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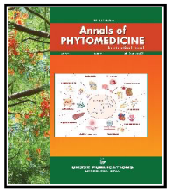

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GC-MS based phytochemical analysis of selected genotypes of *Curcuma caesia* Roxb.

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Abstract

Curcuma caesia Roxb. is known for its medicinal properties and has been traditionally used in Ayurvedic medicine. Research on *C. caesia* have reported several phytochemical compounds like a-santalol, retinal, ar-tumerone, alloaromadendrene, megastigma-3,7(E),9-triene, benzene, 1-(1,5-dimethyl- 4-hexenyl)-4-methyl, 5,8,11,14,17-eicosapentaenoic acid, methyl ester, (all-Z), tricyclo[8.6.0.0(2,9)] hexadeca-3,15-diene, trans-2,9-anti-9,10-trans-1,10, *etc*. Curcumin and epicurzerenone are compounds found in *C. caesia* which has been reported to have antitumor effects by inhibiting cancer cell proliferation and invasion, and induces apoptosis The leaves and rhizomes of this plant are extensively used in Ayurvedic medicine and as traditional remedies for various ailments. Four genotypes of *C. caesia* were collected from different parts of Northeast India and their rhizomes were analyzed using GC-MS to investigate the variations in the content of phytochemicals. GC-MS analysis of the 4 genotypes showed the presence of important phytochemicals which has antitumour and anticancer activities, *viz*., curcuminoids and epicurzerenone. Many other important phytochemicals were also found in the four genotypes of *C. caesia*. Screening of different genotypes of medicinal plants for noble phytochemicals and higher content of important compounds is much needed for higher production of herbal drugs and yield.

1. Introduction

Urbanization has altered our lifestyles and contributed to a rise in many diseases such as diabetes, cancer, and heart conditions. In recent years, herbal medications and therapies have become increasingly popular because of their fewer adverse effects. Common medicinal herbs are a more accessible, efficient, and useful source of medicine (Husain, 2021). Several studies demonstrate the medicinal advantages of different herbal plants and their extracts (Akmar and Mat Noor, 2017). Because of their affordability, accessibility, and safety, the use of herbal plants for disease management has attracted interest around the globe (Hashim *et al.*, 2018; Khalid *et al.*, 2019). Researchers are currently working on several spices and herbs to give a logical basis for their application in the cure and avoidance of common ailments (Mehrotra, 2021). The demand for plant-based health products has skyrocketed in developed and developing nations because they have fewer side effects than allopathic drugs. This has led to the global popularity of herbal products as well as medicine (Phurailatpam *et al.*, 2022). Black turmeric (*Curcuma caesia* Roxb.) is an ancient herb valued both as a spice and for its pharmacological effects. The plant is predominantly found in the Himalayan and Northeastern parts of India. Despite its underutilization compared to other Curcuma species, *C. caesia* holds traditional medicinal value and is part of Ayurvedic medicine. Research has identified diverse phytochemicals and potential antitumor activities in *C. caesia*. Antifungal, smooth muscle relaxant, antiasthmatic, antioxidant, antimicrobial, locomotor depressant, analgesic, muscle relaxant effects, and anticonvulsant, as well as anti-inflammatory qualities, have all been reported for the plant (Baghel *et al.*, 2013). In the Ayurvedic, Unani, and Siddha herbal systems, *C. caesia* has long been used as a traditional herb (Ranemma and Reddy, 2017). It is rich in curcuminoids and other essential oils and exhibits notable antioxidant properties attributed to its phenolic content, while its flavonoids contribute to anti-inflammatory effects. Similar to other curcuma species, *C. caesia* contains curcuminoids, notably curcumin, demethoxycurcumin, and bisdemethoxycurcumin, recognized for their antioxidant and anti-inflammatory properties. These compounds, primarily found in the rhizomes, are fat-soluble and serve multiple roles as spices, pigments, additives, and therapeutic agents (Amalraj *et al.*, 2017; Priyadarsini, 2014; Araújo and Leon, 2001). The biological effects of curcuminoids, such as their anti-inflammatory, antioxidant,

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antitumor, and neuroprotective qualities, have been extensively researched (Mošovská *et al.*, 2016; Shi *et al.*, 2017; Bagad *et al.*, 2013; Zhang *et al.*, 2008). Research has indicated that *C. caesia* methanolic extract may have anticancer properties against Ehrlich's Ascites Carcinoma (EAC) in mice. It prolongs the life of EAC treated mice (57.14% and 88.09%) and significantly reduces tumor volume, weight and viable cell count (Karmakar *et al.*, 2013). Additionally, *C. caesia* shows promise as a complementary treatment with chemotherapeutic drugs like cyclophosphamide, mitigating drug toxicity by reducing micronuclei formation, hepatotoxicity, and nephrotoxicity (Mazumder and Devi, 2016). Research on important phytochemical yield and noble drug discovery from this plant will open up new avenues in the herbal drug industry and treatment of various ailments. The collection and screening of various genotypes from different locations will help us in developing varieties with higher bioactive content and discover of noble phytochemicals which may have immense utility in health care systems. In our present study, 4 genotypes of *C. caesia* were collected from different locations in Arunachal Pradesh and grown on the horticultural research farm of the College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. The matured rhizomes were then sent to NIPER, Guwahati for GC-MS analysis. Then wthe results were compared to check the important phytochemicals present in the different genotypes. In continuation of the study, more number of genotypes can be collected from different parts of the country and checked for important phytochemicals in them.

2. Materials and Methods

2.1 Plant material and experimental site

Four (04) genotypes of *C. caesia* have been collected from various parts of Northeast India (Figure 1). The plants were maintained in the horticultural research farm of the College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, India (Figure 2). The Indigenous collection (IC) numbers of the 4 genotypes were also obtained from the National Bureau of Plant Genetics and Research (NBPGR), New Delhi (Table 1). The two year old matured rhizomes were sent to the National Institute of Pharmaceutical Education and Research (NIPER), Guwahati for GC-MS analysis.

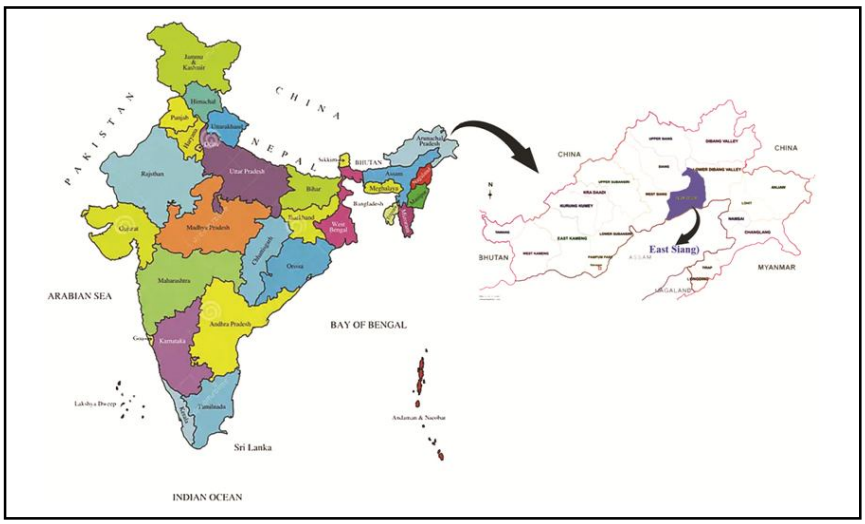

Figure 1: Location of the study- East Siang District, Arunachal Pradesh.

Figure 2: The 4 genotypes of *C. caesia* under study.

2.2 GC-MS study

2.2.1 Phytometabolite extraction and derivatization

In a test tube, 10 mg of the sample was weighed and diluted with methanol (1 ml) was added. It was vortexed for 10 mins and then it sonicated for 30 min. It was then centrifuged for the time of 10 min at a temp of 4°C and 10,000 rpm. The identical process was carried out three times, and a vacuum concentrator was used to collect and concentrate all of the collected supernatants. To prepare the dried sample extracts for GC-MS analysis, polar phytometabolites were derivatized using a variety of derivatizing agents. The following step uses 90 µl of methylation reagent (pyridine and o-methyl hydroxylamine HCL) was added to the dried sample extract. It was then maintained at 60°C for 90 min in a dry bath. After 120 min at 60°C in a dry bath, the mixture was silylated using 250 µl of MSTFA silylation reagent and 1% TMCS as a catalyst. A 120 min vacuum concentration was then applied to the reactant mixture.

2.2.2 GC-MS analysis

The solvent-extracted samples were derivatized according to the earlier reported method with slight changes (Toyo'oka, 1999). Approximately After being dried, the reactant mixture was reconstituted using 200 µl of n-hexane and vortexed. For additional analysis, a 1µl aliquot was injected into a GC-MS (GC 9000 and MS of 5977B, Agilent Technologies, Palo Alto, CA, USA). The oven temperature program was set to start at 40°C for 2 min, then rise to 120°C at a rate of 10ºC/min, held for 10 min, and finally rise to the temp of 280°C at a rate of 10°C/min, held for the time of 10 min. The injector temperature has been then kept at temperature of 300°C throughout this time. The analysis took 46 min to complete. The carrier gas, helium, was used at a flow rate of 1 ml per min. Splitless mode was employed with the DB-5MS capillary column (30 m x 250 µm ID. x 0.25 ìm thickness of film). At 70 eV, the electron ionization mode was used to collect the data. The MS source and transfer temperatures have been adjusted to the temperature of 290°C and 230°C, respectively. Following a 6 min pause to allow for solvent separation, comprehensive mass spectra have been attained within the mass range of m/z 50-800. The identification of GC-MS peaks has been achieved in comparison to their mass spectra with those in NIST library, using Agilent mass hunter workstation qualitative analysis software, version 10.0 (Srikanth *et al.*, 2022).Table 1: Indigenous collection (IC) numbers of the 4 genotypes of *C. caesia*

Table 1: Indigenous collection (IC) numbers of the 4 genotypes of *C. caesia*

S. No.	Accession material type	Coll-No. other-Id	Crop species	Cultivar name biostatus variety	Sample method	Collection date Village/District/State	Source Frequency Habitat	Pedigree donor	Important traits remark
1	IC-0644025 Live plants	APH/CAU/CC1/10	Black turmeric/ Black zedoary *Curcuma caesia*	Primitive cultivar	Individual plant	02 Jul 2018 Seram/East Siang / Arunachal Pradesh	Wild Rare Cultivated	- -	- -
2	IC-0644026 Live plants	APH/CAU/CC1/11	Black turmeric/ Black zedoary *Curcuma caesia*	Primitive cultivar	Individual plant	02 Jul 2018 Mebo/East Siang / Arunachal Pradesh	Wild Rare Cultivated	- -	- -
3	IC-0644027 Live plants	APH/CAU/CC1/12	Black turmeric/ Black zedoary *Curcuma caesia*	Primitive cultivar	Individual plant	27 Jan 2019 Takilalung/ East Siang/Arunachal Pradesh	Wild Rare Cultivated	- -	- -
4	IC-0644028 Live plants	APH/CAU/CC1/13	Black turmeric/ Black zedoary *Curcuma caesia*	Primitive cultivar	Individual plant	13 Apr 2019 Sille Oyan/ East Siang/ Arunachal Pradesh	Wild Rare Cultivated	- -	- -

3. Results

3.1 Chemical constituents

GC-MS analysis of the 4 samples detected many different compounds (Figure 3). It was also observed that there is quite a difference in the chemical content among the genotypes. In G1, a total number of 52 compounds were found expressed. In G2, a total number of 34 compounds were expressed, in G3, a total number of 38 compounds and in G4, a total number of 32 compounds were expressed (Table 2). Epicurzerenone was found to be expressed in all 4 genotypes with a variation in peak %. The highest peak was observed in G2 (24.1) and the least was found in G3 (6.4). Isocurcumenol was found only in G2 (6.6%) and G3 (1.65%). Curcumenone was found in G2 (5.9%), G2 (1.3%) and G4 (4.7%). Curcumenol was found in G1

(0.35%), G3 (0.9%) and G4 (1.0%) (Figure 4). A total of 32 compounds were found which were expressed commonly in all the 4 genotypes. The commonly expressed compounds in the 4 genotypes were Mannose MEOX TMS, heptadecane, lyxose, O,O,O, O-TMS MEOX1, piperidine hydrochloride, ribitol TMS, 1-deuterioheptan-1-ol, myo-inositol, 6TMS derivative, iron tricarbonyl [N-(phenyl-2-pyridinylmethylene) benzenamine-N,N']-, epicurzerenone, isocurcumenol, benzofuran, 6-ethenyl-4,5,6,7-tetrahydro-3,6-dimethyl-5-isopropenyl-trans, hexanol-4-D2.alpha.-cyperone, trehalose TMS, phosphonic acid dioctadecyl ester, palmitic acid, TMS derivative, stearic acid, TMS derivative, 3-hydroxy-4,4-dimethyldihydro (2-13C) furan-2-one, 1-tridecanol, 5-hydroxy-5-dideutero-1,2-pentadiene, 3,4-pentadien-2-d-1-ol, octyl (t-butyl) carbonate, 3-allyl-1,7,7-trimethylbicyclo [2.2.1]hept-2-en-2-yl diethyl phosphate, curcumenone, S,S-dioxide, trans-2-methyl-4-n-pentylthiane, 2,3-dimethylthiirane 1,1-dioxide, desacylin-caspitolide D-5-[O-(2'-methylbutyrate)], .beta.-vetivenene, 2,5,8-trimethyl-nonane and curcumenol.

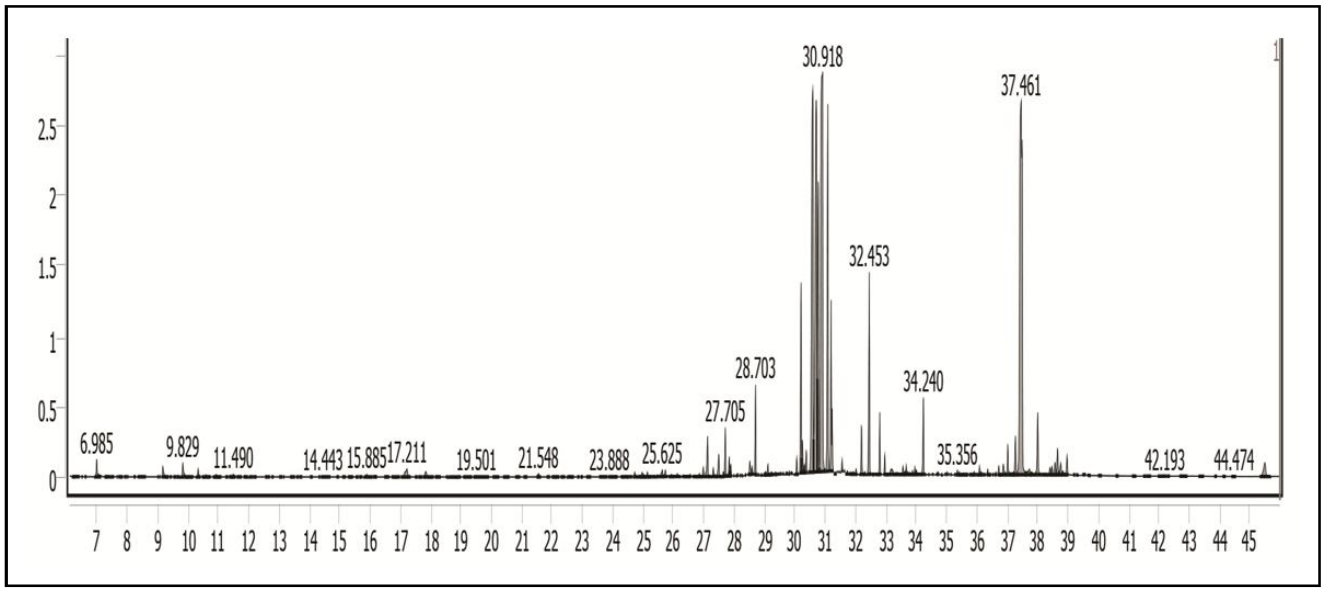

Figure 3: GC-MS chromatograph of methanolic extract of *C. caesia* genotype.

Table 2: Bioactive compounds found in methanolic extract of 4 genotypes of *C. caesia* Roxb.

S.No.	G1	Peak %	G2	Peak %	G3	Peak %	G4	Peak %
1	Sucrose TMS	17.5	Sorbtol TMS	8.3	Trehalose TMS	3.8	Sorbtol TMS	9.6
2	Mannose MEOX TMS	24.1	Mannose MEOX TMS	3.1	Sucrose TMS	13.8	Mannose MEOX TMS	5.2
3	Mannitol TMS	1.1	Trehalose TMS	0.5	Ribitol TMS	3.7	Ribitol TMS	1.3
4	Heptadecane	0.8	Ribitol TMS	1.6	Mannose MEOX TMS	23.0	Trehalose TMS	0.6
5	Lyxose,O,O,O,O-TMS MEOX1	19.5	Piperidine	0.1	Sorbtol TMS	10.7	Lyxose,O,O, hydrochloride O,O-TMS MEOX1	1.6
6	Piperidine hydrochloride	0.0	Heptadecane	2.6	Lyxose,O,O,O,O-TMS MEOX1	16.6	Heptadecane	3.5
7	Ribitol TMS	0.3	3,4-Pentadien-2-d-1-ol	0.1	Heptadecane	1.2	Hexanol-4-D2	0.3
8	di-t-butyl-phenol	0.1	5-hydroxy-5-dideutero-1,2-pentadiene	0.1	Piperidine hydro-chloride	0.0	Erythritol-1-D1, tetrakis-O- (trim-ethylsilyl)-	6.9
9	2,2,8,8-Tetrame-thyl-5-[(trimeth-ylsilyl)oxy]-3,7-dioxa-2,8-disil-anonane	0.1	Epicurzerenone	24.1	1-Deuterioheptan-1-ol	0.1	Myo-Inositol, 6TMS derivative	2.0

10	1-Deuterioheptan-1-ol	0.0	Lyxose,O,O,O,O-TMS MEOX1	1.0	Iron, tricarbonyl [N-(phenyl-2-pyridinylmethylene) benzenamine-N,N']-	0.7	Iron, tricarbonyl [N-(phenyl-2-pyridinyl methylene)benzenamine-N,N']-	2.2
11	Myo-Inositol, 6TMS derivative	4.3	Isocurcumenol	6.6	Epicurzerenone	6.4	Epicurzerenone	21.9
12	Iron, tricarbonyl [N-(phenyl-2-pyridinylmethylene)benzenamine-N,N']-	0.4	Iron, tricarbonyl [N-(phenyl-2-pyridinylmethylene)benzenamine-N,N']-	2.0	Isocurcumenol	1.6	1-(1-Methyl-2, 2-D2-2- trimethylsilyloxyethyl)-4-(2-methyl-2-trimethylsilyloxypropyl) benzene	1.0
13	Epicurzerenone	8.1	Phosphonic acid, dioctadecyl ester	0.1	3,4-Pentadien-2-d-1-ol	0.0	Stearic acid, TMS derivative	2.4
14	Erythritol-1-D1, tetrakis-O-(trimethylsilyl)-	0.3	Hexanol-4-D2	0.7	.alpha.-Cyperone	0.6	.alpha.-Cyperone	2.2
15	1-(1-Methyl-2,2-D2-2-trimethylsilyloxyethyl)-4-(2-methyl-2-trimethylsilyloxypropyl)benzene	0.1	Benzofuran, 6-ethenyl-4,5,6,7-tetrahydro-3,6-dimethyl-5-isopropenyl-, trans-	2.6	Hexanol-4-D2	0.2	3-Allyl-1,7,7-trimethylbicyclo [2.2.1]hept-2-en-2-yl Diethyl Phosphate	0.3
16	Benzofuran, 6-ethenyl-4,5,6,7-tetrahydro-3,6-dimethyl-5-isopropenyl-, trans-	1.8	Curcumenone	5.9	Phosphonic acid, dioctadecyl ester	0.0	Benzofuran, 6-ethenyl-4, 5,6,7-tetrahydro-3,6-dimethyl-5-isopropenyl-, trans-	2.3
17.	Hexanol-4-D2	0.0	Octyl (t-Butyl) Carbonate	0.5	5-hydroxy-5-dideutero-1,2-pentadiene	0.2	Hexadecane, 2,6,10,14-tetramethyl-	0.8
18	Methyl 2,3,4,6-tetrakis-O-(trimethylsilyl) hexopyranoside	1.8	Palmitic Acid, TMS derivative	25.1	Curcumenone	1.3	Octyl (t-Butyl) Carbonate	0.9
19	.alpha.-Cyperone	0.7	3-hydroxy-4,4-dimethyldihydro (2-13C) furan-2-one	0.3	Palmitic Acid, TMS derivative	9.8	2,5,8-Trimethyl nonane	0.2
20	Bis trimethylsilyl derivative of hydrated formaldehyde	0.0	1-(1-Methyl-2,2-D2-2-trimethylsilyloxyethyl)-4-(2-methyl-2-trimethylsilyloxypropyl) benzene	0.2	3-Allyl-1,7,7-trimethylbicyclo[2.2.1]hept-2-en-2-yl Diethyl Phosphate	0.1	Palmitic Acid, TMS derivative	24.5
21	Trehalose TMS	0.6	Methyl (3S*,4S*)-2,3,4,5-tetrahydro-4-methyl-1,5-dioxo-1H-benz[c] azepine-3-carboxylate	0.3	Benzofuran, 6-ethenyl-4,5,6,7-tetrahydro-3,6-dimethyl-5-isopropenyl-, trans-	0.2	Piperidine hydrochloride	0.9
22	Phosphonic acid, dioctadecyl ester	0.1	2,2,5,5-Tetramethyl-3-hexene	1.0	Myo-Inositol, 6 TMS derivative	1.8	2,2,5,5-Tetramethyl-3-hexene	1.2
23	Palmitic Acid, TMS derivative	8.3	Stearic acid, TMS derivative	3.0	Octyl (t-Butyl) Carbonate	0.1	Phosphonic acid, dioctadecyl ester	0.3

24	Glucofuranoside, methyl-tetrakis-O-(trimethy-lsilyl)-	0.6	2,3-Dimethyl-thiirane 1,1 -dioxide	0.2	2,5,8-Trimethy-lnonane	0.0	Curcumenol	1.0
25	Stearic acid, TMS derivative	1.1	Glucofuranoside, methyl-tetrakis-O-(trimethylsilyl)-	4.7	Cyclopropaneme-thanol, 2-methyl -2-(4-methyl-3-pentenyl)-3-(2-methyl-1-propeny-lidene)-, cis	0.1	2-n-propyl-1-D1-aziridine	0.3
26	trans-2,4-Dim-ethylthiane, S, S-dioxide	0.0	Desacylin-Caspit-olide D - 5-[O-(2' -Methylbutyrate)]	0.3	Stearic acid, TMS derivative	1.1	Curcumenone	4.7
27	5-hydroxy-5-did-eutero-1,2-pen-tadiene	0.2	prednisone-M1	0.3	trans-2-methyl-4-n-pentylthiane, S,S-dioxide	0.1	.beta.-Vetivenene	0.6
28	2,3-di(trimethyl-siloxy)-3-(trimet-hylsiloxycarbonyl) -2-propanoic acid	0.1	1-trans-2-cis-3-trans-trimethylcy-clopentane	0.1	Maltose MEOX2 TMS	0.3	2,3,4,4-Tetrame-thyl-4-(1,1-dime-thylethyl)-1-hexene	0.2
29	3,4-Pentadien-2-d-1-ol	0.1	Myo-Inositol, 6TMS derivative	1.8	Borane, diethyl (decyloxy)-	0.1	trans-2-meth-yl-4-n-pentyl-thiane, S,S-dioxide	0.4
30	Octyl (t-Butyl) Carbonate	0.0	1-Deuterioheptan-1-ol	1.5	Dodecyl octyl ether	0.1	Borane, diethyl (decyloxy)-	0.3
31	Pentitol-1,1-D2, 2-desoxy-tetrakis-O-(trimethylsilyl)-	0.3	.beta.-Vetivenene	0.6	Erythritol-1-D1, tetrakis-O-(trime-thylsilyl)-	0.4	3,4-Pentadien-2-d-1-ol	0.1
32	3-Allyl-1,7,7-tri-methylbicyclo[2.-2.1]hept-2-en-2-yl Diethyl Phosphate	0.1	trans-2-methyl-4-n-pentylthiane, S,S-dioxide	0.2	2-amylbuta-2,3-dienylcyclopentane	0.3	2,3-Dimethylt-hiirane 1,1-dioxide	0.2
33	Maltose MEOX2 TMS	0.2	(5S,9S)-5,9-dimet hylpentadecane	0.1	2,3-Dimethylthi irane 1,1-dioxide	0.1		
34	Glycerol monos-tearate, 2TMS derivative	0.2	Butyl tetradecyl ether	0.3	Curcumenol	0.9		
35	2,2,5,5-Tetrame thyl-3-hexene	0.1			.beta.-Vetivenene	0.1		
36	trans-2-methyl -4-n-pentylthiane, S,S-dioxide	0.1			butyl 2,4-dimethyl -2-nitro-4-pente-noate	0.1		
37	2,3-Dimethylthii-rane 1,1-dioxide	0.0			3-hydroxy-4,4-di-methyldihydro (2-13C)furan-2-one	0.1		
38	5-Methyl-6-phen-yl-3-(1-phenyle-thyl)-1,2,3-triazin -4(3H)-one	0.1			Pentadecanoic acid, TMS derivative	0.2		
39	Tris(trimethylsi-lyl)deuteriome-thane	0.2						
40	t-butylpentame-thyldisiloxane	0.3						

41	butyl 2,4-dimethyl-2-nitro-4-pentenoate	0.1						
42	.beta.-Vetivenene	0.2						
43	2,5,8-Trimethylnonane	0.0						
44	1,2-Benzisothiazol-3(2H)-one, 4,6-diazido-2-methyl-, 1-oxide	0.9						
45	1-Propyl-2,2-dimethoxyethylamine Hydrochloride	0.1						
46	Methyl (3S*,4S*)-2,3,4,5-tetrahydro-4-methyl-1,5-dioxo-1H-benz[c]azepine-3-carboxylate	0.1						
47	1,2-Ethenediol, 2TMS derivative	2.1						
48	(S)-6-Hydroxyheptanoic acid	0.6						
49	Curcumenol	0.3						
50	6-Ethyl-4,6-dimethyl-6H-dibenzo-[b,d]pyran	0.1						
51	(4R,9R)-4,9-Diethyl-3,8-dioxa-1,6-diazabicyclo[4.4.1]undecane	1.9						
52	9-Borabicyclo[3.3.1]nonan-9-amine, N-[bis(1,1-dimethylethyl)boryl]-	0.1						

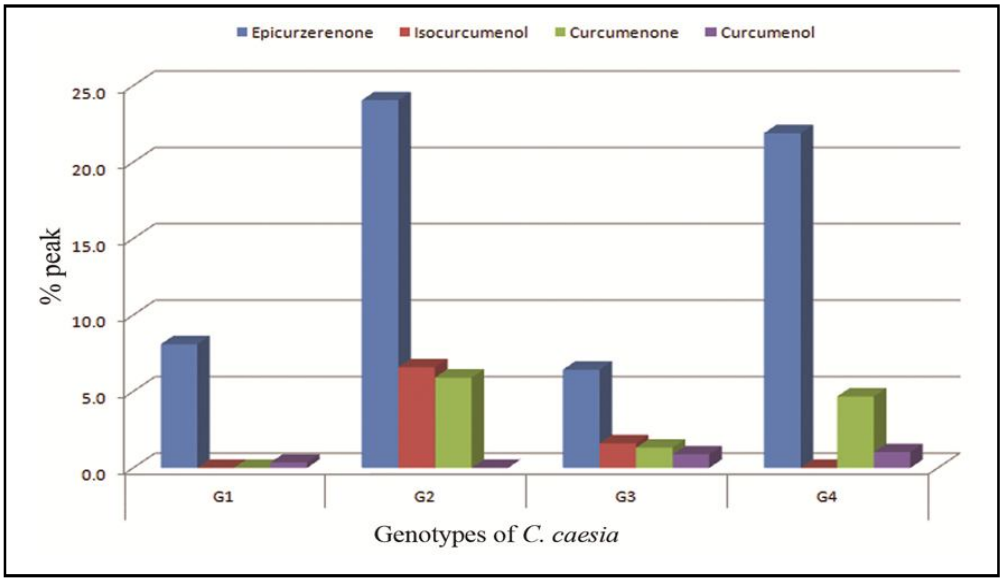

Figure 4: Expression of 4 antitumor compounds in the 4 genotypes of *C. caesia* under GC-MS.

4. Discussion

C. caesia is a significant medicinal plant rich in phytochemicals, including proteins, alkaloids, flavonoids, phenols, tannins, steroids, and tannin-containing phenols. Furthermore, there are compounds like epicurzerenone and zederone that have been shown to be promising in the treatment of cancer and inflammation (Rathi *et al.*, 2024). Curcuminoids having so many biological targets, almost no side effects, and the potential to treat immune-related, metabolic, and cancer diseases have gained therapeutic interest (Siviero *et al.*, 2015; Mahmood *et al.*, 2015). Additionally, it has been noted that curcumin's low systemic bioavailability and poor aqueous solubility have limited the drug's clinical use in the treatment of cancer and other illnesses (Naikodi *et al.*, 2021). The chemical constituents of varied genotypes tend to differ in their expression due to the genotypic make and the climate and soil it grows. The morphological features and yield also vary in many genotypes of the present study. The same has also been reported by Narendhiran *et al.* (2023). They found that among all collected black turmeric genotypes, genotype BTG 12 showed better results with maximum fresh rhizome yield plant-1(321 g), estimated yield ha-1 (23.6 t ha-1), number of rhizomes plant-1 (15.90), number of primary fingers plant-1 (5.95), and curcumin content (2.05 %), followed by BTG 6 genotype and BTG genotype give the lowest values. Significant differences were found between the 18 turmeric genotypes for curcumin content, oleoresin (%), and essential oil (%). The curcumin content ranged between 2.08 and 4.73 per cent. Maximum curcumin content was recorded in var. Prathibha (4.73%), followed by var. Suroma (4.58%), while the minimum was recorded in genotype CLI-327 (2.08%). The oleoresin content ranged between 3.80 and 16.20 per cent. Maximum oleoresin content was recorded in var. Pratibha (16.20 %) which was on par with var. Alleppy (15.69%) while the minimum was recorded in var. Krishna (3.80%). The essential oil content ranged between 2.03 and 6.50 per cent. Maximum essential oil content was recorded in var. Prabha (6.50%) which was on par with var. Pratibha (6.20%), while the minimum was recorded in var. Krishna (2.03%) (Shashidhar *et al.*, 2018). In our investigation, the 4 genotypes have different expression of phytochemicals. The curcuminoids and other anticancer compounds in the 4 genotypes namely epicurzenone, isocurcumenol, curcumenone, and curcumenol were expressed in different degrees under GC-MS, which may be due to the genetic makeup of the genotypes along with the environment it grows (Chantraine *et al.*, 2009; Maia *e. al.*, 2007; Lara *et al.*, 2018). Various unexplored plant materials can be screened for higher phytochemical yield and production for better drug production. Additionally, there is a need to standardize as many Indian plant drugs as possible with respect to "bioactive marker compounds" (Nagaiah, 2022).

5. Conclusion

Because of safety concerns, there is a discernible trend toward a shift from synthetic to natural product bases. A great deal of research has been done on medicinal plants and herbs, yielding many exciting findings. These days, scientists and pharmaceutical companies are turning their interest to *C. caesia* because of its possible health benefits. Its antifungal, antibacterial, anticancer, antiproliferative, analgesic, anti-inflammatory, muscle relaxant, anticonvulsant, locomotor depressant, antidepressant, and thrombolytic qualities have all been highlighted in several scientific investigations. To identify, isolate, and characterize the structures of the novel bioactive compounds found in *C. caesia* that are responsible for these health benefits, more research is required. Additionally, more experimental evidence is needed to determine the variation in phytochemical content among different genotypes and to optimize the extraction methods for maximizing the yield of herbal drugs from these medicinal plants. Research efforts should focus on identifying genotypes and varieties that yield higher economic returns and contain elevated levels of important phytochemicals. The genetic makeup of a plant, or its genotype, influences its biochemical pathways, including those involved in the synthesis of phytochemicals. Different genotypes may produce varying amounts and types of phytochemicals. Plant breeders and researchers often select and breed plants based on their genotypes to enhance specific phytochemical profiles that are desirable for nutritional or medicinal purposes. Therefore, understanding and manipulating genotypes is essential for optimizing the phytochemical content of plants to benefit human health and nutrition. Variations in the genetic makeup of different plants may offer different phytochemicals or higher content of a particular phytochemical can only be reaffirmed by screening many genotypes and large germplasm in the future.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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