Exploration of Drug Science

Open Exploration

Open Access Review

Critical review on nutritional, bioactive and medicinal potential of *Bunium persicum*

Prachi Bhatt, Sonal Pant, Shaifali Bhardwaj, Samna Sneha, Priyanshu Dobhal, Mamta Baunthiyal*

Department of Biotechnology, Govind Ballabh Pant Institute of Engineering and Technology, Pauri 246194, Uttarakhand, India

***Correspondence:** Mamta Baunthiyal, Department of Biotechnology, Govind Ballabh Pant Institute of Engineering and Technology, Pauri 246194, Uttarakhand, India. mamtabaunthiyal@yahoo.co.in

Academic Editor: Fernando Albericio, University of KwaZulu-Natal, South Africa, Universidad de Barcelona, Spain
Received: October 24, 2024 **Accepted:** January 16, 2025 **Published:** February 27, 2025

Cite this article: Bhatt P, Pant S, Bhardwaj S, Sneha S, Dobhal P, Baunthiyal M. Critical review on nutritional, bioactive and medicinal potential of *Bunium persicum*. Explor Drug Sci. 2025;3:100893. https://doi.org/10.37349/eds.2025.100893

Abstract

Bunium persicum Boiss. Fedtsch., a highly valued spice crop from the Apiaceae family, is renowned for its rich phytochemical profile, including compounds such as cuminaldehyde, α-terpinene-7-al, γ-terpinene-7-al, γ-terpinene, p-cymene, and β-pinene. These bioactive constituents contribute to its diverse therapeutic properties, including antioxidant, antimicrobial, anti-inflammatory, lipid and glucose-lowering, and anti-carcinogenic activities. Due to its limited growth in specific wild regions and over-exploitation, *B. persicum* faces significant conservation challenges, both in vitro and in situ. In India, its primary hotspots are in Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. This review provides a comprehensive examination of *B. persicum*'s functional properties, with a focus on its traditional uses, phytochemistry, and pharmacological activities, highlighting the need for its conservation and sustainable use.

Keywords

Bunium persicum, bioactive compound, cuminaldehyde, essential oils

Introduction

Bunium persicum Boiss. Fedtsch., commonly referred to as black cumin or black caraway, is a lesser-known but significant medicinal, aromatic, and culinary spice belonging to the family Apiaceae. Native to Western Asia, this species is primarily found in the dry temperate regions of the Western Himalayan zone in India, where it is locally known as Kala Jeera. The high-altitude regions of Jammu and Kashmir, Himachal Pradesh, and the Almora hills of Uttarakhand are key centers for its cultivation in India [1, 2].

Among the prominent regions for *B. persicum* cultivation in the northwestern Himalayas, the Gurez valley, situated along the Indo-Pakistan border, is a major production area in Jammu and Kashmir. While *B. persicum* is a distinct species, variation in its cultivation methods and local nomenclature exists across different regions [3, 4].

In India, several related species or varieties of *Bunium* are recognized, including:

1. ***B. persicum*** (Kala Jeera): The most commonly known and utilized species, particularly in Kashmir and Himachal Pradesh.
2. ***Bunium bulbocastanum*** (earthnut or great pignut): Although distinct from *B. persicum*, it is a related species and is sometimes used similarly in traditional medicinal practices.
3. ***Bunium elegans***: A less well-known species, which also occurs in similar high-altitude regions but is not as widely used or studied as *B. persicum*.

These species share ecological niches but vary in their regional importance and applications in traditional medicine, as well as in the local agricultural practices surrounding their cultivation [5, 6].

In Uttarakhand, *B. persicum* is primarily cultivated in its typical form without any officially recognized distinct varieties [6]. Differences can be caused by environmental factors such as altitude, microclimate conditions, and soil type, these differences do not classify them as separate species. Due to its niche-specific characteristics, the state of Himachal Pradesh has granted *B. persicum* geographical indication (GI) protection under GI number 432, recognizing its unique geographical and botanical attributes (Table 1).

Table 1. *Bunium persicum* hotspot regions in North Himalayan region [7]

States of India		
Jammu and Kashmir	**Himachal Pradesh**	**Uttarakhand**
Kupwara	Lahaul	Uttarkashi
Bandipore	Spiti	Pithoragarh
Kishtwar	Kinnaur	Pauri Garhwal
Rajouri	Shimla	Almora
Jammu	Una	
Samba	Kangra	

One of the major limitations to the commercial cultivation of *B. persicum* is its extended life cycle. The plant's slow growth and long maturation period have deterred widespread farming, contributing to a decline in its cultivation. Consequently, the species is facing a concerning depletion in its natural habitats, leading to its inclusion in the list of endangered species [8, 9].

B. persicum is often mistakenly known as *Nigella sativa* or *Carum carvi*, however, it has been the focus of extensive phytochemical studies. The seed and fruit extracts of *B. persicum* have demonstrated a variety of bioactive properties, including antimicrobial, antioxidant, anti-inflammatory, and antidiabetic effects. This positions the plant as a potential natural antioxidant and preservative for application in various food systems [10, 11].

Although previous reviews have covered the medicinal properties of *B. persicum*, this review aims to provide a comprehensive, updated analysis of its morphological, biochemical, and molecular characteristics [12]. Additionally, it explores its phytochemical profile, novel food applications, and therapeutic potential, offering valuable insights for consumers, as well as the food and pharmaceutical industries. The review also highlights critical areas requiring policy intervention to ensure the conservation and sustainable use of this valuable species [13, 14].

Ethnobotanical knowledge

B. persicum belongs to the family Apiaceae or Umbelliferae. Apiaceae family consists of 423 genera, which are herbs, shrubs, trees, and some aromatics. *Bunium* consist of 166 species. *B. persicum* is a perennial herbaceous geophyte that generally grows to a height of 30–40 cm [15]. This plant grows primarily in high-altitude regions and is a geophyte, meaning it stores nutrients in underground structures such as tubers, allowing it to survive harsh environmental conditions [16]. The stems are hollow between the nodes and

house secretory vessels that produce oils and resins. The plant's inflorescence, part of the Apiaceae family, consists of a single, convex, or flat-topped flower head. The roots and seeds are used as spices that provide flavor for the food. It is used in a way that gives taste to food. These brown fruits are round in shape and hot in taste [17].

Traditional uses of *B. persicum*

B. persicum seeds are traditionally used in the treatment of digestive problems and urinary problems, and are well recognized in Iranian folk medicine for their diarrhea-relief, respiratory aid, anti-parasitic, and analgesic (anti-nociceptive) properties [18]. The fruits of *B. persicum* are also traditionally employed to treat flatulence, spasms, menstrual pain, and infections due to their antimicrobial effects. However, their use in pregnant women is strictly limited as they may induce abortion [19].

In Kashmir (India), *B. persicum* is used as an alternative to *Carum carvi* (Caraway), which is commonly used to treat menstrual disorders, anorexia, skin conditions, and leucorrhoea. The literature also highlights various therapeutic uses of its seeds, such as antispasmodic and anti-epileptic effects, as well as promoting lactation and lowering blood lipids and lipid levels [20, 21].

In the remote areas of Jammu and Kashmir, and Uttarakhand (India), *B. persicum* seeds are traditionally used to treat diarrhea, indigestion, and dysentery. Additionally, its fruits are considered effective in treating hematomas, dysuria, kidney stones, and hiccups, and are utilized for managing obesity and digestive issues [22]. The fruits are valued for their role as flavoring agents, galactagogues, carminatives, calmatives, and appetite stimulants (Table 2).

Table 2. Most important *Bunium* species and its traditional pharmacological uses

Species	Distributed countries	Traditional uses	Phytochemicals	References
Bunium persicum	Iran, Afghanistan, India, Pakistan, Türkiye	Spice for flavoring; digestive aid; antimicrobial; diuretic; used in colds, respiratory ailments, and indigestion	Carvone, limonene, thymol	[23]
Bunium bulbocastanum	Europe (Spain, France, Italy), North Africa	Tuber consumed as a food source; anti-inflammatory; antispasmodic; analgesic; detoxifying agent	Coumarins, flavonoids, terpenes	[24]
Bunium incrassatum	Morocco, Algeria, Tunisia	Tubers consumed as food; used in traditional medicine for diuretic and detoxification properties	Essential oils, phenolic compounds	[25]
Bunium elegans	Türkiye, Eastern Mediterranean	Carminative; antimicrobial; spice in local cuisines; used for skin infections and inflammation	Terpenoids, flavonoids, polyphenols	[26]
Bunium alpinum	Alpine regions of Europe	Tubers as food; used for gastrointestinal issues and rheumatic pain relief	Flavonoids, tannins, saponins	[27]
Bunium paucifolium	India, Pakistan, Central Asia	Spice for flavoring; used for digestive disorders and respiratory health	Essential oils, polyacetylenes, monoterpenes	[28]
Bunium mauritanicum	North Africa (Morocco, Algeria)	Tuberous roots consumed; believed to boost energy; used for urinary tract health	Alkaloids, phenolics, tannins	[29]

Nutritional potential of *B. persicum*

B. persicum presents a diverse and rich nutritional profile, making it an important food ingredient with potential health benefits. Its moderate carbohydrate content, essential fatty acids, mineral richness, and the presence of vital vitamins, amino acids, and fibers make it a valuable addition to a balanced diet. Regular consumption of black cumin could contribute to improved cardiovascular health, digestive function, immune response, and overall well-being, especially when used in conjunction with other healthy dietary habits [30–35].

1. **Carbohydrates (35–40%)**: *B. persicum* is moderately rich in carbohydrates, which contribute to its energy value. Carbohydrates found in black cumin consist of polysaccharides and simple sugars, which provide a quick source of energy, e.g., glucose, fructose.

2. **Fatty acids (10–12%)**: Though *B. persicum* is not particularly high in fats, the seeds contain essential fatty acids. The presence of unsaturated fatty acids makes black cumin oil a valuable addition to the diet, contributing to the regulation of lipid metabolism and maintaining healthy cholesterol levels, e.g., linoleic acid, oleic acid.
3. **Minerals**: *B. persicum* is an excellent source of various essential minerals, including:
    - Iron (3–5%)
    - Calcium (6–9%)
    - Magnesium (2–4%)
    - Potassium (2–5%)
    - Phosphorus (1–3%)
4. **Vitamins**: The seeds of *B. persicum* are packed with vitamins, especially those with antioxidant properties. Key vitamins include:
    - Vitamin C
    - Vitamin A
    - B-vitamins (B1, B2, and B3)
5. **Amino acids**: Black cumin seeds are an important source of amino acids, including essential ones that the body cannot synthesize. These include lysine, methionine, tryptophan, and phenylalanine, which are crucial for protein synthesis, tissue repair, and various metabolic processes.
6. **Dietary fibers (20–25%)**: The fiber content in *B. persicum* is substantial, which plays an important role in digestive health. The seeds contain both soluble and insoluble fibers:
    - Soluble fiber helps regulate blood sugar levels and reduce cholesterol by absorbing water in the digestive tract.
    - Insoluble fiber contributes to bowel regularity, preventing constipation and promoting healthy gut bacteria growth.

Dietary fiber also has a prebiotic effect, fostering the growth of beneficial bacteria in the gut, which in turn supports better digestion and nutrient absorption.

Bioactive potential of *B. persicum*

Bioactive compounds found in *B. persicum* contribute significantly to its medicinal and therapeutic properties. These compounds are responsible for various biological activities (Table 3) [36–39].

1. **Antioxidant activity**: The seeds are rich in phenolic compounds and flavonoids, both of which are potent antioxidants. These compounds play a key role in scavenging free radicals, reducing oxidative stress, and preventing cellular damage caused by oxidative reactions. The high antioxidant activity makes black cumin a promising agent for preventing degenerative diseases, including cancer, cardiovascular diseases, and neurodegenerative conditions like Alzheimer's.
    - Phenolic compounds such as quercetin, kaempferol, and other flavonoids are the major contributors to the antioxidant profile.
2. **Antimicrobial and antifungal activity**: *B. persicum* has demonstrated significant antimicrobial properties, making it an effective agent against a broad spectrum of bacteria, fungi, and even some viruses. The essential oils (EOs) and extracts of black cumin seeds have been found to exhibit strong inhibitory effects against pathogenic microorganisms, such as *Escherichia coli*, *Staphylococcus aureus*, *Candida albicans*, and *Aspergillus niger*.

- Thymol and carvacrol, key components of *B. persicum* EOs, are primarily responsible for its antimicrobial activity. These bioactive compounds disrupt microbial cell membranes, leading to the inhibition of their growth and proliferation.

3. **Anti-inflammatory properties**: Chronic inflammation is linked to numerous diseases, including arthritis, cardiovascular disorders, and cancer. *B. persicum* has been shown to have strong anti-inflammatory activity. This is associated with the presence of compounds such as flavonoids and terpenoids, which inhibit the production of pro-inflammatory substances such as prostaglandins and cytokines.
    - Terpenes like p-cymene and β-pinene found in black cumin oil have shown significant effects in reducing inflammatory responses, making it a useful agent in managing inflammatory conditions.
4. **Anti-carcinogenic and anti-tumor activity**: In vitro studies have suggested that extracts from black cumin seeds suppress the growth of cancer cells and trigger apoptosis (programmed cell death) in multiple cancer cell lines, including colon and breast cancer cells.
    - Thymoquinone, a bioactive compound present in *B. persicum*, is especially noted for its anti-tumor properties.
5. **Gastroprotective activity**: The bioactive compounds in *B. persicum* also contribute to its gastroprotective properties. Traditional medicine has used black cumin to treat various gastrointestinal disorders such as indigestion, bloating, and stomach ulcers.
    - EOs in the seeds have been shown to possess anti-ulcer activity, potentially offering protection against conditions like gastric ulcers induced by stress or medication [such as non-steroidal anti-inflammatory drugs (NSAIDs)].
6. **Cardioprotective effects**: Cardiovascular health can benefit significantly from the bioactive components in *B. persicum*. Studies indicate that the antioxidant and anti-inflammatory compounds in black cumin help improve lipid profiles by lowering low-density lipoprotein (LDL) and increasing high-density lipoprotein (HDL).
    - Flavonoids and polyphenolic compounds found in black cumin seeds are key players in enhancing cardiovascular protection by reducing oxidative stress and inflammation that can damage heart tissues.
7. **Anti-diabetic and metabolic benefits**: Several studies have demonstrated that *B. persicum* has potential anti-diabetic effects by improving insulin sensitivity and reducing blood sugar levels. The seed extract appears to help regulate glucose metabolism and may offer therapeutic benefits for individuals with type 2 diabetes.
    - Flavonoids and other bioactive compounds in black cumin appear to influence glucose uptake and insulin secretion, making it a promising supplement for managing diabetes and related metabolic disorders.
8. **Neuroprotective potential**: Emerging research suggests that *B. persicum* may possess neuroprotective properties due to its high antioxidant content by reducing oxidative damage and inflammation in neural tissues. Although, some of the bioactive compounds in black cumin seeds have shown potential for improving memory and cognitive function, making it a promising natural agent for supporting brain health.

Recent GC-MS analyses have identified novel bioactive constituents in *B. persicum* EOs, such as dihydrocarvone and bornyl acetate, which show promising anti-inflammatory and antimicrobial activities [54].

Table 3. The main bioactive components of the *Bunium persicum* extract/essential oil and their structures (https://pubchem.ncbi.nlm.nih.gov/)

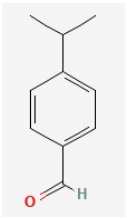
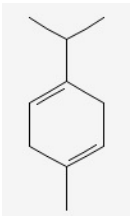
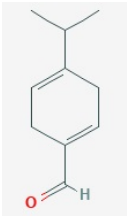
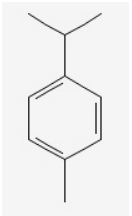
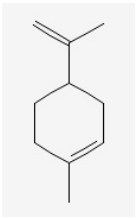
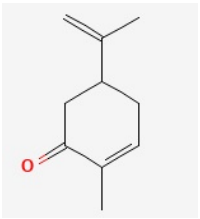
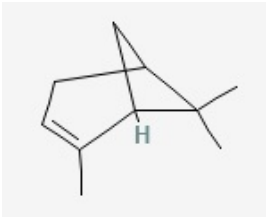
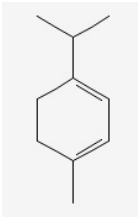
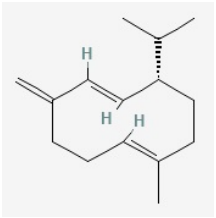
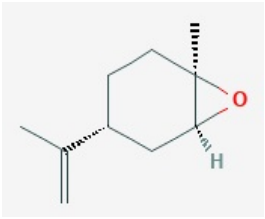
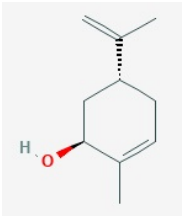
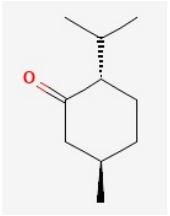
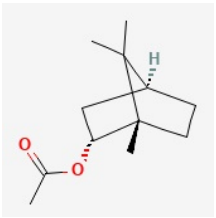
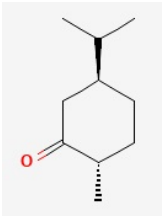
S.No.	Compound name	GC-MS data (%)	Compound structure	PubChem CID	References
1	Cuminaldehyde	27.80–5.96		326	[40]
2	γ-Terpinene	19.20–10.50		7461	[41]
3	γ-Terpinene-7-al	19.20–9.40		6429112	[42]
4	p-Cymene	15.90–4.31		7463	[43]
5	Limonene	48.40–4.42		22311	[44]
6	Carvone	78.80–23.30		7439	[45]
7	α-Pinene	11.27–2.37		6654	[46]
8	α-Terpinene	11.13–7.30		7462	[47]

Table 3. The main bioactive components of the *Bunium persicum* extract/essential oil and their structures (https://pubchem.ncbi.nlm.nih.gov/) (*continued*)

S.No.	Compound name	GC-MS data (%)	Compound structure	PubChem CID	References
9	Germacrene D	16.20		5317570	[48]
10	*cis*-Limonene oxide	1.80		6857487	[49]
11	*trans*-Carveol	1.30		94221	[50]
12	Menthone	1.20		26447	[51]
13	Bornyl acetate	2.90		93009	[52]
14	*trans*-Dihydrocarvone	14		6432474	[53]

Discussion

The present review summarizes the ethnobotanical uses, phytochemical composition, and medicinal properties of *B. persicum*. The traditional uses of its seeds, roots, and EOs are corroborated by modern scientific evidence, highlighting its therapeutic potential [54].

This plant is used in treating a wide range of conditions, including neurological disorders, gastrointestinal diseases, respiratory issues, cardiovascular dysfunctions, microbial infections, and urinary tract diseases.

Furthermore, its beneficial effects in diabetes management are supported by its antioxidant, hypoglycemic, antihyperlipidemic, α-amylase inhibitory, and insulin secretion-enhancing activities.

Advances in molecular studies have elucidated the mechanisms through which *B. persicum* compounds modulate inflammatory pathways and cellular oxidative stress [55].

Moreover, the integration of *B. persicum* into functional foods and nutraceuticals has been gaining traction due to its broad spectrum of health benefits. This dual role in enhancing food safety and delivering therapeutic benefits positions *B. persicum* as a valuable ingredient in the functional food industry.

The antimicrobial properties of *B. persicum* are driven by key secondary metabolites such as thymol and carvacrol. These terpenoids disrupt microbial cell membranes, leading to growth inhibition of pathogens such as *Escherichia coli* and *Staphylococcus aureus*. These findings align with the observed traditional use of *B. persicum* in treating infections and preserving food products. However, the variability in antimicrobial activity across different plant populations underscores the influence of environmental and genetic factors on phytochemical composition [56].

In a present study, the methanolic extracts of *B. persicum* were found to have 683 anti-inflammatory effects by blocking albumin denaturation that contributes to the 684-inflammation process [57]. The EO was obtained from leaves and its constituents were identified using GC-MS analysis. Then, the antifungal ability of the EO and its main constituents against *Colletotrichum lindemuthianum* was investigated using in vitro and in vivo assays. The effects of the EO and its main constituents on cell wall degrading enzymes (CWDEs) activity such as pectinase, cellulase, and xylanase, as well as part of the mechanisms involved in the infection process of this fungus, were demonstrated. On the other hand, the anti-glycation potential of polyphenol-rich plant extracts has been shown previously and *B. persicum* has been demonstrated to possess a high level of polyphenols; so, *B. persicum* hydroalcoholic extract has a good effect on diabetic disease. Moreover, the abortive property might be due to estrogenic and uterine tonic activities.

Phenolic compounds, including caffeic acid and p-coumaric acid, are identified as key contributors to antioxidant and anti-tyrosinase activities. Flavonoids are noted for their roles in providing antioxidant, anti-diabetic, analgesic, anti-inflammatory, and antiulcerogenic effects. Additionally, terpenoids such as p-cymene and γ-terpinene demonstrate analgesic and antimicrobial properties. Cuminaldehyde is associated with various biological functions, while alkaloids exhibit potential anti-hemotoxic effects.

The selection of desired genotypic traits can enhance the efficiency and productivity of species while ensuring their preservation for future generations, particularly as human activities increasingly threaten overall genetic diversity [58].

Recent studies have identified promising antioxidant, anti-inflammatory, and antimicrobial properties in *B. persicum*, positioning it as a potential candidate for developing natural therapeutics. The plant's bioactive compounds have shown efficacy in managing metabolic disorders, such as diabetes and hyperlipidemia, which are of growing concern in modern healthcare.

Conclusion

B. persicum is a highly valued spice and medicinal plant, recognized for its rich phytochemical composition and diverse bioactive properties. It holds significant promise in traditional and modern medicine, with applications ranging from antimicrobial to metabolic disorder management. Further research and sustainable cultivation practices are essential to preserve its therapeutic potential and promote its integration into functional foods and nutraceuticals.

Future prospect

Despite these findings, a significant gap remains in the isolation and characterization of many bioactive constituents responsible for its health related uses. Moreover, in-depth clinical trials are essential to validate its safety and efficacy for human applications, further research must be focused on:

1. Isolating and characterizing unexplored bioactive compounds in *B. persicum*, particularly those linked to its traditional therapeutic applications.

2. Conducting mechanistic studies to understand the molecular pathways through which these compounds exert their pharmacological effects.
3. Undertaking preclinical and clinical trials to assess the safety, efficacy, and potential therapeutic uses of *B. persicum* extracts, especially in treating metabolic disorders, gastrointestinal diseases, and inflammatory conditions.
4. Potential interactions with conventional drugs, highlighting the need for toxicological assessments, particularly for chronic use.
5. Exploring synergistic effects of *B. persicum* compounds with conventional therapies, opening avenues for integrative medicine approaches.
6. Conducting computational studies specifically focusing on the plant's full range of pharmacological activities.

Thus, *B. persicum* holds great potential for modern medicine, and exploring its bioactive constituents could lead to the discovery of novel, natural therapeutic agents to address the growing challenges of metabolic, inflammatory, and microbial diseases.

Abbreviations

B. persicum: *Bunium persicum*

EO: essential oil

Declarations

Acknowledgments

We sincerely thank our institution and colleagues for their support and guidance during the preparation of this review. Additionally, we acknowledge the authors of the studies referenced in this paper for their valuable contributions to the field.

Author contributions

PB: Conceptualization, Investigation, Writing—original draft. SP, SB, SS, and PD: Data curation, Formal analysis, Writing—review & editing. MB: Supervision, Writing—review & editing.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent to publication

Not applicable.

Availability of data and materials

Not applicable.

Funding

Not applicable.

Publisher's note

References

1. Abbasi B, Daniali M, Ramezani H, Derakhshande M, Ghiasvand R. The Effect of *Bunium persicum* on Gastrointestinal Symptoms and Inflammatory Mediators in Irritable Bowel Syndrome Patients. Food Health. 2018;1:43–6.
2. Abbassi A, Mahmoudi H, Zaouali W, M'Rabet Y, Casabianca H, Hosni K. Enzyme-aided release of bioactive compounds from coriander (*Coriandrum sativum* L.) seeds and their residue by-products and evaluation of their antioxidant activity. J Food Sci Technol. 2018;55:3065–76. [DOI] [PubMed] [PMC]
3. Amber R, Adnan M, Tariq A, Khan SN, Mussarat S, Hashem A, et al. Antibacterial activity of selected medicinal plants of northwest Pakistan traditionally used against mastitis in livestock. Saudi J Biol Sci. 2018;25:154–61. [DOI] [PubMed] [PMC]
4. Khan MA, Altaf S, Shafi S, Bhat BA, Dar WA, Parry FA, et al. Exploration, Collection and Characterization of Kala zeera (Bunium persicum Boiss. Fedtsch.) Germplasm from North-Western Himalayas. Research Square [Preprint]. 2021. Available from: https://doi.org/10.21203/rs.3.rs-488157/v1
5. Bansal S, Sharma K, Gautam V, Lone AA, Malhotra EV, Kumar S, et al. A Comprehensive Review of Bunium persicum: A Valuable Medicinal Spice. Food Rev Int. 2023;39:1184–202. [DOI]
6. Ehsani A, Hashemi M, Naghibi SS, Mohammadi S, Sadaghiani SK. Properties of *Bunium Persicum* Essential Oil and its Application in Iranian White Cheese Against *Listeria Monocytogenes* and *Escherichia Coli O157:H7*. J Food Saf. 2016;36:563–70. [DOI]
7. Chizzola R, Saeidnejad AH, Azizi M, Oroojalian F, Mardani H. *Bunium persicum*: variability in essential oil and antioxidants activity of fruits from different Iranian wild populations. Genet Resour Crop Evol. 2014;61:1621–31. [DOI]
8. Baser KHC, Özek T, Abduganiev BE, Abdullaev UA, Aripov KN. Composition of the Essential Oil of *Bunium persicum* (Boiss.) B. Fedtsch. from Tajikistan. J Essent Oil Res. 1997;9:597–8. [DOI]
9. Gloria H, Aguilera JM. Assessment of the Quality of Heated Oils by Differential Scanning Calorimetry. J Agric Food Chem. 1998;46:1363–8. [DOI]
10. Iacobellis NS, Lo Cantore P, Capasso F, Senatore F. Antibacterial activity of *Cuminum cyminum* L. and *Carum carvi* L. essential oils. J Agric Food Chem. 2005;53:57–61. [DOI] [PubMed]
11. Azimzadeh M, Amiri R, Assareh MH, Bihamta MR, Forootan M. Genetic diversity of Iranian *Bunium persicum* germplasm by morphological markers and essential oil components. J Med Plants Res. 2012; 6:1119–29. [DOI]
12. Haghirossadat F, Bernard F, Kalantar M, Sheikhha MH, Hokmollahi F, Azimzadeh M, et al. Bunium Persicum (Black Caraway) of Yazd province: Chemical assessment and Evaluation of its Antioxidant Effects. JSSU. 2010;18:284–91.
13. Chahota RK, Sharma V, Ghani M, Sharma TR, Rana JC, Sharma SK. Genetic and phytochemical diversity analysis in *Bunium persicum* populations of north-western Himalaya. Physiol Mol Biol Plants. 2017; 23:429–41. [DOI] [PubMed] [PMC]

14. Mohammadhosseini M, Frezza C, Venditti A, Sarker SD. A Systematic Review on Phytochemistry, Ethnobotany and Biological Activities of the Genus *Bunium* L. Chem Biodivers. 2021;18:e2100317. [DOI] [PubMed]
15. Saini RK, Keum YS. Tocopherols and tocotrienols in plants and their products: A review on methods of extraction, chromatographic separation, and detection. Food Res Int. 2016;82:59–70. [DOI]
16. Sofi PA, Zeerak NA, Singh P. Kala zeera (Bunium persicum Bioss.): a Kashmirian high value crop. Turk J Bio. 2009;33:249–58. [DOI]
17. Samojlik I, Lakić N, Mimica-Dukić N, Daković-Svajcer K, Bozin B. Antioxidant and hepatoprotective potential of essential oils of coriander (*Coriandrum sativum* L.) and caraway (*Carum carvi* L.) (Apiaceae). J Agric Food Chem. 2010;58:8848–53. [DOI] [PubMed]
18. Shahsavari N, Barzegar M, Sahari MA, Naghdibadi H. Antioxidant activity and chemical characterization of essential oil of *Bunium persicum*. Plant Foods Hum Nutr. 2008;63:183–8. [DOI] [PubMed]
19. Tavakoli Kareshk A, Keyhani A, Mahmoudvand H, Tavakoli Oliaei R, Asadi A, Andishmand M, et al. Efficacy of the *Bunium persicum* (Boiss) Essential Oil against Acute Toxoplasmosis in Mice Model. Iran J Parasitol. 2015;10:625–31. [PubMed] [PMC]
20. Foroumadi A, Asadipour A, Arabpour F, Amanzadeh Y. Composition of the Essential Oil of *Bunium persicum* (Boiss.) B. Fedtsch. from Iran. J Essent Oil Res. 2002;14:161–2. [DOI]
21. Alamgir ANM. Therapeutic Use of Medicinal Plants and Their Extracts: Volume 1. 1st ed. Springer Cham; 2017. [DOI]
22. Mustafa G, Arif R, Atta A, Sharif S, Jamil A. Bioactive Compounds from Medicinal Plants and Their Importance in Drug Discovery in Pakistan. Mat Sc Pharm. 2017;1:17–26.
23. Melrose J. The Potential of Flavonoids and Flavonoid Metabolites in the Treatment of Neurodegenerative Pathology in Disorders of Cognitive Decline. Antioxidants (Basel). 2023;12:663. [DOI] [PubMed] [PMC]
24. Daley DK, Badal S. Chapter 5 - Plant crude drugs. In: McCreath SB, Clement YN, editors. Pharmacognosy (Second Edition). Academic Press; 2024. pp. 75–89. [DOI]
25. Karouche S, Benbott A, Henouda S, Malki S, Boudchicha I. Evaluation of phenolic content and biological activities of *Bunium mauritanicum* tuberss. J Fundam Appl Sci. 2020;12:916–30. [DOI]
26. Bansal S, Malhotra EV, Joshi P. Bioactive Compounds and Biological Activities of Black Cumin (*Elwendia persica* (Boiss.) Pimenov & Kljuykov). In: Murthy HN, Paek KY, Park SY, editors. Bioactive Compounds in the Storage Organs of Plants. Cham: Springer Nature Switzerland; 2024. pp. 1043–60. [DOI]
27. Majidi Z, Bina F, Kahkeshani N, Rahimi R. *Bunium persicum*: A Review of Ethnopharmacology, Phytochemistry, and Biological Activities. Trad Integr Med. 2020;5:150–76. [DOI]
28. Mith H, Duré R, Delcenserie V, Zhiri A, Daube G, Clinquart A. Antimicrobial activities of commercial essential oils and their components against food-borne pathogens and food spoilage bacteria. Food Sci Nutr. 2014;2:403–16. [DOI] [PubMed] [PMC]
29. Mahmoudvand H, Tavakoli Oliaei R, Mirbadie SR, Kheirandish F, Tavakoli Kareshk A, Ezatpour B, et al. Efficacy and Safety of *Bunium Persicum* (Boiss) to Inactivate Protoscoleces during Hydatid Cyst Operations. Surg Infect (Larchmt). 2016;17:713–9. [DOI] [PubMed]
30. Talei GR, Mosavi Z. Chemical Composition and Antibacterial Activity of *Bunium persicum* From West of Iran. Asian J Chem. 2009;21:4749–54.
31. Mahdavi B, Hajar T, Ghodsi A, Mohammadhosseini M, Mehmandost M, Talebi E. Antidiabetic Effect of *Sophora Pachycarpa* Seeds Extract In Streptozotocin-Induced Diabetic Mice: A Statistical Evaluation. J Investig Med. 2021;69:1201–7. [DOI] [PubMed]
32. Oroojalian F, Kasra-Kermanshahi R, Azizi M, Bassami MR. Phytochemical composition of the essential oils from three Apiaceae species and their antibacterial effects on food-borne pathogens. Food Chem. 2010;120:765–70. [DOI]

33. Hajhashemi V, Sajjadi SE, Zomorodkia M. Antinociceptive and anti-inflammatory activities of *Bunium persicum* essential oil, hydroalcoholic and polyphenolic extracts in animal models. Pharm Biol. 2011; 49:146–51. [DOI] [PubMed]
34. Taherkhani P, Noori N, Akhondzadeh Basti A, Gandomi H, Alimohammadi M. Antimicrobial Effects of Kermanian Black Cumin (*Bunium persicum* Boiss.) Essential Oil in Gouda Cheese Matrix. J Med Plants. 2015;14:76–85.
35. Jamshidi A, Khanzadi S, Azizi M, Azizzadeh M, Hashemi M. Modeling the growth of *Staphylococcus aureus* as affected by black zira (*Bunium persicum*) essential oil, temperature, pH and inoculum levels. Vet Res Forum. 2014;5:107–14. [PubMed] [PMC]
36. Padmashree A, Roopa N, Semwal AD, Sharma GK, Agathian G, Bawa AS. Star-anise (*Illicium verum*) and black caraway (*Carum nigrum*) as natural antioxidants. Food Chem. 2007;104:59–66. [DOI]
37. Sekine T, Sugano M, Majid A, Fujii Y. Antifungal effects of volatile compounds from black zira (*Bunium persicum*) and other spices and herbs. J Chem Ecol. 2007;33:2123–32. [DOI] [PubMed]
38. Lahlou S, Tahraoui A, Israili Z, Lyoussi B. Diuretic activity of the aqueous extracts of *Carum carvi* and *Tanacetum vulgare* in normal rats. J Ethnopharmacol. 2007;110:458–63. [DOI] [PubMed]
39. Aminzare M, Amiri E, Abbasi Z, Hassanzad Azar H, Hashemi M. Evaluation of *in vitro* Antioxidant Characteristics of Corn Starch Bioactive Films Incorporated with *Bunium persicum* and *Zataria multiflora* Essential Oils. Annu Res Rev Biol. 2017;15:1–9. [DOI]
40. Sutton KM, Greenshields AL, Hoskin DW. Thymoquinone, a bioactive component of black caraway seeds, causes G1 phase cell cycle arrest and apoptosis in triple-negative breast cancer cells with mutant p53. Nutr Cancer. 2014;66:408–18. [DOI] [PubMed]
41. Thappa RK, Ghosh S, Agarwal SG, Raina AK, Jamwal PS. Comparative studies on the major volatiles of Kalazira (*Bunium persicum* seed) of wild and cultivated sources. Food Chem. 1991;41:129–34. [DOI]
42. Zendehdel M, Torabi Z, Hassanpour S. Antinociceptive mechanisms of *Bunium persicum* essential oil in the mouse writhing test: role of opioidergic and histaminergic systems. Vet Med. 2015;60:63–70. [DOI]
43. Khaledi N, Hassani F. Antifungal activity of *Bunium persicum* essential oil and its constituents on growth and pathogenesis of *Colletotrichum lindemuthianum*. J Plant Prot Res. 2018;58:431–41. [DOI]
44. Soltanbeigi A, Diraman H, Hassanpouraghdam MB. Chemical components of volatile oil and fatty acids of wild Bunium persicum (Boiss.) B. Fedtsch. and cultivated Cuminum cyminum L. populations. Acta Agric Slov. 2021;117:1–11. [DOI]
45. SHAH Z, Ali T, Shafi S. Phytopharmacological review of Bunium persicum (Boiss)B. fedtsch. J Drug Delivery Ther. 2019;9:458–60. [DOI]
46. Abduganiev BE, Rashkes YV, Plugar' VN. GC-MS analysis of the essential oil of the fruit of*Bunium persicum*. Chem Nat Compd. 1994;30:269–70. [DOI]
47. Jamshidi AH, sadeghpour O, Khayatkashani M, Nazem E, Khayatkashani M. Determination of γ-Terpinenes in *Bunium Persicum* by Voltammetric Method and GC/Mass Analysis. Int J Electrochem Sci. 2017;12:10230–8. [DOI]
48. Noori Z, Khanzadi S, Jamshidi A, Seifi HA. Modeling the effects of *Bunium persicum* (Black Zira) essential oil, pH, inoculums size and temperature on the growth of *Listeria monocytogenes*. Iran J Vet Res. 2014;15:272–8.
49. Mandegary A, Arab-Nozari M, Ramiar H, Sharififar F. Anticonvulsant activity of the essential oil and methanolic extract of *Bunium persicum* (Boiss). B. Fedtsch. J Ethnopharmacol. 2012;140:447–51. [DOI] [PubMed]
50. Khaksari M, Ahmadi M, Najafipour H, Shahrokhi N. Effect of *Bunium persicum* aqueous extract plus endurance exercise on cardiorespiratory capacity and serum lipid profile. Avicenna J Phytomed. 2014; 4:118–26. [PubMed] [PMC]

51. Bhatia D, Gupta MK, Bharadwaj A, Pathak M, Kathiwas G, Singh M. Anti-diabetic activity of *Centratherum anthelminticum* kuntze on alloxan induced diabetic rats. Pharmacologyonline. 2008;3: 1–5.
52. Sharopov FS, Zhang H, Wink M, Setzer WN. Aromatic Medicinal Plants from Tajikistan (Central Asia). Medicines (Basel). 2015;2:28–46. [DOI] [PubMed] [PMC]
53. Jayaprakasha GK, Rao LJ. Phenolic constituents from the lichen *Parmotrema stuppeum* (Nyl.) Hale and their antioxidant activity. Z Naturforsch C J Biosci. 2000;55:1018–22. [DOI] [PubMed]
54. Kumar S, Singh P, Kumar D. Comprehensive volatile composition of vegetative parts of *Bunium persicum* B. Fedtsch.: Spice of alpine Himalaya. J Biol Act Prod Nat. 2024;14:187–98. [DOI]
55. Salehi B, Ata A, V Anil Kumar N, Sharopov F, Ramírez-Alarcón K, Ruiz-Ortega A, et al.; Atta-ur-Rahman; Choudhary MI, Cho WC, Sharifi-Rad J. Antidiabetic Potential of Medicinal Plants and Their Active Components. Biomolecules. 2019;9:551. [DOI] [PubMed] [PMC]
56. Merkl R, Hrádková I, Filip V, Šmidrkal J. Antimicrobial and Antioxidant Properties of Phenolic Acids Alkyl Esters. Czech J Food Sci. 2010;28:275–9.
57. Conserving Medicinal Species: Securing a Healthy Future [Internet]. International Union for Conservation of Nature and Natural Resources; c2006. Available from: https://portals.iucn.org/library/efiles/documents/2006-022.pdf
58. Salgotra RK, Chauhan BS. Genetic Diversity, Conservation, and Utilization of Plant Genetic Resources. Genes (Basel). 2023;14:174. [DOI] [PubMed] [PMC]