The comparison of monoterpenoids in *Mentha* and berry plants

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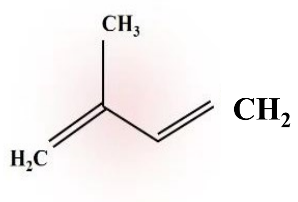
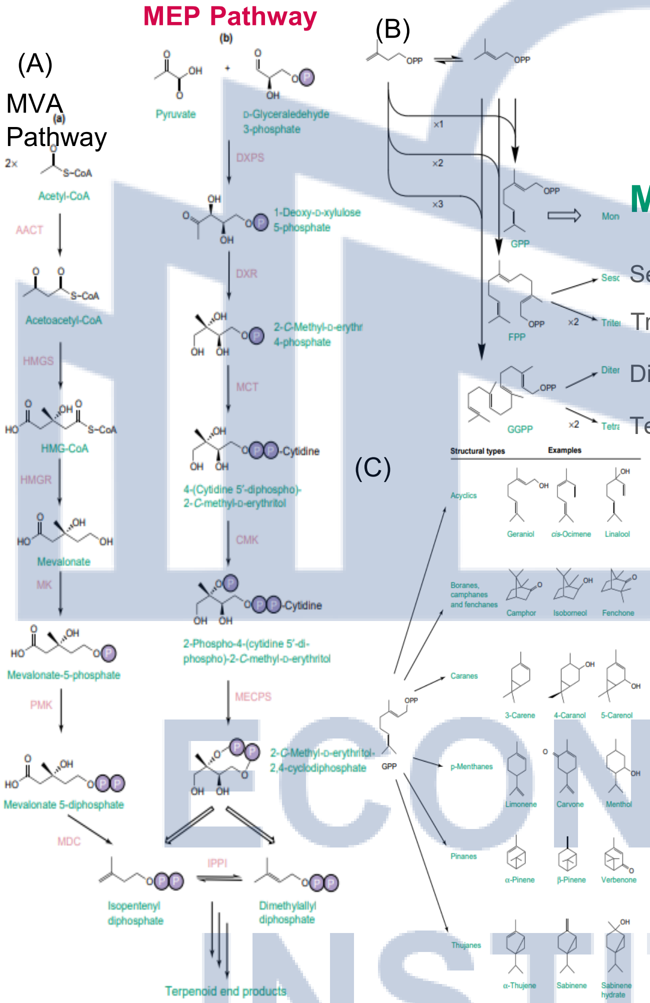
1. Literature research 1.1 Monoterpenes biosynthesis pathway and functions

Terpenoids structure



- ✓ **Terpenoids** are a class of secondary metabolites composed of isoprene as the basic unit；
- ✓ There are more than 500 terpenoids in the world；



Monoterpenes (C_{10})

Sesquiterpenes (C_{15})

Triterpenes (C_{30})

Diterpenes (C_{20})

Tetraterpenes (C_{40})

◆ **Characters of monoterpenes**:

-Volatility:
small molecular size, are highly volatile, making them key components in essential oils and responsible for the distinctive scents of many plants

-Biological Activity:
antimicrobial, anti-inflammatory, and antioxidant, valuable in pharmaceuticals, cosmetics, and food industries

-Rely on MEP Pathway

Juniperus communis

Litsea cubeba

Berry plant

Mentha avensis

Mentha piperita

Mentha plant

1. Literature research

1.2 Geographical distribution and main uses

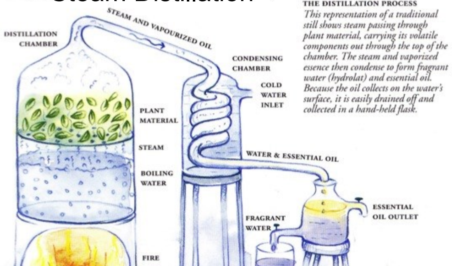
Monoterpenoid-rich plants

Group	Plant	Global Distribution	Ecological Habits
Berry plant	*Juniperus communis* 	**Subarctic** and **temperate** regions of the **Northern Hemisphere**, including **Eurasia** and **North America**	Grows in **bogs**, **forests**, **meadows**, and tundra; prefers acidic, well-drained
Berry plant	*Litsea cubeba* 	Native to **Southeast Asia**, including **China**, and parts of **Indonesia**	Thrives in subtropical and **tropical** climates; found in forests, hillsides, and along streams
Mentha plant	*Mentha avensis* 	Widely distributed across **Europe**, Asia, and **North America**	Prefers **moist**, well-drained soils; commonly found in fields, meadows, and along water bodies
Mentha plant	*Mentha piperita* 	Originally from Europe, now cultivated **worldwide**, especially in **temperate** regions	Grows best in **moist**, shaded environments; often found in gardens and near water sources

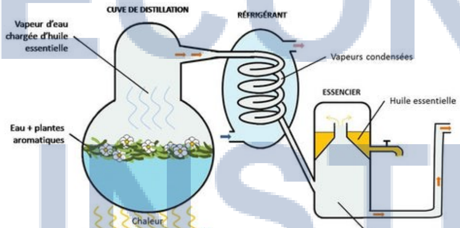
Table 1. Essential Oil Extraction Methods Comparison

Plant Species	Extraction Methods	Key Compounds Extracted	Advantages of Extraction Methods	Challenges/Limitations	References
Juniperus communis 	Steam Distillation, Hydrodistillation	α-Pinene, β-Pinene, Myrcene, Sabinene	Steam distillation efficiently extracts monoterpenes, commonly used in industrial applications	**Steam Distillation** (**0.5-2%**) and **Hydrodistillation** (**0.5-1.5%**) can result in lower yields	Välimaa et al. (2020)
Litsea cubeba 	Steam Distillation, Supercritical CO_2 Extraction	Citral (geranial, neral), Limonene, Linalool	**Steam distillation** (**3.0-4.0%**) is widely used for industrial production. **CO_2 extraction** yields higher purity oils (**14.35%**)	High energy consumption in steam distillation. CO_2 extraction requires expensive equipment	Xie et al. (2019)
Mentha avensis 	Steam Distillation, Hydrodistillation, Solvent Extraction	Menthol, Menthone, Limonene, Pulegone	Steam distillation (**0.1-1.5%**), Hydrodistillation (**0.5-1.5%**) efficiently extracts menthol. Solvent extraction allows for higher yields (**1-3**%)	Solvent extraction may leave residues; requires additional purification steps	Raina et al. (2003)
Mentha piperita 	Steam Distillation, Hydrodistillation, Cold Press Extraction	Menthol, Menthone, Eucalyptol, Limonene	Steam distillation (**0.1-1.3%**), Hydrodistillation (**1-1.05%**) efficiently extracts menthol. Cold press preserves more volatile compounds.	Cold press yields lower amounts. Steam distillation and Hydrodistillation may alter highly volatile compounds' composition	Kokkini et al. (2007)

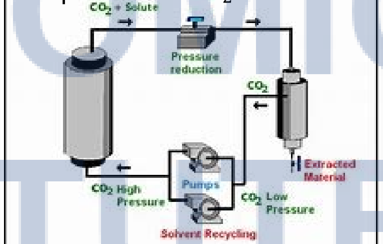
Steam Distillation



Hydrodistillation



Supercritical CO_2 Extraction



- Steam Distillation and Hydrodistillation are the most widely used methods for extracting monoterpene essential oils.

Table 2. Comparative Table of Chemical Components and Their Concentrations in Essential Oils Extracted by Steam Distillation

Plant Species	Key Chemical Components	Component Concentration (%)	Functions/Uses	Bioactivities (with Experimental Data)	References
Juniperus communis 	α-Pinene, β-Pinene, Myrcene, Sabinene, Limonene	α-Pinene: 25-35%, β-Pinene: 10-15%, Myrcene: 5-8%, Sabinene: 2-5%, Limonene: 2-4%	**Anti-inflammatory**: Used in treating arthritis and muscle pain. **Cosmetic**: Used in skin care products for its soothing properties.	**Antimicrobial**: MIC (Minimum Inhibitory Concentration) values: 50-100 µg/mL against *Staphylococcus aureus* and *Escherichia coli*.**Antioxidant**: IC_{50} (50% Inhibitory Concentration) for DPPH radical scavenging: 80-120 µg/mL	Güllüce et al., 2003; Adams, 2012
Litsea cubeba 	Citral (Geranial, Neral), Limonene, Linalool	Citral: 70-85% (Geranial: 45-55%, Neral: 25-30%), Limonene: 10-15%, Linalool: 2-5%	**Insect repellent**: Used as a natural insecticide. **Aromatherapy**: Used for stress relief and relaxation.	**Antimicrobial**: MIC values: 12.5 µg/mL against *Candida albicans*, 25-50 µg/mL against *Staphylococcus aureus*.**Insecticidal**: LD_{50} (Lethal Dose) against *Sitophilus zeamais* (maize weevil): 4.2 µg/cm².	Xie et al., 2019; Adams, 2012
Mentha avensis 	Menthol, Menthone, Limonene, Isomenthone, Pulegone	Menthol: 60-75%, Menthone: 10-25%, Limonene: 3-5%, Isomenthone: 1-3%, Pulegone: 0.5-1%	**Respiratory relief**: Commonly used in cold and flu treatments. **Topical analgesic**: Used for muscle pain relief.	**Antimicrobial**: MIC values: 40 µg/mL against *Candida albicans*, 20-40 µg/mL against *Escherichia coli*.**Analgesic**: Effective Dose (ED_{50}) for pain relief in mice: 20 mg/kg.	Raina et al., 2003; Baser & Buchbauer, 2010
Mentha piperita 	Menthol, Menthone, Eucalyptol, Limonene, Pulegone	Menthol: 40-50%, Menthone: 20-30%, Eucalyptol: 5-8%, Limonene: 1-3%, Pulegone: 1-2%	**Digestive aid**: Used for digestive issues like indigestion and bloating. **Headache relief**: Common in headache balms and oils.	**Antimicrobial**: MIC values: 15-30 µg/mL against Staphylococcus aureus and *Candida albicans*.**Antioxidant**: IC_{50} for DPPH radical scavenging: 85-105 µg/mL.	Kokkini et al., 2007; Baser & Buchbauer, 2010

1. Literature research

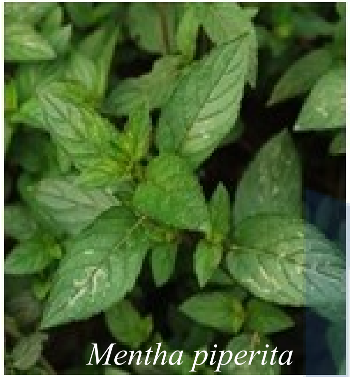
1.4 Effect of light signal on the comparison of monoterpenoids in *Mentha* and berry plants

Table 3. Comparative Table of the Effects of Light on Essential Oil Content and Secondary Metabolite Composition in *Mentha* and berry plants

Plant Species	Effect of Light on Essential Oil Content	Effect of Light on Secondary Metabolites	Experimental Data	References
Juniperus communis 	Increased essential oil yield under full sunlight conditions (20-30% higher compared to shaded conditions).	Higher levels of α-Pinene and β-Pinene in full sunlight; lower levels of Myrcene in shaded conditions.	Full sun: Essential oil yield 2.0-3.0 mL/kg fresh material.Shade: 1.5-2.0 mL/kg fresh material.	Figueiredo et al., 2008; Välimaa et al., 202
Litsea cubeba 	Light exposure enhances essential oil production by up to 40%.	Citral (geranial and neral) content increases significantly with increased light exposure.	Full sun: Citral content 70-85%.Low light: Citral content 55-65%	Wang et al., 2012; Xie et al., 2019
Mentha avensis 	Moderate light intensity (50-70%) increases oil yield, while very high light decreases yield.	Menthol concentration increases with moderate light; excessive light reduces menthol and increases menthone.	Moderate light: Menthol content 60-75%.High light: Menthol content reduced to 50%.	Misra & Sharma, 1991; Raina et al., 20
Mentha piperita 	Full sunlight increases total oil yield but decreases menthol content.	Increased levels of menthone and pulegone under high light intensity; menthol levels decrease.	Full sun: Menthol content 40-50%.Low light: Menthol content 50-60%.	Clark & Menary, 1980; Kokkini et al., 2007

➢ **Light signals affect the content and composition of monoterpenes**

Mentha genus (mint) → Essential oil (EO)


Mentha piperita

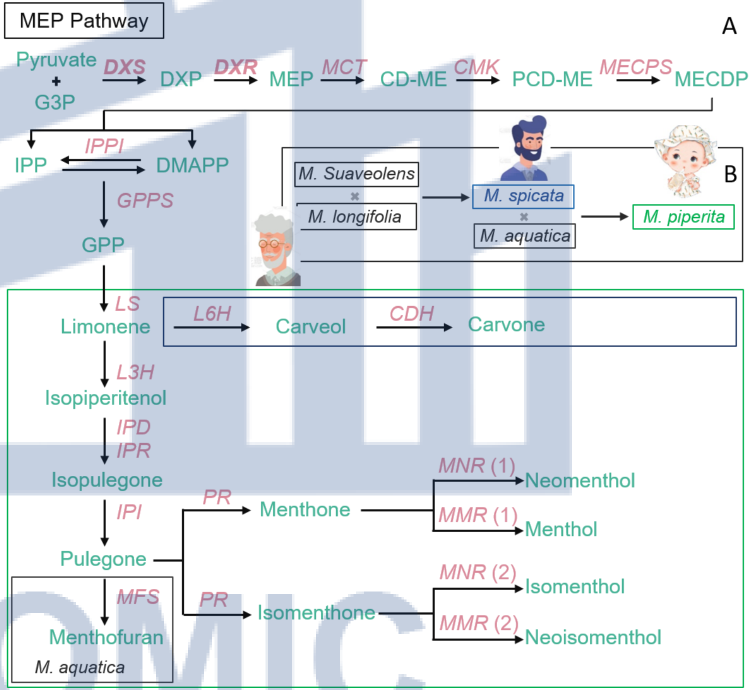

Mentha arvensis

benefits for nervous system, respiratory system, has antibacterial, **antifungal** functions…widely used in **medicine, cosmetics, food** and other fields

- ➢ One of the **3 major spicies** in the word
- ➢ **model plant** for studying aromatic plants

(easy to grow, the genome has been sequenced)

- Mint EO **content is very low** (0.1~1.3%)
- The main components are **terpenoids (Monoterpene)**



➢ Mint is a representative plant for studying monoterpenoid compounds, so it is used as a main research object.

Research aim

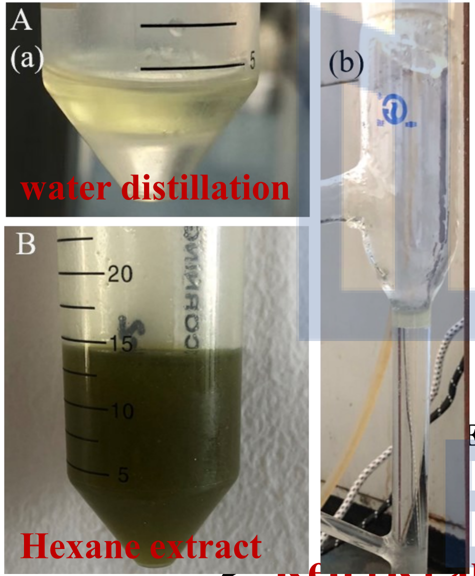
➢ Exploring the effect of light sinal and hydrodistillation on the content and composition of *Mentha* essential oil

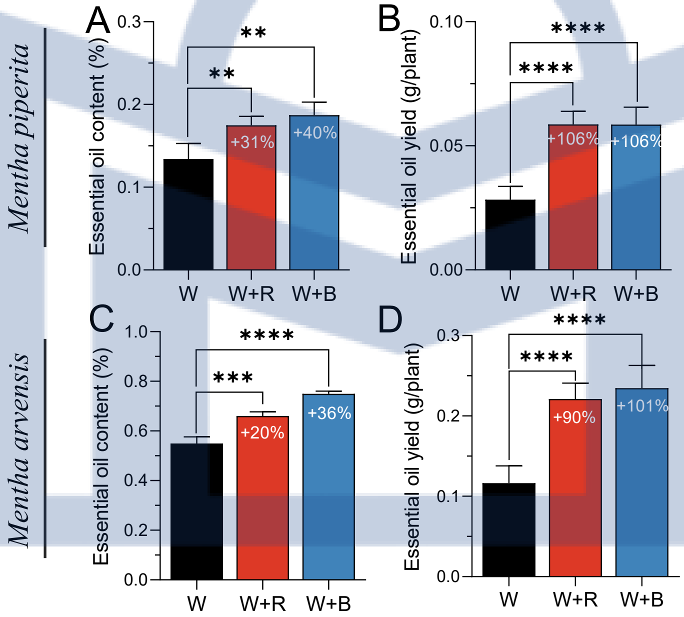
2. Results 2.1. Effects of red light and blue light on essential oil content and yield

Method of extracting EO:

Hydro-distillation,

EO yield: EO content (w/w)*g/plant





Effects of red light and blue light on essential oil content and yield of *Mentha* L.

(A,B) *Mentha piperita* L. (C,D) *Mentha arvensis* L. *$P<0.05$.

➤ **Red (R) and Blue (B) light enhanced EO content and production of mint**

2.2. Effects of red light and blue light on essential oil composition in *Mentha* L.

Method:
GC-MS

▶ Table.4. Effect of different LED lighting treatments on the essential oil composition of ***Mentha piperita***

		Component		Relative content (%)		
No.	**RT**	**Name**	**CAS**	**W**	**W+R**	**W+B**
1	20.21	**L-Menthone**	**014073-97-3**	**51.02**	**9.96** ↓ **80.5%**	**10.73** ↓ **80%**
2	34.34	**L-Menthol**	**002216-51-5**	**14.32**	**5.19** ↓ **63.8%**	**5.88** ↓ **59%**
3	21.76	**Menthofuran**	**000494-90-6**	**9.52**	**15.19** ↑ **60%**	**14.43** ↑ **51.6%**
4	33.13	Pulegone	000089-82-7	6.39	55.22	52.45
5	22.31	Isomenthone	000491-07-6	3.97	0.47	0.55
6	31.12	Isomenthol	000490-99-3	3.42	1.43	1.69
7	8.72	Eucalyptol	000470-82-6	2.51	1.08	1.44
8	60.19	Mintlactone	038049-04-6	1.25	0.26	0.32
9	21.40	cis-4-Thujanol	015537-55-0	0.75	0.02	0.11
10	28.30	Menthyl acetate	000089-48-5	0.70	/	/
11	38.09	Piperitone	000089-81-6	0.47	0.11	0.14
12	8.38	Limonene	000138-86-3	0.46	1.07	1.43
13	56.82	Himbaccol	000552-02-3	0.40	0.14	0.16
14	29.90	beta-Caryophyllene	000087-44-5	0.37	0.72	0.85
15	10.54	p-Cymene	000099-87-6	0.36	0.09	0.08
16	37.10	Germacrene D	023986-74-5	0.29	0.45	0.55
17	61.10	Isomintlactone	075684-66-1	0.19	0.05	0.05
18	37.50	alpha-Terpineol	000098-55-5	0.17	/	/
19	35.92	delta-Terpineol	007299-42-5	0.15	0.08	0.11
20	16.43	3-Octanol	000589-98-0	0.13	0.20	0.20
21	27.73	trans-4-Thujanol	017699-16-0	0.13	/	/
22	58.66	Thymol	000089-83-8	0.11	0.09	0.13
23	15.64	3-Hexen-1-ol, (Z)	000928-96-1	0.08	0.06	0.05
24	5.90	beta-Pinene	000127-91-3	0.08	0.07	0.13
25	28.82	Isopulegol	000089-79-2	0.07	0.12	0.17
26	9.81	gamma-Terpinene	000099-85-4	0.07	0.07	0.09
27	35.68	(E)-beta-Famesene	018794-84-8	0.06	0.08	0.10
28	51.80	Caryophyllene oxide	001139-30-6	0.06	/	0.04
29	57.65	Spathulenol	006750-60-3	0.05	/	/
30	6.25	Sabinene	003387-41-5	0.04	0.04	0.07
31	59.29	alpha-Cadinol	000481-34-5	0.04	/	/
32	10.98	Terpinolene	000586-62-9	0.03	0.05	0.06
33	42.91	(-)-Myrtenol	000515-00-4	0.03	/	/
34	50.28	Jasmone	000488-10-8	0.03	/	/
35	38.59	Bicyclogermacrene	024703-35-3	0.02	/	/
36	9.54	trans-beta-Ocimene	003779-61-1	0.02	0.03	0.04
37	4.14	alpha-Pinene	000080-56-8	0.02	0.02	0.04
38	31.80	(-)-Myrtenal	000564-94-3	0.02	/	/
39	12.42	Cyclohexanone, 3-methyl	000591-24-2	0.02	/	0.03
40	13.21	3-Octanol, acetate	004864-61-3	0.01	0.05	0.05
41	7.44	beta-Myrcene	000123-35-3	0.01	0.02	0.03
42	7.84	alpha-Terpinene	000099-86-5	0.01	0.02	0.03
43	23.13	cis-3-Hexenyl isovalerate	035154-45-1	/	/	/
44	28.22	Isopulegone	029606-79-9	/	3.21	3.71
45	32.03	1-Cyclohexene-1-methanol, alpha,alpha,4-trimethyl	018479-65-7	/	0.17	0.26
46	36.57	Lavandulol	000498-16-8	/	/	/
47	36.76	Benzofuran, 4,7-dimethyl	028715-26-6	/	/	0.05
48	37.48	Borneol	000507-70-0	/	0.51	0.42
49	48.78	Piperitenone	000491-09-8	/	0.29	0.39
50	58.37	tau-Cadinol	005937-11-1	/	/	/
51	58.61	tau-Muurolol	019912-62-0	/	/	/
52	62.27	7a-Hydroxymintlactone	213969-56-3	/	0.66	/

The most important active components in peppermint EO are Menthol and Menthone

- **Addition of R light and B light have a negative impact on the EO quality of *M. piperita***

-This may be due to the high intensity light (more than 500 μmol·m^{-2}·s^{-1})

2.3. Effects of red light and blue light on essential oil composition in *Mentha* L.

For *M. arvensis* EO, higher the menthol content, better the EO quality.

- There was no significant difference in the types and contents of chemicals identified in EO between the W and W+R.
- The W+B showed significant differences between the W and W+R.

Table.5. Effect of different LED lighting treatments on the essential oil composition of *Mentha arvensis*

Component				Relative content (%)		
No.	RT	Name	CAS	W	W+R	W+B
1	**34.34**	**L-Menthol**	**002216-51-5**	**77.10**	**73.77↓4%**	**67.94↓12%**
2	20.21	L-Menthone	014073-97-3	11.46	13.40	13.01
3	33.13	Pulegone	000089-82-7	3.73	4.71	9.64
4	31.12	Isomenthol	000490-99-3	2.11	2.22	2.21
5	22.31	Isomenthone	000491-07-6	1.44	/	1.50
6	37.10	Germacrene D	023986-74-5	0.86	0.87	1.20
7	38.09	Piperitone	000089-81-6	0.50	0.60	0.50
8	16.43	3-Octanol	000589-98-0	0.40	0.41	0.56
9	28.22	Isopulegone	029606-79-9	0.28	0.34	0.35
10	28.82	Isopulegol	000089-79-2	0.28	0.31	0.39
11	29.90	beta-Caryophyllene	000087-44-5	0.28	0.27	0.42
12	37.50	alpha-Terpineol	000098-55-5	0.16	0.21	0.23
13	38.59	Bicyclogermacrene	024703-35-3	0.15	0.15	0.21
14	8.38	Limonene	000138-86-3	0.10	0.12	0.20
15	50.28	Jasmone	000488-10-8	0.08	0.08	0.09
16	23.13	cis-3-Hexenyl isovalerate	035154-45-1	0.07	0.09	0.09
17	36.57	Lavandulol	000498-16-8	0.06	0.07	0.18
18	59.29	alpha-Cadinol	000481-34-5	0.05	0.05	0.08
19	8.72	Eucalyptol	000470-82-6	0.05	0.06	0.07
20	5.90	beta-Pinene	000127-91-3	0.05	0.05	0.06
21	4.14	alpha-Pinene	000080-56-8	0.05	0.04	0.04
22	15.64	3-Hexen-1-ol, (Z)	000928-96-1	0.03	0.04	0.03
23	7.44	beta-Myrcene	000123-35-3	0.03	0.04	0.05
24	48.78	Piperitenone	000491-09-8	0.03	/	0.09
25	58.61	tau-Muurolol	019912-62-0	0.03	0.01	0.02
26	6.25	Sabinene	003387-41-5	0.02	0.02	0.03
27	58.37	tau-Cadinol	005937-11-1	0.01	/	0.01
				99.41	97.92	99.21

- **Addition of R light and B light may have a slight negative impact on the EO quality of *M. arvensis***

5. Conclusion

(1) Berry plant and Mentha plant are important sources of natural monoterpenoid compounds, which have important application and economic value.

(2) Steam Distillation and Hydro-distillation are the most widely used methods for extracting monoterpene essential oils including berry plant and *Mentha* plant.

(3) Light signals affect the content and composition of monoterpenes.

(4) R and B light enhanced the EO content and production of mint

(5) Addition of R light and B light may have a slight negative impact on the EO quality of *M. arvensis*

6. The main references

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THANK YOU