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Unveiling the phytochemical profile of *Asparagus sprengeri* R. using GC-MS analysis: Impact of intercropping and open field cultivation

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Abstract

Asparagus species have long been utilized in folk medicine for its therapeutic properties, including antioxidant, immunostimulant, antihepatotoxic, anticancer, anti-inflammatory and antimicrobial properties. *Asparagus sprengeri* R. is one among them, which is primarily used as an ornamental plant in landscaping. Besides, it also offers curative benefits owing to its strong phytochemical profile. The synthesis of secondary metabolite in plants is influenced by a variety of factors primarily genetic and environmental conditions. This study aimed to screen the phytochemicals in the aerial extracts of *A. sprengeri* grown under two distinct agroecological regimes—open field and intercropped condition using gas chromatography-mass spectrometry (GC-MS), while also validating its medicinal potential. The GC-MS profile revealed that *A. sprengeri* cultivated in open field cultivation produced typical phytochemical compounds such as vitamin E, phytol and γ -tocopherol. In contrast, intercropping with *Pimenta dioica* enhanced the growth performance and phytochemical content of *A. sprengeri*, with higher concentrations of compounds like vitamin E, 2-methoxy-4-vinylphenol and benzoic acid. Additionally, novel metabolites such as eugenol, pinene and spirostanoids were identified, known for their potent biological properties. These improvements could be attributed to factors such as shaded environment, production of allelochemicals, enhanced nutrient uptake and the activation of plant's defence mechanism. Synthesis of these novel compounds in an ornamental herb like *A. sprengeri*, influenced by diverse agroecological conditions, holds the potential to mark a significant advancement in the field of drug development. Given the increasing reliance on herbal remedies, further exploration of these mechanisms and interconnected applications may lead to the discovery of therapeutic agents with diverse pharmacological significance.

1. Introduction

For thousands of years, various cultures have relied on herbs and plants to treat illnesses and preserve health. Many of the drugs used in contemporary medicine are derived from these plant sources (Kadhim and Salah, 2014). Similarly, numerous flowers and ornamental plants, much like medicinal plants, possess significant medicinal properties that extends beyond their primary role in aesthetics and decorations, owing to the notable concentration of their bioactive compounds (Coyago-Cruz *et al.*, 2023; Deepikakrishnaveni *et al.*, 2024). While certain plants have undergone scientific investigations to confirm their therapeutic benefits, many remain largely unexplored (Mirunalini *et al.*, 2024). Thus, comprehensive scientific studies are necessary to validate the medicinal potential of these traditionally used plants and to bridge the gap between folk medicine and scientific understanding (Deka *et al.*, 2021).

Asparagus sprengeri R., an ornamental fern in the Liliaceae family, is widely admired for its lush foliage and aesthetic appeal. It belongs to the genus *Asparagus*, which comprises around 300 herbaceous species, many of which are recognized for their pharmacological properties and diverse ethnopharmacological applications (Asma *et al.*, 2018). Related species within this genus are not only used as a nutritious food supplement, but are also highly valued for their medicinal properties, largely attributed to their rich phytochemical composition (Pegiou *et al.*, 2019). For instance, *A. officinalis* is a potent cardiac sedative used in the treatment of kidney stones, urinary issues, schistosomiasis and tuberculosis. Similarly, *A. racemosus* are useful in treating diseases such as dysentery, biliousness, leprosy, epilepsy and jaundice, while *A. filicinus* serves as a vermifuge (Negi *et al.*, 2010). Additionally, the roots of various *Asparagus* species are known to promote fertility, reduce menstrual cramping and increases milk production in nursing mothers (Rajni *et al.*, 2023). The medicinal potential of *Asparagus* species is largely attributed to their diverse bioactive compounds including lignans, triterpenes, flavonoids, hydroxycinnamic acids and steroidal saponins. These compounds contribute to the genus's notable antibacterial, antioxidant, immunostimulant, antihepatotoxic, anticancer, anti-inflammatory and antimicrobial properties (Negi *et al.*, 2010; Srivastava *et al.*, 2018). In folk medicine, various *Asparagus* species

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have long been utilized to treat ailments such as diabetes, inflammation, arthritis and rheumatism (Sobhy *et al.*, 2024).

Previous studies on *A. sprengeri* have identified its key phytochemical constituents as spirostanol saponins, apigenin, naringenin, myristic acid and linoleic acid, particularly when grown under shade nets-a commercial method of cultivation (Hassan *et al.*, 2014; Sharma *et al.*, 1983). The phytochemical profile of a plant is determined by a range of factors, with the primary influences being its genetic makeup, environmental conditions and cultivation practices (Mohammadi Bazargani *et al.*, 2021). *A. sprengeri* thrives well in environments with indirect sunlight and partial shade (Gilman *et al.*, 2018). However, for small and marginal farmers, open-field cultivation and intercropping systems offer more economical alternatives to shade net cultivation, which requires significant initial investment and periodic maintenance (Kulkarni *et al.*, 2024; Maitra *et al.*, 2021). Both systems provide notable advantages over shade net cultivation by optimizing natural resources utilization and reducing costs (Chacha *et al.*, 2023). Intercropping, in particular, has been shown to enhance yield, improves soil health and promote better land utilization (Sabarivasan *et al.*, 2024). Additionally, plants cultivated under open field and intercropping systems have demonstrated enhanced pharmacological benefits, as these systems influence the concentration of bioactive compounds, potentially leading to more effective herbal remedies (Licata *et al.*, 2022).

Hence, this study aimed to analyse the bioactive compounds present in the aerial parts of *A. sprengeri* cultivated under two distinct agroecological conditions, *i.e.*, open field and intercropping condition,

using gas chromatography-mass spectrometry (GC-MS) technique. Furthermore, it sought to explore the plant's pharmacological and therapeutic potential, emphasizing its relevance for drug development and medicinal research.

2. Materials and Methods

The study was conducted at the main farm of Horticultural Research Station, Tamil Nadu Agricultural University (TNAU), located in Pechiparai (8°26'N latitude, 77°19'E longitude and an elevation of 76 m above MSL), Kanyakumari District, Tamil Nadu during 2024. Following the Good Agricultural Practices, the seedlings were planted and cultivated as a sole crop under open field condition with enough sunlight and also as an intercrop under Allspice (*Pimenta dioica* (L.) Merr.) tree having partial shade.

2.1 Plant material and authentication

The *A. sprengeri* utilized in this study were procured from the farm unit of Department of Horticulture, V.O.C. Agricultural College and Research Institute, Killikulam, Tuticorin, Tamil Nadu. Well-established seedlings from the superior performing lines were chosen for planting and cultivation.

Regarding plant authentication, the specimen was botanically identified and verified by Dr. M. Johnson, Curator, Centre for Plant Biotechnology, St. Xavier's College, Palayamkottai, Tirunelveli, Tamil Nadu. Also, herbarium was deposited and preserved in Centre for Plant Biotechnology Herbarium (Indexed on 2022), St. Xavier's College, Palayamkottai, Tirunelveli with Voucher Specimen Number SXC-CPBH-5481 for future reference.



Figure 1: Morphological appearance of *A. sprengeri*.

2.2 Cultivar description

A. sprengeri is a hardy, evergreen perennial herb characterized by its fine texture and upright, spreading growth habit. It can grow up to 24 inches in height and spread 4 feet wide. It features small, scale-like, needle-like leaves (cladophylls), giving it a feathery appearance as shown in Figure 1. Cladophylls are tiny, slender and flattened structures with a bright green colour, occurring singly or in clusters of three or more at a node. The plant's stems arise from the ground and gradually turn woody and spiny. This drought-resistant plant produces small, fragrant, white or pinkish star-shaped flowers, which are followed by bright red, non-edible berries. It possesses an extensive root system with relatively large tubers.

2.3 Metabolite extraction

After five months of cultivation under open-field and intercropped agroecological conditions, the cladodes of *A. sprengeri* were harvested, shade-dried and ground into a fine powder using a blender. For extraction, 50 mg of the powdered cladodes were mixed with 1.5 ml of methanol as the solvent. The mixture was subjected to overnight shaking at 70 rpm to ensure efficient extraction. The resulting supernatant was carefully transferred into a 2 ml Eppendorf tube and dried completely at 55°C using a speed vacuum microcentrifuge. The dried residues were then reconstituted in 500 µl of 50% HPLC-grade methanol and filtered into a 2 ml vial equipped with a 500 µl conical insert. The filtered extracts were stored until further GC-MS analysis.

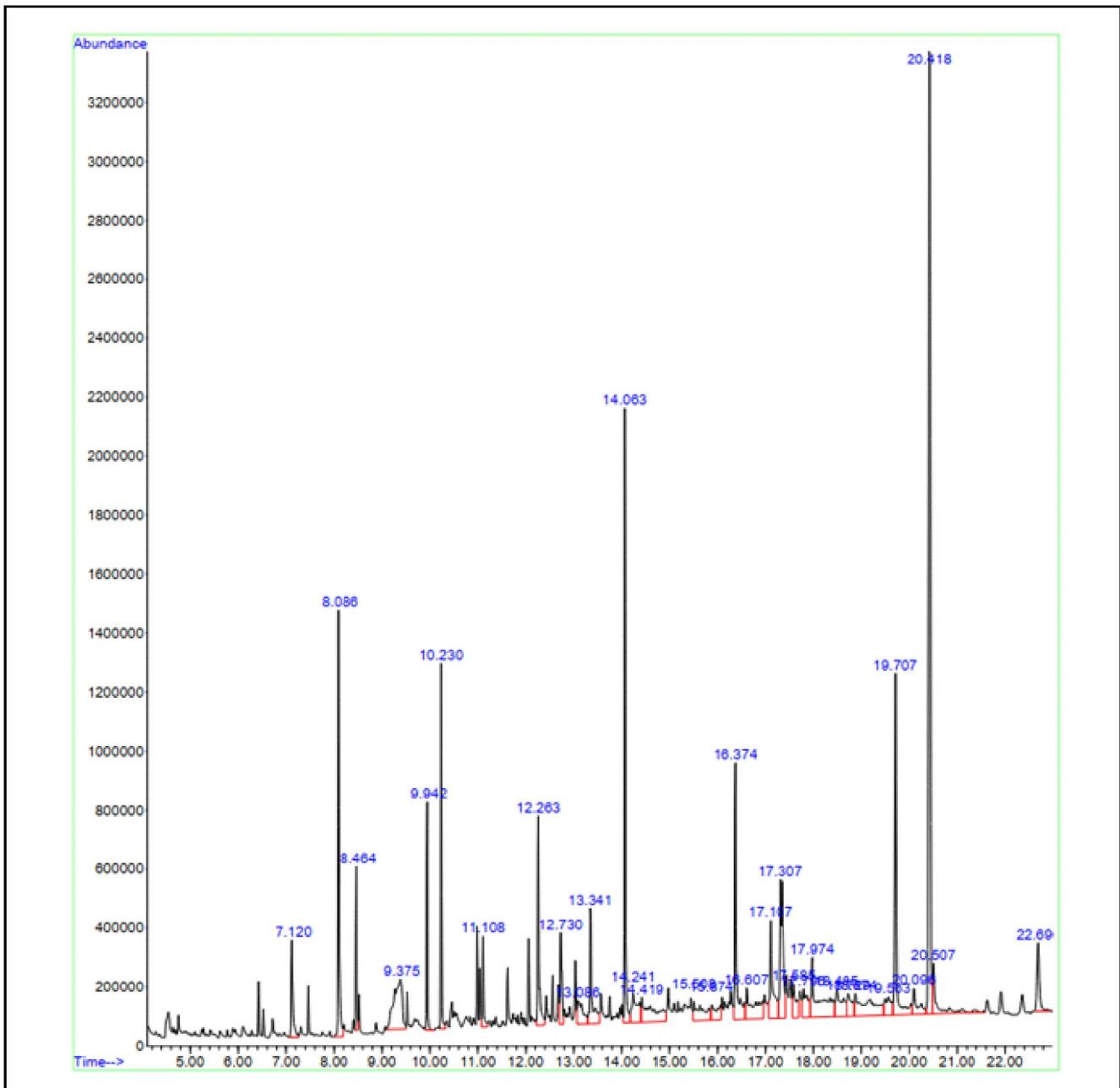


Figure 2: Chromatogram of *A. sprengeri* grown in open field condition.

Table 1: Phytochemical profile of *A. sprengeri* grown under open field condition

S. No.	Compounds	Retention time (min)	Peak area (%)
1	Vitamin E	20.418	20.63
2	Phytol	14.0633	6.74
3	2-Methoxy-4-vinylphenol	8.0863	6.21
4	γ -Tocopherol	19.707	6.02
5	d-Glycero-d-ido-heptose	9.375	5.33
6	9,12-Octadecadienoic acid (Z,Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	17.3073	4.56
7	2',4'-Dimethoxyacetophenone	10.2304	3.84
8	Glycerol 1-palmitate	16.3741	3.58
9	3-Trifluoromethylbenzoic acid, undec-2-enyl ester	12.2635	3.1
10	Benzoic acid, 4-ethoxy-, benzoic acid, ethyl ester	9.9416	2.57
11	Esculin	12.7301	2.29
12	γ -Sitosterol	22.6955	2.15
13	Phenol, 2-methoxy-3-(2-propenyl)-	8.464	2.07
14	Benzofuran, 2,3-dihydro-	7.1197	1.81
15	Benzenepropanoic acid, 2,5-dimethoxy-	13.3411	1.69
16	3,4-Dihydroisoquinoline, 1-[3-hydroxybenzyl]-6methoxy-	17.1073	1.68
17	9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester, (Z,Z,Z)-	14.241	1.48
18	3,4-dimethyl-5-(3,4-methylenedioxy)phenyloxazolidine	11.1081	1.19
19	Diethyl phthalate	10.4526	1.18
20	17-(1,5-Dimethylhexyl)-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro1H-cyclopenta[a]phenanthren-3-ol	20.5069	1.17
21	Daphnetin	12.0524	1.13
22	Glycerin	4.5423	1.11
23	4,4,5,8-Tetramethylchroman-2-ol	10.9859	1.01
24	4-((1E)-3-Hydroxy-1-propenyl)-2-methoxyphenol	11.6191	0.82
25	Squalene	17.9739	0.78
26	Diphenyl sulfone	13.0301	0.77
27	n-Hexadecanoic acid	13.0856	0.7
28	2-Propanamine, 2-methyl-N-(phenylmethylene)-, Noxide	11.0414	0.69
29	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	6.4198	0.64
30	Tetraacetyl-d-xylonic nitrile	9.686	0.61
31	1,2-Dimethoxy-4-n-propylbenzene	9.5194	0.58
32	1-Cyclopentyl-2-propen-1-ol	4.7533	0.57
33	Phenol, 4-(2-propenyl)-	7.4641	0.57
34	Octadecanoic acid, 2,3-dihydroxypropyl ester	17.4406	0.57
35	d-Mannose	10.7526	0.53
36	Pyrimidine, 2-[4-(2-methoxyphenyl)-1-piperazinyl]4,6-dimethyl-	17.5295	0.51

2.4 GC-MS analysis

The GC-MS system, integrated with a Perkin Elmer turbo matrix 150 thermal desorber (USA), was operated at a 10:1 split ratio with helium as the carrier gas at 20 psi. The oven temperature gradually increased from 50°C to 250°C at a rate of 10°C per min. Mass spectrometry was performed in positive ion mode with electron impact ionization at 70 eV, utilizing a DB-5 column (30 m x 0.25 mm, 0.25 µm film thickness).

The solvent-free samples obtained from both agroecological conditions were reconstituted in HPLC-grade methanol for analysis. Gas chromatography (GC) coupled with mass spectrometry (MS) (Agilent GC 7890A/MS 5975C) was employed for the analysis. The column temperature was initially maintained at 60°C for 1.36 min,

then ramped to 325°C and held for 23 min. The injector temperature was set to 280°C with a split ratio of 100:1, and an injection volume of 1 µl was used. Helium was employed as the carrier gas, set at a flow rate of 1 ml/min, with a total analysis time of 23 min. Mass spectra were recorded over a range of m/z 50 to 350.

2.5 GC-MS data interpretation

Compound identification was done by comparing the obtained mass spectra with existing entries in the NIST (National Institute of Standards and Technology) mass spectral database. Quantification of the commonly detected compounds in both open field and intercropped samples was carried out using GC-MS, with concentrations determined by the peak area percentage in the respective chromatograms.

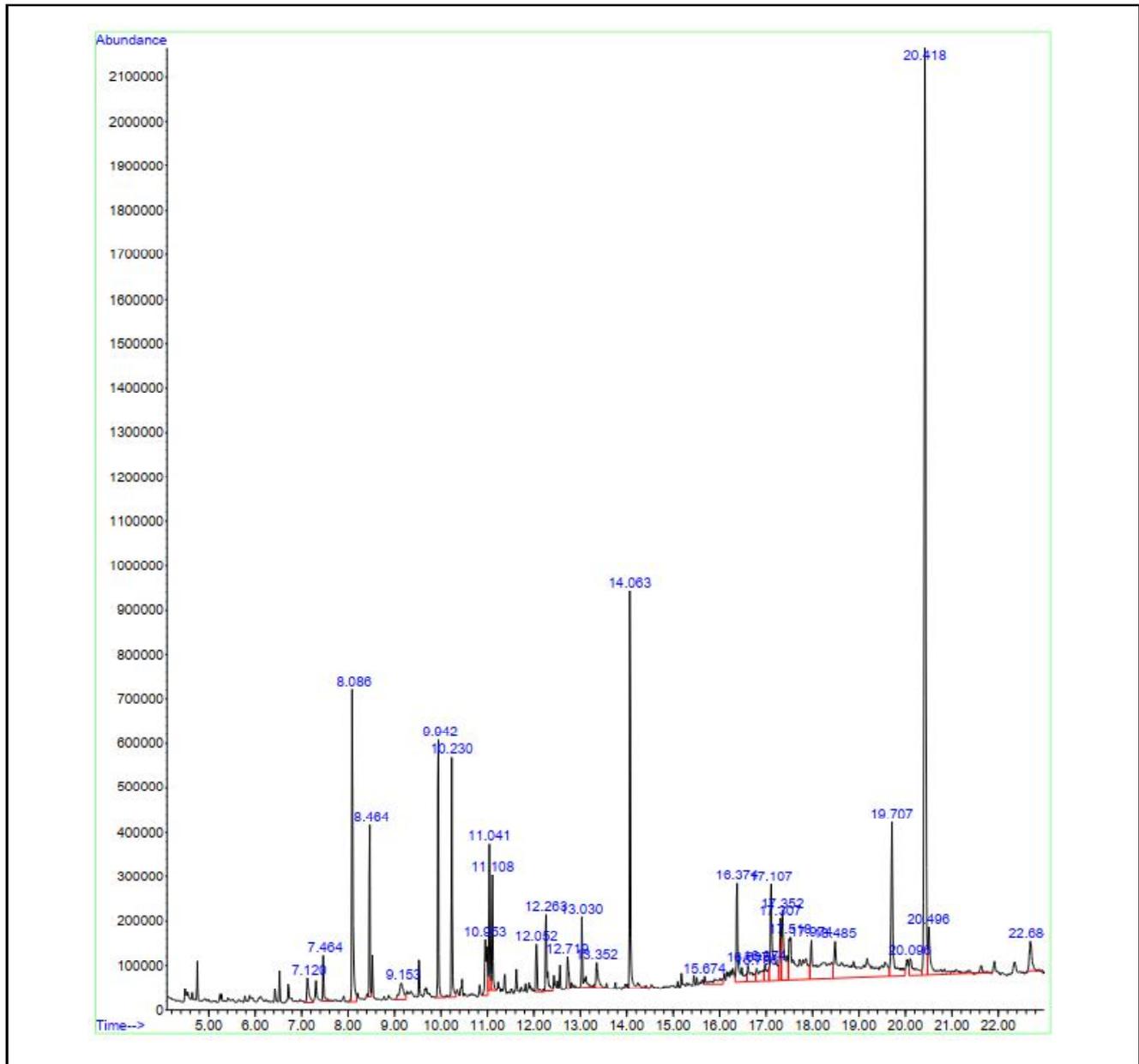


Figure 3: Chromatogram of *A. sprengeri* grown under intercropping condition.

Table 2: Phytochemical profile of *A. sprengeri* cultivated as an intercrop under Allspice

S. No.	Compounds	Retention time (min)	Peak area (%)
1	Vitamin E	20.418	26.25
2	2-Methoxy-4-vinylphenol	8.0862	7.26
3	Phytol	14.063	6.68
4	Benzoic acid, 4-ethoxy-, ethyl ester	9.9415	4.51
5	3',5'-Dimethoxyacetophenone	10.23	3.97
6	γ -Tocopherol	19.707	3.97
7	Linolenic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester (Z,Z,Z)-	17.352	3.36
8	Eugenol	8.4639	3.02
9	3-Hydroxy-N-methylphenethylamine	11.041	2.98
10	3,4-dimethyl-5-(3,4-methylenedioxy)phenyloxazolidine	11.108	2.62
11	3,4-Dihydroisoquinoline, 1-[3-hydroxybenzyl]-6methoxy-	17.107	2.56
12	Phenylephrine	10.953	2.2
13	Glycerol 1-palmitate	16.374	2.12
14	Diphenyl sulfone	13.03	1.82
15	Phytol, acetate	12.264	1.81
16	Cholesterol	20.496	1.56
17	γ -Sitosterol	22.684	1.49
18	Pyrimidine, 2-[4-(2-methoxyphenyl)-1-piperazinyl]4,6-dimethyl-	17.518	1.45
19	3-Phenylbicyclo(3.2.2)nona-3,6-dien-2-one	13.352	1.13
20	Daphnetin	12.052	1.07
21	Esculin	12.719	1.02
22	d-Mannose	9.1528	0.85
23	Phenol, 4-(2-propenyl)-	7.4641	0.82
24	Benzofuran, 2,3-dihydro-	7.1197	0.76
25	2'-Ethylpropiophenone	8.5195	0.73
26	1,2-Dimethoxy-4-n-propylbenzene	9.5194	0.67
27	β -Pinene	4.7533	0.57
28	1,3,6-Trioxa-2-silacyclooctane, 2,2,-dimethylsilyl-	7.3085	0.57
29	Octadecane, 3-ethyl-5-(2-ethylbutyl)-	18.485	0.57
30	Diglycerol	4.4867	0.49
31	Stigmasterol	21.918	0.48
32	Benzoic acid, ethyl ester	6.7086	0.46
33	2,3-Dimethylquinolin-4(1H)-one	11.375	0.46
34	4-((1E)-3-Hydroxy-1-propenyl)-2-methoxyphenol	11.619	0.45
35	Supraene	17.974	0.45
36	(R)-(+)-1-Phenyl-1-propanol	6.5198	0.43
37	Spiro[oxirane-2,1'(1'H)-indene], 2',3',3'a,4',7',7'ahexahydro-5'-acetyl-2',3',3'a,7'-tetrahydroxy-4carboxy-, 3,4-lactone	12.8078	0.34

3. Results

GC-MS analysis of samples from both open-field and intercropping conditions of *A. sprengeri* revealed a diverse array of bioactive compounds and phytoconstituents. The identification and confirmation of these phytochemicals were carried out through the assessment of peak areas and the distinctive properties of the detected metabolites. GC-MS analysis of aerial parts of *A. sprengeri* revealed that cultivation under intercropping conditions recorded a higher peak area and retention time compared to open-field cultivation. Additionally, a diverse range of phytochemicals with significant biological properties exhibited variation across both agroclimatic conditions.

3.1 Open field agroecological condition

The chromatogram displayed in Figure 2 exposes peaks of various compounds documented in the GC-MS screening of *A. sprengeri* when cultivated as a sole crop in open field condition. Major phytochemical compounds in this environment includes vitamin E, phytol, 2-methoxy-4-vinylphenol, γ -tocopherol, d-glycero-d-ido-heptose, 9,12-octadecadienoic acid (Z,Z)-, 2-hydroxy-1-(hydroxymethyl) ethyl ester, 2',4'-dimethoxyacetophenone and glycerol 1-palmitate. These compounds had peak areas of 20.63%, 6.74%, 6.21%, 6.02%, 5.33%, 4.56%, 3.84% and 3.58%, respectively. Together, they account for nearly half of the phytochemical profile. An overview of all the secondary metabolites screened, including their peak areas (%) and retention time, is provided in Table 1.

3.2 Intercropping agroecological condition

The growth performance of *A. sprengeri* was found to be superior when intercropped with Allspice (*P. dioica*) compared to its cultivation

under open field conditions and the same trend was observed in its phytochemical profile. Enormous compounds and their peaks were recorded in the chromatogram of *A. sprengeri* cultivated as an intercrop with *P. dioica* (Figure 3). The principle bioactive compounds identified in *A. sprengeri* grown in this system include vitamin E (26.25%), 2-methoxy-4-vinylphenol (7.26%), phytol (6.68%), benzoic acid, 4-ethoxy-, ethyl ester (4.51%), 3',5'-dimethoxyacetophenone (3.97%), γ -Tocopherol (3.97%), linolenic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester (Z, Z, Z) - (3.36%) and eugenol (3.02%). A list of primary phytochemical compounds that make up significant proportions of *A. sprengeri* grown in this system is shown in Table 2.

Several compounds detected in the aerial parts of *A. sprengeri* through GC-MS analysis were found to be common across both agroecological regimes: open field and intercropped condition. These compounds highlight their importance as essential and characteristics constituents of *A. sprengeri* regardless of the cultivation method. These phytochemicals, along with their pharmacological properties, are listed in Table 3. Among them, bioactive compounds such as vitamin E, 2-methoxy-4-vinylphenol, benzoic acid, 4-ethoxy-, ethyl ester, diphenyl sulfone and phytol, acetate were present in higher proportions in *A. sprengeri* grown as an intercrop with Allspice. In contrast, metabolites such as phytol, γ -tocopherol, d-glycero-d-ido-heptose, glycerol 1-palmitate and γ -sitosterol were found in greater amounts when *A. sprengeri* was cultivated as a sole crop under open field agroecological conditions.

Table 3: Common bioactive compounds in *A. sprengeri* grown in both agroecological conditions and their pharmacological significance

S. No.	Compounds	Molecular weight (g/mol)	Peak area (%)		Pharmacological properties	Reference
			Inter-cropping condition	Open field condition		
1	Vitamin E	430.7	26.25	20.63	Antioxidant, anti-inflammatory, neuroprotection, cardiovascular, skin and bone health	Mohd Zaffarin <i>et al.</i> , 2020
2	2-Methoxy-4-vinylphenol	150.17	7.26	6.21	Anti-cancerous	Luo <i>et al.</i> , 2021
3	Phytol	296.5	6.68	6.74	Anti-inflammatory, antiarthritic, antihyperalgesic	Carvalho <i>et al.</i> , 2020
4	Benzoic acid, 4-ethoxy-, ethyl ester	194.23	4.51	2.57	Antimycobacterial	Pais <i>et al.</i> , 2022
5	γ -Tocopherol	416.7	3.97	6.02	Antioxidant, anti-inflammatory	Jiang <i>et al.</i> , 2022
6	d-Glycero-d-ido-heptose	210.18	0.28	5.33	Antibacterial, antifungal, antitumor, pain relief activities	Guo <i>et al.</i> , 2021
7	Glycerol 1-palmitate	330.5	2.12	3.58	Immunomodulatory	Geng <i>et al.</i> , 2023
8	Diphenyl sulfone	218.27	1.82	0.77	Anti-inflammation	Duan <i>et al.</i> , 2019
9	Phytol, acetate	338.6	1.81	0.42	Antimicrobial, antioxidant	Kether <i>et al.</i> , 2012
10	γ -Sitosterol	414.7	1.49	2.15	Antidiabetic	Balamurugan <i>et al.</i> , 2011

4. Discussion

This study revealed a distinct variation in the metabolite composition of *A. sprengeri* between intercropped and open-field cultivation. The intercropping system exhibited a higher peak area percentage, an elevated synthesis of secondary metabolites. This enhancement may be primarily attributed to the ability of plants to produce specialized bioactive compounds, known as allelochemicals, which interact with the environment and exert both beneficial and adverse effects (Maitra *et al.*, 2021). This is further supported by the production of secondary metabolites particularly eugenol, 1-octen-3-ol, linolenic acid and β -pinene in *A. sprengeri* when cultivated as an intercrop under Allspice (*P. dioica*), as they are known to be key phytochemicals in chemo-profile of *P. dioica* (ALrashidi *et al.*, 2022; Padmakumari *et al.*, 2011; Youssef *et al.*, 2021). This response is likely a result of the plant's defence mechanism, as *A. sprengeri* interacts with *P. dioica*. This finding is similar to results reported by (Fyie *et al.*, 2024), where wheat crop produced more fatty acyls and organooxygen compounds when intercropped with sunflower, but not when monocropped. Besides, intercropping improves soil nutrients, leading to better nutrient uptake essential for growth and phytochemical production (Bai *et al.*, 2022; Vasantharaj *et al.*, 2024). Furthermore, shade imparted by *P. dioica* might affect the phytochemical profile of *A. sprengeri* cultivated beneath (Bai *et al.*, 2022). Moreover, *P. dioica* has a rich phytochemical profile and has been utilized in various biological applications and drug development (Khalid and Dharmackan, 2024). It contains phytochemicals such as eugenol and gallic acid, which contribute to its antimicrobial, antioxidant, anti-inflammatory and analgesic effects (Rao *et al.*, 2012). It is traditionally used to alleviate digestive issues, menstrual cramps and respiratory symptoms. Its extracts have shown potential in managing hypertension and possess anticancer properties. Additionally, it is utilized in perfumery and as a natural pesticide (Zhang and Bal, 2012). These multifaceted applications underscore its significance in both traditional medicine and contemporary research, highlighting its potential for further pharmacological exploration.

Pharmacological and therapeutic applications of few medically important compounds present in the *A. sprengeri* are discussed further. Vitamin E, a predominant metabolite in any plant sources, serves as the primary lipid-soluble antioxidant abundantly distributed in body tissues (Zingg, 2015). 2-methoxy-4-vinylphenol (2M4VP) exhibited anticancer effects on pancreatic cancer cell lines Panc-1 and SNU-213 (Kim *et al.*, 2019). The compound phytol displayed similar values under both conditions and has been recognized for its gastroprotective (Araújo *et al.*, 2024) and it helps reduce inflammatory responses in the joints and spinal cord, highlighting its potential as a novel antiarthritic agent (Carvalho *et al.*, 2020). Also, it has been explored as an innovative anticandidal drug delivery system emphasizing its role in treating fungal infections (Lima *et al.*, 2020) and its applications in neurological disorders (da Silva Oliveira and de Freitas, 2014).

Furthermore, γ -tocopherol is a predominant form of vitamin E and have distinctive antioxidant and anti-inflammatory properties (Jiang *et al.*, 2022), which highlights its ability to selectively inhibit the proliferation of cancer cells while preserving healthy ones (Es-Sai *et al.*, 2025). The accumulation of d-glycero-d-ido-heptose was significantly higher under open-field conditions. Heptose-based natural compounds, including septacidin and spicamycin, exhibit notable antifungal, antitumor and analgesic activities (Tang *et al.*,

2018). Glycerol 1-palmitate (1-monopalmitin), a notable glycerolipid, recognized for its ability to induce apoptosis in lung cancer cells, underscoring its potential as a therapeutic agent, particularly against non-small cell lung cancer (NSCLC). Its dual function in regulating both apoptosis and autophagy presents a promising avenue for cancer treatment strategies (Niu *et al.*, 2023). γ -sitosterol is a phytosterol which offers numerous therapeutic potentials and demonstrated anticancer effects by inhibiting cell proliferation and inducing apoptosis in various cancer cell lines, including those of colon, liver, breast and lung cancers (Endrini *et al.*, 2014; Sundarraj *et al.*, 2012). Additionally, it shows antidiabetic properties, effectively lowering blood glucose levels and enhancing insulin secretion in streptozotocin-induced diabetic rats (Balamurugan *et al.*, 2011).

Above all, spirostanosides was reported as the dominant constituents of *A. sprengeri* (Sharma *et al.*, 1983). It possesses anti-inflammatory, antiasthma, anticancer, neuroprotective effects and used to protect against cartilage degradation in conditions like arthritis (Ramalingam and Kim, 2016). In the present study, they were found only under intercropped condition. Poor growth in open field conditions may have impacted the production of secondary metabolites, resulting in relatively lower proportions. Exposure to sunlight beyond the optimum level can have negative impacts, which aligns with the findings showing that shaded conditions increased the production of phytochemicals, particularly phenolics, in lemon balm, enhancing its antioxidant activity (Tmušič *et al.*, 2021).

5. Conclusion

The findings of this GC-MS study underscore the profound impact of agroecological conditions on the phytochemical profile of *A. sprengeri*. Intercropping with *P. dioica* not only enhances the synthesis of valuable bioactive compounds which have diverse pharmacological significance and therapeutic benefits, but also observed to have greater proportions when compared to open field cultivation. These findings pave the way for further research on the manipulation of agroecological factors to enhance the bioactive content of plants, thereby facilitating the development of novel therapeutic agents. Future studies should explore the underlying mechanisms and broader potential of intercropping to optimize plant-based medicinal resources.

Conflict of interest

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

References

- ALrashidi, A. A.; Noumi, E.; Snoussi, M. and De Feo, V. (2022). Chemical composition, antibacterial and antiquorum sensing activities of *Pimenta dioica* L. essential oil and its major compound (eugenol) against foodborne pathogenic bacteria. *Plants*, **11**(4):540. <https://doi.org/10.3390/plants11040540>.
- Araújo, R. P. N.; da Silva Freitas, F. V.; Nunes, D. B.; da Silva Brito, A. K.; da Costa, D. S.; de Sousa, D. P.; de Cássia Meneses Oliveira, R. and Dos Santos, R. F. (2024). Investigating the pharmacological potential of phytol on experimental models of gastric ulcer in rats. *Naunyn-Schmiedeberg's Arch. Pharmacol.*, **397**(10):7757-7766. <https://doi.org/10.1007/s00210-024-03085-9>.
- Asma, A.; Summiya, F. and Wajid, M. (2018). Impact of different environmental temperature on chemical composition of *Asparagus densiflorus sprengeri* L. collected from different areas of Punjab, Pakistan. *J. Biochem. Microb. Toxicol.*, **1**(1):103.

- Bai, Y.-C.; Li, B.-X.; Xu, C.-Y.; Raza, M.; Wang, Q.; Wang, Q.-Z.; Fu, Y.-N.; Hu, J.-Y.; Imoulan, A. and Hussain, M. (2022). Intercropping walnut and tea: Effects on soil nutrients, enzyme activity, and microbial communities. *Front. Microbiol.*, **13**(1):852342. <https://doi.org/10.3389/fmicb.2022.852342>.
- Balamurugan, R.; Durairandiyar, V. and Ignacimuthu, S. (2011). Antidiabetic activity of γ -sitosterol isolated from *Lippia nodiflora* L. in streptozotocin induced diabetic rats. *Eur. J. Pharmacol.*, **667**(1-3):410-418. <https://doi.org/10.1016/j.ejphar.2011.05.025>.
- Carvalho, A. M.; Heimfarth, L.; Pereira, E. W. M.; Oliveira, F. S.; Menezes, I. R.; Coutinho, H. D.; Picot, L.; Antonioli, A. R.; Quintans, J. S. and Quintans-Júnior, L. J. (2020). Phytol, a chlorophyll component, produces antihyperalgesic, anti-inflammatory, and antiarthritic effects: Possible NF κ B pathway involvement and reduced levels of the proinflammatory cytokines TNF- α and IL-6. *J. Nat. Prod.*, **83**(4):1107-1117. <https://doi.org/10.1021/acs.jnatprod.9b01116>.
- Chacha, J. M.; Thirumalai, M.; Mathias, N. M.; Idawa, O. K.; Chilwea, J. P.; Kilamba, C. J.; Hussy, B. D.; Rajendran, K. and Ishaq, H. (2023). Greenhouse and open-field farming: A comparison through yield and growth parameters investigated in Dar es Salaam, Tanzania. *Innov. Agric.*, **6**(1):1-9.
- Coyago-Cruz, E.; Moya, M.; Méndez, G.; Villacís, M.; Rojas-Silva, P.; Corell, M.; Mapelli-Brahm, P.; Vicario, I. M. and Meléndez-Martínez, A. J. (2023). Exploring plants with flowers: From therapeutic nutritional benefits to innovative sustainable uses. *Foods*, **12**(22):4066. <https://doi.org/10.3390/foods12224066>.
- Da Silva Oliveira, J. and de Freitas, R. M. (2014). Phytol a natural diterpenoid with pharmacological applications on central nervous system: A review. *Recent Pat. Biotechnol.*, **8**(3):194-205. <https://doi.org/10.2174/187220830803150605162745>.
- Deka, N. J.; Nath, R.; Tamuly, S.; Hazorika, M.; Pegu, S. R. and Deka, S. M. (2021). Green synthesis and characterization of silver nanoparticles using leaves extract of Neem (*Azadirachta indica* L.) and assessment of its *in vitro* antioxidant and antibacterial activity. *Ann. Phytomed.*, **10**(1):171-177. <http://dx.doi.org/10.21276/ap.2021.10.1.17>.
- Duan, J. J.-W.; Lu, Z.; Jiang, B.; Stachura, S.; Weigelt, C. A.; Sack, J. S.; Khan, J.; Ruzanov, M.; Galella, M. A. and Wu, D.-R. (2019). Structure-based discovery of phenyl (3-phenylpyrrolidin-3-yl) sulfones as selective, orally active ROR α t inverse agonists. *ACS Med. Chem. Lett.*, **10**(3):367-373. <https://doi.org/10.1021/acsmchemlett.9b00010>.
- Endrini, S.; Rahmat, A.; Ismail, P. and Taufiq-Yap, Y. H. (2014). Cytotoxic effect of α -sitosterol from Kejibeling (*Strobilanthes crispus*) and its mechanism of action towards c-myc gene expression and apoptotic pathway. *Med. J. Indones.*, **23**(4):203-208. <https://doi.org/10.13181/mji.v23i4.1085>.
- Es-Sai, B.; Wahnou, H.; Benayad, S.; Rabbaa, S.; Laaziouez, Y.; El Kebbj, R.; Limami, Y. and Duval, R. E. (2025). Gamma-tocopherol: A comprehensive review of its antioxidant, anti-inflammatory, and anticancer properties. *Molecules*, **30**(3):653. <https://doi.org/10.3390/molecules30030653>.
- Fyie, J. Q.; Stratton, C. A.; Morrison, W. R. and Murrell, E. G. (2024). Intercropping alters phytochemical defenses against insect herbivory. *Research Square*, **3**(1):4920649. <https://doi.org/10.21203/rs.3.rs-4920649/v1>.
- Geng, Q.; Liu, B.; Cao, Z.; Li, L.; Lu, P.; Lin, L.; Yan, L. and Lu, C. (2023). Ethnobotany, phytochemistry and pharmacological properties of *Fagopyri Dibotryis Rhizoma*: A review. *Front. Pharmacol.*, **14**(1):1095554. <https://doi.org/10.3389/fphar.2023.1095554>.
- Gilman, E.; Klein, R. W. and Hansen, G. (2018). *Asparagus densiflorus 'Sprengeri'* Sprengeri *Asparagus* Fern: FPS051/FP051, 8/2018. EDIS, **2018**(5):1-3. <https://doi.org/10.32473/edis-fp051-1999>.
- Guo, Z.; Tang, Y.; Tang, W. and Chen, Y. (2021). Heptose-containing bacterial natural products: structures, bioactivities, and biosyntheses. *Nat. Prod. Rep.*, **38**(10):1887-1909. <https://doi.org/10.1039/D0NP00075B>.
- Hassan, R. A.; Tawfeek, W. A.; Habeeb, A. A.; Mohamed, M. S. and Abdelshafeek, K. A. (2014). Investigation of some chemical constituents and antioxidant activity of *Asparagus sprengeri*. *Int. J. Pharm. Pharm. Sci.*, **6**(11):46-51.
- Jiang, Q.; Im, S.; Wagner, J. G.; Hernandez, M. L. and Peden, D. B. (2022). Gamma-tocopherol, a major form of vitamin E in diets: Insights into antioxidant and anti-inflammatory effects, mechanisms, and roles in disease management. *Free Radic. Biol. Med.*, **178**(1):347-359. <https://doi.org/10.1016/j.freeradbiomed.2021.12.012>.
- Kadhim, E. J. and Salah, Z. (2014). Phytochemical investigation & antibacterial activity of the essential oils from two species of *Asparagus* (*Asparagus officinalis* and *Asparagus sprengeri*) family Liliaceae cultivated in Iraq. *Int. J. Compr. Pharm.*, **5**(3):1.
- Kether, F. B. H.; Mahjoub, M. A.; Mahjoub, S. A.; Salah, K. B.; Helal, A. N. and Mighri, Z. (2012). Chemical composition, *in vitro* antifungal and antioxidant activities of essential oil from *Cotula coronopifolia* L. growing in Tunisia. *Afr. J. Microbiol. Res.*, **6**(20):4388-4395. <https://doi.org/10.5897/AJMR11.259>.
- Khalid, I. M. and Dharmackan, J. (2024). Study on the therapeutic potential of *Pimenta dioica* phytochemicals isolated from stem extract and its analysis through GC-MS profiling. *Asian J. Biol. Life Sci.*, **13**(1):90-99. <https://doi.org/10.5530/ajbls.2024.13.1.3>.
- Kim, D. A.-H.; Han, S.-I.; Go, B.; Oh, U. H.; Kim, C.-S.; Jung, Y.-H.; Lee, J. and Kim, J.-H. (2019). 2-methoxy-4-vinylphenol attenuates migration of human pancreatic cancer cells *via* blockade of FAK and AKT signaling. *Anticancer Res.*, **39**(12):6685-6691. <https://doi.org/10.21873/anticancer.13883>.
- Kulkarni, D. A.; Zambare, A. V.; Srivastava, H. and Patole, M. B. (2024). Study of response of chilli under shade net and open field cultivation. *Int. J. Creat. Res. Thoughts*, **12**(8):975-982.
- Licata, M.; Maggio, A. M.; La Bella, S. and Tuttolomondo, T. (2022). Medicinal and aromatic plants in agricultural research, when considering criteria of multifunctionality and sustainability. *Agriculture*, **12**(4):529. <https://doi.org/10.3390/agriculture12040529>.
- Lima, T. L. C.; Souza, L. B. F. C.; Tavares-Pessoa, L. C. S.; Santos-Silva, A. M. d.; Cavalcante, R. S.; Araújo-Júnior, R. F. d.; Cornélio, A. M.; Fernandes-Pedrosa, M. F.; Chaves, G. M. and Silva-Júnior, A. A. d. (2020). Phytol-loaded solid lipid nanoparticles as a novel anticandidal nanobiotechnological approach. *Pharmaceutics*, **12**(9):871. <https://doi.org/10.3390/pharmaceutics12090871>.
- Luo, Y.; Wang, C.-Z.; Sawadogo, R.; Yuan, J.; Zeng, J.; Xu, M.; Tan, T. and Yuan, C.-S. (2021). 4-Vinylguaiaicol, an active metabolite of ferulic acid by enteric microbiota and probiotics, possesses significant activities against drug-resistant human colorectal cancer cells. *ACS omega*, **6**(7):4551-4561. <https://doi.org/10.1021/acsomega.0c04394>.
- Maitra, S.; Hossain, A.; Brestic, M.; Skalicky, M.; Ondrisik, P.; Gitari, H.; Brahmachari, K.; Shankar, T.; Bhadra, P.; Palai, J. B.; Jena, J.; Bhattacharya, U.; Duvvada, S. K.; Lalichetti, S. and Sairam, M. (2021). Intercropping-A low input agricultural strategy for food and environmental security. *Agronomy*, **11**(2):343. <https://doi.org/10.3390/agronomy11020343>.
- Mohammadi Bazargani, M.; Falahati-Anbaran, M. and Rohloff, J. (2021). Comparative analyses of phytochemical variation within and between congeneric species of willow herb, *Epilobium hirsutum* and *E. parviflorum*: Contribution of environmental factors. *Front.*

- Plant Sci., **11**(1):595190. <https://doi.org/10.3389/fpls.2020.595190>.
- Mohd Zaffarin, A. S.; Ng, S.-F.; Ng, M. H.; Hassan, H. and Alias, E. (2020). Pharmacology and pharmacokinetics of vitamin E: Nano-formulations to enhance bioavailability. *Int. J. Nanomed.*, **15**(1):9961-9974.
- Negi, J. S.; Singh, P.; Joshi, G. P.; Rawat, M. S. and Bisht, V. K. (2010). Chemical constituents of *Asparagus*. *Pharmacogn. Rev.*, **4**(8):215-220. <https://doi.org/10.4103/0973-7847.70921>.
- Niu, L.; Li, W.; Chen, X.; Su, X.; Dong, J.; Liao, Q.; Zhou, X.; Shi, S. and Sun, R. (2023). 1 Monopalmitin promotes lung cancer cells apoptosis through PI3K/Akt pathway *in vitro*. *Environ. Toxicol.*, **38**(11):2621-2631. <https://doi.org/10.1002/tox.23897>.
- Padmakumari, K. P.; Sasidharan, I. and Sreekumar, M. M. (2011). Composition and antioxidant activity of essential oil of pimento (*Pimenta dioica* (L) Merr.) from Jamaica. *Nat. Prod. Res.*, **25**(2):152-160. <https://doi.org/10.1080/14786419.2010.526606>.
- Pais, J. P.; Magalhães, M.; Antoniuk, O.; Barbosa, I.; Freire, R.; Pires, D.; Valente, E.; Testa, B.; Anes, E. and Constantino, L. (2022). Benzoic acid derivatives as prodrugs for the treatment of tuberculosis. *Pharmaceuticals*, **15**(9):1118. <https://doi.org/10.3390/ph15091118>.
- Pegiou, E.; Mumm, R.; Acharya, P.; de Vos, R. C. H. and Hall, R. D. (2019). Green and white asparagus (*Asparagus officinalis*): A source of developmental, chemical and urinary intrigue. *Metabolites*, **10**(1):17. <https://doi.org/10.3390/metabo10010017>.
- Rajni; Rani, V.; Sindhu, S. C. and Neha. (2023). Nutritional analysis of *Asparagus racemosus* (Willd.) root powder and its efficacy in increasing prolactin level in lactating women. *Ann. Phytomed.*, **12**(2):912-917. <http://dx.doi.org/10.54085/ap.2023.12.2.108>.
- Ramalingam, M. and Kim, S.-J. (2016). Pharmacological activities and applications of Spicatoside A. *Biomol. Ther.*, **24**(5):469-474. <https://doi.org/10.4062/biomolther.2015.214>.
- Rao, P. S.; Navinchandra, S. and Jayaveera, K. N. (2012). An important spice, *Pimenta dioica* (Linn.) Merrill: A review. *Int. Curr. Pharm. J.*, **1**(8):221-225. <https://doi.org/10.3329/icpj.v1i8.11255>.
- Sharma, S. C.; Sharma, R. and Kumar, R. (1983). Spirostanosides of *Asparagus sprengeri*. *Phytochemistry*, **22**(10):2259-2262.
- Sobhy, Y.; Mahgoub, S.; Abo zeid, Y.; Mina, S. A. and Mady, M. S. (2024). *In vitro* cytotoxic and anti-inflammatory potential of *Asparagus densiflorus* Meyer and its phytochemical investigation. *Chem. Biodivers.*, **21**(11):e202400959. <https://doi.org/10.1002/cbdv.202400959>.
- Srivastava, P. L.; Shukla, A. and Kalunke, R. M. (2018). Comprehensive metabolic and transcriptomic profiling of various tissues provide insights for saponin biosynthesis in the medicinally important *Asparagus racemosus*. *Sci. Rep.*, **8**(1):9098. <https://doi.org/10.1038/s41598-018-27440-y>.
- Sundarraj, S.; Thangam, R.; Sreevani, V.; Kaveri, K.; Gunasekaran, P.; Achiraman, S. and Kannan, S. (2012). γ -sitosterol from *Acacia nilotica* L. induces G2/M cell cycle arrest and apoptosis through c-Myc suppression in MCF-7 and A549 cells. *J. Ethnopharmacol.*, **141**(3):803-809. <https://doi.org/10.1016/j.jep.2012.03.014>.
- Tang, W.; Guo, Z.; Cao, Z.; Wang, M.; Li, P.; Meng, X.; Zhao, X.; Xie, Z.; Wang, W. and Zhou, A. (2018). d-Sedoheptulose-7-phosphate is a common precursor for the heptoses of septacidin and hygromycin B. *Proc. Natl. Acad. Sci.*, **115**(11):2818-2823. <https://doi.org/10.1073/pnas.1711665115>.
- Tmušić, N.; Ilić, Z. S.; Milenković, L.; Šunja, L.; Lalević, D.; Kevrešan, Ž.; Mastilović, J.; Stanojević, L. and Cvetković, D. (2021). Shading of medical plants affects the phytochemical quality of herbal extracts. *Horticulturae*, **7**(11):437. <https://doi.org/10.3390/horticulturae7110437>.
- Youssef, F. S.; Labib, R. M.; Gad, H. A.; Eid, S.; Ashour, M. L. and Eid, H. H. (2021). *Pimenta dioica* and *Pimenta racemosa*: GC-based metabolomics for the assessment of seasonal and organ variation in their volatile components, *in silico* and *in vitro* cytotoxic activity estimation. *Food Funct.*, **21**(12):5247-5259. <https://doi.org/10.1039/D1FO00408E>.
- Zhang, L. and Bal, L. L. (2012). Medicinal properties of the Jamaican pepper plant *Pimenta dioica* and Allspice. *Curr. Drug Targets*, **13**(14):1900-1906. <https://doi.org/10.2174/138945012804545641>.
- Zingg, J.-M. (2015). Vitamin E: a role in signal transduction. *Annu. Rev. Nutr.*, **35**(1):135-173. <https://doi.org/10.1146/annurev-nutr-071714-034347>.

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