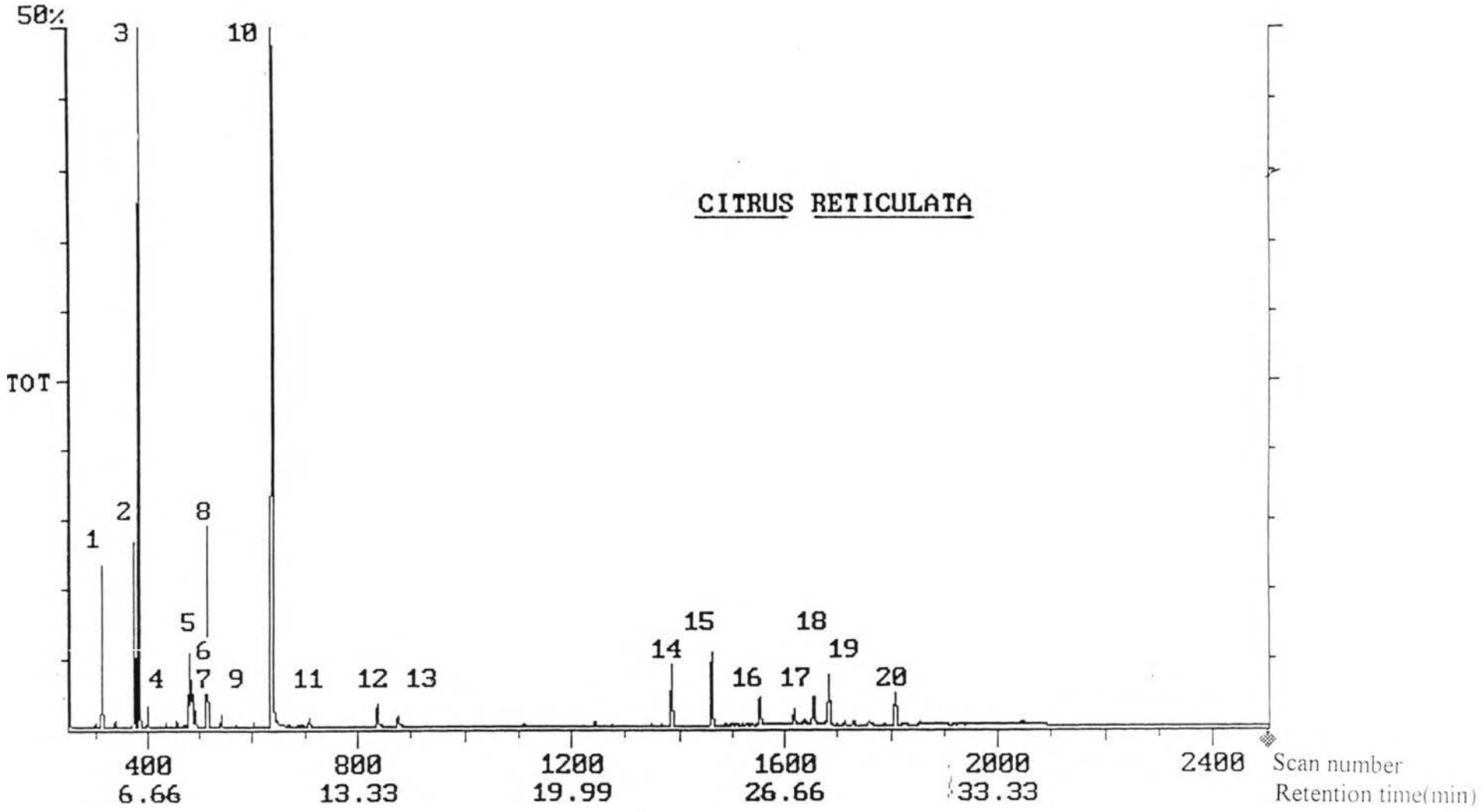


Figure 14 GC chromatogram of the essential oil from *Citrus reticulata* Blanco. leaves

Table 8 Essential oil composition of *Citrus reticulata* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.19	3.89
2	α-pinene	6.23	4.20
3	sabinene	6.39	22.25
4	myrcene	6.66	0.52
5	limonene	7.99	2.04
6	β-phellandrene	8.06	1.68
7	*(Z)*-β-ocimene	8.11	0.82
8	*(E)*-β-ocimene	8.56	5.36
9	γ-terpinene	10.03	t
	Oxygenated monoterpenes		
10	linalool	10.63	47.77
11	*cis-para*-menth-2-en-1-ol	11.79	t
12	terpin-4-ol	13.94	0.81
13	α–terpineol	14.56	t
	Sesquiterpene hydrocarbons		
14	β-elemene	23.10	2.22
15	*9-epi-(E)*-caryophyllene	24.34	2.82
16	α-humulene	25.88	1.03
17	γ-gurjunene	26.96	t
18	bicyclogermacrene	27.58	1.16
19	germacrene A	28.06	2.13
20	germacrene B	30.14	1.27

t = trace

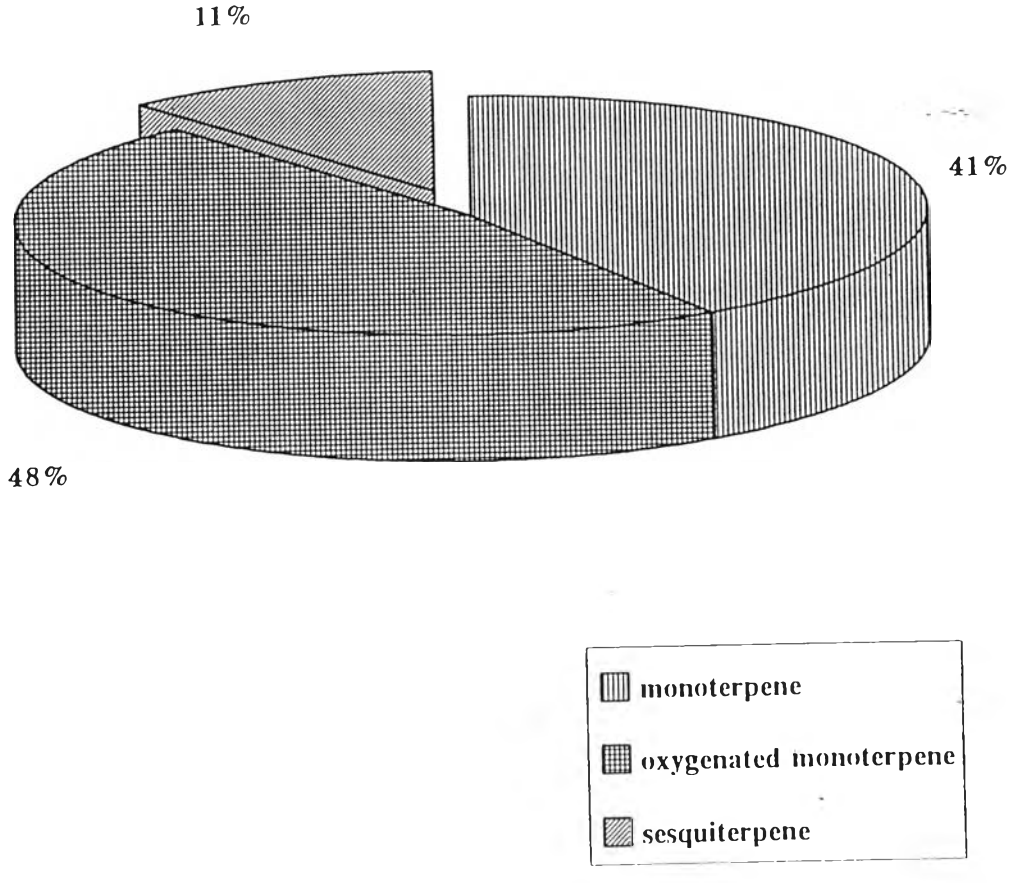
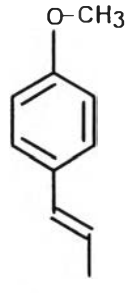


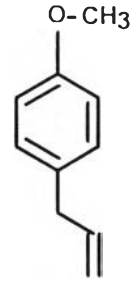
Figure 15 The percentage composition of various terpenoid groups present in the essential oil of *Citrus reticulata* leaves.

8 Essential Oil Composition of *Clausena anisata* Hook.

The yield of the essential oil from *Clausena anisata.* leaves was found to be 3.5% (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that there were only 2 peaks well separated from each other (Fig. 16) These peaks were identified as both phyenylpropanoids, namely *(E)*-anethol (98.40%) and methylchavicol (1.60%) (Table 9). Therefore, the essential oil of this plant contain only the phenylpropanoids (Fig. 17)..



(E)-anethole
(*phenylpropanoids*)



methyl chavicol
(*phenylpropaoids*)

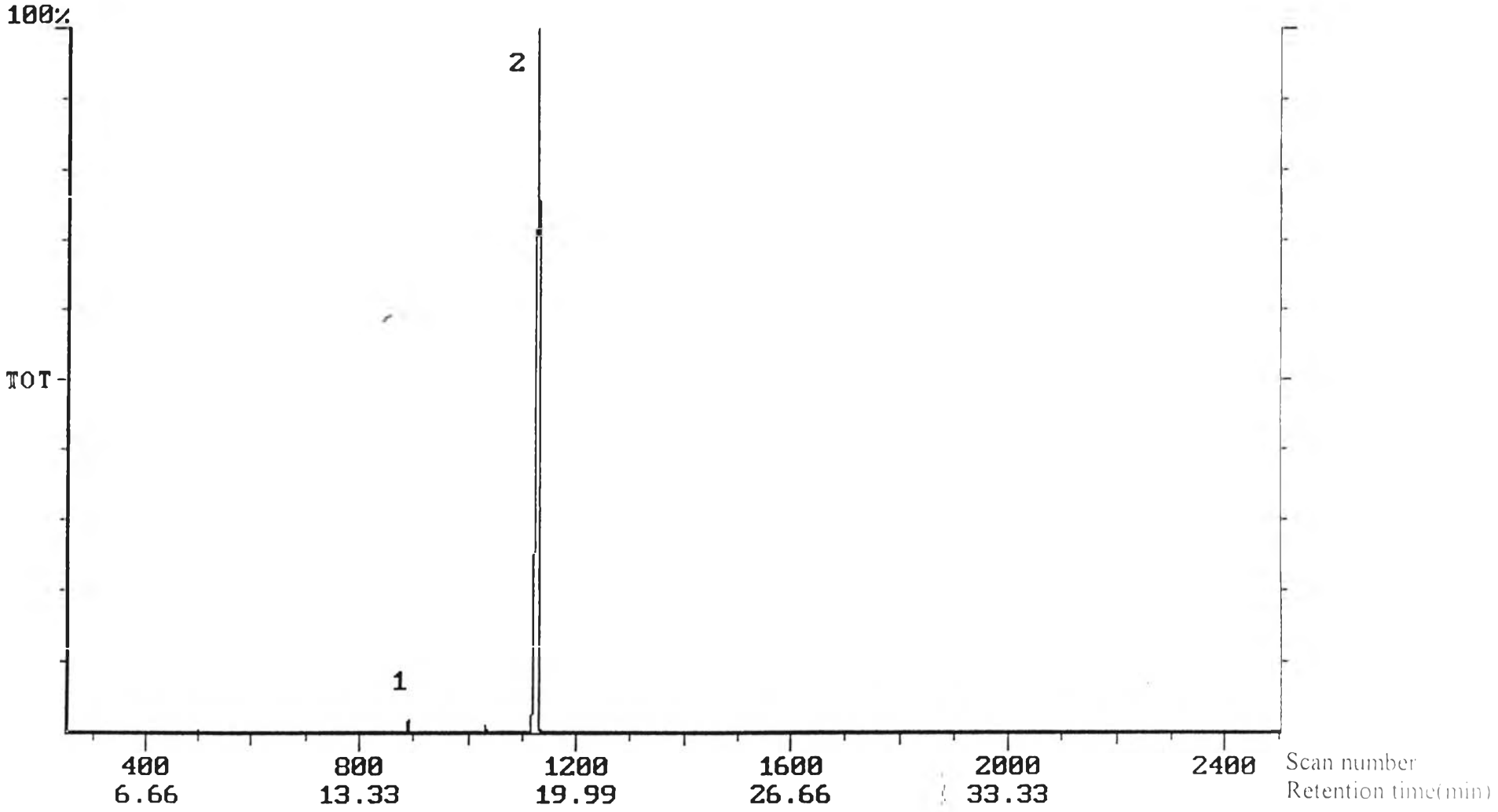
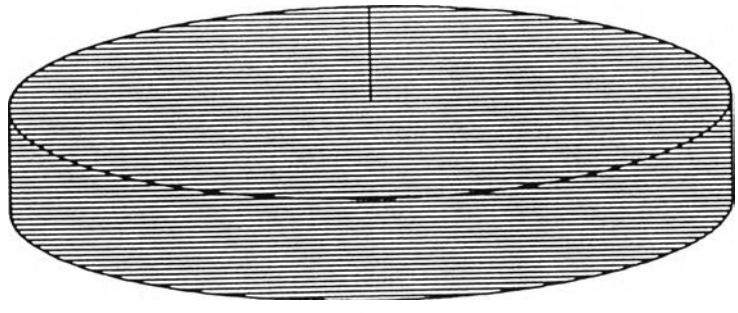


Figure 16 GC chromatogram of the essential oil from *Clausena anisata* Hook. leaves

Table 9 Essential oil composition of *Clausena anisata* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Phenyl propanoids		
1	methyl chavicol	13.73	1.60
2	*(E)*-anethol	19.84	98.40



100%

phenylpropanoid

Figure 17 The percentage composition of various terpenoid groups present in the essential oil of *Clausena anisata* leaves.

9 Essential Oil Composition of *Clausena excavata* Burm.

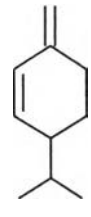
By hydrodistillation, the yield of the essential oil from *Clausena excavata* leaves was found to be 0.1% (v/w) of fresh weight. GC/MS analysis of the essential oil showed that 32 peaks were separated from each other (Fig. 18). These peaks were identified as 12 monoterpenes, 6 oxygenated monoterpenes, 9 sesquiterpenes, 4 oxygenated sesquiterpenes and 1 non-terpenoids compounds (Table 10). Among these, tricyclene (35.35%) appeared to be the major component, followed by 9-epi-*(E)*-caryophyllene (18.17%) and *β*-phellandrene (13.74%).

In terms of relative amount, the monoterpenes appeared to be the major terpenoid group, accounting for 70% of the essential oil. Sesquiterpenes and oxygenated sesquiterpenes were present in a lesser content, with 26% and 4%, respectively (F-g. 19).

In terms of structure, the major components of tricyclene and β–phellandrene belong to the monoterpenoid group of menthane whereas 9-epi-*(E)*-caryophyllene belongs to the sesquiterpenoid group of caryophilane.

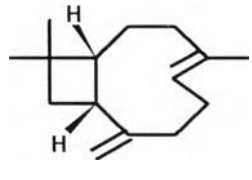
tricyclene

(*tricyclic monoterpenoid*)



β-phellandrene

(*menthane*)



9-epi-*(E)*-caryophyllene

(*caryophilane*)

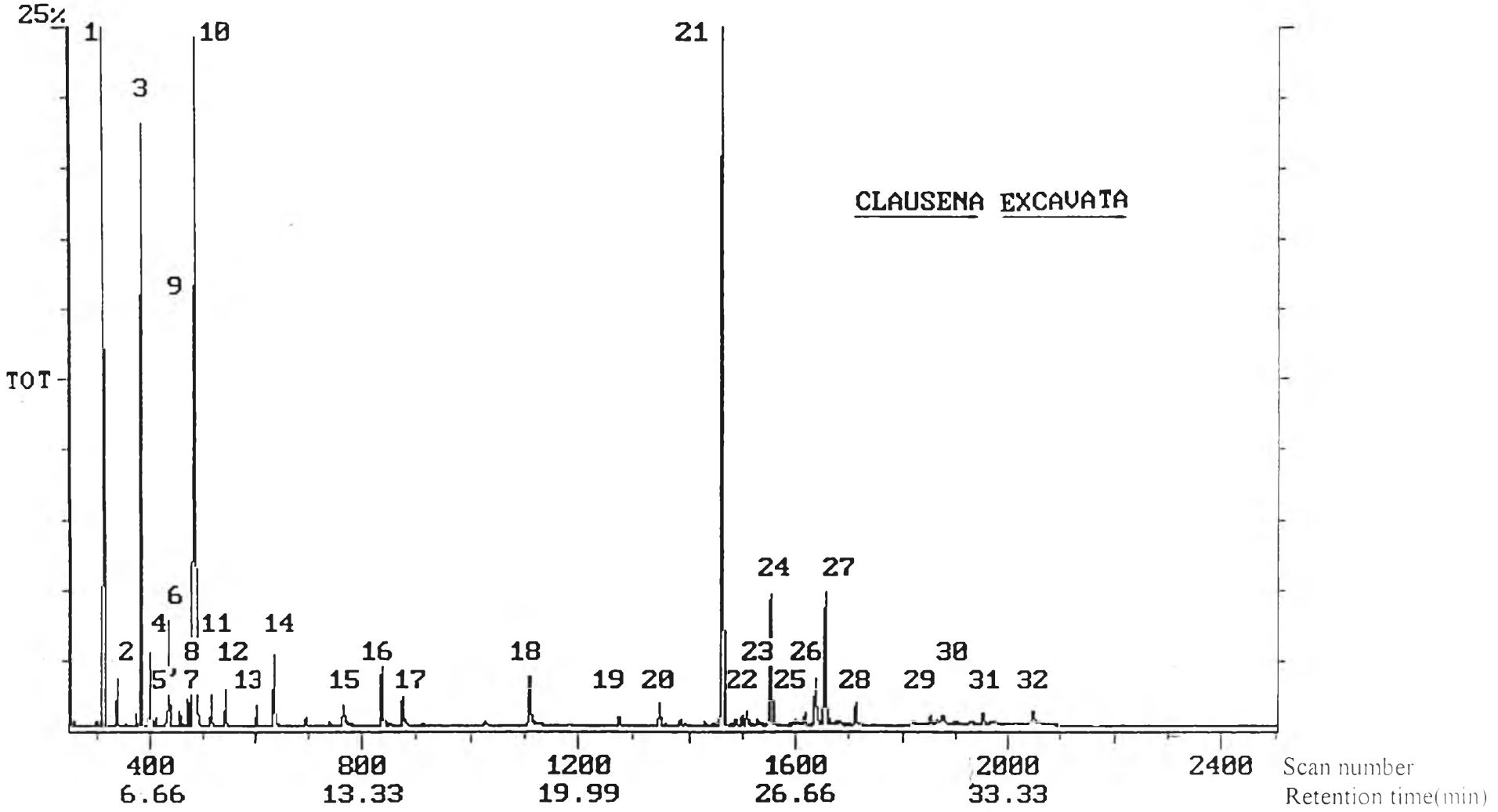


Figure 18 GC chromatogram of the essential oil from *Clausena excavata* Burm. leaves

Table 10 Essential oil composition of *Clausena excavata* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.21	35.35
2	camphene	5.64	0.77
3	sabinene	6.39	8.08
4	myrcene	6.66	1.14
6	*meta*-mentha-1(7),8-diene	7.25	1.66
7	*δ-2*-carene	7.58	t
8	*o*-cymene	7.81	t
9	limonene	7.99	8.10
10	*β*-phellandrene	8.06	13.74
11	*(E)*-*β*-ocimene	8.56	0.48
12	*γ*-terpinene	9.01	0.64
13	terpinolene	10.03	t
	Oxygenated monoterpenes		
14	linalool	10.59	1.56
15	citronellal	12.74	t
16	terpin-4-ol	13.95	1.02
17	*α*-terpineol	14.58	t
18	bornyl acetate	18.51	1.53
19	citronellyl acetate	21.61	t
	Sesquiterpene hydrocarbons		
20	*α*-copaene	22.48	t
21	*9-epi-(E)*-caryophyllene	24.36	18.17
22	*α*-trans-bergamotene	24.98	t

Table 10 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
23	*allo*-aromadendrene	25.16	t
24	α-humulene	25.88	3.18
25	seychellene	26.96	t
26	β-selinene	27.28	1.17
27	α-selinene	27.58	3.39
28	δ-cadinene	28.53	t
	Oxygenated sesquiterpenes		
29	spathulenol	30.88	t
30	caryophyllene oxide	31.23	t
31	selin-11-en-4-alpha-ol	32.51	t
32	juniper camphor	34.11	t
	Miscellaneous		
5	mesitylene	6.83	t

t = trace

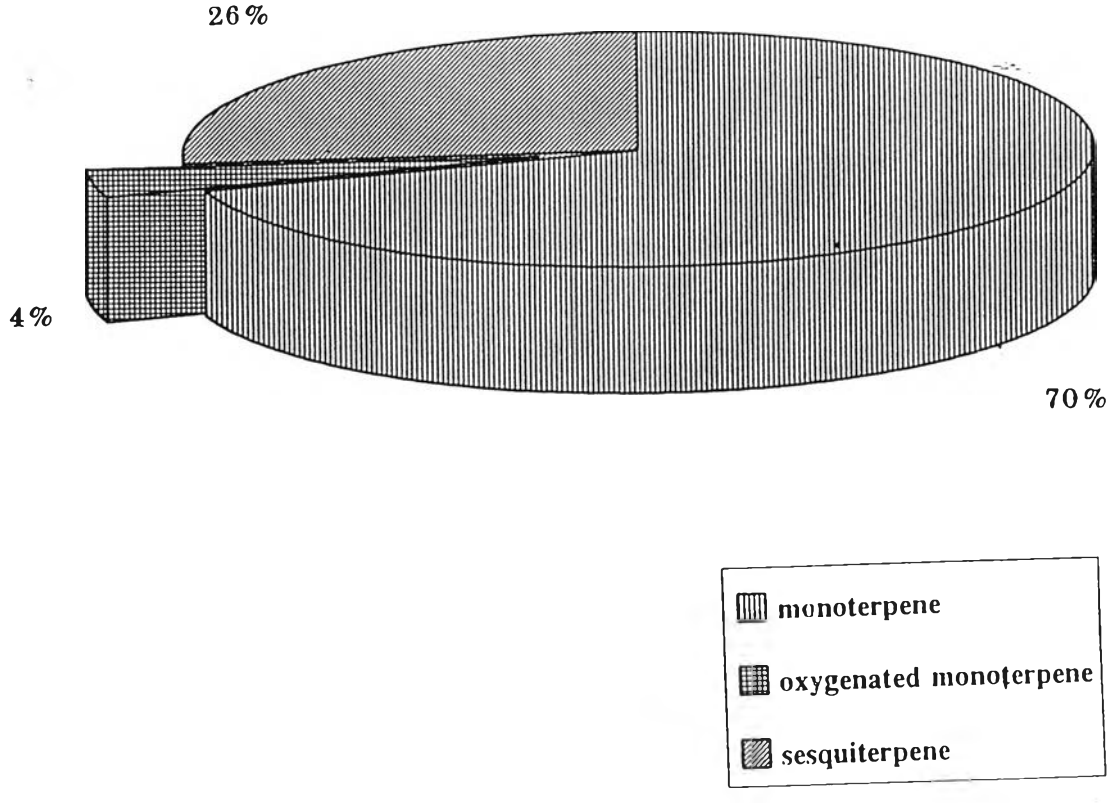


Figure 19 The percentage composition of various terpenoid groups present in the essential oil of *Clausena excavata* leaves

10 Essential Oil Composition of *Ferronia limonia* Swing.

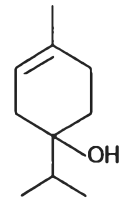
The essential oil from *Ferronia limonia* leaves was found to have the yield of 0.1 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that there were at least 23 components (Fig. 20) These components were identified as 8 monoterpenes, 12 oxygenated monoterpenes, 1 sesquiterpenes and 2 oxygenated sesquiterpenes (Table 11). Among these, sabinene (33.99%) appeared to be the major component, followed by terpin-4-ol (38.67%) and o-cymene (6.88%).

The oxygenated monoterpene was found to be the major terpenoid group, accounting for 47% of the essential oil. Monoterpenes, sesquiterpenes and oxygenated sesquiterpenes were present in lesser amount, with 45%, 6% and 2%, respectively (Fig. 21).

Structurally, the major component of sabinene belongs to the monoterpenoid group of thujane, where as terpin-4-ol and o-cymene belong to the oxygenated monoterpenoid group of menthane and o-menthane, respectively.

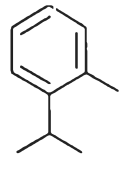
sabinene

(*thujane*)



terpin-4-ol

(*menthane*)



o-cymene

(*o-menthane*)

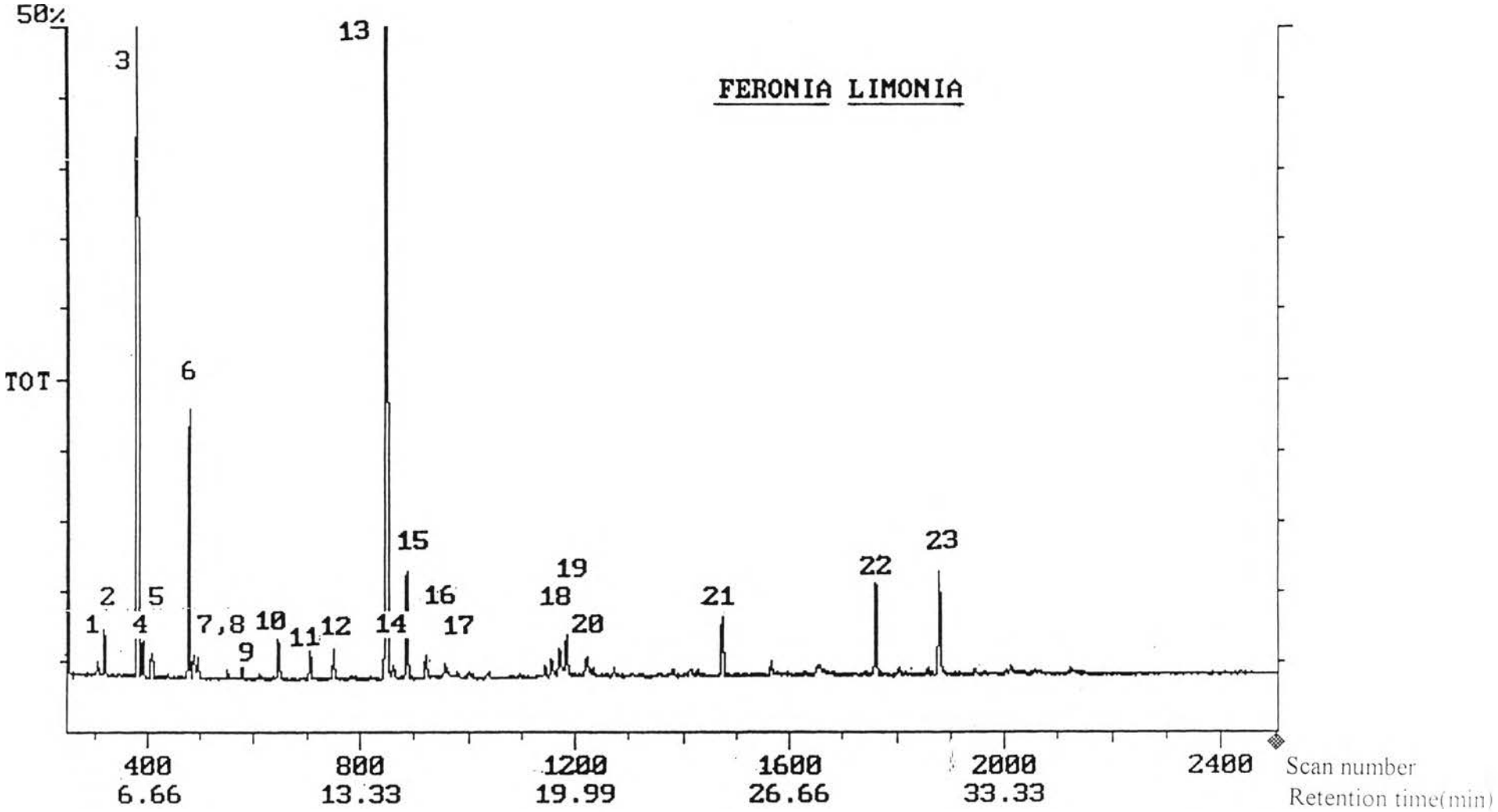


Figure 20 GC chromatogram of the essential oil from *Ferronia limonia* Swing. leaves

Table 11 Essential oil composition of *Ferronia limonia* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	*α*-thujene	5.08	t
2	tricyclene	5.29	1.35
3	sabinene	6.34	33.99
4	*β*-pinene	6.51	0.96
5	myrcene	6.79	0.75
6	*o*-cymene	7.98	6.88
7	limonene	8.13	0.73
9	*γ*-terpinene	9.16	t
	Oxygenated monoterpenes		
8	*1,8*-cineol	8.26	0.55
10	linalool	10.74	1.10
11	*cis-para*-menth-2-en-1-ol	11.76	0.61
12	*trans-para*-menth-2-en-1-ol	12.50	0.80
13	terpin-4-ol	14.14	38.67
15	*α*-terpineol	14.76	2.91
16	*cis*-piperitol	15.36	0.60
17	*trans*-ascaridole	15.94	t
18	carvenone	19.26	1.16
19	geranial	19.51	t
20	*cis*-pinene hydrate	19.71	1.03
	Sesquiterpene hydrocarbons		
21	*9-epi-(E)*-caryophyllene	24.54	1.67

Table 11 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated sesquiterpenes		
23	caryophyllene oxide	31.29	2.88
	Miscellaneous		
14	*(Z)-3*-hexenyl-butyrate	14.34	t
22	musk ambrette	29.34	3.37

t = trace

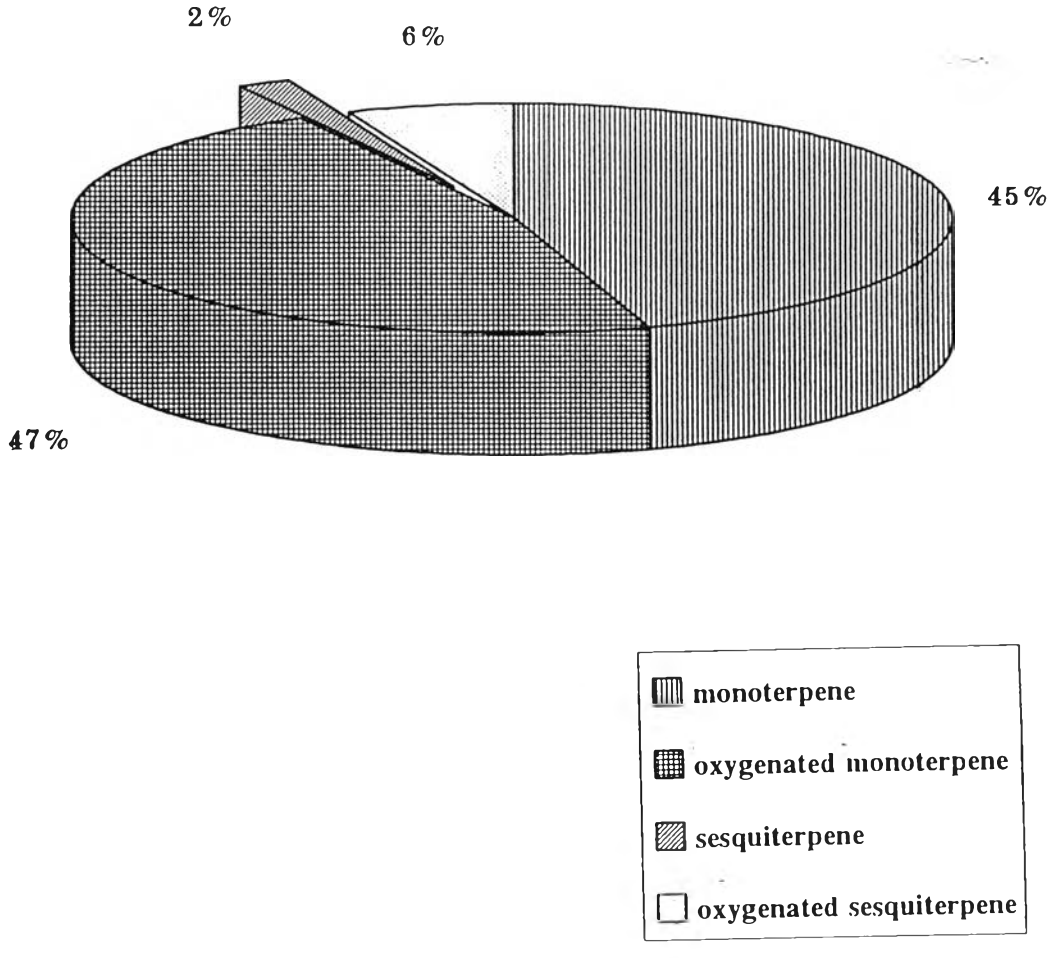


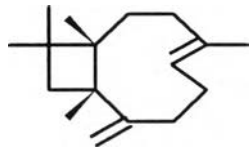
Figure 21 The percentage composition of various terpenoid groups present in the essential oil of *Ferronia limonia* leaves.

11 Essential Oil Composition of *Glycosmis pentaphylla* Corr.

The essential oil hydrodistillated from *Glycosmis pentaphylla* leaves was found to have the yield of 0.1 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that 32 peaks were well separated from each other (Fig. 22) These peaks were identified as 7 monoterpenes, 5 oxygenated monoterpenes, 12 sesquiterpenes and 8 oxygenated sesquiterpenes (Table 12). Among these, 9-epi-*(E)*-caryophyllene (28.55%) was found to be the major component followed by tricyclene (18.51%) and α-humulene (6.22%).

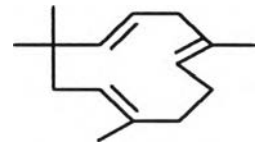
From a result, the sesquiterepenes appeared to be the major terpenoid group, accounting for 53% of the essential oil. Monoterpenes, oxygenated monoterpenes and oxygenated sesquiterpenes were present in lesser amount, with theircontent of 28%, 8% and 11%, respectively (Fig. 23).

In terms of structure, the major components of 9-epi-*(E)*-caryophyllene and α-humulene belong to the sesquiterpenoid group of caryophilane and humulane, respectively.



9-epi-(E)-caryophyllene

(*caryophilane*)



α-humulene

(*humulane*)

tricyclene

(*tricyclic monoterpenoid*)

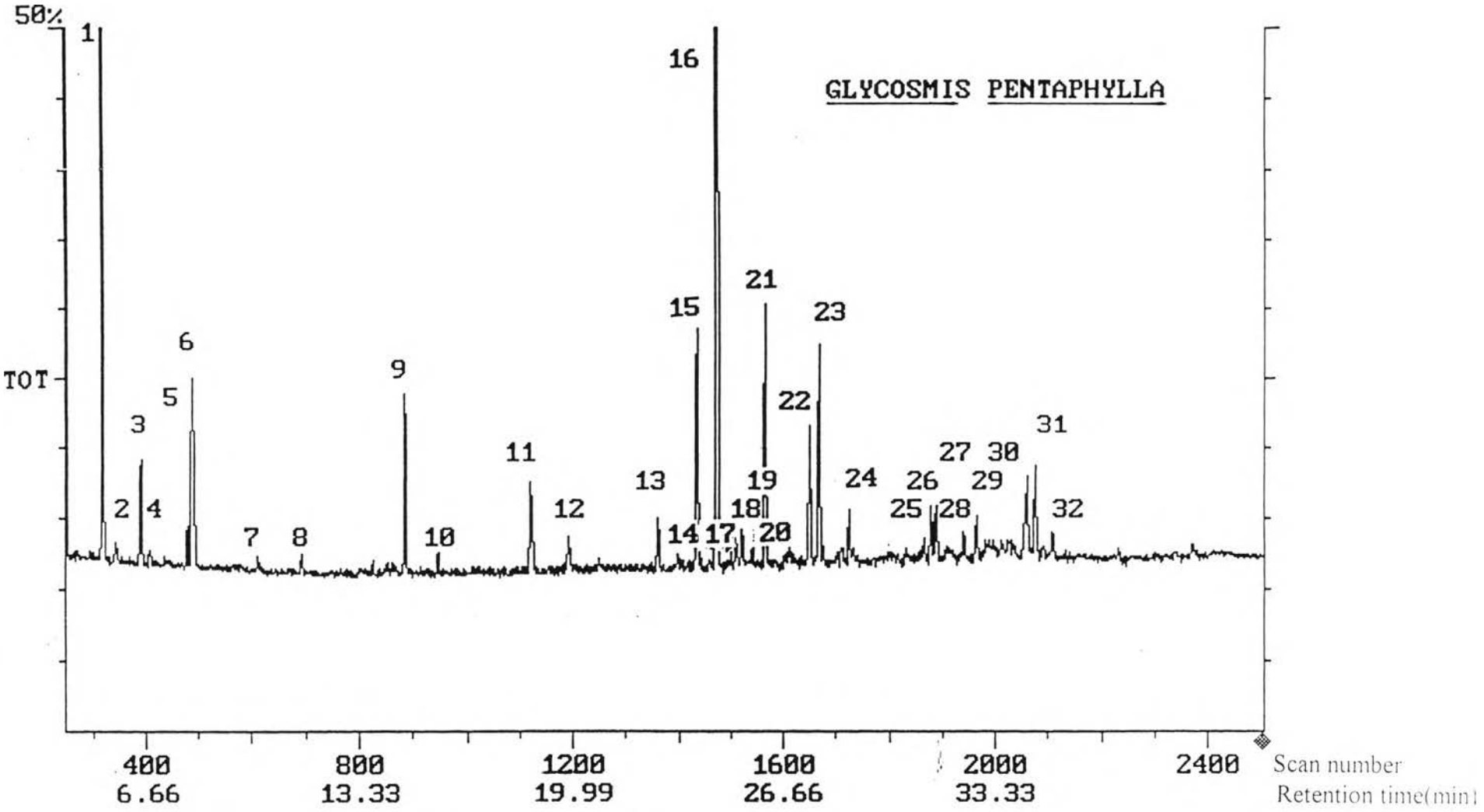


Figure 22 GC chromatogram of the essential oil from *Glycosmis pentaphylla* Corr leaves

Table 12 Essential oil composition of *Glycosmis pentaphylla* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.29	18.51
2	camphene	5.75	t
3	*β*-pinene	6.51	2.67
4	myrcene	6.79	t
5	*o*-cymene	7.98	0.84
6	limonene	8.13	6.21
7	terpinolene	10.14	t
	Oxygenated monoterpenes		
8	*endo*-fenchol	11.54	0.50
9	*α*-terpineol	14.74	3.80
10	*trans*-carveol	15.78	0.51
11	bornyl acetate	18.68	2.65
12	*(E)*-citral dimethoxy	19.88	0.80
	Sesquiterpene hydrocarbons		
13	*α*-copaene	22.26	1.29
14	*β*-elemene	23.29	t
15	*(Z)*-caryophyllene	23.91	5.38
16	*9-epi-(E)*-caryophyllene	24.56	28.55
17	1,7-di-epi-*β*-cedrene	24.99	t
18	*α*-bergamotene	25.18	t
19	longifolene	25.34	0.79
20	aromadendrene	25.68	t
21	*α*-humulene	26.08	6.22
22	*α*-selinene	27.49	3.68

Table 12 (Continued)

Number of peak	Compound	Retention time (min)	% Area
23	α-selinene	27.79	5.46
24	δ-cadinene	28.74	1.09
	Oxygenated sesquiterpenes		
25	spathulenol	31.09	0.58
26	caryphyllene oxide	31.29	1.61
27	globulol	31.46	1.49
28	eudesmol<*beta*->	32.33	0.53
29	selin-11-en-4-alpha-ol	32.75	1.03
30	juniper camphor	34.33	2.30
31	tumerone	34.58	2.87
32	foeniculin	35.11	0.63

t = trace

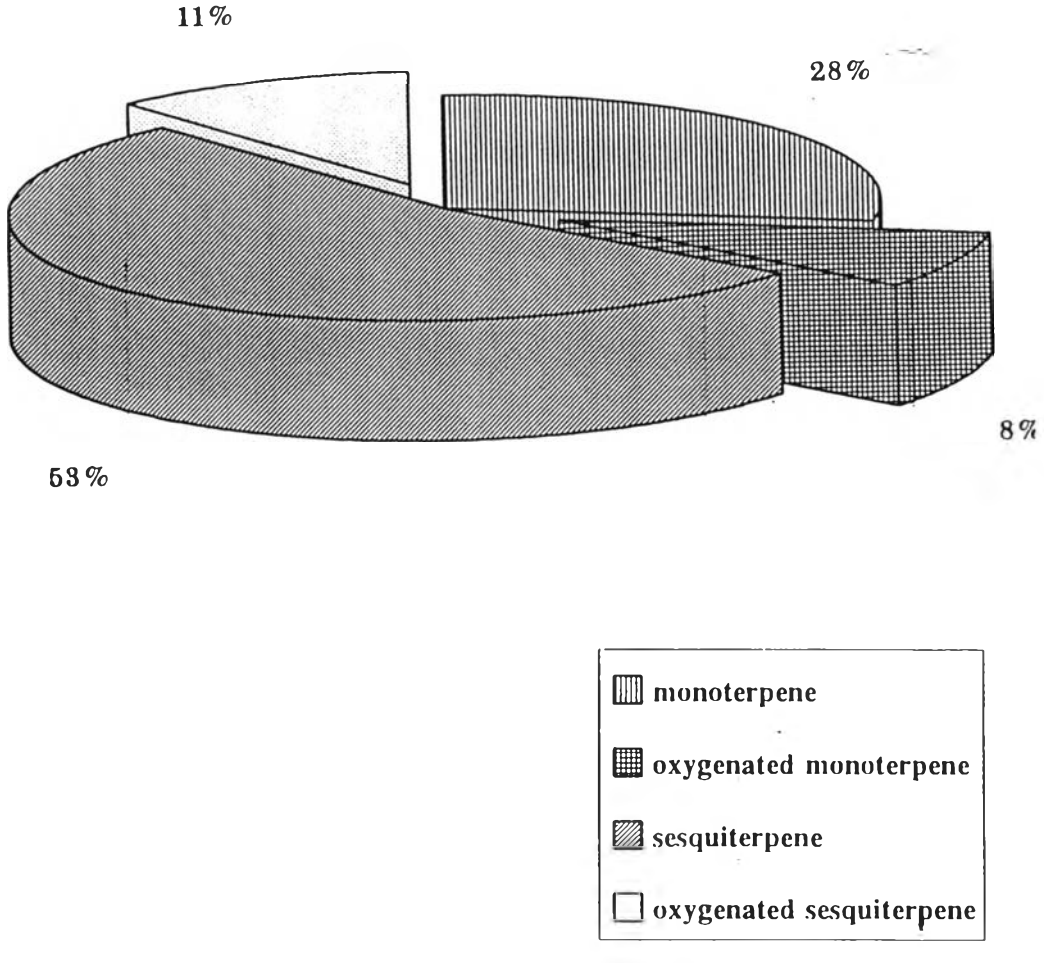
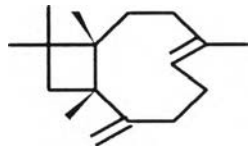


Figure 23 The percentage composition of various terpenoid groups present in the essential oil of *Glycosmis pentaphylla* leaves

12 Essential Oil Composition of *Hesperethusa crenulata* Roem.

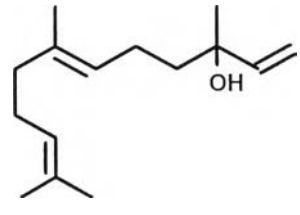
The essential oil hydrodistillated from *Hesperethusa crenulata* leaves was found to have the yield of 0.4% (v/w) of fresh weight. Analysis of this essential oil by GC/MS showed that 31 peaks were well separated from each other (Fig. 24). These peaks were identified as 2 monoterpenes, 2 oxygenated monoterpenes, 17 sesquiterpenes and 10 oxygenated sesquiterpenes (Table 13). Among these, 9-epi-*(E)*-caryophyllene (23.92%) appeared to be the major component, followed by (E)-nerolidol (17.02%), germacrene D and bicyclogermacrene (12.56%). Therefore, the sesquiterpenes was found to be the major terpenoid group, accounting for 68% of the essential oil. Oxygenated sesquiterpenes, monoterpenes and oxygenated monoterpenes were present in lesser amount, with their content of 29%, 2%, 1%, respectively (Fig. 25).

The major components of 9-epi-*(E)*-caryophyllene, *(E)*-nerolidol, germacrene D and bicyclogermacrene belong to the sesquiterpenoid group of caryophilane, simple farnesane, simple germacrane and bicyclogermacrane, respectively.



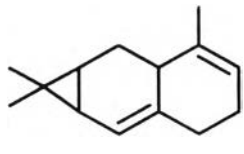
9-epi-*(E)*-caryophyllene

(*caryophilane*)



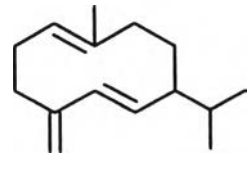
(E)-nerolidol

(*simple farnesane*)



bicyclogermacrene

(*bicyclogermacrane*)



germacrene D

(*simple germacrane*)

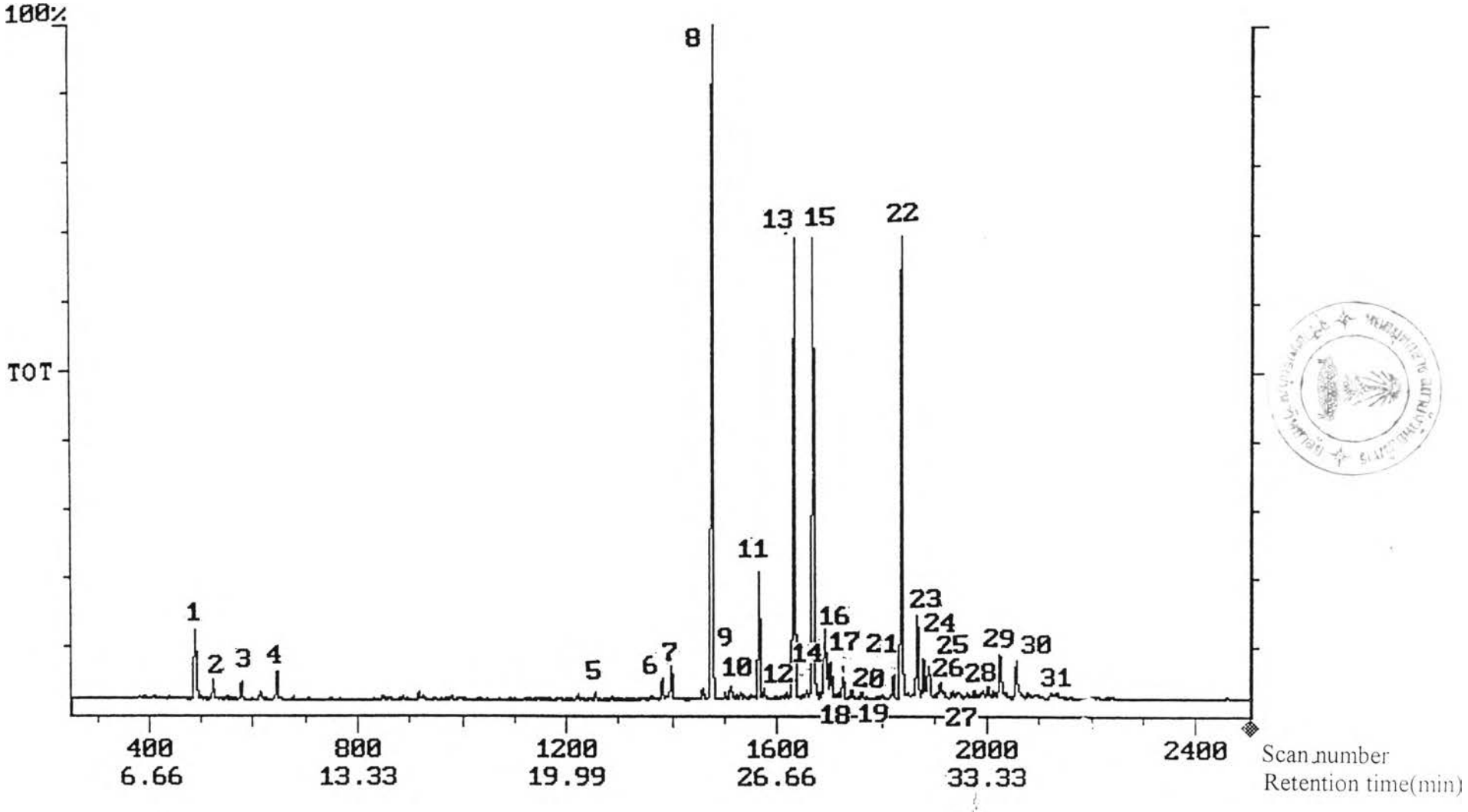


Figure 24 GC chromatogram of the essential oil from *Hesperethusa crenulata* Roem. leaves

Table 13 Essential oil composition of *Hesperethusa crenulata* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	limonene	8.13	1.50
2	*(E)*-β-ocimene	8.71	0.40
	Oxygenated monoterpenes		
3	linalool oxide	9.64	0.50
4	linalool	10.76	0.79
	Sesquiterpene hydrocarbons		
5	α-cubebene	20.94	0.22
6	bourbonene	23.05	0.74
7	β-elemene	23.31	1.12
8	*9-epi-(E)*-caryophyllene	24.61	23.92
10	α–*trans*-bergamotene	25.21	0.44
11	α–humulene	26.11	4.30
12	*allo*-aromadendrene	26.28	0.42
13	germacrene D	27.23	14.77
14	β-selinene	27.61	1.02
15	bicyclogermacrene	27.83	12.56
16	*cis*-β-guaiene	28.19	1.96
17	germacrene A	28.30	1.06
18	β-bisabolene	28.39	1.17
19	δ-cadinene	28.78	1.45
21	germacrene B	30.40	0.93

Table 13 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated sesquiterpenes		
22	*(E)*-nerolidol	30.64	17.02
23	spathulenol	31.13	2.92
24	caryophyllene oxide	31.34	1.49
25	globulol	31.60	1.80
26	β-eudesmol acetate	31.84	0.45
27	hinesol	32.06	0.74
28	*bicyclo*-vertivenol	33.38	0.45
29	epi-α-cadinol	33.74	2.26
30	α-cadinol	34.28	1.52
31	longiborneol acetate	34.73	0.35
	Miscellaneous		
9	unknown	25.03	0.24
20	unknown	29.26	0.26

t = trace

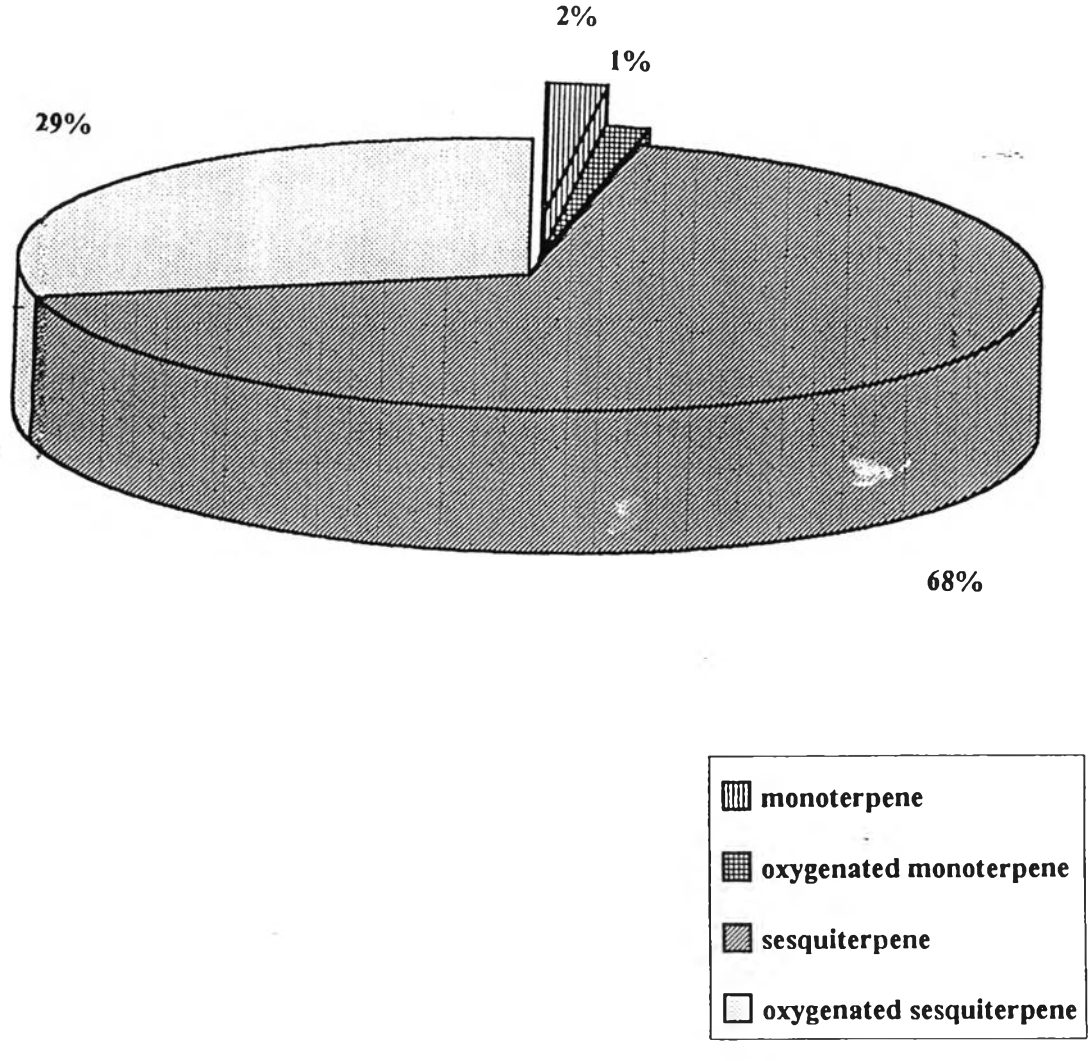


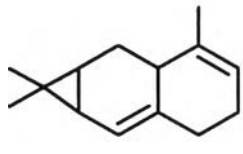
Figure 25 The percentage composition of various terpenoid groups present in the essential oil of *Hesperethusa crenulata* leaves.

13 Essential Oil Composition of *Micromelum minutum* Wight & Arn.

The yield of the essential oil isolated from *Micromelum minutum* leaves was found to be 0.2 % (v/w) of fresh weight. GC analysis of the essential oil showed that there were at least 37 components present in the oil (Fig. 26). These components were identified as 4 monoterpenes, 3 oxygenated monoterpenes, 11 sesquiterpenes , 12 oxygenated sesquiterpenes and 5 non-terpenoid compounds (Table 11). Among these, bicyclogermacrene (19.79%) was found to be the major component followed by 9-epi-*(E)*-caryophyllene (15.65%) and tricyclene (8.74%).

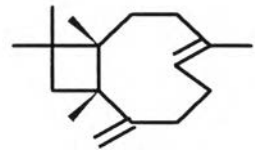
In terms of relative amount, the sesquiterpenes appeared to be the major terpenoid group, accounting for 54% of the essential oil. Oxygenated sesquiterpenes , monoterpenes and oxygenated monoterpenes were present in a lesser amount, with 19%, 13% and 2%, respectively (Fig.27).

Structurally, the major components of bicyclogermacrene and 9-epi-*(E)*-caryophyllene belong to the sesquiterpenoid group of bicyclogermacrane and caryophilane, respectively.



bicyclogermacrene

(*bicyclogermacrane*)



9-epi-*(E)*-caryophyllene

(*caryophilane*)

tricyclene

(*tricyclic monoterpenoid*)

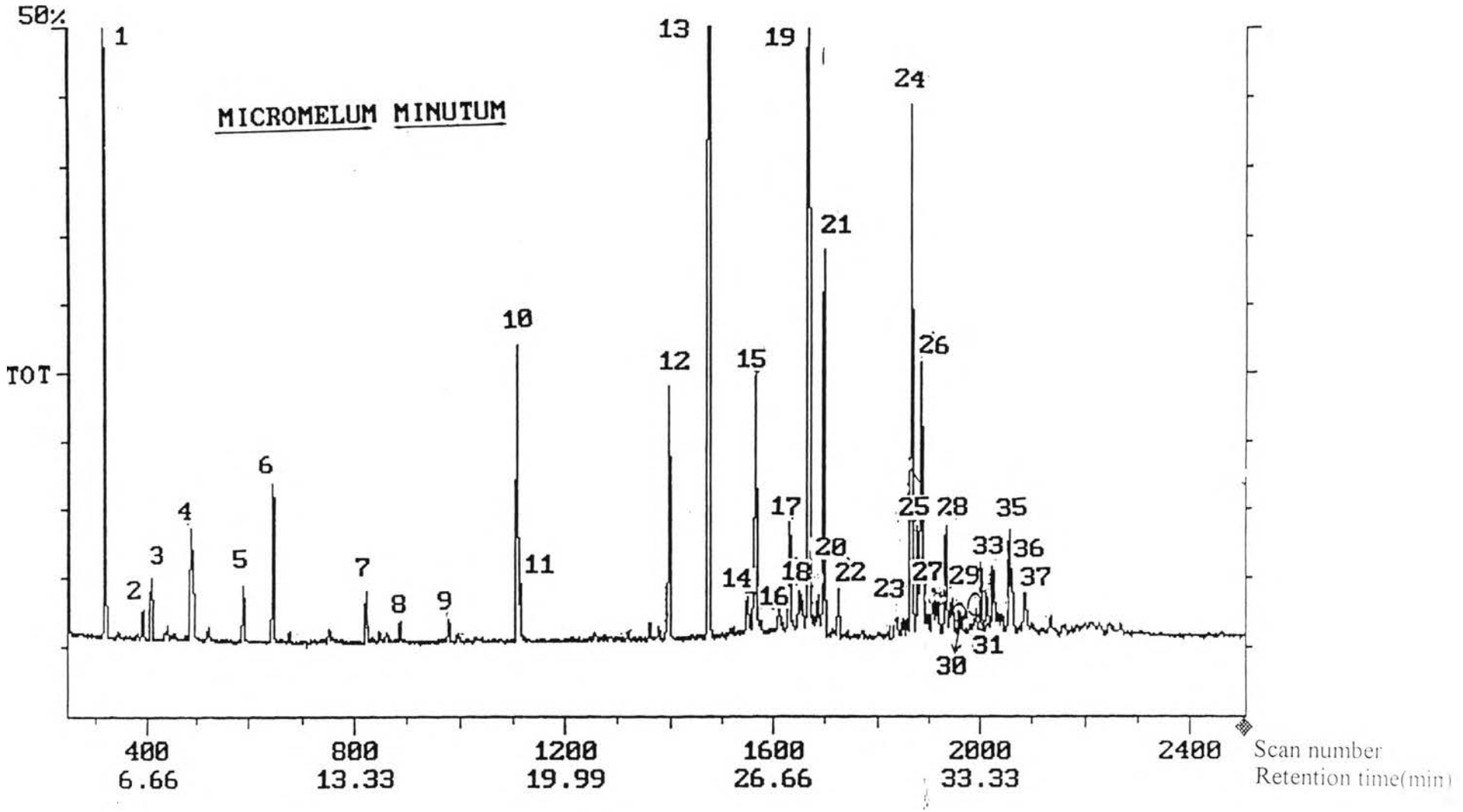


Figure 26 GC chromatogram of the essential oil from *Micromelum minutum* Weight&Arn. leaves

Table 14 Essential oil composition of *Micromelum minutum* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	tricyclene	5.30	8.74
2	*β*-pinene	6.51	0.42
3	myrcene	6.78	0.95
4	limonene	8.13	2.58
	Oxygenated monoterpenes		
6	linalool	10.74	1.90
8	*α*-terpineol	14.76	0.26
9	citronellyl formate	16.33	0.26
	Sesquiterpene hydrocarbons		
12	*β*-elemene	23.30	3.63
13	*9-epi-(E)*-caryophyllene	24.56	15.65
14	viridiflorene	25.81	0.71
15	*α*-humulene	26.09	4.23
16	*β*-selinene	26.84	0.27
17	germacrene D	27.18	1.46
18	*α*-selinene	27.51	0.78
19	bicyclogermacrene	27.79	19.79
20	*(E)*-caryophyllene	28.11	0.92
21	germacrene A	28.28	5.68
22	*δ*-cadinene	28.74	0.64

Table 14 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated sesquiterpenes		
23	*(Z)*-nerolidol	30.60	0.64
24	spathulenol	31.11	7.68
25	caryophyllene oxide	31.31	1.56
27	globulol	31.81	0.80
28	*β*-oplopenone	32.21	1.74
31	*bicyclo*-vertivenol	33.34	0.96
32	*14-hydroxy-9-Epi-(E)*-caryophyllene	33.53	0.64
33	*epi*-*α*-cadinol	33.73	1.15
34	*β*-bisabolenal	34.03	0.30
35	*α*-cadinol	34.24	1.62
36	*epi*-*α*-muurolol	34.34	1.12
37	longiborneol acetate	34.76	0.76
	Long chain hydrocarbons		
5	*n*-nonanal	9.79	0.67
7	*n*-decanal	13.69	0.66
10	undecanal	18.46	4.14
11	*n*-undecanol	18.56	0.89
	Miscellaneous		
26	unknown	31.43	4.86
29	unknown	32.43	0.72
30	unknown	33.18	0.20

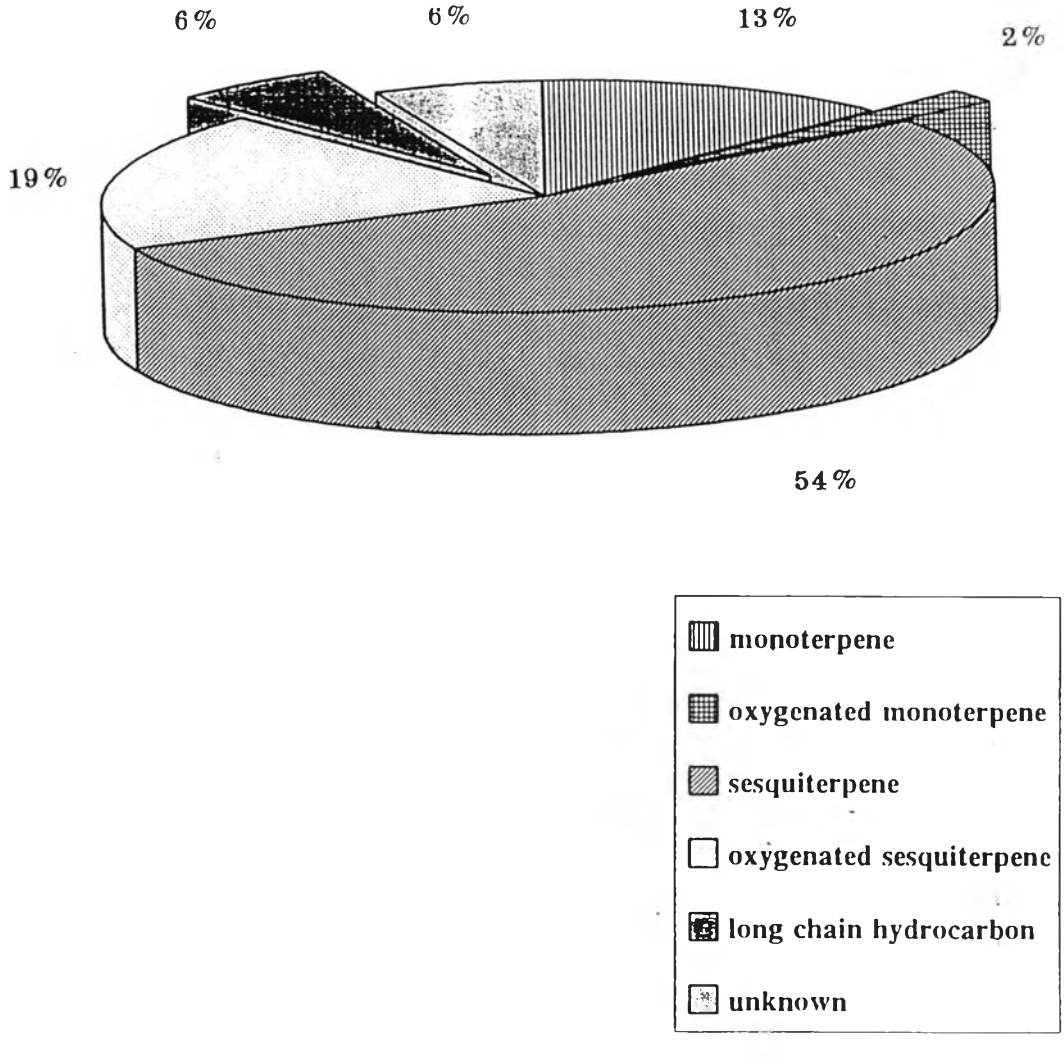
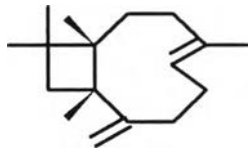


Figure 27 The percentage composition of various terpenoid groups present in the essential oil of *Micromelum minutum* leaves.

14 Essential Oil Composition of *Murraya paniculata* Jack.

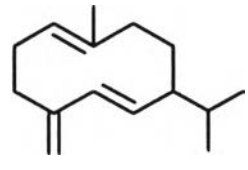
By hydrodistillation, the yield of the essential oil from *Murraya paniculata.* leaves was found to be 0.9 % (v/w) of fresh weight. GC/MS analysis of the essential oil showed that there were 20 peaks of the components present in the oil (Fig. 28). These peaks were identified as 15 sesquiterpenes and 5 oxygenated sesquiterpenes (Table 15). Among these two groups, bicyclogermacrene (26.25%) was found to be the major component, followed by 9-epi-*(E)*-caryophyllene (20.05%), germacrene D (18.86%) and *(E)*-nerolidol (15.96%).

As for the component, the sesquiterpenes appeared to be the major terpenoid group, accounting for 80% of the essential oil. Whereas the oxygenated sesquiterpenoids were present in lesser amount, at 20%. In terms of structure, the major components of bicyclogermacrene, 9-epi-*(E)*-caryophyllene, germacrene D and *(E)*-nerolidol belong to the sesquiterpenoid groups of bicyclogermacrane, caryophilane, simple germacrane and simple farnesane , respectively.



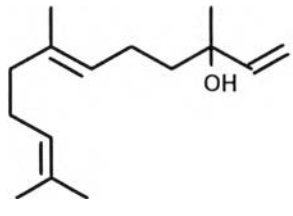
9-epi-*(E)*-caryophyllene

(*caryophilane*)



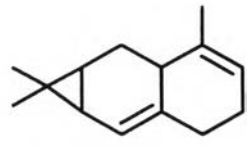
germacrene D

(*simple germacrane*)



(E)-nerolidol

(*simple farnesane*)



bicyclogermacrene

(*bicyclogermacrane*)

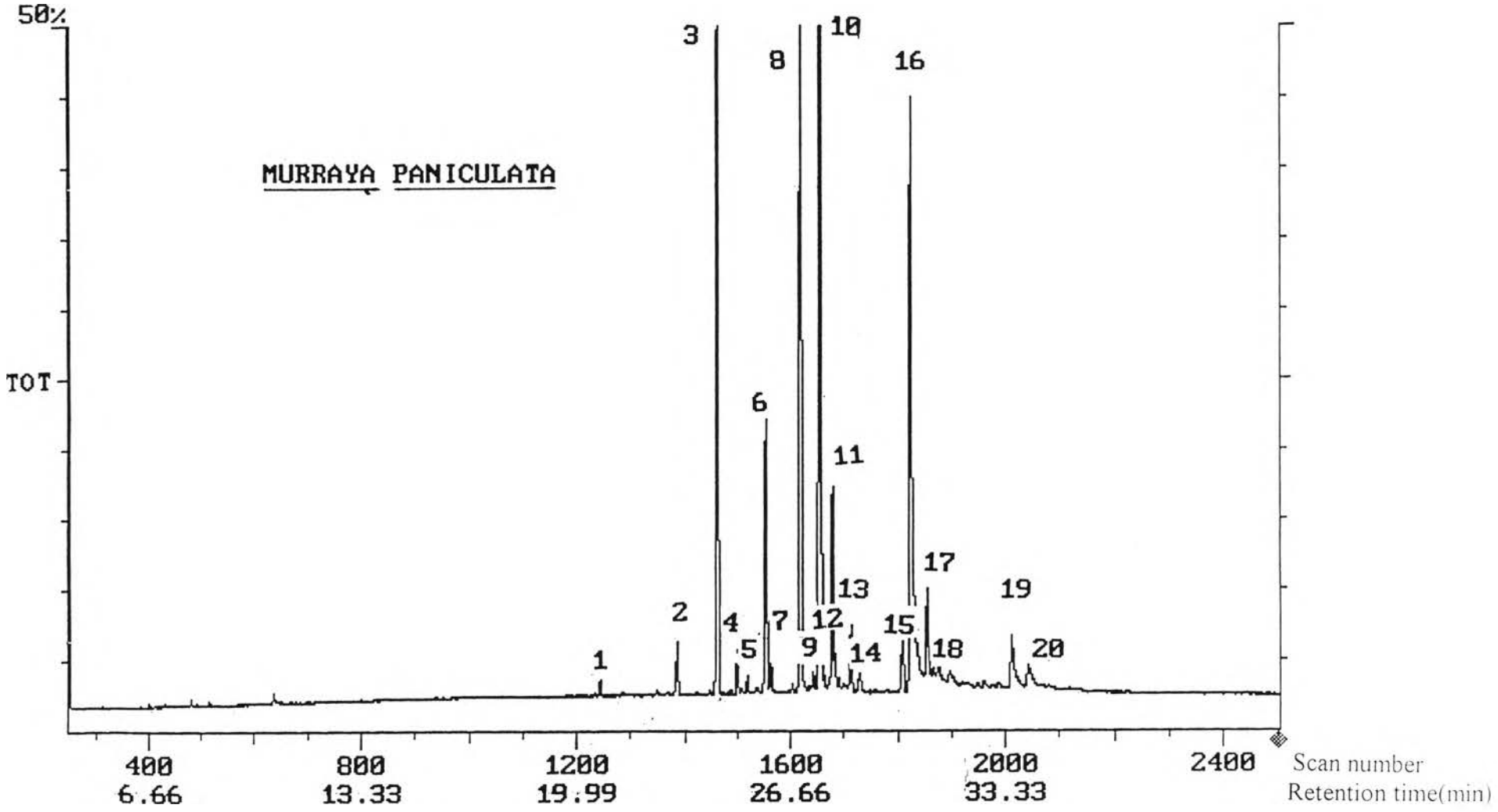


Figure 28 GC chromatogram of the essential oil from *Murraya paniculata* Jack. leaves

Table 15 Essential oil composition of *Murraya paniculata* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
1	δ-elemene	20.76	t
2	β-elemene	23.31	1.04
3	*9-epi-(E)*-caryophyllene	24.58	20.05
4	α-*trans*-bergamotene	25.19	0.70
5	α-gurjunene	25.53	5.09
6	α-humulene	26.11	1.16
7	*allo*-aromadendrene	26.28	0.61
8	germacrene D	27.19	18.86
9	viridiflorene	27.56	0.29
10	bicyclogermarene	27.81	26.25
11	cyperene	28.19	4.08
12	germacrene A	28.28	0.58
13	δ-cadinene	28.79	1.19
14	*(E,E)*-α-farnescene	28.85	t
15	germacrene B	30.36	1.05
	Oxygenated sesquiterpenes		
16	*(E)*-nerolidol	30.39	15.96
17	spathulenol	30.90	1.92
18	caryophyllene oxide	31.33	t
19	*epi*-α-cadinol	33.51	2.00
20	α-cadinol	34.28	t

t = trace

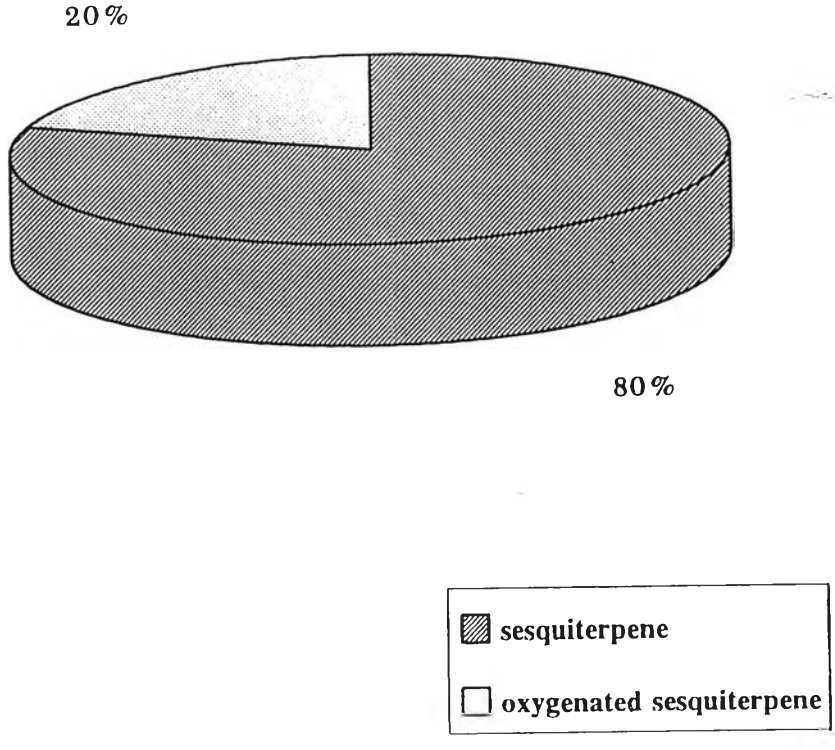


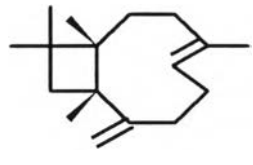
Figure 29 The percentage composition of various terpenoid groups present in the essential oil of *Murraya paniculata* leaves.

15 Essential Oil Composition of *Paramignya scandens* Craib.

The yield of the essential oil isolated from *Paramignya scandens* leaves was found to be 0.6 % (v/w) of fresh weight. GC/MS analysis of the essential oil showed 23 peaks well separated from each other (Fig. 30) These peaks were identified as 13 sesquiterpenes and 10 oxygenated sesquiterpenes (Table 16). Among these, 9-epi-*(E)*-caryophyllene (45.98%) appeared to be the major component, followed by bicyclogermacrene (19.01%) and α-humulene (7.22%).

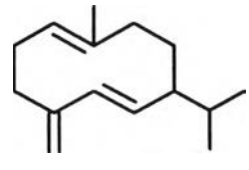
Quantitatively, the sesquiterpenes appeared to be the major terpenoid group, accounting for 91% of the essential oil. Whereas oxygenated sesquiterpenoides were present in lesser amount, at 9% (Fig. 31).

Structurally, the major components of 9-epi-*(E)*-caryophyllene, bicyclogermacrene and α-humulene belong to the sesquiterpenoid groups of caryophilane, bicyclogermacrane and humulane, respectively.



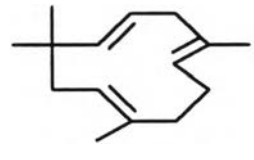
9-epi-*(E)*-caryophyllene

(*caryophilane*)



bicyclogermacrene

(*bicyclogermacrane*)



α-humulene

(*simple farnesane*)

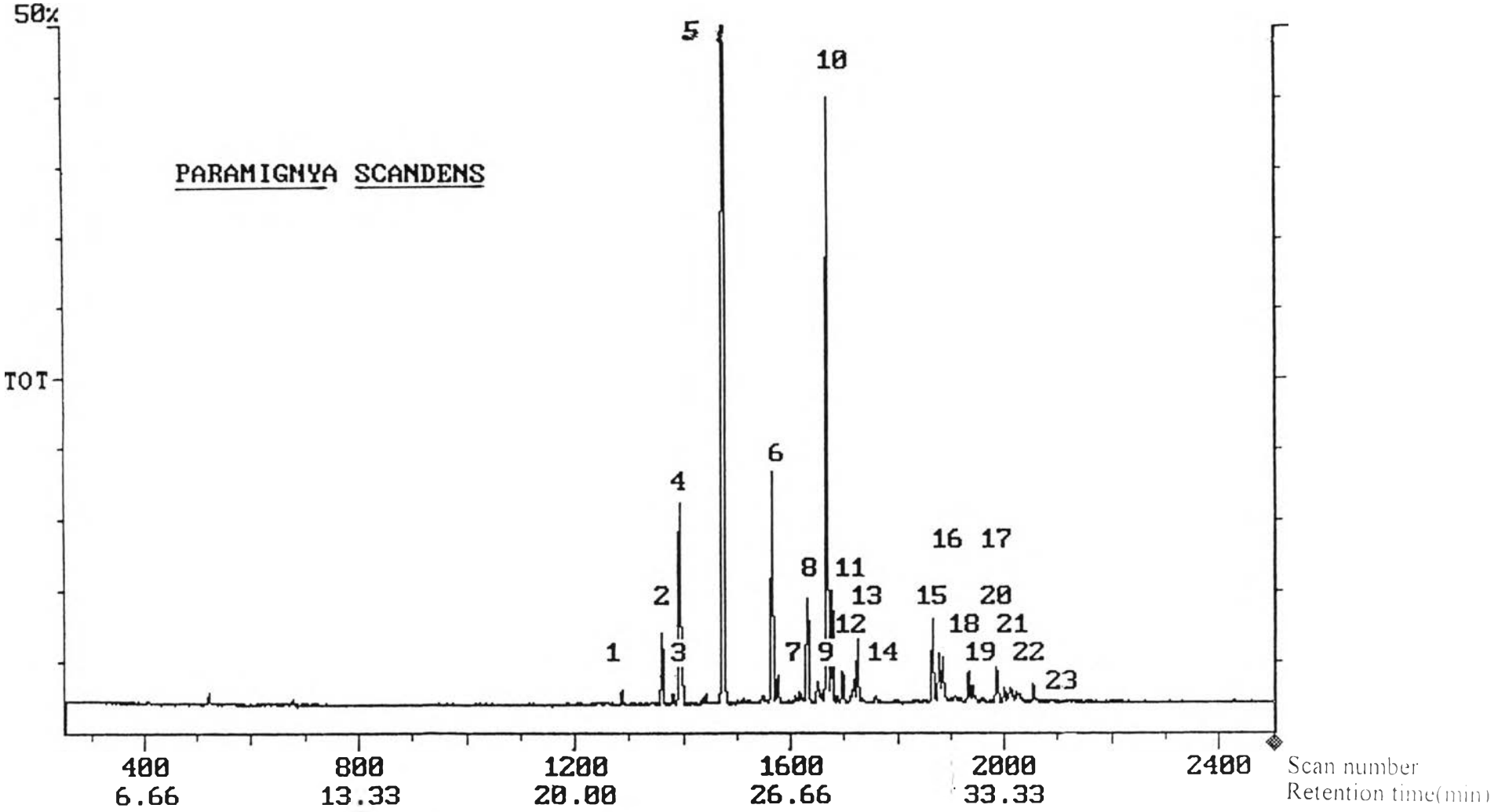


Figure 30 GC chromatogram of the essential oil from *Paramignya scandens* Craib. leaves

Table 16 Essential oil composition of *Paramignya scandens* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
1	α-cubebene	21.43	t
2	α-copaene	22.66	2.14
3	β-bourbonene	23.00	t
4	β-cubebene	23.21	6.82
5	*9-epi-(E)*-caryophyllene	24.59	45.98
6	α-humulene	26.08	7.22
7	aromadendrene	26.26	0.86
8	germacrene D	27.16	3.23
9	β-selinene	27.48	t
10	bicyclogermarene	27.80	19.01
11	cis-β-guaiene	27.94	3.42
12	germacrene A	28.26	0.90
14	δ-cadinene	28.74	1.71
	Oxygenated sesquiterpenes		
13	*epi*-cubebol	28.61	0.53
15	spathulenol	31.09	2.55
16	caryophyllene oxide	31.29	1.58
17	*(E)*-nerolidol acetate	31.41	1.71
18	globulol	32.21	0.97
19	guaiol acetate	32.33	t
20	α-eudesmol acetate	33.09	1.34
21	*epi*-α-cadinol	33.51	t
22	α-muurolol	33.71	t
23	α-cadinol	34.23	t

t = trace

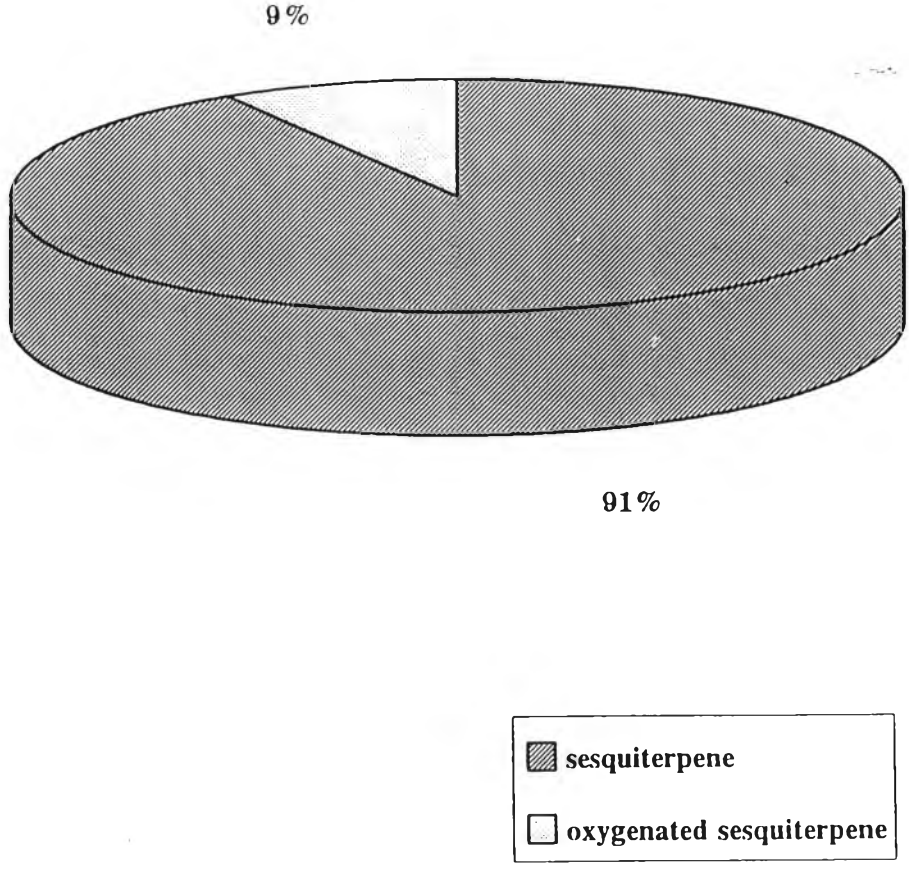


Figure 31 The percentage composition of various terpenoid groups present in the essential oil of *Paramignya scandens* leaves

16 Essential Oil Composition of *Toddalia asiatica* Lamk.

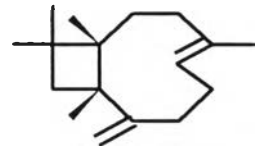
The leaves of *Toddalia asiatica* was found to contain essential oil at 0.5 % (v/w) of fresh weight. By GC/MS analysis the essential oil was showed to have at least 35 peaks in it GC chromatogram (Fig. 32) These peaks were identified as 13 monoterpenes, 6 oxygenated monoterpenes, 8 sesquiterpenes and 5 oxygenated sesquiterpenes (Table 17). Among these, tricyclene (12.75%) appeared to be the major component, followed by *9-epi-(E)*-caryophyllene (10.95%) and *(E)*-nerolidol (8.88%).

In terms of relative amount, the monoterpenes appeared to be the major terpenoid group, accounting for 48% of the essential oil. Sesquiterpenes, oxygenated monoterpenes and oxygenated sesquiterpenes were present in lesser amount, at 27% , 13% and 12%, respectively.

In terms of structure, the major components of tricyclene belong to the monoterpenoid group of tricyclic monoterpenoids, whereas *9-epi-(E)*-caryophyllene and *(E)*-nerolidol belong to the sesquiterpenoid group of caryophilane and simple farnesane , respectively.

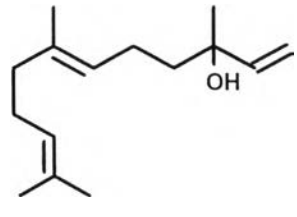
tricyclene

(*tricyclic monoterpenoid*)



9-epi-(E)-caryophyllene

(*caryophilane*)



(E)-nerolidol

(*simple farnesane*)

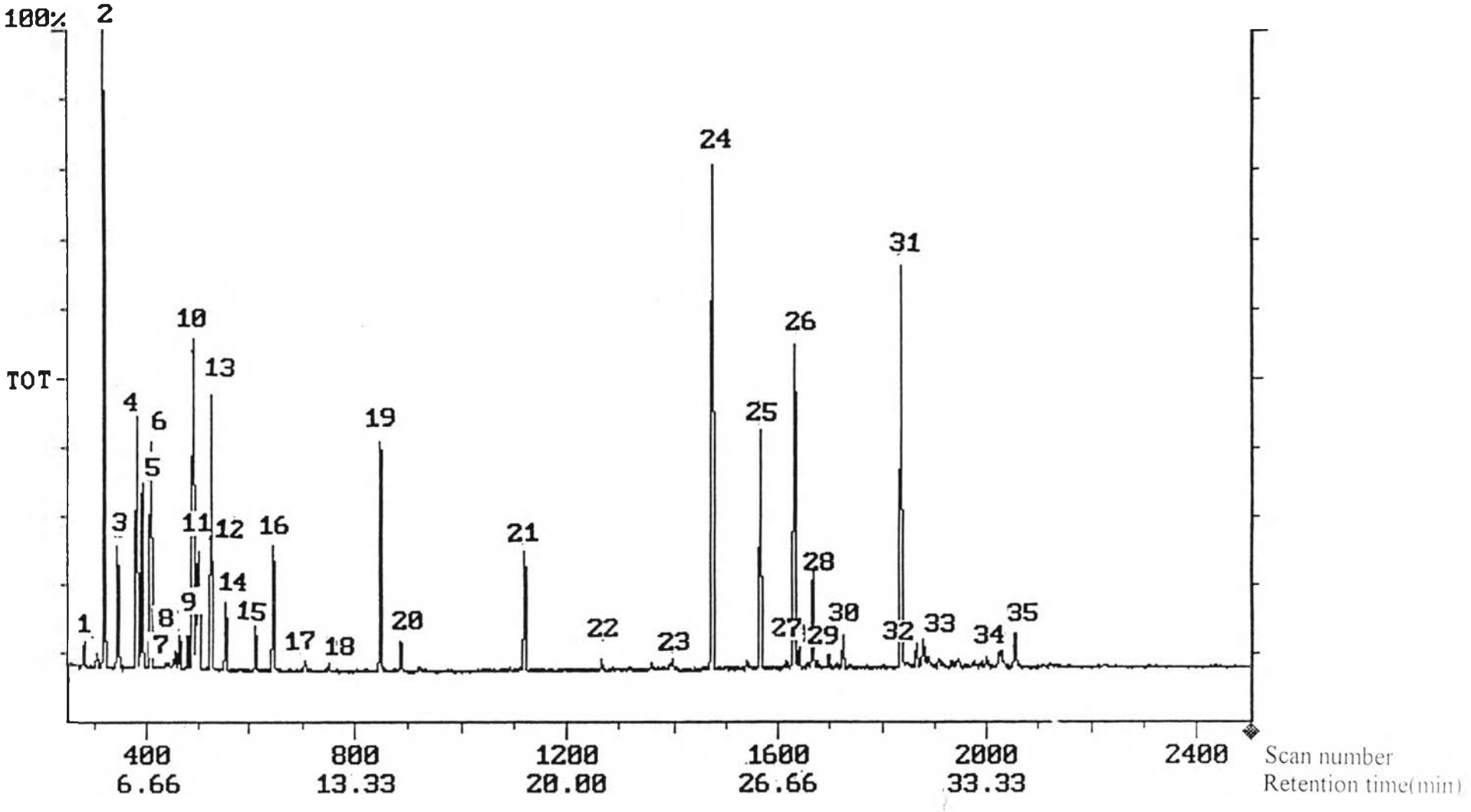


Figure 32 GC chromatogram of the essential oil from *Toddalia asiatica* Lamk. leaves

Table 17 Essential oil composition of *Toddalia asiatica* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	α-thujene	5.10	0.33
2	tricyclene	5.29	12.75
3	camphene	5.74	2.67
4	sabinene	6.35	5.57
5	β-pinene	6.51	3.98
6	myrcene	6.79	4.70
8	α-terpinene	7.71	0.66
9	*o*-cymene	7.98	0.74
10	limonene	8.13	6.82
11	*1,8*-cineol	8.26	2.47
12	(Z)-β-ocimene	8.33	2.32
13	(E)-β-ocimene	8.71	5.28
14	γ-terpinene	9.16	1.36
15	terpinolene	10.18	0.79
	Oxygenated monoterpenes		
11	*1,8*-cineol	8.26	2.47
16	linalool	10.74	2.24
17	*cis-para*-menth-2-en-1-ol	11.74	0.19
18	*trans-para*-menth-2-en-1-ol	12.49	0.16
19	terpin-4-ol	14.11	4.56
20	α-terpinolene	14.75	0.68
21	bornyl acetate	18.68	2.35

Table 17 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Sesquiterpene hydrocarbons		
23	*β*-elemene	23.30	0.21
24	*9-epi-(E)*-caryophyllene	24.56	10.95
25	*α*-humulene	26.08	5.32
26	germacrene D	27.18	7.24
27	*β*-sesquiphellandrene	27.33	0.48
28	bicyclogermacrene	27.78	2.07
29	*β*-bisabolene	28.26	0.27
30	*δ*-cadinene	28.74	0.72
	Oxygenated sesquiterpenes		
31	*(E)*-nerolidol	30.58	8.88
32	spathulenol	31.09	0.56
33	caryophyllene oxide	31.30	0.68
34	*epi-α*-cadinol	33.79	0.42
35	*α*-cadinol	34.23	1.05
	Miscellaneous		
7	unknown	7.58	0.33
22	unknown	21.08	0.20

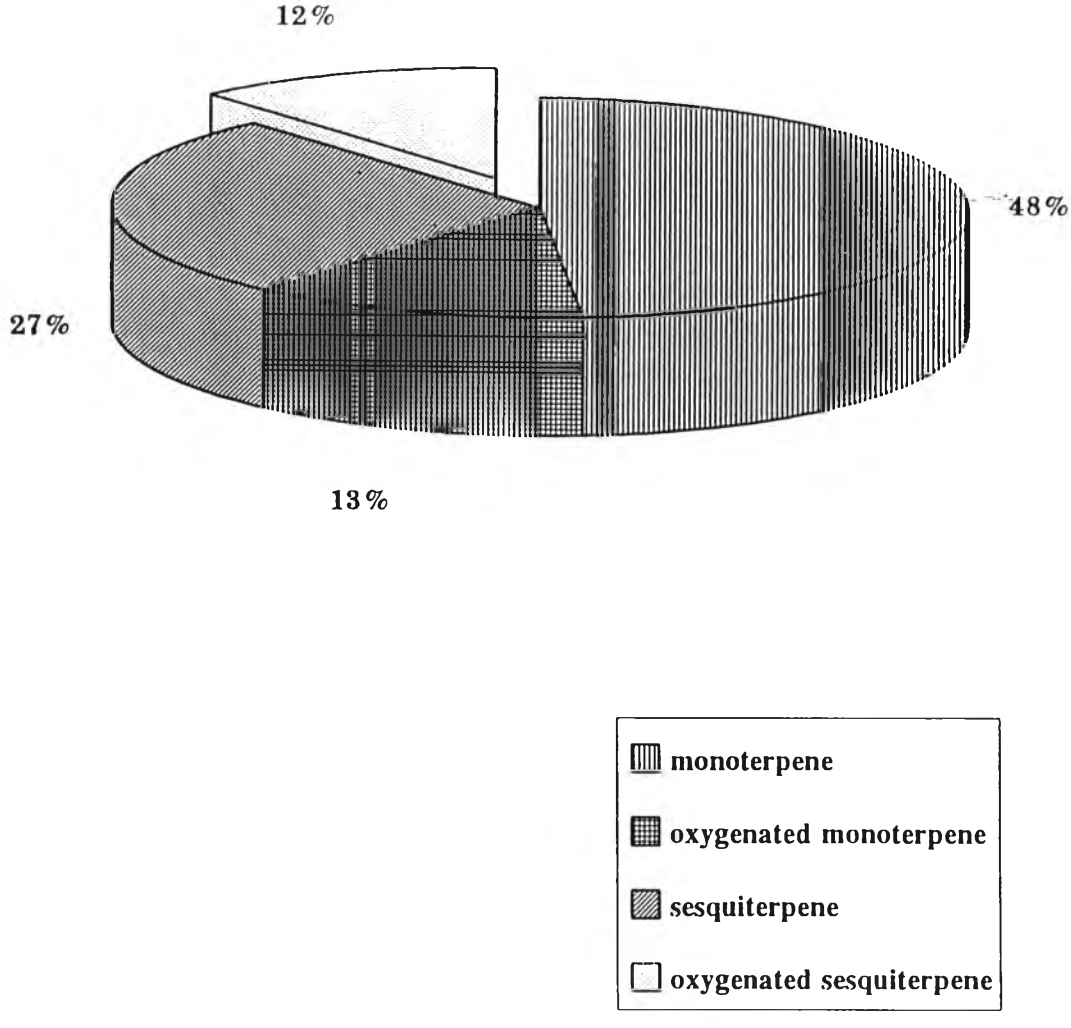


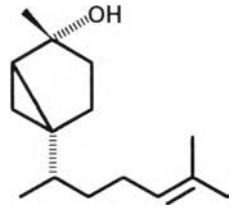
Figure 33 The percentage composition of various terpenoid groups present in the essential oil of *Toddalia asiataca* leaves.

17 Essential Oil Composition of *Triphasia trifolia* P. Wils.

The yield of the essential oil isolated from *Triphasia trifolia* leaves was found to be 0.2 % (v/w) of fresh weight. By GC/MS analysis the essential oil was showed to contain at least 37 components in the chromatogram (Fig. 34). These components were identified as 8 monoterpenes, 8 oxygenated monoterpenes, 6 sesquiterpenes, 10 oxygenated sesquiterpenes, 2 unknowns and others (Table 18). Among these, *cis*-sesquisabinene hydrate (35.86%) appeared to be the major component followed by sabinene (13.52%) and β-pinene (13.29%).

Quantitatively, the oxygenated sesquiterpenes appeared to be the major terpenoid group, accounting for 49% of the essential oil. Monoterpenes, oxygenated monoterpenes and sesquiterpenes were present in a lesser amount, at 34%, 10% , 2.44% and 2%, respectively.

Structurally, the major component of *cis*-sesquisabinene hydrate belongs to the sesquiterpenoid group of cyclobisabolane, whereas sabinene and β–pinene belong to the monoterpenoid group of thujane and pinane.



cis-sesquisabinene hydrate
(*cyclobisabolane*)

β-pinene
(*pinane*)

sabinene
(*thujane*)

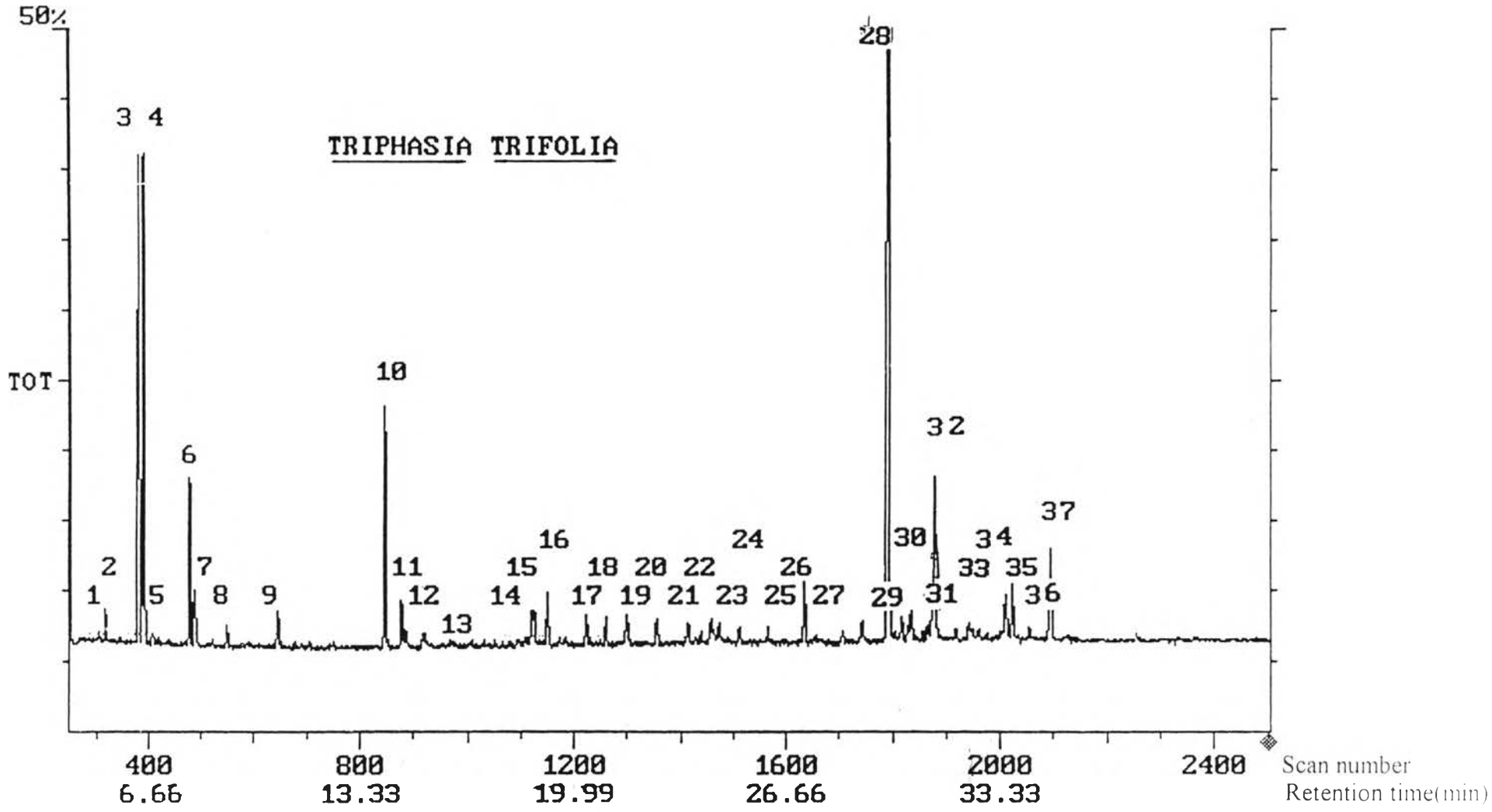


Figure 34 GC chromatogram of the essential oil from *Triphasia trifolia* P.Wils. leaves

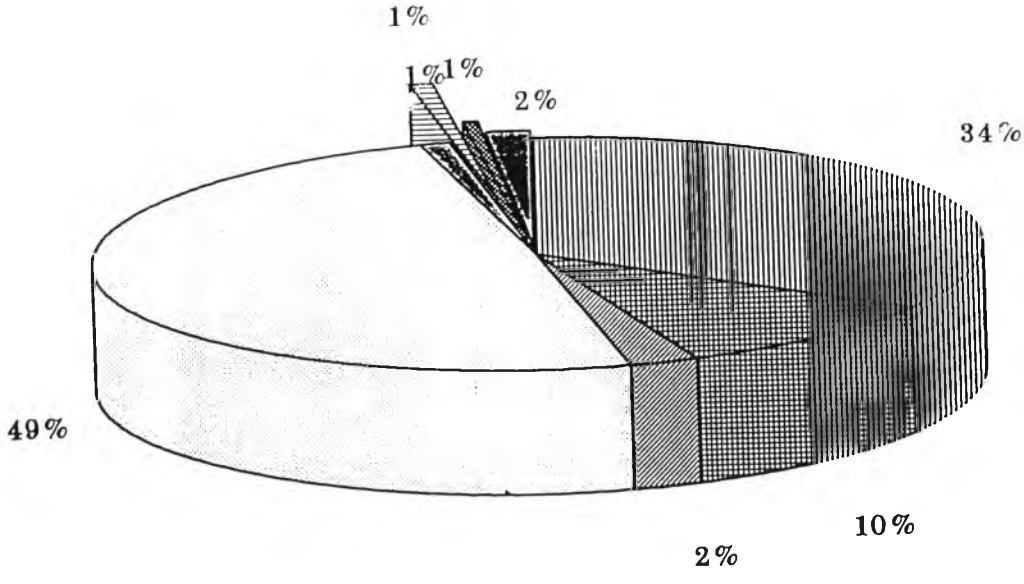
Table 18 Essential oil composition of *Triphasia trifolia* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	*α*-thujene	5.08	t
2	tricyclene	5.29	0.84
3	sabinene	6.34	13.52
4	*β*-pinene	6.51	13.29
5	myrcene	6.76	t
6	*o*-cymene	7.96	4.23
7	limonene	8.13	1.57
8	*γ*-terpinene	9.14	0.60
	Oxygenated monoterpenes		
9	linalool	10.75	0.75
10	terpin-4-ol	14.11	5.41
12	*α*-terpineol	14.76	t
13	dihydro carveol	15.34	t
14	*trans*-pinocarvyl acetate	18.68	0.84
16	*cis*-bornyl acetate	19.16	1.20
17	*cis*-pinocarvyl acetate	20.38	0.82
19	*α*-terpinyl acetate	21.64	1.15
	Sesquiterpene hydrocarbons		
21	*γ*-elemene	23.56	1.67
23	*9-epi-(E)*-caryophyllene	24.54	0.44
24	*α-trans*-bergamotene	25.18	t
25	*β*-misabolene	26.04	t
26	*ar*-curcumene	27.23	1.61
27	*β*-curcumene	28.46	t

Table 18 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated sesquiterpenes		
28	*cis*-sesquisabinene hydrate	29.85	35.86
29	humulene epoxide II	30.28	0.66
30	*(E)*-nerolidol	30.58	1.07
31	spathulenol	30.95	t
32	caryophyllene oxide	31.08	5.82
33	*(Z)*-α-*trans*-bergamotol acetate	32.33	t
34	α-acorenol	33.49	1.16
35	*epi*-α-cadinol	33.71	1.30
36	*epi*-α-muurolol	34.24	t
37	α-cadinol	34.89	3.34
	Long chain hydrocarbons		
11	*1*-dodecene	14.63	0.94
	Phenylpropanoids		
15	*(E)*-anethol	18.74	0.92
	Benzenoids		
20	*2,3,6*-trimethyl benzadehyde	22.58	0.71
	Miscellaneous		
18	unknown	20.99	0.74
22	unknown	24.28	0.80

t = trace

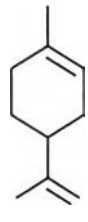

1%
1%
1%
2%
34%
49%
10%
2%
monoterpene
oxygenated monoterpene
sesquiterpene
oxygenated sesquiterpene
long chain hydrocarbon
phenylpropanoid
benzenoid
unknown

18 Essential Oil Composition of *Zanthoxylum limonella* Alston.

By hydrodistillation, the yield of the essential oil from *Zanthoxylum limonella* leaves was found to be 4.3 % (v/w) of fresh weight. Analysis of the essential oil by GC/MS showed that 33 peaks were well separated from each other (Fig. 36) These peaks were identified as 13 monoterpenes, 15 oxygenated monoterpenes, 2 sesquiterpenes and 3 non-terpenoid compounds (Table 19). Among these, limonene (31.09%) appeared to be the major component, followed by terpin-4-ol (13.94%) and sabinene (9.13%).

These major components contributed to the monoterpenes as the major terpenoid group, accounting for 67% of the essential oil. Oxygenated monoterpenes , on the other hand, were present in lesser amount, at 27% (Fig. 37).

In terms of structure, the major components of limonene and sabinene belong to the monoterpenoid group of menthane and thujane, whereas terpin-4-ol belongs to the group of menthane .

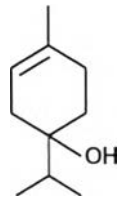


limonene

(*menthane*)

sabinene

(*thujane*)



terpin-4-ol

(*menthane*)

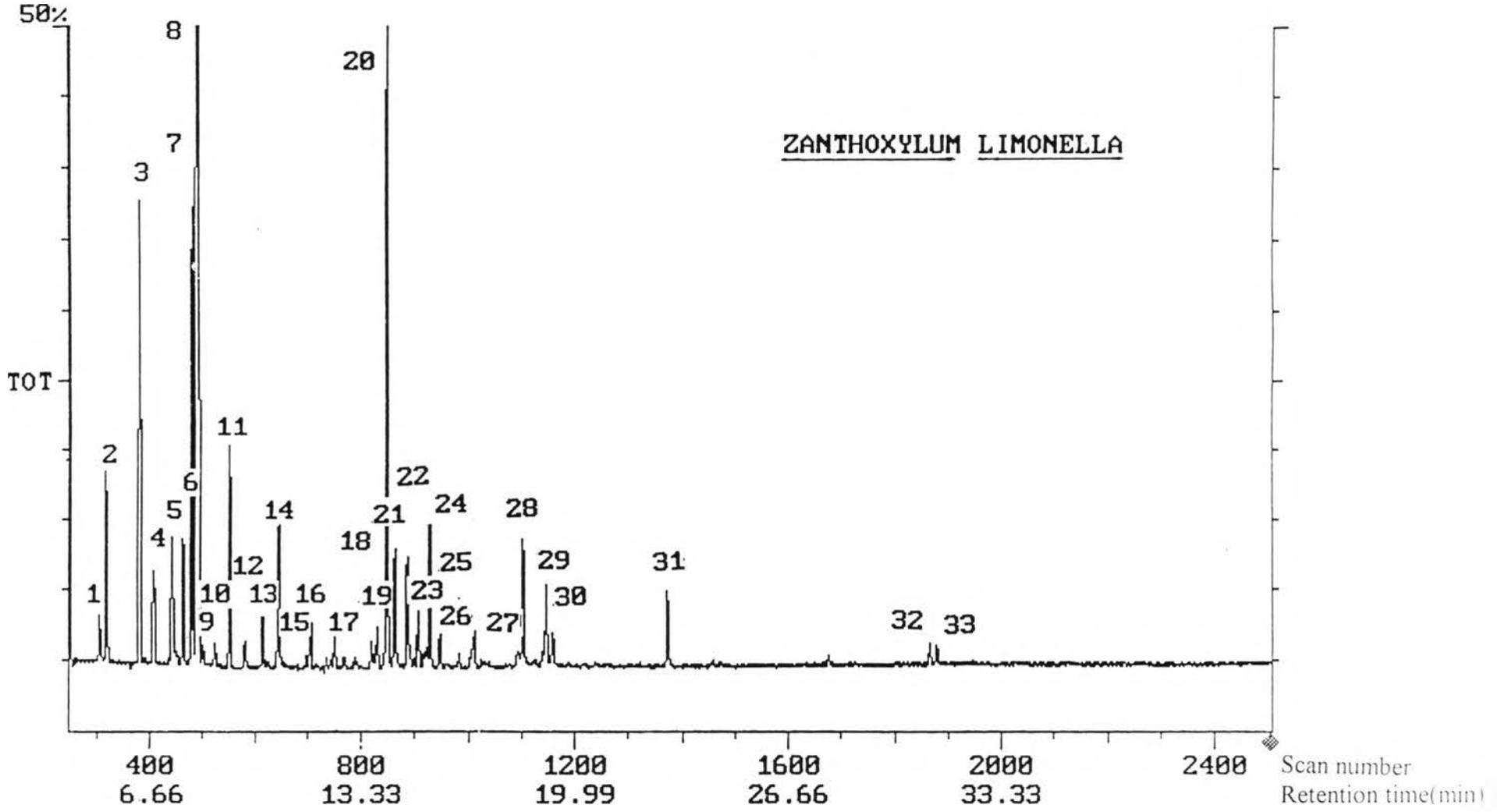


Figure 36 GC chromatogram of the essential oil from *Zanthoxylum limonella* Alston. leaves

Table 19 The essential oil composition of *Zanthoxylum limonella* leaves.

Number of peak	Compound	Retention time (min)	% Area
	Monoterpene hydrocarbons		
1	α-thujene	5.09	0.89
2	tricyclene	5.30	3.29
3	sabinene	6.34	9.13
4	myrcene	6.81	1.92
5	α-phellandrene	7.38	2.77
6	α-terpinene	7.71	2.51
7	*o*-cymene	7.98	9.02
8	limonene	8.15	31.09
9	*(Z)*-β-ocimene	8.34	0.38
10	*(E)*-β-ocimene	8.71	0.38
11	γ-terpinene	9.16	3.70
12	*para*-mentha-2,4(8)-diene	9.63	0.53
13	terpinolene	10.19	0.92
	Oxygenated monoterpenes		
14	linalool	10.76	2.48
15	*trans*-verbenol	11.64	t
16	*cis-para*-menth-2-en-1-ol	11.76	0.80
17	*trans-para*-menth-2-en-1-ol	12.51	0.59
18	*cis*-thujone	13.66	0.31
19	*trans*-thujone	13.83	0.58
20	terpin-4-ol	14.13	13.94
22	α-terpineol	14.76	2.10
23	*trans*-sabinol	15.09	0.97

Table 19 (Continued)

Number of peak	Compound	Retention time (min)	% Area
	Oxygenated monoterpenes		
25	*trans*-carveol	15.78	0.69
26	*cis*-carveol	16.36	t
27	carvone	18.68	0.59
28	*β*-pinene oxide	18.36	2.39
29	2-undecanone	19.09	1.08
30	carvacrol	19.31	0.52
31	geranyl acetate	22.88	1.28
	Oxygenated sesquiterpenes		
32	spathulenol	31.09	t
33	caryophyllene oxide	31.31	t
	Miscellaneous		
21	sabina ketone	14.38	2.23
	Long chain hydrocarbons		
24	decanol acetate	15.46	2.68
29	2-undecanone	19.09	1.08

t =trace

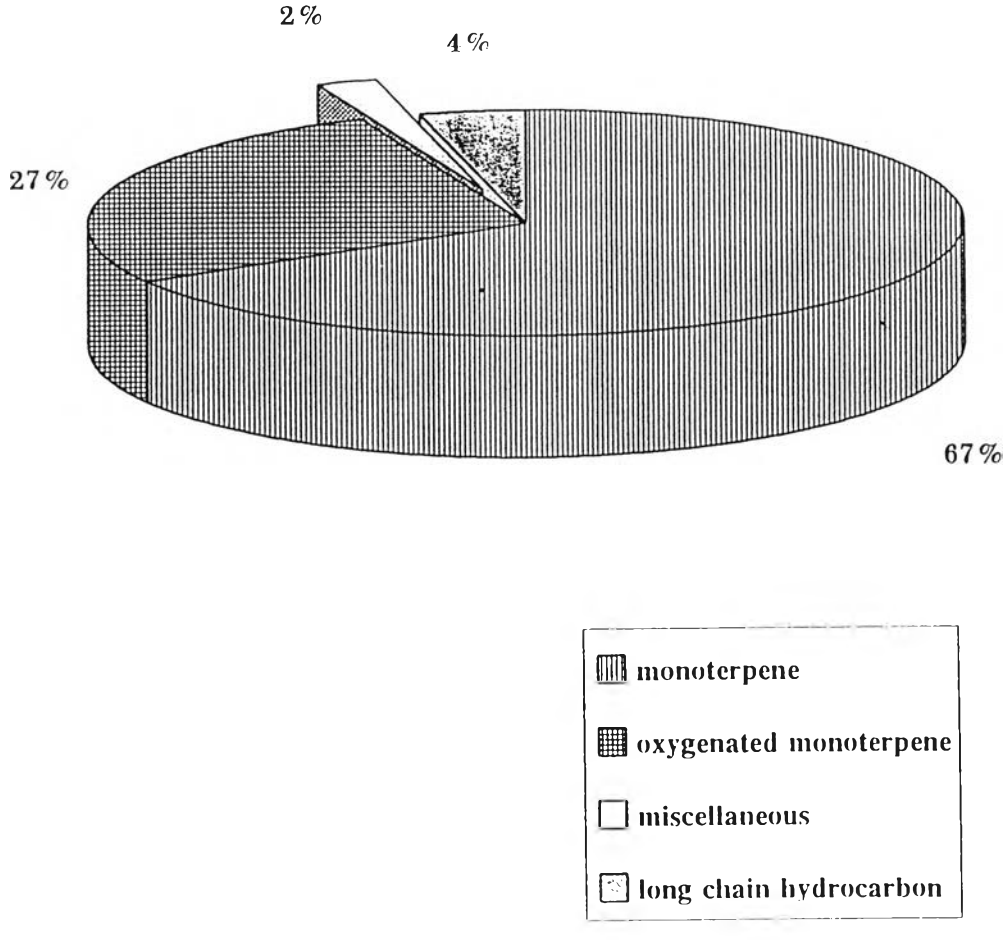


Figure 37 The percentage composition of various terpenoid groups present in the essential oil of *Zanthoxylum limonella* leaves