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Review Article

Exploring The Anti-Anaemic Potential of Medicinal Plants Found in Uttarakhand: A Comprehensive Review

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ABSTRACT

The main root cause of anaemia is iron deficiency, and it is a prevalent nutritional health issue. Anaemia is still a significant public health concern in both developed and underdeveloped nations. Due to inadequate intake or absorption, infants, children, women of reproductive age, pregnant women, and the elderly are thought to be most susceptible to iron deficiency. Around 15% of the world's population, 35% of women, and 43% of small children suffer from iron insufficiency, the most prevalent single-nutrient deficiency disorder. It happens when the body's iron reserves are exhausted, and it becomes evident that different tissues are receiving insufficient amounts of iron. Because of medicinal plants accessibility, low cost, and few adverse effects, herbal therapy presents a possible substitute or adjunct to traditional medicines. This study uses a thorough assessment that includes in vivo, in vitro, in silico, and ex vivo approaches to investigate the anti-anaemic potential of medicinal plants that are native to Uttarakhand. Plants that have shown hematopoietic and antioxidant properties in animal models include *Allium sativum*, *Aloe vera*, *Amaranthus cruentus*, *Beta vulgaris*, *Carica papaya*, *Ficus palmata*, *Moringa oleifera*, *Vigna Radiata*, and *Solanum nigrum*. They can improve erythropoiesis and lessen oxidative stress. In managing anaemia, these results jointly highlight the medicinal potential of the state's ethnobotanical assets and call for more clinical verification.

INTRODUCTION

Anaemia is a condition that occurs when the level and percentage of RBC cells decrease. [1]

Anaemia causes the percentage of red blood cells or haemoglobin in the blood to drop, which lowers the quantity of oxygen that reaches tissues.[2] However, sex, ethnicity, and age all affect the

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haemoglobin concentration that characterises anaemia. Furthermore, there is disagreement over whether patient groups should receive routine screening for anaemia. Additionally, the objective of treatment and the threshold for starting treatment vary based on the underlying problems and medical expertise. Anaemia can present with a wide range of symptoms, such as weakness, State of fatigue, headache, pallor or jaundice, palpitations, tachycardia, chest pain, shortness of breath, cold extremities, and claudication. The frequency and severity of these symptoms vary from person to person.[3] According to the WHO diagnostic criteria for anaemic patient in 2010, the level of haemoglobin is below 12g/dl for premenopausal women, but in case of postmenopausal women and all age men the haemoglobin level below then 13 g/dl. For anemic condition WHO citing new data which suggested new level of anemia this condition depends on age, race and gender the level of hemoglobin below then 13.7g/dl for males and below then 12.2g/dl in female [4]. The Himalayan regions are home to some of the richest biodiversity hotspots in the world. They offer various opportunities in all fields of biological research related to life support systems in an integrated manner. [5,6] The Himalayan region of India contains about 8,644 plant species, which are grouped under 1,748 plant families. These medicinal plants are mainly found at elevated regions of up to 1,800 m. The abundant growth of these valuable medicinal plants is chiefly attributed to the region's exceptional biodiversity and distinct climatic conditions. [6] The Uttarakhand state, nestled in the majestic lap of the Himalayas, is revered as 'Dev Bhoomi' or the Land of the Gods, and is acclaimed for its stunning views, rich medicinal flora, and wealth of traditional plants. Ever since ancient times, medicinal plants and their derivatives have served as humanity's primary resources for both therapeutic and nutritional needs across the globe.

[6,7] Medicinal plants are an integral part of the Himalayan forests and are renowned for their efficacy in treating a wide range of ailments. [6] The therapeutic potential of Himalayan flora has been extensively documented in ancient Hindu scriptures, including the Rigveda, Atharvaveda, and the ayurvedic books such as Charaka Samhita. [8] Even in this present era, various plant parts such as leaves, stems, and roots continue to be widely used in traditional medicines by communities across rural and peri-urban regions of India and beyond. These remedies are often favoured over allopathic alternatives due to their minimal adverse side effects and longstanding cultural acceptance. [6]. According to the World Health Organization (WHO) the 80% of the world's population is still dependent upon traditional medicines. [6,9] Plants are a natural source of various phytoconstituents such as alkaloids, chalcones, lignans, steroids, phenols, simple aromatics, terpenes, peptides, polyketides, coumarins, alkynes, alkanes, alkenes, and flavonoids. All these bioactive compounds have various therapeutic applications. [6,10] Due to their vast therapeutic potential, medicinal plants are increasingly being used as drug-like molecules in the present drug discovery era. [11,12] Bioactive compounds found in plants play an important role in the healthcare system in developing nations like India, where traditional knowledge intersects with contemporary therapeutic practices. [13,14,15] In recent decades, medicinal plants have gained global recognition, particularly in the biotechnology sector, for their potential to yield novel, plant-derived pharmacological agents. [16,17,18]

GEOGRAPHICAL DESCRIPTION

Uttarakhand is situated in the eastern part of the North-West Himalayas, which have been divided into two regions: Kumaon and Garhwal. The state



lies between the latitudes 28°42' and 31°28' N, and the longitudes 77°35' and 81°50' E, and is bounded in the east by Nepal, in the northwest by Himachal Pradesh, in the north by Tibet, and in the south by Uttar Pradesh. The southern edge of Uttarakhand is home to the sub-Himalayan area, which is made up of a lengthy chain of low-altitude, narrow mountain ranges that are between 300 and 1000 meters above sea level. This intermediate region between the Gangetic plains and the mountainous Himalayas has a width of about 30-40 kilometres and features scattered mountains. [19] Uttarakhand is blessed with a rich cultural heritage and excellent biological wealth. The unique geographical features and diverse climatic zones are the key elements for the large number of plant species found here. In Uttarakhand, 93% of the land area is mountains, and approximately 64.79% is covered by forests, resulting in an abundance of medicinal plant growth. [20]

PLANTS WITH ANTIANAEMIC ACTIVITY

***Allium sativum*:** In this experiment, anaemia was induced by the administration of phenyl hydrazine (20mg/kg) in intraperitoneal injection of rats. Nanoparticles of *Allium sativum* were used in this experiment. In these experimental studies total of six groups were used, and the dose administration of the nanoparticle of *Allium sativum* was 34.5mg/kg. At the end of the experiment, animal sacrifice and blood sample (5ml) were collected and 1ml put into EDTA tube for CBC measured and another one ml was put into tube with sodium citrate for obtained plasma which use for fibrinogen biomarker remaining 3ml into disposable tube and centrifuged for 3 minutes. Then sera obtain at store at (−20°C) until physio-biochemical analysed which include total protein, albumin and electrolytes. After treatment of *Allium sativum* and nanoparticle of *Allium sativum* increased level of Haemoglobin, PCV, RBC, while

the level of WBC, MCV, MCH decreased. Treatment group K^+ and Fe^+ decreased and Na^+ and Ca^{++} increased. *Allium sativum* nanoparticle have antianemia and ability to prevent haemolysis. [21]

***Amaranthus cruentus*:** study evaluated the antianemia potential of *Amaranthus cruentus*, a nutrient-rich leafy vegetable commonly grown in the Indian subcontinent. The ethanol extract of the plant, containing polyphenols, flavonoids, saponins, terpenoids, and essential vitamins and minerals like iron, calcium, and folic acid, was tested for its hematinic effect. Using phenylhydrazine to induce anaemia in rats, doses of 200 and 400 mg/kg of the extract significantly restored haemoglobin levels, RBC, WBC, and haematocrit. The findings indicate that *A. cruentus* possesses potent hematopoietic activity, supporting its traditional use, though further studies are needed to isolate and characterize the specific active compounds. [22]

***Calotropis procera*:** Administration of phenylhydrazine (40mg/kg) in anaemic rat group for two days and treatment group given hydroalcoholic extract of *Calotropis procera* at 100mg/kg and 200mg/kg body weight for 28 days. Blood sample were collected by rat tail incision method on day D0, D2 to 1st, 2nd and 3th, 4th week of treatment and then analysis the RBC, Hb, PCV level. The extract increased the haematological parameter in the 4th week of treatment when compared to the anaemic control group. [23]

***Crotalaria juncea*:** evaluated the anti-anaemic potential of *Crotalaria juncea* seed powder suspension in rats with phenylhydrazine-induced haemolytic anaemia. Following a phytochemical analysis revealing the presence of alkaloids, tannins, flavonoids, phenolic compounds, and an iron content of 5 mg/100 ml, the seeds were administered at doses of 200 and 400 mg/kg for 21 days. Anaemia induced by phenylhydrazine



significantly reduced RBC count, Hb, and PCV, but these parameters were notably restored by *C. juncea* treatment. The extract also normalised clotting time and improved pathological changes in the kidney, liver, and heart. These findings suggest that *C. juncea* has promising anti-anaemic properties with minimal side effects. [24]

***Curcuma longa*:** Assessed the effectiveness of encapsulated curcumin in the treatment of phenylhydrazine-treated anaemic Wistar rats. When curcumin loaded into phytosomes was administered, it was discovered that the phytosomes had a potent ability to reduce the anaemic effects of phenylhydrazine. *Curcumin* and its liposomes were found to be an effective treatment for anaemia in rats by improving blood parameters and lessening the genotoxic effect of phenylhydrazine [25]

***Glycyrrhiza glabra*:** Evaluated the antianemia potential of aqueous extract of *G. glabra* at different doses, such as 30,60, and 160mg/kg concentration. In this study, five groups are used, each containing eight animals. The induction method of anaemia is Phenylhydrazine(20mg/kg) rat model at different times (Days 1,3, and 5). On the 15th day, animals were sacrificed, then blood samples were taken from the heart to analyse different biochemical parameters, haematological parameters and immunological parameters. *G. glabra* enhanced the HDL, PCV, MCV, MCH, MCHC, interleukin 4,5,10,13 and also interferon α and decrease the level of alkaline phosphate, aspartate aminotransferase, alanine aminotransferase gamma-glutamyl transferase, ferrous, ferritin, erythropoietin, cholesterol, LDL, triglyceride, total and conjugated bilirubin, urea, creatinine, interleukin 1, interleukin 6, interleukin 12, interleukin 18, interferon gamma, and tumour necrosis factor alpha. [26]

***Helicteres isora L.*:** Reported that a phenylhydrazine-induced haemolytic anaemic rat model was used to assess the anti-anaemic properties of an aqueous extract of *Helicteres isora L. fruits (AEHI)* at three different doses. It was found that AEHI considerably improved the reduced RBC, haemoglobin, and haematocrit levels in a dose-dependent manner. The author also concluded that the AEHI treatment avoided the pathological alterations in the liver and spleen [27]

***Hibiscus sabdariffa*:** The aqueous extract of hibiscus sabdariffa was evaluated in this study total of one hundred and eighty animals divided into twelve groups. According to the OECD acute toxicity guideline, the 5000 mg/kg dose of HSS shows no toxicity. For the induction of haemolytic anaemia induced by Zidovudine-containing highly active antiretroviral therapy regimen for 1 week via oral intubation. When the level of PCV is significantly reduced, which is characteristic of anaemic rats. HSS significantly increase the level of Haemoglobin, RBC, PCV, WBC, and neutrophil. [28]

***Hypoestes triflora*:** A study assessed the antianemic and hepatoprotective effects of *Hypoestes triflora* leaf aqueous extract in guinea pigs. Anaemia was induced using phenylhydrazine, and liver damage with paracetamol. The test group (T) received the plant extract, while the reference group (R) received iron (for anaemia) or silymarin (for liver protection). Both single and repeated dosing over 7 days were used. The extract significantly boosted RBC production in anaemic animals and offered 80–90% liver protection in hepatotoxic animals—effects that were comparable to or even better than the standard treatments. These findings confirm the plant's traditional use in treating anaemia and

liver disorders and suggest potential supportive benefits in HIV-related blood deficiencies. [29]

***Justicia secunda*:** Investigated the hematinic effects of *Justicia secunda* leaf extracts in phenylhydrazine-induced anaemic Sprague-Dawley rats. Rats were treated with water, methanol, or ethyl acetate extracts at 200 mg/kg and compared to those given Feroglobin and a saline control. Over 21 days, red blood cell (RBC) count and haemoglobin (Hb) concentration were measured at 3-day intervals. The water extract showed the most significant increase in both RBC and Hb levels, fully restoring RBC count by the end of the study. The methanol extracts also showed notable hematinic activity. These results support the traditional use of *J. secunda* in Ghanaian medicine for anaemia, especially the water-soluble components. [30]

***Moringa oleifera*:** Reported that the anti-anaemia capability of the *Moringa oleifera* tree and its components in phenylhydrazine-induced haematotoxicity in 48 male Wistar albino rats utilising suitable standard procedures. Parts of *Moringa oleifera* have antioxidant properties and contain flavonoids, saponins, and steroids, according to qualitative phytochemical screening. WBC, MCH and MCHC greatly increased in anaemic rats when compared to the normal control, but they significantly decreased when various portions of *Moringa oleifera* were administered. Anaemic rats' histopathology revealed moderate myeloblastic and lymphoblastic cellular characteristics. Different frequencies of minor myeloblastic and lymphoblastic cellular characteristics were observed in the groups treated with hydroxyurea and portions of *Moringa oleifera*, suggesting that the bone marrow had improved. Using a rat model of phenylhydrazine-induced hemotoxicity, the study demonstrated that *Moringa oleifera*

possesses both antioxidant and anti-anaemic properties. [31]

***Psidium guajava*:** This study assessed the antianemia effect of aqueous leaf extract of *Psidium guajava* (guava) in phenylhydrazine-induced anaemic Wistar rats. Anaemia was induced by administering 20 mg/kg of phenylhydrazine for 14 days. Rats treated with *P. guajava* extract at 300 mg/kg and 600 mg/kg showed significant increases in haemoglobin (HGB), packed cell volume (PCV), and red blood cell (RBC) count compared to the untreated anaemic group. The higher dose (600 mg/kg) demonstrated stronger effects, with HGB in the anaemic group, PCV at and RBC count. These results suggest that *P. guajava* leaf extract has promising antianemia potential, comparable to standard iron therapy. [32]

***Solanum nigrum*:** Methanolic extract administration of *Solanum nigrum* in phenyl hydrazine induces an anaemic model in albino rats at different doses 100,200,300, and 400mg/kg b.w. After induction of phenyl hydrazine at 10mg/kg for 8 days, make sure the PCV level is less than 29% in anaemic rats. Then, after this, *Solanum nigrum* extract was administered at different doses according to their body weight for 3 weeks orally by gastric intubation. The findings showed that the methanolic extract of *Solanum nigrum* reversed the anaemic rat state by increasing the levels of haemoglobin, red blood cells, mean capsulated haemoglobin, MCV, and platelets in a dose-dependent manner, as well as a three-week drop in WBC, lymphocytes, and neutrophils. Phytochemicals, including alkaloids, flavonoids, saponins, phenols, and tannins, were found in the plant. Vitamins A, K, B6, C, E, and folic acid are all present in the extract in amounts. The plant extract also contained mineral components, including iron, magnesium, calcium, zinc, and

copper. The impact of phenylhydrazine was lessened by a 400 mg/kg dosage of *Solanum nigrum* methanolic extract than by another dose.[33]

***Terminalia catappa*:** Reported that *Terminalia catappa* aqueous leaf extract's hepato-renal, antihyperlipidemic, and haematinic properties in male Wistar rats exposed to phenylhydrazine-induced toxicity. By lowering liver enzymes, creatinine, urea, and undesirable lipid parameters, the extract restored normal biochemical markers, strengthened antioxidant defences in the liver, kidney, and spleen, and markedly improved haematological indices (erythrocytes, haemoglobin, and haematocrit). These results imply that *T. catappa* protects against organ damage and haemolytic anaemia by enhancing antioxidant activity, lipid homeostasis, and erythropoiesis. [34]

***Trigonella foenum-graecum*:** Study the ant-anaemic effect of hydroalcoholic extract of seeds of *T. foenum-graecum* against phenylhydrazine induced anaemic rat model. Haemolytic anaemia was induced by ip administration of phenylhydrazine HCl at doses of 40 mg/kg of body weight during two successive days. Then one day after the animals were treated orally by the hydroalcoholic extracts with the amounts of 200 mg/kg and 400 mg/kg of body weight, and Dexorange (Standard drug), up to 13 days. Then analysed for haematological parameters on days 2 and 13. Analysis of haematological parameters on day 13 showed that the extract significantly improved Hb, RBC, and WBC count at a dose of 400 mg/kg body weight. [35]

***Vaccinium myrtillus* L.:** Reported that blueberries (*Vaccinium myrtillus*) can partially protect Wistar rats from acute haemolytic anaemia brought on by phenylhydrazine. Supplementing with blueberries reduced some of the effects of phenylhydrazine, which induced severe haematological changes, oxidative stress, splenomegaly, and immune-inflammatory responses. In particular, blueberries increased antioxidant capacity by raising sulfhydryl group levels, decreasing interleukin-10 levels, and lowering neutrophil and lymphocyte numbers. According to these results, blueberries may be used therapeutically to treat the inflammation and oxidative stress linked to haemolytic anaemia. [36]

Comparative studies of *Azadirachta indica* leaves and its combination with *Emblica officinalis*: This study evaluated the antianemic effects of *Azadirachta indica* (neem) leaves alone and in combination with *Emblica officinalis* (amla) in rats with phenylhydrazine-induced anaemia. Seven groups of rats were tested: Group 1 (normal control), Group 2 (anaemia control), Group 3 (standard treatment with Fefol), and Groups 4–7 received either neem extract alone (200 & 400 mg/kg) or neem-amla combinations (200 & 400 mg/kg) for 14 days. Blood analysis on Day 15 revealed that all treatments improved haematological parameters. However, the neem-amla combination showed superior results compared to neem alone, likely due to enhanced iron absorption from neem facilitated by the vitamin C in amla. This suggests the potential of this plant-based combination as a natural alternative to conventional iron supplements. [37]

Table 1: List of plants used in the treatment of anaemia

Sr. No.	Botanical name	Family	Habit	Part Used	Study Type	Reference
1	<i>Aerva javanica</i>	Amaranthaceae	Shrub	Leaves	<i>In vitro</i>	[38]
2	<i>Allium sativum</i>	Liliaceae	Herb	Bulb	<i>In vivo</i>	[21]
3	<i>Aloe vera</i>	Liliaceae	Herb	Gel	<i>In vivo</i>	[39]



4	<i>Amaranthus cruentus</i>	Amaranthaceae	Herb	Leaves	<i>In vivo</i>	[22]
5	<i>Amaranthus hybridus</i>	Amaranthaceae	Herb	Leaves	<i>In vivo</i>	[40]
6	<i>Asparagus racemosus</i>	Liliaceae	Climbing shrub	Root	<i>In vivo</i>	[41]
7	<i>Azadirachta indica</i>	Meliaceae	Tree	Leaves	<i>In vivo</i>	[42]
8	<i>Beta vulgaris</i>	Chenopodiaceae	Herb	Root	<i>In vivo</i>	[43]
9	<i>Brassica oleracea</i>	Brassicaceae	Herb	Broccoli sprouts	<i>In vivo</i>	[44]
10	<i>Brassica rapa</i>	Brassicaceae	Herb	Leaves	<i>In vitro, In vivo</i>	[45]
11	<i>Bryophyllum pinnatum</i>	Crassulaceae	Herb	Leaves	<i>In vivo</i>	[46]
12	<i>Calotropis procera</i>	Asclepiadaceae	Shrub	Flower	<i>In vivo</i>	[23]
13	<i>Canna indica</i>	Cannaceae	Herb	Leaves	<i>In vitro</i> (Antisickling activity)	[47]
14	<i>Carica papaya</i>	Caricaceae	Tree	Leaves	<i>In vivo</i> (Renal anaemia)	[48]
15	<i>Cassia fistula</i>	Caesalpiniaceae	Tree	Fruit	<i>In vitro</i> (Antisickling activity)	[49]
16	<i>Citrus sinensis</i>	Rutaceae	Tree	Fruits	<i>In vivo</i>	[50]
17	<i>Cucumis Sativus</i>	Cucurbitaceae	Climber	Juice	<i>In vivo</i>	[51]
18	<i>Curcuma longa</i>	Zingiberaceae	Herb	Rhizome	<i>In vitro, In vivo</i>	[52,51]
19	<i>Cyperus esculentus</i>	Cyperaceae	Herb	Tuber	<i>In vivo</i>	[53]
20	<i>emblica officinalis</i>	Euphorbiaceae	Tree	Fruit	<i>In vivo</i>	[42]
21	<i>Eruca sativa</i>	Brassicaceae	Herb	leaves	<i>In vitro, In vivo</i>	[45]
22	<i>Ficus palmata</i>	Moraceae	Tree	Leaves	<i>In vitro</i>	[38]
23	<i>Hibiscus sabdariffa</i>	Malvaceae	Under shrub	Seeds	<i>In vivo</i>	[54]
24	<i>Hygrophila spinosa</i>	Acanthaceae	Herb	Arial part, Leaves	<i>In vivo</i>	[55]
25	<i>Justicia secunda</i>	Acanthaceae	Herb	Leaves	<i>In vivo</i>	[30]
26	<i>Khaya senegalensis</i>	Meliaceae	Tree	Stem bark	<i>In vitro</i>	[56]
27	<i>Lycopersicon esculentum</i>	Solanaceae	Herb	Fruits	<i>In vivo</i>	[50]
28	<i>Mangifera indica</i>	Anacardiaceae	Tree	Stem bark	<i>In vivo</i>	[57]
29	<i>Mentha piperita</i>	Lamiaceae	Herb	Leaves	<i>In vivo</i>	[58]
30	<i>Moringa oleifera</i>	Moringaceae	Tree	Bark, Flower, Root, Seed, Leaves	<i>In vivo</i>	[31]

31	<i>Murraya koenigii</i>	Rutaceae	Tree	Leaves, Fruits	<i>In vivo</i>	[59,60]
32	<i>Ocimum gratissimum</i>	Lamiaceae	Under shrub	Leaves	<i>In vivo</i>	[61]
33	<i>Pergularia daemia</i>	Asclepiadaceae	Climber	Leaves	<i>In vitro</i> (Antisickling activity)	[47]
34	<i>Petiveria alliacea</i>	Phytolaccaceae	Under shrub	Leaves	<i>In vitro</i> (Antisickling activity)	[47]
35	<i>Piper betle</i>	Piperaceae	Climbing shrub	Leaves	<i>In vitro, In vivo</i>	[62]
36	<i>Psidium guajava</i>	Myrtaceae	Tree	Leaves	<i>In vivo</i>	[32]
37	<i>Raphanus sativus</i>	Brassicaceae	Herb	Leaves	<i>In vitro, In vivo</i>	[45]
38	<i>Senna alexandrina</i>	Caesalpiniaceae	Shrub	Leaves	<i>In vitro</i>	[38]
39	<i>Sesamum indicum</i>	Pedaliaceae	Herb	Seeds	<i>In vivo</i>	[63]
40	<i>Solanum lycopersicum</i>	Solanaceae	Herb	Fruit	<i>In vivo</i>	[64]
41	<i>Solanum nigrum</i>	Solanaceae	Herb	Leaves	<i>In vivo</i>	[33]
42	<i>Sorghum bicolor</i>	Poaceae	Herb	Leaves	<i>In vivo</i>	[65]
43	<i>Syzygium cumini</i>	Myrtaceae	Tree	Fruit	<i>In vivo</i>	[66]
44	<i>Talinum triangulare</i>	Portulacaceae	Shrub	Leaves	<i>In vivo</i>	[40]
45	<i>Taraxacum officinale</i>	Asteraceae	Herb	Arial part	<i>In vivo</i>	[67]
46	<i>Tectona grandis</i>	Verbenaceae	Tree	Leaves	<i>In vivo</i>	[68]
47	<i>Terminalia catappa</i>	Combretaceae	Tree	Leaves	<i>In vivo</i>	[69,70]
48	<i>Tribulus terrestris</i>	Zygophyllaceae	Herb	Leaves	<i>In vivo</i> (Renal anemia)	[71]
49	<i>Trigonella Foenum-graecum</i>	Fabaceae	Herb	Seeds	<i>In vivo</i>	[35]
50	<i>Vigna radiata</i>	Fabaceae	Herb	Seeds	<i>In vivo</i>	[72]
51	<i>Vitis vinifera</i>	Vitaceae	Liana	Whole Plant	<i>In silico</i>	[73]
52	<i>Wrightia tinctoria</i>	Apocynaceae	Tree	Bark	<i>In vivo</i>	[74]
53	<i>Zea mays</i>	Poaceae	Herb	Silk	<i>In vitro</i>	[75]

FUTURE PROSPECTS

To ensure the safety and efficacy of herbal remedies used in both the prevention and treatment of anemia, future research should prioritize standardization and quality control. Researchers can create focused, evidence-based therapies by utilizing sophisticated techniques, such as molecular docking and in silico screening, to

identify active molecules and elucidate their mechanisms of action. However, pharmacokinetic research and clinical trials are essential for determining long-term safety, the best dosage, and effectiveness. Researchers may build a solid basis for herbal remedies that help both rural as well as urban people by fusing centuries-old wisdom with cutting-edge experimental along computational techniques. Worldwide efforts to manage and



lessen the burden of anemia will be greatly aided by such an integrated strategy, which will help identify herbal remedies as dependable, affordable alternatives or additions to conventional medication.

CONCLUSION

About thirty percent of the human population worldwide suffers from Anemia, which continues to be one of the most urgent global health issues with significant socioeconomic and clinical ramifications. Because of its intricate pathophysiology, which involves oxidative damage, iron shortage, and reduced erythropoiesis, successful prevention and therapy need a multimodal approach. Herbal medicine has become a viable, affordable, and easily available therapeutic alternative in this regard. Various medicinal herbs that are high in iron, vitamins, polyphenols, flavonoids, and other bioactive compounds may be able to promote erythropoiesis, enhance hematological parameters, and lessen the levels of oxidative stress linked to anemia, according to the data currently available from both *in vitro*, *in silico*, *ex vivo*, and *in vivo* research.

Herbal remedies for anemia have drawn a lot of interest, and both conventional wisdom and scientific studies support their effectiveness. Common and indigenous plants in Uttarakhand, including *Amaranthus* species (Chaulai), *Beta vulgaris* (Chukandar), *Solanum nigrum* (Anar), *Moringa oleifera* (Sahjan), and *Vigna radiata* (Moong) have shown promising results in a variety of experimental models.

Together, these results demonstrate the effectiveness of herbal remedies as affordable, secure, and reasonably priced treatments for anemia, especially in environments with low resources, such as the mountainous areas of

Uttarakhand, where these plants are widely available. The combination of *in vivo*, *in vitro*, *ex vivo*, and *in silico* data gives the traditional usage of these plants a solid scientific basis and creates opportunities for the creation of standardized, plant-based anemia treatment formulations. Further research is necessary to convert these encouraging findings into clinical practice, though, including carefully planned clinical trials on humans, pharmacokinetic profiles, and toxicity evaluations to guarantee effectiveness as well as safety. The significance of Uttarakhand's vast biodiversity in tackling a significant public health issue like anemia is further supported by the fact that these herbs not only provide nutritional advantages but also show medicinal potential through a variety of mechanisms.

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