HSPI The Open Access Publisher

I J B M R INTERNATIONAL JOURNAL OF BONE MARROW RESEARCH
ISSN 2994-2594

Mini Review

Exploring the Potential of Medicinal Plants in Bone Marrow Regeneration and Hematopoietic Stem Cell Therapy

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Abstract

Blood cell production through hematopoiesis within the bone marrow serves both to maintain blood equilibrium and to respond to tissue injury and infectious demands. Hematopoietic stem cell (HSC) therapy developments have revolutionized medical treatment approaches for anemia leukemia and bone marrow failure caused by chemotherapy or radiation exposure. The therapeutic compounds present in medicinal plants have traditionally supported blood health and researchers now understand these plants could help regenerate bone marrow tissue. The analysis investigates how phytochemicals affect HSC proliferation and differentiation while supporting HSC survival. The medicinal plants *Panax ginseng*, *Astragalus membranaceus,* and *Curcuma longa* receive special attention for their documented ability to enhance hematopoiesis in preclinical and clinical settings. This review examines the challenges that include standardization issues, toxicity concerns, and regulatory barriers alongside future perspectives about combining plant-based therapies with traditional treatments to improve bone marrow recovery and health results.

More Information

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Submitted: January 17, 2025
Approved: January 30, 2025
Published: January 31, 2025

How to cite this article: Paul-Chima UO, Ugo AE. Exploring the Potential of Medicinal Plants in Bone Marrow Regeneration and Hematopoietic Stem Cell Therapy. Int J Bone Marrow Res. 2025; 8(1): 001-005. Available from: https://dx.doi.org/10.29328/journal.ijbmr.1001019

Keywords: Hematopoiesis; Hematopoietic stem cells; Bone marrow regeneration; Medicinal plants; Phytochemicals; *Panax ginseng; Astragalus membranaceus; Curcuma longa*; Bioactive compounds; Chemotherapy-induced myelosuppression

Introduction

Bone marrow functions through hematopoiesis to create blood cells which represent a critical human tissue [1]. Hematopoietic stem cells function as pluripotent self-renewing cells that produce all blood cellular types including red and white blood cells and platelets while maintaining their residence within the body [2]. Stem cells regulate blood homeostasis while providing the body with essential capabilities to respond to injuries, infections, and other physiological requirements [3]. The regenerative power of bone marrow depends on Hematopoietic Stem Cells (HSCs) which help treat anemia, leukemia, and myelodysplastic syndromes while providing crucial insights into cancer immunotherapy [4]. Chemo and radiation therapy and other treatment methods that focus on rapidly dividing cells can harm the bone marrow leading to hematopoietic failure which doctors treat through bone marrow transplants or HSC therapy [5].

Medicinal plants and their historical use in hematopoietic disorders

Traditional medicinal plant therapies for blood health support exist in various cultural practices [6]. The bioactive compounds found in numerous plants demonstrate their ability to modify cellular processes which include HSC proliferation, differentiation, and regeneration [7]. Traditional Chinese medicine and Ayurveda alongside other indigenous healing practices have recognized for ages that particular plants demonstrate healing properties for blood disorders, immune system enhancement, and bone marrow damage recovery [7]. The study analyzes how medicinal plants enhance bone marrow regeneration while exploring their potential to boost hematopoietic stem cell therapy effectiveness.

Aim of the review

The review evaluates the feasibility of using medicinal plants to regenerate bone marrow tissues. The review investigates plant-derived bioactive compounds that control hematopoiesis alongside the mechanisms that boost HSC functionality. This review evaluates preclinical and clinical data about medicinal plant treatments for bone marrow recovery while outlining present obstacles and future research opportunities.

Potential medicinal plants for bone marrow regeneration

Medicinal plants key phytochemicals: Research shows that medicinal plants produce multiple biological effects from their flavonoids, alkaloids, terpenoids, and polysaccharides [8]. Phytochemicals found in medicinal plants show the

potential to enhance bone marrow health through their ability to activate HSC proliferation and differentiation while supporting survival. For example: Flavonoids display antioxidant effects along with anti-inflammatory properties which help optimize the bone marrow microenvironment through antioxidant stress reduction and controlled immune responses according to research [9]. Berberine along with camptothecin as alkaloids demonstrate their ability to control cell cycle patterns and trigger apoptosis processes while potentially supporting hematopoietic tissue regeneration [10]. The terpenoid compounds known as ginsenosides in *Panax ginseng* demonstrate their ability to regulate immune activity and promote blood vessel growth necessary for bone marrow blood supply [11]. The polysaccharides found in *Astragalus membranaceus* demonstrate immunomodulatory properties that help restore bone marrow health in patients with compromised immune systems [12]. These compounds demonstrate their effects through multiple mechanisms that involve the modulation of stem cell signaling pathways, inflammatory responses, and angiogenic processes [13].

Investigation of medicinal plants for bone marrow support

A screening process evaluated medicinal plants for their ability to restore bone marrow tissue while supporting HSC activity according to Table 1. Notable examples include: *Panax ginseng* (Ginseng) demonstrates its ability to enhance HSC proliferation while supporting differentiation which makes it a potential candidate for restoring bone marrow after chemotherapy suppression [14,15]. The scientific community has determined ginsenoside functions as the main active compound responsible for its therapeutic effects. *Astragalus membranaceus* (Astragalus): Chinese traditional medicine has used this plant to boost immune function and life energy according to historical records [16]. Aplastic anemia treatment with Astragalus polysaccharides has demonstrated both HSC proliferation stimulation and bone marrow support according to research [17]. *Withania somnifera* (Ashwagandha): Research has shown that Ashwagandha functions as an adaptogen and preclinical trials indicate it reduces inflammation while promoting bone marrow regeneration [18,19]. These studies found Ashwagandha increased both erythropoiesis and white blood cell counts. *Curcuma longa* (Turmeric): The active anti-inflammatory and antioxidant compound curcumin can be found in its highest concentrations in turmeric. Scientific evidence demonstrates that manipulating the bone marrow niche environment together with HSC differentiation leads to better HSC performance [17]. *Echinacea purpurea*: The studied applications of Echinacea as an immune-boosting remedy suggest that its use may help improve bone marrow functions through cytokine regulation and enhanced hematopoietic niche recovery after myelosuppression [19]. The bone marrow regeneration support activity of *Glycyrrhiza glabra* (licorice), Reishi mushrooms (*Ganoderma lucidum*), and *Zingiber officinale* (ginger) works through distinct biological mechanisms [17].

Interaction of phytochemical with Hematopoietic Stem Cells (HSCs)

Medical plant compounds modify HSCs through the regulation of self-renewal mechanisms, differentiation pathways, and cell migration patterns [20]. For instance: The Wnt/β-catenin signaling pathway presents itself as crucial to both stem cell renewal and differentiation and researchers demonstrated how ginseng affects these processes [21]. Research shows that curcumin's binding to Notch signaling pathways helps maintain healthy HSC populations in bone marrow tissue [20].

Inflammatory pathways modulation

Chronic inflammation creates a barrier to bone marrow regeneration which potentially leads to stem cell exhaustion and damages hematopoiesis [22]. Medical plant extracts containing *Withania somnifera* and *Curcuma longa* demonstrate anti-inflammatory properties by reducing the levels of TNF-α, IL-1β, and IL-6 pro-inflammatory cytokines in the hematopoietic environment which supports stem cell function [23]. The creation of new blood vessels through

Table 1: Medicinal Plants for Bone Marrow Support.

Serial Number	Plants	Mechanism of Action	Function in Bone Marrow	References
1	Panax ginseng (Ginseng)	Promotes HSC proliferation and differentiation; active compound: ginsenoside	Enhances bone marrow recovery post-chemotherapy	[15]
2	Astragalus membranaceus (Astragalus)	Stimulates HSC proliferation; supports immune function; active compound: Astragalus polysaccharides	Supports HSC proliferation in aplastic anemia	[17]
3	Withania somnifera (Ashwagandha)	Adaptogenic properties; reduces inflammation; promotes bone marrow regeneration	Increases erythropoiesis and white blood cell counts	[18,19]
4	Curcuma longa (Turmeric)	Anti-inflammatory and antioxidant activity via curcumin; modulates bone marrow niche	Improves HSC function and differentiation	[17]
5	Echinacea purpurea (Echinacea)	Cytokine modulation; enhances hematopoietic niche; recovery after myelosuppression	Enhances bone marrow function and recovery	[19]
6	Glycyrrhiza glabra (Licorice)	Bone marrow regeneration support via anti-inflammatory and immunomodulatory activity	Supports bone marrow regeneration	[17]
7	Ganoderma lucidum (Reishi mushrooms)	Supports HSC function and immune regulation through polysaccharides	Enhances hematopoiesis and immune function	[17]
8	Zingiber officinale (Ginger)	Bone marrow support via anti-inflammatory and circulatory benefits	Promotes bone marrow support and regeneration	[17]

angiogenesis combines with Nutrient Delivery mechanisms which deliver nutrients to burn-wounded areas [24]. Stem cell function requires a properly vascularized environment to deliver oxygen and nutrients effectively [23]. The medicinal plants Ginseng and Astragalus demonstrate their ability to enhance angiogenesis by increasing Vascular Endothelial Growth Factor (VEGF) which stimulates bone marrow blood supply and improves HSC survival and function [24].

Hematopoiesis in vitro studies on medicinal plant extracts

Laboratory tests demonstrate that plant extracts influence both HSC proliferation and differentiation processes [14]. Laboratory experiments show that ginseng extracts enhance HSC colony growth while Astragalus polysaccharides improve the number of hematopoietic progenitor cells [25]. Medical research indicates that medicinal plants might trigger partial bone marrow regeneration through direct cellular activity [25].

Animal model studies

The pharmaceutical industry utilizes Ginseng, Ashwagandha, and *Curcuma longa* medicinal plants to boost animal model bone marrow recovery rates during chemotherapy myelosuppression and anemia treatments [17]. As one example: A mouse study demonstrated that Ginseng treatment raised both white blood cell and platelet counts thus indicating its potential to help patients recover from chemotherapy [26].

Human clinical trials and observational studies

The data from clinical trials alongside observational studies has shown limited positive results regarding medicinal plant-based interventions [27]. The findings from human trials of Astragalus administration for immunomodulation as well as blood cell count regulation during chemotherapy showed encouraging benefits for treating chemotherapy-induced neutropenia [28].

Challenges and limitations

Standardization of plant extracts: The translation of medicinal plant therapies into clinical practice faces significant obstacles because plant extract standardization remains inconsistent [29]. The wide range of active compound concentrations combined with different plant materials and preparation techniques creates barriers to achieving reliable therapeutic effects [30].

Toxicity and safety concerns: A wide range of medicinal plants are generally considered nontoxic yet they present toxicity risks when consumed in large amounts or over extended periods of time as illustrated in Table 2 [31]. Chemotherapy patients and those undergoing other treatments experience herb-drug interactions which modify both drug effectiveness and safety characteristics [32].

Table 2: Challenges and Limitations in Medicinal Plant Therapies.

S/N	Challenge	Description	References
1	Standardization of Plant Extracts	Lack of standardization in plant extracts leads to variability in potency and composition, affecting therapeutic outcomes.	[29,30]
2	Toxicity and Safety Concerns	Medicinal plants can be toxic in large amounts or for long-term use; potential herb-drug interactions with chemotherapy or other treatments.	[31,32]
3	Lack of Large Scale Clinical Data	Absence of large-scale, randomized clinical trials to confirm safety and efficacy; more robust human clinical data needed.	[33,34]
4	Regulatory and Ethical Issues	Regulatory approval is a hurdle due to lack of necessary clinical evidence; and ethical concerns in vulnerable populations such as cancer patients.	[35,36]

Lack of large scale clinical data: The promising preclinical results from medicinal plants in bone marrow regeneration remain unproven because large-scale randomized clinical trials have yet to demonstrate their safety and efficacy [33]. These materials find extensive use in human clinical practices yet human clinical data needs to be strengthened [34].

Regulatory and ethical issues: The main challenge involves seeking regulatory approval for plant-derived medical treatments [35]. Some medicinal plants face regulatory barriers because they lack sufficient clinical data needed for approval from regulatory bodies and ethical concerns exist about their use among vulnerable patient populations (i.e. cancer patients) [36].

Authors' perspective on future directions

Scientific investigation of bone marrow regeneration and Hematopoietic Stem Cell (HSC) therapy benefits significantly from medicinal plants. The study of plant-derived bioactive compounds at their molecular level enables researchers to identify potential therapeutic targets that improve HSC functionality. The identification of bioactive compounds demands modern analytical tools such as metabolomics and computational drug discovery approaches in research efforts. Researchers use traditional medicinal knowledge together with modern biotechnological approaches to develop innovative medical therapies for treating hematological disorders. Plant-based regenerative medicine has gained increasing attention which demands modifications to current regulatory frameworks. The therapeutic use of plants needs standardized extraction procedures alongside strict clinical trials to achieve both safety and effective reproducible therapeutic outcomes. The full medical potential of medicinal plants in HSC therapy requires collaborative efforts between pharmacology specialists, geneticists, and medical practitioners. Studies demonstrate that blending plant-based treatments with existing regenerative techniques will create improved treatment accessibility for patients who need hematological disease care.

Conclusion

Research into medicinal plants that promote bone marrow

regeneration shows compelling evidence of their healing properties. The therapeutic compounds flavonoids, alkaloids, terpenoids, and polysaccharides demonstrate their capacity to enhance Hematopoietic Stem Cell (HSC) functions through pathway regulation and anti-inflammatory mechanisms. Preclinical and clinical research demonstrates that *Panax ginseng*, *Astragalus membranaceus,* and *Curcuma longa* plants possess strong potential to treat bone marrow suppression caused by chemotherapy and other therapeutic interventions. The broader implementation of these treatments faces barriers from unstandardized extracts combined with toxicity concerns, drug interactions, and regulatory complexities. The combination of medicinal plant treatments with existing hematopoietic therapies demonstrates substantial promise for improving patient results despite current implementation barriers. The full potential of these natural resources requires extensive clinical testing, complete standardization protocols, and precise regulatory frameworks.

Recommendations

Standardization of Plant Extracts: Standardization protocols need development for medicinal plant preparations which will provide consistent therapeutic effects throughout different populations and healthcare environments.

Toxicity studies and herb-drug interactions: Researchers must conduct extensive studies to determine the safety characteristics of medicinal plants that patients take with chemotherapy drugs or other pharmaceutical medications.

Clinical trials: The process demands dedicated funding for extensive randomized clinical trials that develop bone marrow regenerative abilities of medicinal plants while addressing present evidence deficiencies.

Public awareness and education: Healthcare providers and patients need better information regarding both the advantages and possible risks that occur when medicinal plants are used in hematopoietic treatment.

Policy and regulation: The development of ultimate clarification procedures for plant-based therapeutic applications and approval protocols needs cooperation with regulatory bodies that manage clinical locations.

Future research directions: Scientists need to learn the molecular processes that phytochemicals activate within HSC cells and the hematopoietic environment while studying how these substances can work together with standard medical treatments.

Acknowledgement

The authors are grateful to Kampala International University Uganda for providing the necessary support and facilities in the course of this study.

Author contributions

Conceptualization: OPCU, AEU; Methodology: OPCU, AEU; Resources: AEU; Supervision: OPCU; Validation: AEU; Visualization: OPCU; Writing – original draft: OPCU, AEU; Writing – review & editing: OPCU, AEU.

Consent for publication

All authors read and approved the manuscript for publication.

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