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# Ethnobotanical Review of Medicinal Plants Used for the Treatment of Hypertension in the Southern Provinces of Iran

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## ABSTRACT

Hypertension is a chronic condition that can lead to serious health issues such as cardiovascular diseases and strokes. In addition to pharmacological treatments, traditional medicine, particularly the use of medicinal plants, plays a significant role in the prevention and management of high blood pressure. This review aims to identify medicinal plants used in the ethnobotanical knowledge of the southern provinces of Iran for controlling hypertension. This review involved searching for relevant articles on medicinal plants and their role in treating hypertension using keywords such as "hypertension," "medicinal plants," and "ethnobotany," along with the names of southern Iranian provinces and their cities, including Sistan and Baluchestan, Bushehr, Hormozgan, Khuzestan, Fars, and Kerman. Credible databases, including Google Scholar, SID, Magiran, PubMed, and Scopus, were used to gather scientific resources for this study. The ethnobotanical review of the southern provinces of Iran revealed that medicinal plants such as *Dorema aucheri*, *Ferula assafoetida* L., *Cichorium intybus* L., *Crataegus aronia* (L.) Bosc ex DC., *Amygdalus scoparia*, *Pistacia atlantica* Desf., *Achillea eriophora* DC., *Allium sativum* L., *Berberis integerrima*, *Silybum marianum* L., *Tragopogon aureus* Boiss., *Securigera securidaca* Degen & Dorfl., *Rumex pulcher* L., *Olea ferruginea* are utilized for managing hypertension. Among plant families, Asteraceae is the most frequently represented with 7 species. The aerial parts of plants were the most commonly used plant parts, with 6 occurrences. This study highlights the use of a variety of medicinal plants in the southern provinces of Iran for the management of hypertension. The Asteraceae family showed the highest frequency among the medicinal plants. These findings underscore the importance of utilizing indigenous medicinal plants in the treatment of hypertension and the development of effective herbal medicines.

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## Introduction

The prevalence of chronic diseases such as hypertension, diabetes, and cancer is rising due to lifestyle changes, poor diet, and lack of physical activity (Jalili et al., 2024; Gharabagh et al., 2024). Preventing and treating these conditions requires fundamental changes in lifestyle and support for medical research (Gharabagh et al., 2024; Esfahanian et al., 2021). Hypertension is a chronic and multifactorial disorder characterized by sustained elevated blood pressure (Messerli et al., 2007). It is one of the most significant risk factors for cardiovascular diseases, stroke, and kidney failure (Staessen et al., 2003). Hypertension often progresses without any apparent clinical symptoms, and if left uncontrolled, it can lead to severe damage to vital organs (Staessen et al., 2003).

Blood pressure is influenced by cardiac output and peripheral vascular resistance. An increase in the volume of pumped blood or the narrowing of arteries results in elevated arterial pressure (Mills et al., 2020). Over time, this condition can disrupt the structure and function of the heart and blood vessels, increasing the risk of heart failure and damage to heart valves, including the mitral valve (Mills et al., 2020). Several factors, including genetics, lifestyle, poor diet, obesity, stress, and underlying health conditions, contribute to the development of hypertension (Ibrahim and Damasceno, 2012). Blood pressure is measured as systolic and diastolic, and its value depends on factors such as age, physiological conditions, and the presence of comorbidities. Values higher than 120/80 mmHg are considered hypertensive (Oparil et al., 2003). Hypertension is classified into primary and secondary types (Williams, 2009). Primary hypertension develops over many years without a clear cause, while secondary hypertension results from underlying conditions such as kidney disease, thyroid disorders, and obstructive sleep apnea (Williams, 2009).

Despite therapeutic advancements, hypertension remains a major public health challenge (Carey et al., 2022). Both pharmacological and non-pharmacological interventions can play a significant role in managing this condition (Carey et al., 2022). Lifestyle modifications, such as reducing salt intake, increasing physical activity, quitting smoking, and managing stress, are key strategies in the prevention and treatment of hypertension (Carey et al., 2022; Borzecki et al., 2003). Traditional medicine plays an important role in preventing and managing hypertension, emphasizing the use of medicinal plants, proper nutrition, and lifestyle adjustments (Xiong et al., 2013). Certain medicinal plants, due to their antioxidant, anti-inflammatory, and vasodilatory properties, can be effective in reducing and controlling high blood pressure (Lassale et al., 2022). Plants such as garlic, saffron, hibiscus tea, cinnamon, and ginger help improve blood circulation and reduce pressure on vessel walls (Ghods et al., 2014). Plants like lemon balm and valerian, due to

their calming effects, can play a vital role in reducing stress, one of the factors contributing to elevated blood pressure (Neamsuvan et al., 2018).

The aim of this study is to identify medicinal plants used in the southern provinces of Iran for controlling hypertension and to explore their ethnobotanical applications.

## Methodology

In this review, a search was conducted using the keywords "ethnobotany," "hypertension," and "medicinal plants" along with the names of southern Iranian provinces (including Fars, Kerman, Hormozgan, Khuzestan, Bushehr, and Sistan and Baluchestan) and their cities. This search was performed across credible databases such as PubMed, Scopus, Google Scholar, SID, and Magiran. A map of Iran and its southern provinces is provided in Figure 1.



**Figure 1:** Map of Iran (Provinces of Fars, Kerman, Hormozgan, Khuzestan, Bushehr, and Sistan and Baluchestan)

## Results

The findings from the ethnobotanical sources related to the ethnobotanical knowledge of the southern provinces of Iran revealed that plants such as Bihler, Asafoetida, Chicory, Hawthorn, Wild Almond, Mastic, Yarrow, Garlic, Barberry, Milk Thistle, Shank, Bitter Lentil, Sorrel, Saffron Flower, Marigold, and Olive are widely used in traditional medicine for the treatment of hypertension (Table 1).

**Table 1.** Medicinal plants effective against hypertension in the ethnobotanical knowledge of the southern provinces of Iran

Scientific Name	Common Name	Family	Used Part	Ecological Status	Traditional Use	Region	Reference
<i>Dorema aucheri</i>	Bihlar	Apiaceae	Stem and leaves	Perennial	Decoction	Abadeh, Shiraz	Kiasi et al., 2019
<i>Ferula assafoetida</i> L.	Anghouzeh	Apiaceae	Leaf, Gum	Perennial	Decoction	Abadeh, Shiraz	Kiasi et al., 2019
<i>Cichorium intybus</i> L.	Kasni	Asteraceae	Leaf, Root	Biennial	Decoction	Abadeh, Shiraz	Kiasi et al., 2019
<i>Crataegus aronia</i> (L.) Bosc ex DC.	Zalzalak	Rosaceae	Fruit	Perennial	Decoction	Abadeh, Shiraz	Kiasi et al., 2019
<i>Ferula assafoetida</i> L.	Anghouzeh	Apiaceae	Leaf	Perennial	Decoction	Iranshahr	Arbabi et al., 2023
<i>Amygdalus scoparia</i>	Badamekouhi	Rosaceae	Fruit	Perennial	Infusion	Baluchestan	Keshtegar et al., 2015
<i>Cichorium intybus</i> L.	Kasni	Asteraceae	Aerial Parts	Biennial	Decoction	Behbahan	Razmjoue et al., 2017
<i>Pistacia atlantica</i> Desf.	Saghez	Anacardiaceae	Gum	Perennial	Chewing gum	Pasargad, Fars	Hosseini et al., 2023
<i>Achillea eriophora</i> DC.	Boumadaran	Asteraceae	Aerial Parts	Perennial	Decoction	Pasargad, Fars	Hosseini et al., 2023
<i>Cichorium intybus</i> L.	Kasni	Asteraceae	Aerial Parts	Biennial	Decoction	South Kerman	Hosseini et al., 2020
<i>Allium sativum</i> L.	Sir	Amaryllidaceae	Leaf and Bulb	Perennial	Decoction	Dashtestan, Bushehr	Dolatkhahi et al., 2013
<i>Berberis integerrima</i>	Zereshk	Berberidaceae	Fruit	Perennial	Decoction	Sirjan	Sharifi Far et al., 2010
<i>Silybum marianum</i> L.	Kharmaryam	Asteraceae	Fruit, Root	Annual	Decoction	Northeast Khuzestan	Khodaiari et al., 2014
<i>Tragopogon aureus</i> Boiss.	Sheng	Asteraceae	Leaf, Fruit	Biennial	Decoction	Northeast Khuzestan	Khodaiari et al., 2014
<i>Securigera securidaca</i> Degen & Dorfl.	Adasetalkh	Fabaceae	Seed	Perennial	Decoction	Northeast Khuzestan	Khodaiari et al., 2014
<i>Rumex pulcher</i> L.	Torshak	Polygonaceae	Root	Perennial	Decoction	Northeast Khuzestan	Khodaiari et al., 2014
<i>Achillea eriophora</i> DC.	Golesarzardo	Asteraceae	Aerial Parts	Perennial	Decoction	Fasa	Ramezani and MinaeiFar, 2016
<i>Silybum marianum</i> (L.) Gaertn	Martiqal	Asteraceae	Aerial Parts	Annual	Decoction	Fasa	Ramezani and MinaeiFar, 2016
<i>Olea ferruginea</i>	Zeytouni	Oleaceae	Leaf	Perennial	Decoction	Genu, Bandar Abbas	Soltani Poor et al., 2005
<i>Silybum marianum</i> (L.) Gaerth.	Kharmaryam	Asteraceae	Flower	Annual	Decoction	Kazeroon	Mardaninejad and, Vazirpour, 2013

The analysis of the table indicates that more than 65% of the listed plants are perennials, highlighting their resilience and adaptation to various environmental conditions. The Asteraceae family has the highest number of species recorded. Fars Province (Abadeh, Shiraz, Pasargad, Fasa and Kazeroun) is home to nine plant species, reflecting the region's rich diversity of medicinal plants.

## Discussion

Studies conducted in various regions of Iran demonstrate that a wide range of medicinal plants are used to treat hypertension. In the West Azerbaijan province, plants such as *Allium sativum* L. and *Juglans regia* L. are utilized for this purpose (Azizi and Keshavarzi, 2015). In the Arasbaran region, located in the northwest of Iran, species like *Berberis vulgaris* L., *Achillea millefolium* L., *Ecbalium elaterium*, *Ribes orientale*, and *Crataegus monogyna* are recognized as herbal remedies for hypertension (Zolfaghari et al., 2013). In Ilam province, plants such as *Crataegus pontica* C. Koch., *Paliurus spina-christi* Miller., and *Rheum ribes* L. are used to manage high blood pressure (Ghasemi Pirbalouti et al., 2013). In Mobarakeh, Isfahan, the use of medicinal plants like *Rumex crispus* L., *Ziziphus jujuba* (L.) H.Karst., *Olea europaea* L., and *Echium amoenum* L. is common for treating hypertension (Mardaninejad and Vazirpour, 2013). In Marivan, Kurdistan province, two plants, *Nasturtium officinale* R. Br. and *Fumaria asepal* Boiss., are known for their natural antihypertensive effects (Aref-Tabad et al., 2014). Additionally, in Lorestan province, species such as *Nectaroscordeum tripedale*, *Nectaroscordeum coelzi*, *Falcaria vulgaris*, *Smyrniun cordifolium*, *Crocus hasskenechtii*, and *Berberis integrima* are used in traditional medicine for hypertension (Asadi-Samani et al., 2015). Furthermore, in Natanz, Isfahan, *Rumex conglomeratus* Murr is recognized as an herbal treatment for hypertension (Abbasi et al., 2012). A study also indicated that herbs like *Foeniculum vulgare* Mill., *Achillea millefolium* L., *Fumaria officinalis* L., *Apium graveolens*, *Urtica dioica* L., *Crataegus pontica* C. Koch., *Rheum ribes* L., *Allium schoenoprasum*, *Achillea biebersteinii*, *Achillea millefolium*, *Prunus cerasifera*, *Gentiana olivieri*, *Olea europaea* L., *Rumex pulcher* L., and *Crataegus monogyna* L. exhibit antihypertensive effects and are used in western Iran to reduce blood pressure (Mivefroshan and Pirhadi, 2024). In central Iran, several medicinal plants such as *Echium amoenum*, *Hyssopus officinalis*, *Rheum ribes*, *Valeriana officinalis*, *Silybum marianum*, *Mentha piperita*, *Thymus vulgaris*, *Bupleurum falcatum*, *Olea europaea*, and *Cinnamomum verum* possess anti-inflammatory, sedative, and antioxidant properties, and show potential in lowering high blood pressure. These plants can be used as natural remedies for preventing cardiovascular diseases (Ghazizadeh and Khalili, 2025). The comparison of the mentioned

plants shows that certain medicinal plants, such as *Allium sativum* L., *Berberis integrigerrima*, and *Berberis integrima*, are common in various cultural practices for treating hypertension. Various medicinal plants have been recognized as natural remedies for lowering blood pressure, and they work through different mechanisms. One of these mechanisms involves reducing vascular resistance and improving heart function by dilating blood vessels and reducing the workload on the heart. Some plants also aid in regulating blood pressure by reducing sodium levels in the body or increasing its excretion through urine. Additionally, many medicinal plants contain antioxidant compounds that prevent damage to blood vessel cells, helping maintain their health (Rawat et al., 2016; Al Disi et al., 2016).

## Conclusion

This study demonstrated that various medicinal plants are used in the southern provinces of Iran to manage hypertension. These findings underscore the significance of utilizing native medicinal plants in the treatment of high blood pressure and the development of effective herbal medicines.

## Declarations

### Conflict of interest

The author declares no conflict of interest related to the publication of this article.

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## Consent for Publication

The author confirms that the final version of the manuscript has been reviewed and approved for publication.

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## Author's Contributions

Laya Hooshmand Garehbagh was responsible for conceptualization, data collection, analysis, and manuscript preparation.

## Ethical Considerations

As this study is a review article, it does not involve human or animal subjects and therefore does not require ethical approval or informed consent.



## References

- Abbasi SH, Afsharzadeh S, Mohajeri A. Ethnobotanical study of medicinal plants in Natanz region (Kashan), Iran. *Journal of Herbal Drugs*. 2012; 3:157-66.
- Al Disi SS, Anwar MA, Eid AH. Anti-hypertensive herbs and their mechanisms of action: part I. *Frontiers in Pharmacology*. 2016; 19: 323. doi: 10.3389/fphar.2015.00323.
- Arbabi M, Raissi A, Valizadeh M. Ethnobotanical survey of medicinal plants of Iranshahr in Sistan and Baluchestan Province. *Journal of Integrative Traditional Medicine*. 2023;14(1):29-38. Available from: <http://jiitm.ir/article-1-1595-fa.html>.
- Aref-Tabad M, Jalilian N. Ethnobotanical study of medicinal plants of Zarival region of Marivan city. *Journal of Medicinal Plants*. 2014; 14: 55-75.
- Asadi-Samani M, Kafash-Farkhad N, Azimi N, Fasihi A, Alinia-Ahandani E, Rafeian-Kopaei M. Medicinal plants with hepatoprotective activity in Iranian folk medicine. *Asian Pacific Journal of Tropical Biomedicine*. 2015; 5:146-57. [https://doi.org/10.1016/S2221-1691\(15\)30159-3](https://doi.org/10.1016/S2221-1691(15)30159-3).
- Azizi H, Keshavarzi M. Ethnobotanical study of medicinal plants of Sardasht, Western Azerbaijan, Iran. *Journal of Herbal Drugs*. 2015; 6: 113-9.
- Borzecki AM, Wong AT, Hickey EC, Ash AS, Berlowitz DR. Hypertension control: how well are we doing? *Archives of Internal Medicine*. 2003;163(22):2705-2711. doi: 10.1001/archinte.163.22.2705.
- Carey RM, Moran AE, Whelton PK. Treatment of hypertension: a review. *JAMA*. 2022;328(18):1849-1861. doi: 10.1001/jama.2022.19590.
- Dolatkhahi M, Ghorbani Nehoji M. Introduction of commonly used medicinal plants in Dashtestan County, Bushehr Province, with an emphasis on traditional applications. *Medicinal Plants* 2013;12(46):85-105. Available from: <https://sid.ir/paper/15517/fa>.
- Esfahanian F, Hazaveh MM, Garehbagh LH, Falahati K, Ataei M, Sanati MH, Jadali Z. Increased mitochondrial DNA copy number and oxidative damage in patients with Hashimoto's thyroiditis. *Iranian Journal of Public Health*. 2021;50(8):1697. doi: 10.18502/ijph.v50i8.6817.
- Gharabagh LH, Shargh A, Mohammad Hosseini Azar MR, Esmaeili A. Comparison between the effect of Empagliflozin and Pioglitazone added to metformin in patients with type 2 diabetes and nonalcoholic fatty liver disease. *Clinics and Research in Hepatology and Gastroenterology*. 2024;48(3):102279. doi: 10.1016/j.clinre.2023.102279.
- Gharabagh LH, Shargh A, Mohammad Hosseini Azar MR, Esmaeili A. Comparison between the effect of Empagliflozin and Pioglitazone added to metformin in patients with type 2 diabetes and nonalcoholic fatty liver disease. *Clinics and Research in Hepatology and Gastroenterology*. 2024;48(3):102279. doi: 10.1016/j.clinre.2023.102279.
- Ghasemi Pirbalouti A, Momeni M, Bahmani M. Ethnobotanical study of medicinal plants used by Kurd tribe in Dehloran and Abdanan districts, Ilam Province, Iran. *African Journal of Traditional, Complementary and Alternative Medicines*. 2013;10:368-000. doi: 10.4314/ajtcam.v10i2.24.
- Ghazizadeh F, Khalili N. Hypertension Treatment in Central Iran with Medicinal Plants: A Review of Ethnobotanical Evidence from Iran. *Plant Biotechnology Persa* 2025; 7 (3): 1.
- Ghods R, Gharooni M, Amin G, Nazem E, Nasrabadi AN. Hypertension from the perspective of Iranian traditional medicine. *Iranian Red Crescent Medical Journal*. 2014;16(3): 16449. doi: 10.5812/ircmj.16449.
- Hosseini Seyed Hamzeh, Bibak Hossein, Ramazani Ghara Abdollah. Ethnobotanical Study of Medicinal Plants in the Southern Region of Kerman. *Ecophytochemistry of Medicinal Plants [Internet]*. 2020;8(1) (Serial No. 29):30-63. Available from: <https://sid.ir/paper/368836/fa>.
- Hosseini SH, Yousefi N, Fattahi F. Ethnobotanical knowledge of medicinal plants in Pasargad County, Fars Province. *Iranian Journal of Medicinal and Aromatic Plants Research*. 2023;39(4):515-33. doi: 10.22092/ijmapr.2023.361366.3284.
- Ibrahim MM, Damasceno A. Hypertension in developing countries. *Lancet*. 2012;380(9841):611-619. doi: 10.1016/S0140-6736(12)60861-7.
- Jalili A, Hooshmand Gharabagh L, Heydaroghli M, Esmaeili A. Role of N-Acetyl-Cysteine as an Adjuvant Therapy in Patients with Diabetic Foot Osteomyelitis: A Randomized Controlled Trial. 2024;45. doi: 10.4081/hi.2009.e7.
- Keshtegar S, Ghaeramani Nejad F, Minab Poodineh H, Farzanjo M. Ethnobotanical study of some medicinal plants in Sistan and Baluchestan Province. *Third National Conference on Medicinal Plants and Sustainable Agriculture, Hamedan*; 2015. Available from: <https://civilica.com/doc/416449>.
- Khodaiari H, Amani Shahriyar S, Amiri H. Ethnobotany of medicinal plants in the northeastern region of Khuzestan Province. *Eco-phytochemical Journal of Medicinal Plants*. 2014;2(4, consecutive issue 8):12-26. Available from: <https://sid.ir/paper/247818/fa>.
- Kiasi Y, Forouzeh MR. Ethnobotanical study of the medicinal plants in Abadeh (Case study: Almalicheh rangelands). *Traditional and Integrative Medicine*. 2019;10(1):71-8. Available from: <http://jiitm.ir/article-1-1093-fa.html>.

Lassale C, Gaye B, Diop IB, Mipinda JB, Kramoh KE, Kouam CK, et al. Use of traditional medicine and control of hypertension in 12 African countries. *BMJ Global Health*. 2022;7(6): 008138. doi: 10.1136/bmjgh-2021-008138.

Mardaninejad SH, Vazirpour M. Ethnobotany of medicinal plants by Mobarake people (Isfahan). *Journal of Herbal Drugs*. 2013; 3:111–29.

Messerli FH, Williams B, Ritz E. Essential hypertension. *Lancet*. 2007;370(9587):591–603. doi: 10.1016/S0140-6736(07)61299-9.

Mills KT, Stefanescu A, He J. The global epidemiology of hypertension. *Nature Reviews Nephrology*. 2020;16(4):223–237. doi: 10.1038/s41581-019-0244-2.

Mivefroshan A, Pirhadi M. Ethnobotanical Insights into Medicinal Plants and Their Mechanisms for Blood Pressure Control. *Plant Biotechnology Persa* 2024; 6 (2) :25–30. URL: <http://pbp.medilam.ac.ir/article-1-226-en.html>.

Neamsuvan O, Komonhiran P, Boonming K. Medicinal plants used for hypertension treatment by folk healers in Songkhla province, Thailand *Journal of Ethnopharmacology*. 2018; 214:58–70.

Oparil S, Zaman MA, Calhoun DA. Pathogenesis of hypertension. *Annals in Internal Medicine*. 2003;139(9):761–776. doi: 10.7326/0003-4819-139-9-200311040-00011.

Ramezani M, MinaeiFar AA. Ethnobotanical study of medicinal plants in Fasa county. *Traditional and Integrative Medicine*. 2016;7(2):221–31. Available from: <http://jiitm.ir/article-1-680-fa.html>.

Rawat P, Singh PK, Kumar V. Anti-hypertensive medicinal plants and their mode of action. *Journal of Herbal Medicine*. 2016; 1;6(3):107–18. doi:10.1016/j.hermed.2016.06.001.

Razmjoue D, Zarei Z, armand R. Ethnobotanical Study (Identification, Medical Properties and How to Use) of some Medicinal Plants of Behbahan city of Khuzestan Province, Iran. *Journal of Medicinal Plants*. 2017; 16 (64) :33–49.

Sharifi Far F, Koohpayeh Abad A, Motaghi MM, Amirkhosravi A, Pour Mohseni Nasab E, Khodashenas M. Ethnobotanical study of medicinal plants in Sirjan County, Kerman Province. *Herbal Medicine*. 2010;1(3):19–28.

Soltani Poor MA. Medicinal plants of the Gano Protected Area. *Natural Resources* [Internet]. 2005;18(3):27–37. Available from: <https://sid.ir/paper/19065/fa>.

Staessen JA, Wang J, Bianchi G, Birkenhäger WH. Essential hypertension. *Lancet*. 2003;361(9369):1629–1641. doi: 10.1016/S0140-6736(03)13302-8.

Williams B. The year in hypertension. *Journal of the American College of Cardiology*. 2009;55(1):65–73. doi: 10.1016/j.jacc.2009.08.037.

Xiong X, Yang X, Liu W, Chu F, Wang P, Wang J. Trends in the treatment of hypertension from the perspective of traditional Chinese medicine. *Evidence-Based Complementary and Alternative Medicine*. 2013;2013(1):275279. doi: 10.1155/2013/275279.

Zolfaghari A, Adeli A, Mozafarian V, Babaei S, Habibi-Bibalan G. Identification of medicinal plants and indigenous knowledge of local people Arasbaran. *Journal of Medicinal and Arumatic Plants*. 2013; 28:534–50.

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